How a Guide Robot Should Behave at an Airport - Insights Based on Observing Passengers

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1 Introduction

This report describes a contextual analysis conducted as part of the EU FP7 project SPENCER. This contextual analysis is based on the specifications in SPENCER Deliverable 1.1 (D1.1). In accordance with the use case specification, we specify aspects of the contextual analysis that we conducted at Schiphol airport.

As part of the SPENCER project a robot demonstrator will be developed which provides location based services (information, guiding) to passengers in the context of an international airport. Based upon the use case meeting held 7 April 2013, the following four main tasks for the robot[1] have been defined:

1. Give directions to passengers at gate
2. Guide MCT[2] passengers (non-runners) to the fast-track Schengen filter
3. Guide non-MCT passengers
4. Help passengers who miss their connection by use of a boarding card printer

Our specific work package (WP4) is concerned with the identification and evaluation of social normative motion behaviors for the robot. Given that the robot should act, and be perceived as, a companion, or intelligent agent, insight is needed into which norms, routines and rituals people adhere to when in transit. For the sake of simplicity, we refer to these as norms.

We use the term contextual analysis here to describe a scientific method to discover how people behave in a given context (here Schiphol airport) and in relevant situations within this context. Thus, the data for this contextual analysis has been collected at Schiphol Airport. Generally spoken, the main goal of the contextual analysis is to analyze human behavior at Schiphol airport in order to identify normative behaviors that the SPENCER robot should employ in the same context. The goal is explained in more depth below. The Method section will describe the research design in more detail, and provides information on the specific locations where we collected data. These data include observations from researchers, interviews with KLM staff and video recordings in representative environments. We will conclude with the data analysis in which we specify how we analyzed and structured the video data. In the results section we will describe the results gained from the observations, and finally in the conclusions section we will provide recommendations for the SPENCER robot's behavior (see 5).

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[1] Robot, or the robot refers to the demonstrator robot that will be developed.

[2] MCT: Minimum Connection Time; for a transfer between an intercontinental and domestic flight this is 50 minutes or less before next flight departs

Figure 1: The Schengen barrier, seen from the Non-Schengen area. The fast-track lane is at the left side (but not visible)

1.1 Goal

As specified in the description of work, the goal of this contextual analysis is *"to identify [] socially normative motion behaviors that humans adopt when navigating through crowded environments and interacting with groups in real world settings relevant to the project such as airports"*.

In order to attain this goal of the contextual analysis we have specified a set of contexts in which people navigate at the airside (behind customs) of an airport (see Method section). This data has been analyzed and transformed into a set of behavior recommendations for the SPENCER robot.

2 Method

To achieve our goal, we first specified situations and places that were of interest for the scenario (see Section 2.1). In these places we collected data as described in Section 2.2 and analysed it as explained in Section 2.3.

2.1 Situations and places of interest

In the current scenario, passengers disembark an aircraft, and walk to their next destination, which can either be the exit if Schiphol Airport is their destination or another aircraft if Schiphol serves as a connecting hub. Thus, the arrival gate and the ways taken to the next destination are of interest for us. As we mainly focus on passengers with connecting flights, we chose to observe people who walked to the Schengen barrier rather than the ones walking towards the exit.

MCT for international flights is 50 minutes. On average 80% of the passengers from a Chinese flight are transferring to a connecting continental flight, and have to pass the Schengen barrier (Figure 1) to enter the Non-Schengen area. The Non-Schengen area is a clean area, e.g. your hand luggage is checked before entering the area. Passengers first have to pass a passport control, followed by a security check. There is a fast-track lane, and a staff member is always present to direct passengers to which lane they should take. Only passengers whose flight will department within 20 minutes are allowed to use the fast-track lane.

Along the way, connecting passengers are provided with flight information by way of the information monitors positioned at various locations throughout the terminals. Passengers can also use the Self-Service Transfer Machines, which are placed throughout the terminal building. With these machines passengers can (among others) get travel information and rebook their flight without the assistance of staff. Given that the SPENCER robot is envisioned to assist passengers with these functions, these machines are of interest to us. The self-service transfer machines (SSTM's) are placed at various locations, some are placed in the middle of the gate (Figure 2), others at strategic points called "transfer areas" (Figure 3). These transfer areas are numbered, and positioned throughout the airport. Transfer 6 (Figure 3, Figure 4) is the largest transfer desk area in the Non-Schengen area, Transfer 2 in the Schengen area.

Figure 2: Four SSTM's located in the hallway of the E-gates; near gate E9

Figure 3: Transfer 6 self-service area

SSTM's support a variety of languages, including Chinese. It is possible for passengers to rebook flights, check flight information among others. At times the transaction cannot be completed at the SSTM, and the passenger will receive instructions to ”report to the transfer desk”. Nancy, a member of KLM's ground staff at Schiphol told us that older people in particular are more comfortable with a person helping them; they prefer a person to the machine. She told us that this could be because they are not used to work with computers.

The SPENCER robot will not be the first driving vehicle at Schiphol. For passengers with disabled or reduced mobility, Schiphol provides assistance in the form of staff-operated vehicles to bring passengers from the arrival gate to departure gate. We decided to observe how these passengers moved around. With the knowledge above we defined the six situations described in Table 1 of which we think information could benefit the development of the SPENCER robot.

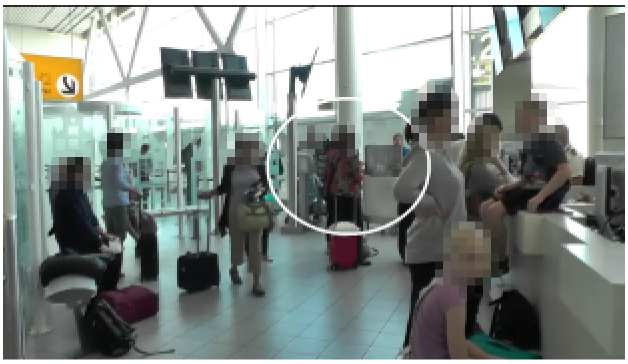


Figure 4: Transfer desk of transfer 6. Note that the ticket officer (seated in the back) first screens the needs of passengers

	Description of situations	Questions of interest	Observation method	Place(s) for data recording
1	passengers walking around without guidance	How does the group make decisions? Is there a leader? How do group members position themselves with respect to each other? (while walking or waiting)	non- participatory, hidden	on the way between gate and Schengen filter
2	groups approaching staff	How do people approach staff? Is there a leader in the group? Is the group leader in a specific position?	non-participatory, hidden	a) gate; b) on the way between gate and Schengen filter
3	staff approaching groups	How do staff approach groups? How are people instructed to use the fast-track?	participatory, hidden	a) gate; b) on the way between gate and Schengen filter
4	information screen	How do people position themselves around information screens? Do they stop to read the information?	non-participatory	a) gate; b) on the way between gate and Schengen filter
5	passengers at self-service transfer desks	How do people approach? How do they position themselves?	non-participatory, hidden	self-service transfer desk
6	airport vehicles	How do the airport vehicles interfere with other passengers?	non-participatory, hidden	b) on the way between gate and Schengen filter

Table 1: Situations to be observed at Schiphol Airport

The observations as described in Table 1 are non-participatory. In a participatory observation a person who knows about the study interacts with the participants (as opposed to a non-participatory observation). As the situations should be influenced as little as possible, non-participatory observations were preferred. Furthermore, observations can be open or hidden. In an open observation the participants know that and why they are observed. In a hidden observation, people do not know about it. Again, as the goal was to interfere as little as possible in the situation, hidden observations were preferred.

2.2 Data collection

Data was collected by the SPENCER consortium on 11 and 12 June 2014. Both days were average days in terms of traffic at Schiphol airport; it was not yet extremely crowded due to the holiday season. During our observations at the airside we were guided by two KLM staff members from the Translator Team (Dicky and Nancy). Their job is to assist passengers from China (a language members of this team speak fluently) when they arrive at Schiphol Airport. The UT group was guided around by Nancy, and before providing an overview of the data collected we will briefly describe their job.

Nancy has worked for seven years at Schiphol, before that she worked as a flight attendant for 4 years. The job of Nancy and Dicky is to be present at the arrival gate when a KLM flight from Japan, Korea or China arrives and assist in directing them to the right gate. Usually this does not entail physically walking with them, just giving directions, or sometimes helping them use the self-service transfer kiosk. The main reason is the language. More and more (young) people are starting to speak English, however, a lot of passengers do not. This is offered as a service by KLM. There is no staff at the airport which specifically roams around the airport looking for people in need of help. As we will also discuss

Figure 5: Layout of observerations around lounge 2

in Section 3.1.10 passengers ask help to staff who walk from A to B at the airport. Nancy explained that she rarely approaches people to assist them. They always come up to her (and her colleagues) because she's wearing a KLM uniform. What Nancy also mentioned was that even when she wasn't wearing the uniform, people did still tend to ask her for assistance.

2.3 Description of collected data

Data was recorded at various locations in the Non-Schengen part of the terminal - in particular lounges 2 and 3, and gates D, E, and F. Figure 5 and Table 2 provide further details of these observations. These data cover the situations as specified in Table 1. One situation we were also interested in was a situation in which participants would be approached by staff. However, as Nancy indicated there is no specific staff for this on Schiphol. During our time at Schiphol Airport we did notice some spontaneous staff-passenger interactions in the hallway. These interactions have been analyzed in the results section. However, for the purpose of our analysis these interactions were limited in that they were between staff and single passengers; not between staff and groups of participants as would be more relevant for the SPENCER project.

Video recordings were made from passengers exiting aircrafts, either assisted or not assisted by KLM ground staff. By following the general flow of passengers, we collected data on passengers using the SSTM's and information monitors.

