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Do Chairs Reduce a Navigator's Mobility? Pilot Study on the Influence of Navigation Bridge Design on Lookout Routines

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ABSTRACT

Despite technological progress in the maritime industry, navigators are still the final link of the decision-making chain and rely not only on equipment, but also on human senses. Visual observation of the vessel's surroundings still plays a crucial role in navigation. Four different ships in service were visited to investigate the work of professional navigators and carry out a pilot experiment on real crews to test the methods for future full-scale research. The main objective was to better understand the influence of bridge design on lookout routines of navigators, while the additional goals were to check the presence of navigators in certain parts of the bridge and to determine if it is reasonable to forbid navigators to sit, as the practice is still used on some ships. Considering space limitations and differences in layouts of the wheelhouse, rarely mentioned in this kind of study, the movement of watch-keeping officers was analysed. In total, twenty observations were made to generate the heatmaps of presence during the routine duties. The results of the research indicate that many factors, including bridge design and layout of equipment, might affect lookout routines but it is possible to find similar patterns on the bridges of different shapes and arrangements. The pilot experiment confirms that it is reasonable to carry out a full-scale study, as there is still room for improvement in the area of ergonomic bridge design. Better understanding of modern lookout and movement routines might lead to the development of adequate ergonomic regulations and result in increased work comfort and the well-being of seafarers.

Keywords: Bridge design, Navigation, Lookout

INTRODUCTION

Navigation is a complex process, which can be broken down into plans, deeds and activities performed in good order, sequentially, and according to events and hazards occurring around the ship [1]. As per Rule 5 of the Convention on the International Regulations for Preventing Collisions at Sea (COLREG): *"every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision"* [2]. Lookout duties involving the use of human senses are assigned to qualified onboard personnel, not to the ship's structure itself and cannot be fully replaced by technology [3]. An improper lookout can definitely be considered to be human error. In the years 2002-2016, it was the most common immediate cause of collisions, close quarters and contact accidents, contributing to as much as 24.6% of those events [4]. This number might even be developing in the twenty first century, as an overreliance on technological aids reduces watch-keeping standards [5]. There is no clear border between reliance and overreliance on electronic aids, thus the modern problems of ineffective lookouts and reduced involvement in observations are addressed by this paper.

Physical ergonomics covers topics including, but not limited to, workplace layout, physical safety, health and work-related musculoskeletal disorders [6]. Additionally, when the observation of surroundings plays a crucial role in safety, a properly designed work area might be an essential support for operators' decision-making processes, not only for physical health. Previous studies have been carried out on the role of 'lookout' for professional navigators, including the research by Wynn et al. [7]; however, they rarely considered the impact of ergonomic factors or space limitations. Thus, a pilot experiment on this topic was conducted for a better estimation of the duration, costs and feasibility of a full-scale study in the future, while the main purpose of our research is to better understand the lookout routines and current practices in navigation. An additional goal is to initially test two hypotheses:

- Hypothesis 1: "The central parts of the navigational bridge are the most frequently used during navigation";
- Hypothesis 2: "If a chair is present on the bridge, the officer will spend a significant amount of time near to or on it".

The results of this research might lead to a better understanding of the influence of bridge design on navigators, guiding improvements of their performance and future health and safety by tackling the modern problem of ineffective lookouts. Technological progress advances rapidly, therefore it is reasonable to study the present needs and habits of professionals, compare them to the past and try to predict the ergonomic design of future ships. In order to achieve these goals and conduct a pilot experiment, four different operational ships were visited and the routine work of officers was investigated.

NAVIGATION BRIDGE DESIGN

A bridge can be defined as an area from which the navigation and control of a ship is exercised [8]. Chapter V, Regulation 15 of the International Convention for the Safety of Life at Sea (SOLAS) states the requirements regarding its design. Accordingly, a properly designed bridge should support many activities and functions, including minimising the risk of human error, preventing or minimising any conditions causing fatigue and excessive or unnecessary work [9]. The rules are general, therefore navigation bridge design is supported by additional documents. Whilst not being obligatory, and only applying to newly built ships, 'MSC/Circ.982: Guidelines on ergonomic criteria for bridge equipment and layout' was issued in 2000.

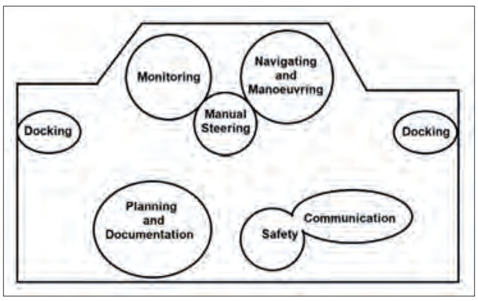

Fig. 1. Suggested location of workstations on the bridge based on International Maritime Organization [10]

Due to the complexity and diversity of the duties of navigators, MSC/Circ.982 recommends specific workstations along with their suggested location, as shown in Fig. 1.The recommended workstations and their general purposes are:

- Workstation for navigating and manoeuvring – it should be possible to safely operate the ship from this place in a seated/standing position, providing optimum visibility, whilst being presented with the information and equipment required, controlling ship movements. The proposed accessories include an adjusTable chair;
- Workstation for monitoring – it should allow permanent observation of equipment and the surrounding environment from a seated/standing position, also providing support for a person working on the workstation for navigation and manoeuvring during operations where more than one navigator is required to work on the bridge. The proposed accessories include an adjusTable chair;
- Workstation for manual steering – it should be possible to steer the vessel by a helmsman located at this position, preferably from a seated position. The proposed accessories include an adjusTable chair;
- Workstation for docking – it should allow navigators to observe sufficient external and internal information and control manoeuvring of the ship from the wings (the parts of the bridge on both sides of the wheelhouse, which extend to the ship's side). There can be open wings or a totally enclosed bridge, where wings form an integral part of an enclosed wheelhouse [8]. Examples of workstations on open and totally enclosed wings are shown in Fig. 2;

Fig. 2. Example of workstation for docking on open wing (left) and on totally enclosed wing (right)

- Workstation for planning and documentation – it should be used to plan routes, fill logbooks and document all ship operations;
- Workstation for safety – it should contain monitoring displays and other elements of systems serving safety;
- Workstation for communication – it should allow the operation of Global Maritime Distress and Safety System (GMDSS) equipment and general communication. The suggested accessories include a chair [10].

