The Investigation Human-Computer Interaction on Multiple Remote Tower Operations

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Abstract. The aim of current research is to develop an effective human-computer interaction framework for multiple remote tower operations. Five subject-matter experts familiar with multiple remote tower operations and human performance participated in current research. The Hierarchical Task Analysis (HTA) method is used to break down activities, scenarios, and tasks into single separate operations. The step by step breakdown of multiple remote tower operations included ATCO's operational behaviors involving human-computer interaction such as interaction with EFS, OTW, RDP, and IDP during task performance were noted. Designing and managing human-computer interactions require an understanding of the principles of cognitive systems, allocation of functions and team adaptation between human operators and computer interactions. It is a holistic approach which considers distributed cognition coordination to rapidly changing situations. The human-centred design of multiple remote tower operations shall be based on a strategic, collaborative and automated concept of operations, as the associated high performance of remote tower systems in conflict detection and resolution has the potential to increase both airspace efficiency and the safety of aviation. The focus is on the human performance associated with new technology in the RTC and the supported tools used by an Air Traffic Control Officer, to ensure that these are used safely and efficiently to control aircraft both remotely and for multiple airports. The advanced technology did provide sufficient technical supports to one ATCO performing a task originally designed to be performed by several ATCOs, however, the application of this new technology also induced huge workload on the single ATCO.

Keywords: Multiple remote tower operations · Human computer interaction · Situation awareness · Workload

1 Introduction

The innovative concept of multiple remote tower operations is an evolution of the use of remote tower technologies and can maximize cost savings through the implementation of Remote Tower Operation (RTO). In recent years, Air Traffic Management has

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had to confront difficulties of infrastructure and airspace capacity which has resulted in aircraft delays. To address these concerns, the Single European Sky initiative, a European Union project, has been established up to improve safety, minimize costs and environmental impact, and at the same time increase efficiency and capacity in order to meet the requirements of expanding air traffic (Eurocontrol 2014). A novel solution of these issues is for a single air traffic controller (ATCO) to deliver control services to multiple airports from a single working position in appropriate traffic load circumstances. The multiple remote tower operation offers the potential of providing aerodrome control services for several small airports from a remotely-located control centre, without needing direct physical presence at the airports under control The aim of multiple remote tower operations is to deliver benefits in line with SESAR's high-level objectives, to increase ATCO's situation awareness, to create productivity for training, and to enhance contingency and reduce workload. Air traffic controllers must make rapid judgments of the situation that is being presented by their respective ATM systems, and then take appropriate decisions to ensure aviation safety. Interestingly research spanning from 1977 to 2008 has demonstrated that decision errors in aviation may be contributing to up to 60% of all aviation accidents (Jensen and Benel 1977; Buch and Diehl 1984; Diehl 1991; Li and Harris 2008).

The initial remote tower control of low traffic airports has emerged as a new paradigm to reduce the costs of air traffic control service provision. The application of advanced technology suggests that air traffic controllers can visually supervise airports from remote locations using videolinks to monitor many airports from a remote tower center (RTC). It is also clear that visual features of aircraft detection, recognition, and identification by RTO go beyond that required by regulators and air navigation service providers (ANSP's) (Furstenau et al. 2014). As the concept of RTC was being researched, it became clear that it would differ fundamentally from traditional modes of local tower operation. Cameras and sensors could be placed anywhere on the field, and ATCOs would be presented a virtual picture of reality, enhanced by a number of advanced technical devices such as panoramic digital reconstruction with high resolution pan-tilt zoom (PTZ), and electronic flight strip (EFS). The design and development of the human-computer interaction (HCI) for RTC can be supported by a formal cognitive work and task analysis. The results of this cognitive work and task analysis serve as input data for the simulation of the controller decision making processes at the controller working position (CWP). The anticipated outcomes of this project will develop a conceptual framework of HCI for multiple remote tower operations based on ATCO's cognitive processes and task performance.