The flights that we observed originated from destinations in Asia (Tokyo, Beijing), but also the United States (San Francisco) and Canada (Vancouver). One flight originated from the United Kingdom, which is a European country, though not part of the Schengen zone. Therefore passengers also disembark at the Non-Schengen gates. From the flight we followed two passengers from gate until they went to the lounges area. This proved to be difficult as it was obvious to the passengers that we were following them, and this also attracted the attention of other passengers, thus intruding in the context. Therefore, it was decided to not repeat this with more passengers. The data gathered elsewhere does provide sufficient information to arrive at conclusions concerning situation #2.

In two situations we collected data in the main terminal building for an extended amount of time. In the first situation, two cameras were placed in Lounge 2 for 30 minutes. The specific area is shown in Figure 5 and Figure 7, and as can be seen this area leads from one of the passengers' entrances to the Non-Schengen area, as well as the Schengen barrier, and two shops. The area also contains two series of information monitors. The second situation includes a camera placed for 15 minutes at the junction between the D-gates and lounge 2.

The total duration of the video data collected during this data collection session was 4.5 hours.

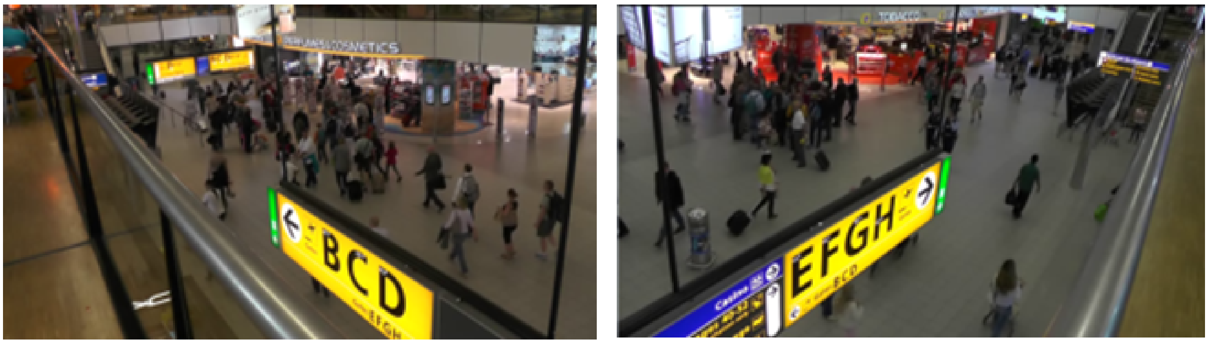


Figure 6: Data in lounge 2 was captured with 2 cameras

	Day	Time	Observation:	Gate	Type of observation	# of cameras
1	Wednesday	10.30	Arrival of flight from Vancouver (KL 0682)	E24	hidden observation of arriving passengers	1
2	Wednesday	15.15	Arrival of flight from Beijing (KL 0898)	E20	hidden observation of arriving passengers	2
3	Wednesday	15.00	Arrival of flight from Tokyo (KL 0862)	E19	hidden observation of arriving passengers	2
4	Thursday	9.50	Arrival of flight from San Francisco (KL 0606)	F8	hidden observation of arriving passengers	2
5	Thursday	10.10	Arrival of flight from Vancouver (KL 0682)	F4	hidden observation of arriving passengers	2
6	Thursday	13.35	Arrival of flight from Aberdeen (KL 1444)	D8	Followed two passengers	1
7	Thursday	12.00	Observed passengers at T-junction between Gate D and lounge 2		hidden observation of people walking	2
8	Thursday	14.15	Observed passenger behavior in lounge 2		hidden observation of people walking	2

Table 2: Specification of video observations at Schiphol airport terminal

2.4 Data analysis

Data analysis has been conducted in three phases, which were based upon an inductive data analysis approach by Lofland, Snow, Anderson, and Lofland (2006). Phase 1 consisted of preparing the raw video data for analysis, which included merging, splitting and renaming video files. During phase 2, the open coding phase, a first categorization was made using open coding (Strauss, 1987, p.28). Two researchers went through all video materials and noted down what they saw. For instance, "passengers are running". No quantitative statements were made about the data. Also, how the behavior was conducted was not described at this point of time (e.g. one passenger was running behind the other). Based on what we observed, we developed a coding scheme. An overview of these categories can be seen in Table 3. The behaviors identified in the open coding were grouped according to the situations that were observed. However, we had to adapt these based on the data. As a first adaptation we divided situation 1 (passengers walking around without guidance) into narrow hallways and wide hallways because we had the impression that the space made a difference on how people behaved. As we did not encounter situations where staff pro-actively approached groups, we eliminated that category. We added a situation called "using moving walkways" as this turned out to be another interesting situation in the data collection.

Based on the categories from the open coding, we watched all videos again looking for situations where we observed examples for each of the categories. We cut the scenes and put them into a folder

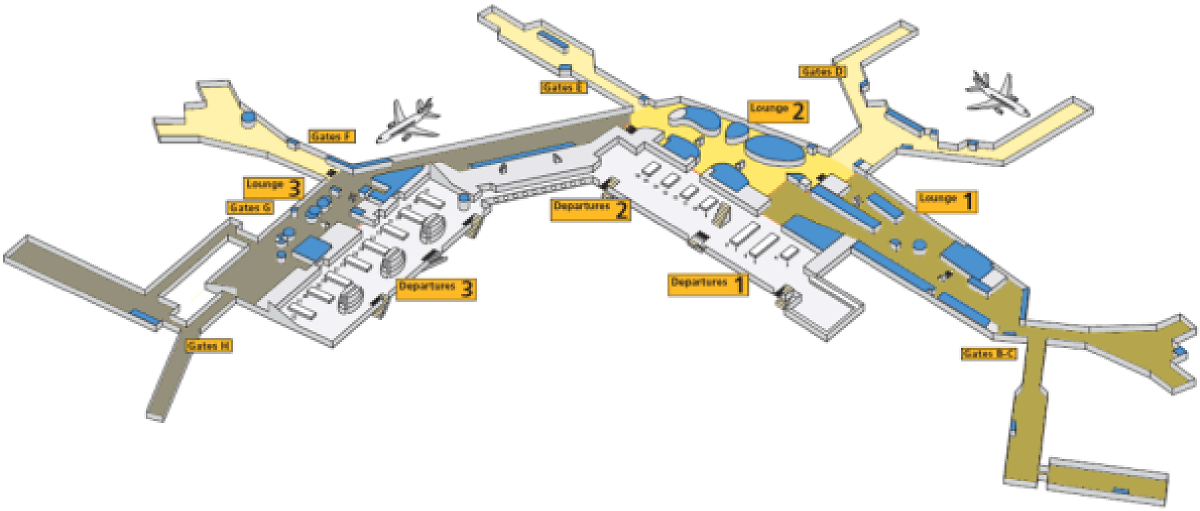


Figure 7: Map showing Schiphol filming locations. Legend: Narrow hallway, Wide hallway, Schengen area; no data recorded, Non-Schengen area; no data recorded

for the respective category. It was possible to have certain parts of the video in multiple folders. In some cases it was not immediately clear to which passenger(s) a video applied, for example in some of the scenes in the wide hallway, where numerous passengers and staff were present at a given moment. In those cases, the videos were edited with circles indicating where to watch so as to avoid confusion for the coders during the final phase of the analysis.

Interaction occurred in either a *narrow hallway* or *wide hallway*. The difference between those two was that we defined a wide hallway as the primary hallways to get from A to B, and the narrow hallways as the secondary hallways which in reality were the gate areas. This is shown in Figure 7. The five other categories (using SSTM, using moving walkway, using information monitors, encounters with staff and encounters with vehicles) can occur in either of those two hallways, and those situations have been categorized independently of the specific hallway (a situation having a passenger look at an information monitor situated in a narrow hallway will thus be categorized in the same category as a similar situation which takes place in a wide hallway).

All video material was cut and placed into one or multiple of the subcategories. This resulted in a total of 406 short video clips. As some material fitted multiple categories, these do not constitute 406 unique clips. In the third step, the focused coding phase, all video material was watched by subcategory, to get to an understanding of how people behaved in certain situations (e.g. how did they position themselves with respect to others and the environment). In the final phase, observations from the data were written down in tables, and from this conclusions were drawn as for the robot behavior. This phase is described in the results section and summarized in the discussion section in which we relate some of our findings to literature.

2.4.1 Exclusion criteria

During the first phase of coding the principal researchers defined behavior which was considered normal, thus occurring everywhere. One of the most common examples of normal behavior was passengers who were walking either in a pair or alone in a straight line in the hallway. If there was no interference between these people's behaviors and other passengers, staff or vehicles, this data was not coded as it was not informative for our analysis and potential robot behaviors. This information about normal passenger behavior was used however to determine the passenger flow which we will later use in this analysis.

