Paper 105

Safety hazards in nighttime offshore helicopter operations

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ABSTRACT

In offshore energy exploration and production activities, helicopters play a vital role in the movement of people and machinery to and from installations at sea. However, such operations are prone to accidents, especially in conditions where visibility is poor, e.g. at night. Despite this, the continuing search for energy sources towards the poles, attendant pressure to ferry personnel and cargo beyond daylight hours and increasing demand for emergency evacuation, amongst other factors, point to a significant increase in nighttime operations in the near future. Therefore, there is an urgent need to understand the factors that underlie such accidents and to develop interventions. To date, empirical and scientific studies, often with the involvement of regulators and operators in the North Sea, have successfully addressed some of the potential causal factors, such as poor helideck lighting and inaccurate instrument descent procedures, with significant improvements in safety. However, this is not replicated in other regions of the world. Furthermore, recent accidents have shown that there should be a broader range of factors, some of which are very localised, that influence safety in real operational scenarios. Therefore, this paper proposes a systemic approach that accurately and reliably accounts for all the factors, with a particular focus on the approach and landing flight phases where the majority of accidents are concentrated. It presents the results of semi-structured interviews of pilots from four different scenarios (the British Northern North Sea and Irish Sea, Brazil's Campos basin and the Norwegian North Sea), using a well-established knowledge elicitation technique (cognitive task analysis), followed by rigorous analyses of the narratives using Grounded Theory and Template Analysis. The interview results are used to compile a comprehensive list of the factors that affect the ability of pilots to fly offshore night approach segments, thereby addressing the gap between theoretical design and practical knowledge of offshore nighttime operations.

INTRODUCTION

The importance of helicopters for offshore oil and gas Exploration and Production (E&P) activities has been highlighted by many authors (e.g. [1]). Unfortunately helicopter operations are the biggest contributor to the overall risk of fatal accidents in the offshore environment (e.g., [2-3]). There are many drivers for safer helicopter operations in the oil and gas business, e.g., the need to avoid loss of reputation [4], demands from workers' unions and close public scrutiny following accidents [5]. Therefore stakeholders in the offshore oil and gas helicopter industry have assumed a key role in the advancement of safety for the wider rotary community [6]. However, despite considerable investment in the improvement of safety, helicopter operations in degraded visual conditions, especially at night, is still a major concern to both regulators and operators (e.g. [7-8]).

BRIEF ACCIDENT ANALYSIS

Ross and Gibb [8] studied the offshore helicopter accidents that occurred between 1990 and 2007, and concluded that the nighttime accident rate was more than 5 times greater than in daylight, with a preponderance of human factors-related occurrences. Expanding on Ross and Gibb's study, further analysis in this paper, of the 165 offshore helicopter accidents that occurred worldwide between 1997 and 2007 (sources: [8-17]) showed that:

- The fatal accident rate at night was 15 times greater than in daylight (Fig. 1), a statistically significant result, as measured by the Mann-Whitney test (U=110.00, z=3.256, p=.001);

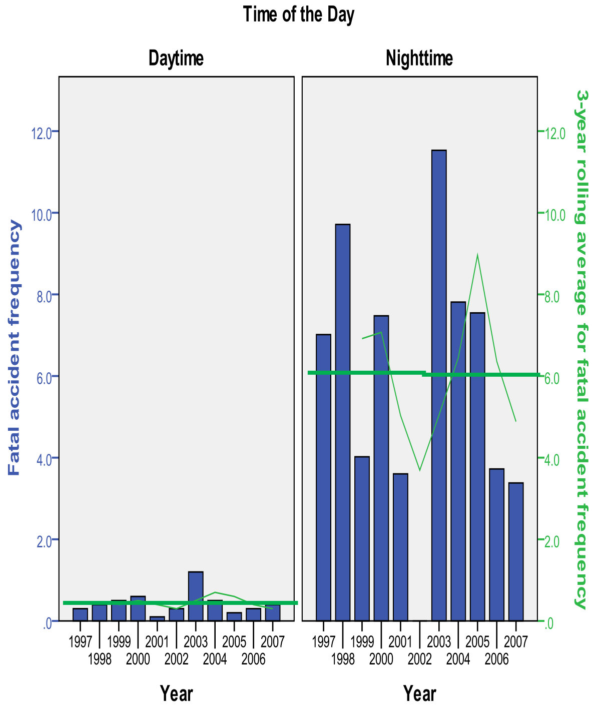

Figure 1 – Fatal accident rates for offshore helicopters, with the 3-year rolling average and the average for the period

- The number of fatalities in nighttime accidents was significantly greater than in daylight (Table 1. Mann-Whitney test: U=2,490.0, z=3.36, p=.001).

