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Zusammenfassung:

Abstract:
The research presented in this paper was motivated by the central role of infrastructure charging in European transport policy. It is dedicated to the question whether and to what extent marginal infrastructure costs of airports, e.g. the marginal costs of maintaining, renewing and operating airport infrastructure, play a significant role for charging. The analysis presented in this paper is based on hourly cost and traffic data for the airport of Helsinki. In contrast to the standard formulation of cost function analysis our research focuses on one factor input only, the labour cost which is the dominant cost component for the case study airport. This factor input can safely assumed to be the most relevant category for analysing cost variability and deriving marginal costs. The analysis makes use of a multivariate time series approach with specific models for correlated error terms to account for random shocks such as delays. The major result is for almost all airport service areas a linear relationship between labour cost and aircraft movements with an average marginal cost of € 22.60. An exception is the relationship between the staff costs for passenger services and international departing flights where a cubic cost relationship was estimated. Our quantitative findings are comparable with earlier findings for U.S. airports.

Keywords: Cost functions, time series analysis, airports, marginal costs, infrastructure charging

JEL codes: R48, L932 C32

1. Introduction

Charging for the use of infrastructure has become a central issue in European transport policy. Several Green and White papers (*EC* (1995), *EC* (1998), *EC* (2001)) have emphasised the importance of fair and efficient charging schemes in order to curb congestion, to pay for external costs of transport and to finance infrastructure. The EU charging policy has postulated the principle of social marginal cost pricing as the leading principle for charging policies in the member states. Implementing this principle requires empirical evidence on the different cost components such as the marginal costs of infrastructure maintenance, repair, renewal and operation, the marginal environmental and accident costs and the marginal congestion costs. This paper is dedicated to the question whether and to what extent marginal infrastructure costs of airports, e.g. the marginal costs of maintaining, renewing and operating airport infrastructure, play a significant role. So far this issue has not been well researched, mainly due to the presumed lesser importance of these cost components while environmental, congestion and scarcity costs are believed to be decisive for the overall level of charges.

The majority of available cost function studies in aviation has rather been motivated by analytical issues, notably deregulation issues in the airline industry, than attempts to estimate infrastructure costs and marginal costs, (*Baltagi et al.* (1995), *Barla/Perelman* (1989), *Caves et al.* (1984), *Caves et al.* (1987), *Encaoua* (1991, *Gillen et al.* (1990), *Windle* (1991)). Only a few studies have dealt with the costs of airport infrastructure services (for example *Doganis* (1996), *Morrison/Winston* (1989)). The analysis summarised in this paper was aimed at closing this gap. It presents the results of an econometric analysis based on cost and traffic data for the airport of Helsinki. This analysis continues research originally performed as part of a series of case studies on estimating social marginal transport costs within the EU funded research project UNITE[1] by using a refined methodological approach.

While the studies mentioned above are based on the standard formulations of cost function analysis which links total cost of production to production output, production

1 The UNITE project (UNIfication of accounts and marginal costs for Transport Efficiency) was dedicated to estimate total and marginal costs for all types of costs and all modes of transport and to analyse the welfare impacts of different charging policies. All project reports can be found under http://www.its.leeds.ac.uk/projects/unite/.

factors and input prices, our analysis focuses on labour costs as the dominant cost component for the case study airport and analyses the relationship between labour costs and aircraft movements in an hourly pattern by means of multivariate time series analysis.

This paper is organised as follows. Chapter 2 outlines the methodology used. Chapter 3 describes the characteristics of the case study airport and the data. Chapter 4 discusses the estimation results and derives the marginal costs. Chapter 5 concludes.

2. Modelling issues

Methodologies to estimate marginal infrastructure costs have not been a central issue in transportation research in the past. Just over the last few years, driven by the appearance of the EU policy documents on charging marginal costs of infrastructure use, several studies have been dedicated to the question how to measure the marginal cost of infrastructure use, for a summary see *Link/Nilsson* (2005). As far as the cost of maintaining, renewing and operating transport infrastructure such as roads and rail tracks are concerned two main approaches can be distinguished. Given the important role which wear and tear costs play in these modes there is a tradition in engineering-based approaches which establish a functional relationship between infrastructure damage and traffic load by using physical measurements of infrastructure condition. A prominent example for this is the AASHTO road test (*Highway Research Board* (1961)), other examples include *Small/Winston* (1988), *Small et al.* (1989) and *Lindberg* (2002). An alternative is the econometric analysis of observed spending for infrastructure maintenance and renewal and traffic load. The obvious approach is here to employ state-of-the-art cost function analysis which aims at identifying the dependency between the costs of producing goods or services, the production output and the input prices, and to use the estimation results for deriving marginal costs. The most common functional form is the translog cost function[2] as proposed by *Berndt/Christensen* (1972). The empirical basis consists usually of cross-sectional data, mostly obtained for more than one time period and pooled together. Applications

2 Meanwhile there are also studies using a Box-Cox function approach, for example *De Borger* (1992), *Gaudry/Quinet* (2003).

of this approach for road and rail can be found in *Schreyer et al.* (2002), *Johansson/Nilsson* (2001), *Gaudry/Quinet* (2003) and *Link* (2005).[3]

Although this paper makes use of an econometric approach for estimating marginal airport operating costs an alternative approach to traditional cost function analysis has been chosen, motivated by the specific characteristics of airports and due to the nature of available data. First, in contrast to roads where the cost of wear & tear and renewal are the major components for estimating marginal costs, the operating costs play the major role for terminal infrastructure such as airports. Initial analysis of the cost structure of our example airport has revealed that three quarter of the overall costs are staff costs. Given the objective of our analysis to estimate the marginal costs of airport operation as the price-relevant costs, the quantitative importance of staff costs suggests to focus the analysis on this category. The major question is here to what extent the number of airport staff varies with aircraft movements and passengers. Furthermore, we can safely assume that activities such as maintenance, repair and renewals of terminals as well as non-staff related airport operation (electricity, runway lighting and signalling, tower control, cleaning) are to a large extent fixed costs which can be neglected for estimating marginal costs. An exception might be the maintenance and renewal costs of runways where similar cost-traffic load relationships as for the road sector can be assumed. The second reason lies in the nature of our data. We use data on an hourly basis instead of cross-sectional data, e.g. we have to treat time series data with a short-run time horizon of observations. The data reflect the fluctuations of aircraft and passenger movements and of scheduled staff over the day. Initial multiple linear regression analysis performed in *Himanen et al.* (2002) has shown that random shocks (for example delays) influence the pattern significantly and cause autocorrelation problems in the residuals if not treated properly. For these reasons we have chosen a multiple regression model with an explicit modelling of correlated error terms.