Since 2000, the year of adoption of MSC/Circ.982, the carriage requirements for shipborne navigational systems and equipment changed numerous times. For example, the Automatic Identification System (AIS), Bridge Navigational Watch Alarm System (BNWAS) and Electronic Chart Display and Information System (ECDIS) were made mandatory for various ships. Those systems certainly affected and changed watch-keeping and the routines of navigators. The main changes offered by ECDIS were the possibility of continuous monitoring of a ship's position, displayed on an electronic chart, and plotting the position fixes from a place where the navigation is carried out, not in a separated chartroom. According to the International Association of Classification Societies (IACS) Recommendation No.95, in normal operational conditions, a workstation for navigating and manoeuvring should be in use in coastal waters. A workstation for monitoring should also be in use in narrow waters [8]. This document clarifies that this is only a suggested example and is not meant to govern the factual manning during different operational conditions.

FATIGUE AND ERGONOMIC PROBLEMS IN THE WORKPLACE

Fatigue is a common problem for seafarers nowadays. There are many conditions and factors on board ships that can cause or develop a lack of focus, sleepiness or monotony. The International Maritime Organization (IMO) highlights the importance of proper ergonomics and environmental conditions on board, to maintain safe levels of alertness and performance, but also the opportunity to rest properly after duties. The workplace should have an optimum layout, allow good working position, protect from hazards and have good usability [11].

An important, but also controversial, part of the bridge is a simple chair. In many cases in the past, such as the one investigated by Britannia P&I Club [12], the officer of the watch's decision to sit in the bridge chair and watch videos on their mobile phone resulted in a reduced ability to monitor the situation. The second contributing factor was not related directly to seating; however, the seated position was described as making it impossible to operate navigation equipment and, even, creating the possibility of falling asleep, considering the bridge environment at night. Of course, the case is more complex and describes a single incident but the problem of the navigator sleeping in the chair is commonly known to the maritime industry. Moreover, research carried out by Leung et al. [13] found that night shift officers suffer from overall fatigue more than those working in the daytime. Nowadays, many vessels still do not have chairs on the bridge. According to research published in 2023 [14], professional navigators consider having an adjusTable chair on the wheelhouse as an attractive feature, providing additional value to their workplace, that can result in increased employee satisfaction. The IMO recommended that bridges are supplied with chairs (MSC/Circ.982, issued in 2000); however, after all these years it is still not something that is obviously provided or be expected to be there.

On the other hand, not only the comfort, but the health of the operator should also be considered. Anatomically non-neutral posture, accelerated movements, externally applied compressive forces and vibrations can affect musculoskeletal, nerve and circulatory tissues, while the risk is especially noticeable when a combination of two or more factors is experienced during the job [15]. This can all be experienced on a ship, especially during heavy rolling or pitching in rough weather. The motions transmitted through the feet are expected to be the highest vibration levels for seafarers to be exposed to, while resilient or non-rigid surfaces on seats will lower those values [16]. Many scientific papers have already been published on the topic of prolonged standing at work, along with searching for the solutions that reduce its negative effects, e.g. floor mats or seat-stand stools [17]. Working long hours in a standing position, even if static or not involving a lot of mobility, might result in muscle pains and fatigue, while intermittent seating was found to be the best solution in minimising the related discomfort [18].

MATERIAL AND METHODS

Visiting different ships was necessary, to investigate real life situations and the routines of navigators. In this experiment, officers and their movement during the watch were observed on four vessels, all equipped with ECDIS as a primary source of navigation and back-up. No paper charts were used; however, ship movements were documented in paper logbooks.

Two different Ro-Ro/Passenger ferries (Ro-Pax) with a totally enclosed bridge, operating in the Baltic Sea, were visited. In both cases, the bridge was located in the forward part of the ship. On both vessels, two officers carried out the navigational watches in a pattern of six hours of work and six hours of rest. One-way voyages were less than 24 hours long, with intensive and short cargo operations in ports. On one of the voyages, the officer of the watch was assisted by a rating look-out whilst at sea while, on another voyage, only during the hours of darkness. Both bridges of the visited Ro-Pax ferries were equipped with an adjusTable chair.

Two different oil tankers with open bridge wings, transiting the Persian Gulf, were also visited. In both cases, the bridge was located in the aft part of the ship. The visited vessels were operating in a common pattern of navigational watches, four hours of work and eight hours of rest, involving three watch-keeping officers. The tankers were of medium range type and their voyages usually took 7-14 days one way, which could differ due to the voyage orders. While transiting the Persian Gulf, the rating look-out was assisting the officer at all times. The bridges of the oil tankers were of a standing type. All of the visited vessels are grouped in Table 1, along with selected particulars.

Tab. 1. Particulars of visited ships.

	Length overall [m]	Breadth [m]	Year built [-]
Oil tanker 1	186.00	32.2	2014
Oil tanker 2	183.06	32.2	2020
Ro-Pax 1	175.48	30.3	1988
Ro-Pax 2	169.80	25.8	2000

The areas of passages during the observations were assumed to be similar. The Baltic Sea and the Persian Gulf belong to the group of 'enclosed' or 'semi-enclosed' seas, according to the United Nations Convention on the Law of the Sea (UNCLOS) [19] and both areas are considered to have a heavy marine traffic density [20, 21]. Apart from merchant ships, the navigators can experience a lot of fishing vessels and offshore installations in that area. All of the observations were carried out in good visibility.

METHODS

Heatmaps were used to represent the results of the experiment, as they are a popular method for visualising and analysing large data sets [22]. Applying the colour scale on the bridge scheme according to the time spent in each area allowed the determination of the usability of certain parts of the wheelhouse during routine work. Some bright colours, like yellow, attract the eye and may lead to unfair highlighting of a particular section while obscuring other parts [23]. In this paper, a two-colour scale was used to avoid improper data perception, where the lowest value is white (Html Code: #FFFFFF), the highest is red (Html code: #FF0000), and the values in between are expressed by the relevant, graded shades.

The period of transferring watch-keeping duties is a critical part of the watch. Studies have shown that the highest percentage of groundings occur during this procedure, or shortly after [24]. What is more, it is not completely defined by legislation or regulations, as it is not clearly stated how long such a handover should take to properly adopt night vision [7]. In the above mentioned study, related to dark adaptation, but also studying the routines of the lookout, 30 minute samples were analysed. However, performance testing has shown that the concentration of lookouts diminishes after about half an hour [25]. Therefore, the first 60 minutes after taking over the watch was chosen to be monitored and investigated in this pilot experiment, for the purpose of testing the methods of data collection and results visualisation.

DATA COLLECTION, SAMPLING RATE AND AWARDING POINTS

To simplify the data collection process, the bridges were divided into squares of dimensions 1.0 x 1.0 m each and marked with masking tape for easy removal, as shown in Fig. 3.