Table 1 – Summary of statistics for fatalities per lighting conditions

	Mean	Standard deviation
Daytime	1.3	3.4
Nighttime	2.7	3.2

- Using the classification scheme adopted by the International Association of Oil and Gas Producers – OGP, there was a significant association between lighting conditions and accident causes, with more pilot-related accidents occurring at night (Table 2. Chi-square test: $\chi^2(2)=18.867$, $p < .000$);

Table 2 - Percentage of accident causes per lighting condition

	Pilot-related	Technical	Other
Daytime	43.9	36.7	19.4
Nighttime	88.5	7.7	3.9

- For both day and night operations, CFIT/W[1] was the most frequent cause of accidents, totalling 19.4%;

- 84.6% of the nighttime accidents were cases of CFIT/W, with a significant association to lighting conditions (Chi-square test: $\chi^2(1)=83.983$, $p<.000$);

- 11 of the 26 nighttime accidents (over 40%) occurred in the approach and landing phases;

- There was a significant association between accident cause and phase of flight (Fisher's exact test p=.008), with a relatively higher number of pilot-related accidents in the approach and landing phases (Fig.2).

Although the accident rates were high, only approximately 3% of the flying hours were undertaken at night during the study timeframe [8]. This would perhaps justify focusing solely on the issues associated with daylight flights instead. However, future trends suggest that nighttime flights will increase.

THE FUTURE

Some of the drivers for the expected increase in nighttime operations are:

Exploration towards polar circles: the search for energy sources increasingly towards the poles presents new challenges to helicopter operations as daylight hours are considerably shorter during several months of the year, and severe weather conditions are relatively frequent. This is the case, for example, in the Barents and Kara seas [19]

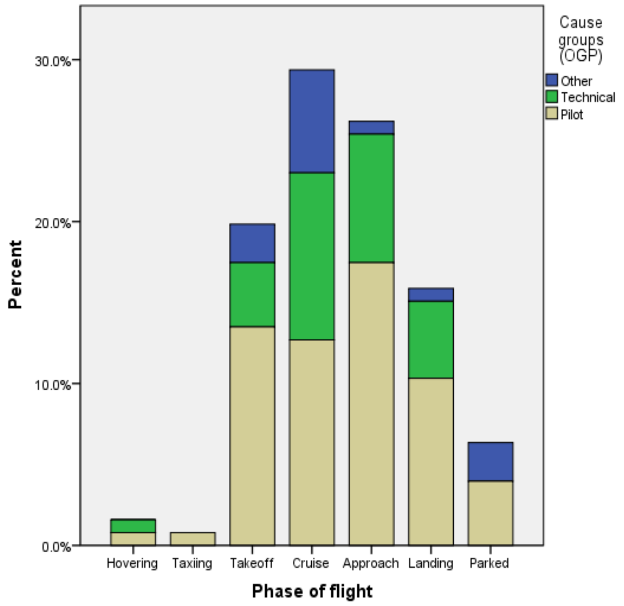

Figure 2 – Percentage of accident causes per flight phases, using OGP's classification scheme for causes

In the UK, the plan to develop the Laggan and Tormore gas fields to the west of the Shetland islands will require considerable operational infrastructure, potentially including substantial helicopter operations [20].

In South America, from the Falkland islands [21] to Chile and Argentina, offshore helicopter operations in support of oil and gas exploration are expected to grow substantially and to move southwards towards Antarctica [22].

Repressed demand: in some regions of the World, economic reasons have led to pressure to intensify offshore helicopter operations at night. Whereas in 2007 the worldwide average monthly flight hours for offshore helicopters was around 70 [9], Brazilian helicopters flew approximately 120 hours per month [23], limited only by the regulatory framework which bans night flying for the ferrying of passengers [24]. However, in anticipation of an increase in activities, the Brazilian regulator recently commissioned a study of the viability of regular offshore night operations [24], and to assess the impacts of changing the regulatory framework. Likewise, in the Middle East, production demands require night operations, with the acknowledgment that any associated accidents are a serious cause for concern [25].

Emergency evacuation: as the offshore population grows, the requirements to evacuate workers, including at night, will increase. Emergency evacuation might be the case both on an individual basis, as well as for the entire offshore population in regions distressed by natural catastrophes, such as extreme storms in Norway [26]

CURRENT SAFETY INITIATIVES

[1] CFIT/W: controlled flight into terrain or water. According to the Flight Safety Foundation [18], it occurs when an airworthy aircraft under the control of the crew is unintentionally flown into terrain, obstacles or water.

In recent years, many initiatives have delivered improvements to the safety of offshore helicopter operations in degraded visual conditions, with a focus on the approach and landing phases.

