# DATA COLLECTION METHODOLOGIES USED IN THE SAFEGUARD PROJECT TO COLLECT HUMAN FACTORS DATA

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## SUMMARY

This paper presents the methodologies used to collect human factors data relating to the passenger assembly process on large passenger ships at sea undertaken as part of the EU FP7 SAFEGUARD project. As part of the data collection exercise, passenger response time data was collected using video cameras and passenger starting location, end location and assemble time data was collected using a novel infra-red (IR) based position logging system. Questionnaires were also used to collect demographic data and to understand the behaviour of the passengers. This paper describes the development and testing of the data acquisition systems.

## NOMENCLATURE

| | |
|---|---|
| AAT | Alarm Activation Time |
| CCTV | Close Circuit Television |
| EPC | Electronic Product Code |
| ERP | Effective Radiated Power |
| ERP | End of Response Phase |
| EU | European Union |
| FP | Framework Package |
| FP | Fire Protection |
| FSEG | Fire Safety Engineering Group |
| GB | Gigabyte |
| IMO | International Maritime Organization |
| IR | Infra Red |
| MS | Microsoft |
| MSC | Maritime Safety Committee |
| RF | Radio Frequency |
| RFID | Radio Frequency Identification |
| Ro-Pax | Ro-on Roll-off passenger vessel |
| SAS | Start of Activity Stage |
| UHF | Ultra High Frequency |
| UOG | University of Greenwich |

## 1. INTRODUCTION

Understanding how people behave in emergency situations within maritime settings is vital if we are to; design and develop evacuation efficient vessels and crew evacuation procedures, train crew in the management of evacuation situations, develop reliable ship evacuation models and regulate the design and operation of vessels. An essential component of this understanding is the collection and characterisation of human performance data. Unfortunately, little data relating to passenger response time or full-scale validation data in maritime environments exists. In the first International Maritime Organization (IMO) document to specify protocols for the use of ship evacuation models for the analysis and certification of passenger ship design, IMO MSC Circ. 1033 [1], an arbitrary uniform random distribution was set to represent the response time behaviour of passengers. This has been shown to be unrepresentative of actual passenger response time and liable to produce incorrect or miss leading conclusions concerning the suitability of ship design for evacuation [2]. As part of the EU framework 5 project FIRE EXIT, passenger response time data was collected for a passenger ship at sea [3]. This data was accepted by the IMO and used in the formulation of IMO MSC Circ. 1238 [4], the modified protocols for passenger ship evacuation analysis and certification. However, the response time data produced by FIRE EXIT related to only a single passenger vessel. As such the data cannot be considered representative of passenger ships as a whole. The IMO Fire Protection (FP) Sub-Committee in their modification of MSC Circ. 1033 at the FP51 meeting in February 2007 [5] invited member governments to provide, "...further information on additional scenarios for evacuation analysis and full scale data to be used for validation and calibration purposes of the draft revised interim guideline."

The EU framework 7 project SAFEGUARD aims to address this requirement by providing (a) full-scale data for validation of ship based evacuation models, (b) response time data sets for RO-PAX ferries and cruise ships and (c) propose and investigate additional benchmark scenarios to be used in certification analysis. As part of project SAFEGUARD, five response time data sets and two full-scale validation data sets from three different types of passenger vessels were collected, a RO-PAX ferry, a RO-PAX ferry with a significant number of cabins and a Cruise ship. This paper will discuss the data collection techniques employed in the SAFEGUARD.

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## 2. THE TRIALS

As part of the EU funded project SAFEGUARD, five full scale assembly exercises were carried out on three different types of passenger vessel; RO-PAX ferry, RO-PAX ferry with cabins and a cruise ship. The trials involved the ship's Captain sounding the alarm and crew moving the passengers into the designated assembly areas. The trials took place at an unspecified time on the crossing, however passengers knew that on their crossing an assembly exercise was going to take place. The data collected consisted of passenger response time data and validation data for ship based evacuation models.

The first two trials were performed on a large RO-PAX vessel which only had a small number of cabins (approximately 30 cabins). The vessel could carry approximately 2000 passengers and 700 vehicles. The ship contains a mixture of spaces spread over three passenger decks including; business and traveller class seating areas (airline style seating), large retail and restaurant/catering areas, bar areas, in-door and out-door general seating areas and general circulation spaces. This vessel will be referred to as RO-PAX1 throughout this paper. There were 2780 passengers on board RO-PAX1 during the first two trials, 1431 for first trial and 1349 for the second trial.

The third trial was performed on board a cruise ship. This vessel had an operating capacity of 2501 passengers which are spread over 12 passenger decks. The vessel contains a mixture of spaces including; cabins, restaurants, bars, retail, casino, theatre and recreational spaces (such as swimming pools and saunas). There were 2292 passengers on board the cruise ship during the trial.

The fourth and fifth trials were performed on board a large RO-PAX vessel which had sufficient berthing capacity for all the passengers. The vessel had an operating capacity of 2200 passengers spread across four passenger decks. On the upper most deck was a disco while a swimming pool was located on the outer deck space. There were two cabin decks and the lower deck consisted of restaurants, a cinema, recreational spaces and airline style seating. This vessel will be referred to in this paper as RO-PAX2. There were 510 passengers on board RO-PAX2 during the last two trials, 240 for first trial and 270 for the second trial.

