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UNIfication of accounts and marginal costs for Transport Efficiency

Annex A5

Deliverable 10: Infrastructure Cost Case Studies

Case study 5e: Helsinki-Vantaa Airport

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Helsinki-Vantaa Airport – Infrastructure Costs Case Study

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Executive Summary

The UNITE project is designed to support policy-makers in the development of pricing and taxation policies for the transport sector. The Helsinki-Vantaa Airport Case Study is one of the activities of the UNITE project. It aims to describe and analyse the cost structure of infrastructure services produced by Helsinki-Vantaa Airport and to derive short term marginal costs for these services.

Short term marginal costs include only those items that can be varied in the short term to meet changes in demand such as any additional costs of extra staff. Investment costs in additional facilities are excluded since new projects cannot be undertaken in the short term.

Airport services can be divided into aeronautical activities focusing on the operation of aircraft, and non-aeronautical activities connected to the movement of passengers and freight. Further categorisation is obtained in relation to customers and producers.

This case study is oriented towards infrastructure services. Other services - transport operator services, commercial services and public sector services – are ecluded. Also excluded are cargo services related to non-aeronautical activities, but services for freight flights on the aeronautical side are included.

The infrastructure services of air transport in Finland are mainly produced by the Finnish Civil Aviation Administration (CAA), which is the official Finnish aviation authority. The CAA is a governmental enterprise funded by its customers. Helsinki-Vantaa Airport is a financial unit of the CAA.

On an average day in 2000 at Helsinki-Vantaa airport there were almost 500 aircraft movements with 26 000 passengers. The airport was dominated by passenger aircraft used for scheduled flights.

The infrastructure services are divided into: Air Traffic Control, Manoeuvring Area, Apron Area, Passenger and Ground Transport Services. The three first belong to aeronautical services, the others to non-aeronautical services.

The approach for assessing short-term marginal costs in this case study is based on the cost allocation for different services and on comparing the number of personnel with the number of aircraft movements and the number of passengers.

The total operating costs for infrastructure services in the year 2000 in Helsinki-Vantaa airport were 44 million euros, excluding capital costs. The share of personnel costs of the total costs was 52 per cent. However, when adding the personnel costs of outside companies some 80 per cent of total costs can be estimated to be due to personnel costs.

The average number of scheduled person-hours per one aircraft movement was 5,3. In winter more person-hours are needed, because the Manoeuvring Area Services need more people for snow removal.

The total number of personnel follows an hourly pattern: very low occupancy during the night, rapid increase in the morning, rather stable occupancy during daytime and then straight reduction towards midnight. When considering different service categories, it can be noticed that on average all follow the same pattern except the Manoeuvring Area Services where the number of personnel decreases only very slightly during the night. Many more people work in Passenger Services than in any other service.

It was noticed that the number of personnel is, in principle, paralleling the number of aircraft movements and passengers. However, there were limits so that some minor changes could be neglected and the big ones paralleled in a slow fashion.

Models could be developed to estimate the number of personnel in infrastructure services with the aid of variables representing traffic volumes, extra salaries for evening and night work, and dummies for weekends and seasons.

Marginal costs - measured in person-hours – could be derived from the models**: an extra aircraft movement needs on average one person-hour more from the airport personnel.**

The above person-hours can be expressed also in monetary terms. However, it has to be noticed that the monetary values bring more uncertainties and so marginal costs expressed in person-hours should be preferred. The marginal costs can be estimated to € 38 for an extra aircraft movement.

However, the study left open what would be the best function form for describing the relationship between the number of personnel and the number of aircraft movements. In that way it is also open if any model can satisfactorily explain that relationship during every hour of a day. The above marginal cost can therefore be considered only as the best current estimate, which hopefully will be confirmed or changed through future research.

The derived results are, in principle, comparable with other middle-sized airports. However, it must be remembered that climatic conditions noticeably impact on costs and the used person-hours include both the airport's own and outsourced personnel.

1 Objectives

The UNITE project is designed to support policy-makers in the development of pricing and taxation policies for the transport sector (see Bossche et al., 2000). The Helsinki-Vantaa Airport Case Study is one of the activities of the UNITE project. It pursue the following objectives:

- describe and analyse the cost structure of infrastructure services produced by Helsinki-Vantaa Airport and
- derive short term marginal costs for these services.

Marginal cost studies about airport infrastructure services are very rare. For those that do exist very little data is revealed (cf. Doganis, 1996).

In section 2 cost categories and cost drivers in airport infrastructure services are presented according to a literature survey. Methodological issues and data requirements are discussed in section 3. The current operating and business environment of Helsinki-Vantaa airport is presented in section 4. Data on which the assessment of marginal costs will be based is described in section 5. The marginal costs of infrastructure services are assessed in section 6. Generalisation of the derived results is made in section 7 and, finally, conclusions are made in section 8.

2 Cost categories and cost drivers

2.1 Airport infrastructure services

Airports are complex systems where different actors - airport authorities, custom and security authorities, airlines, and other private companies - provide various services in order to facilitate, for both passengers and freight, the interchange between air and surface transport.

Airport services can be divided into aeronautical activities focusing on the operation of aircraft, and non-aeronautical activities connected to the movement of passengers and freight (see Table 1). Further categorisation is obtained in relation to customers and producers.

This case study is oriented towards infrastructure services. The other services - transport operator services, commercial services and public sector services – are excluded (cf. Table1). Also excluded are cargo services related to non-aeronautical activities. Services for freight flights on the aeronautical side are included.

2.2 Main cost categories

Airport infrastructure costs fall into two spatial categories: those related to the runway system and those associated with terminal buildings. The costs can, further on, be categorized according to provided services (see Table 1) and then linked to normal accounting categories - i.e. costs for personnel, material purchase, rents, municipal charges, maintenance and repair - detailed cost structures can be obtained (cf. Table 2).

Table 1. Airport services and their customers and producers

	Customer	Producer	Service Category
AERONAUTICAL SERVICES			
Terminal Air Traffic Control Services (pure infra)			
• 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 infra)			
• 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 infra)			
• 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 infra)			
• 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 infra)			
• 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 infra)			
• 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 and	AP,OC	IM	C
• VIP-services together with advertising and media services.	AP,OC	IM	C
Ground transport services (partly infra)			
• development and maintenance of terminal land side exit nad 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

2.3 Cost drivers

In principle it can be supposed that the costs related to the runway system are determined by the number of aircraft movements processed and the costs associated with terminal buildings depend on passenger and freight flows. Of course, there exists a close relationship between the number of aircraft movements and the passenger flows. As stated above services needed for the processing of freight flows are not considered in this study.

According to Doganis (1996) the proportion of international passengers within its total traffic has an important effect on an airport’s cost. International passengers need more terminal space and use more services, such as customs, sanitation, immigration, and waiting, than do domestic passengers.

According to Doganis (1996) the simplest way to measure labour inputs is to use the total number of employees. When comparing different airports with eachother the total number of employees may give wrong impressions if the share of full time, part time and temporary staff varies between airports. This problem can be relieved by using person-hours instead of the total number of employees. However, also person-hours can be defined in different ways: person-hours paid, scheduled or worked. The first one includes holidays, training, sick leave and other paid non-working time. The second one includes a part of training and sick leaves but not holidays. The last one indicates best the actual resources used but because it is difficult to measure accurately, it is not usually included in any statistics. In this study scheduled person-hours are used.

2.4 Measurements of traffic output

As stated above, major cost drivers could be measured in terms of numbers of aircraft movements handled (a movement is a landing or a departure) or the volumes of passengers embarked and disembarked. In theory it seems to be best to use the number of aircraft movements for aeronautical services and the number of passengers for non-aeronautical services (for service categories see Table 1).

The number of aircraft movements is an uncomplicated measure because all airplanes receive similar aeronautical services. The number of passengers is much more complicated. First there is the difference between domestic and international passengers. As stated above, international passengers require much more services than domestic ones. Secondly transfer or interline passengers are different compared to departing or arriving passengers. A transfer passenger is counted twice in airport traffic statistics but should only be regarded as one passenger when considering the use of passenger services.

According to Doganis (1996) very few airports are able to make even an approximate estimate of the cost of handling different types of passengers. As an exception he mentions BAA, which has used a marginal cost model. By indexing the costs associated with domestic passengers at 100 the BAA has found that costs related to international passengers range from 250 to 300 in the peak to just over half of these values at other times.

3 Methodological issues

3.1 The concept of marginal costs

In the UNITE project, marginal social cost is defined as the cost of an additional transport unit. Infrastructure capacity is assumed to be fixed, while the rolling stock may vary (see Bossche et al., 2000). In any airport the obvious transport unit is an airplane, which is either arriving to or departing from the airport.

Short-run marginal costs include only those items that can be varied in the short term to meet changes in demand such as any additional costs of extra staff. In a wider sense they may also include external marginal costs, such as congestion costs imposed by aircraft users on other airport users (see Betancor et al., 2001) or noise costs imposed on the surrounding community. Investment costs in additional facilities are excluded since new projects cannot be undertaken in the short term.

3.2 Approach

The approach for assessing short-term marginal costs in this case study is based on the cost allocation for different services, and on comparing the number of personnel with the number of aircraft movements and the number of passengers.

Cost allocation includes the identification of costs per service and per cost category. The availability of detailed cost data does not allow further allocation.