Fig. 3. Squares marked on the bridge deck with masking tape

At 30 second intervals, during the first 60 minutes after taking over the watch, the position of the officer was noted and assigned to the marked square. If there was no movement (e.g. during filling in the logbook or while seating/standing), the position was assumed to be static (S) and the area was awarded with 10 points. The position was described as being dynamic (D) when the registered navigator was moving, the assigned square was awarded with 2 points but 1 point was also added to all adjacent squares, as shown in Fig. 4.

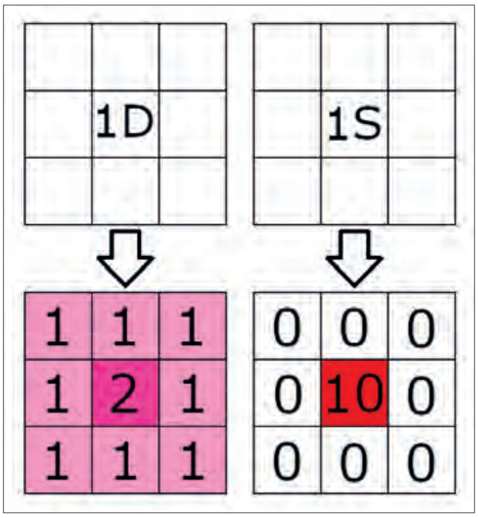

Fig. 4. Points distribution to the squares in the moment of registering a position (officer in the central square). On the left, the dynamic position (D) and, on the right, the static position (S)

With this sampling rate and period, 120 recorded positions were registered for each officer on each ship, twice a day, according to watch arrangements. The obtained databases were used to create a heatmap for each vessel, cumulatively. The calculated points were summarised and then divided by the amount of observations separately for each ship, resulting in the mean values assigned to squares.

LIMITATIONS AND RISK OF BIAS

The registration of a navigator's position was not constant but in specific moments, according to the sampling rate, which does not fully reflect the exact movement of a person. This limitation was caused by security and technical issues. Permission for the video registration of movement was not obtained from ship owners due to potential breaches of ship security (to prevent identification of the tankers trading in High Risk Areas) and the possibility of the navigators feeling uncomfortable. To avoid unnatural behaviour of the officers, and minimise the risk of bias, the observations were performed during visits related to a large number of other activities and measurements. The officers were not informed about the purpose of the squares on the bridge deck, as they were also used for the measurement of wheelhouse lighting for further ergonomic studies.

The pilot experiment was conducted on a relatively small sample. The navigational situation is unlikely to be the same on different ships and in different areas or voyage phases. During the observations, officers carried out multiple tasks which could affect the decision-making process, with regard to building situational awareness of the ship's surroundings. To minimise the risk of bias, it was decided to consolidate the observations for each ship and compare bridges rather than particular officers' behaviour.

RESULTS

The static and dynamic positions of each observation are presented in Appendix A. For a better description of the area

layout, the location of some equipment is marked with letters:
- E – ECDIS;
- R – radar;
- L – paper logbook;
- P – personal computer (desktop computer);
- C – chair.

The results of the research are presented in the form of the heatmaps, generated for the schemes of the visited bridges, separately for each ship. For each vessel, information is provided about the total number of observations, the possibility of using a chair designated for use while carrying out navigation from a seated position, and the presence of the curtains separating the aft part of the bridge, preventing any sources of light from disturbing navigators in their duties after sunset. The square that received the most points and the amount of fields that received 0 points are also highlighted (the latter referring to a lack of presence in those areas during observations). The heatmaps representing the presence of navigators on each ship are shown in Fig. 5, Fig. 6, Fig. 7, and Fig. 8 and they are presented, together with the other results (from crew to designers) below:

a) Oil tanker 1 with open wings.
- six observations were made in total (twice for three watch-keeping officers);
- no chair was designated for navigation;
- curtains separated the workstation for communication and safety and the workstation for planning and documentation;
- the hottest field obtained 112.17 points;
- 35 out of 159 possible fields received 0 points (22.01%);
- the proportions of static to dynamic positions: 459 (63.75%) to 261 (36.25%).

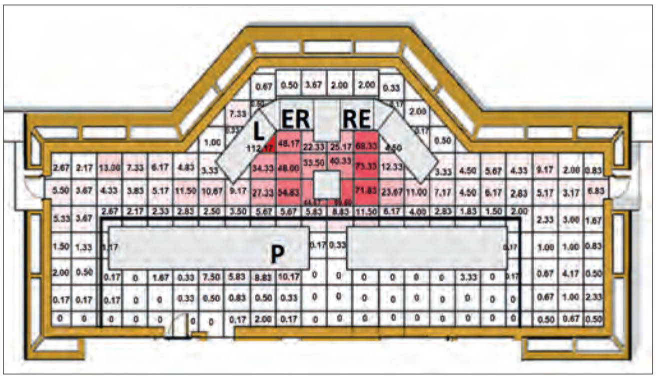

Fig. 5. Heatmap of presence of navigators on oil tanker 1

b) Oil tanker 2 with open wings.
- six observations were made in total (twice for three watch-keeping officers);
- no chair was designated for navigation;
- curtains separated the workstation for communication and safety and the workstation for planning and documentation;
- the hottest field obtained 130.67 points;
- five out of 81 possible fields received 0 points (6.17%);
- the proportions of static to dynamic positions: 422 (58.61%) to 298 (41.39%).

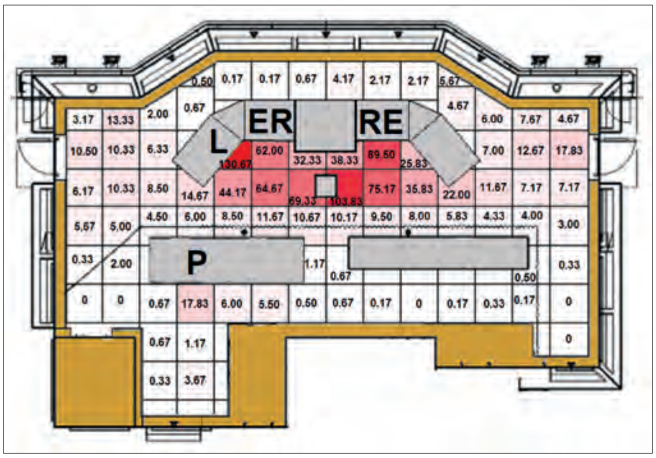

Fig. 6. Heatmap of the presence of navigators on oil tanker 2

c) Ro-Pax 1 with totally enclosed wings.
- four observations were made in total (twice for two watch-keeping officers);
- two chairs designated for navigation;
- no curtains on the bridge;
- the hottest field obtained 187.00 points;
- six out of 117 possible fields received 0 points (5.13%);
- proportions of static to dynamic positions: 259 (53.96%) – 221 (46.04%).