2 Method

2.1 Participants

Five subject-matter experts participated in six focus group sessions. The subject matter experts ages ranged between 41 and 53 year old (M = 47.2, SD = 4.5); the working experience as qualified ATCO is between 13 and 25 years (M = 17, SD = 5.9).

2.2 Apparatus

The multiple remote tower research has included following equipment.

2.2.1 The Remote Tower Centre is equipped with 2 Remote Tower Modules comprising of 15 screens in each (14 active & 1 spare). Each of the modules is equipped with the SAAB Electronic Flight Strip (EFS) and Radar Data Processing (RDP) display which is used only as a distance to touch down indication and not to provide a Radar Service. Each of the modules accommodates 2 controller positions, Surface Movement Control (SMC) and Air Movement Control (AMC).

2.2.2 The SAAB Remote Tower camera system (Fig. 1) was installed at Shannon airport and Cork airport Remote Tower Sites. The Cameras are located at suitable positions to provide the exact same viewing aspect as the current Tower. The out the window (OTW) visualization is made up of 15 full HD displays in a 220° configuration. 14 displays are normally used to present the images from the 14 cameras, while the last display is a stand-by unit in the event of equipment failure. The displays match the camera resolution of 1920 × 1080 pixels, and have a refresh rate of 60 Hz.

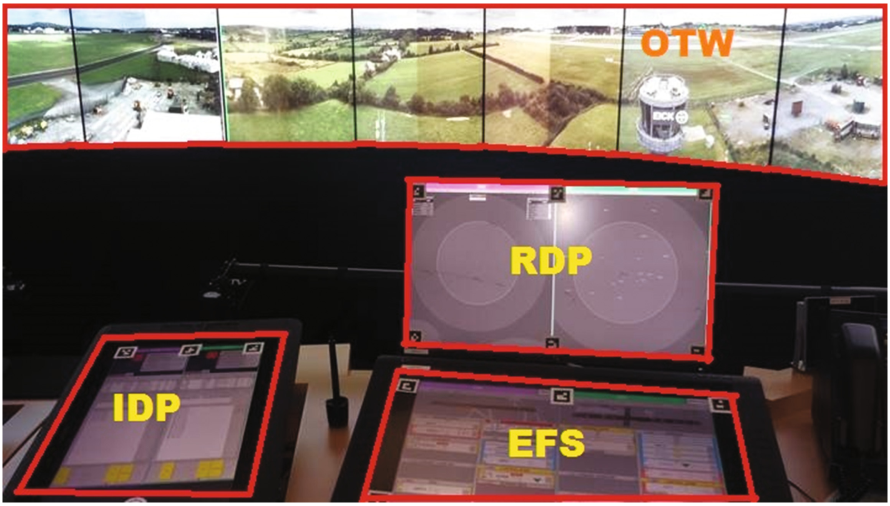

Fig. 1. The Module of multiple remote tower control centre comprised by Electronic Flight Strip (EFS), Out of the Window (OTW), Radar Data Processing (RDP), and Information Data Processing (IDP)

2.3 Scenario

One ATCO controlling a Boeing-737 landing at Shannon airport whilst controlling a Boeing-737 departing from Cork airport from a Remote Tower Centre situated 120 miles away at Dublin airport.

2.4 Data Collection Process

Five subject-matter experts familiar with multiple remote tower operations and human performance participated in current research. The Hierarchical Task Analysis (HTA) method was used to break down activities, scenarios, and tasks into single separate operations. This methodology enables a comprehensive step-by-step description of the task activities associated with the scenario described above (Annett 2004). The scenario of landing at Shannon airport and departing from Cork airport were broken down by 5 domain experts based on the principles of HTA for multiple remote tower operations. The step by step breakdown of multiple remote tower operations included ATCO's operational behavior involving human-computer interaction such as interactions with EFS, OTW, RDP, and IDP (Fig. 1) during task performance were noted. The dimensions of HCI on multiple remote tower operations including time to complete a task (sub-task and operational action), effort of cognitive workload, accuracy, and consistency were analyzed.

