A Systematic Literature Review on Decision-Making Processes among Air Traffic Controllers (ATCOs) in Managing the Arrival of the Aircrafts during Conflict Resolution

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Abstract
The number of flights has started to increase as economy has started to recover slowly in which it has greatly affected due to the pandemic of COVID-19. To ensure the safety and efficiency in aviation industry, Air Traffic Controllers (ATCOs) hold great responsibilities in ensuring the minimum separation between the aircrafts. Therefore, the researcher conducts a systematic literature review of previous related studies on decision-making among the ATCOs from the year 2000 to 2022. The main aim of this paper is to present the analysis of findings from previous related studies on decision-making among the ATCOs based on the formulated questions. The main findings of the 22 articles which have been reviewed and analyzed have been discussed and were being displayed in tables in the discussion section. Findings of this review indicated that it is crucial for the ATCOs to ensure minimum separation between the aircrafts while making a quick decision and at the same time to make sure the safety aspect in the aviation industry.
Keywords: Decision-Making, Air Traffic Controllers, Arrival of Aircrafts, Conflict Resolution, Systematic Literature Review

Introduction
People are now returning to work and starting to travel to various places and for various purposes either for working purpose or for vacation. Working as ATCOs required them to make decision in a very dynamic environment which might be very challenging task for them. Decision-making varies in various fields such as in management, accounting, psychology, education and in aviation industry. In the aviation industry, the ATCOs need to plan their strategies wisely and communicate with each other as well as with the pilots, technical staff and the management. This research is focusing on decision-making processes by the ATCOs while they are managing the arrival of the aircrafts especially during conflict resolution. According to D'Arcy and Rocco (2001, p. 1), ATCOs often need to make tough decision but with very limited information, under time pressure as well as in high workload situation. This

is supported by Furuta et al (2009, p. 764) who mentioned that in Naturalistic Decision-Making (NDM), recognition of situation directly leads to decision-making without the need to compare many other options for decision-making purpose. ATCOs shall not cause any delay to the flights and need to decide wisely without having much time to consider other options regardless of the situation. However, they need to prepare several backup plans in case of any emergency or maybe their first decision is impossible to be done. One of the factors that can influence the way the ATCOs make decision is their thinking style. This is supported by research conducted by E and Zhang (2017) which found that the ATCOs who think more holistically will have higher possibility to make interventions.

As stated in Tharikh et al (2021), Air Traffic Management (ATM) sector is the biggest sector in the Civil Aviation Authority of Malaysia (CAAM) and the major role of the ATCOs is to control the movement of the aircraft while take-off and landing. It can be identified that based on the systematic literature review, most of the previous studies focused on specific types of ATCOs. In CAAM, there are three main types of ATCOs namely area controllers, approach controllers and aerodrome controllers. Each type of ATCOs have their own roles and responsibilities. Area controllers are based at the control centres and their main role is to direct the aircraft and decide the most efficient route for the aircraft. Approach controllers are also based at the control centres but their main role while managing the arrival of aircrafts is to determine the sequence of the aircrafts as they are approaching the airport. Last but not least, aerodrome controllers are based at the control tower and they are responsible in managing the movement of the aircrafts on the ground specifically (Civil Aviation Authority of Malaysia, n.d.). From the perspective of categories of air traffic controllers ratings in Malaysia, there are six categories. These include aerodrome controller rating, approach control procedural rating, approach control surveillance rating, approach precision radar control rating, area control procedural rating and area control surveillance rating (Civil Aviation Authority of Malaysia, 2022). As stated in the official website, some of the criteria required to become an Air Traffic Controller include having excellent communication skills, able to work under pressure, able to make fast and decisive decisions and should be able to be a team player (Civil Aviation Authority of Malaysia, n.d.).

There were several real incidents took place that has shown the importance of decision-making by the ATCOs in managing the arrival as well as departure of the aircrafts. One of the incidents took place was reported by Loh (2022) in which ITA Airways A330 continued its flight to Rome after striking an Air France 777 while taxiing for departure. Apart from that, there were two incidents took place in Malaysia Airlines which involved MH370 and MH17 (Hassan, 2022; Lewin, 2022).