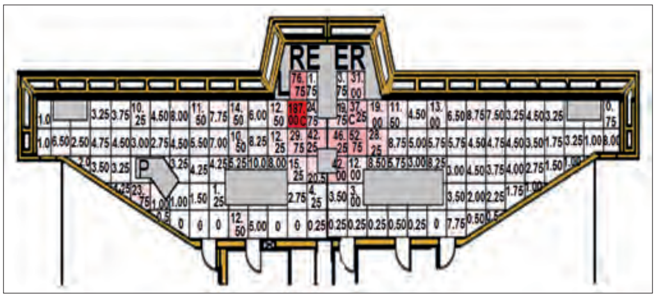

Fig. 7. Heatmap of the presence of navigators on Ro-Pax 1

d) Ro-Pax 2 with totally enclosed bridge.
- four observations were made in total (twice for two watch-keeping officers);
- one chair was designated for navigation;
- curtains separated the workstation for communication and safety and the workstation for planning and documentation;
- the hottest field obtained 469.75 points;
- 11 out of 106 possible fields received 0 points (10.38%);
- the proportions of static to dynamic positions: 310 (64.58%) to 170 (35.42%).

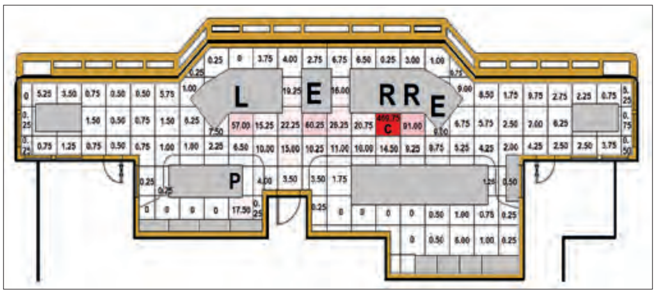

Fig. 8. Heatmap of the presence of navigators on Ro-Pax 2

Tab. 2. Static and dynamic positions observed on each visited ship

	DAY WATCH			NIGHT WATCH		
	STATIC	DYNAMIC	S/D RATIO	STATIC	DYNAMIC	S/D RATIO
Oil tanker 1 (no chair)	226	134	1. 687	233	127	1.835
Oil tanker 2 (no chair)	198	162	1.222	224	136	1.647
Ro-Pax 1 (chair)	128	112	1.143	131	109	1.202
Ro-Pax2 (chair)	145	95	1.526	165	75	2.200
TOTAL	697	503	1.386	753	447	1.685

In addition to the generated heatmaps, all of the dynamic and static positions during the day and night watches on each ship were grouped as shown in Table 2. During the daytime, navigators were static 58% of the time (697 out of 1200 positions) and during the night time, almost 63% of the time (753 out of 1200). On every vessel, more positions were found to be static, regardless of the presence of a chair or the time of day. The highest and lowest ratios of static to dynamic positions were observed on bridges with chairs: during the night time on Ro-Pax 2 and the daytime on Ro-Pax 1. On the bridge of Ro-Pax 1, the lowest ratio of static to dynamic positions was observed during both the daytime and night time, although it was equipped with two chairs. The highest ratio of static to dynamic positions during the daytime (S/D ratio = 1.687) occurred on oil tanker 1, which was not equipped with a chair designated for navigators.

DISCUSSION

Despite differences in the shapes of the visited navigation bridges, it is possible to find similar patterns of movement on the generated heatmaps and test the first hypothesis. The most frequently attended area of the wheelhouse is the central part, where the crucial equipment for navigation is located. This is hardly surprising in an era of integrated bridge and centralised information displays. This also matches examples of workstation usage during navigation provided by IACS Recommendations No.95, which suggest that, in normal operational conditions, the workstation for navigating and manoeuvring should be in use in coastal waters [8]. However, on Ro-Pax 2, both of the radars, one ECDIS and the chair, are clearly shifted to the starboard side of the axis of symmetry. This condition reduces the use of the second ECDIS, located in the central panel on the bridge, that could be used for crosschecking the first one in the event of failure or unintended position offset. This bridge was also the only one that did not fully meet the suggested workstation layout, as the workstation for monitoring was not clearly separated. Despite the wings of the wheelhouse being used less frequently, the presence is still noticeable there, which results in a gradual fading of colours on the scale. There is, however, a significant difference between open and totally enclosed bridge wings, as not a single position was registered outside of the wheelhouse on the ships of an open type. The unused areas occurred mainly on the aft part of the bridges, highlighting the fact that, as much as 22.01% of all possible fields on oil tanker 1 received 0 points on the heatmap. The workstations for planning and documentation, and for communication and safety, indicate little to no presence during the navigation. This is also understandable, especially at night time when the spaces were cut off by a curtain after sunset, on three out of four of the visited ships. Hypothesis 1 cannot be disproven, as the same patterns were observed on all visited vessels taking part in this experiment.

To test hypothesis 2, a deeper study was made of the heatmaps, as well as Table 2 in Section 3. A total of 697 static and 503 dynamic positions were assigned during the daytime. In the hours of darkness, there was less movement observed in a total of 753 static and 447 dynamic positions. The most static positions during a single observation were registered during the night watch on the Ro-Pax ferry; 66 positions were then assigned as being static, mainly seated in the chair, which is more than half registered in the period. Watches performed at night were more static on each ship. The ratios of static to dynamic positions show that the least mobility of officers during the daytime occurred on oil tanker 1, which was not fitted with a chair. The lowest S/D ratios, suggesting increased mobility, during the daytime and night time, both occurred on Ro-Pax 1, regardless of the fact that the bridge was equipped with two chairs. Therefore, the presence or absence of a chair did not result in the reduced or increased mobility of navigators and did not influence their attitude to movement. However, undoubtedly, the squares with the chairs were "the hottest" in all cases (the eight observations on Ro-Pax ferries), proving that navigators spent a significant amount of time sat on them. The mean values obtained by areas with chairs were the highest in the research: 469.75 and 187.00. On the bridges without the chairs, the points were more spread out and evenly distributed in the area of the workstations containing crucial equipment. According to recent research, navigators' opinions about equipping the bridge with a chair are clearly positive [14] and they were significantly used in this pilot experiment. Therefore, the second hypothesis was not disproved.

