MODELLING OF PASSENGER MOVEMENT BEHAVIOUR ON LONG-HAUL FLIGHTS

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OVERVIEW

This study focuses on investigations and afterwards modelling of passenger movement behaviour on long-haul flights. For this investigation, a survey was conducted at Munich Airport 2005, where exclusively passengers had been interviewed after being on a long-haul flight. Based on a sample of 706 usable responses, movements were investigated regarding their reasons and durations. In the first analysis step, a detailed overview about movements onboard during long-haul flights will be given. In the second step -with statistical analysis- flight, cabin and passenger parameters had been checked against each other to identify which parameters influence individual passenger movement behaviour onboard. Summarizing, following parameters significantly influence individual movement behaviour:

- total flight time
- day-night-ratio
  - departure/arrival time and location
- number and relationship of disturbed passengers depending on:
  - number of adjacent seats
  - travel party size
  - load factor
- leg room space
  - cabin class and cabin layout
  - stored hand luggage under the seat

With the identification of significances, distributions were analysed in detail and with help of probability functions. These distributions were transformed into discrete mathematical formulations for future applications. The final result of this paper is the mathematical description between passenger movement behaviour and influencing parameters, which can be used for simulation applications and further investigations of different conventional and unconventional aircraft as well as cabin configurations in the future.

1. INTRODUCTION

To maintain competitive advantage it is vital for new aircraft standing at the beginning of a long life and product cycle to be as attractive as possible for the manufacturer, airlines and passengers over a maximum period of time. Moreover to make air transportation service economically feasible, one must understand to design the system to be attractive to the user community – being airlines or passengers. Regarding attractiveness, in today's long-haul aircraft cabins, up to 20%[8,9] of all passenger rated at their seats installed galleys and lavatories as a negative effect onto their well-being during flight, whereas 10%[8,9] of all passengers reported being disturbed by passenger movements and crowds close to installed cabin items like lavatories and galleys. In accordance to reduce these negative effects due to passenger movements in future aircraft cabins, this paper describes the investigation approach of these movements. Since the last years, a methodology for assessment of passenger´s acceptability regarding aircraft cabins has been developed. For the improvement and extension of this methodology, this paper presents investigations and analysis of passenger's movement behaviour on long-haul flights. Results of this paper will feed simulation models as well as developed assessment methodology to include effects of passenger movements in today's and future long-haul aircraft.

2. RESEARCH DESIGN AND METHODOLOGY

The scope of this study is the investigation of individual passenger movement behaviour during long-haul flights with the identification of dependencies between movement behaviour and passenger, flight and aircraft parameters. For that purpose, a quantitative survey at Munich International Airport as the second biggest airport in Germany, with 30.8 Mio passengers and 78 non-European destinations in 2006[1], was conducted. An anonymous, self-completion, 4-page questionnaire was designed to collect information from long-haul passengers at the baggage claim area in Terminal 1 and 2 at Munich International Airport. Exclusively long-haul passengers have been asked about their movement behaviour direct after being on a long-haul flight of at least 6h flight duration while they were waiting for their baggage. The survey was conducted on 14 different days (including a Saturday and Sunday) during August 2005, where overall 706 usable responses were collected.

2.1. Survey design

With the constraint of time for completion while waiting for the baggage, the questionnaire consisted of only 3 parts of 4 pages in total. In the first part, passengers were asked about their travel and flight details including among other things trip origin, travel purpose, travel party size, booked class, seat number and row. The second questionnaire part dealt with questions about personal movement behaviour during the prior undertaken long-haul flight including reasons why leaving the seat, total number of getting up from seats, number of disturbed seating neighbours, durations and questions about seat properties. The last part included all important socio-demographic questions for this scope like age, gender, nationality, body size and weight, occurrence of mobility problems, previous flight experiences (long-haul and short-haul).

3. SURVEY RESULTS – PASSENGER PROFILE

To ensure a representative sample, flight and socio-demographic details of the surveyed passengers will be analysed in the following subchapters in detail. No exact definition of a long-haul flight regarding flight durations or ranges of long-haul flights can be given[6]. This refers to geographical differences between Europe, North America, Asia or Australia. In these last three continents, short to medium haul flights would count in Europe as long-haul flights. Nevertheless, all interviewed passengers had been on intercontinental flights to Europe and hence long haul flights were here defined with more than 7 hours flight duration.

3.1. Flight details of surveyed passengers

Long-haul passengers from nine different airlines have been interviewed (7 full service carrier and 2 German charter airlines). Full service carriers were, beside the Lufthansa, United Airlines, US Airways, Air Canada, Qatar Airways, Thai Airways and Delta Airlines. The two German charter airlines were LTU and Condor.