Research Objectives
The extensive systematic literature review try to identify several research objectives as below:
  i.   To explore on the processes of decision-making among the ATCOs especially for Naturalistic Decision Making (NDM)
 ii.   To examine the effect of workload among the ATCOs on their job performance
iii.   To identify the related issues and challenges based on past related researches on decision-making processes among the ATCOs
 iv.   To identify the coping strategies implemented by the ATCOs in decision-making process while managing the air traffic

Research Questions

i. What are the the processes of decision-making among the ATCOs especially for Naturalistic Decision Making (NDM)?

ii. What are the effect of workload among the ATCOs on their job performance?

iii. What are the related issues in decision-making process among ATCOs in managing the arrival of aircrafts during conflict resolution?

iv. What are the coping strategies implemented by the ATCOs in decision-making process while managing the air traffic?

Literature Review

Decision-Making among the Air Traffic Controllers (ATCOs)

Decision-making is basically a process of choosing one option based on the alternatives available (Robbins & Coulter, 2014, p. 188). Empirically, most of the past related studies conducted overseas were focusing on NDM (Bonaceto et al., 2005; Corver & Grote, 2016; Furuta et al., 2009). Other than that, there was research done towards decision-making and planning among the Air Traffic Control Specialists as well as the related cognitive processes which include learning, memory and situation awareness (D'Arcy & Rocco, 2001). Based on the study, ATCOs are more careful to make decision in tough situation such as during conflict resolution. In Malaysia, there were a few related studies that has been carried out. One of the most recent studies was conducted by Tharikh et al (2021) which investigated on the self-efficacy of the ATCOs towards their wellbeing. A similar study was conducted which aimed to examine the wellbeing of the ATCOs by implementing the Wellbeing Theory (WBT) (Tharikh & Hamzah, 2020).

Generalized ATC Process Model

Generalized ATC Process Model which was presented by Histon et al. (2014, p. 2) analyzed the Cognitive Complexity of ATCOs. According to this model, the ATCOs gain surveillance information on the condition of air traffic before processing the information to commands and there are four observation channels which are subjective responses of controllers, system state measurements, communication analysis of controllers and codified structure. In addition, the decision-making process as stated in this model include the process of monitoring, evaluating and planning.
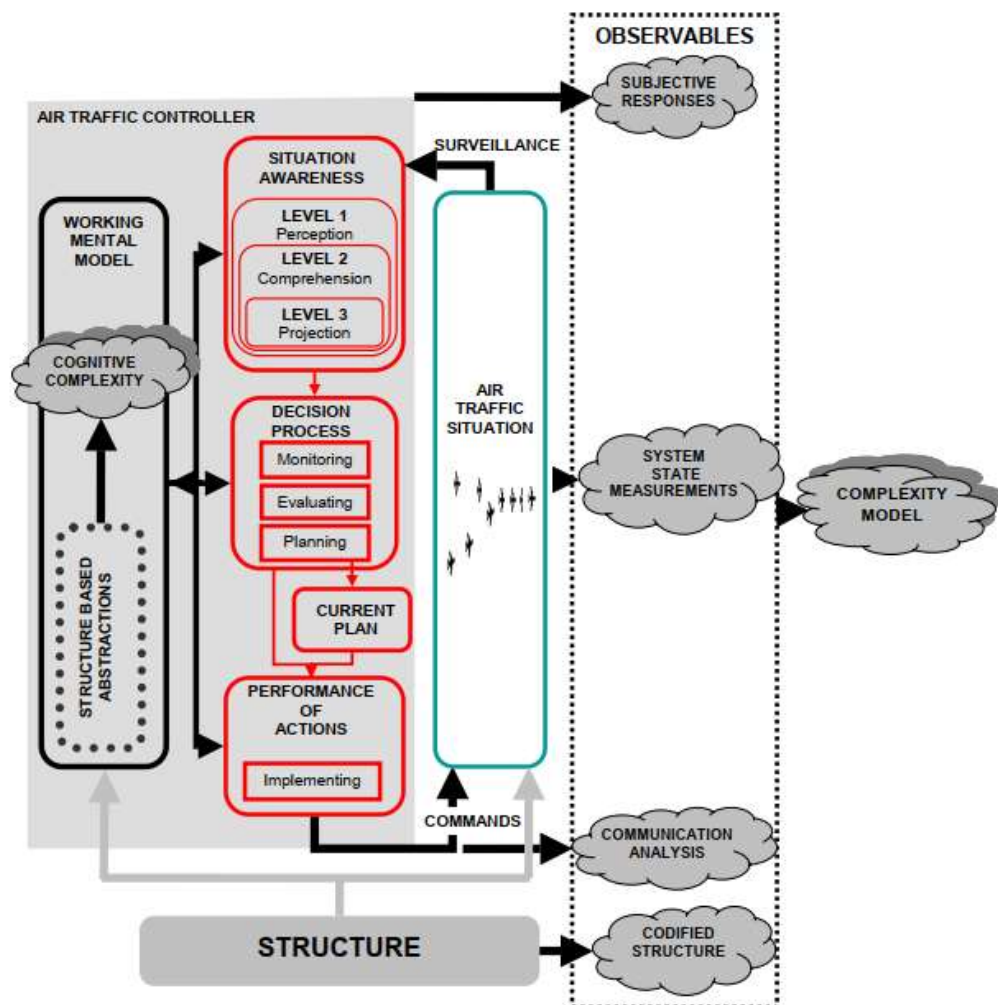
Figure 1 Observability Channels of the ATC System