Each of the trials was planned by designed by staff from the University of Greenwich Fire Safety Engineering Group (FSEG). The trial teams needed to setup the equipment and run each of the trials consisted of 25 staff (9 FSEG staff, 12 SAFEGUARD and 4 crew) for RO-PAX1, 25 staff (5 FSEG staff, 6 SAFEGUARD and 14 crew) for the cruise ship and 22 staff (5 FSEG, 4 SAFEGUARD and 13 crew) for RO-PAX2.

Three types of data sets were collected in each trial. The first consisted of passenger response time and was collected using video cameras positioned throughout the vessel. In total, 30 battery powered mini digital video cameras were used to collect the response time data. The cameras were placed at strategic locations throughout the vessel to record not only the time at which passengers responded, but also the nature of the activities that they were involved in at the time. In the case of the cruise ship, the on board CCTV system was also used to capture passenger response time data and response phase behaviour. The second type of data collected comprised validation data for ship based evacuation models. This consisted of start and end locations of passengers and the arrival time at the designated assembly areas. This data was collected using a novel data acquisition system consisting of over 30 Infra-Red (IR) beacons, each emitting unique IR signals and data logging tags that were worn by each passenger. The third type of data consisted of a questionnaire that was completed by passengers after the assembly trial was over.

## 3. PERSON TRACKING METHODOLOGY

Previous efforts at collecting comprehensive full-scale ship evacuation validation data have been less than successful due to the complication of the associated data analysis. Previous efforts have attempted to use video footage to manually track individuals through the vessel [6]. However, tracking individuals through the complex layout of a large passenger vessel is extremely time consuming. Depending on the complexity of the structure, the analyst may have to track an individual through tens of different video camera locations. Attempting to track a handful of individuals this way can be extremely tedious and prone to error. In the case of the cruise ship, tracking over 2000 passengers across twelve large decks would have been unthinkable! Automated video tracking systems also have problems as they require a 'birds eye' view of the targeted individuals if they are to accurately monitor an individual's progress through a particular location, making installation of the video equipment difficult due to the low head room often found on ships [7]. Furthermore, the problem still persists of tracking individuals passing through many different camera locations.

A comprehensive investigation was undertaken of technologies that may be useful in addressing this problem. This identified two specific technologies - passive radio frequency identification (RFID) and infra-red (IR) position logging. Both systems rely on similar underlying concepts - devices are mounted throughout the structure that generate uniquely identified radio frequency or IR fields and passengers wear a device that allows for their unique identification as they move



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throughout the structure and pass through each field. If a sufficient number of unique fields are generated, then as a person moves around the structure, their tag either logs or permits the logging of the different field IDs and the time they were passed (see Figure 1).

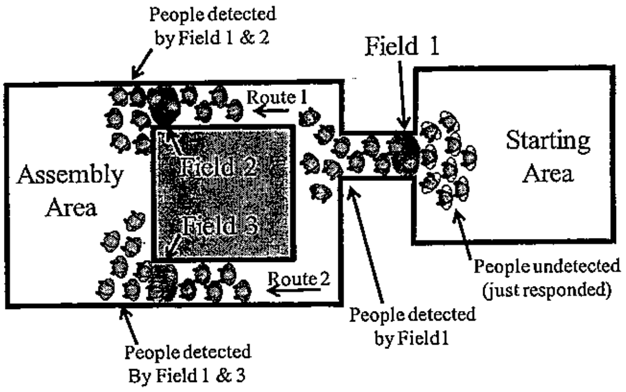


Figure 1 - Example of tracking system following individuals from a starting area to an assembly area or exit point via two different routes

Both systems rely on the population agreeing to wear a tag for the purposes of the trial. As the trial may take place at any time, the participant population must be prepared to wear the tag for an extended period of time (possibly all day/night) and so it must not interfere with normal activities, be comfortable, and if possible must blend in with their normal attire. For example, attaching the tags to a hat or cap, while ideal for detection, would not be acceptable.

However, there are fundamental differences between the RFID and IR systems, particularly the way in which the fields are generated and the way in which communication takes place between the tag and field for logging of position and time. The passive RFID technology examined (see Figure 2) relies on a pair of antennae that generate a radio frequency (RF) field with sufficient power to energise tags that enter it. The tags use the RF energy from the field to wirelessly transmit a signal to the receiving antennae (the same antennae that generate the RF field). The receiving antennae then sends the information to a processor that logs the tag's unique ID and the time at which the signal was received. For this system, the RFID tag acts as a passive device with no built-in power source and no data storage capacity. The data for people tracked is stored either by the component that generates the RF field or an attached computer. The main difficulty with this technology is that human bodies attenuate RF signals, sometimes in an unpredictable manner, thus making the placement of RFID antennae and tags of critical importance. In large crowds, especially, data can be lost creating inaccuracies in the validation dataset. In a recent series of evacuation trials using RFID [8, 9], it is suggested that read rates "will be better than 50% if proper alignment and measurement power of reader antennas is found through experiments" in crowded situations [8]. The success rate is also critically dependent on how the tag is worn, whether it is in contact with the skin, near metal objects or concealed by clothing. In addition, RFID systems tend to be bulky for temporary applications and logistics of setup becomes time consuming due to the need to carefully run cables and ensure suitable antennae orientations. Further, while RFID tags tend to be inexpensive in large quantities required for test series, they can be damaged relatively easily jeopardising the dataset quality. Considerable effort is required to select the correct tag and form factor for the planned application, in order to ensure the highest read-rate possible.

