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Occupational Stress and Human Factors Among Air Traffic Controllers at Tribhuvan International Airport: An Application of the Job Demand-Control-Support Model

by

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A THESIS
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The undersigned certify that they have read and recommended to the institute of engineering for acceptance, a thesis entitled '**Occupational Stress and Human Factors Among Air Traffic Controllers at Tribhuvan International Airport: An Application of the Job Demand-Control-Support Model**' submitted by Manoj Dangal (074MSTIM019), in partial fulfillment of the requirements for the degree of Master of Science in Engineering in Technology and Innovation Management.

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ABSTRACT

The job of Air Traffic Control involves intense mental effort, strict time constraints and operations that permit almost no tolerance for mistakes. This thesis examines work related stress and human factors among Air Traffic Controllers (ATCOs) at Tribhuvan International Airport (TIA), Nepal with the application of Job-Demand-Control-Support framework. A quantitative cross-sectional census survey was conducted among 58 licensed ATCOs using Job Content Questionnaire and the Perceived Stress Scale (PSS-10). Descriptive statistics, correlational analysis, and hierarchical regression were applied. Hierarchical regression shows the JDCS model explains 62.9% of stress variance ($R^2 = 0.629$), with social support emerging as the strongest predictors. Linking these insights to the 2024 TIA safety report, the study recommends that the Civil Aviation Authority of Nepal (CAAN) implement Peer Support Programs and Fatigue Risk Management Systems to bolster aviation safety and organizational well-being.

Keywords: Occupational Stress, Air traffic Controllers, JDCS Model, Human Factors, Social support, Tribhuvan International Airport

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ABBREVIATIONS

ATCO	Air Traffic Controller
ANSP	Air Navigation Service Provider
TIA	Tribhuvan International Airport
ICAO	International Civil Aviation Organization
CAAN	Civil Aviation Authority of Nepal
ILO	International Labor Organization
JDCS	Job Demand Control Support
PSS/PSS-10	Perceived Stress Scale
VFR	Visual Flight Rules
STOL	Short Takeoff and Landing
JCQ	Job Content Questionnaire
SD	Standard Deviation
CNS	Communication Navigation and Surveillance
AIRPROX	Aircraft Proximity
TCAS	Traffic Collision Avoidance System
FRMS	Fatigue Risk Management System
CPDLC	Controller Pilot Data Link Communication
ATC	Air Traffic Control

R/T	Radio Telephony
OHS	Occupational Health Safety
TWR	Aerodrome Control Tower (Working Unit)
APP	Approach Control Unit (Working Unit)
ACC	Area Control Center (Working Unit)
VIF	Variance Inflation Factor
SSP	State Safety Program

CHAPTER ONE: INTRODUCTION

1.1 Background of study

Civil Aviation Authority of Nepal (CAAN), a government entity in Nepal functions as Air Navigation Service Provider (ANSP) as well as civil aviation regulator in context of Nepal. Air Traffic Controllers (ATCOs) are responsible for safe, orderly and expeditious flow of aircraft. ATCOs communicate continuously with pilots and other Air Traffic Controllers while ensuring the safety of flight. Air traffic controlling is a highly demanding job that requires alertness, attentiveness, quick decision making and also precise judgements. Due to these heavy demands ATCOs are exposed to occupational stress which can affect performance of work as well as well-being of ATCOs. However empirical evidence in Nepalese context remains limited.

1.2 Introduction

Air Traffic Controllers perform highly safety critical work characterized by intense mental effort, time pressure, shift work and responsibilities for huge numbers of passengers and aircraft. ATCOs are required to maintain constant situational awareness, process rapidly changing information, and make precise decision within limited timeframes, while adhering strictly to ICAO standards and procedures. Errors in Air traffic control have consequences that can be very serious, immediate and catastrophic. The nature of work place ATCOs at elevated risk for occupational stress and fatigue.

To fully understand the occupational stress experienced by Air Traffic Controllers (ATCOs) in TIA, it is necessary to examine the specific operational environment of Tribhuvan International Airport. While aviation is a standardized global industry governed by ICAO and locally by CAAN, operating environment at TIA presents a distinct list of stressors that differs largely from other flat terrain, multi-runway airports common elsewhere. These unique constraints directly influence job demands and job control variables which are indispensable to this thesis.