Similarly, in situations where the mobile data collection stroller of our project partners was visible in the videos, these were not coded as it was observed this stroller attracted a lot of attention and thereby created a situation which was not normal - in contrast to the general hidden non-participatory observations.

category	subcategory	#
Narrow Hallway (NH)	1. Pair/Triad exceptions; deviations from normal behavior	2
	2. People walking together with ¿3 people next to each other	5
	3. People search for the way	27
	4. People re-packing luggage	8
	5. Group waiting in the hallway	18
	6. Individuals waiting in the hallway	2
	7. Passengers evading other passengers who move in the opposing direction	4
	8. Pairs walk in 1+1 behind each other	5
	9. Passengers explaining the way to other passengers	1
	10. People are running	3
	11. People overtaking others	2
	12. Passenger sitting on the floor	1
	13. People waving to others	1
	14. Groups organize themselves in pairs	3
Wide Hallway (WH)	1. Pair / Triad exceptions; deviations from normal behavior	n/a
	2. People search for the way	5
	3. People re-packing luggage	7
	4. Groups waiting in the hallway	11
	5. Individuals waiting in the hallway	7
	6. People pass through other groups	3
	7. Groups organize themselves into pairs	7
	9. People are running	20
	10. Pairs walk in 1+1 behind each other	13
	11. Passengers watch their luggage while standing still	3
Encounters with staff (ES)	1. People queuing for staff member	1
	2. Staff member looking around to assist passengers	2
	3. Staff member assisting passengers	17
	5. Passengers are getting information from staff at the SSTD	4
	6. Passenger showing documents to staff	7
Using information monitors (IM)	1. Passenger standing next to (1) other passenger (strangers)	4
	2. Passengers form a 2nd row	2
	3. Passenger looking at boarding pass	2
	Information monitors in wide hallway (Schengen)	
	1. Passenger standing next to (1) other passenger (strangers)	30
	2. Passengers form a 2nd row	21
	3. People take the place of others	2
Using moving walkway (CB)	1. Walking people overtake those who are standing still	12
	2. Passengers do not step on moving walkways currently not in use	1
	3. Passengers walking on the moving walkway	72
	4. Group stands still at the right; leaving left side open for passengers to overtake.	1
	5. Standing still on the moving walkway	11
Using SSTM (TD)	1. Passengers approaching machines	8
	2. Passengers using machines	9
	3. Passenger looking in bag to find documents	2
Encounters with vehicles (EV)	1. Airport vehicles driving around passengers	14
	2. People making way for airport vehicles	2
	3. No interference	13
	(undecided)	9

Table 3: Categories and subcategories after phase II data analysis. Underlined number indicates this NH subcategory is not present in WH category (and vice-versa)

3 Results

In this section we describe our findings and formulate recommendations for the SPENCER robot. Specifically for each subcategory we described the behavior which was observed, where possible supplemented with descriptive statistics. Each section ends with conclusions, which are implications for the behavior or for the perception capabilities of the SPENCER robot. Also we have provided references to illustrative video clips. These clips are referenced to using a path, consisting of a 2-character main category, followed by a 1-digit folder number, and finally the name of the file. The 2-character main category explanation can be found in Table 3 as well as the Section 5 at the end of this report.

3.1 People passing in the hallways

In the first subsection we will discuss all general behavior that we observed when people were walking through the hallway. We will present findings for the narrow and wide hallways together, and where possible we will compare and differentiate between both categories. In some cases subcategories only existed in either the ”narrow hallway” or ”wide hallway” category. Those subcategories will be discussed at the end of this subsection.

3.1.1 Passenger flows

The passenger flows in the wide and narrow hallways differed somewhat. When traversing a space people walking into the same direction organize themselves into flows in order to reduce time needed to traverse. Among others, Daamen and Hoogendoorn (2006) conducted a study where the walking speed of various passenger flows was recorded. Examples of situations include unidirectional, opposite- and crossing flows. Daamen and Hoogendoorn (2006) found, in support of evidence, that for instance speed decreases when encountering a situation with opposite- and crossing pedestrian flows.

In our observations the narrow hallway situations contained various unidirectional flows. To achieve this the flows were seperated by infrastructure, such as a moving walkway (Figure 8). In the wide hallway the flows were more complex, among others due to the multitude of destinations passengers could go to within that hallway (e.g. Schengen barrier, various gates, shops). The various passenger flows in our wide hallway observations have been visualized by ways of a schematic with arrows depicting the various flows over time (Figure 9).

3.1.2 People searching for the way

General search behavior consisted of strolling, sometimes stopping (WH2-Lounge1; NH3-SanFrancisco17; NH3-Vancouver8). We further observed that these people turned their head more than those passengers not searching. In case of a group searching for the way, hand- and arm gestures were observed (WH2-Lounge3; WH2-Lounge4; WH2-Lounge5). In most cases people were looking, and stopping, while walking in a general straight direction, however, at times the opposite was observed in that

Figure 8: The D-gates constitute a narrow hallway, with passenger traffic divided into two unidirectional flows by ways of the moving walkway

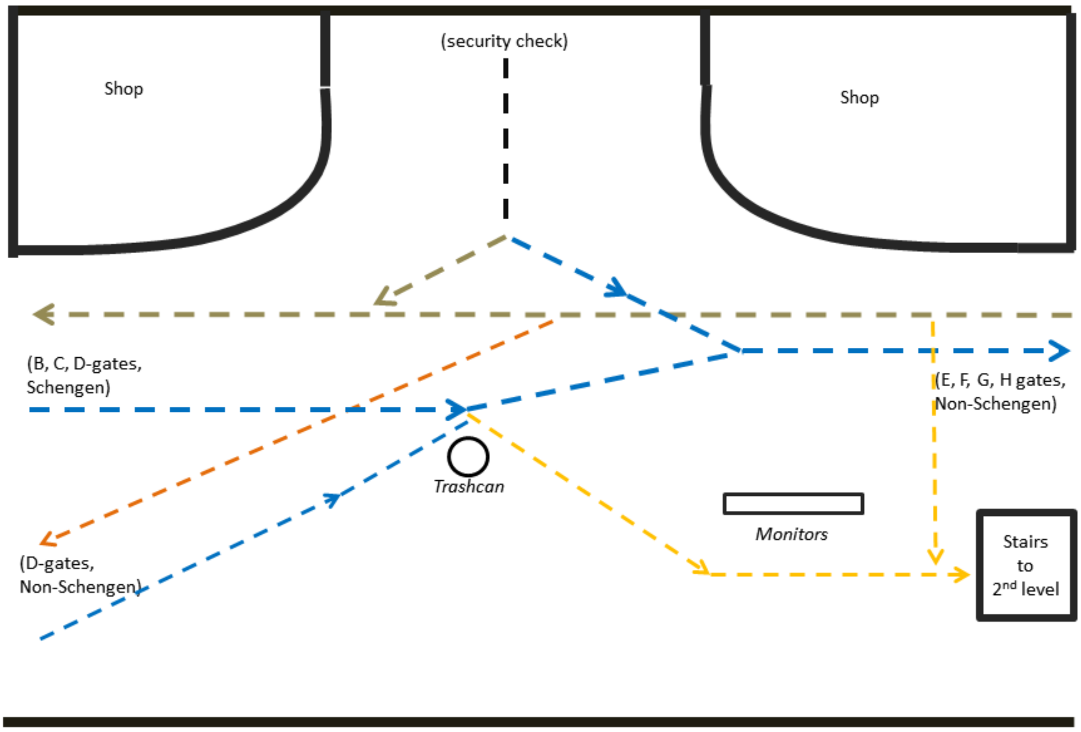


Figure 9: Schematic depicting the various passenger flows in the wide hallway

passengers continued walking, however, they did so while making a zigzag-like pattern through the hallway(NH3-SanFrancisco10; NH3-SanFrancisco13).

When people were exiting the aircraft, they were also observed looking for the way to go. In general, this behavior did not deviate that much from the other "search" behavior (NH3-Beijing1; NH3-Beijing3). However, what we did see was that after observing the Tokyo flight, more people stopped at an "inconvenient" place, causing (minor) problems for their fellow passengers (NH3-Tokyo5; NH3-Tokyo7) by standing in their way. We did not observe this for the disembarking process of the Beijing flight. One of the differences between these flights was that at the Beijing flight, KLM staff were visibly present. Furthermore, passengers from the Beijing flight could almost directly step onto a moving walkway, whereas the passengers from the Tokyo flight first had to walk a few meters to the left or right. This situation is illustrated in Figure **??**. Instead of standing in the way to figure out where to go, a better solution could have been the one observed by someone who seemed to be a tour guide in (NH3-Beijing5). She looked for a good place to collect her group, which was not in the walking direction of the majority of the other passengers. In a later video it was observed that she collected and guided a group of passengers. Two conclusions can be drawn:

- Behavior: a robot which collects passengers should place itself, if possible, near the gate exit but opposite the walking direction (Figure **??**) when collecting passengers.
- Perception: "above average" head turning, especially in combination with a lower walking speed, could be an indication that someone is searching for the way.

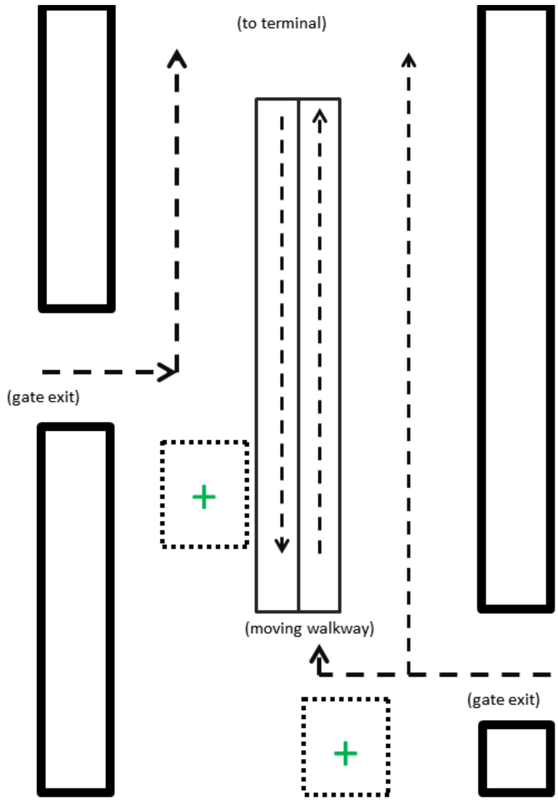


Figure 10: A robot collecting passengers at the gate exit best positions itself opposite the walking direction (marked with a green "+"). Arrows indicate various passenger flows.