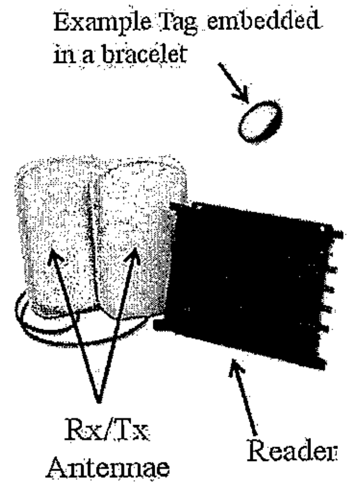


Figure 2 - Example RFID system tested (top) and example of field test (bottom)

A series of tests was undertaken of a representative RFID system, first in a corridor at the University of Greenwich and then on-board the first Ro-Pax vessel. The RFID system was manufactured by Alien Technology Corp. and consisted of an Alien model ALR-8800 reader and a pair of Alien model ALR-8610 circular polarised multistatic antennae (i.e. capable of both generating the RF field and receiving tag transmission data for logging). This system was designed to operate in the European UHF band in the 865.7 - 867.5 MHz range with power

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levels of 2W ERP and is compliant with European radio regulations. The system was designed to read EPC Class 1 Generation 2 UHF tags. In addition to the RFID system, various types of EPC Class1, Gen2 UHF tags were purchased in different form factors, specifically; peel and stick labels, silicone rubber wristbands and plastic wrist/ankle hospital-style bands. The corridor tests consisted of some 12 people walking down a 1.89 m wide corridor of which all 12 were wearing the RFID tags. Trials with both wrist and ankle bands were undertaken. Subjects were asked to walk together past the antennae as a group keeping their speed, position and group density consistent from test to test, Fig. 5. Tag reads were stored on a computer for each test. The maximum read rate was 75% for tests where subjects were permitted to walk normally (i.e. with arms swinging by their side). One test case was conducted where the subjects were asked to fold their arms, thereby shielding the tags somewhat. For this test, it was found that the read rate decreased significantly to just 17%. A series of trials was also conducted in a passageway on-board the first Ro-Pax vessel. Unfortunately, the trials on-board the Ro-Pax vessel were conducted using only nine people wearing tags and so do not represent a reliable test under crowded situations; nevertheless, these trials returned an average read rate of 86%. The ship trials demonstrated that the RFID system could work within the confines of the metal environment of a passenger ship. The corridor tests suggest that read rates of up to 75% can be achieved using the RFID technology in crowded situations.

The IR technology examined, Figure 3, relies on a beacon that generates an IR light field. As a tagged individual passes through the field, IR light sensors in the tag detect the IR light and log its ID and the time at which it was detected in the tag's own internal memory. For the IR system, no data is transmitted from the tag until it is presented to an IR data reader at a later date. Following the test, tags must be retrieved in order to determine the occupant's route data. The main disadvantage with this technology is that occupant route data is not collected unless tags are returned following the test. In addition, the IR tag is also considerably more expensive than the passive RFID tag, costing approximately 15 times more. This is very different than the (passive) RFID tags which, due to their low individual price and inability to log route data, do not need to be returned at the end of the tests. However, the IR tags, if collected after the trial, can be reused time and time again. In addition, the disadvantage of the IR tag turns into an advantage for the IR beacons. Since the path history of the individual is recorded in the tag itself, the IR beacons are less complex which reduces their cost (by a factor of approximately 60), as well as their size and power requirements compared to the RFID system. This allows many IR beacons to be placed through the structure, thus allowing for more granular definition of occupant routes. In addition, the beacons are much easier to set-up, greatly simplifying instrumentation setup and due to their reduced size, simplifying logistics involved in transporting the equipment to the test site.

Figure 3 Image of an IR beacon (left) and IR tag (middle). The CD is shown for comparison only.

The IR system was manufactured by RFID Centre Ltd. A modified version of their *TagMobile* system was employed which includes IR generating beacons and logging tags that are hung around the neck using a lanyard. The RFID Centre worked with FSEG to modify this system and make it more appropriate for use in evacuation study applications. This involved a redesign of the standard IR tag. The modified IR system was put through a similar series of tests as the RFID system. In corridor tests at the University of Greenwich, the beacon was mounted on one side of the corridor at a height of 2.13 m above the floor, facing perpendicular to the opposite wall. A total of 10 tags were used and a group of 23 individuals was formed with the ten tags worn by subjects mixed throughout. The group was instructed to walk past the beacon keeping speed, position and group density consistent from test to test, Figure 4. Subjects were asked to raise their hand when the tag indicated a successful read. These tests always returned a 100% read rate. Shipboard tests using the IR system involved 10 test subjects wearing the IR tags. These tests returned an average of 93.5% successful read rate however, as with the RFID trials on the ship, these trials were not under heavily crowded situations and so were not considered representative of the intended application. However, the tests demonstrated that the system could work in a shipboard environment.

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(a)

(b)

Figure 4 - IR corridor test (a) tagged people (down arrows), IR beacon out of view (up arrow) and IR tag (circled) (b) tagged people raising hands when tag is detected with IR beacon out of view (circled)

Based on the results generated in the various trials, it was concluded that the IR-based tracking system was better able to accurately track large numbers of individuals in high-density crowds. While the RFID system provided reasonable read rates, performance of the IR system was superior in all cases. The success of the IR system is due in part to it not relying on direct line-of-sight between the beacon and the detector, the IR beams being readily reflected from surfaces and not distorted by human bodies. Furthermore, considering the logistical issues associated with using the two systems, the IR system was considered more versatile being; easier for setup and knock-down, not requiring external power supplies or cables, being relatively cheap to add additional fields and easier to transport. On completion of the trial, data was transferred from each retrieved tag to a computer via an IR reader. Software developed by FSEG is used to read the tag information and, for each tag, identifies when the participant passed a numbered beacon and when they arrived at the assembly station.