The objective of our modelling work is to identify whether there exists a significant relationship between the number of scheduled person-hours Y_i in service area i (i = 1, …, 6) and the traffic volume measured as aircraft movements M_j (j = 1, …, 4) where j denotes the type of aircraft movement (international departures/arrivals, domestic

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3 However, except *Link* (2005) these studies do not estimate full systems of cost and factor input share equations due to lack of cross-sectional data on factor inputs and input prices. They argue that input prices do not vary across track sections or regions and estimate a cost equation only, either as log-linear models (*Schreyer et al.* (2002)), translog models (*Johansson/Nilsson* (2001)) or as a Box-Cox model (*Gaudry/Quinet* (2003)).

departures/arrivals). Since the link between traffic volume and the number of personnel may be influenced by season and weekday/weekend, and in order to account for the inflexibility of working times and contracts, we have constructed three further variables. The categorical variable A indicates the influence of additional salaries to be paid for evening and night work which might play a role for scheduling staff, the dummy variable S reflects the seasonal influence of summer and winter and W is a dummy variable representing the influence of weekends. The general model to be estimated is

$$Y_t = f(M_t, A_t, W_t, S_t, \varepsilon_t) \quad (1)$$

where t indicates the time, expressed in hours, ε denotes the residuals of the regression model and f is an unknown functional form.

Initial analysis (*Himanen et al.* (2002)) has shown that a linear regression model is capable to provide a plausible interpretation of the coefficients but faces the problem of autocorrelated residuals. The analysis presented in this paper was therefore aimed at supplementing the linear regression model with an appropriate model for the error terms.

We describe here exemplified the residual modelling for the relationship between the number of staff scheduled in the passenger service area and the total number of all types of aircraft movements. Visual inspection of the sequential diagrams and the scatterplots (figure 1) indicate first, a dominant day pattern and second, a linear relationship between the two variables Y(t) and M(t). The cross-correlogram (figure 2) shows no cut at the first values and rejects therefore a delay between aircraft movements and scheduled person hours. Both the extended *Dickey-Fuller* test (*Dickey/Fuller* (1979)) and the *Phillips-Perron* test (*Phillips/Perron* (1988)) reject the existence of unit roots (table 1) indicating that the time series is a stationary process.[4] It is therefore possible to model the residuals by means of an AutoRegressive Moving Average Model ARMA(p,q) based on the *Box-Jenkins* technique (see *Brockwell/Davis* (2002)). This model type allows to treat the autocorrelation in the residuals by estimating two parameters, p which indicates the order of the correlated model errors, and q which represents the order of random shocks. For our airport data we can

[4] Testing for unit roots in the residuals seeks to identify whether the time series is a stationary process. Instationarity would indicate that the residuals include for example a trend component. This would require a different modeling approach than the one we used in this paper.

interpret these random shocks as external events causing delays of departing and/or arriving aircrafts. Furthermore, we have introduced a cyclical term $(p_8, q_8)_8$ with p_8 representing the shift weights of the model errors, and q_8 indicating the shift weights of the random shocks.[5]

The finally estimated model is a SARMA model (Seasonal AutoRegressive Moving Average Model) of the form

$$Y(t) = \alpha_0 + \alpha_1 \cdot M(t) + \alpha_2 \cdot A(t) + \alpha_3 \cdot W(t) + \alpha_4 \cdot S(t) + \varepsilon(t) \qquad (2)$$

with

$$\varepsilon(t) = \frac{(1 + c_1 \cdot B + c_2 \cdot B^2)}{(1 + d_1 \cdot B + d_2 \cdot B^2) \cdot (1 + d_8 \cdot B^8)} \cdot a(t)\,. \qquad (3)$$

B is the so-called backshift operator, defined by

$$B\,a(t) \quad = \quad a(t-1)\,. \qquad (4)$$

ε(t) denotes the errors of the regression model, a(t) represents the random shocks.

While for the relationship between scheduled staff in almost all service areas and the different types of aircraft movements equations (2) and (3) were used for model estimation, the visual inspection of the scatterplot between scheduled staff for passenger services (i.e. check-in and gate services, security, baggage handling, delivery and trolley service) and the number of international departing flights (ID) has revealed a different pattern (figure 3). For this specific case a cubic model

$$\begin{aligned} Y(t) = \beta_0 + \beta_1 \cdot ID(t) + \beta_2 \cdot ID(t)^2 + \beta_3 \cdot ID(t)^3 + \beta_4 \cdot A(t) + \\ \beta_5 \cdot W(t) + \beta_6 \cdot S(t) + \varepsilon(t) \end{aligned} \qquad (5)$$

again with equation (3) for ε(t) was estimated.

In order to identify parsimoneously specified models[6] we used two information criteria, the *Akaike* Information Criterion AIC and the *Schwarz Bayes*ian Criterion SBC:

$$\begin{aligned} AIC &= -2 \cdot \frac{L}{n} + 2 \cdot \frac{k}{n} \\ SBC &= -2 \cdot \frac{L}{n} + k \cdot \frac{\log(n)}{n}\,, \end{aligned} \qquad (6)$$

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5 This is supported by the fact that the dependent variable shows a cyclical pattern with a peak at lag 8, the average shift length of airport staff, and by the observation that for some service areas the correlogram analysis of residuals reveals a remaining cyclical pattern indicated by a peak at lag 8.

6 The principle of parsimony means that everything else being equal, simpler models with fewer parameters are better. It has been found to be very effective when choosing between models with approximately the same explanatory power, or conversely the same model error.

where L represents the value of the Log-Likelihood function, k stands for the number of parameters estimated and n for the number of observations. All estimations presented in this paper were conducted with the time series package EViews 5.0.