The comparison of the number of personnel is based on the concept that with increasing numbers of aircraft movements, and passengers, there is a need for more personnel. The quality of the results in this approach depends on the following two questions:

1) Can the number of the personnel providing services be linked to the number of aircraft movements/passengers, i.e. do they happen at the same time period?
2) Is it possible in practice to schedule staff according to the demand?

In this case study we have obtained detailed data on the number of personnel, which makes this approach pertinent.

4 Helsinki-Vantaa Airport characteristics

4.1 Administrative framework

The infrastructure services of air transport in Finland are mainly produced by the Finnish Civil Aviation Administration (CAA) which is the official Finnish aviation authority. CAA’s operational and profit objectives are set by the Finnish Government. The CAA is responsible for country’s air safety operations as well as air traffic policy, in conjunction with the Ministry of Transport and Communications and the Ministry of Foreign Affairs.

The CAA is a governmental enterprise funded by its customers. Although CAA’s responsibility includes the promotion of some social objectives, it aims to achieve business profitability. Despite its public ownership and some public operations, it is commercially oriented. The basic principles for pricing are set by the Government Enterprise Act. One of the principal strategies of the CAA is to develop and maintain the Finnish airport network as a single entity: traffic charges are mainly set on network level, not on single airport level.

Helsinki-Vantaa Airport is a financial unit of the CAA. The operational and profit targets are set by the CAA, who also retains a share out of the airport's profit. As the profitability is much higher at Helsinki-Vantaa airport than at the regional airports, the latter are subsidised by Helsinki-Vantaa.

CAA’s strong position in decision-making is not limited to financial flows because final investment decisions are also in the hands of the CAA. The role of the airport is to be an introducer and promoter of investment. However the airport has the freedom to decide on the use of operating expenditures as far as they are within the accepted budget.

4.2 The market situation

Helsinki-Vantaa airport is clearly the primary airport in Finland, handling some 90 per cent of all passenger traffic. As the Finnish population and business activity is concentrated in the Southern-Finland, and especially in the Helsinki Metropolitan Area, most international flights happens via Helsinki-Vantaa airport. At the same time it is the dominant departure and arrival point for domestic flights, as well as, for cargo. However since the 1980s Stockholm airport has emerged as a competitor and it has acquired a part of international traffic originating from Finnish airports outside Helsinki-Vantaa. The competition between these two airports is at the same time the competition between two airlines - Finnair and SAS (see also Himanen et al., 1995).

The number of airline passengers has grown rapidly at Helsinki-Vantaa airport during the past twenty years: the number of international passengers has more than trebled and the number of domestic passengers more than doubled (see Fig.1). The number of aircraft movements (Fig. 2) has increased somewhat slower than passenger throughput, indicating bigger airplanes and improved use of aircraft capacities. The drop off of passengers and aircraft movements observed in the early 1990s was due to an economic recession in Finland.

Figure 1. Domestic and international passengers at Helsinki-Vantaa Airport in 1980 –1999 (source: the Finnish Civil Aviation Administration)

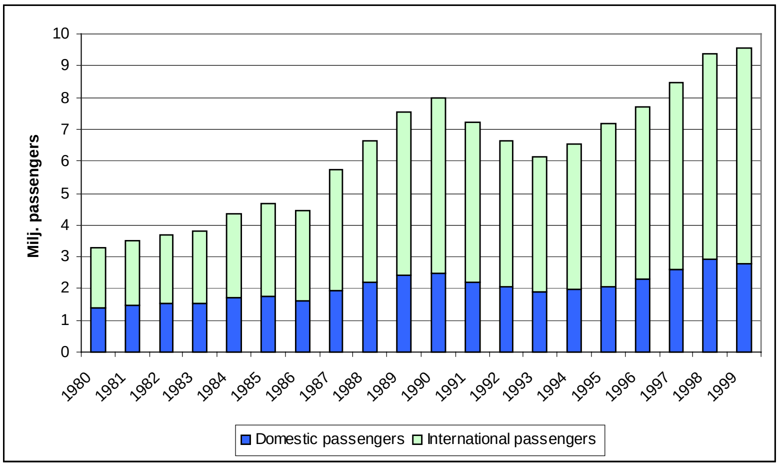
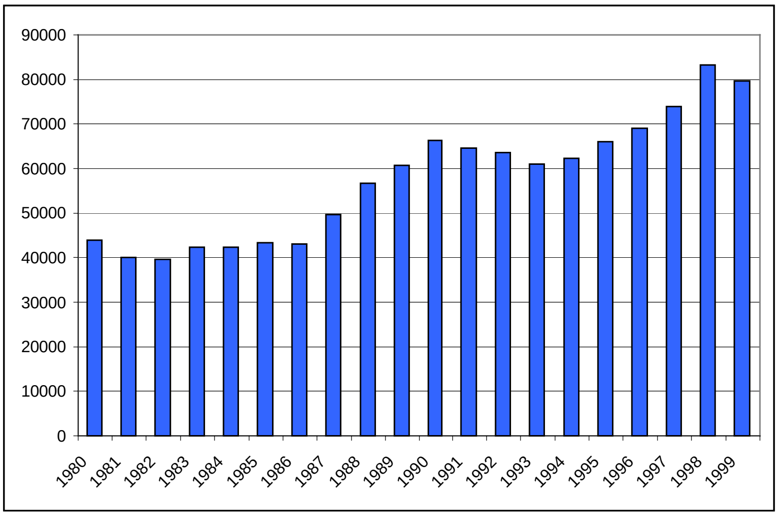


Figure 2. The number of aircraft movements at Helsinki-Vantaa Airport in 1980 –1999 (source: the Finnish Civil Aviation Administration)



Although Helsinki-Vantaa airport is a sovereign domestic hub airport, in international markets its position is more modest. According to the Airport Council International (ACI) its rank in Europe varies between 24th and 29th depending on the ranking measure. According to Graham (1998) Helsinki-Vantaa airport is classified as one of the fifteen European airports serving free-standing metropolitan regions. They are effectively interconnected with each other and to the five international hubs in Europe.

5 Data description

5.1 Cost data

The cost data used in this study includes the following elements:

- total costs for the year 2000 per service and cost category obtained in written form from the Finnish Civil Aviation Administration;
- detailed descriptions on the contents of cost categories obtained in interviews with the representatives of Helsinki-Vantaa airport;
- detailed schedules for staff use – including both the airport´s own staff and that of contractors - obtained from the representatives of Helsinki-Vantaa airport.

The total operating costs for infrastructure services at Helsinki-Vantaa airport were 44 million euros in the year 2000. Passenger Terminal Services´ share of the total costs was the biggest (see Table 2).

Table 2. Costs (in euros) of infrastructure services for the Finnish Civil Aviation Administration during the year 2000 at Helsinki-Vantaa airport

Services Cost categories	Air Traffic Control Services	Manoeuvr. 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 charg.	-3 795	-3 310 357	-262 683	35	170	-3 576 630	8
Repair/mainten.	-163 981	-480 435	-556 044	-4 149 302	-405 882	-5 755 643	13
Other	-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	**-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

Source: The Finnish Civil Aviation Administration

Personnel costs´ share of the total costs was 44 per cent (see Table 2). An especially high share – 71 per cent - for personnel costs was with respect to Air Traffic Control Services. Internal costs originated from the central administration and they included only personnel costs. When this is considered, the share of personnel costs can be estimated to 52 per cent. Other costs included services bought from outside companies. These services were provided by employees of outside companies working in the airport. When these people are also included at the airport work force the number of personnel is almost doubled (see Table 3). Air Traffic Control and Manoeuvring Area Services were the only service categories not using outside personnel.

Table 3. The average number of personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport

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

Source: The Finnish Civil Aviation Administration

As stated above, the share of personnel costs of the total costs was 52 per cent. However when the personnel costs of outside companies are included it is evident that actually some 80 per cent of total costs were due to personnel costs. Obviously costs for materials, rents and municipal charges – together 13 per cent – were non-personal costs. Also repair and maintenance costs and other costs included some non-personal costs. The high share of personnel costs makes our approach based on the comparison of the number of personnel with the number of aircraft movements and passengers most relevant.

According to Doganis (1996) labour costs represent on average 42 per cent of total airport costs in Western Europe. In a few cases labour costs may rise over 65 per cent of total costs depending on the airport authority's level of involvement in the provision of services. Capital costs- interest paid and depreciation - are on average 22 per cent of airport costs. Helsinki-Vantaa airport costs, detailed above, did not include capital costs. These should be considered when comparing the results with other airports. If capital costs are removed from the other airports´ costs, the above figures change: average from 42 to 54 and the highest from 65 to 83. Helsinki-Vantaa airport's figure of 52 is near the average and the other airport's highest figure 83 is of the same magnitude as that of Helsinki-Vantaa airport when all outsourced activities are included.

Personnel data

Helsinki-Vantaa airport is open for 24 hours per day, which makes it obligatory to have some 30 persons in work also during the night. The maximum number of personnel during the sample weeks was 173. This number included outsourced personnel also (see Table 4). In the winter more personnel is needed in the Manoeuvring Area Services because of possible snow removal.

Table 4. The minimum and maximum number of personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport

	Weekday		Saturday		Sunday	
	min	max	min	max	min	max
Winter	31	173	33	135	37	148
Summer	28	155	30	121	31	138

Source: The Finnish Civil Aviation Administration

5.2 Traffic data

The traffic data used in this study includes the following elements:

- the observed number of departing and arriving flights obtained from the representatives of Helsinki-Vantaa airport;
- the observed number of departing and arriving passengers obtained from the representatives of Helsinki-Vantaa airport.