The IR beacons were strategically placed about all three vessels to ensure that the starting location and end location of all passengers could be determined. The main areas monitored were the entrances and exits of public spaces and the corridors associated with cabins. IR beacons were positioned at all of the entrances to assembly stations thus capturing the assembly times of the passengers. Figure 5 provides an example of where the IR beacons were positioned on one of the vessels.

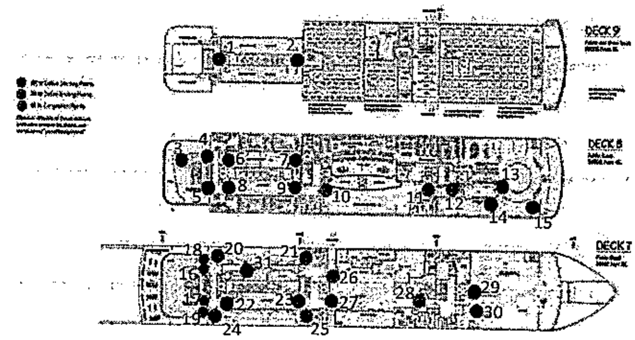


Figure 5 – Example locations of IR beacons

Once all of the data had been collected from the IR tags the analysis could begin. The start and end locations of each passenger (IR tag) could be obtained. This information then built up a picture of where the entire population started and finished. Figure 6 depicts the starting location of 93 passengers starting on Deck 9 in the airline seating area. The image also depicts that 24 passengers assembled on Deck 8 and 59 passengers assembled on Deck 7 (6 passengers at the port side assembly station, 45 passengers moving to the starboard assembly station and 18 passengers moving to the assembly station amidships). With this approach it is possible to identify the starting location and end location of all the passengers on all five ships.

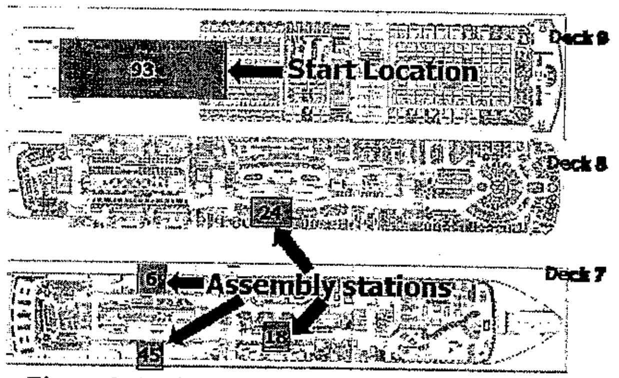


Figure 6 - End locations of passengers starting in the airline seating area

The arrival times of the passengers (IR tags) can also be obtained from the extracted data. This information can be used to build up an arrival curve such as that in Figure 7. This information, along with the start and end location of each tag can be used to develop a validation data set by which to assess the performance, reliability and suitability of evacuation models in modelling the assembly process on board passenger vessels.

Over the five trials, 5034 IR tags were issued, 1170 for trial 1 and 1192 for trial 2 on RO-PAX1, 2299 for trial 3 on the cruise ship, 199 for trial 4 and 174 for trial 5 on

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RO-PAX2. Of the 5034 IR tags issued, 4696 were returned, a retrieval rate of 93%. The data from trial 2 and trial 3 were considered suitable for the development of validation data-sets. These data-sets consisted of 764 assembly times for trial 2 (RO-PAX1) and 1779 assembly times for trial 3 (cruise ship).

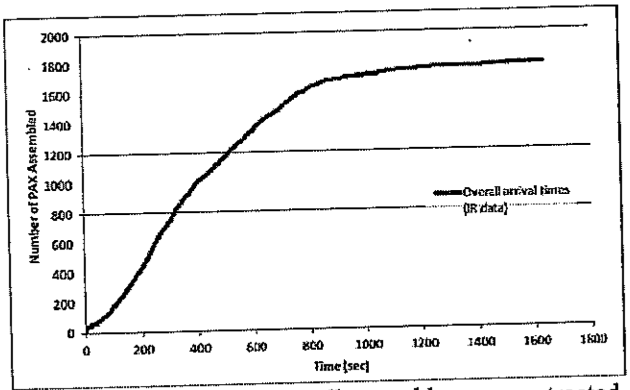


Figure 7 – Example of overall assembly curve extracted from the IR data for trial 3

## 4. VALIDATING THE ASSEMBLY TIME MEASUREMENTS

In order to validate the accuracy of the arrival times derived from the IR system, video cameras were installed on the vessels to monitor the entry points to the assembly stations of the cruise ship. The arrival time derived from the IR system could be compared with the arrival time extracted from the video record. Thus, it could be determined whether the IR system readings lagged a passenger's actual entry into an assembly region and, if so, by how much on average. In addition, the total number of passengers assembling through a given door determined by the IR system can be compared with the actual number determined from the video record. The comparison was carried-out for two locations on the cruise ship – one forward and one near amidships on the starboard side of Deck 5 (see Figure 8). The forward location (at Beacon 73, Camera UOG12) was a doorway with a vestibule leading to assembly station group B. The location near amidships (at Beacon 50, Camera UOG10) was a doorway that opened directly into the same external assembly station group.