3 Results and Discussion

The application of HTA for analyzing the task of multiple remote tower operations was conducted at the remote tower control center, where the participants could practically use all the relevant systems and equipment to simulate task performance. This permitted an accurate assessment of the actions required and the cost of the effort and time required to complete the operational steps, such as checking the RDP to estimate the distance and timing of arrival flight, monitoring moving aircraft/vehicles on the runway by OTW, or input information into EFS. The objective was to understand the limitations of human-computer interaction on multiple remote tower operations, as a crucial first step in the certification process for multiple remote tower operations in future air traffic management.

3.1 Scope of the Task Under Analysis

The remote tower services were demonstrated in sequence for both Shannon and Cork airports during periods of low traffic density. The application of OTW visualization reinforced by RDP and EFS technology and the existing data and communications network will provide the necessary technical supports for the provision of air traffic services remotely and without any degradation to the standard of ATS provided. Safety management processes and procedures were applied to ensure that levels of safety were at least equal to those which are provided by the local control towers at both airports. The scope of task under analysis is 'one ATCO safely directing a Boeing-737 landing on Shannon airport whilst controlling a Boeing-737 departing from Cork airport from a remote tower center situated at Dublin airport'.

3.2 Data Collection Process

Data regarding the goals, standard operation procedures (SOPs), task steps involved the analysis of the technology used, human-computer interaction, teamwork, and task constraints related to a simultaneous landing at Shannon airport and departure from Cork airport were collected by 3 focus group sessions in the RTC at Dublin airport. HTA development commenced once sufficient data regarding required task performance was collected. The main focus of this data collection was on the cognitive process of ATCO's controlling aircraft landing and departing from two different airports, a critical concern related to a new configuration where one ATCO is performing a task previously designed to be done by six ATCOs', and the solution of dealing with the associated potential risks.

3.3 Define the Overall Goal

The single overarching goal is maintenance of the safety level of air traffic services without any degradation whilst a single ATCO controls two aircraft landing and departing from two different airports using new technology. It is a novel Air Traffic Control challenge for one ATCO performing two different air traffic control tasks for two aircraft at two different airports. SOPs for ATCO controlling aircraft landing and departing are considerably different. Task analysis methodologies have been defined by (Kirwan and Ainsworth 1992) as the analysis of actions and cognitive processes carried out by an operator (or a team of subjects) to reach the objectives of a specific system. The application of relevant systems along with step-by-step operational actions makes HTA particularly useful for the evaluation of task performance in response to overall goal achievement.

3.4 Determine Task Sub-goals

HTA enables a comprehensive step-by-step description of the task activity under consideration to be achieved, and has become the most extensively used of all the Human Factors methodologies available (Annett 2004; Stanton 2006; Stanton et al. 2013). The flexibility and practicality associated with the HTA technique has seen it applied in a diverse range of domains. Despite the comprehensive insight provided by the HTA methodology, the HTA output will only provide descriptive information – rather than analytical data – for the task under analysis. Consequently, the description presented by the task analysis is typically the input to additional methodologies for further analysis, such as the Human Error Identification (HEI) technique (Stanton et al. 2010). Notwithstanding the importance of the calls and visual controls which contribute to a shared mental picture of the situation between operators such as pilots, ATCOs, ground vehicle drivers and rescue teams, it was decided to give the controllers a specific version of the diagram with these steps to complete the task by interacting with the system. The sub-goals include co-ordination calls from all stakeholders, monitoring all moving vehicles/aircraft between two airports, providing line up/take off instruction, and establishing communication (such as handover to the next ATS sector and parking stand information. The subject-matter experts raised a safety concern regarding the time interval for task performance, as ATCO's will be under time pressure constantly not only due to shifting attention between two airports for many moving targets (aircraft, vehicles, birds), but they must also make decisions providing control instructions for air/surface movement control (Fig. 2). Sufficient time to complete a sub-goal is a critical safety issue of HCI with multiple remote tower operations, as it influences the efficiency of interface design, time pressure and perceived workload.