3. The case study airport and the data

Helsinki-Vantaa airport is the primary airport in Finland handling about 90% of all passenger traffic. It is the dominant departure and arrival airport both for domestic and international flights as well as for cargo. Helsinki-Vantaa has only a modest position in international markets with a ranking position between 24 and 29, depending on the ranking measure. It can be classified as one of the 15 European airports serving free-standing metropolitan regions (*Graham* (1998)). The airport is a financial unit of the Finnish Civil Aviation Authority (CAA), a governmental enterprise funded by its customers. Despite public ownership and the promotion of some social objectives, CAA is commercially oriented. Helsinki-Vantaa airport has to act according to operational and profit targets set by CAA, however, can freely decide on the allocation of operation expenditures as far as they fit within the margins of the accepted budget.
The data used for our analysis refer exclusively to infrastructure services (items in cursive letters in table 2). While transport operator services, commercial services and public sector services and cargo services related to non-aeronautical activities are excluded, services for freight flights on the aeronautical side are included. Two types of data were obtained:

Type I data: Total costs per service category in 2000

This data includes all costs of providing airport services (including central administration staff) independent on the question whether the staff was employed directly at Helsinki-Vantaa airport or by subcontractors (outsourced services). Depreciation is excluded.

Type II data: Hourly data on scheduled staff, aircraft movements and passengers

This data was collected for one winter and one summer week, both during the year 2000, with a total of n = 336 observations. The staff data is differentiated by service areas of the airport. The information on aircraft movements and passengers is disaggregated for international and domestic flights, departures and arrivals.
An analysis of the type I data shows first of all the quantitative importance of out-

sourced services which made almost half of the staff employed at Helsinki-Vantaa airport (table 3 and table 4). Second, total operating costs for infrastructure services amounted in 2000 to about € million 44, with the passenger terminal services causing the highest share of this total. Staff costs (airport's personnel, outsourced staff and central administration staff) were with a share of 74% the most important cost category. *Doganis* (1996) reports for Western European airports an average share of labour costs of 42% with a few exceptions lying above this average up to even 65%, depending on the airport authority's level of involvement in the provision of services. The comparably lower figure for Helsinki can be explained by two reasons: First, in contrast to *Doganis* (1996), our figures do not include depreciation. Second, the figures reported in *Doganis* (1996) exclude outsourced staff.[7]

The quantitative importance of labour costs suggested to focus the modelling work on the relationship between staff costs and the number of aircraft movements. Both the initial descriptive analysis summarised below and the modelling work made use of the type II data with the number of scheduled person-hours as dependent variable. This variable includes part of training and sick leaves but not holidays.[8] Furthermore, in contrast to official transport statistics transit passengers were counted only once since our analysis was aimed at analysing the use of services by passengers.

On average, 2,522 person hours per day were scheduled in winter and 2,175 in summer (table 5) with a corresponding average annual figure of 857,203. On average, an aircraft movement needed 5.3 person-hours varying from 4.0 to 6.9 during the sample weeks. Descriptive analysis of the data shows that in principle, the number of personnel parallels the number of aircraft movements and passengers, both for the daily and the hourly pattern. On weekends fewer person hours were scheduled than during weekdays, paralleling the number of aircraft movements and a seasonal impact can be observed when comparing the summer and winter week. Most interesting, however, for our analysis is the hourly pattern with a very low occupancy during the night, rapid increase in the morning, stable occupancy during daytime, and straight reduction towards midnight (figure 4). This pattern is also reflected in high correlation coeffi-

[7] According to *Doganis* (1996), capital costs – interest paid and depreciation – are on average 22% of airport costs. Furthermore, almost half of the personnel working at Helsinki airport is outsourced staff, with a varying quantitative importance per service area.

[8] In contrast to this, the person-hours paid embrace holidays, training, sick leaves and other non-paid working time. Note, that the ideal measure would be person-hours worked since this indicates best the actual resources used. This type of information, however, was not available.

cients (table 6) between aircraft movements and the number of personnel (both for total personnel and the number of staff by service area) which amount to 0.80 (all services) and range between 0.26 (manoeuvring area) and 0.77 (passenger services).

4. Estimation results

The linear model (2) with the error model (3) has proven to provide a high explanatory power for the relationship between scheduled staff both overall in the airport and in the specific service areas and the total number of aircraft movements (measured as aggregated number without disaggregation by domestic/international, departing/arriving flights). The R^2 ranges from 87% to 96% (table 7) and has improved considerably compared to the initial modelling described in *Himanen et al.* (2002).

For all service areas we have estimated a two hours term (p = 2) to account for correlated model errors (table 8). The parameter q which represents the hours needed by the airport to proceed with random shocks (delays etc.) varies across the service areas between 1 and 2 hours. Obviously, traffic control and manoeuvring services need 1 hour to tackle with random shocks while the influence of external random events lasts 2 hours in all other service areas. The shift weights of the model errors were, except for the ground transport services, identified as $p_8 = 1$. No shift weights for the random shocks could be identified. A seasonal influence was only estimated for the manoeuvring and the apron area where winter maintenance plays an important role. Salary agreements have a significant influence on the number of scheduled person hours in air traffic control, apron area and in the passenger services. A weekend influence was only identified for the air traffic control staff and for the apron area staff. The manoeuvring area was the only category where no significant influence of aircraft movements on the number of scheduled person hours was estimated. An explanation for this is the fact that these services are rather general and have to be provided independent of traffic volume (maintenance of runways, cleaning, guidance systems, environmental protection, security and fire services).

The model offers a plausible interpretation. Overall, increases in the number of aircraft movements per hour require about 0.6 person hours from the airport staff. The salary arrangements are reflected in α_2 which indicates that the airport authority as far as possible attempts to schedule the number of personnel in a cost-minimising way, e.g. avoiding additional salaries for overtime and night work. The seasonal dummy variable has a negative sign, e.g. during winter more personnel is scheduled than in summer. The same is true for the weekend where less staff is scheduled.

The linear structure of the model allows a simple calculation of marginal costs:

$$MC_t = \frac{\partial Y_t}{\partial M_t} = \alpha_1 \, AC_t \qquad (7)$$

where AC is the average staff costs. This information can be obtained from table 3 and is estimated to € 37.70 per hour, a value which, however, includes also non-personnel costs. Consequently, the marginal costs of an extra aircraft movement amount to € 22.60. This result lies in the same magnitude like earlier findings for U.S. airports. *Morrison/Winston* (1989) report for maintenance, operation and administration of US airports a marginal cost of $ 22.09 per aircraft movement which gives after inflation to 2000 dollars and adjusted to €, an estimate of € 32.97 per aircraft movement.