OTHER OBSERVATIONS AND SUGGESTIONS FOR FUTURE STUDIES

Apart from testing the two hypotheses, the results of the research might also lead to other observations. One of them is the fact that navigators now use computers in their work. For example, during the watch they are often required to review a risk assessment, search for something in the electronic publications or check the weather forecast. In the research, a total of 37 static positions were assigned to the squares directly next to computers. What is more, on the heatmaps, these positions are the hottest spots in the aft part of the bridges on each visited vessel. The majority of static positions near to a desktop computer (32) were observed during the daytime, while all of the similar positions at night (5) occurred on Ro-Pax 1, the only bridge not separating the computer from navigational areas with curtains. The possible routines of a look-out are, therefore, not limited to the presence, absence or improperly placed chairs on the bridge. This suggests that there might be other factors contributing to movement habits and time spent in certain areas of the bridge. Bearing in mind the importance of desktop computers, including the fact that they sometimes contain digital nautical publications, it might be reasonable to study this case in the future.

Each ship participating in this pilot experiment was using ECDIS as a primary and secondary means of navigation and there were no paper charts on board. On every visited vessel, a paper logbook was placed in the central part of the bridge, at the panel of the workstation for monitoring. No voyage documentation was entered into the dedicated workstation for planning and documentation, although it was possible but not practical. Comparing the observations to the research carried out by Wynn et al. (2012) [7], there are apparent changes in watch routines. In the above mentioned paper, visits to the chart room on a ship with paper charts were frequent while, for a ship equipped with ECDIS, they were infrequent and related to position plotting and logbook entries. Placing the logbook in the area where all the information is gathered and centralised, not in a separated chartroom or behind the curtains, not only makes entries faster, but also reduces the possibility of making a mistake while transferring data from one workstation to another. However, the amount of time spent near the logbook on every vessel gives an indication that it is still an important part of modern navigation. The squares where navigators made logbook entries obtained 112.17 and 130.67 points on oil tankers and 76.75 and 57.00 points on Ro-Pax ferries. Interestingly, in the case of oil tankers, these were also the hottest spots on the bridges (no chairs present). The United Kingdom Hydrographic Office (UKHO) has already announced its intention to withdraw from paper chart production by the end of 2026 [26], while marine electronic logbooks also become more and more popular, replacing standard paper logbooks. In the era of digitalisation, habits and routines may shift accordingly. In future studies, it would be useful to assess whether electronic logbooks have an influence on the time that a navigator spends making entries, and determining the best position to place them on modern, ergonomic bridges.

The research carried out indicates the areas attended the most on different bridges of various shapes and layouts. These are usually the workstations for navigation and manoeuvring, together with workstations for monitoring. Night watches were more static and navigators depended on equipment even more than in the daytime, mainly because of difficulties in visually estimating the distance to an obstruction or another vessel. The paper by Hadnett (2008) [5] suggested that overreliance on equipment, including radars, AIS and ECDIS, lead to reduced overall standards of watch-keeping. Bearing this in mind, along with the case study by Britannia P&I Club [12] (mentioned previously in this paper), the possibility of comforTable seating in front of displays, especially at night, might be worrisome for the safety of navigation. The presence of the chair affected the spread of positions; however, it did not result in an increased amount of static positions overall. Due to the potential discomfort and pain caused by prolonged standing and vibrations, seating should not be related to negligence in lookout duties. Since the adoption of BNWAS, the time spent on a night watch could be significantly reduced, rather than practicing imposed standing. If, for whatever reason, sitting on the bridge is still not possible, or is forbidden, the collected data and visualised results might indicate the areas where the use of anti-fatigue floor mats is reasonable, to support seafarers.

Due to the discontinuity in movement registration, in future full-scale research, it is recommended that tracking vests or similar devices are attached to navigators, bearing in mind the possible restrictions experienced, with the use of cameras. Observations should be prolonged for the entire shift duration, to check the correlations between performance and mobility in the different phases of the watch. Assuming the possible impact of the presence of a chair on the mobility of officers, data should ideally be collected on sister ships of at least the same type and similar dimensions, working in the same area (preferably on the same route), when one bridge is equipped with the chair and the other is not. The tracking vests may be helpful when measuring the exact time spent being motionless (standing or seated) and walking, eliminating the need to use static and dynamic coefficients. The representation of a navigator's presence on the heatmaps can be considered as valuable for determining the usability of certain areas in modern navigation. In addition, constant records of movement could be used for studying statistical correlations in walking patterns, guiding a better understanding of the behaviours and habits of navigators. Future studies should plan to use a simple, scaled questionnaire to get to know navigators' willingness to sit at the beginning, middle and end of their watch. It would provide additional information to study the preferences and routines of professional seafarers.

The range of potential hypotheses to be tested, based on the movement of navigators, is wide. It would be ideal to create an open database, where the collected records would be publicly available and anonymised. It is, however, important to standardise the data collection process to be included in such a database, together with a timestamp, dimensions, type of ship and the phase of voyage (open sea/coastal waters/narrow waters etc.). Creating such a database would probably require the cooperation of many ship owners but making it open to the community of researchers may result in various independent studies and observations. This might include topics related not only to ergonomic design but also reducing the time spent away from being an effective lookout or reducing occupational diseases and discomfort.

CONCLUSIONS

The real life scenarios and observations of professionals during their work are still valuable and should be taken into consideration when improving the ergonomics of a workplace. Working on board a ship nowadays remains a serious challenge and people should be supported, not only by equipment, but also by proper design. This paper analysed the lookout routines of ten navigators on four vessels with different bridges. Both hypotheses were tested experimentally and both could not be disproved, which makes them worthy to be tested by full-scale research. Studying the movement of deck officers might be useful for a wide range of independent studies, based on the same datasets. It is reasonable to create a publicly available database, open to other researchers, after standardising the data collection process. This pilot experiment revealed possible limitations and experienced deficiencies in movement registration, offering guidance for better quality full-scale studies in the future. Therefore, studying a relatively small sample was valuable.

In the experiment, it was found that, during night watches, navigators were more static than during daytime duties. Regardless of different bridge designs and the presence or absence of a chair, it was observed that, for the majority of the time, the watch was spent in the central part of the bridge, near the workstations for navigation and manoeuvring and monitoring. This suggests a high usability of this area, and so a properly placed chair, allowing optimal visibility and access to the equipment, might not be considered as a potential danger for improper lookout or reducing involvement in observations. In the research, it was found that there was no increased ratio of static to dynamic positions of navigators on ships with a chair on the bridge, compared to those without a chair. Therefore, it may be unreasonable to forbid officers to sit during watches. Highlighting the fact that MSC/Circ.982 proposed adjusTable chairs on the bridge for navigators in the year 2000, it is still not mandatory and only two out of four of the visited ships were equipped with them. Seating during the watch could potentially reduce musculoskeletal disorders and fatigue. Clear regulations on the matter would be considered as a potential room for improvement in the area of ergonomic bridge design because lookout routines slightly differ on the bridges with and without chairs, as shown in this research.