3.5 Sub-goal Decomposition

Task decomposition is a structured way of developing sub-goals into a series of detailed descriptions relating to each operational step (Stanton et al. 2008). Task decomposition involves the breakdown of a task description that explains how each step of the task is performed and the time needed for completing the task. Adding the time to complete each operational step is critical to identifying potential risk related to human performance, as there are some prioritized issues for task performance between two airports and two different tasks, landing and departing. Available time is always critical for flight operations. This allows the total information for each operational step to be decomposed into a series of statements describing the tasks of multiple remote tower operations. The sub-heading used to decompose the task steps should be chosen by the analyst based on the requirements of the analysis. The bottom level of HTA should always be an operational step and specify what action needs to be taken. For example, the task decomposition of (1.3) First contact from EINN Arrival (20 s to complete the task) can be breakdown as (1.3.1) Acknowledge call and reply (8 s); (1.3.2) Assume FLT strip for aircraft (2 s); (1.3.3) Make cross check on EICK by OTW (2 s); (1.3.4) Cross check position on RDP (2 s); (1.3.5) Utilize OTW picture to identify aircraft on approach (3 s); (1.3.6) Scan predicted aircraft track using PTZ on OTW (3 s). To maintain ATCO's situation awareness, it is not only necessary to shift attention between Shannon and Cork constantly by performing interlude sub-task (1.1, 1.3, 1.5, 1.7, 1.9 & 1.11 for Shannon, and 1.2, 1.4, 1.6, 1.8 & 1.10 for Cork), but the ATCO is also required to conduct a cross check for each sub-goal decomposition (green operational steps on Shannon, such as 1.1.3, 1.3.3 & 1.5.4; and red operational steps on Cork, such as 1.2.4, 1.4.5 & 1.6.5) (Fig. 2). The agreement among subject-matter experts was that task description should provide enough information to determine exactly what has to be done to complete each task element safely by increasing ATCO's situation awareness for air movements and surface movements at each airport.

3.6 Plans Analysis

Once all of the sub-goals and operational steps have been fully described, plans need to be added. The plans of current HTA 'one ATCO safely directing a Boeing-737 landing at Shannon airport while controlling a Boeing-737 departing from Cork airport from a