Methods

This systematic literature review was performed using five steps as introduced by Khan, Kunz, Kleiznen and Antes (Khan et al., 2003). In relations with that, the searched articles were done using search engine such as Google Scholar and the searches include English articles published from the year 2000 to 2022. Plus, there were some keywords used in searching for the related articles. Then, the researcher done the screening by looking at the related title as well as the abstract of each article. At the end, there are 22 articles selected based on the criteria mentioned above to be included in the systematic literature review. The five steps of Systematic Literature Review according to Khan et al (2003) are shown in Figure 1.
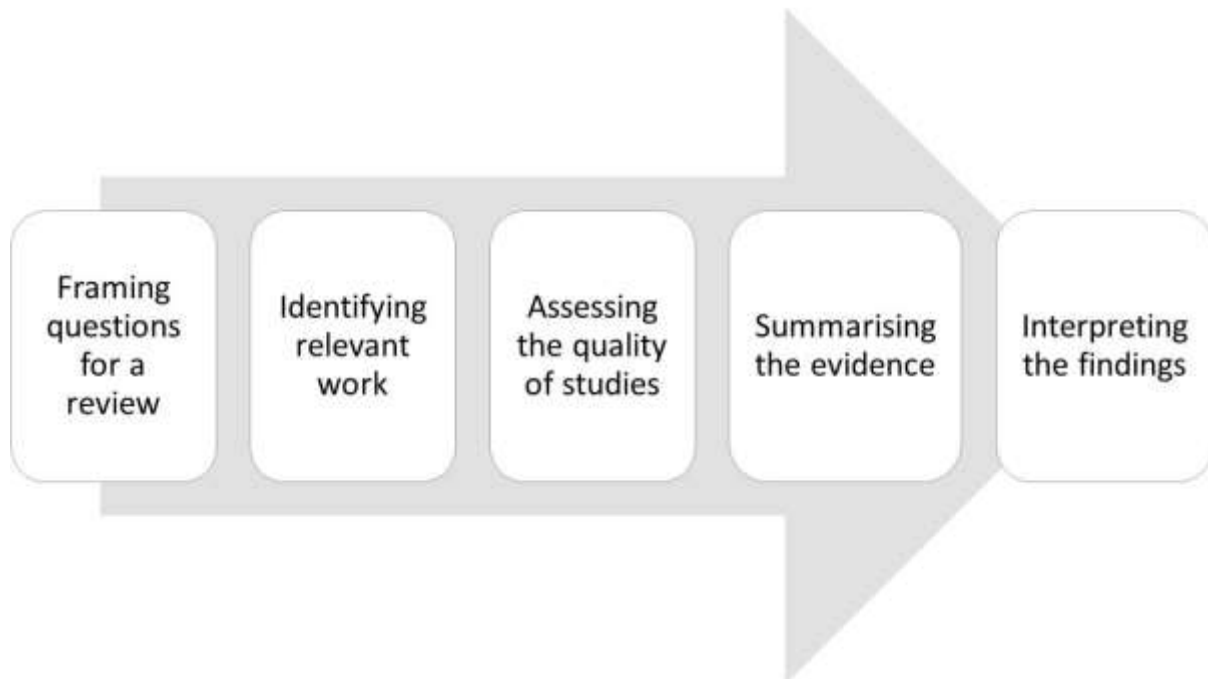
Figure 2 Five Steps of Systematic Literature Review (Khan et al., 2003).