To sum up the pilot study, it can be concluded that bridge design, equipment and layout can affect the routines of navigators. Technological progress is very fast and ergonomics should follow it, so as to maximise the performance of operators. There are areas of the bridge with high usability but also others that do not really take part in modern navigation and could be organised in some other way. Efforts should be taken to find a proper balance and maintain the highest possible standard of lookouts. Communication between crews and designers barely exists nowadays. The ship owners could become a link between both groups and support a full-scale study with the use of constant movement registration devices, in order to improve ergonomic bridge design in the future. The pilot experiment suggests that there is still room for improvement, in the area of ergonomic bridge design; however, further full-scale studies are required to determine which direction should be followed.

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The author reports that there are no competing interests to declare.

The author confirms sole responsibility for the preparation of the paper.

The public repository containing the file with static and dynamic positions from every observation was created using GitHub: https://github.com/00mist/Static-and-dynamic-positions-on-navigational-bridges.

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APPENDIX A

The registered amount of static (S) and dynamic (D) positions on visited ships.

The public repository containing the file with static and dynamic positions, from every observation, was created using GitHub for future works: https://github.com/00mist/Static-and-dynamic-positions-on-navigational-bridges.

The location of some equipment on the bridge is marked with letters:

- E – ECDIS;
- R – radar;
- L – paper logbook;
- P – personal computer (desktop computer);
- C – chair.

1) Observation 1 on oil tanker 1 (night)

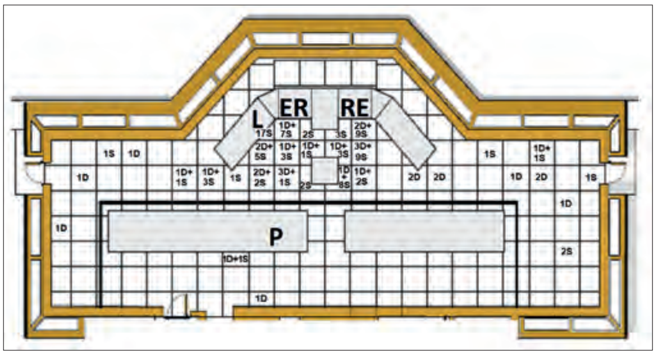

Fig. A.1. Static and Dynamic positions during observation 1 on oil tanker 1

2) Observation 2 on oil tanker 1 (day)

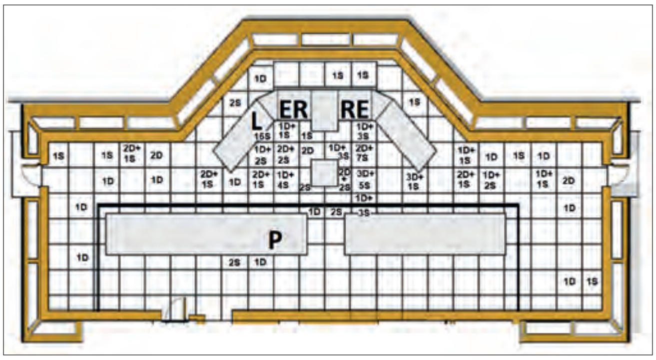

Fig. A.2. Static and Dynamic positions during observation 2 on oil tanker 1

3) Observation 3 on oil tanker 1 (day)

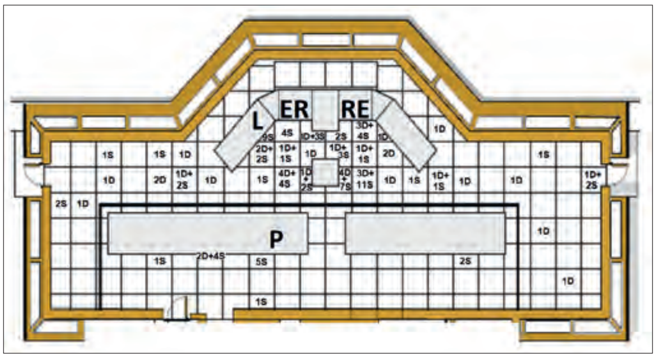

Fig. A.3. Static and Dynamic positions during observation 3 on oil tanker 1

4) Observation 4 on oil tanker 1 (night)

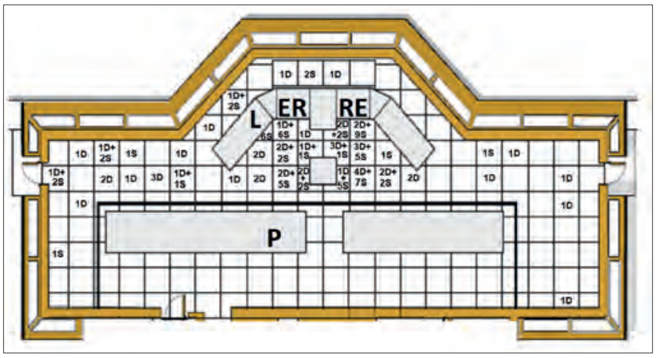

Fig. A.4. Static and Dynamic positions during observation 4 on oil tanker 1

5) Observation 5 on oil tanker 1 (day)

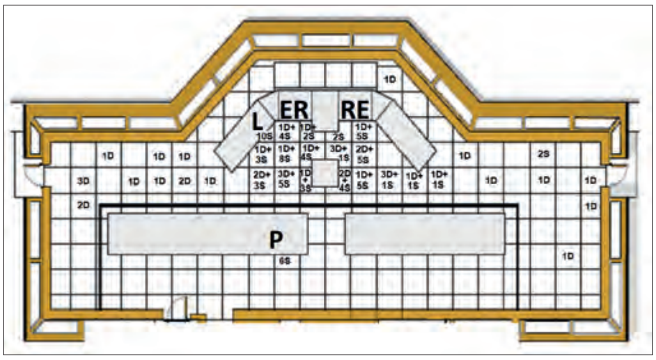

Fig. A.5. Static and Dynamic positions during observation 5 on oil tanker 1

6) Observation 6 on oil tanker 1 (night)