The traffic volume data is for two sample weeks. The example weeks are chosen in a way that the one represents a winter season week (5-11.2.2000) and the other a summer season week (28.5.-3.6.2000). Actually the latter week includes a month end from May to June, when the number of aircraft movements goes down (cf. Table 6). These weeks correspond also with the data on staff use.

On an average day almost 26 000 passengers were using Helsinki-Vantaa airport. The airport was dominated by passenger aircraft used for scheduled flights (see Table 5). On an average day the number of freight flights was only 16.

Table 5. Average number of passengers and passenger aircraft movements per day during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport

	Passengers		Aircraft movements	
	Number	(%)	Number	(%)
Scheduled flights	22 781	88	393	86
Charter flights	3 044	12	29	6
Other	18	0	35	8
Total	**25 844**	**100**	**457**	**100**

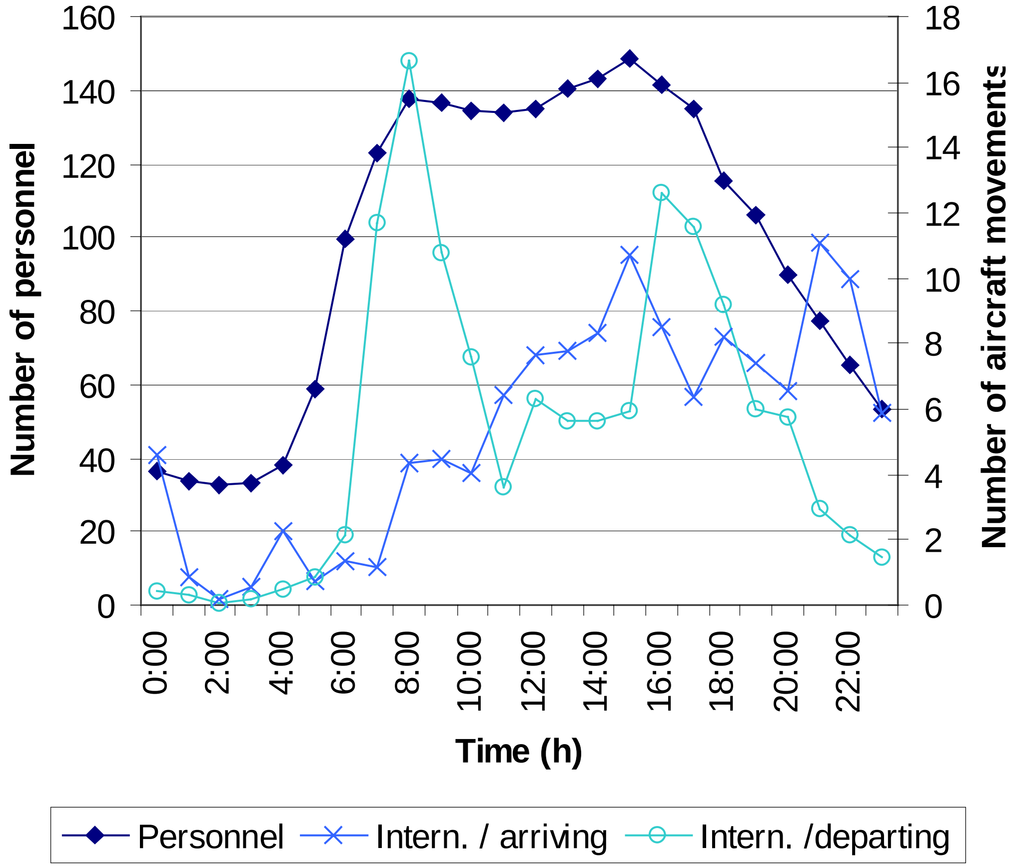
Source: The Finnish Civil Aviation Administration

Arriving and departing flights

There were two clear peaks for departing international flights, in the morning at hour 8[1] and in the afternoon at hour 16. Very few international flights arrived in the morning, and the two peaks were at hours 15 and 21 (see Fig. 3). These patterns were probably due to the peripheral location of Finland and the difference in time - one hour - compared to major destinations in the Western Europe.

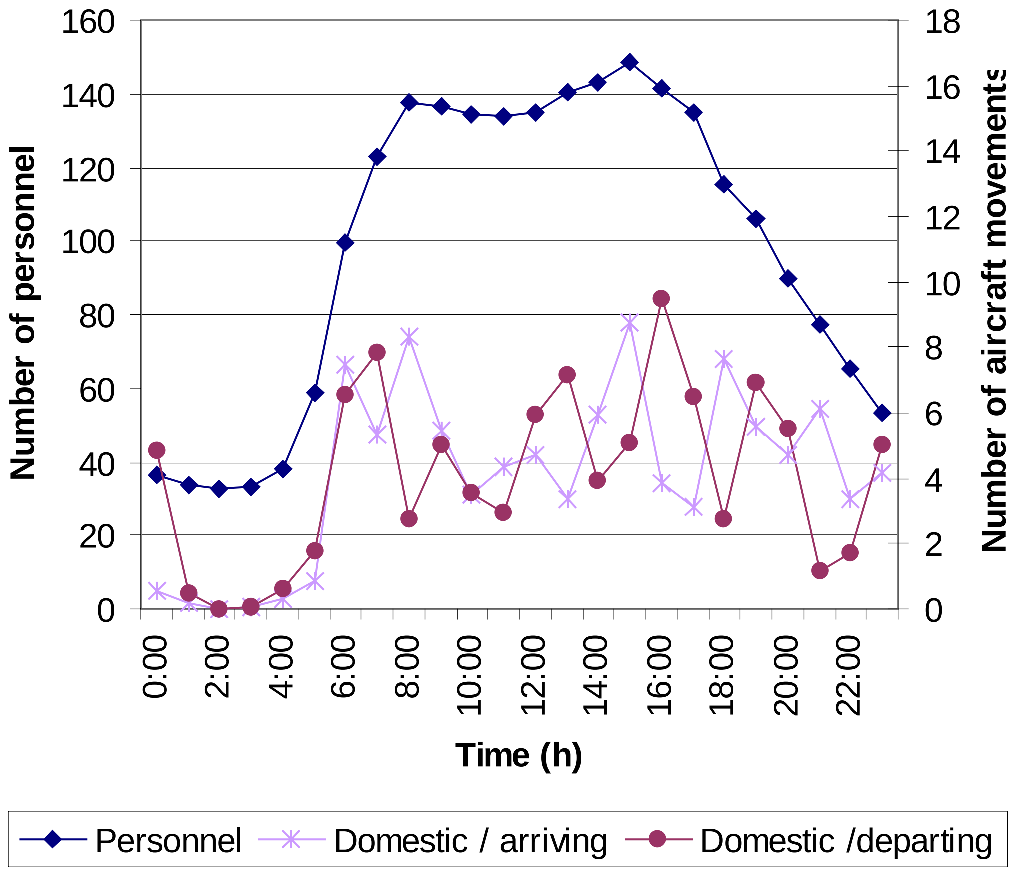
[1] Hour 8 means time from 8:00 to 8:59

Figure 3. The average number of international flights and airport personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



The hourly variation in the domestic traffic was more modest than in the international traffic. The other difference was that there are departing domestic flights also around midnight (see Fig. 4).

Figure 4. The average number of domestic flights and airport personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



Arriving and departing passengers

The variation of passenger flows follows that of aircraft movements. There was a clear peak for international passengers departing in the morning, and a next peak at hour 16. Very few international passengers arrived in the morning, and the two peaks were at hours 15 and 22 (see Fig. 5).

Hourly variation was much more peaked for domestic passengers than for domestic flights which means that there were large differences in the occupancy rates. Domestic passengers departing had peaks at hours 16 and 19. Domestic passengers arriving had peaks at hours 8 and 15 (see Fig. 6).

Figure 5. The average number of international passengers and airport personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)