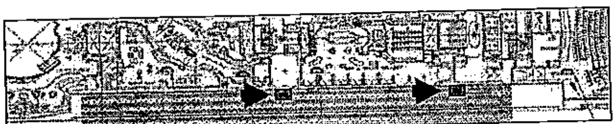

Figure 8 - The comparison of the IR and video systems took place on data collected from camera UOG10 and IR beacon 50 plus camera UOG12 and IR Beacon 73

When analysing the video for both locations, the time at which a passenger passed across the door line was taken as their entry time. Because a comparison was being made with the IR data, times were recorded only for passengers that could be clearly seen wearing or holding an IR tag. In addition, because of the way the IR tag data was analysed, the entry times were recorded only for passengers who entered the assembly station and remained there. In some cases, it was necessary to make a subjective judgement of whether a passenger had actually assembled in the relevant assembly station (e.g. when a passenger entered into the assembly station and walked out of the view of the camera).

The comparison between the IR and video data is presented in Figure 9 and Figure 10. From these plots, it can be clearly seen that the arrival times derived from the IR system closely matched that derived by from the video system at both locations. For the doorway near amidships (Beacon 50, UOG Camera 10 - Figure 9), the IR system counted the correct number of tagged passengers through the door (20) and timing results consistently lagged camera results (by 2.95 sec on average with a standard deviation of 0.53 sec). For the forward location (Beacon 73, UOG Camera 12 - Figure 10), the IR system, once again, correctly counted the number of passengers through the door (138) and timing results consistently lagged the camera results (by 5.04 sec on average with a standard deviation of 1.11 sec).

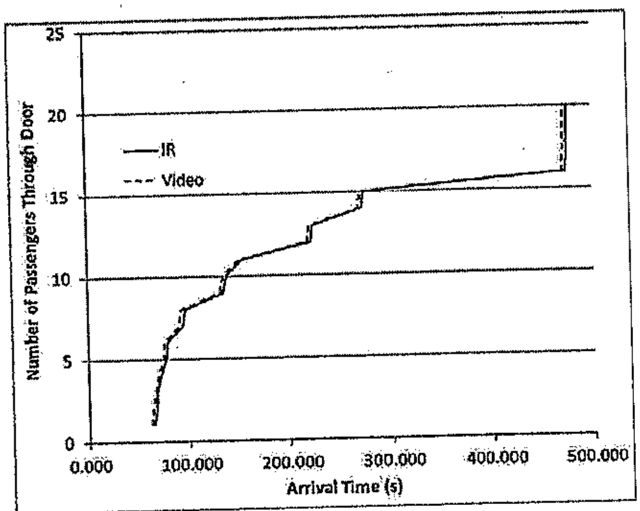


Figure 9 Comparison of passenger arrival times at Beacon 50 on board the cruise ship compared to Camera UOG10

Given these results, it is clear that the IR system provides an accurate measure of the arrival times for passengers when compared against a synchronised video system, despite a small lag between the actual arrival time and what the IR data collection system actually measures. Using this system one can determine arrival times at each assembly station for those passengers who assemble at that location. While using a video camera system to determine passenger arrival times tends to provide a more precise measure (sub-second) of when a passenger actually arrives through a doorway, unless the passenger then stays in that assembly station and within the field of

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view of the camera, it is impossible to determine whether he/she has actually stayed in the assembly station or moved to another location outside that assembly station and, thus, can give erroneous results for arrival times.

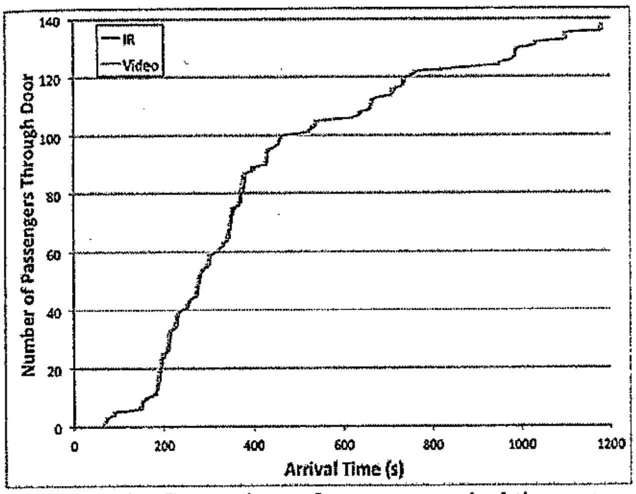


Figure 10 - Comparison of passenger arrival times at Beacon 73 on board the cruise ship compared to Camera UOG12

## 5. VIDEO DATA

Video footage was used to collect passenger response time data and response phase behaviours. Video cameras were strategically positioned throughout the vessel to record the passenger behaviours at the start of the trial. The response time and response phase behaviours for each individual were determined through analysis of video footage by defining specific start and end points of the response phase. In order to achieve as wide a coverage as possible, video cameras were placed in all public areas including: restaurants, cafes, indoor and outdoor seating areas, general circulation areas, shops, bars etc. - in essence, every part of the vessel where passengers can be present were monitored. In the cabin regions, video camera's monitored the corridors and were used to determine when the passenger left the cabin, entered the corridor and made a decisive move towards the assembly stations. To capture this information, some 30 cameras were installed on the RO-PAX vessels and 12 cameras were installed and used alongside 94 on-board CCTV cameras on the cruise ship. The locations of the cameras and mounting methods were determined during pre-trial visits to the vessels. An example of the video camera positioning for RO-PAX1 is presented in Figure 11.