More detailed modelling of the relationship between scheduled staff per service area and specific types of aircraft movements (domestic departures/arrivals, international departures/arrivals) does not suggest to prefer other model types than equations (2) and (3), e.g. the linear structure with the error model appears to be the best approach with estimation results which can plausibly interpreted. The only exception is the relationship between the number of staff scheduled in the passenger service area and the number of international departing aircrafts. As indicated in chapter 2, we have fitted a cubic model (table 9). The estimated model for the error terms is an ARMA(2,2) model. In contrast to the models for the aggregated aircraft movements summarised in table 7 and 8, the inclusion of a SAR term would lead to over-specification with the existence of unit roots. The model fit is with 95% very good. The ARMA(2,2) structure indicates that for this specific relationship a two hours term ($p = 2$) accounts best for correlated model errors while the MA(2) term means that the passenger service area needs 2 hours to tackle with random shocks such as delays. The exclusion of the SAR term implies that no shift weights neither for the correlated model errors nor for the random shocks were considered. The cubic relationship leads to an u-shaped marginal cost curve (figure 5) with marginal costs ranging between € 25 and € 72 per additional international departure. Economies of scale are very low and amount to RTS = 0.17.

It should be noted that the linear model structure applied to the relationship between scheduled staff and aggregated aircraft movements implies the absence of economies of scale. This assumption needs to be debated and verified within further research for other airports. It is, however, supported by the discussion in *Doganis* (1996) which reports that airports with a traffic volume below 3 million passengers have higher unit costs than larger ones while for a traffic volume between 3 and 10 million passengers unit costs seem to decrease not much[9]. It is also reinforced by the very low economies of scale obtained with the non-linear model for the relationship between scheduled staff in passenger services and international departing flights.

5. Conclusions

This paper has presented an approach to analyse the relationship between airport staff costs and aircraft movements in an hourly pattern and to derive marginal costs as information for determining airport user charges. It provides an approach suitable to analyse data with an hourly disaggregation where random shocks such as delays of arriving and/or departing aircrafts, the influence of shift cycles, salary agreements for evening and night work and other factors play a role. All models estimated are based on the principle of parsimony and offer a plausible interpretation of the parameters.

Furthermore, our models allow an easy calculation of marginal airport costs as an information relevant for charging policies. Aggregated over all service areas of the airport, the marginal effort for an extra aircraft movement has been estimated to be on average 0.6 person-hours from the airport personnel. Expressed in monetary terms this yields a marginal cost of € 22.60 for an extra aircraft movement. This result implies that the marginal cost is 11% of total costs (5.3 person-hours per an aircraft movement or € 199.80), e.g. a marginal cost pricing scheme would only cover 11% of total costs. The marginal staff costs in the passenger service area for an additional international departure follows an u-shaped curve and ranges between € 25 and € 72 again indicating that no full cost recovery is possible.

Due to the fact that studies on airport costs are rare it is hard to conclude to what extent our findings are representative and transferable to other airports. Unit costs at airports are influenced by a wide range of factors which will vary from country to country, and even between airports in the same country. According to *Doganis* (1996)

[9] No information is available for airports with more than 10 million passengers.

smaller airports with a traffic volume below 3 million passengers have higher unit costs than larger ones. For a traffic volume between 3 and 10 million passengers unit costs seem to decrease not much while no information is available for airports with more than 10 million passengers. These figures indicate that our results seem to be relevant for most airports except the smallest ones and the largest ones. Another important factor is the share of international passengers. They require more services than domestic ones and are, therefore, more expensive. Any airport with a higher share of international passengers than our case study airport Helsinki would need more staff, and vice versa. Furthermore, differences may arise on the scope of out-sourcing. When comparing our results with those for other airports it has to be borne in mind that the person-hours used in our analysis include all outsourced activities.

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Table 1
t_α statistics for Unit Roots Tests[1)]

Model[2)]	Dependent variable	Augmented *Dickey-Fuller* test	*Phillips-Perron* test
1	All services	-8.06	-7.49
2	Air Traffic Control	-9.25	-9.45
3	Manoeuvring area	-6.04	-7.13
4	Apron area	-7.79	-7.58
5	Passenger services	-5.92	-12.80
6	Ground transport services	-4.85	-6.74
7	Passenger services	-6.44	-11.61

[1)] Hypothesis tested: $\mathbf{H_0}$: An unit root exists. $\mathbf{H_A}$: An unit root does not exist. The Decision rule on a level α is: Reject the H_0 if the statistics t_α is less than or equal to the critical value. Do not reject the H_0 if the statistic t_α is greater than the critical value. The critical value at 5% level is -2.87. - [2)] Models 1-6: Linear models with the independent variables: All aircraft movements (M), Salary agreements (A), Weekend dummy (W), Seasonal dummy (S). Model 7: Cubic model with the independent variables: International departures (ID), Salary agreements (A), Weekend dummy (W), Seasonal dummy (S).

Source: Own estimations.