In the North Sea for example, new helideck lighting systems based upon green perimeter lights were developed, to reduce the workload of pilots whilst they seek the landing zone amidst the platform structure. Additionally, the incorporation of GPS into the Airborne Radar Approach (ARA) procedure has enhanced the reliability of the instrument navigation task towards offshore installations [27]. Further benefits are expected to come from the vertical guidance, autopilot coupling and shorter visual segment due to the Satellite-Based Augmentation System Offshore Approach Procedure (SOAP) [28] currently under test.

Recent accidents (e.g. [3, 25, 29-31]), have shown that the improvements above, have yet to be transferred to many regions of the globe. In addition, from a human factors' perspective, other improvements are also important, if the limitations to the human ability to fly in degraded visual environments (DVE) are to be surmounted [7-8].

HUMAN LIMITATIONS IN DVE

The current technologies and cockpit layouts do not support offshore helicopter auto-land capabilities and flying in non-visual environments respectively. Therefore, arrival operations still rely on the ability of pilots to manually fly aircraft with reference to surrounding visual cues. As such, pilots are expected to make the necessary decisions to separate their aircraft from others, obstacles and water. However, human visual perception and decision-making are both prone to impairment in degraded visual conditions.

<u>*Visual perception and spatial orientation:*</u> the human ability to move in space depends on information captured by many senses, among which vision accounts for approximately 80% of the necessary inputs [32]. It also depends on the central nervous system being able to integrate such inputs and interpret them against internal models of locomotion [33]. Therefore, perception and orientation, depends not only on 'bottom-up' neural sensing mechanisms, but also 'top-down' interpretative processes [34]. As a consequence, misperceptions (and spatial disorientation) might result from the:

- absence or insufficiency of external visual stimuli;
- breakdown in the capture of external stimuli;
- breakdown in the stimuli integration mechanism;
- breakdown in the retrieval of internal models from one's long-term memory;
- breakdown in the matching process between external cues and internal models;
- inadequacy of the internal models.

For the problem of offshore helicopter nighttime approaches, better helideck lighting systems and more accurate approach procedures should facilitate the capture of external stimuli. However, their integration, memory retrieval and interpretation against internal models are more dependent on the availability of cognitive resources, workload and task complexity [35], which largely depends on the pilots' chosen use of automation and familiarity with the task under the existing internal and external conditions. Additionally, the development of adequate internal models is more directly affected by repetitive exposure to relevant stimuli. This is a key consideration in the context of nighttime offshore helicopter operations because of the following.

<u>*The treacherous nature of human decision-making in DVE:*</u> because humans most often spend their lives in presence of daylight, their internal models for orientation are built upon redundant visual cues, with many of the human perception mechanisms (e.g., convergence, relative size, linear perspective) working efficiently and effortlessly to de-bias and interpret such cues. This promotes confidence in visual abilities, which is transferable (to an extent) across to degraded environments. However, in such conditions not only are fewer cues available but also barely none of the human visual perception mechanisms work properly [34, 36-37]. As a result, humans tend to make wrong decisions, for example, in aviation where relatively high accident rates have persisted (e.g. [34, 37-40]).

<u>*Decision-making in multi crew cockpits:*</u> whereas part of the decision-making problem might be solved with the introduction of a discussion forum for situation assessment in multi crew cockpits [41], social influences and communication problems are also inherited. Without clear communication standards and unambiguous intervention policies, the intended shared decision-making can be expected to breakdown [38, 42]. However, communication and intervention standards do not seem to have been the focus of ongoing safety initiatives. Nevertheless, visual misperception and disorientation are potential causes of failure, degrading even the best of the crew communication and procedural interventions.

A SYSTEMIC VIEW TO THE PROBLEM

It is clear that human perception, orientation and decision-making are correlated to the internal and external factors present as tasks are executed (hereby labelled 'contextual factors'). Among such factors, external luminescence is important, in addition many other influences to the crews' ability to fly safely. Therefore, a systemic approach is required for the identification of the factors, their characteristics and specification of interventions.

METHODOLOGY

<u>*Eliciting operational knowledge:*</u> due to a lack of peer-reviewed material on the safety hazards of offshore night

operations, in addition to paucity of accidents, in some cases unavailability of detailed reports and inadequate original investigations, a methodology was proposed to capture the expertise of a sample of pilots involved in such missions.

Task analysis methods are particularly useful for knowledge elicitation, among which cognitive task analysis was used to investigate the roles of human perception, information processing and decision-making. Additionally, in order to facilitate participants' immersion into task contexts, the Talk-Through technique [43] was used in a semi-structured interview schedule. Demographic and open-ended questions were devised, discussed and refined with carefully selected Subject Matter Experts (SME) before the data were collected.