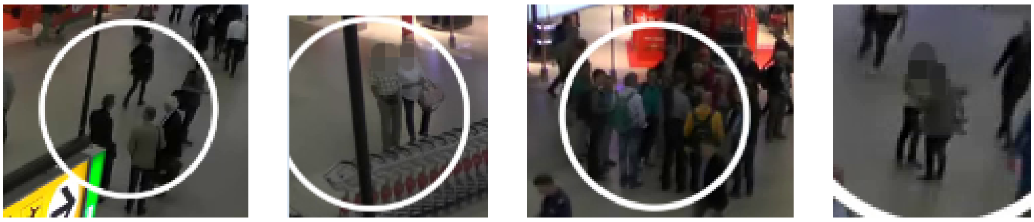
3.1.3 People re-packing luggage

At times we observed people who stopped briefly (NH4-SanFrancisco11), for instance to re-pack their luggage, or search for documents. We observed this kind of behavior 8 times in the narrow hallway, and 7 times in the wide hallway. Also here we observed that there are positions which might be considered inefficient (or inappropriate) by other passengers (WH8-Lounge5). A particularly good position to stand appeared to be the side of the hallway just before entering the T-junction (WH8-Lounge4), or the side in general (NH4-Vancouver5; NH4-Vancouver14). A schematic for appropriate locations in the wide hallway can be found in Figure 19. In general, the insights gained from this is that people could be expected to stop suddenly to re-pack, or re-arrange their luggage. There were two ways for people to re-pack their luggage: either they moved their bag to the front to search something, or they put it on the floor kneeling down. The first behavior resulted in shorter waiting times than the second. So in the first case the robot might just slow down while it might have to stop in the second case.

- Behavior: when the robot detects passengers being guided are "repacking luggage", it should slow down or stop
- Perception: passengers holding their bags in front of them, passengers stopping, kneeling down and searching in their bags

3.1.4 Groups waiting in the hallway

We observed several groups of people waiting in the hallway. In total 11 groups were observed in the narrow hallways, and 14 groups in the wide hallway. The size of these groups varied from small groups (2-4 people) to larger groups of 7 and 11. In particular these last two groups seemed to pose an obstacle for other passengers. As can be seen in (NH5-Beijing8, from about 00:10) passengers have to overtake. Of particular interest could be (NH5-Beijing7) where one can see how this group slowly forms, from 2



(a) Circular formation (b) Side-by-side formation (c) Circular formation (d) Vis-a-vis formation

Figure 11: Pairs and triads in the hallway were observed to stand in side-by-side formations, and vis-a-vis formations, while the larger group (c) formed a circular formation

people who do not pose an obstacle to a large group of 11 people. The group of 7 passengers also first stop in the middle of the hallway, however, afterwards reposition themselves to the side of the hallway (NH5-SanFrancisco14). We could not conclude that a larger group size necessarily leads to providing more hindrance, as also a small group appeared to be standing in a particularly bad position for a period of 6 minutes (NH5-SanFrancisco3), and got overtaken on several occasions (NH5-SanFrancisco1), which for the group could have provided an indication that they were standing in the way.

Of the eleven groups observed to be standing still in the wide hallway, only one group was a ”big” group (WH4-Lounge28). It appeared that they all came from the Non-Schengen passport control, and grouped before moving on. Similar behavior was observed for four other groups. The remaining six groups were observed to walk from the Non-Schengen area to the D-gates (either the Schengen barrier, or the Non-Schengen D-Gates), or vice-versa. One of the places groups were standing still more than once was before the exit of the shop (WH4-Lounge27; WH4-Lounge18), also sometimes to wait for a travel companion who was in the shop. Overall it did not appear as if there were big differences between the narrow- and wide hallway here. Given that we have more observations from the same area we made a map of better and worse locations where a group could stand still if necessary.

For the ”groups standing in the hallway”, we believe that there were different reasons for as why they would stand still. The San Francisco group of four people is standing there for conversation. On the other hand, in one instance (NH5-Vancouver3) numerous individuals form a group as they are all waiting to go to the bathroom. Also, sometimes people stand still to get their bearings, as can be seen in (NH5-Tokyo7). Pairs and triads were observed to be more likely to stand in side-by-side formations, the two large groups all stood in circular formations (Figure 11).

From this we conclude that there are spots in the wide hallway which are suited for waiting with passengers. These spots are mostly located at the sideways of the hallway, and in general away from junctions and information screens as shown in Figure 12.

- Behavior: the robot should wait in appropriate places such as the ones shown in Figure 12.
- Perception: In general, locations outside the passenger flow are appropriate to wait.

3.1.5 Individual passengers waiting in the hallway

We observed only one instance of individual people waiting in the narrow hallway and seven in the wide hallway. The person in the narrow hallway stood still and continued strolling on (NH6-SanFrancisco12).

Individual people seem to be waiting for different reasons. These could be to kill the time, but also waiting for travel companions who might be buying something in a shop or taking a bathroom break. From our observations we noted that individuals more often wait in the wide hallway compared with the narrow hallway, and we speculate that this could be because there are more facilities. A popular place appeared to be the trashcan, which could be as it is an obstacle anyway, they would not be standing ”in the middle of the hallway”, nor form an extra obstacle (NH5-Lounge22; NH5-Lounge13). In one instance we observed that a woman was waiting while her travel partner was buying something in a shop (NH5-Lounge17). We noticed that when people are texting (or otherwise engaged with their cellphone) they do not appear to pay that much attention to their surroundings (NH5-Lounge19).

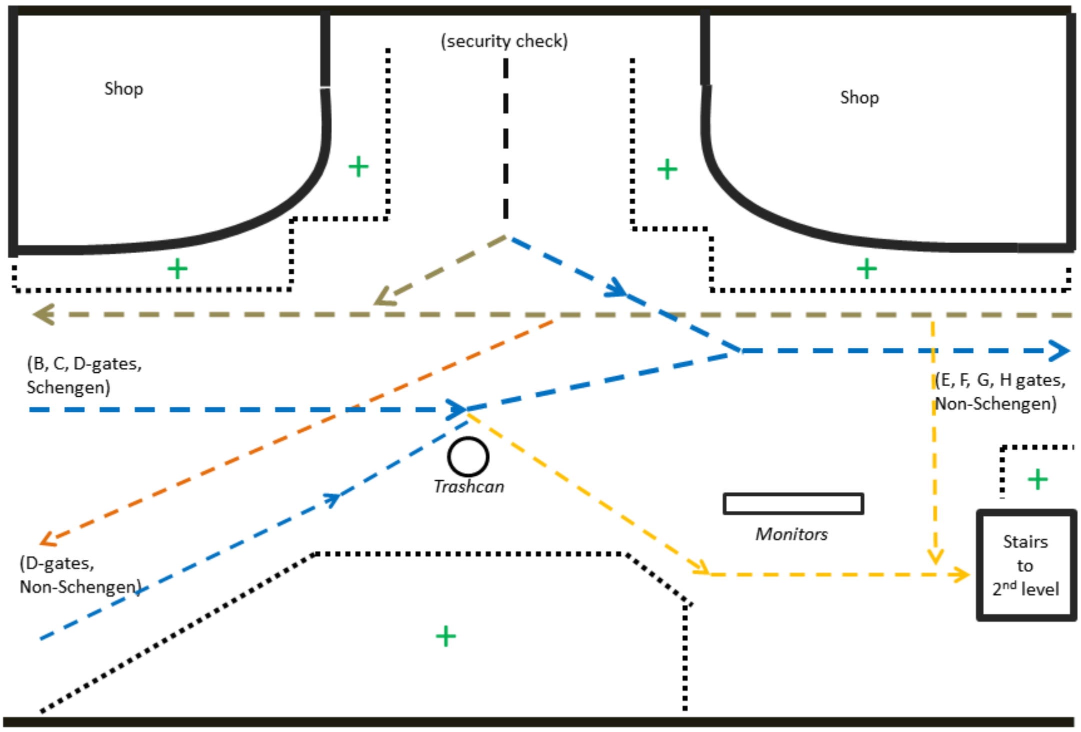


Figure 12: Appropriate positions for waiting with a group in the wide hallway are indicated with green "+"-signs within dotted lines. Colored arrows indicate various passenger flows (different colors represent different directions).

- Behavior: the robot should wait in appropriate places such as the ones shown in Figure 12.
- Perception: not every individual who is standing still is lost, they might just be waiting for someone/something; people might roam around without goal while waiting

3.1.6 Passengers avoiding collisions with other passengers

In the narrow hallway we observed people evading others in the opposing direction. Here the rule of thumb seemed to be that both parties adapt by (slightly) modifying their path. We once observed that a group with a luggage cart seemed to take priority over a group without one (NH7-Beijing7). However, given that we only observed one such a situation we cannot draw any conclusions based upon this.

Encounters with people walking in the opposite direction were more subtle in the wide hallway. At three times we noticed one group split, or forced to split, by passengers moving in the opposite direction. Once a group of three walking next together was passed through by a single person (WH6-Lounge31). Walking with more than 2 people next together seems to happen in a minority of situations, as we will discuss in the next section. If the group had walked in pairs (here 2 + 1) behind each other, this might not have occurred. Two situations with pairs occurred, in one situation two pairs (of equal composition) both split up when encountering each other. The reason for this could be "historical" as one of the pairs was already forced to split mere seconds earlier by an airport vehicle (NH6-Lounge32). In the third occurrence, one of two staff pairs split up when overtaking someone for unknown reasons (NH6-Lounge33).