Most of the passengers had been on flights from North America (68.7%) followed by flights from Asia (17.8%) and Africa (10.8%). The rest (2.6%) can be counted to South America (1.8%) and Middle East (0.8%).

The following figure shows the distribution of real flight durations including delays or earlier arrivals. More than one-third (34.6%) of all surveyed passengers had been on flights of a flight duration between 8-9 hours, whereas 48.2% of the passengers had been on flights with a flight duration of more than 9 hours.

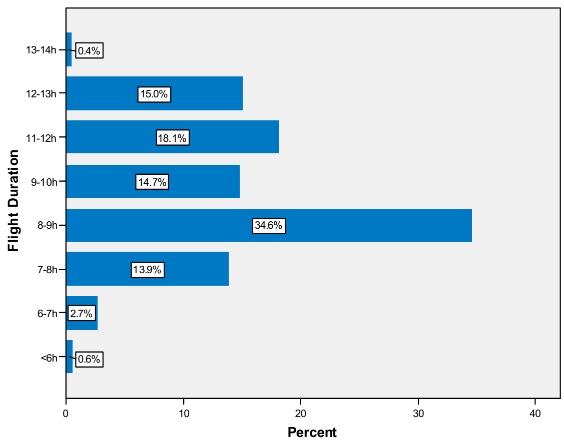

FIG 1. Flight duration distribution of surveyed passengers

Due to the circadian rhythm of each individual passenger, departure and arrival time have an influence onto passenger's movement behaviour. Hence, a day-night ratio R_{DN} has been calculated which describes the relationship between hours of daylight and total flight hours. Therefore, all flights were divided into five different categories in 0.25 steps ranging from a flight during day (R_{DN}=1) to a flight during night with a R_{DN}=0. This ratio depends on departures and arrival locations, dates and times and were calculated[2] for each flight. The result for all flights is shown below:

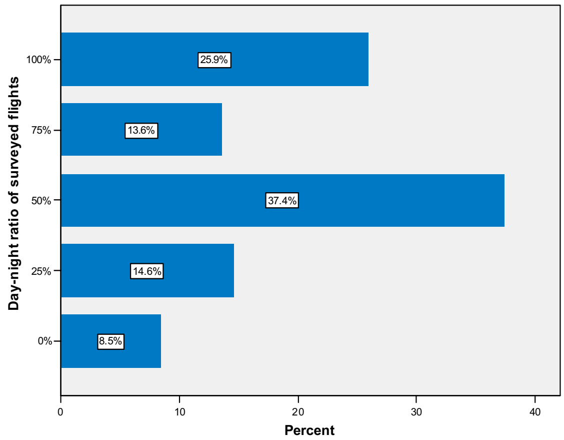

FIG 2. Day-night ratio distribution of surveyed flights

3.2. Socio-demographic analysis of surveyed passengers

The following socio demographic analysis deals with investigation and discussion of results regarding, age, travel purpose, nationality, gender, travel party size and anthropometrics. This analysis will be taken for further investigations to identify socio-demographic parameters having a significant influence onto passenger movement behaviour. On of the most important socio-demographic parameter is the age distribution of travellers. Figure 3 shows the age distribution of all surveyed passengers. The age profile of this survey was found to be similar to other statistics[3,4] with a mean age value of this sample of 35.6 years giving confidence in the veracity of the sample as being representative of long-haul passenger age distribution.

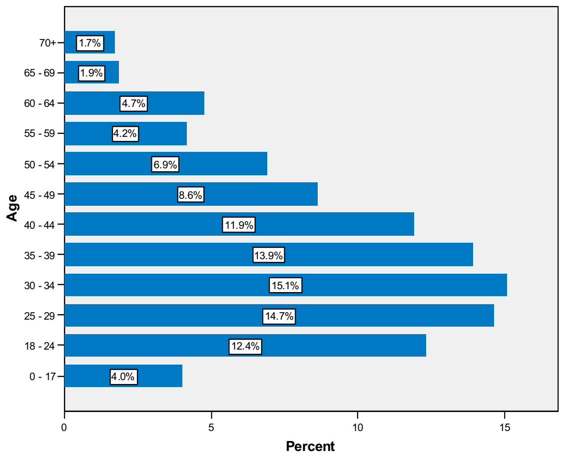

FIG3. Passenger profile-age distribution

Regarding the distribution of travel purpose, 78.7% of the surveyed passengers indicated travelling for private reasons, including holidays and VFR. Only 21.3% of the passengers marked travelling to Munich for business purposes. Comparing the percentage of private traveller (PT) with other references (e.g. PT=69%[5], PT=63%[4]) the proportion of private traveller is much higher. The reason for this higher proportion can be explained because of holiday period. As written above the survey was conducted during August 2005, especially between July to September, proportion of business travellers reaches its minimum where simultaneously the percentage of private traveller reaches its maximum[3].