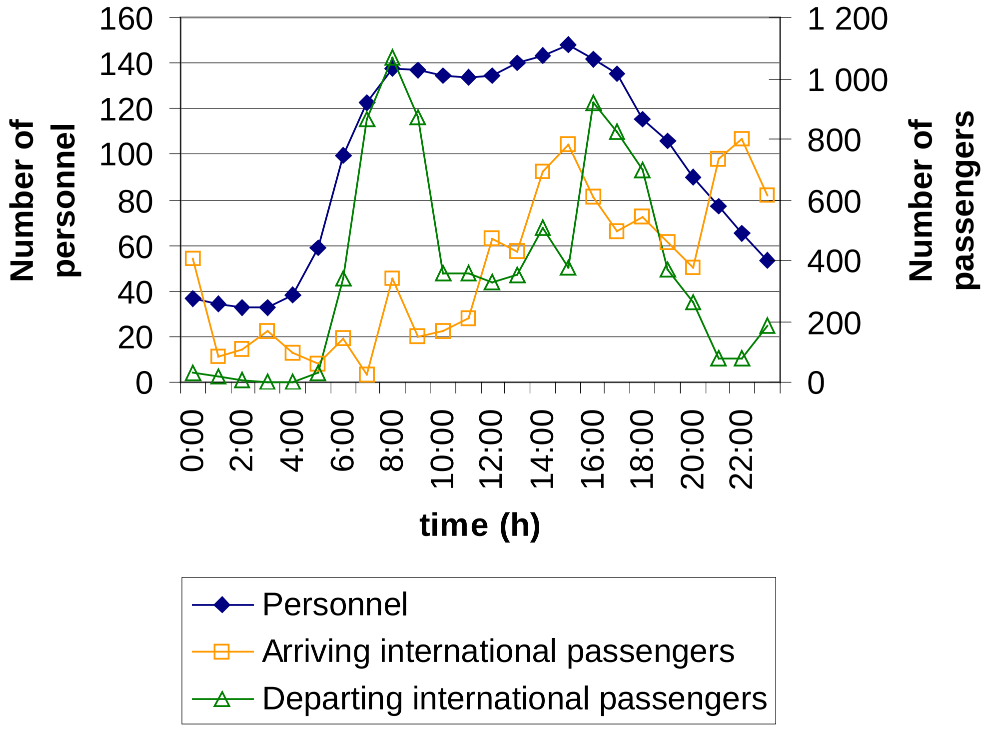
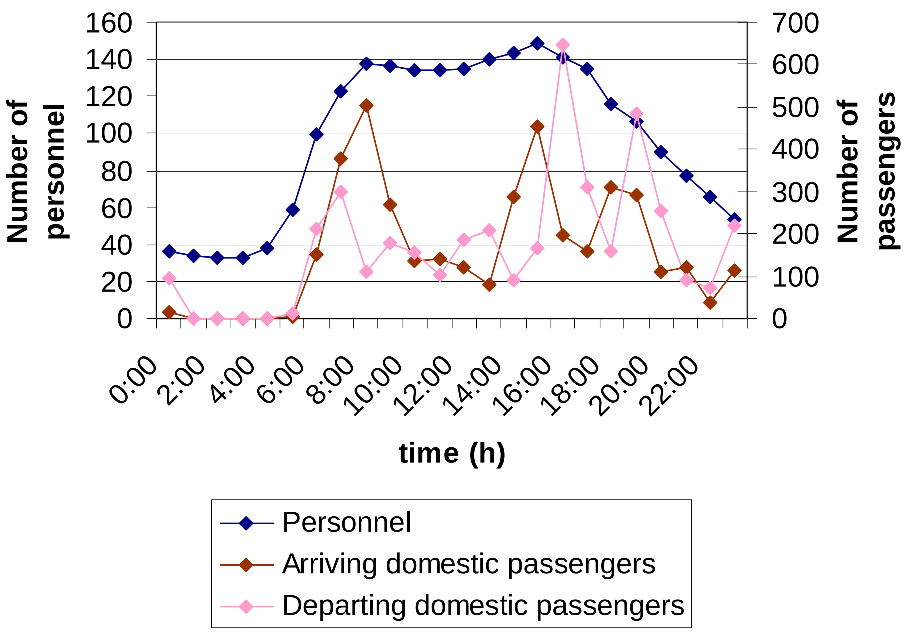


Figure 6. The average number of domestic passengers and airport personnel per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



5.3 Relationship between numbers of personnel and aircraft movements

Daily pattern

The average number of scheduled person hours per day was 2 522 in winter and 2 175 in summer. On weekends fewer person hours were scheduled than during weekdays, paralleling the number of aircraft movements (see Table 6).

The yearly scheduled person-hours in Helsinki-Vantaa airport can be estimated into 857 203 when multiplying the daily average (cf. Table 6) by 365.

The number of aircraft movements during February and May weekdays was usually over 500 but in June it dropped to below 400. On weekends the corresponding figure was always below 400 (see Table 6).

The average number of person-hours - 5,3 - per one aircraft movement varied daily between 4,0 and 6,9 during the sample weeks. The corresponding average figure - 0,1 person-hours per passenger - varied daily from 0,07 to 0,12 (see Table 6). In winter more person-hours were needed because of possible snow removal.

During weekends there have been higher numbers of personnel per an aircraft movement. However per passenger the number of personnel has been on the average level. This means that the occupancy per flight is higher during weekends, probably due to charter flights.

It is obvious that, in principle, the number of personnel parallels the number of aircraft movements and passengers. However, this paralleling may have a limited manner - minor changes can be neglected and major changes followed slowly:

- on Monday 7.2.2000 the number of aircraft movements, as well as that of passengers, was low but the number of personnel stayed on a normal level resulting in the maximum number of personnel per a passenger and also a relatively high number of personnel per an aircraft movement;
- on Sunday 28.5.2000 the number of passengers was quite high but the number of personnel was not increased correspondingly, resulting in the lowest rate of personnel per passenger;
- in June, when aircraft movements and the number of passengers dropped, person-hours also went down. However the decline was not as great as the decline in aircraft movements and the number of passengers.

Table 6. Scheduled person-hours, aircraft movements and passengers during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport

Date			Person-hours	Aircraft movements	Passengers	P-h/Am 1)	P-h/ Pass 2)
Winter	**Monday**	**7.2.2000**	2 626	485	22 651	5,4	0,12
	Tuesday	**8.2.2000**	2 525	515	25 386	4,9	0,10
	Wednesday	**9.2.2000**	2 593	510	25 673	5,1	0,10
	Thursday	**10.2.2000**	2 638	541	28 738	4,9	0,09
	Friday	**11.2.2000**	2 672	525	30 386	5,1	0,09
	Saturday	**5.2.2000**	2 203	356	21 155	6,2	0,10
	Sunday	**6.2.2000**	2 398	347	26 000	6,9	0,09
	Average		**2 522**	**468**	**25 713**	**5,5**	**0,10**
Summer	**Monday**	**29.5.2000**	2 237	557	28 817	4,0	0,08
	Tuesday	**30.5.2000**	2 253	546	29 116	4,1	0,08
	Wednesday	**31.5.2000**	2 362	542	29 198	4,4	0,08
	Thursday	**1.6.2000**	2 136	355	20 807	6,0	0,10
	Friday	**2.6.2000**	2 235	379	20 594	5,9	0,11
	Saturday	**3.6.2000**	1 934	345	23 660	5,6	0,08
	Sunday	**28.5.2000**	2 069	371	29 235	5,6	0,07
	Average		**2 175**	**442**	**25 918**	**5,1**	**0,09**

Source: The Finnish Civil Aviation Administration

1) P-h/Am means scheduled person-hours per an aircraft movement
2) P-h/Pass means scheduled person hours per a passenger

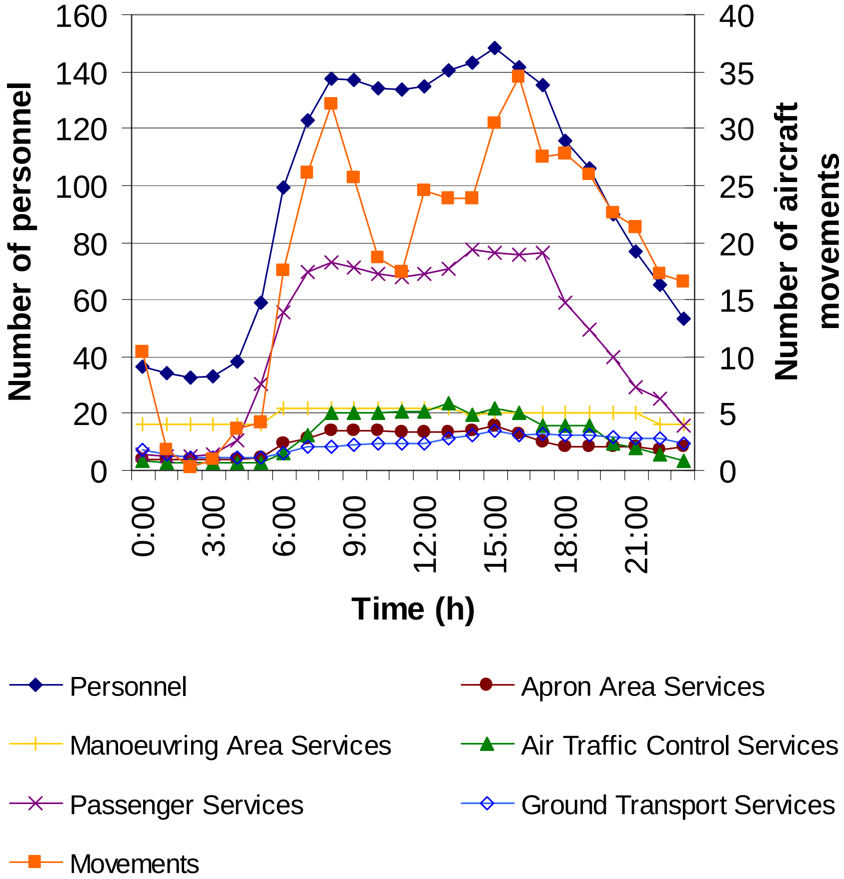
Hourly pattern

The total number of personnel follows an hourly pattern: very low occupancy during the night, rapid increase in the morning, stable occupancy during daytime, and straight reduction towards midnight (see also Fig. 7). When considering different service categories, it can be noticeable that all on average follow the same pattern, except the Manoeuvring Area Services where the number of personnel only very slightly decreases during the night. It differs also from other services with a strong seasonal variation. In winter season 18 - 33 persons were scheduled per hour for Manoeuvring Services, but in summer season only 13. As was discussed above (Table 3), many more people work in Passenger Services than in the other services.

The number of personnel parallels the number of aircraft movements quite well for most of the time also when considering the hourly variation (see Fig. 7). However, between morning and afternoon peaks this paralleling is limited:

- during the late morning the number of aircraft movements drops heavily, but only a very small decrease can be seen in the number of personnel; and
- only a minor increase in the number of personnel can be seen before the heavy peak in the afternoon.