All these groups were of different composition, and this situation was not observed enough to draw

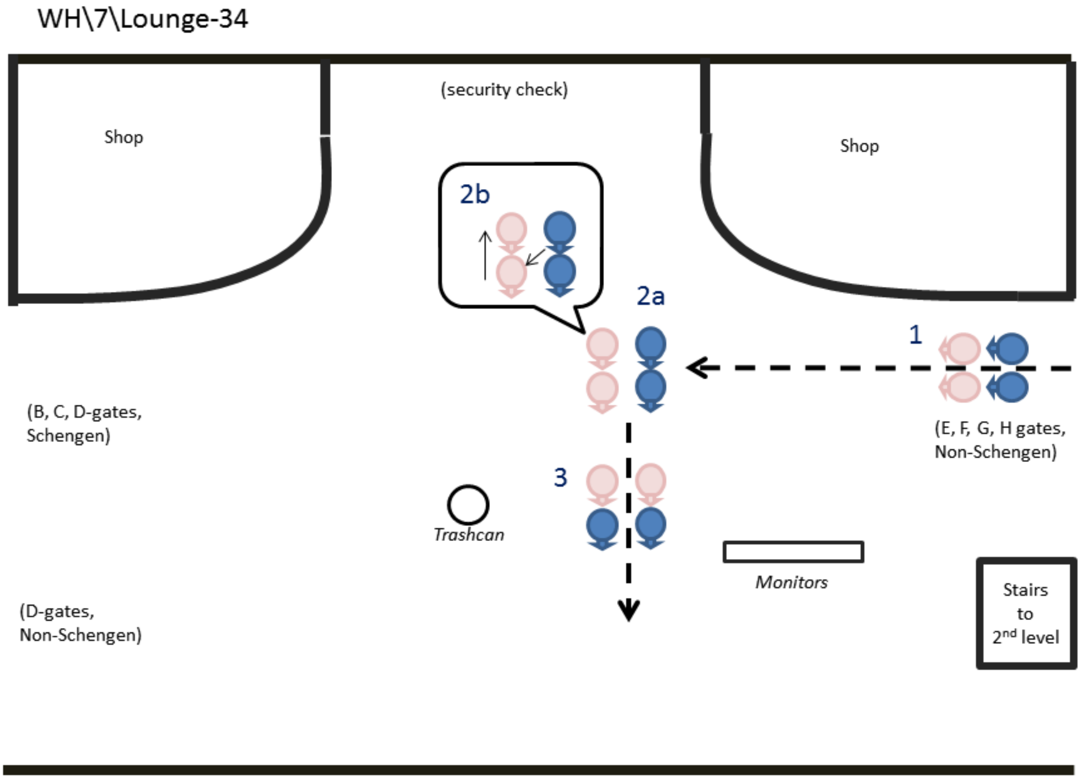


Figure 13: A group consisting of 2 pairs makes a 90 degree turn.

conclusions for how the SPENCER robot should deal with this situation. Thus, we believe that under normal circumstances the SPENCER robot will not encounter situations in which it will force other groups to split up.

3.1.7 Groups organize themselves in pairs and suddenly start walking behind each other

One of the most unexpected findings was that groups mostly organized themselves in pairs. And they always seemed to do so, even when the hallway was wide enough, and the area traversed not crowded thus providing ample space for more people walking next to each other. These pairs also seemed to walk behind each other most of the times. This was noted seven times in the narrow hallways, and also seven times in the wide hallway. For the narrow hallway it should be noted that we here grouped some big groups together, for instance the flight for Beijing (NH14-Beijing9), but also with a 4-person family group (NH14-Junction5) and two groups of staff members (WH7-Aberdeen1; WH7-Lounge36) with 13 and 9 persons, respectively.

Of the five times a 4-passenger group walked into pairs, all but one group organized them in a ”block” of 2x2 passengers. One interesting example (WH7-Lounge34) shows a 4-person group making a 90 degree turn; particular attention should be paid to the way of how the two male persons positioned themselves at the head of the group (Figure 13.

Sometimes the pairs split up and started to walk behind each other as we observed in both types of hallways; 5 times in the narrow hallway, and 13 times in the wide hallway. In most of the cases people did this because of an obstacle being in the way (twice in the narrow hallway, 9 times in the wide hallway). This obstacle was crowds of other people (WH10-Lounge70; WH10-Lounge71), other people looking at information screens (WH10-Lounge68) or people who decided to stop and talk (NH8-SanFrancisco26). We observed three elderly pairs who walked behind each other for no obvious reasons; there was hardly any crowd, or other obstacle (NH8-Vancouver7; WH10-Lounge64; WH10-Lounge69). The reason could be in different levels of individual fitness as will be explained in the discussion.

- Perception: groups of passengers will most likely organize themselves in pairs when following the robot, elderly people might walk one behind the other

3.1.8 Passengers explain the way to others

Once we observed that passengers explained each other the way. It should be noted that no audio recordings were made, so these two could also have been just friendly chats (NH9-Tokyo9). The reason that we believed this is a case of ″explain the way″ was that the two passengers were not part of the same group of people (they were individuals), and both were observed to make sense of the information screen together, by use of various pointing gestures.

- Perception: people from different groups can be observed explaining things to each other by gesturing (see also ″encounters with staff″)

3.1.9 People are running

From our observations in the wide hallway we observed recurring behaviors when people tried to run, or otherwise hurry up to make their way through a (semi-)crowded area. When people encountered groups of people (small crowds), they slowed down, and started running again when the area was clear of other people (WH9-Lounge13; WH9-Lounge3). In the case of passengers travelling together, Kendon's side-by-side formation arrangement (Kendon, 1990, p. 250) could be observed with a father and son who were trying to overtake others (WH9-Lounge6). This was ineffective as they could not pass. However, if they were to split up and run behind each other this would make overtaking more successful, as we observed multiple times (WH9-Lounge10; WH9-Lounge15; WH9-Lounge19; WH9-Lounge20). In some of these situations the distance between the members of the groups increased due to some of them being faster than others.

- Behavior: if the robot walks fast (runs) it hast to slow down when encountering crowded areas
- Perception: passengers belonging to one group while running might be one behind the other, the distance between these passengers might increase considerably

3.1.10 Encounters with staff

While KLM (or Schiphol) does not provide staff to actively search for passengers in need of help, staff do walk around, and from what we noticed they are always willing to direct passengers. This was of course not limited to KLM ground staff, but also applies to security- and cleaning staff. Assisting someone generally consisted of establishing contact, exchanging information (multiple times) and saying goodbye; leaving. In the event that there were multiple passengers waiting for one staff member, people waited, or queued. While we have initially looked at this queuing behavior as well we only found one example (ES1-Beijing6), and whether or not this was a queue was also arguable hence we did not go into this further. We categorized the videos from passenger encounters into two categories, these being ″staff member assisting passengers″ and ″staff looking around to assist passengers″.

Staff member looking around to assist passengers Twice we observed that a staff member actively approached passengers (ES2-Vancouver2; ES2-Vancouver3). This occurred at the disembarkation from the Vancouver flight, and the staff members were part of the company which assists passengers requiring assistance. Therefore, the staff already knew they were looking for certain passengers. Apart from this we have not seen this behavior during the remainder of our observations; the initiation of contact seemed to occur at the side of the passenger, who would approach a staff member walking around.

Staff member assisting passengers We observed (partial) interactions with staff and passengers 16 times. Five of these were during the disembarking of the Beijing flight; these staff were specifically there to assist passengers who were either in need of directions or in need of a transfer. Four formations were observed after the interaction had started; side-by-side (3), vis--vis (6), L-shaped (5) and circular formations (2). It should be noted that there are three or more actors required for a circular formations; whereas in 9 interactions only two actors were present. This conforms with existing research findings that groups of size 2 tend to occur much more often than bigger sizes (Ciolek, 1976).

We observed that passengers showed travel documents to airport staff seven times. One of these encounters was identified as being "showing documents", however, due to the angle of the camera it was impossible to make out what document it was (ES4-Vancouver1). In four of the remaining six cases, the staff member physically took the boarding card and read it out loud (i.e. ES4-Beijing5), in the other two cases (ES4-SanFrancisco3), the staff member only read what was stated on the boarding card.

Out of the remaining 15 encounters, in 9 encounters staff were observed to gesture with their arms where the passenger had to go (i.e. ES3-SanFrancisco5). In four of these encounters the staff member also used his/her head to indicate direction (i.e. ES3-Beijing2; ES3-SanFrancisco7). In one encounter (ES3-Beijing1) we observed the staff member only using her head to indicate direction. Overall, indicating direction could be important as a way to end the guiding scenario for the SPENCER robot.

- Behavior: having finished the conversation about where to go, the robot should indicate the direction with a gesture
- Perception: the robot should be enabled to read boarding cards as they seem to be a common way to share information

3.1.11 Passengers overtaking

We also noted behaviors which did not occur frequently, but nonetheless could be important for the SPENCER consortium, at least to be aware of. In two instances we observed passengers actively overtaking passengers in front of them. With actively overtaking we refer to situations where people speed up, overtake, and then slow down. In both instances people overtook at their left side because the people in front of them walked right and there was no room (NH11-Vancouver15; NH11-SanFrancisco21). This could be culturally motivated as people in Western Europe mostly walk at the right and overtake at the left side.

- Behavior: if the robot needs to overtake people, the left side in many situations might be the better side to do so

3.1.12 Children running around

In two situations we observed children running away from their parents (WH9-Lounge54; ES3-SanFrancisco5). They moved rather quickly and not in line with passengers' general walking direction.