Step 1: Framing the question
To begin this systematic literature review, the researcher must establish related research questions in order to address the research objectives accordingly. ATCOs involve in decision-making while managing the arrival of aircrafts. They are required to make decision by considering the minimum separation standard between the aircrafts. Thus, the related research questions are: i) What are the decision-making processes among the ATCOs in managing the arrival of aircrafts during conflict resolution especially in bad weather condition? ii) What are the workloads faced by ATCOs in decision-making while managing the arrival of aircrafts? iii) What are the related issues in decision-making process among ATCOs in managing the arrival of the aircrafts during conflict resolution? iv) What are the coping strategies by ATCOs in decision-making process while managing the arrival of aircrafts during conflict resolution?

Step 2: Identifying Relevant Publications
The second step in this review is to find out relevant articles. First of all, the researcher has to gather all the previous related studies. Then, the researcher will have to select the most related articles according to the inclusion as well as exclusion characteristics that have been set out. Other than that, types of articles in the searches process have been limited to the full-text articles as well as journal articles.

Step 3: Assessing Studies Quality
To assess the quality of the studies is the next step in conducting the systematic literature review. In this step, the researcher must state explicitly the inclusion characteristics in order to determine which article to be include or exclude for the purpose of this review. This is crucial to make sure that only articles who fulfill these characteristics will be selected in this review. The characteristics of the articles chosen are as follows:

i.   Decision-making practices among ATCOs and factors affecting
ii.   ATC cognitive process
iii. Conflict resolution among the ATCOS
iv.   Workload faced by the ATCOs
v.   English written articles
vi.   Articles published since the year 2000 to 2022

Step 4: Summarizing the Evidences
 The researcher search for the related articles from search engine such as Google Scholar and applied several keywords which include "decision-making among the Air Traffic Controllers in managing the arrival of the aircrafts" and "decision-making among the Air Traffic Controllers during conflict resolution".

Step 5: Interpreting the Findings
Last but not least, the researcher needs to interpret the results by analyzing the content. There are only 22 articles selected for this review that match the criteria being set up. Based on the findings of the related articles, the informants involved were from various types of ATCOs such as approach controllers, area controllers and aerodrome controllers. The results of the past related studies based on the selected articles for this systematic literature review are summarized in Table 1.

Table 1
Summaries on Findings of Previous Related Studies

No.	Author(s)	Year	Title	Findings
1.	Sohel M. Imroz, Farhan Sadique and Nidhi Trambadia	2022	An Analysis of Air Traffic Controllers' Job Satisfaction	Identifies the most critical factors for future researchers to improve ATCs' job satisfaction
2.	Shafazawana Mohamed Tharikh, Siti Raba'ah Hamzah, Nasrudin Baidi and Jegatheesan Rajadurai	2021	Self-Efficacy Beliefs in Air Traffic Management Setting	ATCOs with high self-efficacy will have the tendency to be more determined in performing their tasks.
3.	Yanjun Wang, Liwei Wang, Siyuan Lin, Wei Cong, Jianfei Xue and Washington Ochieng	2021	Effect of Working Experience on Air Traffic Controller Eye Movement	Working experience has significant effect on controllers' eye movement behavior
4.	Samrudhi Mohdiwale, Mridu Sahu, G. R. Sinha and Varun Bajaj	2020	Automated Cognitive Workload Assessment Using Logical Teaching Learning-Based	1. The PROMETHEE method suggested that the Logical TLBO is best among all the other compared approaches. 2. This paper presents an automated model for cognitive workload assessment to