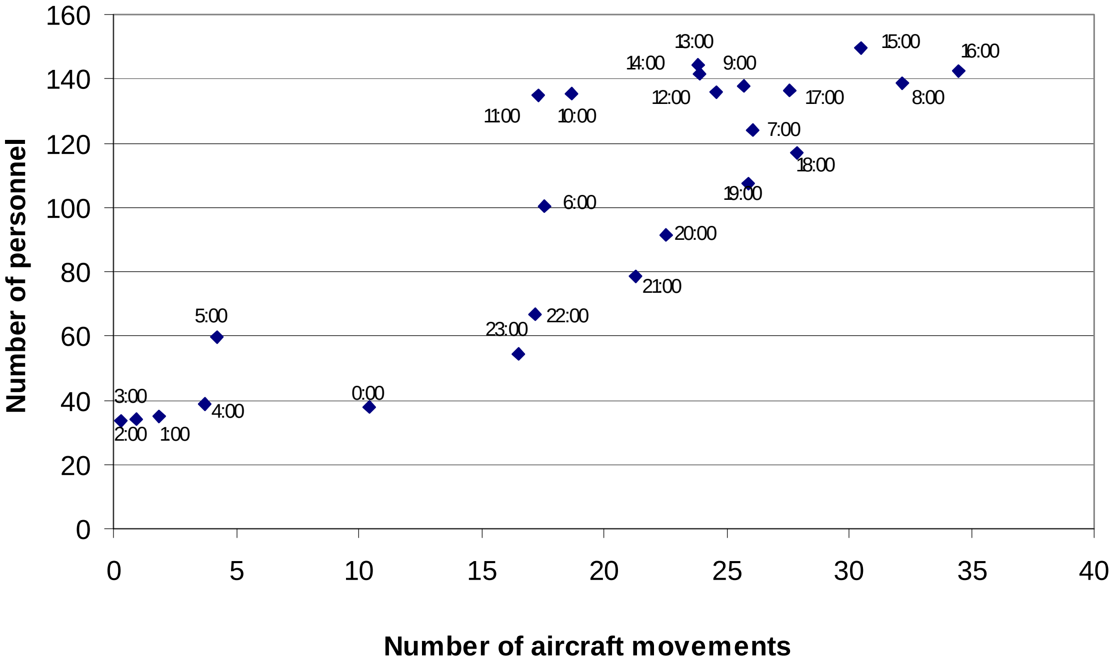
Figure 7. Average hourly number of personnel per service and aircraft movements during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



An average day can be divided into seven periods each with special characteristics when regarding the numbers of personnel and aircraft movements (see also Fig. 8):

1) during the night (hours 1-4) there were on average less than 5 aircraft movements per hour handled by fewer than 40 persons;
2) the early morning (hours 5 and 6) was a transmission period between night and morning peak when the number of aircraft movements, and the personnel, started to increase;
3) during the morning peak (hours 7, 8, 9) about 30 aircraft movements per hour were handled by almost 140 persons;
4) traffic declined during the next two hours (hours 10 and 11) and there were fewer than 20 aircraft movements per hour handled by almost the maximum staff;
5) during next three hours (hours 12, 13 and 14) on average 24 aircraft movements per hour were handled by 140 persons;
6) during the afternoon peak (hours 15, 16, 17 and 18) a maximum of 35 aircraft movements per hour was reached at hour 16, but the number of personnel reached a maximum level at hour 15 and then started to decline;
7) in the remaining six hours (19, 20, 21, 22, 23 and 00) traffic went down and the number of personnel decreased correspondingly.

Figure 8. Average number of personnel and aircraft movements per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



Stability of the relationship

As has been stated, the number of personnel parallels, in principle, the number of aircraft movements. However, this paralleling may happen in a limited manner. The major reason behind this can be traced to the inflexibility of agreed working times. All employees work for continuous periods – from six to twelve hours - per day. This means that even though the aircraft movements are low during the mid-day the number of employees can be diminished only marginally. Another reason for the high number of personnel during mid-day is related to extra salaries attached to hours outside of normal working hours. That is why it is cheaper to do all work which can be done during normal working hours.

Because people have permanent contracts, their daily numbers cannot be changed very much. This can be seen in relatively small drop in the number of personnel from May to June despite a large drop in the number of aircraft movements (cf. Table 6).

Some flexibility can be obtained by utilising overtime. Additional flexibility is obtained through seasonal variations in the work force. During the winter the need for more staff is arranged through a group of employees who are willing to work half year at the airport and half year elsewhere. The remaining necessary flexibility comes from variations in levels of service, which is demonstrated, for example, in different lengths of passenger queues during a day.

Even though there are limits – described above - in the flexibility for the number of personnel to parallel the number of aircraft movements, there is a clear tendency that as aircraft movements increase the number of personnel will also increase. This tendency can be clearly seen from the average data in Figures 7 and 8 above, and also from Figures 9 -11 presenting all available observations.

Figure 9. The numbers of personnel and aircraft movements per hour during 5-11.2.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)

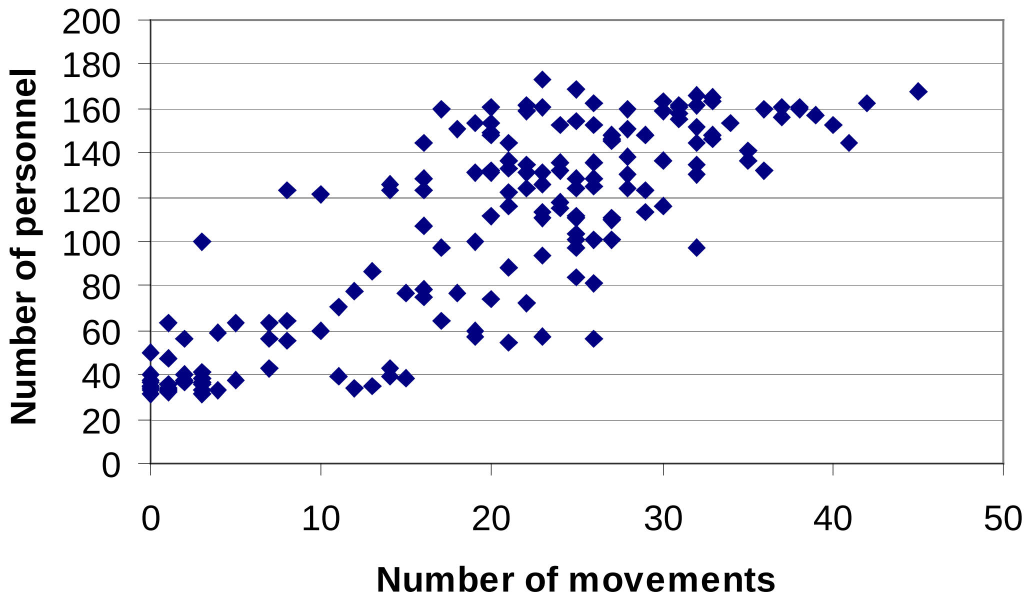


Figure 10. The numbers of personnel and aircraft movements per hour 28.5.-3.6.2000 in Helsinki-Vantaa airport
(*Source: The Finnish Civil Aviation Administration)*