- Behavior: the robot might have to slow down or stop when detecting a running child
- Perception: it might be beneficial to be able to detect running children

3.2 Self-service transfer machines

It was, in general, observed that there were hardly any queues in front of the self-service transfer machines. We observed seven situations in which passengers approached the self-service transfer machine where it was clear to see what actually happened. In the other cases we observed passengers' usage of the machines without the actual approach to the machine. In most cases passengers just walked slowly up to the machine (i.e. TM1-SanFrancisco5; TM1-SanFransisco3). Two exceptions have been observed; one in which the passenger had to queue (TM1-SanFransisco10), and another example in which two passengers appeared to approach, however, it turned out that one passenger just had to find a place to tie his shoelaces while the other passenger was looking at the machine (TM1-SanFrancisco2).

After having made use of the SSTM it appeared that most people were still wondering where to go. We arrived at this conclusion as passengers who had help from staff as well as those who did not were

(a) Circular formation (b) Side-by-side formation (c) Circular formation

Figure 14: Passengers at the SSTM. In case of a group used a SSTM the number of passengers operating the machine was limited to 1 or 2

observed to look around after leaving the SSTM. Staff members who assisted in using the machines did provide directional cues to passengers (see below).

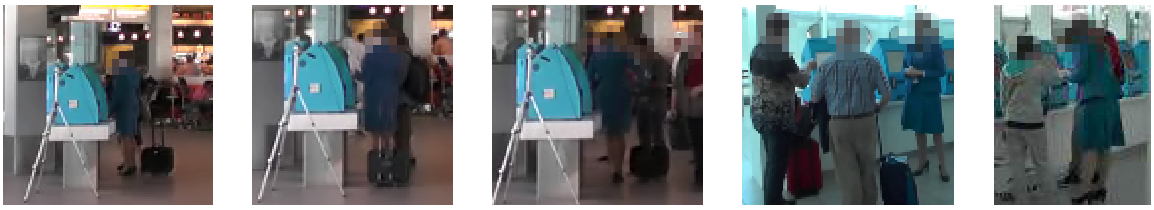
3.2.1 Passengers using machines without help of staff

10 times passengers were observed using a self-service transfer machine without help of staff. Of these nine videos, four were single passengers, the other small groups consisting of 2-4 persons each. Single passengers, were standing right in front of a machine (TM2-Vancouver1). Also in the groups at all times there was only one passenger operating the machine, however, usually one of the fellow passengers stood next to him/her (TM2-SanFrancisco4; see Figure 14), and the others all behind these two passengers (TM2-SanFrancisco9).

3.2.2 Staff member assisting passengers at SSTD

At the SSTM's we observed five interactions between staff, passengers, and machine. Three times these interactions took place at the F-gates. Here, the same staff member assisted three (single) passengers (Figure **??**: A, B and C). We observed that the staff member and individual passengers always formed a side-by-side formation facing the machine. At the conclusion of the transaction with the passenger, the staff member used a pointing gesture to indicate where the passengers had to go.

Two other interactions were (partially) observed at Transfer 6 (Figure 15: D and E). Here, a staff member assisted two couples. In both situations the staff member formed a rectangular formation; where the passengers were closest to the SSTD machine. No gestures by the staff member were observed; however this could be as we observed partial interactions.

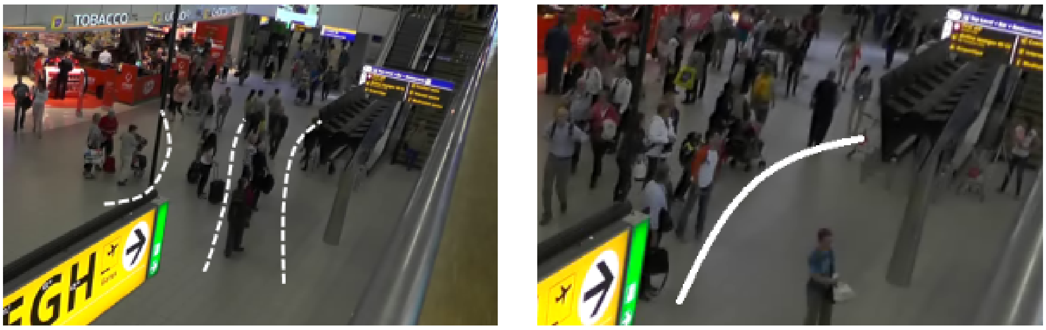


(a) Single passenger (b) Single passenger (c) Single passenger (d) Pair (e) Pair

Figure 15: Staff assisting passenger at the SSTD; usually took the form of a circular or rectangular formation

Overall it can be noted that the formations of people in front of the machines seem to differ depending if staff is present or not. If staff is present, the formations are more circular or rectangular, whereas if no staff is present, the users rather position themselves in pairs directly facing the machines.

- Behavior: the robot should indicate the direction at the end of the interaction
- Perception: when the robot acts as SSTM, it might be useful to recognize from the positions of the users if a staff member is present who takes over some of the tasks for the robot



(a) (b)

Figure 16: Participants formed a formation around the information screen resembling a half circles

3.3 Information monitors

Within the ”information monitors” category we found four main spatial behaviors: *passenger standing next to a stranger*, *passengers forming a 2nd row*, *passengers forming a half circle around the information monitors* and *passengers looking at their boarding pass*. For the analysis, we looked separately at the data collected from the videos in the wide hallway and in the narrow hallway. The difference here was that the wide hallway appeared to allow for more people to look at the monitors, and that they were positioned more prominently. A second reason is that the fourth spatial behavior (looking at boarding pass) could not be observed in the wide hallway due to the distance between camera and passengers. Also, significantly more observations were made in the wide hallway (53 versus 7).

At two times we observed a passenger standing next to a stranger in the narrow hallway. In both cases we did not have measurements of the distances between both actors, and therefore did not know whether or not one would come too close. We estimated that in both cases there was about 30-40 centimeters space in between both actors. However, given that no physical compensatory behaviors such as stepping away were observed we are proceeding with the assumptions that this is not the case (IM2-Vancouver1; IM2-Aberdeen1). It could be that it is socially acceptable to stand next to a stranger provided that you keep at least some distance between one another, especially if there is not much space around. In the discussion we will briefly reflect on this.

For the information monitors in the wide hallway, similar behavior was observed: the passengers appeared to stand quite close together (IM2-Lounge11). One passenger displayed what might be a physical avoidance behavior to personal space invasion. In clips (IM52-Lounge15 and IM52-Lounge16) we observed that a passenger stepped to the left and right respectively when someone stood next to him (at the other side). One explanation could be a reaction to personal space invasion; e.g. the other one stood too close to him (see Section 4.1); another explanation is that coincidentally he was looking at another screen; therefore requiring him to make a small step.

In the wide hallway we have looked at people’s formations when standing next to each other, and facing the information monitors. What we observed in general was that the passengers were forming half-circles around the information monitors as can be seen in Figure 17. The crowdedness varied greatly. Even when it was not crowded around the monitors it could be observed that there are multiple layers (one very close, one halfway the hallway), and that the people were spread out more or less in a half circle. The boundaries of the area where you ”should” watch the information monitors appeared to be given by the surroundings; i.e. there were 6 monitors determining from where people could read the information. Also the hallway was at times crowded (IM51-Lounge34; IM51-Lounge42).

Similarly, at the temporary information monitors at the end of the E-gates (Figure 17a) 4 times passengers formed a second row instead of standing next to other passengers who were already there. From what we observed in the four videos, it appeared as if people started to form a second row as soon as they could either not see the monitors from the particular angle where they would have to stand, or that they would be in the way of other passengers by doing so (f.e. IM1-Vancouver4). An illustration of this problem is provided in Figure 17b. In the wide hallway this could be observed as well. Figure 19 enriches the figure of passenger flow and waiting areas with locations that appear to be appropriate for watching the information monitors in the wide hallway. As can be seen from the pas-

(a)

(b) Schematic showing socially appropriate area to watch monitors. Dotted lines indicate various passenger flows.

Figure 17: Three temporary information monitors located at the end of the E-gates

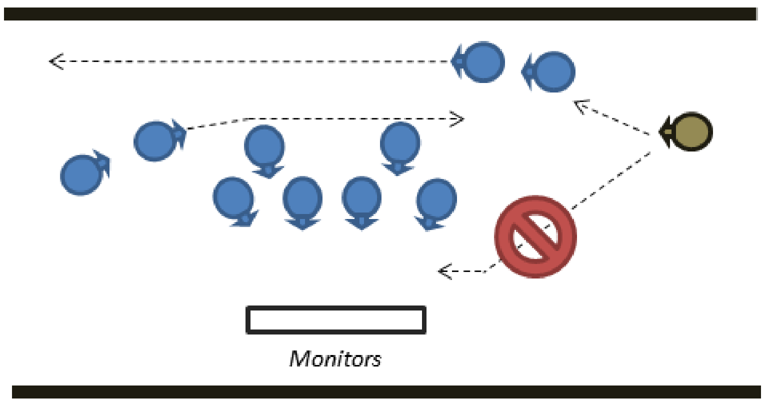


Figure 18: Scenario recommendation: do not drive in between information monitors and people looking at them. Dotted lines indicate various passenger flows.

senger flow, crossing between the people who look for information and the information screens might not be a good option. This particular robot behavior is also illustrated in Figure 18.

- Behavior: it appears that it might be inappropriate for the robot to drive between information monitors and people looking at them
- Perception: the robot might have to be able to recognize people looking at information screens (groups facing the same direction, standing in half-circles or multiple of these behind each other)

3.4 Encounters with vehicles

All powered vehicles driving at Schiphol are operated by airport staff. The size and purpose of these vehicles varies, as can be seen in Figure 20. From our observations we can make two general assumptions. The first assumption is that the vehicles drive relatively fast and are not equipped with a horn, or anything to signal. In order to make way the drivers would slow down, and usually raise their voice to indicate they would like to pass (see f.e. EV-Vancouver3). They do this in a polite way, as passengers are customers and should thus be treated as such. The second assumption is that people sometimes just do not hear the vehicle. There is a lot of ambient noise and the vehicles are battery-powered so the noise generated by the engines is low. For the SPENCER robot one recommendation could be to equip the robot with some sort of functional noise, as proposed in (Lohse et al., 2013).