As part of the pre-trial visits, the research team familiarised themselves with the layout of the vessel and developed an understanding of where passengers were likely to congregate at the proposed time of the trial. The research team identified possible locations for video cameras IR beacons and determined mounting methods for the video cameras. Various mounting methods were available, including magnetic clamps or pressure clamps. The camera's chosen were Sony Handycams fitted with extended duration battery packs and wide angle lenses. The extended duration battery packs were necessary to ensure that the even after a number of charge cycles and usage across the projects timeline they would continue provide a long enough recording window to be able to be started unobtrusively before the passengers board and to keep recording until past the end of the assembly exercise.

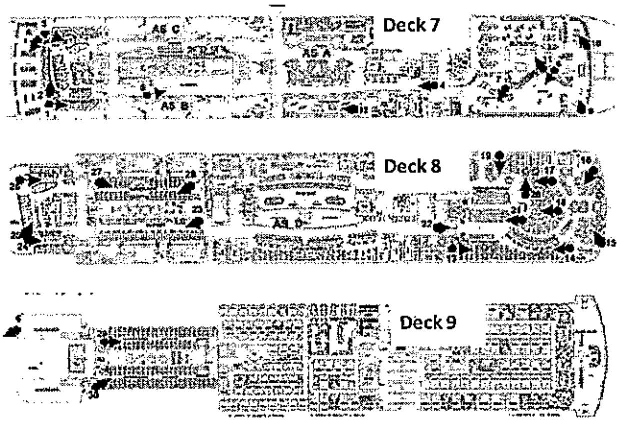


Figure 11 - Camera locations and direction of view

The wide angle lenses allowed a single camera to record data from a large area, enabling fewer cameras to be used. Whilst a wide angle lens might degrade the quality of the recorded image slightly it nevertheless provided sufficient detail for analysis.

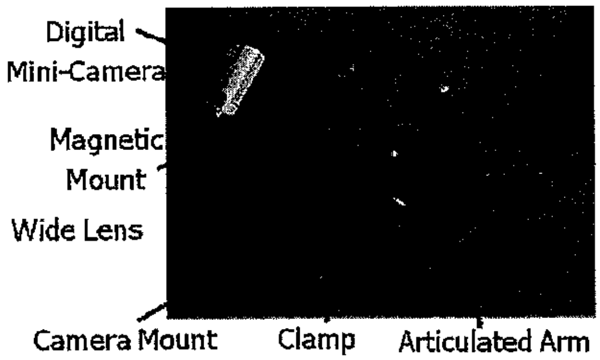


Figure 12 - Camera's and mounts

## 6. EXTRACTING DATA FROM VIDEO FOOTAGE

From the five full scale sea assembly trials conducted as part of the SAFEGUARD project some 584 GB of video data was collected from the video cameras, representing over 186 hours of video footage.

The amount of video footage that was collected during first trial on RO-PAX1 was approximately 115 GB representing almost 49 hours of video footage. For second trial 106 GB of video data was collected representing 45 hours. Approximately 328 GB of raw video footage (76 hours) was collected for the trial on the cruise ship. 20 GB (9 hours) of raw video footage was collected from the first trial on RO-PAX2 and 15 GB (7 hours) of raw video footage was collected from the second trial.

The video analysis was performed using Adobe Premier Pro CS4, a professional non-linear video processing software tool (see Figure 13). The analysis involved frame by frame examination of each video file. Each visible passenger in a video file is examined separately, a marker is placed on the video timeline indicating the time when various events take place. The events recorded include: alarm activation time (AAT), the start of activity stage (SAS) and the end of response phase (ERP). Additional information for each passenger was also collected including passenger number, gender, age group, passenger activity, group status and whether staff intervened during the response phase. All of this information was included on the timeline marker.

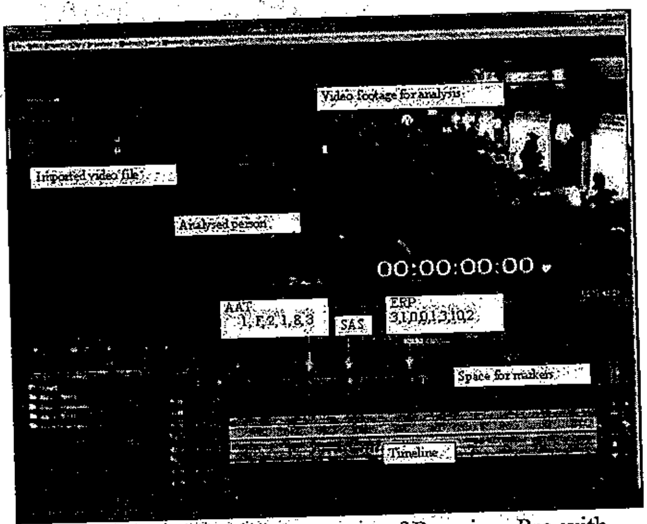


Figure 13 – Work environment of Premiere Pro with person under investigation highlighted with a red circle and appropriate markers in green indicating various phases of that person's assembly process placed on the timeline

For each video, a passenger identity key was created (see example in Figure 14) so that each passenger analysed had a unique identifier. A computer program was developed to extract the data from Premiere Pro for each passenger analysed and store as a text file that could be imported into commercially available software such as MS Excel or Matlab for further analysis.