1.3 Operational context of TIA

Terrain-related constraints at TIA

Many International airports situated on flat plains with advance infrastructures. But TIA is in Kathmandu Valley, surrounded by mountainous terrain. This geographical reality presents severe limitations on the available airspace for maneuvering aircraft. In context of the JDCS model, this terrain significantly reduces job control (decision latitude) for the controller. In a flat airspace ATCOs can vector an aircraft in almost any direction (360 degrees) to separate traffic and to resolve conflict. However, at TIA the flyable airspace is constricted by high terrain. When the traffic volume increases, the already constricted airspace gives ATCOs fewer option to space out aircraft thereby increasing cognitive workload. This contributes to reduced job control. This reduced decision latitude is directly related to job control component of JDCS model.

Single runway bottleneck

Another infrastructure constraint is TIA operates with single runway (Runway 02 & Runway 20) which serves as sole runway for international wide body jets, domestic trunk routes, mountain flights and extensive helicopter operations. This creates a bottleneck that drastically increases job demand with time pressure. The heterogeneous mix of traffic poses unique challenge for ATCOs at TIA as controller must sequence aircraft with vastly different performance capacity. For example, an arriving Airbus A330 followed by slower STOL aircraft such as Twin otter (DHC6) requires wake turbulence separation and precise timing of runway occupancy. Using the same runway for both takeoff and landing require ATCOs to make split-second decisions to utilize gaps in arrival streams for departures. These continuous high stakes decision makes intense mental processing
demands.

Lack of advance navigational facilities

While the global aviation is moving towards high level automation and advanced navigational facilities TIA lacks advanced navigational precision approach and landing system such as ILS (Instrument Landing System), which limits operational flexibility. Major STOL (Short Takeoff and Landing) sector flights have limited radar coverage due terrain and system relies heavily on procedural control (voice reporting) for which controller must maintain a 3D mental map of airspace without solely relying on automation to detect conflict. This necessitates high level of alertness which over the time contributes to mental fatigue. Helicopters operate under VFR (Visual Flight Rules) and often crosses the Runway axis which add the element of randomness to air traffic controlling.

Inter-Unit coordination

The complex structure of APP, ACC and TWR units requires continuous inter-unit communication. During high workload collaboration between ATCOs, supportive supervisors and effective teamwork can buffer stress, capturing the social support component of the JDCS model.

The Job Demand-Control-Support (JDCS) model gives an important framework for examining occupational stress by integrating three important elements: Job workload, the freedom workers have to influence their work, and the degree of practical and emotional backing from co-workers and supervisor. When demands exceed available control and support, the model predicts elevated stress level and degraded wellbeing. These contextual features places TIA as a natural candidate for human-factors research where structural constraints shape job demands and job control, and where social support within and between units become a critical resource for maintaining situational awareness and resilience under stress. By embedding the JDCS model ATCOs psychosocial experience is explicitly linked to human factors concern such as workload, fatigue, communication quality and error management.

1.4 Statement of problem

Although global research consistently demonstrates that Air Traffic Control is a high-stress profession, Nepal lacks theoretically grounded studies that examine the occupational stress of ATCOs using validated psychological models and human-factor relevant model such as JDCS model. Existing studies in Nepalese aviation are limited and lacks strong theoretical foundations and fails to examine the combined effect of job demands, job control and social support collectively. Existing local research such as (Gautam, 2024) have successfully quantified the prevalence of stress but lack of theoretical framework to explain the cause and moderating factors. They fail to examine the combined effects of core psychosocial variable which are job demand, job control and social support which are outlined in established models such as JDCS framework.

Further TIA presents unique set of operational challenges such as mountainous surrounding terrain, mixed traffic complexity, weather constraints, constricted airspace, lack of advanced navigational facilities which differs from environment presented in international studies. Therefore the core problem this study addresses is the lack of systematic, JDCS framework based research into the occupational stress experienced by ATCOs at Tribhuvan International Airport. This study aims to move beyond merely measuring stress prevalence to understanding the dynamic drivers and potential buffers within the specific Nepalese context.