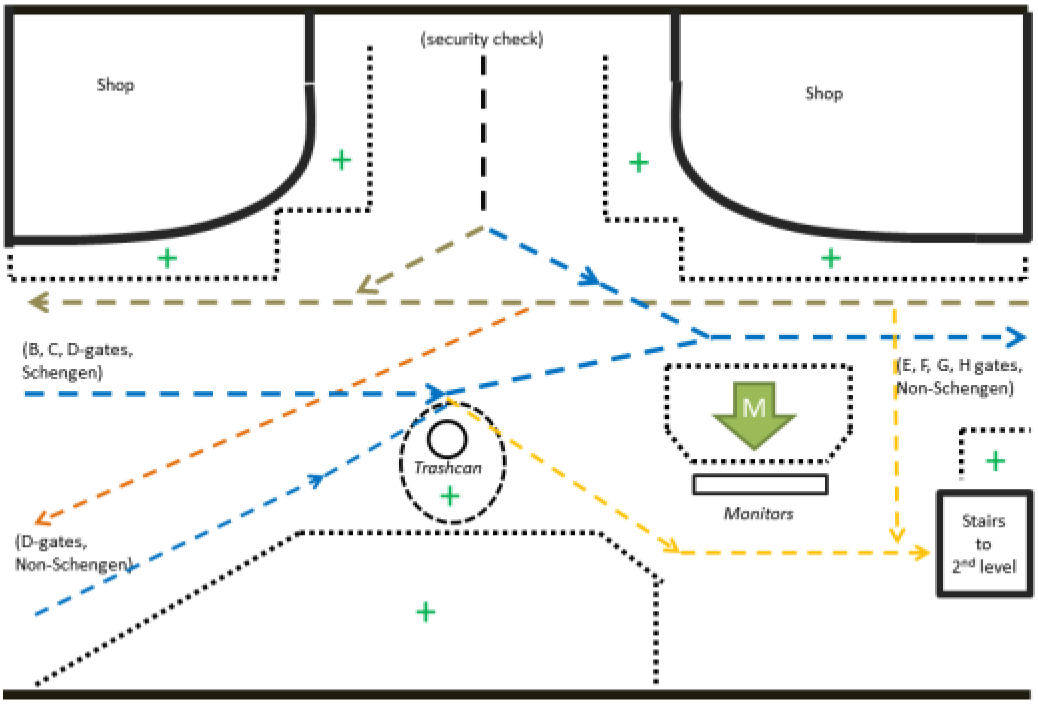


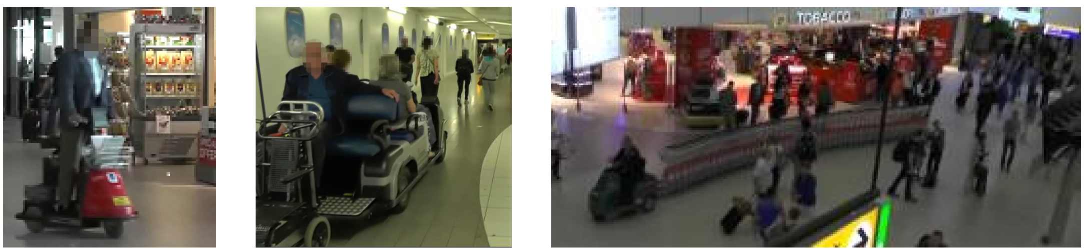
Figure 19: Wide hallway schematic showing appropriate locations to wait (or look at information monitors), indicated with green ”+”-signs within dotted lines. Colored arrows indicate various passenger flows (different colors represent different directions).

In total we observed 38 encounters with vehicles and passengers. Of these 38 encounters, a lot of times (13) there was no interference between vehicle and passengers; the driver of the vehicle would just drive around the passenger without having to slow down. 14 times we observed the driver of the vehicle going out of the way and making way for the passengers. Only 2 times we observed that the passengers went out of the way; which translated into going a little bit more to the right or left side of the hallway. Therefore it appears that passengers take priority at the airside. The remaining nine encounters did not show clearly whether it was the driver or passenger who adapted to the situation.

- Behavior: signal to other passengers in a polite way that the robot is approaching; give priority to passengers, e.g. by slowing down or adapting walking direction
- Perception: the robot should detect if its path will collide with other passengers’ paths

3.5 Moving walkway

The narrow hallways are equipped with moving walkways for passengers, so as to reduce walking distance for passengers. Most moving walkways have a width that allows people to overtake others.



(a) Staff transportation (b) Passenger transportation (c) A number of luggage carts

Figure 20: Various of the powered vehicles at Schiphol

Walking	Single passengers				Dyads of passengers			Percentages
speed	Left	Middle	Right	Undecided	Left	Middle	Right	(single/dyad)
Standing still	2		1		1	2	1	8% / 13%
Slow	6	2	1	1	1	5	1	29% / 22%
Normal	9		5	1	4	10	2	42% / 55%
Fast	2	1	4	1	2		1	21% / 10%

Table 4: Comparison of single and dyad passengers motion behavior on a moving walkway

This can be necessary as we observed situations where all people are walking (such as CB3-Tokyo13 and CB3-Tokyo10) or where some passengers are just standing still (CB1-Tokyo3). In one situation we observed that a moving walkway was out of use. In this case the passenger did not walk on the moving walkway but next to it (CB2-Vancouver3).

In total we observed 83 situations on the moving walkway. The total duration of video material containing a moving walkway was 12 minutes. One independent coder coded these fragments to indicate whether people either were standing still (11), walking slowly (20), walking at a normal speed (39), or walking fast (13). 38 of these situations contained single passengers, 31 a pair of people, and the remaining situations featuring groups containing respectively three (4), four (1), five (3), six (3) and ten (2) passengers.

In Table **??** we compared the motion behaviors of single passengers and dyads of passengers. Of the 37 situations identified as containing single passengers, 19 were identified as walking at the left side, 3 in the middle, 11 at the right side and 3 undecided. Of the 31 situations with pairs of people, 8 pairs walked at the left side, 17 stood next together and thus occupied the whole width, and 5 passengers stood at the right side. From this it appears that passenger, if any, have a preference to stay at the right side of the moving walkway for other passengers to overtake. However, it is also possible that dyads block the whole walkway for other passengers behind them. If the people approaching from behind are the ones that the robot guides, this might pose a challenge for person tracking.

Overall there are no obvious differences between the individual passengers and the dyads. Compared to the dyads, more single passengers walk fast but then again also more walk quite slowly. A general trend is that passengers walk on the moving walkway instead of standing still. As the robot cannot get onto the walkways, this implies that it would have to drive quite fast to reach the other end of the walkway at the same time as the passengers.

- Behavior: the robot might have to adapt its speed to people walking on the mobile walkways
- Perception: the robot might have to track passengers while they are walking on the moving walkway, are overtaking, being overtaken, or blocked by other passengers

4 Literature related to our findings

In this section we will relate our findings to the existing related literature such as on pedestrian behavior and interpersonal distance. Where possible we relate to literature related to relevant contexts such as airports and train stations. We will discuss different topics, these being related to formations of groups (Section 4.1), speed (Section 4.2) and politeness-related behaviors (Section 4.3).

4.1 Formations & spatial organizations of small passenger groups

Based upon our general observations we found two important re-occurring patterns, which deal with how passengers navigate through a crowded area. The first general behavior was that a group would split itself into pairs (walking behind each other), even when there is enough space (width) in the hallway. The second observation deals with crowding, in that guided passengers will likely change formation in order to successfully traverse crowded areas.

A question would be how the robot should deal with this, from a technical point of view. For the first observation it would be necessary to know how many people walking behind each other the robot can track, and related to that if it would be possible for the robot to remember these persons even while they are not being tracked as still belonging to the group.

During our observations of passengers who were looking at information monitors, we observed that people frequently stood next to a stranger, at a distance that could be seen as socially inappropriate (too close), given the lack of crowdedness in the situations. In a normal situation, people maintain a minimum interpersonal distance between each other, not only when facing each other, but also when they stand next together. The reason why people stood seemingly close together could perhaps be explained by a combination of the theories of (Kendon, 1990) and (Hall, 1966).

The first thing to consider in that there is basically only one type of focused encounter. Due to the limited viewing angle people have to be able to see what is actually written on the monitors (see Figure 11 and Figure **??** for an illustration). This could be similar to a situation of a crowded shop, where people lean close to each other to grab products from a shelve. For the situation observed near the information monitors this implies: because people focus on the information monitors (and thus make no eye-contact with people standing next to them), they can stand closer together.

4.2 Walking speed

We observed that people tend to slow down when they encounter a crowd. In literature we could not find this exact finding, however, Young (1999) observed (adult) average walking speed at an airport. He observed that passengers tend to slow down when they are either:

1. Approaching a travel-path decision
2. Approaching / in the presence of directional signs and/or aircraft arrival-and-departure boards

We also observed people who slowed down in these situations, even though we did not actually measure speed. However, we can back this up by our observations. Young's results indicate that the average walking speed was 1.34 m/s (sd=0.27 m/s) under normal walking conditions (Young, 1999). Small differences were observed between man and woman, with man walking on average slightly faster. Furthermore, it was, perhaps unexpectedly, observed that people carrying bags walked significantly faster than people without bags. Our analysis was not detailed enough to either support or reject his final finding. However, it might be worthwhile to keep them in mind.