According to gender distribution, 52.4% of all passengers were male, 47.6% female. Differences between gender distributions can also be seen in this sample. If travelling for business purposes, 64.4% were male, whereas if passengers were travelling for private reasons, the percentage of males drops down to 49.3%.

Most of the passengers, which have been interviewed, are Germans (51.5%), followed by Americans (24.6%), Canadians (8.7%), Austrians (3.1), Japanese (2.3%) and Thai (2%) and 7.7% with various nationalities.

The last property of the passenger's socio-demographic analysis is the investigation of travel party size. More detailed explained in 4.2, the number of passengers travelling together has an influence onto individual movement behaviour during long-haul flights. The total distribution of travel party sizes in dependency of travel purpose is shown in figure 4 below.

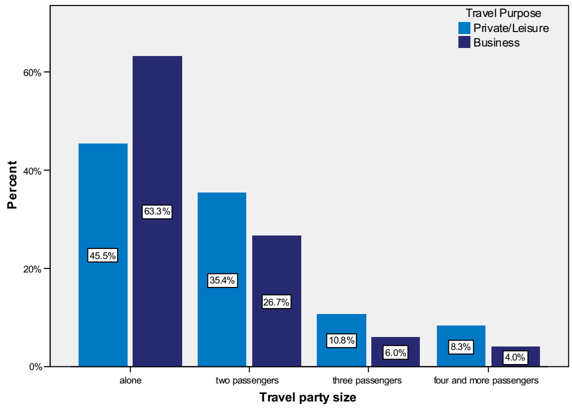

FIG. 4 Passenger profile-travel party size distributions

As shown in figure 4, travel party size varies with travel purpose and can also be obtained from other references[5]. For private/leisure traveller the average travel party size is 1.89 compared to 1.50 for business travellers. 63.3% of all business travellers were travelling alone whereas only 45.5% of leisure travellers declared travelling with nobody else.

3.3. In-flight analysis of surveyed passengers

Most of the surveyed passengers flew Economy Class (82.8%), followed by 14.2% with Business Class tickets. 2.3% of the passengers seated inside an Economy Plus Class and only 0.7% of the interviewed passengers flew First class. The relatively low number of First Class passengers refers to the operating airlines and their aircraft types. To 56.8% of all interviewed passengers, only two classes (Business and Economy Class) were offered, followed by tri-class layout which was offered to 30.8% of the passengers. United Airlines was the only airline at Munich Airport, offering their passengers four different classes. Furthermore, only in United Airlines and in some Lufthansa aircraft, a First Class is installed. Therefore, only 42% of all passengers had been in aircraft, where a First Class is installed. Distribution of passengers by booked cabin class is shown below:

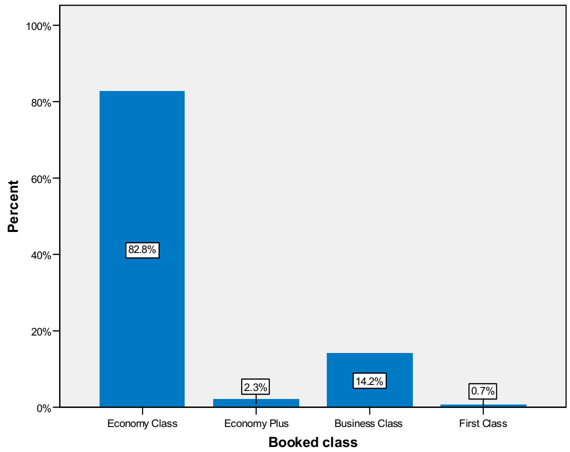

FIG. 5 In-flight analysis-Booked class of surveyed passengers

Seat's accessibility has a significant impact onto passenger's individual movement behaviour. This accessibility is mainly influenced by provided leg room, type of seat (window, aisle or middle seat), number of adjacent seats, number of seating neighbours (depending on seat layout and load factor) and stored hand luggage under seat in front. Most of the passengers (48.0%) had an aisle seat, followed by window seat (38.8%) and middle seat (13.2%). No middle seats in First Class and Business Class could be observed. Number of disturbed passengers for leaving a seat, are directly linked to cabin layout of an airline with its seat abreast and number of adjacent seats. The following figure shows the distribution of disturbed passengers by cabin class:

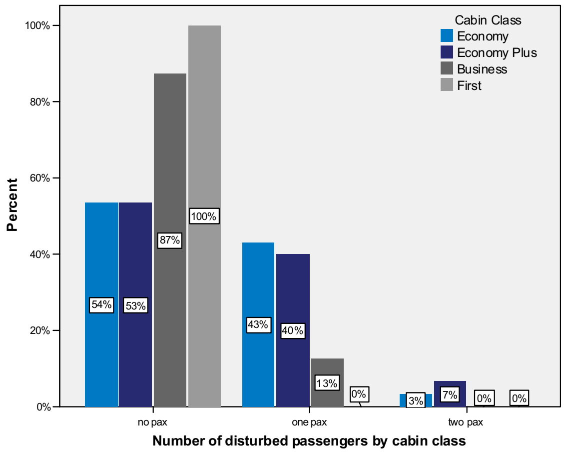

FIG. 6 Number of disturbed passengers by cabin class

As mentioned above, leg room have a significant impact onto individual passenger movement behaviour. 27.5% of all passengers indicated having a seat with improved legroom. Reasons for improved legroom are Business or First Class seats. In the Economy Class, seats with improved leg room can be found in a first row of that class, in the first row after cabin monuments or at emergency exits.

Storing hand luggage can reduce seat's accessibility, hence passengers were asked, if hand luggage was stored under the seat in front. 34.9% of passengers declared that hand luggage was stored under the seat in front. Passengers were divided into two groups. First group is storing hand luggage in front of the seat and second group of passengers is not storing any hand luggage under the seat in front. T-tests (χ^2-tests in case of ordinal-scaled variables) were conducted for cabin class, day-night ratio, departure continent, nationality, travel purpose, travel party size, travel habits, age, body height and body weight in order to confirm or reject the significant difference between these two groups. Significance between these two groups have been set at $\alpha<0.05$ level.

No differences between these two groups can be obtained regarding cabin class (α=0.163), departure continent (α=0.666), travel party size (α=0.159) and nationality (α=0.235). Results showed differences between these two groups regarding type of seat (α=0.005). Hand luggage is stored less at aisle seats than window or middle seats. Storage rates are the highest at middle seats. 47.1% of all passengers on middle seats – compared to 29.0% for passengers with aisle seats-declared that their hand luggage was stored under the seat in front of them.

With a significance of α=0.001, day-night ratio influences the percentage of passengers with under-seat hand luggage storage. Especially on flights during daylight, only 18.3% of all passengers stored hand luggage under the seat and for flights during night, this ratio increases to 35.4%. Differences between these two groups can also been seen regarding their travel purpose. Private traveller (37.2%) tends to store more often their hand luggage under the seat than business travellers (27.0%) (α=0.013). Furthermore, it could be identified (α=0.000) that female passengers (44.6%) do more often store their hand luggage under the seat then male passengers (26.7%). Regarding age, younger passengers tend to store more luggage under the seat than older passengers. The distribution is shown below:

	Stored hand luggage under seat			
Age	yes	number	no	number
0-17	59.3%	16	40.7%	11
18-24	44.6%	37	55.4%	46
25-29	38.2%	39	61.8%	63
30-34	28.8%	30	71.2%	74
35-39	28.1%	27	71.9%	69
40-44	38.0%	30	62.0%	49
45-49	28.1%	16	71.9%	41
50-54	25.5%	12	74.5%	35
55-59	37.9%	11	62.1%	18
60-64	32.3%	10	67.7%	21
65-69	38.5%	5	61.5%	8
70+	58.3%	7	41.7%	5

TAB 1. Dependency of age onto hand luggage storage behaviour

With a significance of α=0.000, passengers body height, weight as well as body mass index (BMI) influences the hand luggage storage behaviour. The following table shows the storage behaviour depending on body height:

	Stored hand luggage under seat			
Body height	yes	number	no	number
<165cm	51.7%	45	48.3%	42
166-170cm	46.1%	53	53.9%	62
171-175cm	28.3%	36	20.6%	91
176-180cm	32.6%	56	67.4%	116
181-185cm	29.1%	30	70.9%	73
186-190cm	25.9%	14	74.1%	40
191-195cm	37.5%	6	62.5%	10
>196cm	0%	0	100%	7

TAB 2. Dependency of body height onto hand luggage storage behaviour

In general, taller passengers with higher body weight tend to store their hand luggage more often in the provided overhead bins. This might refer to the provided room at constant seat pitch which is personally reduced for this group. Last table shows hand luggage storage behaviour depending on passenger's body weight.