Choice of scenarios: purposive sampling guided the choice of scenarios anticipated to be very different in relation to a number of factors, e.g., meteorological conditions, aeronautical infrastructure, types of platform, culture and regulatory framework. This was predicted to lead to the generation of a comprehensive list of contextual factors, most probably transferable to other scenarios. The following sections provide brief descriptions of each scenario and further details on the specific methods applied.

The British Northern North Sea (NNS[2]): in this area, oil and gas reserves are often in excess of 100 kilometres from the shore. The platforms are usually settled in deep water, isolated from one another and are large, hosting hundreds of people [26]. These characteristics determine the use of long range heavy payload helicopters, such as EC225s, S-92s, S-61s and the EC332L family. Usually flights occur from land-based airports to the platforms or ships and back, with considerably fewer sorties in between platforms/ships. Aberdeen is the main operations' hub, but some flights also occur from other places such as the Shetland islands.

Thirty-three pilots from all offshore helicopter operators based at Aberdeen's Dyce airport were interviewed during the summer of 2009. They were selected by non-probability convenience sampling, due to various constraints including availability and individual circumstances. All interviews were recorded ($17^h42^m41^s$) and transcribed.

The analysis was initiated by the Strauss and Corbin's [44] line-by-line technique, aimed at extracting from the narratives meaningful and self-sufficient chunks of text related to pilots' experiences with factors that affect safety during task execution. This was followed by interview fidelity and statement extraction checks [45], undertaken with the aid of two independent and knowledgeable raters.

[2] The generic term Northern North Sea (NNS) also includes North Atlantic ocean waters to the west of the Shetland islands [31].

The analysis progressed to the use of grounded theory [44]. This methodology enables the generation of categories regardless of any pre-conceived theories. Therefore, it was suitable for the creation of an unbiased list of factors tailored to the needs of the offshore helicopter industry, as opposed to the adaptive fitting of identified factors into pre-existing taxonomies derived from other domains. Intra and inter-rater reliability checks using Cohen's Kappa [46] were undertaken throughout the analysis to ensure unbiased categorisation of statements. Additionally, consultation with SMEs and checks of the template against raw data increased validity. Figure 3 below shows the methodology for the NNS analysis.

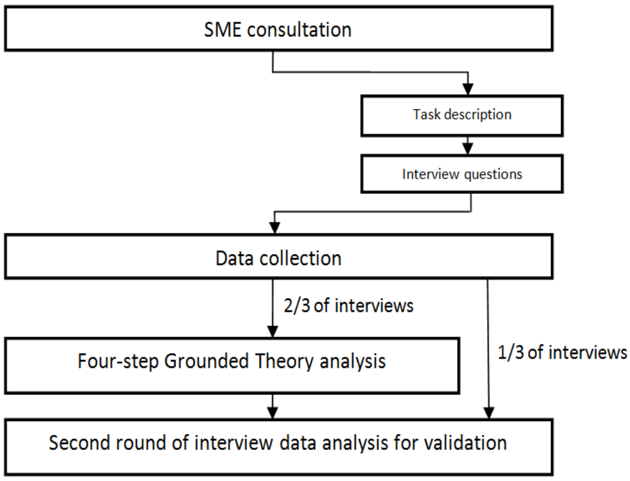

Figure 3 – Research methodology for the NNS

The British Irish Sea: in the oil and gas business, the UK's Irish Sea and the English Channel are usually referred to as part of the Southern North Sea (SNS) [20]. Platforms in these areas are often anchored in shallow waters close to land. They are small, some are unmanned, and many are clustered and interconnected through sets of bridges [26]. These characteristic ask for smaller helicopters, such as the AS365N and S-76 families, AW139s and EC155s. Differently from the NNS, shuttling between platforms/ships is considerably more intense, leading to multiple landings offshore before transits back to the coast occur. Flights to the SNS depart from many cities in England, including Humberside, Norwich, North Denes, and Blackpool. Three pilots were selected by convenience sampling, using the interview schedule of the previous step, in Blackpool in summer 2009.

The line-by-line analysis technique mentioned above was applied to the transcriptions of the interviews ($02^h30^m51^s$). Subsequently, Template Analysis [47] was employed to group the statements into categories. This technique starts from a list of codes defined *a priori* (a template), which is then modified as prompted by the narratives. The codes developed in the previous step were used, refined and amended accordingly. Intra-rater reliability checks based on Cohen's kappa [46] were undertaken to minimise any bias on the categorisation process.