Table 2
Classification of airport services and their customers and producers

	Customer	Producer	Service Category
AERONAUTICAL SERVICES			
Terminal Air Traffic Control Services (pure infrastructure)			
maintenance and development of equipment,	**AL**	**IM**	**I**
approach control services and	**AL**	**IM**	**I**
tower control services.	**AL**	**IM**	**I**
Manoeuvring Area Services (pure infrastructure)			
maintenance and development of runways and taxiways,	**AL**	**IM**	**I**
cleaning and prevention of the slippery condition,	**AL**	**IM**	**I**
guidance systems of air and ground traffic,	**AL**	**IM**	**I**
environmental protection and	**OS**	**IM**	**I**
security and fire services of manoeuvring area.	**AL**	**IM**	**I**
Apron Area Services (mainly infrastructure)			
maintenance and development of apron area and machinery,	**AL**	**IM**	**I**
aircraft parking,	**AL**	**IM**	**I**
aircraft handling,	**AL**	**AL**	**O**
bus transportation,	**AL**	**IM**	**I**
environmental protection,	**AL**	**IM**	**I**
security and fire services of apron area and	**AL**	**IM**	**I**
control of vehicle traffic operations and safety.			
NON-AERONAUTICAL SERVICES			
Passenger services (partly infrastructure)			
maintenance and development of air terminals,	**AP,AL,OC**	**IM**	**I,C,O**
check-in and gate services,	**AP**	**AL**	**I,O**
passport check and customs services,	**AP**	**IM,PS**	**P?**
guidance and information services,	**AP,OC**	**IM**	**I,C,O**
baggage handling, delivery and trolley service,	**AP**	**IM,AL**	**I**
security services.	**AP**	**IM**	**I**
Cargo services (partly infrastructure)			
maintenance and development of cargo terminals,	**AL,OE**	**AL,OE**	**O**
freight handling services,	**AL,OE**	**AL,OE**	**O**
mail handling services and	**AL,OE**	**AL,OE**	**O**
customs services.	**AL,OE**	**PS**	**P?**
Commercial services (no infrastructure)			
shops, cafés, restaurants and kiosks,	**AP,OC**	**IM,OE**	**C**
tax free shops,	**AP**	**IM,OE**	**C**
hotels,	**AP,OC**	**OE**	**C**
posts and banks,	**AP,OC**	**OE**	**C**
auxiliary services (e.g. car rental),	**AP,OC**	**OE**	**C**
conference rooms, VIP-services, advertising + media services.	**AP,OC**	**IM**	**C**
Ground transport services (partly infrastructure)			
development/maintenance of terminal land side exit and entry roads,	**AP,OC,OE**	**IM**	**I**
parking services,	**AP,OC**	**IM,OE**	**I**
taxi and public transport services and	**AP,OC**	**OE**	**O**
car rental.	**AP,OC**	**OE**	**C**

Customers: AL = Airlines, AP = Air passengers, OC = Other customers, OS = Other society. **Producers: IM = Infrastructure manager (airport), AL = Airlines, OE = Other enterprises, PS = Public sector.** Service Category: I = Infrastructure service, O = Transport operator service, C = Commercial service, P = Public sector service.

Source: *JP-Transplan Ltd.*

Table 3
Costs (€) of infrastructure services at Helsinki-Vantaa airport in 2000

Cost categories	Air Traffic Control Services	Manoeuv-ring Area Services	Apron Area Services	Passenger Terminal Services	Ground Transport Services	Total	(%)
Salaries	-6 345 322	-3 173 599	-1 319 544	-2 966 485	-1 203 266	-15 008 215	34
Social	-1 738 025	-1 088 109	-424 641	-1 092 429	-327 992	-4 671 196	11
Personnel	**-8 083 347**	**-4 261 708**	**-1 744 185**	**-4 058 914**	**-1 531 258**	**-19 679 411**	**44**
Material	-153 239	-1 528 254	-238 446	-345 905	-171 312	-2 437 155	5
Rents	-45 031	-116 357	2 169	-49 227	-6 932	-215 377	0
Municipal charges	-3 795	-3 310 357	-262 683	35	170	-3 576 630	8
Repair/Maint.	-163 981	-480 435	-556 044	-4 149 302	-405 882	-5 755 643	13
Other[1)]	-1 956 097	-990 005	-1 450 733	-3 541 044	-1 393 241	-9 331 120	21
Non-personnel	**-2 322 142**	**-6 425 408**	**-2 505 737**	**-8 085 536**	**-1 977 197**	**-21 316 020**	**48**
Internal[2)]	**-999 400**	**-595 723**	**-411 903**	**-1 153 520**	**-212 620**	**-3 373 166**	**8**
Total	**-11 404 889**	**-11 282 839**	**-4 661 824**	**-13 297 970**	**-3 721 075**	**-44 368 597**	**100**
(%)	26	25	11	30	8		100

[1)] Includes outsourced services. [2)] Central administration, staff costs only.
Source: *The Finnish Civil Aviation Administration*.

Table 4
Average number of personnel per hour at Helsinki-Vantaa airport[1)]

Type of Personnel	Service area					Total	(%)
	Air Traffic Control	Manoeuvring Area	Apron Area	Passenger Terminal	Ground Transport		
Own staff	12	20	5	9	5	51	52
Outsourced staff	0	0	5	38	5	48	48
Total	**12**	**20**	**10**	**48**	**9**	**99**	**100**

[1)] Collected during 05/02 – 11/02 2000 and 28/05 – 03/06 2000.
Source: *The Finnish Civil Aviation Administration*.

Table 5
Scheduled person-hours, aircraft movements and passengers at Helsinki-Vantaa airport[1)]

Date			Person-hours	Aircraft movements	Passengers	P-h/Am [2)]	P-h/ Pass [3)]
Winter	Monday	07/02 2000	2 626	485	22 651	5.4	0.12
	Tuesday	08/02 2000	2 525	515	25 386	4.9	0.10
	Wednesday	09/02 2000	2 593	510	25 673	5.1	0.10
	Thursday	10/02 2000	2 638	541	28 738	4.9	0.09
	Friday	11/02 2000	2 672	525	30 386	5.1	0.09
	Saturday	05/02 2000	2 203	356	21 155	6.2	0.10
	Sunday	06/02 2000	2 398	347	26 000	6.9	0.09
	Average		2 522	468	25 713	5.5	0.10
Summer	Monday	29/05 2000	2 237	557	28 817	4.0	0.08
	Tuesday	30/05 2000	2 253	546	29 116	4.1	0.08
	Wednesday	31/05 2000	2 362	542	29 198	4.4	0.08
	Thursday	01/06 2000	2 136	355	20 807	6.0	0.10
	Friday	02/06 2000	2 235	379	20 594	5.9	0.11
	Saturday	03/06 2000	1 934	345	23 660	5.6	0.08
	Sunday	28/05 2000	2 069	371	29 235	5.6	0.07
	Average		2 175	442	25 918	5.1	0.09

[1)] Collected during 05/02 –11/02 2000 and 28/05 – 03/06 2000. [2)] Scheduled person-hours per an aircraft movement. [3)] Scheduled person hours per passenger.

Source: *The Finnish Civil Aviation Administration*.