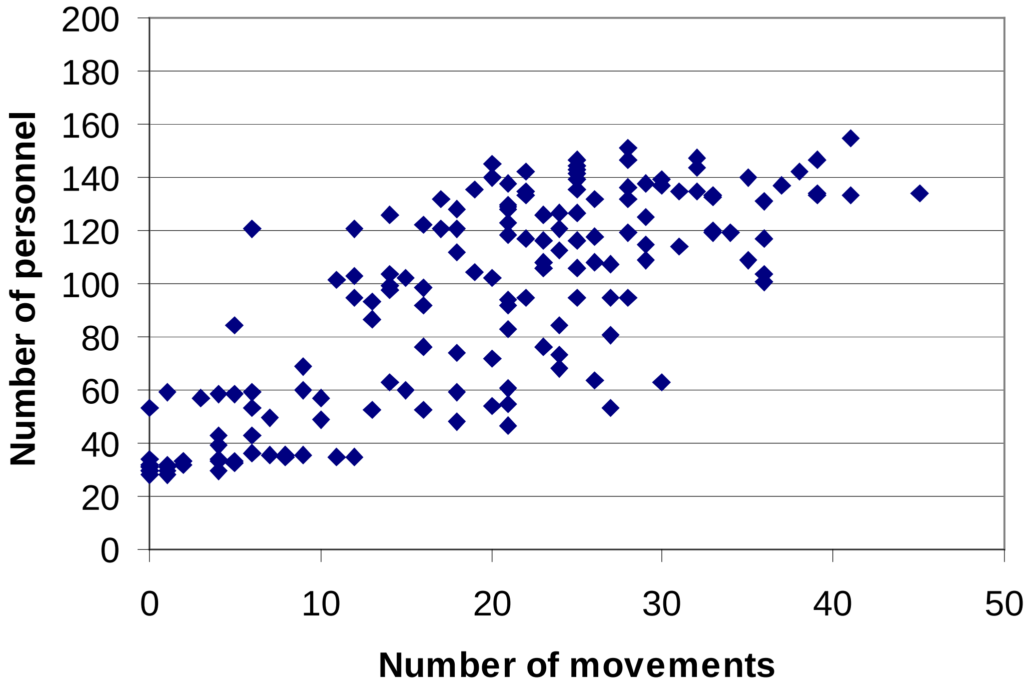
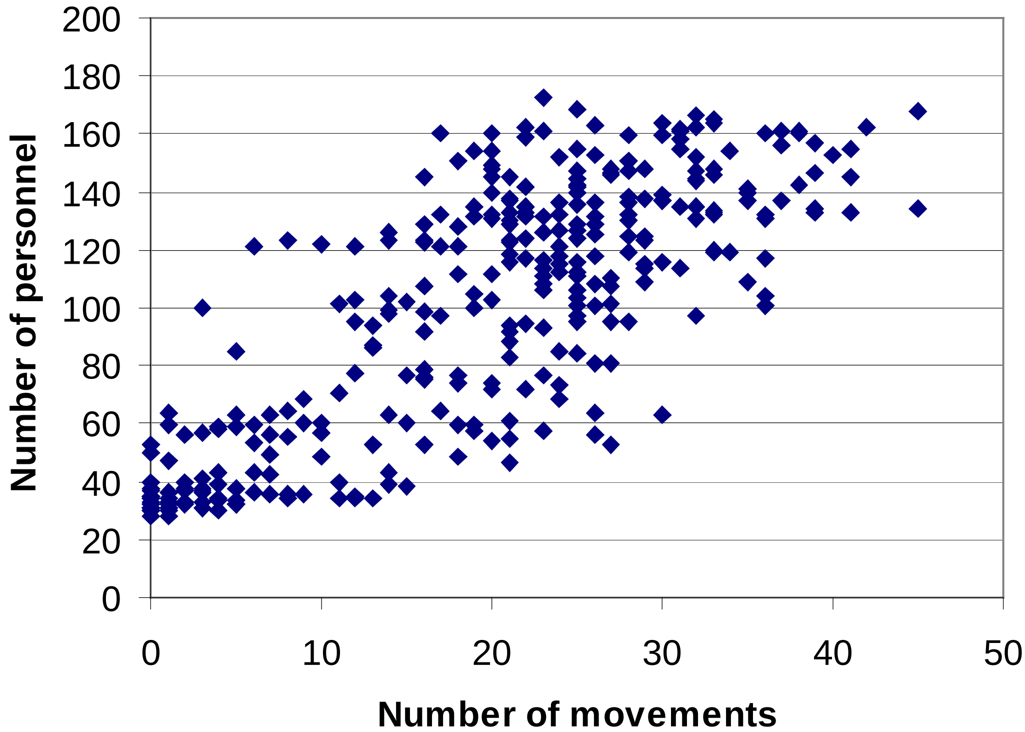


Figure 11. The numbers of personnel and aircraft movements per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport
(Source: The Finnish Civil Aviation Administration)



6 Quantification of marginal costs

6.1 Correlations

As stated above (see section 3.2) the chosen approach for assessing short-term marginal costs is based both on cost allocation and on comparing the number of staff with the number of aircraft movements. The results from chapter 5 show the approach to be very relevant when some 80 per cent of total costs are related to personnel and the number of personnel followed - even though in a limited manner - the number of aircraft movements.

A correlation matrix (see Table 7) provides information on the relationship between the number of personnel per service and the number of aircraft movements/passengers:

- The number of **total personnel** had highest correlation (0,81) with the number of passenger aircraft movements and almost as high (0,80) with the number of aircraft movements. Correlations with the number of aircraft movements were higher than with the number of passengers. Correlations with the number of international aircraft movements were higher than with the domestic movements.
- The number of **personnel in the Traffic Control Services** had highest correlation (0,71) with the number of aircraft movements, as could be expected, and almost as high (0,70) with the number of passenger aircraft movements.
- The number of **personnel in the Manoeuvring Area Services** did not have high correlation with the number of aircraft movements nor with the number of passengers. This is an obvious result when remembering that these services do not follow traffic, because they keep the runways open all the time (see section 5.3).
- The number of **personnel in the Apron Area Services** had highest correlation (0,75) with the number of aircraft movements, as could be expected.
- The number of **personnel in the Passenger Services** had highest correlation (0,78) with the number of passenger aircraft movements and almost as high (0,77) with the number of aircraft movements. Correlations with the number of aircraft movements were higher than with the number of passengers, which is somewhat difficult to understand. As stated above (section 2.3) it could be natural that the number of passengers is a cost driver for non-aeronautical services. One explanation can be that the amount of personnel is scheduled according to the scheduled number of aircraft movements. The number of passengers cannot be known exactly beforehand. However, it was noticed (see section 5.2) that the higher occupancy during weekends did influence the number of scheduled personnel.
- The number of **personnel in the Ground Transport Services** had highest correlation (0,71) with the number of arriving international aircraft. However, the correlation (0,67) with the number of passenger aircraft movements and (0,66) with the number of aircraft movements was not much lower. Again correlations with the number of aircraft movements were higher than with the number of passengers. Probably the same explanation as above can be given. The Ground Transport Services differs from all other services in that its correlation with arriving flights is higher than with departing. Also the difference in the correlation with international and domestic flights is higher than in the other services.

Table 7. Correlation between the number of personnel per service and the number of aircraft movements/passengers per hour during 5-11.2.2000 and 28.5.-3.6.2000 in Helsinki-Vantaa airport

	The number of personnel in					
The number of	All services	Traffic Control Services	Manoeuvring 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 aircraft	0,62	0,58	0,20	0,63	0,56	0,68
Departing aircraft	0,76	0,64	0,24	0,66	0,77	0,47
International aircraft	0,77	0,70	0,17	0,69	0,75	0,68
Domestic aircraft	0,68	0,58	0,31	0,66	0,65	0,49
Domestic/ arriving aircraft	0,60	0,51	0,28	0,62	0,56	0,44
Domestic /departing aircraft	0,54	0,46	0,23	0,49	0,53	0,38
International/ arriving aircraft	0,47	0,49	0,08	0,47	0,40	0,71
International/ departing aircraft	0,73	0,62	0,18	0,62	0,75	0,42
Passengers	**0,69**	**0,56**	**0,15**	**0,59**	**0,69**	**0,61**
Arriving domestic passengers	0,61	0,52	0,29	0,60	0,57	0,40
Departing domestic passengers	0,47	0,38	0,23	0,37	0,44	0,43
Arriving international passengers	0,21	0,17	-0,08	0,21	0,19	0,52
Departing international passengers	0,64	0,50	0,11	0,52	0,70	0,34

Source: JP-Transplan Ltd

As can be seen from table 7 there are numerous alternatives for the presentation of traffic volumes as well as that of passenger volumes. In the following modelling exercises the number of aircraft movements has been used as an independent variable. It has high correlations with number of personnel in all services. It is also a simple measure which will aid the transferability of the results. As an alternative, models will also be developed with the number of passengers as an independent variable, even though correlations coefficients in this case are much lower. However, the results may have value for possible comparisons between airports.

6.2 Modelling principles

Based on examinations developed in chapter 5.3, it was decided to model the hourly number of personnel by using as independent variables traffic volumes, extra salaries for evening and night, and dummies for weekends and seasons (see Equation1).

$$P_t=g(V_t, A_t, W_t, S_t, \varepsilon_t)=g(x_t, \varepsilon_t) \qquad \textbf{\textit{Equation 1}}$$

Where
P is the number of personnel,
t is time represented by an hour,
V is traffic volume,
A is a categorical variable for additional salaries paid for evening and night work,
W is a dummy variable for weekends,
S is a seasonal dummy for winter and summer week and
g is unknown functional form.

In each service and even within the same service, there are different kind of agreements on extra salaries for evening and night work. Variable **A** summarizes this information into three categories. During daytime (8.00-16.00) there are normally no extra salaries (**A** gets value zero). During early morning 6.00-7.00 and evening 17.00-21.00 some extra salaries are paid (**A** gets value one) and during night 22.00-5.00 even higher additional salaries are paid (**A** has value two).

Extra salaries and possible other characteristics of weekends are described by a dummy variable **W**. On working days from Monday to Friday **W** gets value zero and on Saturdays and Sundays **W** gets value one.

Seasonal dummy **S** has value zero in winter and value one in summer.

6.3 Linear models

In this stage the relationship between the number of personnel and its explanatory variables (**g**) is assumed to be linear. In this way the above equation can be expressed as follows:

$$P_t=\alpha_t+\ \beta_1 V_t+\beta_2 A_t+\beta_3 W_t+\beta_4 S_t+\varepsilon_t \qquad \textit{Equation 2}$$

In the following regression models are made for the number of personnel in all services, and also separately in each service. The variables used in estimations are summarized in table 8. On the independent variable side the traffic volume (V) is indicated by the number of aircraft movements or by the number of passengers (for basic data on variables see Table 8).

Table 8. Description of data: Means, standard deviations minimum and maximum values of variables (N=336)

Variable			Mean	Std. Dev	Min	Max
Number of Personnel in	All services	P_1	97.9	44.0	28	173
	Traffic Control Services	P_2	12.4	9.0	1	38
	Manoeuvring Area Services	P_3	19.4	7.2	13	35
	Apron Area Services	P_4	9.5	4.5	3	21
	Passenger Services	P_5	47.3	27.7	4	88
	Ground Transport Services	P_6	9.2	3.5	3	19
Number of aircraft movements		V_1	19.0	11.4	0	45
Number of passengers		V_2	1076	752	0	3639
Additional		A	0.96	0.84	0	2
Weekends		W	0.29	0.45	0	1
Season		S	0.50	0.50	0	1

The correlations between the number of personnel and traffic volumes were discussed in section 6.1. Regarding the new variables, the most promising one seems to be A (see Table 9). On the other hand A correlates with the number of aircraft movements, and also with the number of passengers, which points to the danger of multicollinearity.