Brazil's Campos basin: over 85% of the oil and gas in Brazil comes from offshore fields [48], and mainly from the Campos basin [49], based from Macae. Fewer movements to this basin also occur from Cabo Frio, Campos, Sao Tome and Rio de Janeiro. Until recently, operations were dominated by medium twin turbine helicopters (e.g., the S-76 and AS365N families, AW139s and Bell 212/412s) and fewer heavy aircraft (from the EC332L family). With the recent need to support exploration activities in deep water wells, progressively heavier aircraft have been introduced (e.g., S-92s, EC225s). Unlike the North Sea though, night operations in Brazil occur randomly throughout the year, only in response to medical emergencies or in the aid to the rare catastrophies occuring to platforms/ships.

Twenty-eight offshore helicopter pilots were chosen by convenience sampling and interviewed in Macae and Cabo Frio in December 2009. The same cognitive task analysis, semi-structured interview schedule from the previous steps was used. Twenty-two individual and two group interviews were undertaken, totaling $06^{h}50^{m}05^{s}$. As in the previous step, line-by-line analysis [44] was applied to the transcribed narratives, leading to the extraction of meaningful statements then categorised by Template Analysis [47]. Intra and inter-rater reliability, as well as validity checks were undertaken much as during the NNS research step. Figure 4 below shows the methodology for the Brazilian analysis.

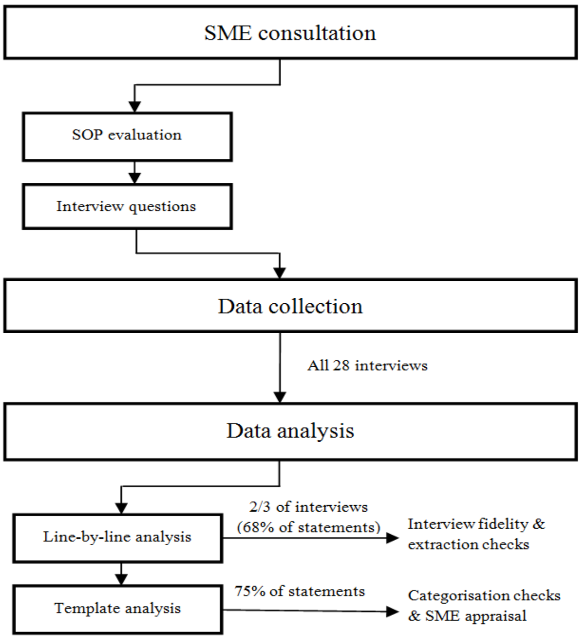

Figure 4 – Research methodology for Brazil

The Norwegian North Sea: the Norwegian and British NNS oil and gas basins are fairly similar [7], and the same types of heavy helicopters are used. Unlike in the UK sector, there are a few offshore-based helicopters in Norway dedicated to in-field shuttle missions in platform-dense areas, e.g. over the Heidrun and Ekofisk reservoirs. The main cities hosting operations are Stavanger and Bergen, with fewer helicopter movements from other locations along the coast up to Hammerfest in the extreme north. The uniqueness of the Norwegian scenario apparently stems from the synergies between the different stakeholders in the industry for aviation safety [7].

Three offshore helicopter pilots employed to the main helicopter operators based in Stavanger in key safety and flight operations positions were selected by purposive sampling in November 2010. Through Template Analysis [47], the contents of the interviews were analysed, and intra-rater reliability checks followed much as before. This research step was aimed at encapsulating any issues particularly relevant to Norway, and at assessing if *'exhaustiveness'* [45] had been achieved in the development of the template.

RESULTS

In total, 67 pilots (64 male, 3 female; 48 captains, 19 first officers) were interviewed in sessions 24 minutes in length on average. The major demographic features of participants are recorded in Table 3, and the aircraft on which they were type rated are shown in Table 4.

Table 3 – Major demographic characteristics of pilots

Characteristic	Mean	Standard deviation
Age, years	43.4	10.1
Experience flying helicopters, hours	7441.4	5593.1
Experience flying Instrument Flight Rules (IFR), hours	1931.5	2894.0
Experience of night flying, hours	957.2	920.3
Number of night deck landings	620.1	1255.4

Table 4 – Aircraft flown by participants

EC135	AS365N2	AS365N3	S76A	S76C+	S76C++	EC155	AW139	Bell222	Bell412	AS332L1	AS332L2	EC225	S92
4	3	5	11	4	3	1	4	1	1	7	16	14	6

The interim results of each research step were as follows:

UK's NNS: 1264 statements extracted, leading to the generation of an initial template formed by 74 categories, regrouped into 13 codes.

UK's Irish Sea: 367 statements extracted, leading to the incorporation of 18 categories into the initial template.

Brazil's Campos basin: 700 statements extracted, leading to the incorporation of 9 categories into the template.

Norwegian North Sea: 67 statements extracted leading to the incorporation of only 2 categories into the template. Such diminished returns indicated the exhaustive and mature nature of the template.