Thus the key problem addresses critical literature gap in this study which is the lack of systematic JDCS framework study on occupational stress experienced by ATCOs at Tribhuvan International Airport.

1.5 Research Objectives

1.5.1 General Objectives

Ø To analyze the occupational stress experienced by Air Traffic Controllers in Tribhuvan International airport using the Job Demand Control Support (JDCS) model.

1.5.2 Specific Objectives

Ø To assess the level of job demands, job control, and social support perceived by Air Traffic Controllers at Tribhuvan International Airport using the JDCS measures.

Ø To examine the relationship between job demands, job control, and social support with perceived stress among ATCOs.

Ø To evaluate the moderating effect of social support on relationship between job demands and job control with perceived stress.

- Ø To analyze variations in occupational stress based on demographic variables such as age, gender, and work experience.

1.6 Scope and limitations of study

This study focuses solely on ATCOs stationed at Tribhuvan International Airport during the data collection period. The scope includes controllers from Area Control Center (ACC), Approach Control Unit (APP), and Aerodrome Control tower (TWR). Self-reported measures may introduce potential bias. The research does not include physiological stress markers. It also does not include Air Traffic Controllers from other airports which limits generalizability beyond TIA context.

1.7 Significance of Study

This thesis makes an academic contribution in field of aviation in Nepal. The results would also provide practical implication, and insight would be beneficial to TIA management. Further it will establish the concern for occupational health safety and be beneficial in improving overall health of Air traffic Controllers. By identifying specific source of stress and potential buffers the study can inform targeted intervention related to rostering, training, teamwork and workplace policies. Increasing awareness of the importance of ATCOs psychological wellbeing will directly help in promoting healthy and sustainable work environment. Thus, this research has potential to make important contribution in Nepalese aviation safety. The finding of the study can help in implementation of the State Safety Programme (SSP) required by ICAO.

1.8 Research Gap

Existing literature on stress in Air Traffic Controllers predominantly originates from European and Northern American centres with advanced technology and different work cultural context. Nepalese Air Traffic control operation remains unexplored. No prior study has jointly examined stress with application of PSS and JDCS models among ATCOs. This thesis aims to bridge this gap by providing insights into the challenges faced by ATCOs at TIA, thereby contributing to both academic knowledge and possibly for recommendation for improving workspace and well-being of ATCOs which in turns help in improvement of Nepal's aviation sector.

CHAPTER TWO: LITERATURE REVIEW

2.1 Occupational Stress

The International Labor Organization defines Occupational stress as ‘a state in which harmful physical and emotional responses emerges when individuals perceived demands exceed an individual’s perceived resources and ability to cope with those demands.’ It is widely documented as workplace hazard as it links to fatigue, decreased well-being, reduced productivity across the professions. ICAO (International Civil Aviation Organization) and ILO (International Labor Organization) highlight the need to understand occupational stress in safety critical professions. Occupational stress has been extensively studied in safety critical profession where human performance failures can lead to catastrophic consequences. Air Traffic Controlling share job characteristics such as high cognitive workload, time critical decision making, complex human-machine
interaction and minimal tolerance for error. Understanding occupational stress is fundamental to both employes well-being and operational safety management.

2.2 Stress in Air Traffic Control

Occupational stress in air traffic control has direct implications for aviation safety. (Christopher D. Wickens, 2022) Human factor research consistently demonstrates that elevated stress impairs cognitive functionals essential for safe ATC job performance, including attention allocation, working memory, decision making accuracy and communication effectiveness. From an occupational health perspective, stress resulted when work requirements exceed the individual’s overall capacity to respond effectively. In safety critical profession such as air traffic control, this imbalance is shaped not only by workload but also by organizational structure, procedural flexibility and limited work recovery opportunities. Occupational stress can lead to serious health issue such as cardiovascular disease, burnout, depression and anxiety.

From a system safety perspective, (Reason, 1997) Swiss Cheese Model conceptualizes occupational stress and fatigue as latent condition that weakens multiple layers of defense within complex socio-technical system. In Air traffic control operations, elevated stress can degrade the individual performance, team coordination, and procedural compliance thereby increasing the probability that active failures can lead into safety occurrences. These finding align with the International Civil Aviation Organization’s emphasis on integrating human factors, stress management, and fatigue mitigation within State Safety Programs (SSP) and Fatigue Risk Management System (FRMS).