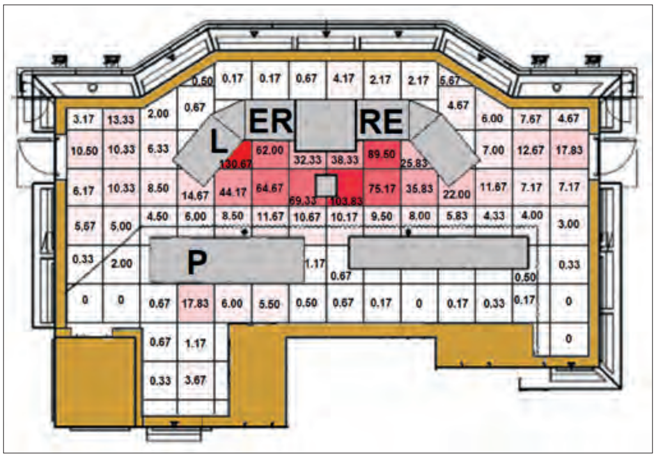

Fig. A.6. Static and Dynamic positions during observation 6 on oil tanker 1

7) Observation 1 on oil tanker 2 (night)

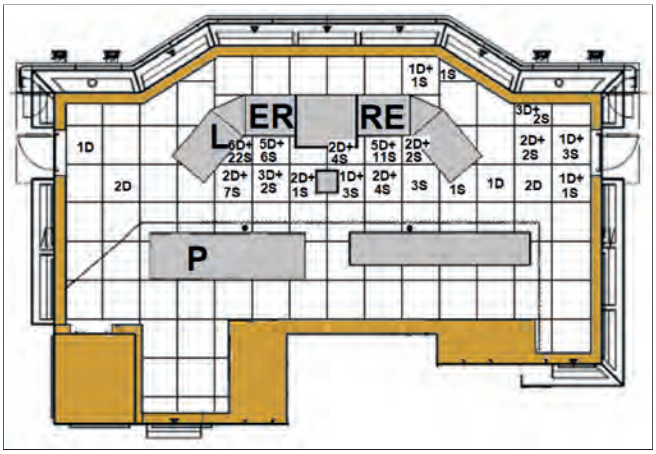

Fig. A.7. Static and Dynamic positions during observation 1 on oil tanker 2

8) Observation 2 on oil tanker 2 (day)

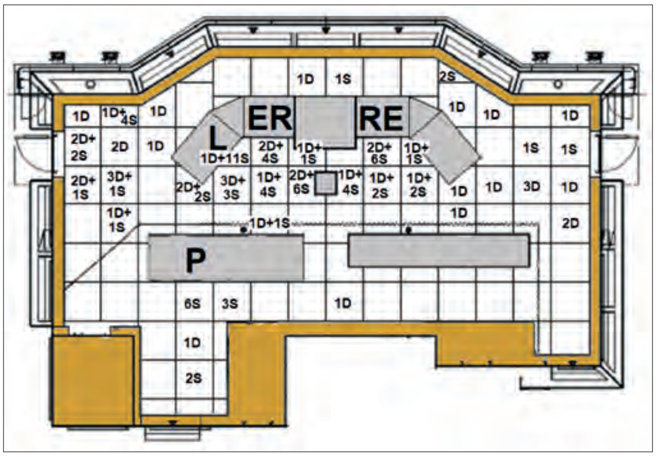

Fig. A.8. Static and Dynamic positions during observation 2 on oil tanker 2

9) Observation 3 on oil tanker 2 (day)

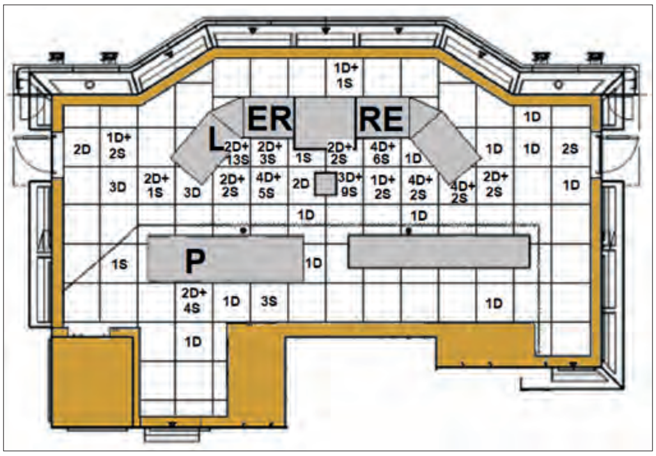

Fig. A.9. Static and Dynamic positions during observation 3 on oil tanker 2

10) Observation 4 on oil tanker 2 (night)

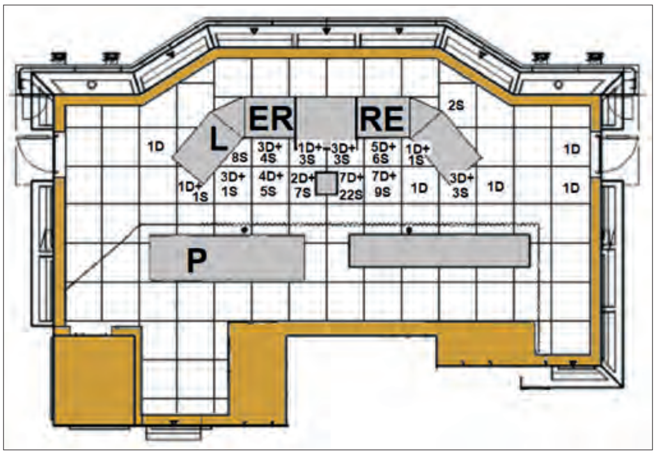

Fig. A.10. Static and Dynamic positions during observation 4 on oil tanker 2

11) Observation 5 on oil tanker 2 (day)

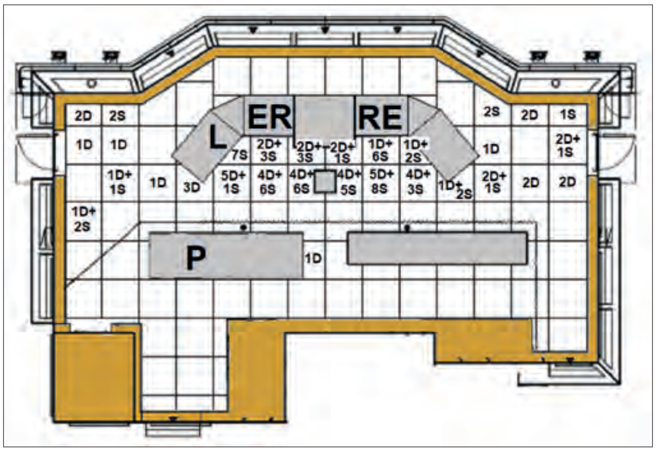

Fig. A.11. Static and Dynamic positions during observation 5 on oil tanker 2

12) Observation 6 on oil tanker 2 (night)