			Optimization and PROMETHEE Multi-Criteria Decision Making Approach	provide accurate categorization on intensity of workload induced by multitasking situations
5.	Ahmad Nabil Saroni, Muhammad Asraf Abd Samad, and Jamaludin Ibrahim	2019	The Case Study of Emergency Response Plan (ERP) Implementation During The Malaysia Airlines (Mas) Flight Mh370 Disappearance	There are several loopholes identified that have prompted the ineffectiveness of the ERP implementation
6.	Sakiko Ogawa, Taro Kanno, Kazuo Furuta	2019	Modelling and Simulation of Cognitive Processes In Air-Traffic Control Based on Mutual Beliefs	1. Cognitive processes involved in ground control communications between ATCOs and pilots is operationalized with three layers of mutual beliefs 2. Ground control operations are simulated using an agent-based cognitive model that incorporates this three-layer structure 3. Team cognition processes (ATCOs & pilots) are replicated using the simulation. 4. Simulation provided various possible cognitive processes that explain the behavior leading up to the accident.
7.	Kouroush Jenab and Joseph Pineau	2018	Automation of Air Traffic Management Using Fuzzy Logic Algorithm to Integrate Unmanned Aerial Systems into the National Airspace	Theory of Fuzzy Logic
8.	Mohamad Fuad Sidik, Siti Mariam Binti Abdul Rahman and Wan Mazlina Wan Mohamed	2017	Evaluation of Controller Strategies in Air Traffic Management for	1. The most prominent issue was on delays 2. Minimum differences between FPL and XFL can be achieved by pre-planning the traffic prior to ETD

			KLFIR Oceanic Sector	
9.	Xiaotian E and Jingyu Zhang	2017	Holistic Thinking and Air Traffic Controllers' Decision Making in Conflict Resolution	1. Specifically, controllers were more likely to make interventions when the minimum distance decreased. 2. Controllers who think more holistically tend to maintain a higher level of risk perception which drops slowly when actual risks start to decrease
10.	F Nusyirwan and J Mohd Rohani	2017	Study of Air Traffic over KLFIR	1. Managed to collect information related to air traffic movement 2. Long-term analysis on the air traffic performance in Malaysia,
11.	Sifra Corver and Gudela Grote	2016	Uncertainty Management in Enroute Air Traffic Control: A Field Study Exploring Controller Strategies and Requirements For Automation	1. The purpose of this study was to identify the sources of uncertainty occurring in enroute air traffic control, and the strategies that controllers adopt to respond to these sources of uncertainty. 2. Controllers also preferred to increase uncertainty, in order to increase the flexibility of operations, and described new underlying tactics. Theory: Naturalistic decision-making
12.	Nizamuddin Zainuddin, Dayang Shalbia Abdul Ghani and Adam Mohd Saifudin	2015	Multi Criteria Decision Making: A Case of Locating Low Cost Carrier Terminal (Air) In Malaysia	AHP facilitates decision making in a shorter period of time - decision makers were more able to analyze complex problem in making multi criteria decision
13.	Jingyu Zhang, Jinrui Ren and Changxu Wu	2014	Modeling Air Traffic Controllers' Decision Making Processes with Relational Complexity Network	1. RCN properties are related to the occurrence of omission and commission errors of ATCOs. 2. ATCOs do not always choose those highly centered aircraft to intervene in the first place. 3. Those high in Network Sensitivity (NetSen) have a relative longer reaction time in average, but showed a faster response when the RCN is centralized as compared to those with lower NetSen. Theory: Relational Complexity Network (RCN) framework

14.	Daisuke Karikawa, Hisae Aoyama, Makoto Takahashi, Kazuo Furuta, Akira Ishibashi, Masaharu Kitamura	2014	Analysis of The Performance Characteristics of Controllers' Strategies In En Route Air Traffic Control Tasks	1. There were 2 strategies used (A & B) 2. According to the instructor, strategy A is more efficient even though it has higher potential safety risk. 3. The analysis results using COMPASi are similar to the results given by instructor, thus proves the validity of COMPASi - workload * COMPASi can be used to analyze control strategies for further complex and high-density traffic situations.
15.	Marian J. Schuver-van Blanken, Hans Huisman and Mariska I. Roerdink	2010	The ATC Cognitive Process & Operational Situation Model	1. The model provides a clear framework for analysis in depicting how cognitive complexity is influenced by factors in the operational situation.
16.	Kazuo Furuta, Yusuke Soraji, Taro Kanno, Hisae Aoyama, Daisuke Karikawa and Makoto Takahashi	2009	Analysis of Team Communication and Collaboration in En-Route Air Traffic Control	1. A cognitive model of an ATC team has been established Theory: Naturalistic Decision Making
17.	Andrew Neal	2008	The Effect of Workload on Conflict Decision Making in Air Traffic Control	Controllers became more conservative in high workload and avoided monitoring strategies
18.	Andrea Lecchini Visintini, William Glover, John Lygeros, Jan Maciejowski	2006	Monte Carlo Optimization for Conflict Resolution in Air Traffic Control	There is a framework for conflict resolution
19.	Craig Bonaceto, Steven Estes, Peter Moertl and Kevin Burns	2005	Naturalistic Decision Making in the Air Traffic Control Tower: Combining Approaches to Support Changes in Procedures	1. Workload and task completion time are important aspects of controller performance, cognitive modelling as a suitable approach. Theory: Cognitive Task Analysis (CTA), coordination framework, Naturalistic Decision Making