The final version of the template is formed by 103 hazard categories, re-grouped in 13 codes, split into two sections: 'contextual factors' and 'impacts on crew' (Tables 5 and 6, respectively, with the codes vertically to the left and categories to the right). The following font styles indicate in which scenarios the categories were generated:

- Normal font: British Northern North Sea;
- **Bold font**: British Irish Sea;
- *Italic font*: Brazil's Campos basin;
- Underlined font: Norwegian North Sea.

Table 5 – Contextual factors affecting crews' ability to fly night visual approach segments offshore, with the number and percentage of participants who commented on each factor (from 67 interviewees)

Platform and surroundings (53 pilots, 79%)	Lack of depth and texture cues	35	52%
	Destination obstacles (e.g., unlit wires)	28	42%
	Inaccurate weather reports	12	18%
	Turbulence	11	16%
	Moving references due to vessel movement	10	15%
	Lack of visual references when circling to the far side of the platform/ship	9	13%
	Water surface obstacles (e.g., boats)	8	12%
	Variability in the visual picture for the approach (unequal platform shapes)	7	10%
	Bow decks and loss of visual cues	4	6%
	Clustered / isolated rigs	3	4%
	Deck height	3	4%
	Process thermal effects	3	4%
	Helideck illumination	3	4%
	Aids' conspicuity (e.g., windsocks)	2	3%
	Orientation of the deck out of the prevailing winds	1	1%
	Asymmetric ground effect in small decks	1	1%
	Loss of visual cues in small decks	1	1%
	Substandard helideck nets	1	1%
Procedures (51 pilots, 76%)	Lack of communication standards (call-outs/intervention policies)	29	43%
	Lack of written SOPs for the visual segment or discouragement to use them	23	34%
	Interpretative descent technique based on the ovality of the aiming circle	18	27%
	Standards for automation use (e.g., call-outs and specific decoupling point)	15	22%
	Appropriateness of instrument flight profile (e.g., ARA *versus* visual gates)	14	21%
	Procedures requiring mental computation	4	6%
	Shuttling and unstable flight paths due to manoeuvring needs	4	6%
	Not using aircraft's external light	3	4%
Training (50 pilots, 75%)	Currency of training	45	67%
	Quality of training	14	21%
	Inadequacy of simulators	12	18%
	Under usage of simulators	6	9%
	Make and model transfer training	5	7%
	Diversity of scenarios not covered by training	4	6%
	Sponsorship cuts/unavailability for training-only sorties	4	6%
	Not practicing in daytime	2	3%
	Wrong use of simulators (surrogate to in-flight training)	2	3%
	Too stringent / bureaucratic legislation for nighttime training	2	3%
	Under usage of HFDM for training	1	1%
	Lack of experienced instructors	1	1%
Internal issues (49 pilots, 73%)	Experience	29	43%
	Dread	19	28%
	Seniority gradient: dealing with/being a junior pilot	17	25%
	Self-induced pressure	16	24%
	Pressure by mission unpreparedness	13	19%
	Stress and fatigue	10	15%
	Overall experience not a guarantee for success	9	13%
	Excessive self-confidence	7	10%
	'Complacency' due to exposure (habituation)	4	6%
	Inaptitude to fly at night	3	4%
	Anxiety	2	3%
	Perished skills	2	3%
	Wearing glasses	1	1%
	Irregular meals	1	1%
Aircraft (47 pilots, 70%)	Automation limitations (e.g., upper modes de-coupling speeds)	34	51%
	Aircraft limitations (e.g., windscreen wipers speed limitations)	22	33%
	Wind-caused handling qualities variability	15	22%
	Cockpit limitations (e.g., awkward arrangement of gauges)	12	18%
	Non-handling pilot blocked vision on transition to helideck	8	12%
	Engines limitations	4	6%
	Loss of manual flying skills induced by automation	4	6%
	OEM's unawareness of offshore needs	2	3%
Environment (35 pilots, 52%)	Illusive weather conditions (e.g., millpond water)	26	39%
	General (unspecific) lack of visual cues	19	28%
	Late loss of visual references (e.g., low level patchy clouds)	6	9%
	Crosswinds	5	7%
	Rapid weather changes	3	4%

Regulator (32 pilots, 48%)	Low limits (e.g., MAP's[3] height in the ARA procedure)	20	30%
	Lacking resources for night flying (e.g., NDBs for platform identification)	8	12%
	Congested airspace	4	6%
	Legislation vacuum	5	7%
Organisational issues (23 pilots, 34%)	Commercial pressure	9	13%
	Corporate mindset (e.g., low understanding of the requirements for night operations)	8	12%
	Rosters (e.g., incompatible crew members)	7	10%
	Pressure for not going around	7	10%
	Flight programme (e.g., too many flights in a single day)	6	9%
	Reporting culture	2	3%
	Hiring standards	1	1%
	Learning culture	1	1%
	Ineffective unions	1	1%