	Stored hand luggage under seat			
Body weight	yes	number	no	number
<39kg	0%	0	100%	1
40-49kg	76%	19	24%	6
50-59kg	52.2%	48	47.8%	44
60-69kg	37.7%	57	62.3%	94
70-79kg	21.8%	36	78.2%	129
80-89kg	37.1%	49	62.9%	83
90-99kg	30.3%	23	69.7%	53
100-109kg	28.6%	6	71.4%	15
110-119kg	25%	3	75%	9
120-129kg	33.3%	2	66.7%	4
>130kg	25%	1	75%	3

TAB 3. Dependency of body weight onto hand luggage storage behaviour

Furthermore, travel habits influences the proportion of stored hand luggage under seat (α=0.005). Frequent flyers store less hand luggage under the seat than non-frequent flyers. If passengers were flying 20 or more times per year, only 20% of these passengers stored hand luggage under the seat, whereas for passenger flying only 1-2 times per year, 42% of this group stored hand luggage under the seat.

4. SURVEY RESULT – ANALYSIS OF PASSENGER MOVEMENT BEHAVIOUR

Before investigating individual passenger movement behaviour, first an overview about reasons for leaving seat will be presented.

According to the survey, visiting lavatories is the common reason why leaving a seat. In average 79% of all passenger movements occur due to visiting lavatories. The second most common reason for leaving a seat is making a walk through the cabin. In average 8.6% off all movements can be counted to that reason. Stretch exercises near the seat occurred with 4.9%, followed by getting personal hand luggage with a mean value of 4.0%. Reasons like visiting galleys or other passengers have values of only 1.9% and 1.4% respectively. The survey offered passengers the opportunity to indicate other reasons than the previous presented six ones for leaving their seats. Only 0.2% of passenger movements can not be segmented into the presented six reasons and hence other reasons will be neglected for further investigations.

The survey covers besides counting quantity of leaving seats, also duration for these six leaving seat reasons. Hence, a proportion between total flight time and time of not sitting can derive. Nearly 98% of the total flight time, people are sitting.

4.1. Parameters influencing passenger´s movement behaviour

With statistical analysis, parameters have been identified, which influences total number of leaving seat. First of all, an influence of total flight duration and total number of leaving seats n_{LS} can be identified. With flight duration of 6-7 hours, n_{LS} has a mean value of 2.63 and increases to 4.41 for flights between 12-13 hours total flight time. With this dependency, n_{LS} can be set in dependency of total flight time and hence, for further investigations, a ratio of leaving seat per flight hour r_{LS} has been set up.

As mentioned before, day-night-ratio R_{DN} has significant impact onto passengers movement behaviour. With a decrease of R_{DN}, a decrease of mean n_{LS} can be obtained.

R_{DN}	mean n_{LS}	N	std. deviation
0%	2.78	60	1.932
25%	2.56	103	1.813
50%	2.54	264	1.748
75%	2.90	96	1.638
100%	3.70	183	2.239
total	2.92	706	1.954

TAB 4. Dependency of n_{LS} on day-night-ratio R_{DN}

Number of seating neighbours and number of seating neighbours, who have to be disturbed (n_{DP}) for leaving a seat, have significant impact onto passenger movement behaviour. Furthermore, number of seating neighbours and their relationship among themselves influences r_{LS} significantly. It could be obtained that passenger's individual r_{LS} depends on individual travel party size (TPS), aircraft seat configuration (mainly seat abreast and hence number of adjacent seats), seat properties (window, middle or aisle seat) and load factor.

Number of disturbed seating neighbours	mean r_{LS}	N	std. deviation
no passenger	0.465	392	0.1745
one passenger	0.344	257	0.1636
two passengers	0.310	20	0.1506

TAB 5. Dependency of r_{LS} on number of disturbed seating neighbours

The dependency of travel party size and number of disturbed seating neighbours is shown in the following tables below. For single traveller, if one passenger has to be disturbed, the average number of leaving seat n_{LS} is less than the half (1.61) compare to no disturbed seating neighbour (3.43). Therefore, passengers with no seating neighbour leave their seats more then two times often than passengers with one unknown seating neighbour and more than three times for two disturbed passengers.

Number of disturbed seating neighbours	mean n_{LS}	N	std. deviation
no passenger	3.43	199	1.730
one passenger	1.61	118	1.062
two passengers	1.03	13	1.528

TAB 6. Dependency of n_{LS} and number of disturbed seating neighbours (travel party size =1)

Comparing n_{LS} values for different travel party sizes, it can be obtained that with an increase of travel party size, n_{LS} increases as well. The following table shows mean n_{LS} for a travel party size of two passengers. No significant differences in average number of leaving seat between single traveller (TPS=1) and (TPS=2) can be obtained. Hence, travel party size has no effect onto individual passenger movement behaviour, if no passenger has to be disturbed for leaving a seat.