20.	Sylvie Athènes, Philippe Averty, Stephane Puechmore, Daniel Delahaye and Christian Collet	2002	ATC Complexity and Controller Workload: Trying to Bridge the Gap	It is possible to calculate parameter to bridge the gap between these two variables (ATC complexity and workload) using Traffic Load index (TLI) with Autonomic Nervous System (ANS) recording
21.	Jean-François D'Arcy and Pamela S. Della Rocco	2001	Air Traffic Control Specialist Decision Making and Strategic Planning – A Field Survey	This study investigated the perspective of Air Traffic Control Specialists regarding decision making and planning as well as related cognitive processes such as learning, memory, and situation awareness
22.	Philip Nuli Anding and Peter Songan	2000	Cognitive Modelling as a Systematic Approach for Designing Training Programs in Air Traffic Control	1. There are two main tasks in approach ATC are managing aircraft arrival and departure 2. Cognitive model is developed

Findings and Discussions

This section describes the decision-making processes among the ATCOs in managing the arrival of aircrafts during conflict resolution especially in bad weather condition (RQ1) and then explores the workloads faced by them in decision-making while managing the arrival of aircrafts (RQ2). This section also presents the related issues (RQ3) and the coping strategies in decision-making process among ATCOs in managing the arrival of the aircrafts during conflict resolution (RQ4).

Research Objective 1: To explore on the processes of decision-making among the ATCOs especially for Naturalistic Decision Making (NDM)

According to Klein (2008, p. 456), NDM would assist people in generating productive decision by categorizing the circumstance. It has existed since 1980s and it is used in explaining the process of decision-making in the real-world situation. NDM approach has greatly contributed in the explanation of how individual actually involves in decision-making in the real-world scenario. Previous related studies have proved the application of NDM theory when they integrate NDM in investigating the process of decision-making among the ATCOs.

The findings from systematic literature review showed that most studies focused on Naturalistic Decision Making (NDM) theories while analyzing the decision-making among the ATCOs. Corver and Grote (2016) studied on the uncertainty management in controlling the air traffic situation and thus, the strategies as well as the requirements for automation support. The study concerned on the ability of automation support to integrate naturalistic decision-making models among the ATCOs. On top of that, Furuta et al (2009) recommended that NDM model can be applied to the distributed cognitive process in team collaboration among the ATCOs. There was another related research conducted which aimed to develop NDM methodology which will help the ATCOs during simulation exercises (Bonaceto et al., 2005). Based on the systematic literature review, most of the previous studies explored on

decision-making processes among specific targeted type of ATCOs. For example, study done by Bonaceto et al (2005) focused on decision-making among Air Traffic Control Tower (ATCT) or also known as aerodrome controllers. Another study was conducted by Anding and Songan (2000) which targeted on approach controllers only in establishing cognitive modelling to design training programs in air traffic control.

Research Objective 2: To examine the effect of workload among the ATCOs on their job performance

In addition, based on the findings of studies as analyzed in the systematic literature review, the researchers highlighted on the issues of workload among the ATCOs and their job satisfaction. For example, Mohdiwale et al (2020, p. 13630) stated that Cognitive Workload (CW) assessment can be used to keep track of the ATCOs state of mind. Workload is an important element which can contribute to job satisfaction of the ATCOs. This is supported by a study conducted by Imroz et al (2022, p. 8) that has identified overwhelming workload as one of the factors. Plus, a research conducted to study the relationship between ATC complexity and workload shown that there is significance increased psychological responsiveness when the workload increase (Athènes, et al., 2002). Hence, this study need to be conducted in order to identify the types of workload faced by the ATCOs and how to manage the workload efficiently.