Figure 14 – Example of a passenger identity key

Three FSEG staff were used to analyse the video footage. Prior to the commencement of the video analysis process the three staff were trained in the data analysis techniques. As part of this process, a dictionary of definitions was developed to describe as precisely as possible the nature of the events to be identified and measured. Once trained, the analysts undertook an inter-rater reliability assessment to ensure that they could analyse the video footage accurately and consistently. Only once an acceptable level of performance was attained on the inter-rater reliability assessment could the video footage derived from the trials be processed. The inter-rater reliability assessment was an iterative process. Each rater analysed 16 passengers independently, selected from different parts of the vessel, and compared the results with the analysis of the other raters. If the raters did not achieve at least a 90% level of agreement, the differences were analysed, corrective measures were put in place and where necessary, the definition dictionary was updated. The inter-rater process was then repeated with a new batch of 16 passengers until a level of agreement of at least 90% was achieved. The inter-rater reliability process for the first set of trials required five iterations to achieve a level of agreement of over 90%.

On completion of the inter-rater reliability tests, three raters commenced the analysis of all video captured onboard each of the vessels. This was a lengthy process that took approximately four months to complete for RO-PAX1 and generated 1003 passenger response times, approximately nine months for the cruise ship generating 1228 passenger response times and approximately one month for RO-PAX2 generating 135 passenger response times.

When all video from each vessel had been analysed, the response time distributions for each trial could be determined as shown in Figure 15. Response time distributions for the entire ship could be constructed or specialist response time distributions based on parameters such as gender, age and starting location could be constructed.

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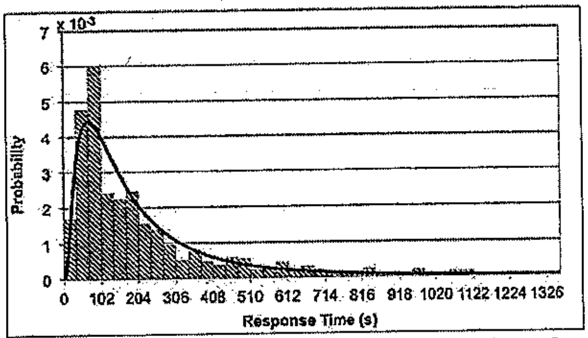


Figure 15 – Example distribution of response times from the RO-PAX1 trials

## 7. QUESTIONNAIRE DATA

The third means of data collection involved the collection of questionnaire data (Figure 16 - Figure 18). The purpose of the questionnaire was to capture information from the passengers that cannot be obtained from the video footage or the IR tracking devices. The questionnaire provides essential additional information for reinforcing, correlating or verifying the data collected by the video camera and IR systems. The questionnaires allowed participants to describe what they did and why they did it.

The questionnaire was compiled by FSEG and tailored for each vessel. For RO-PAX1 the questionnaire consisted of 21 questions while the questionnaires for RO-PAX2 and the cruise ship consisted of 24 questions. The questionnaires consisted of; three questions relating to the population demographics (age, gender and impairments); three questions on passenger experience of maritime travel and maritime assembly exercises; seven questions on wayfinding relating to how the passengers navigated to the assembly stations, including questions relating to the effectiveness of the crew and emergency signage; seven questions relating to where the passengers were at the start of the alarm and how they reacted to it. The questionnaire also inquired whether the passenger was in a group of people at the start of the assembly process or whether they travelled to the assembly station as part of a group.

The questionnaire was developed in English and translated into appropriate languages for the target population. The selected languages for the RO-PAX1 vessel were Norwegian, German and English. The questionnaire was designed such that all three languages appear on the same page. For the RO-PAX2 trials, the questionnaire languages were English, Greek, German and Italian. The questionnaire for the cruise appeared in English and Spanish (see Figure 18). The number of completed questionnaires was 1534 for RO-PAX1, 1862 for the cruise ship and 252 for RO-PAX2. As a thank you to passengers for taking part in the assembly trials, passengers who completed a questionnaire were entered into a raffle with a chance to win one of several prizes. FSEG also developed a database for entry of questionnaire replies allowing rapid analysis of the questionnaire data.

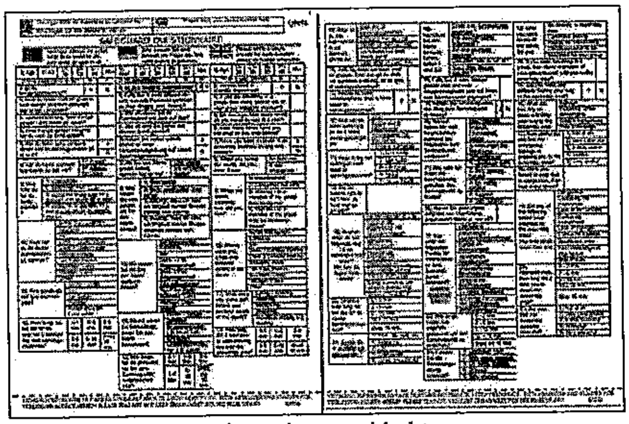

Figure 16 - Questionnaire provided to passengers on completion of the RO-PAX1 trial.