Number of disturbed seating neighbours	mean n_{LS}	N	Std. deviation
no passenger	3.50	121	1.853
one passenger	2.62	101	1.548
two passengers	1.51	2	2.828

TAB 7. Dependency of n_{LS} and number of disturbed seating neighbours (travel party size =2)

Further comparing of mean n_{LS} values, it can be seen that the relationship between seating neighbours and travel party sizes influences mean number of leaving seat. Passengers travelling with somebody else who have to disturb two passengers, have nearly the same n_{LS} as passengers travelling alone and have to disturb one passenger. Passengers travelling with somebody else and having one seating neighbour, who has to be disturbed for leaving the seat, have a higher n_{LS} than single traveller but a smaller n_{LS} than single traveller with no seating neighbour. Hence, even a known seating neighbour will reduce the mean number of leaving seat during flight. Not only the number of seating neighbours and travel party size have a significant influence.
Also leg room influences significantly passenger movement behaviour. Passengers who indicated having a seat with improved leg room, have a mean r_{LS} of 0.456 compared to 0.395 for seats with no improved leg room.

Improved leg room can be found at emergency exit rows, at first rows of each cabin class or after cabin monuments. Also the effect of stored hand luggage under the seat in front was investigated. It could be seen that with a significance of α=0.049, passengers have a reduced r_{LS} if hand luggage is stored in front under the seat (r_{LS}: 0.394 versus 0.423).

Furthermore, passengers were asked to rate (1= very easy to 6=very difficult), how easy it was to leave their seats. Passengers in higher classes rated leaving seats easier than in lower classes. Furthermore, passengers rated getting up from the seats easier, if improved leg room can be found. The correlation between rating of leaving the seat and n_{LS} can be found in the following table:

Rating for getting up from seat	mean n_{LS}	N	std. deviation
1: very easy	3.60	293	1.995
2	3.03	166	1.766
3	2.73	70	2.064
4	2.20	65	1.583
5	1.34	44	.680
6: very difficult	1.22	18	.548
Total	0.416	654	0.1823

TAB 8. Dependency of n_{LS} on rating for getting up from seat

Due to the influences of seating neighbours, leg room, stored hand luggage under the seat and seat rating for getting up, it can be assumed that higher cabin classes, with its lower number of adjacent seats, higher leg room and higher storage capability for hand luggage, will have higher n_{LS}. As shown in the following table, in higher cabin classes like Business Class and First Class n_{LS} reaches higher values. Even if sample number for higher cabin classes is lower, the increase from Economy Class to First Class can be obtained in the following table.

Cabin class	mean n_{LS}	N	std. deviation
Economy	2.82	584	1.912
Economy Plus	3.13	16	2.527
Business	3.42	100	2.056
First	3.67	6	1.366
Total	2.92	706	1.954

TAB 9. Dependency of n_{LS} and cabin classes

Furthermore, passengers have been asked, if they could leave their seats all the time. 65.3% passengers indicated getting up with no restrictions, while 34.7% with. Reasons for these restrictions are shown below:

Leaving seat restrictions	Frequency	Percent
occupied lavatories	141	61.6
sleeping seat neighbour	70	30.6
cabin attendants blocked aisles	10	4.4
turbulences	4	1.7
other reasons	4	1.7
Total	229	100.0

TAB 10. Reasons for leaving seat restrictions

These restrictions have an influence onto mean value of n_{LS}. With restrictions while wanting to leave the seat, n_{LS} is 2.63 and 3.24 for no restrictions.

No significance between age and n_{LS} could be obtained (α=0.097), the same refers to gender (α=0.576). Also travel behaviour in terms of number of undertaken flights (α=0.333) and average flight durations (α=0.861) have no impact onto individual movement behaviour. Frequent traveller Furthermore, mobility problems like arthritis, rheumatism or back problems have also no significant effect (α=0.820) onto passenger's movement behaviour.

5. MODELLING PASSENGER'S MOVEMENT BEHAVIOUR

Individual passenger movement behaviour and dependency on other parameter, as described in the previous chapters, will be used to derive conditional probability functions. These functions describe probabilities for number of leaving seat for each passenger depending on following cabin and passenger properties. As mentioned in chapter 4.1, passenger movement behaviour strongly depends on:

- total flight time (t_{FD})
- day-night-ratio (R_{DN})
- travel party size (TPS)
- type of seat (window, aisle and middle seat)
- number of disturbed passengers (n_{DP})
- cabin class
- seat with an improved legroom
- stored hand luggage under the seat

5.1. Conditional probability density functions

Passenger movement behaviour bases on individual conditions and decisions. Therefore, instead of exact value of n_{LS} or r_{LS}, only distributions and hence probabilities for these two values can be given. Therefore, mathematical description of passenger movement behaviour will be described with conditional probability density functions. There are a wide range of density probability functions for mathematical description. In this paper, passenger movement behaviour was described with the usage of beta distributions. Beta distribution is a family of continuous probability distributions defined on the interval [0, 1] differing in the values of their two non-negative shape parameters, α and β.