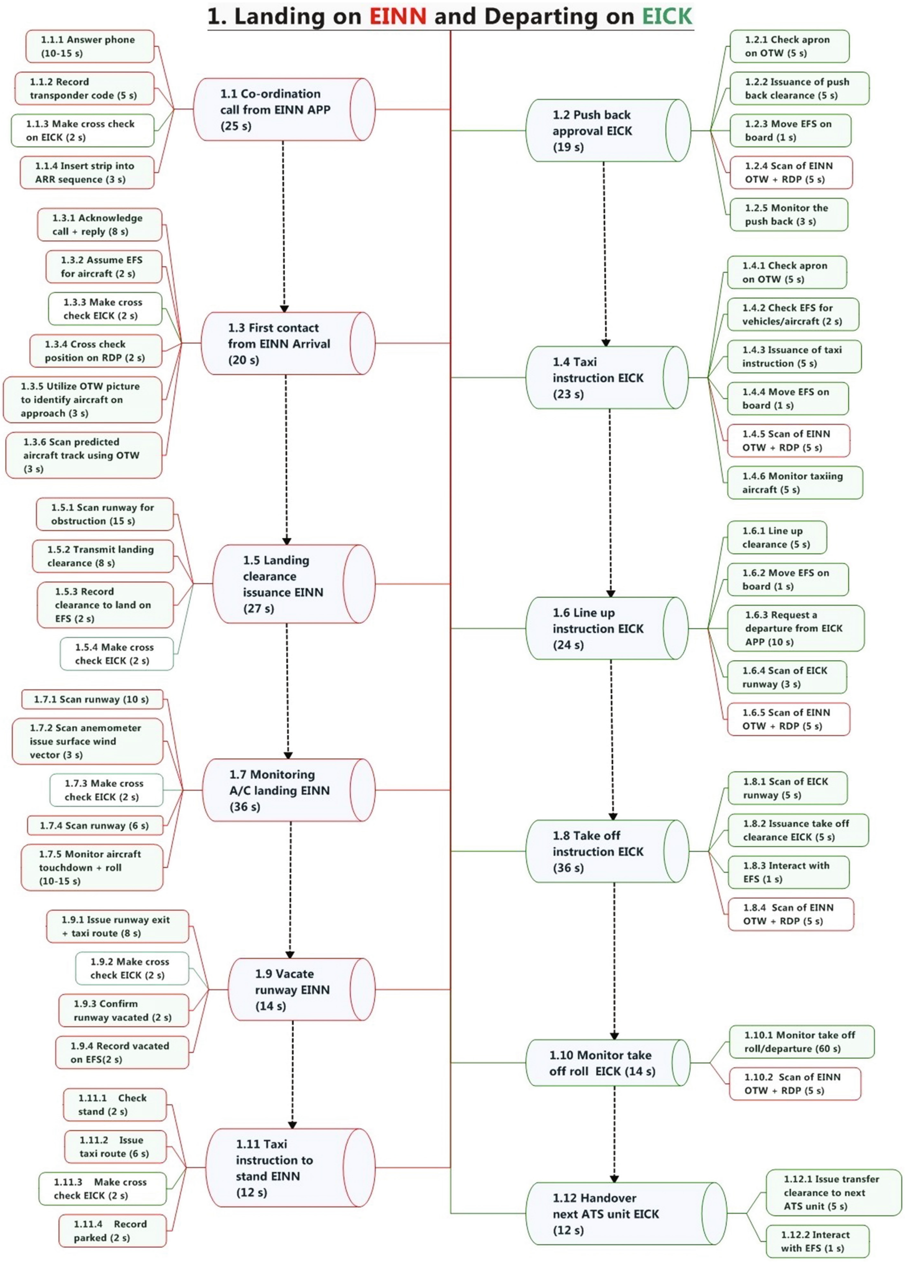

Fig. 2. The HTA of multiple remote tower operation for one ATCO commanding two B-737 land on Shannon and departing on Cork (Color figure online)

remote tower center situated in Dublin airport' is linear, for example do 1 (1.1, 1.2, 1.3…) then 2 (2.1, 2.2, 2.3…) then 3 (3.1, 3.2, 3.3…). Despite the use of the term landing and departing used to describe the scenario, there is always a prioritization in human being's cognitive process and decision-making involved in the task performance. Human operators are simply just not able to speak to two different people. Nor are they able to listen to two different flight crews describe their problems and provide suitable solutions by radio transmission to these flight crews. The linear sequence is an important application in HTA, and occasionally the linear sequence must be sufficiently flexible to manage critical urgent situations, such as an intervention in the case of an unexpected event such as a runway incursion.

4 Conclusion

HTA was originally developed in response to the need to understand cognitive tasks, it achieves this by describing the activities under analysis in terms of a hierarchy of goals, sub-goals, operations and plans. Further development of HTA involves the application of numerous other human factors analysis methods including human error identification function allocation, workload assessment, interface design, and training (Stanton et al. 2013). Designing and managing human-computer interactions require an understanding of the principles of cognitive systems, allocation of functions and team adaptation between human operators and computer interactions. It should be a holistic approach considering how distributed cognition coordination in rapidly changing situations can be safely achieved. The human-centred design of multiple remote tower operations shall be based on a strategic, collaborative and automated concept of operations, as the associated high performance of remote tower systems in conflict detection and resolution has the potential to increase both airspace efficiency and the safety of aviation (Schuster and Ochieng 2014). The focus is on the human performance associated with new technology in the RTC supported tools used by an Air Traffic Control Officer, and ensuring that these are used safely and efficiently to control aircraft both remotely and for multiple airports. The advanced technology did provide sufficient technical supports to one ATCO performing a task originally designed to be performed by several ATCOs, however, the application of this new technology also induced huge workload one the ATCO. This creates a need for further research on how to deal with the HCI issues identified, including high workload for multiple remote tower operations in the future.

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