Variables W and S do not have high correlations with the number of personnel. The only exception is the correlation between S and the number of personnel in Maneuvering Area Services (for the seasonal character of Maneuvering Area Services see section 5.3).

9. Description of data: the correlation table

Variable		Number of aircraft movements	Number of passengers	Additio-nal	Week-ends	Season
Number of aircraft movements		1,00				
Number of passengers		0,86	1,00			
Additional		-0,68	-0,57	1,00		
Weekends		-0,23	-0,03	0,00	1,00	
Season		-0,05	0,01	0,00	0,00	1,00
Number of personnel in	All services	0,80	0,69	-0,90	-0,12	-0,16
	Traffic Control Services	0,71	0,56	-0,81	-0,27	0,03
	Maneuvering Area Services	0,28	0,15	-0,28	0,02	-0,88
	Apron Area Services	0,73	0,59	-0,83	-0,26	-0,16
	Passenger Services	0,78	0,69	-0,89	-0,05	-0,01
	Ground Transport Services	0,67	0,61	-0,51	-0,14	-0,01

Estimation results

The number of personnel in all services can well be estimated with model 1 - the derived R^2 value is some 90 per cent (see Table 10). When regarding each service separately (see models 2 - 6), lower, but still quite good fits were evident. An exception was Ground Transport Services, where R^2 value remains below 50 per cent.

The number of aircraft movements is highly statistically significant in all equations except in Manoeuvring Area Services, where the number of personnel is best predicted by the Season variable. This depends on the special character of this service as described above.

The Additional variable is also highly statistically significant in all other equations except in Ground Transport Services where it is also statistically significant but at a lower level.

The Weekends variable is statistically significant only in half of the equations.

The Season variable is statistically significant in Manoeuvring and Apron Area Services, which both are impacted upon by snow removal and slippery control in winter. Because of this impact, the Season variable is also statistically significant for all services.

When using the number of passengers instead of the number of aircraft movement as a variable, quite similar results are obtained (see Table 11). A major difference can be seen with the Weekends variable, which has more significance. This is probably connected to the higher occupancy of the aircraft during weekends (cf. section 5.2).

For reasons of comparison, models with only one variable - traffic volume - have also been estimated (see equations 7 and 14). It can be noticed that the β-coefficients are much higher than in the case with more variables, and the values for R^2 are much lower.

Table 10. Estimation results: traffic volume represented by the number of aircraft movements

Model no:	**Dependent variable**	**R^2**	**Number of aircraft movements**		**Additional**		**Weekends**		**Season**		**Constant**	
	number of personnel in	%	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)
1	All services	90,5	1,239	(13,14)	-35,72	(-28,7)	-4,25	(-2,44)	-13,07	(-8,76)	116,4	(36,7)
2	Traffic Control Services	76,1	0,1566	(5,10)	-7,31	(-18,0)	-4,55	(-8,04)	0,71	(1,47)	17,5	(16,8)
3	Maneuvering Area Services	85,6	0,0388	(2,03)	-2,01	(-8,03)	0,56	(1,61)	-12,65	(-42,1)	26,8	(41,9)
4	Apron Area Services	81,2	0,0903	(6,63)	-3,65	(-20,3)	-2,03	(-8,09)	-1,32	(-6,16)	12,6	(27,3)
5	Passenger Services	85,1	0,7773	(10,47)	-22,24	(-22,7)	1,78	(1,30)	0,45	(0,38)	53,1	(21,3)
6	Ground Transport Services	44,0	0,1761	(9,56)	-0,51	(-2,12)	-0,06	(-0,19)	-0,25	(-0,87)	6,6	(10,6)
7	All services	64,8	3,10	(24,8)	–		–		–		39,1	(14,1)

Table 11. Estimation results: traffic volume represented by the number of passengers

Model no:	**Dependent variable**	**R^2**	**Number of passengers**		**Additional**		**Weekends**		**Season**		**Constant**	
	number of personnel in	%	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)	β-coeff.	(t)
8	All services	89,6	0,0144	(11,4)	-39,80	(-35,2)	-10,83	(-6,29)	-14,55	(-9,35)	130,9	(52,5)
9	Traffic Control Services	74,1	0,0015	(3,66)	-8,01	(-22,3)	-5,40	(-9,89)	-0,40	(1,07)	19,8	(25,1)
10	Maneuvering Area Services	85,4	-0,00004	(-0,16)	-2,39	(-10,9)	0,34	(1,00)	-12,70	(-42,1)	28,0	(57,9)
11	Apron Area Services	80,5	0,0010	(5,48)	-3,99	(-25,0)	-2,51	(-10,4)	-1,43	(-6,55)	13,7	(39,1)
12	Passenger Services	85,0	0,0098	(10,3)	-24,40	(-28,5)	-2,32	(-1,78)	-0,48	(-0,41)	61,0	(32,4)
13	Ground Transport Services	42,6	0,0022	(9,02)	-1,04	(-4,88)	-0,99	(-3,05)	0,46	(-1,58)	8,5	(18,0)
14	All services	47,0	0,0401	(17,2)	–		–		–		54,8	(17,9)

Estimation tests

Regression analyses were executed by using Equation 2 above. The standard assumptions of ordinary least squares (OLS) method were then tested. The tests showed no significant level of heteroskedasticity or multicollinearity. However, there is a problem with autocorrelation. There exists positive autocorrelation of residuals of first order: Durbin-Watson was 1.445, e.g. $d < d_u$ (d_u = 1.59, d_o = 1.76 for m=4, n=336). This finding can be interpreted so that the above models are miss-specified.

In a second step a further analysis of autocorrelation of residuals was performed. An autoregressive model of first order was fitted. The lag 2 could also be considered, but seems to lie at the margin. - see the plots for the autocorrelation function and the partial autocorrelation function (Fig. 12).

The model for Y (With lag 1) would than have then the following form:

$$\begin{aligned} Y_t &= \beta_0 + \beta_1 x_t^{(1)} + \beta_2 x_t^{(2)} + \beta_3 x_t^{(3)} + \beta_4 x_t^{(4)} + \varepsilon_t \\ \varepsilon_t &= -0.276\varepsilon_{t-1} + A_t \qquad with \quad A_t : white\ noise. \end{aligned}$$

Equation 3

Linear model with lags

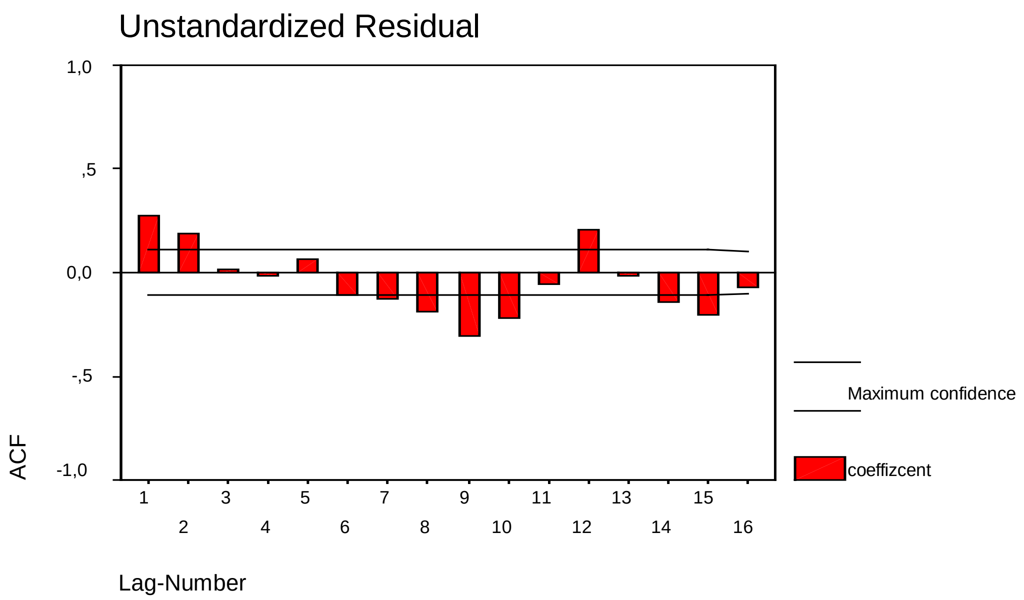
Starting from equation 3 new modelling - considering the correlated residuals - was done. A model with 2 lags proved to be the best while considering 3 lags for the error terms turns the weekend dummy to insignificance. When comparing the coefficients from model 1 (linear with 3 dummies) and from model 15 - the approach with correlated error terms (2 lags) - some changes can be noticed (see Table 12). The problem with interpreting the coefficients, however, is even more tricky than above since the correlated error terms depend also on the independent variables.

6.4 Functional form - non-linearity versus linearity

In search of the functional form some non-linear regression analyses were also performed. For all regression analyses with only one independent variable (without dummies) a non-linear (cubic) regression yielded a higher R-square than the linear (see Table 13). However, as soon as dummies (additional payments, weekend, season) are added to the linear regression then the linear approach contributes most to the explanation of labour costs, i.e. has the highest R-square. This result raises the following questions:

1. The question is whether the focus of our interest is; i) to explain as much as possible of variations in the labour costs, i.e. to achieve a high R-square, or ii) to find the “best” functional form (linear versus non-linear) for the relationship between airport costs and traffic volume. The functional form has a consequence for pricing: constant marginal costs versus non-constant. Ideally both would be good but obviously we have two alternative results: One with a high R-square and a linear form, another with a lower R-square and a non-linear form. The question - what is the “correct” or “best” model given UNITE´s aim to derive marginal costs for pricing - cannot be answered inside this study only.