(eq.1) $$f(x;\alpha,\beta)=\frac{x^{\alpha-1}\cdot(1-x)^{\beta-1}}{\int_0^1 u^{\alpha-1}\cdot(1-u)^{\beta-1}du}$$

(eq.2) $$=\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\cdot\Gamma(\beta)}\cdot x^{\alpha-1}\cdot(1-x)^{\beta-1}$$

(eq.3) $$=\frac{1}{B(\alpha,\beta)}\cdot x^{\alpha-1}\cdot(1-x)^{\beta-1}$$

with:

(eq.4) $$B(\alpha,\beta)=\frac{\Gamma(\alpha\cdot\Gamma(\beta))}{\Gamma(\alpha+\beta)}=\int_0^1 u^{\alpha-1}\cdot(1-u)^{\beta-1}du$$

The beta function, B in equation 4, appears as a normalization constant to ensure that the total probability integrates to unity, whereas $\Gamma(\alpha)$ or $\Gamma(\beta)$ represent a gamma function. For the calculation of gamma functions, an approximation according to Stirling[7] was used:

(eq.5) $$\Gamma(\alpha) \cong e^{-\alpha} \cdot \alpha^{\alpha-0.5} \cdot \sqrt{2\pi} \cdot \left(1 + \frac{1}{12\alpha} + \frac{1}{288\alpha^2} - \frac{571}{2488320\alpha^4}\right)$$

Following figure shows three different probability density functions and cumulative distributions depending on α and β.

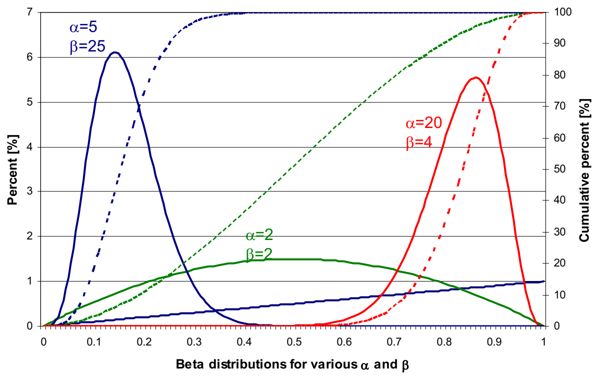

FIG. 7 Probability density and cumulative distribution functions for

For example, traveller's age distribution can be described with beta distribution, ranging from an age of zero years to 100 years. Description of age distribution with help of beta distribution regarding survey results is given below.

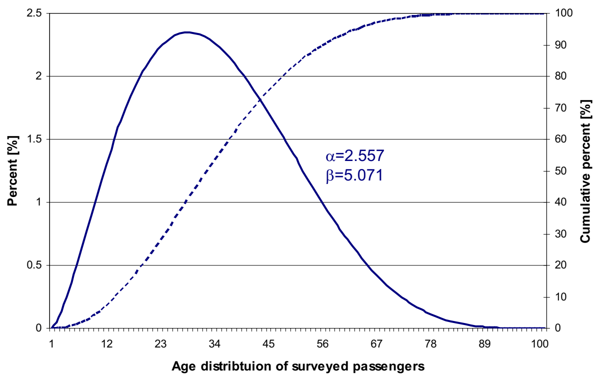

FIG. 8 Passenger's age probability density and cumulative distribution functions

5.2. Description of passenger movement behaviour

This last subchapter deals with the mathematical description of passenger movement behaviour depending on identified parameters affecting density functions based on prior presented survey results, identification of influencing parameters and presentation of probability functions to describe passenger's movement behaviour. Hence, impact of day-night ratio and number of disturbed passengers will be presented in more detail.

5.2.1. Day-Night-Ratio R_{DN}

As mentioned above, day-night ratio R_{DN} has a significant influence onto passenger's movement behaviour. The following figure shows the probability density functions of r_{LS} depending on the day-night ratio for a single traveller (TPS=1), no seating neighbours (n_{DP}=0) for Economy Class and no stored hand luggage.