Table 6
Correlation between the number of personnel per service area and the number of aircraft movements per hour at Helsinki-Vantaa airport

Number of …	Number of personnel in …					
	All services	Traffic Control Services	Manoeu-vring Area Services	Apron Area Services	Passenger Services	Ground Transport Services
Aircraft movements	**0.80**	**0.71**	**0.26**	**0.75**	**0.77**	**0.66**
Passenger aircraft movements	0.81	0.70	0.28	0.73	0.78	0.67
Arriving aircrafts	0.62	0.58	0.20	0.63	0.56	0.68
Departing aircrafts	0.76	0.64	0.24	0.66	0.77	0.47
International aircrafts	0.77	0.70	0.17	0.69	0.75	0.68
Domestic aircrafts	0.68	0.58	0.31	0.66	0.65	0.49
Domestic/ arriving aircrafts	0.60	0.51	0.28	0.62	0.56	0.44
Domestic /departing aircrafts	0.54	0.46	0.23	0.49	0.53	0.38
International/ arriving aircrafts	0.47	0.49	0.08	0.47	0.40	0.71
International/ departing aircrafts	0.73	0.62	0.18	0.62	0.75	0.42

Source: *JP-Transplan Ltd*.

Table 7
Estimation results for the linear model structure with SARMA(p,q) error models – model coefficients[1)]

Model	Dependent variable	Independent variables					Model type for residuals	Information criteria	
	Staff in service areas	Aircraft movements (M)	Salary agreements (A)	Weekend-Dummy (W)	Seasonal Dummy (S)	Constant	SARMA (p, q) $(p_8, q_8)_8$	AIC	SBC
1	All services	0.6003 (0.0687)				87.0 (2.3)	(2, 1) $(1, 0)_8$	7.120	7.190
2	Air Traffic Control	0.1385 (0.0289)	-4.99 (0.52)	-3.35 (1.10)		15.7 (1.1)	(2, 1) $(1, 0)_8$	5.186	5.255
3	Manoeuvring area				-12.54 (0.28)	25.6 (0.2)	(2, 1) $(1, 0)_8$	4.080	4.161
4	Apron area	0.0536 (0.0120)	-2.89 (0.23)	-1.60 (0.25)	-1.88 (0.06)	12.9 (0.4)	(2, 2) $(1, 0)_8$	3.494	3.610
5	Passenger services	0.1647 (0.0456)	2.76 (0.80)			41.9 (1.4)	(2, 2) $(1, 0)_8$	6.389	6.482
6	Ground transport services	0.0361 (0.0113)				8.7 (0.3)	(2, 2) $(0, 0)_8$	3.361	3.430

1) Standard error in brackets.
Source: Own estimations.

Table 8
Estimation results for the linear model structure– error model[1)]

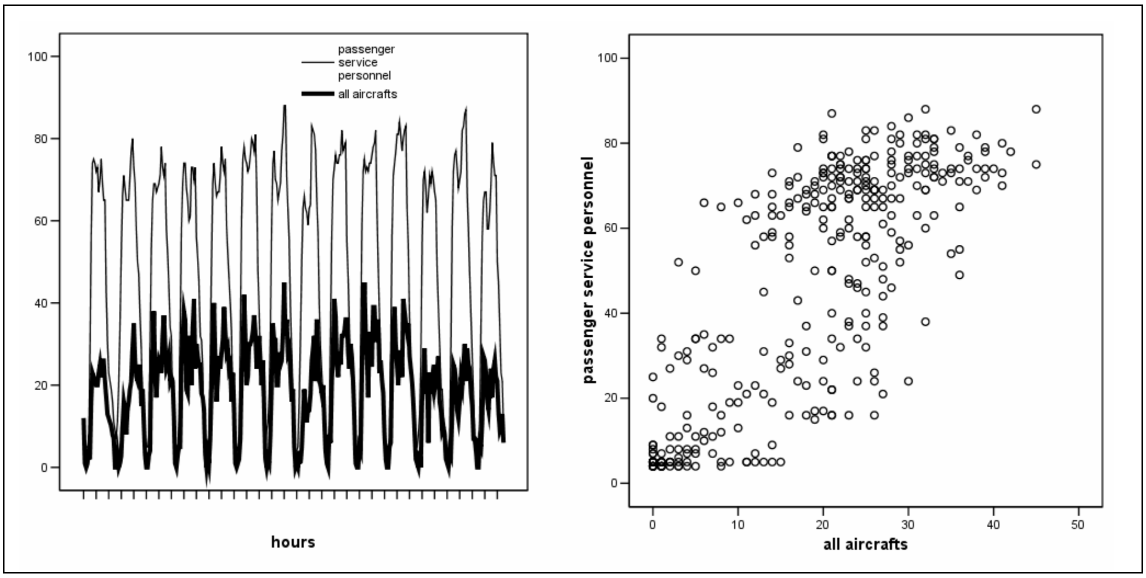
Model	Staff in service areas	AR(1)	AR(2)	SAR(1)	MA(1)	MA(2)	R^2 (%)	Durbin-Watson-Statistics
1	All services	1.902 (0.014)	-0.971 (0.014)	0.209 0.055	-0.787 (0.039)		96.29	1.857
2	Air Traffic Control	-0.235 (0.040)	0.757 (0.038)	-0.239 (0.057)	0.954 (0.024)		87.71	1.968
3	Manoeuvring area	1.737 (0.044)	-0.795 (0.037)	-0.382 (0.052)	-0.904 (0.047)		93.46	2.035
4	Apron area	1.803 (0.033)	-0.871 (0.033)	0.431 (0.054)	-1.161 (0.069)	0.165 (0.068)	90.90	2.002
5	Passenger services	1.899 (0.014)	-0.969 (0.014)	0.239 0.055	-0.599 (0.054)	-0.387 (0.054)	95.50	2.019
6	Ground transport	1.837 (0.034)	-0.897 (0.031)		-0.933 (0.067)	0.142 (0.064)	86.69	2.006

1) Standard error in brackets.
Source: Own estimations.