Figure 52: Autocorrelation function and partial autocorrelation of unstandardised residuals



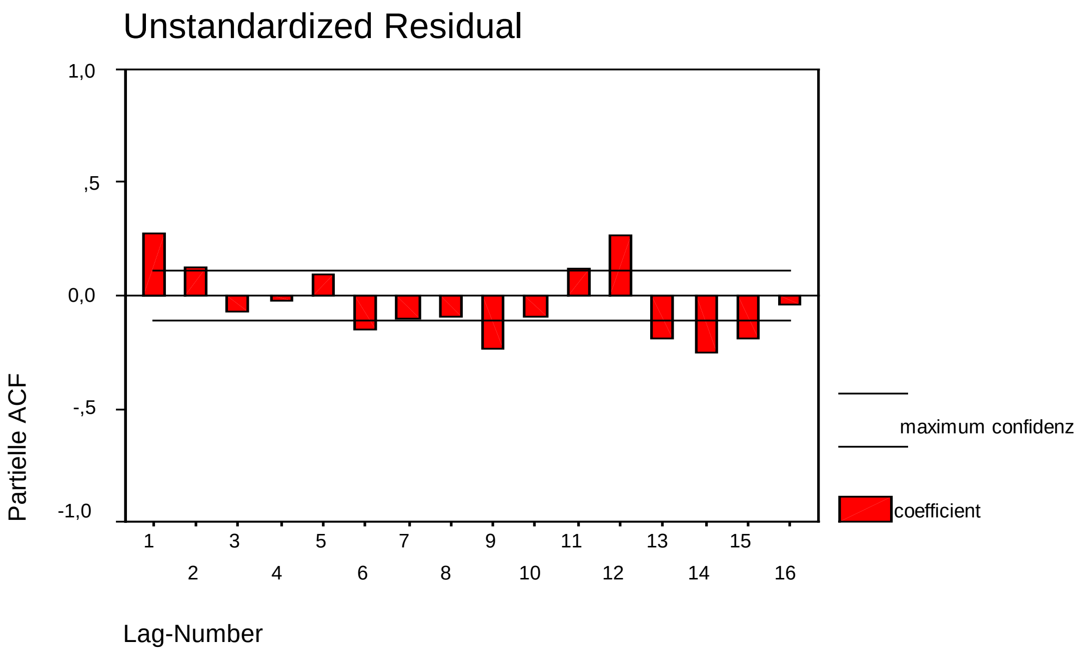


Table 12: Comparison of the linear model with dummies - with and without modelling of correlated error terms

	Coefficients	Standard deviation	t	Significance
1. Linear model with dummies (Model 1)				
Constant	116,437	3,176	36,659	,000
Number of aircraft movements	1,239	,094	13,145	,000
Additional Payments (0,1,2)	-35,720	1,244	-28,716	,000
Additional Season (0,1)	-13,071	1,492	-8,760	,000
Weekend dummy (0,1)	-4,247	1,738	-2,444	,015
2. Linear model with dummies and correlated error terms (lag 2) (Model 15)				
MA1	-,437	,0537	-8,145	0,000
MA2	-,344	,0555	-6,205	0,000
Number of aircraft movements (V10)	0,983	0,114	8,645	0,000
Additional Payments (A)	-31,140	1,648	-18,890	0,000
Additional Season (S)	-13,189	2,443	-5,399	0,000
Weekend dummy (W)	-5,256	2,684	-1,958	0,051
Constant	117,203	4,062	28,856	0,000

A dependent variable: the total number of personnel

Table 53. Different functional forms: R^2 -comparison of different regression models

Dependent variable number of personnel in	Independent variable	Linear	Linear with dummies	Squares	Cubic
All services	International departing flights	0,54	:	0,69	0,73
Passenger services	International departing flights	0,56	0,89	0,71	0,74
Passenger services	All departing flights	0,58	:	0,66	0,66

2. If we analyse our findings in detail we can see that the dummies add a lot to the higher R-square of the linear regression. If we only compare the "pure" approaches with only one independent variable then the cubic form fits best (see Table 13). The question is however, whether we needed to add the dummies simply because we had to cope with features of the data which were caused by the way data was collected (e. g. a summer and a winter week, collection of all

weekdays and weekend). It is possible that with other types of data (for example only collected in winter and only from Tuesday to Thursday) the need for dummies would be different. As stated above this question remains open in this study.

6. 5 Deriving marginal costs

The best model obtained was no:15 (Table 10). In it the relationship between the number of personnel and the explanatory variables was assumed to be linear and therefore a marginal cost is represented by a β-value for the number of aircraft movements. Therefore, it can be stated that **an extra aircraft movement needs on average one person-hour more from the airport personnel.**

The marginal costs can be expressed also in monetary terms. However, it should be noted that monetary values bring more uncertainties and so marginal costs expressed in person-hours should be preferred. In section 5.1 it was noticed that the total costs for infrastructure services were 44,4 million euros. Because rents and municipal charges cannot be influenced in the short term, and because the costs for the Manoeuvring Area Services are not related to the traffic volumes, they can be subtracted from the total costs and € 32,7 million are then left. Dividing this total by the yearly person-hours, 857 203, the average cost per person-hour – including also non-personnel costs – can be estimated at € 38, which represents then extra cost per an extra aircraft movement.

The above marginal cost for all services represents 19 per cent of the total costs - 5,3 person-hours per an aircraft movement (cf. section 5.3).

As noticed in section 5.3, a day can be divided into seven time periods with different relationships between the numbers of personnel and traffic volume. Because of that, it can be supposed that the marginal cost differs also between these periods. It remains open in this study, if it is possible to develop a model which could describe all these different relationships.

7 Transferability of the results

According to Doganis (1996) smaller airports - below three million annual passengers - have higher unit costs than bigger ones. From 3 million to 10 million annual passengers unit costs do not decrease much. Because Doganis´ data ends at 10 million we do not know the situation in very big airports. This means that the above results are relevant for most other airports, except the smallest ones and possibly the largest ones.

The second economic characteristic of airports according to Doganis (1996), is that major development programs push up unit costs. Many airports seem, these days, to be under rather continuous development. This is also the case in Helsinki-Vantaa airport there major construction of passenger terminals has just ended and the construction of the third runway is ongoing.

The share of international passengers has also importance in a comparison. As stated in sections 2.2 and 2.4, international passengers need more services than do domestic ones and are, therefore, more expensive. Any airport with a higher share of international passengers would also need more personnel, and vice versa (for the share of international passengers in Helsinki-Vantaa airport see section 4.2).

According to Doganis (1996) when comparing airports it is better to use person hours than staff costs. This is because staff costs will not only indicate the amount of labour resources being used, but will also reflect differences in the relative level of wages paid by different airports.

Unit costs at individual airports are influenced by a whole range of factors which will vary from country to country, and even between airports in the same country. One of the differences may arise on the scope of outsourcing. When comparing the above results with that of other airports it should be kept in mind that the person-hours from all outsourced activities are included (cf. section 5.1).

According to Doganis (1996) airport costs will also be affected by varying accounting procedures used in different countries. Depending on the type of ownership - public or private - public accounting procedures or commercial practices are used. The type of ownership may also have impact on depreciation matters. In this case it should be remembered that the airport authority in Finland acts as a commercial company. Possible differences between depreciation policies do not matter because capital costs are not included in above calculations.

Other comparability problems, according to Doganis (1996), are direct and indirect government subsidies, sources of finance, differences in design and service standards. Because the above costs of Helsinki-Vantaa airport do not include depreciation costs the possible subsidies and sources of finance do not matter. The possible differences in design and service standards are more difficult to define. When regarding service standards the following characteristics of Helsinki-Vantaa airport have to be considered:

- the airport is open for 24 hours per day;
- the general target in normal weather conditions is that not more than 2 per cent of flights are delayed because of airport services and the number of flights delayed over 15 minutes because of airport services is not more than 1 per cent of all flights (see Finnish Civil Aviation Administration, 2001);
- the target for snow removal is that a runway is always available for arriving/departing aircraft;
- during the six months of the year that extra personnel are needed for snow removal, extra costs are included.

8 Conclusions

The study has calculated short-term marginal costs: an extra aircraft movement needs on average one person-hour more from the airport personnel. If monetary values are required then the above person-hours ought to be multiplied by the average cost per person-hour – including also non-personnel costs - and the marginal costs of € 38 for an extra aircraft movement can be estimated. However, the study left open what would be the best function form for describing the relationship between the number of personnel and the number of aircraft movements. In that way it is also open if any model can satisfactorily explain that relationship during every hour of a day. The above marginal cost can therefore be considered only as the best current estimate, which hopefully will be confirmed or changed through future research.

It can be seen that the above marginal cost is 19 per cent of the total costs, which are 5,3 person-hours per an aircraft movement.

The questions posed in section 3.2 can be answered as follows:
1. It is obvious that the provision of services and aircraft movements do not always happen at the same time period - in this case at the same hour. In order to take account these differences Equation 18 includes time lags for two hours.
2. It was also noted that the number of personnel paralleled the number of aircraft movements/passengers – even though sometimes in a somewhat limited fashion (see section 5.3). Therefore it is obvious that the personnel can be scheduled - inside some limits - according to demand.

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