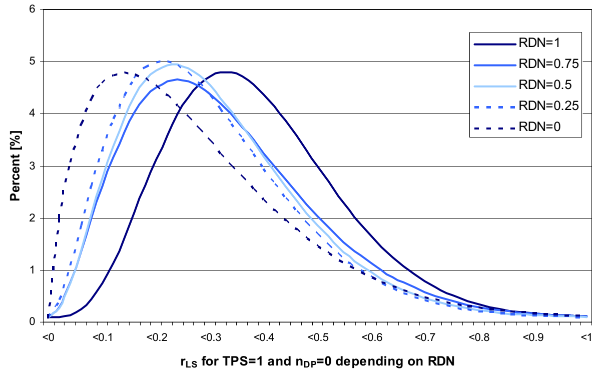

FIG. 9 Distribution of r_{LS} for n_{DP}=0 and TPS=1 depending on R_{DN}

With an increase of percentage of night during flights, number of leaving seat per flight hour decreases. For a 100% day flight, average r_{LS} is about 0.468 and decreases to 0.358 for a flight during night. Mean values of r_{LS} are shown below:

Day-Night ratio	Mean values of r_{LS} for single traveller, no seating neighbour, depending on day-night ratio
100%	0.468
75%	0.416
50%	0.402
25%	0.395
0%	0.358

TAB 11. Mean values for r_{LS} (TPS=1, n_{DP}=0) depending on R_{DN}

Next table shows α and β values of movement density functions for a single traveller with no seating neighbour depending on day-night-ratio.

Day-Night ratio	α	β
100%	4.692	19.802
75%	2.921	15.163
50%	3.066	16.798
25%	2.793	16.176
0%	1.802	11.471

TAB 12. α and β values for (TPS=1, n_{DP}=0) depending on R_{DN}

5.2.2. Number of disturbed passengers

Number of disturbed passengers and their relationship (known/unknown) has a significant impact onto passenger's movement behaviour. This number is depending on:

- Number of seating neighbours
- Travel party size

Whereas number of seating neighbours depends on cabin class, including number of adjacent seats and seat's position as well as load factor. The influence of number of disturbed passengers for leaving the seat is shown in the following figure for a day-night-ratio of 100%.

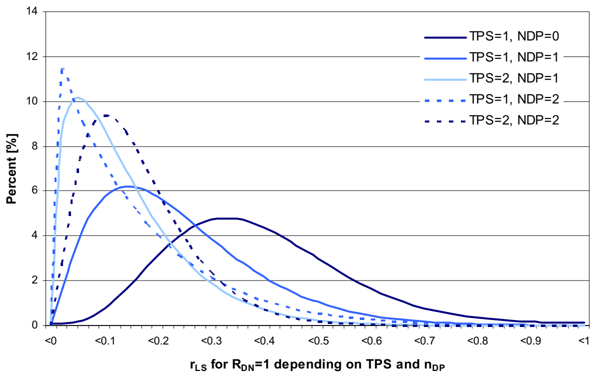

FIG. 10 r_{LS} for R_{DN} depending on TPS and n_{DP}

As mentioned before, the strong effect of seating neighbour and number of disturbed passenger onto individual passenger movement behaviour can be clearly obtained from figure 10. Regarding different travel party sizes and number of disturbed passengers, the following two tables show mean values of r_{LS} for RDN=1 depending on n_{DP} as well as α and β values for distributions as shown in figure 10..

Day-Night ratio	Values of r_{LS}
No disturbant	0.468
One disturbant (unknown) - Single traveller	0.320
One disturbant (known) - Group traveller	0.330
Two disturbants (both unknown) - Single traveller	0.210
Two disturbants (known/unknown) - Group traveller	0.233

TAB 13. Mean values for r_{LS} depending on n_{DP} and TPS for R_{DN}=1

	α	β
No disturbant	4.692	19.802
One disturbant (unknown) - Single traveller	2.208	16.416
One disturbant (known) - Group traveller	1.479	19.454
Two disturbants (both unknown) - Single traveller	1.001	11.918
Two disturbants (known/unknown) - Group traveller	2.441	27.652

TAB 14. α and β values for R_{DN}=1 depending on TPS and n_{DP}

6. CONCLUSIONS

Summarizing, passenger movement behaviour mainly depends on seat's accessibility, number of disturbed passenger's for leaving a seat, the relationship between them and flight schedule properties, like total flight time and day-night ratio.

The results have shown that passenger movement behaviour significantly depends on following flight, cabin and passenger conditions:

- total flight time (t_{FD})
- day-night-ratio (R_{DN})
- travel party size (TPS)
- number of disturbed passengers (n_{DP})
  - type of seat (window, aisle and middle seat)
  - cabin class
  - seat layout
  - travel party size
- provided legroom
- stored hand luggage under the seat

No influences of following flight, cabin and passenger conditions onto passenger movement behaviour could be observed:

- age
- gender
- occurrence of mobility problems
- nationality
- number of undertaken flights last 12 months as well as average flight duration

7. REFERENCES

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