Table 6 – Impacts on the crews flying night visual approach segments offshore, with the number and percentage of participants who commented on each impact category (from 67 interviewees)

Handling (50 pilots, 75%)	Speed control	41	61%
	Height control	33	49%
	Maintaining levelled after autopilot disengaged	9	13%
	Climbing up into bad weather	8	12%
	Performing the S turn after an offset instrument descent procedure	7	10%
	Overcontrolling	6	9%
	Overtorquing	1	1%
	Mistimed upset recovery	1	1%
Attentional resources (49 pilots, 73%)	Switching between visual and instrument scans	45	67%
	Double monitoring breakdown	12	18%
	Cognitive overload	11	16%
	Distractions	4	6%
	Fixation	2	3%
	Low awareness of surrounding environmental conditions	1	1%
Perception (42 pilots, 63%)	Visual illusions	28	42%
	Misidentification of the helideck	17	25%
	Impaired vision by excessive lighting	15	22%
	Seeing small rigs	8	12%
	Noticing own errors	5	7%
	Proprioceptive illusion	1	1%
	Vestibular illusions	1	1%
Decision-making (14 pilots, 21%)	Deciding at the missed approach point (MAP)	11	16%
	Going back to VMC when thrown into IMC	8	12%
	Accepting to do marginal tasks	1	1%
Crew cooperation (11 pilots, 16%)	Communication breakdown	11	16%

[3] MAP: the Missed Approach Point of instrument descent procedures.

DISCUSSION

Following the rationale for the development of the template, this discussion focuses on the findings across all interviews undertaken instead of on regional differences. This was also important to avoid drawing conclusions based on the low sample sizes of the Irish Sea and Norwegian North Sea projects. However, the significant differences in the number of Brazilian *versus* UK NNS' pilots commenting on the codes and categories were highlighted in the discussion.

<u>*Contextual factors (Table 5):*</u> the code mentioned by the largest number of participants was 'platform and surrounding' related factors, closely followed by sub-standard operating 'procedures', 'training', 'internal issues', and sub-optimal 'aircraft' resources. Fewer participants commented on the hazards related to the 'environment', 'regulator' and 'organisational issues'.

Among the categories grouped under the 'platform and surroundings' code, 'lack of depth and texture cues' was mentioned by the largest number of pilots. Despite being directly related to a poor visual environment upon arrival, it does not relate to the luminescence of the helideck in itself. Instead, it refers to the whole visual environment in the segment between the end of the instrument procedure and the landing on the helideck. This endorses the SOAP aspiration to make such a segment shorter than current practices, favouring the capture of visual cues closer to the offshore installations [28].

Concerns about the potential for collisions with obstacles at the installations (e.g., misplaced or unlit cranes, derricks, aerials and wires) were also mentioned by a large number of participants ('destination obstacles', 42%). This represents a different problem altogether as compared to CFIT/W cases suggested by the accident analysis presented at the beginning of this paper, deserving special attention from platform/ship operators and designers. The remainder of the categories were mentioned by comparatively few participants, suggesting that, based on the experiences of the sample investigated, these were issues of less relevance.

Regarding the code 'procedures', there seems to be considerable scope for improvements in what would in fact be low cost measures. Additionally, a significant association exists between the region of operation (Brazil *versus* UK NNS) and the number of commentators ($\chi^2(1)=4.560$, $p<.043$), with a significantly greater number of British pilots commenting on issues associated with substandard procedures. The reasons behind this difference requires further investigations, but it could be that the British pilots are simply more skeptical about their procedures than the Brazilian pilots, or that there is a cultural trait whereby (for example) the British feel greater need for structured and clearer operating procedures.

It is in the code 'training' that the category commented upon by the largest number of pilots lies ('currency of training', 67%). It highlights an important agreement among pilots from all scenarios in that the frequency with which they practice offshore night operations is too poor to ensure that the skills needed for the task are properly developed and maintained. This is an important challenge for the offshore helicopter industry, particularly for operators based in regions where night operations can only be undertaken during the winter. Investments in more advanced simulation technology should prove beneficial.

In relation to the code 'internal issues', conflicting information emerged from the interviews. Although 43% of the participants agreed that the lack of pilot 'experience' would affect safety during night operations, 13% understood that even the most experienced pilots would be vulnerable to accidents ('overall experience not a guarantee for success'). The reasons behind this deserve further investigations, as in fact the literature endorses both standpoints. It might be the case that, whilst experience favours the development of robust internal models for the approach task, it could at the same time excessively enhance self-confidence, affecting pilot decision-making towards more risk-taking attitudes. In any case, the accrual of experience should prove difficult as practicing opportunities are few.