While age was not a main focus of our observations, it is not unlikely that the SPENCER robot will guide elderly passengers. As described above, we saw that sometimes couples of elderly walk behind each other, which could be due to one of the two being in a physically healthier state. When looking at the videos it seemed that elderly in general walked slower.

Bohannon (1997) compared both average and maximum gait speeds[3] of pedestrians from different age groups (N=230). Speed was measured by having participants walk in a lab over a distance of 7.62 meters (or 25 feet). He found that the maximum speed declined by age, whereas the comfortable walking speed was more or less stable over time (Figure 21). For the SPENCER robot this would imply that if people have to hurry and the robot drives faster than 1.6 m/s, it is imperative that the robot has some awareness of the age of the passengers. However, given that these speeds were measured over a short distance, other tests which yield reference values such as the 6-Minute Walking Test (6MWT) are potentially more useful in our context.

4.3 Politeness- and predictability-related recommendations

Oftentimes passengers were holding up, or strolling in the hallway. We have interpreted these situations as being one of two categories: searching for the way or waiting. For the SPENCER robot this would be an important feature to distinguish as the changes of a successful interaction would be greater when approaching those people who are likely in the need of help.

Based upon our observations from the airport vehicles, we noted that if one of the parties went out of the way to avoid a collision, this would be the vehicle driver. However, usually these vehicles drove at a high speed; not a speed a healthy human could easily keep up with. Therefore, this will not likely require the robot to manoeuver quickly through a crowd, and hoping the passengers who follow

[3]Gait speed is measured over a short distance, thus does not include endurance as a factor.

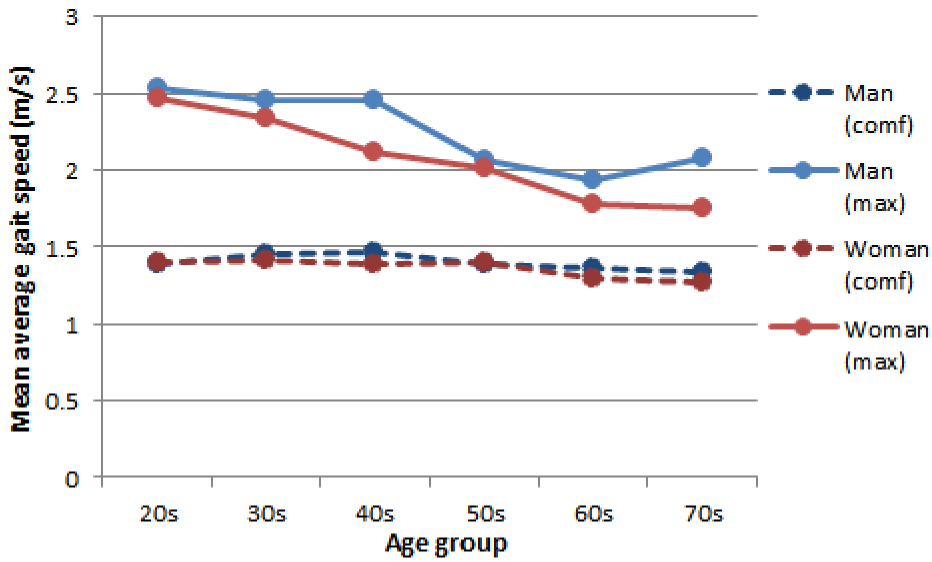


Figure 21: Average maximum gait speed (max) decreases significantly by age group, especially compared with comfortable gait speed (comf).

the robot keep up with the robot. We recommend that the robot displays politeness, and legibility (Lichtenthäler & Kirsch, 2013), for instance by slowing down and driving forward without making a lot of abrupt turns (Lichtenthäler & Kirsch, 2014).

In line with our observations of the closing of the interaction between staff and passengers, and with the KLM brand value ”positive concluding of the interaction”, we recommend that the robot provides the direction in a way which is as unambiguous as possible, by pointing where to go. We do not know yet whether or not the SPENCER robot should use its whole body to point or rather only its head.

Above recommendation is also related to research by Hicheur, Vieilledent, and Berthoz (2005), who found that head motion is a predictor of future walking direction. In an experiment where participants (n=10) were asked to walk along a 20-meter figure of 8, head motion was found to be a predictor of future walking direction. Similarly Hollands, Patla, and Vickers (2002) found that people use a combination of head and eye movement to indicate their heading. This unconscious nonverbal behavior could explain why people do not bump into each other when traversing a crowded public space, and might thus warrant implementation on the SPENCER robot.

A question which arose during the analysis was how to deal with the moving walkway. If the robot cannot track people who are walking on the walkway, we should design the instructions to the users in a way that they also will not do so; or are not encouraged to do so.

While a robot can be designed to have a humanoid appearance, and some behavior can indeed be matched, so as to copy human behavioral norm (such as slowing down, and adjusting speed), other behaviors are required to be robot-specific. For instance, we recommend, or observed, that in order to pass a crowded area effectively, the group has to break its formation. After having cleared a crowded area the robot could collect its passengers before moving on. This was not observed at Schiphol Airport, as the ”guiding” itself does not take place in this form.

One final recommendation perception-wise would be to consider that a robot in public space will be considered being a ”celebrity”, in that people will take pictures of the robot. How to deal with this during mission execution has yet to be decided, also, what to do when people block the way because they want to touch the robot, or take a picture with it.

5 Conclusion

In order to inform the design of the SPENCER guide robot’s motion behavior we have conducted a contextual analysis at the envisioned deployment location, Schiphol Airport. As this robot will guide passengers from their arrival gate to the Schengen barrier, we have collected video data at a variety of places which are relevant for the SPENCER robot, including the disembarkation of several flights, passengers making use of self-service transfer machines, encounters with staff members providing directions to passengers and current passenger movement through crowded areas.

We analyzed these data using an inductive data analysis approach by Lofland et al. (2006). This method consists of three phases, and after the third phase we made inferences about the data which were then structured into various categories. The results can roughly be divided into two categories: implications for the SPENCER robot's motion behavior and for the perception of the robot. For a brief list of all recommendations and observations we refer to Appendix A. In the discussion section these recommendations are related to existing literature.

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Abbrevations

KL	KLM flight number
KLM	Koninklijke Luchtvaart Maatschappij, or: Royal Dutch Airlines
MCT	Minimum Connection Time
SPENCER	Social situation-aware perception and action for cognitive robots. EU FP7 project FP7-600877
SSTM	Self-Service Transfer Machine
f.e.	For example
Abbreviations used for reference to video files in results section:	
WH	Wide hallway
NH	Narrow hallway
CB	Moving walkway
ES	Encounters with staff
EV	Encounters with vehicles
TD	Passengers using self-service transfer machines (either in the hallway or at the transfer area)
IM	Passengers looking at information monitors

A List of recommendations

This appendix provides a summary of the recommendations we have formulated in the Results section. These recommendations are either implications for the behavior or implications for the perception capabilities of the SPENCER robot.

Section 3.1.2

- Behavior: a robot which collects passengers should place itself, if possible, near the gate exit but opposite the walking direction (Figure **??**) when collecting passengers.
- Perception: ”above average” head turning, especially in combination with a lower walking speed, could be an indication that someone is searching for the way.

Section 3.1.3

- Behavior: when the robot detects passengers being guided are ”repacking luggage”, it should slow down or stop
- Perception: passengers holding their bags in front of them, passengers stopping, kneeling down and searching in their bags

Section 3.1.4

- Behavior: the robot should wait in appropriate places such as the ones shown in Figure 12.
- Perception: In general, locations outside the passenger flow are appropriate to wait.

Section 3.1.5

- Behavior: the robot should wait in appropriate places such as the ones shown in Figure 12.
- Perception: not every individual who is standing still is lost, they might just be waiting for someone/something; people might roam around without goal while waiting

Section 3.1.7

- Perception: groups of passengers will most likely organize themselves in pairs when following the robot, elderly people might walk one behind the other

Section 3.1.8

- Perception: people from different groups can be observed explaining things to each other by gesturing (see also ”encounters with staff”)

Section 3.1.9

- Behavior: if the robot walks fast (runs) it hast to slow down when encountering crowded areas
- Perception: passengers belonging to one group while running might be one behind the other, the distance between these passengers might increase considerably

Section 3.1.10

- Behavior: having finished the conversation about where to go, the robot should indicate the direction with a gesture
- Perception: the robot should be enabled to read boarding cards as they seem to be a common way to share information

Section 3.1.11

- Behavior: if the robot needs to overtake people, the left side in many situations might be the better side to do so

Section 3.1.12

- Behavior: the robot might have to slow down or stop when detecting a running child
- Perception: it might be beneficial to be able to detect running children

Section 3.2

- Behavior: the robot should indicate the direction at the end of the interaction
- Perception: when the robot acts as SSTM, it might be useful to recognize from the positions of the users if a staff member is present who takes over some of the tasks for the robot

Section 3.3

- Behavior: it appears that it might be inappropriate for the robot to drive between information monitors and people looking at them
- Perception: the robot might have to be able to recognize people looking at information screens (groups facing the same direction, standing in half-circles or multiple of these behind each other)

Section 3.4

- Behavior: signal to other passengers in a polite way that the robot is approaching; give priority to passengers, e.g. by slowing down or adapting walking direction
- Perception: the robot should detect if its path will collide with other passengers' paths

Section 3.5

- Behavior: the robot might have to adapt its speed to people walking on the mobile walkways
- Perception: the robot might have to track passengers while they are walking on the moving walkway, are overtaking, being overtaken, or blocked by other passengers