Research Objective 3: To identify the related issues and challenges based on past related researches on decision-making processes among the ATCOs

Most of the past related studies were conducted overseas such as in China and Japan (Karikawa et al., 2014; Wang et al., 2021; Zhang et al., 2014). For instance, Zhang et al. (2014) explored on the decision-making processes among the trainee controllers in Civil Aviation Flight University of China meanwhile Karikawa et al (2014) analyzed the performance features of ATCOs' strategies in Japan. Another research done in China was done by Wang et al (2021) which was to investigate on the factors of eye movement in decision-making among the ATCOs. There were several studies conducted in Malaysia context however, the studies put less emphasized on decision-making process among the ATCOs compared to researches conducted overseas (Anding & Songan, 2000; Nusyirwan & Rohani, 2017; Saroni et al., 2019; Sidik et al., 2017; Tharikh et al., 2021; Zainuddin et al., 2015). Other than that, there was research found out that the ATCOs holistic thinking style affects the way they make decision during conflict resolution in which ATCOs who will make interventions are ATCOs who think more holistically (E & Zhang, 2017). Thus, thinking style of the ATCOs is influencing the intervention decision-making of the ATCOs. The most crucial decision-making by the ATCOs is any decision related to maintaining the separation standards between the aircrafts. In aviation industry, this is known as conflict resolution. It is the process in which the ATCOs would ensure that there is minimum separation standard between the aircrafts (Visintini et al., 2006).

Research Objective 4: To identify the coping strategies implemented by the ATCOs in decision-making process while managing the air traffic

Monte Carlo (MC) methods was introduced to manage air traffic conflict resolution (Visintini et al., 2006). According to Visintini et al (2006, p. 470), conflict resolution is the process applied by the ATCOs in order to ensure the separation standard between the aircrafts.

Besides, one of the selected articles in this systematic literature review analyzed the perspectives of Air Traffic Control Specialists towards decision-making and planning and related cognitive processes (D'Arcy & Rocco, 2001). The results of the study proved that ATCOs are more conservative while in difficult circumstances.

Conclusion

In conclusion, this paper presented the systematic literature review on the decision-making among ATCOs in managing the arrival of the aircrafts. There are 22 articles being chosen and have been analyzed in this review. Based on the discussions above, there are many types of ATCOs. Thus, this research will include each type of ATCOs as the informants to study their decision-making processes as well as their workload. Workload is one of the critical factors in determining the performance of the ATCOs in decision-making as stated by (Imroz et al., 2022). The researcher also found out that thinking style of the ATCOs also influence the way they make decision as mentioned in E and Zhang (2017). Plus, the literature review showed that the studies on decision-making among ATCOs in Malaysia is still lacking and there is a need to explore this field deeply and thus to understand their importance roles in ensuring the safety of the aircraft as well as the passengers. Other than that, this systematic literature review has shown that the ATCOs are practicing Naturalistic Decision Making (NDM) as supported by several past related studies. In fact, this systematic literature review will provide reference for future researchers to conduct related studies among the ATCOs. The researcher believes that this research will contribute to the body of knowledge, policy maker, HR practitioner as well as in terms of methodological aspect.

Theoretical and Contextual Contribution

Each research conducted has their own significant contributions in terms of theoretical aspect and contextual aspect. From theoretical aspect, this research will expand the knowledge on decision-making processes among the ATCOs in managing the aircrafts during conflict resolution and can be applied in other related situation by considering any benefits and boundaries of the processes. On top of that, this research shall contribute to the policy development which in turn would offer guidelines for any necessary amendments to the existing policy. The contribution of this research is also towards the effectiveness and the efficiency of decision-making processes of any related issues among the practitioners. Apart from that, this research has contextual contribution in which it provides decision-making processes among the ATCOs in Malaysian context. The findings of this research share new input on the process of decision-making among the ATCOs especially using Naturalistic Decision Making (NDM). It also provides better and deeper understanding on the effect of workload among the ATCOs on their job performance. Besides, this research will identify related issues on decision-making processes among the ATCOs as well as the coping strategies for them to overcome the issues.

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