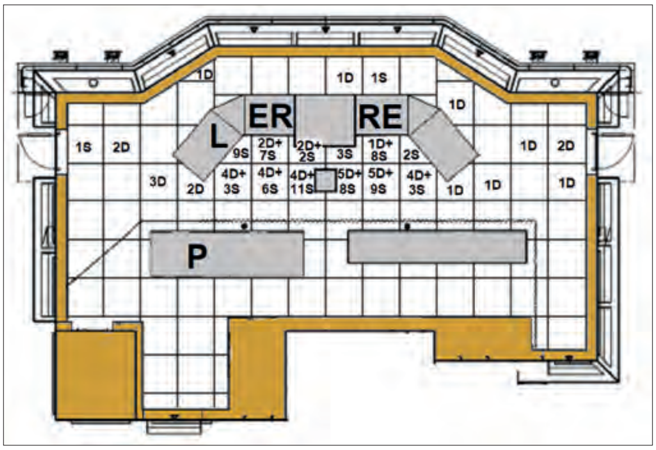

Fig. A.12. Static and Dynamic positions during observation 6 on oil tanker 2

13) Observation 1 on ro-pax 1 (night)

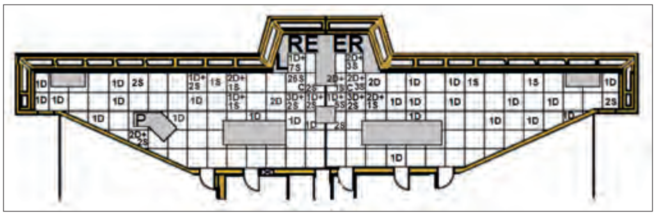

Fig. A.13. Static and Dynamic positions during observation 1 on ro-pax 1

14) Observation 2 on ro-pax 1 (day)

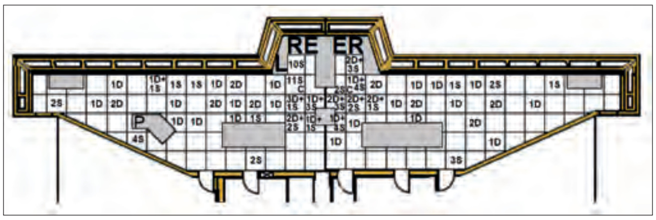

Fig. A.14. Static and Dynamic positions during observation 2 on ro-pax 1

15) Observation 3 on ro-pax 1 (night)

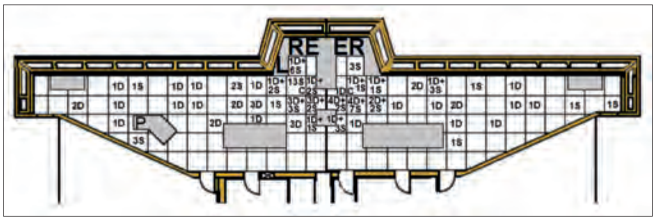

Fig. A.15. Static and Dynamic positions during observation 3 on ro-pax 1

16) Observation 4 on ro-pax 1 (day)

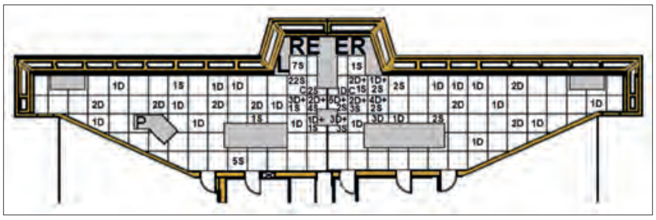

Fig. A.16. Static and Dynamic positions during observation 4 on ro-pax 1

17) Observation 1 on ro-pax 2 (day)

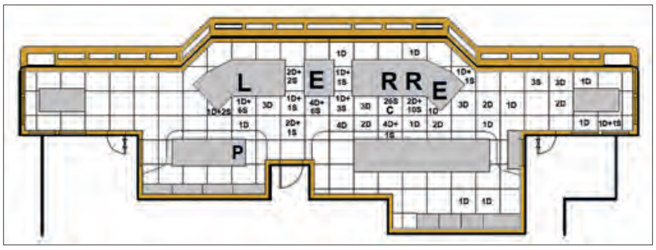

Fig. A.17. Static and Dynamic positions during observation 1 on ro-pax 2

18) Observation 2 on ro-pax 2 (night)

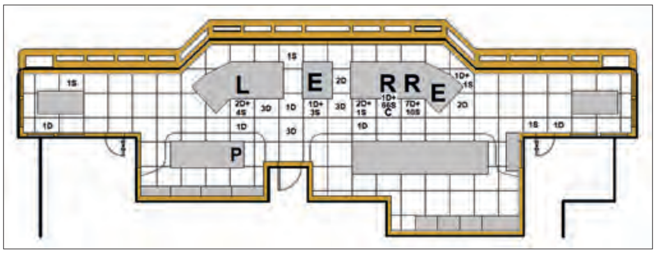

Fig. A.18. Static and Dynamic positions during observation 2 on ro-pax 2

19) Observation 3 on ro-pax 2 (day)

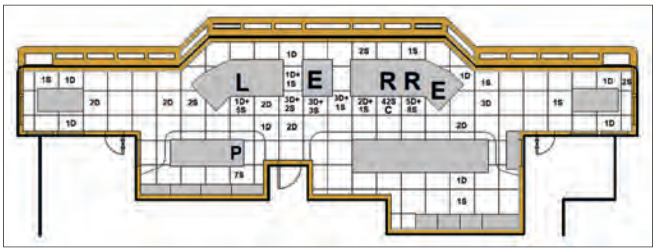

Fig. A.19. Static and Dynamic positions during observation 3 on ro-pax 2

20) Observation 4 on ro-pax 2 (night)

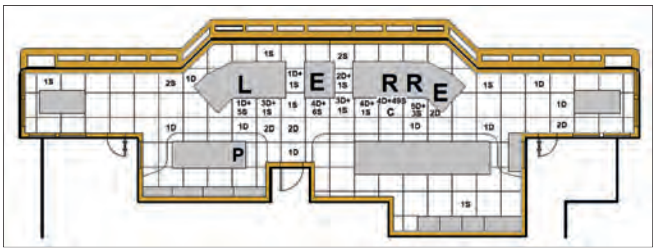

Fig. A.20. Static and Dynamic positions during observation 4 on ro-pax 2