Table 9
Estimation results for the nonlinear model (relationship between scheduled staff in passenger services and international departures)

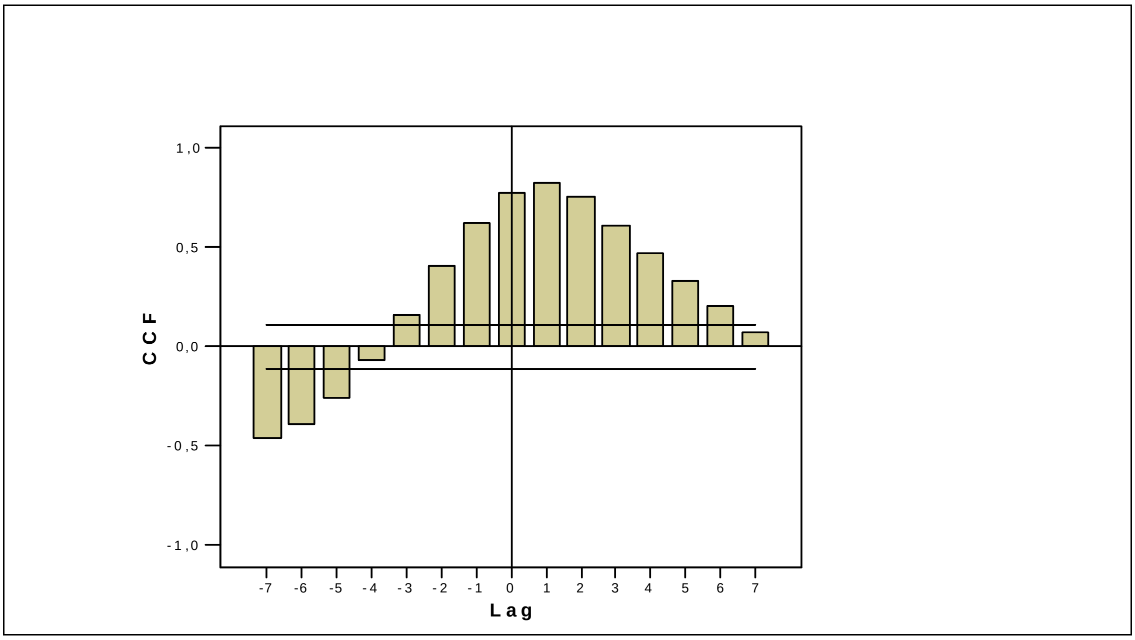
Independent variables	Coefficient	Std. Error	t-Statistics	Prob.
Constant	43.44024	1.058767	41.02909	0
ID (international departing flights)	0.816153	0.360346	2.264918	0.0242
ID^2	-0.083624	0.039425	-2.121103	0.0347
ID^3	0.002819	0.001258	2.240915	0.0257
Salary agreements (A)	2.467507	0.79483	3.104448	0.0021
Error model				
AR(1)	1.881043	0.017204	109.3379	0
AR(2)	-0.952404	0.017123	-55.62005	0
MA(1)	-0.489132	0.052965	-9.235089	0
MA(2)	-0.44419	0.052275	-8.497205	0
Adjusted R^2	0.951678			
Akaike information criterion	6.470083			
Schwarz criterion	6.572779			
Durbin-Watson statistics	2.00236			
Source: Own estimations.				

Figure 1
Sequential diagram and scatterplot for scheduled staff in passenger services and total number of aircraft movements



Source: Own estimations.

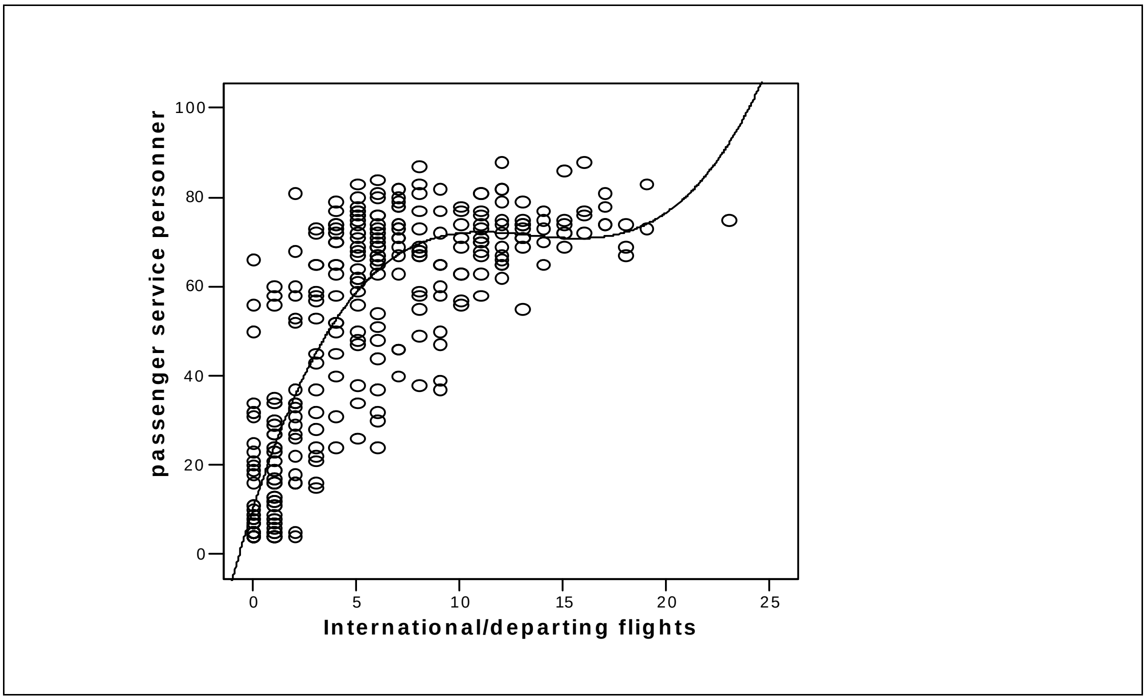
Figure 2
Cross-correlogram for scheduled staff in passenger services against all aircraft movements



CCF: Cross-correlation function.