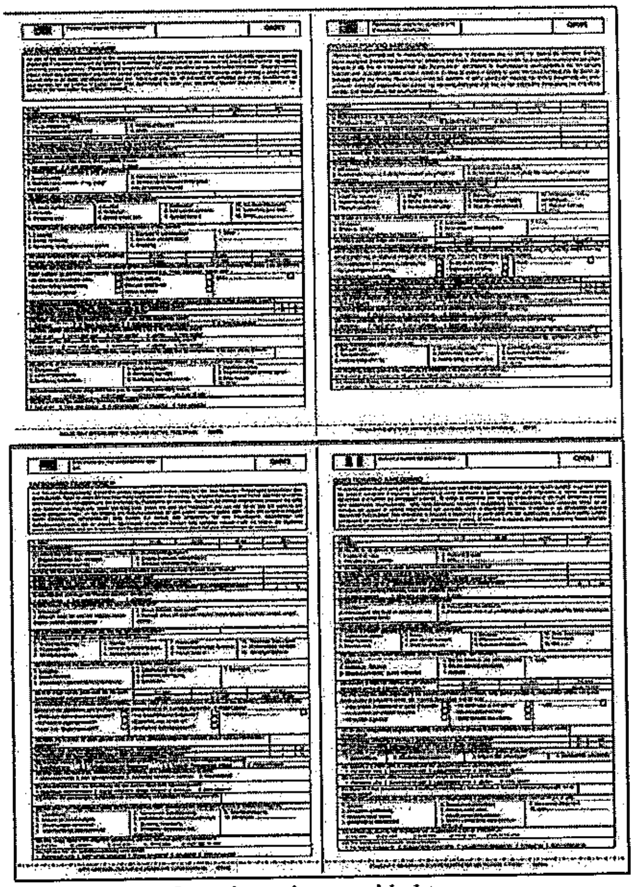

Figure 17 - Questionnaire provided to passengers on completion of the RO-PAX2 trials

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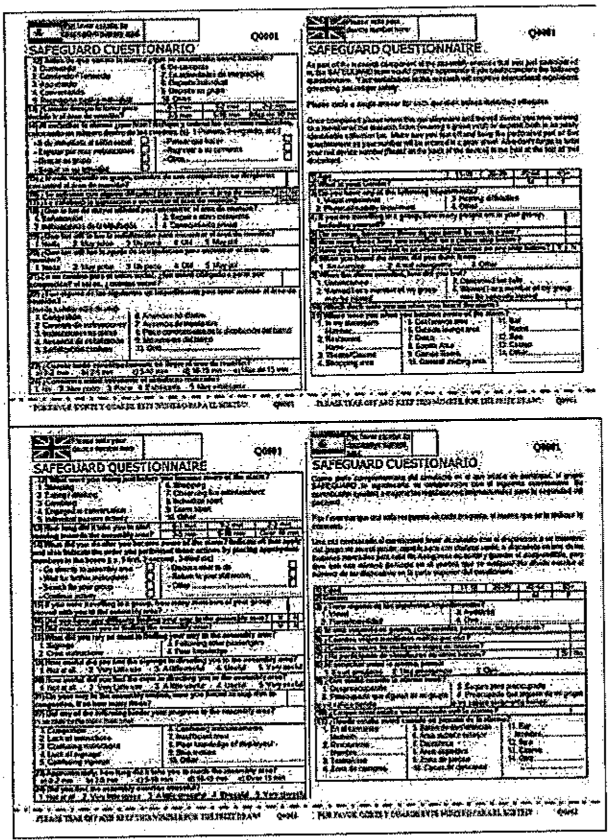
SAFEGUARD CUESTIONARIO

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Figure 18 - The questionnaire provided to the passengers on completion of the Cruise ship trial

## 8. CONCLUSIONS

In each of the five SAFEGUARD semi-unannounced assembly trials three types of data-sets were collected:

- Passenger response time data. This was generated from 30 specially positioned battery powered mini digital video cameras (RO-PAX1 and RO-PAX2) and a combination of 12 video cameras and 94 ship CCTV cameras (cruise ship).
  - Some 2366 passenger response times were collected from the five trials; 1003 from RO-PAX1, 135 from RO-PAX2 and 1228 from the cruise ship.
  - This passenger response time data was used to develop response time distributions for RO-PAX and cruise ships for both cabin spaces and public spaces.
  - Passenger assembly data. This consisted of passenger starting locations, end locations and assembly times. The data was generated using 30 IR beacons and 5034 IR tags.
  - In total 3680 assembly times were generated, 902 for trial 1, 764 for trial 2 (RO-PAX1), 1779 for trial 3 (cruise ship) and 116 for trial 4 and 119 for trial 5 (RO-PAX2).
  - The assembly data was used to develop two validation data-sets, one for RO-PAX1 (trial 2) and one for the cruise ship (trial 3).
- Passenger behavioural data. This was collected using a questionnaire.
- 3648 questionnaires were completed by the passengers in the five trials, 1534 for RO-PAX1, 1862 for the cruise ship and 252 for RO-PAX2.
- The questionnaire provided additional information for reinforcing, correlating or verifying the data collected by the video camera and IR systems. The questionnaires allowed participants to describe what they did and why they did it.

The SAFEGUARD trials involved five semi-unannounced full-scale assembly trials at sea, three different passenger vessels and 5582 passengers. It generated 2366 response time data points, 3680 passenger assembly times and 3648 completed passenger questionnaires.

This represents the largest collection of human factors evacuation data ever collected from sea going assembly trials. The collected data is being used to propose response time distributions for RO-PAX and cruise ships for use in ship evacuation analysis and two validation data-sets for ship evacuation models. It is hoped that this data will be used to up-date the IMO MSC Circ 1238 Guidelines for New and Existing Passenger Ships.

## 9. ACKNOWLEDGEMENT

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