Amidst the 'aircraft'-related factors, participants highlighted that automation levels might still be sub-standard for the task at hand ('automation limitations' category). This was caused by the minimum speeds required for the use of the upper modes of the auto-pilots. The greater they are, the further away from the installations the pilots have to switch to manual flight, suffering with the associated poorer visual references. In contrast, the longer the aircraft can be flown on automation, the fewer cognitive resources the pilots will use for the stabilisation and tracking tasks of flying, thus favouring the appreciation of the external environment for the assessment of the sufficiency of the visual cues in support of the manual approach task to come. Therefore, commercially viable auto-pilots with lower de-coupling speeds should bring great benefits. Other 'aircraft limitations' can be addressed at low cost (e.g., the quality of windscreen wipers and the installation of a second steering light in some models of aircraft).

The issues associated with the environmental conditions for task execution ('environment' code) seem less of a problem when compared to the previous codes, and they have mainly concentrated on 'illusive weather conditions'. This lower frequency of comments might be caused by the dependency of such conditions to atmospheric and sea states which do not happen frequently, such as steady water and misty air, for example. However, this assumption needs to be verified by real data.

The factors related to the regulatory framework ('regulator' code) were also mentioned less often by participants. Within this code though, a significant association between flying region and the number of participants who commented on the 'low limits' category was identified ($\chi^2(1)=16.739$, $p<.000$), meaning that a significantly greater number of NNS pilots were concerned about the meteorological minima to be abided by while following the prescribed night descent procedures. This seemed to be a reflex of the greater focus on ARA procedures in the North Sea, as opposed to the looser procedures based upon visual gates used in Brazil. Or, alternatively, that the British pilots have a greater tendency to fly all the way down to the procedural minima, whereas the Brazilians might avoid it. The reasons behind such differences would require further investigations.

Similarly, 'organisational issues' were mentioned infrequently by the participants. This could be that the pilots do not find them relevant for task execution, for example, or that, the stakeholders involved in offshore night operations have been doing a fairly good job. However, the authors acknowledge that this might in fact have been caused by the task-based approach chosen for the research, pointing to one of its limitations.

<u>*Impacts on the crews (Table 6):*</u> the literature shows that the hazard categories most frequently mentioned by the pilots ('speed control', 'height control', 'switching between visual and instrument scans' and 'visual illusions') are all well known problems identified in previous night accidents/incidents. Therefore, these findings confirm that offshore helicopter pilots are prone to similar problems as those faced by pilots flying other types of ships in impoverished visual conditions.

An interesting result though, relates to the low incidence of comments in the categories within the decision-making code. Although this contradicts the findings of recent accident studies (e.g. [40]), it apparently endorses the discussion over the treacherous nature of human decision-making mentioned above. Accident analyses have emphasised flawed pilot decision-making as a major cause to accidents in degraded visual environments. The literature, however, supports that, unless pilots are trained to understand their decision-making limitations in DVE, seldom do they realise that they are prone to making wrong decisions on such conditions. This seems to justify why pilots did not confess their potential flawed decisions so often, and therefore supports the ongoing efforts (e.g., that by the EHEST[40]) to enhance crews' awareness of the potential for decision-making impairment in DVE. With the benefit of hindsight, alternative routes might be chosen before impairment occurs, thereby avoiding accidents in nighttime operations.

CONCLUSIONS

Flying offshore helicopters at night is a complex task, as shown by the number of hazard categories developed. Especially, the codes of contextual factors listed in Table 5 have highlighted that safer night sorties require concerted efforts by the different stakeholders involved in offshore helicopter operations, that aims to improve the:

- visual environment in and around offshore installations;
- standard operating procedures in which tasks are based;
- training requirements for the pilots;
- internal states of the pilots;
- capabilities of the aircraft for the intended job;
- regulations concerning night operations;
- organisational support to the crews onboard the aircraft.

The template developed discriminates further such codes into categories, which should be used as a guide to the information collected, e.g. for normal operations and incident analysis.

In addition to this, the codes and categories within the 'impacts on crews' section of the template (Table 6) should indicate which overt and covert behaviours mean that safety is in jeopardy during operations, prompting the search for their causes. For example, whereas flawed height and speed control could be identified by the analysis of recorded flight data, the need for intense switching between visual and instrument scans whilst flying on a particular weather condition or towards an specific ship could be logged in standard debriefing sheets, helping the identification of combinations of contextual factors unfavourable to the human ability to fly at night.

It is the desire of the authors that the template can be further refined by operational use. This should assist more complex modelling of combinations of factors intrinsically riskier to flight operations. This would then be used for the early warning of impending problems to the flight crews, helping in accident prevention.

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