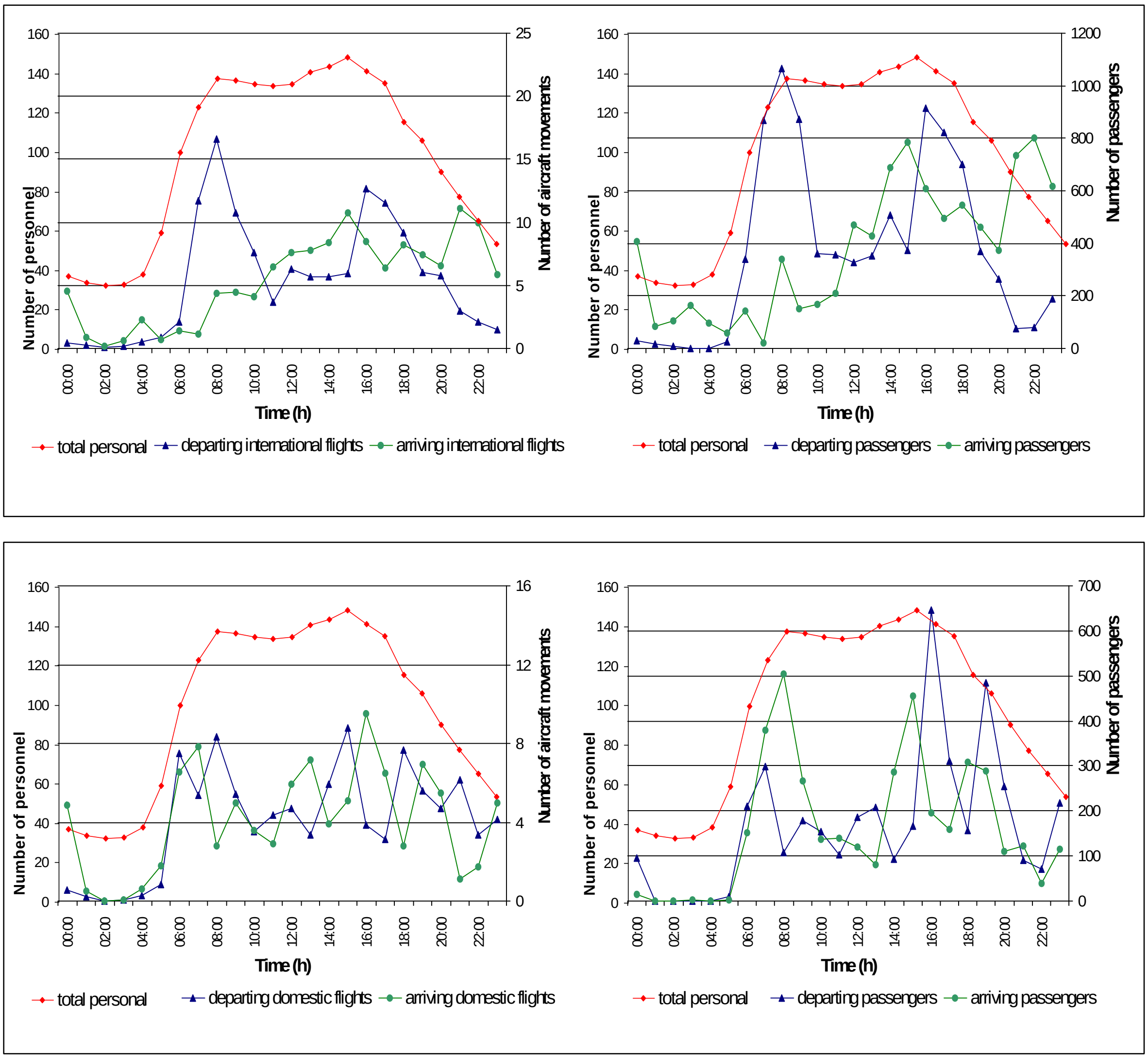
Source: Own estimations.

Figure 3
Scatterplot for scheduled staff in passenger services versus number of international departing flights



Source: Own estimations.

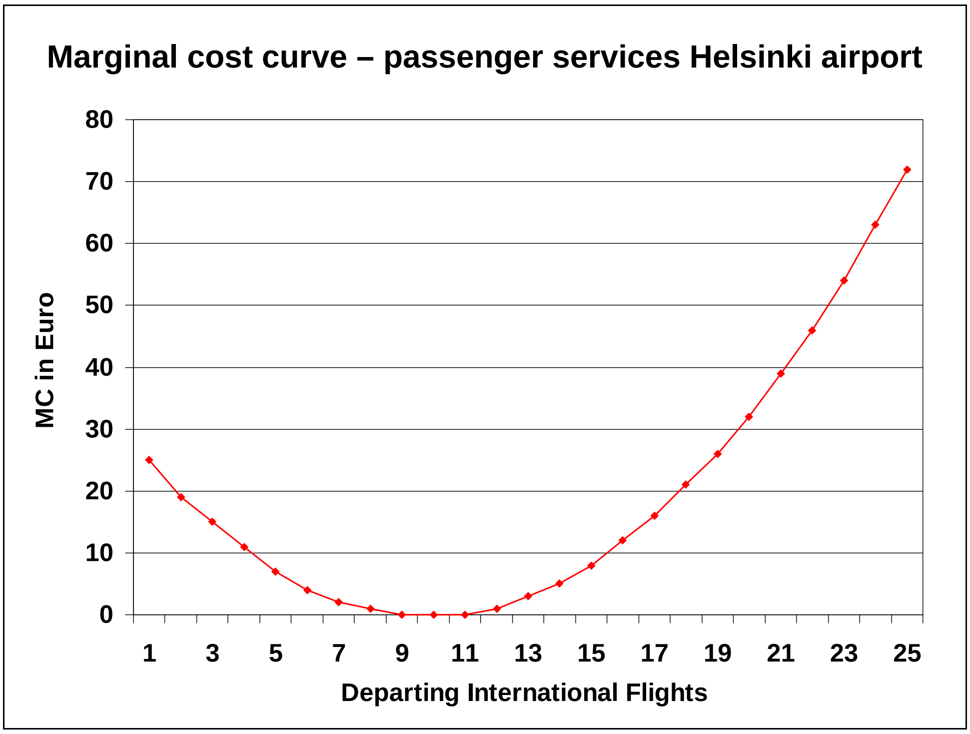
Figure 4
Average number of flights and airport personnel per hour at Helsinki-aircrafts Vantaa airport[1)]



[1)] Collected during 05/02 – 11/02 2000 and 28/05 – 03/06 2000.

Source: Own estimations.

Figure 5
Marginal cost curve for staff costs in passenger services per international departure



Source: Own estimations.