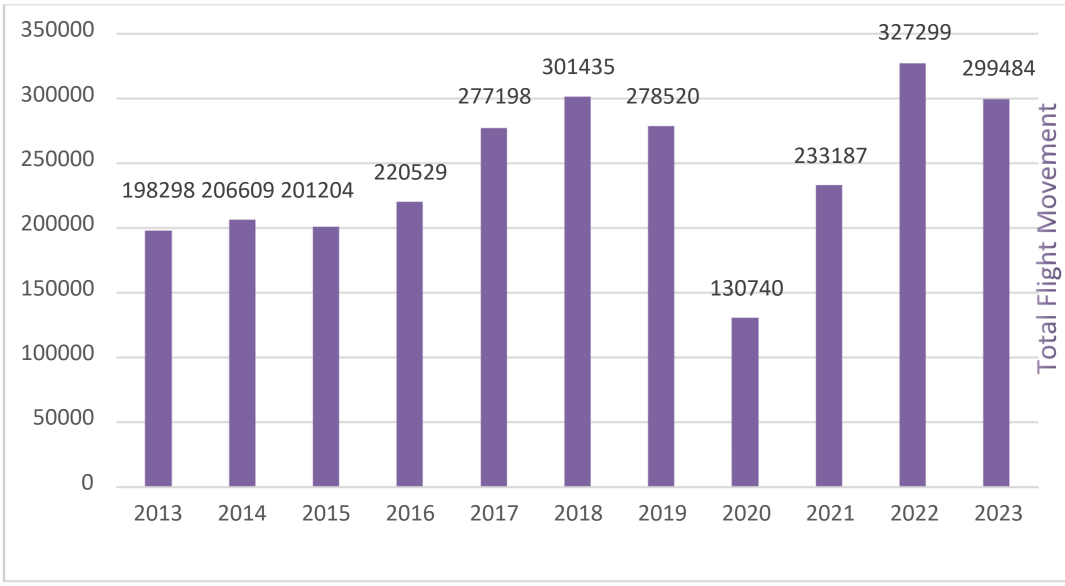


Figure 1: Yearly flight movement data (Aviation safety report, 2024)

From (Aviation safety report, 2024) we can see the yearly flight movement traffic data is nearing pre-pandemic peaks which objectively increases job demand while the key resources(runway capacity, airspace, technological tools) largely remains static. This imbalance can lead to increased occupational strain.

(Costa, 1996) in working paper prepared for the International Labour Organization, characterizes air traffic controllers as a profession exposed to exceptionally high job demands. The air traffic controlling job involves managing a complex of responsibilities that require advanced technical knowledge, substantial expertise, and the effective application of specialized skills. These skills extend across different cognitive domains, including spatial awareness, rapid information and data processing, logical reasoning, and real time bound decision making, in addition to strong communication abilities and interpersonal coordination. The main sources of stress in Air Traffic Controlling are considered under different domain as classified in the table:

Table 1: Sources of Stress in Air Traffic Controlling (ILO, 1996)

Domain	**Factors**
Demand	Traffic volume under area of jurisdiction, peak congestion period, irregular traffic flow, unanticipated occurrences
Operating Demand	Time pressure, the necessity for non-standard adaption, feeling of loss of control, fear of consequences of mistakes
Working times	Continuous service period without breaks, rotational shift pattern and night work
Technical Infrastructure	Hardware dependability and constraints, VDT, R/T and telephone clarity, ergonomic workstation configuration
Work environment	Illumination quality, optical reflection, noise/distractors, microclimate, bad posture, and the adequacy of break, dining amenities
Institutional Structure	Uncertainty regarding job responsibilities , relationship with supervisor and colleague, lack of control over process, compensation, external reputation

2.3 Theoretical framework: Evolution of Occupational Stress Models

2.3.1 Job Demand Resource (JD-R) Stress model Job-Demand-Resource model is a framework developed by Bakker and Demerouti to explain how interaction between job demands and job resources impacts employee overall performance and well-being. It further emphasizes that stress is a response to imbalance between actual job demands for the individual and the resources he /she have to deal with those demands. (Demerouti, 2006)

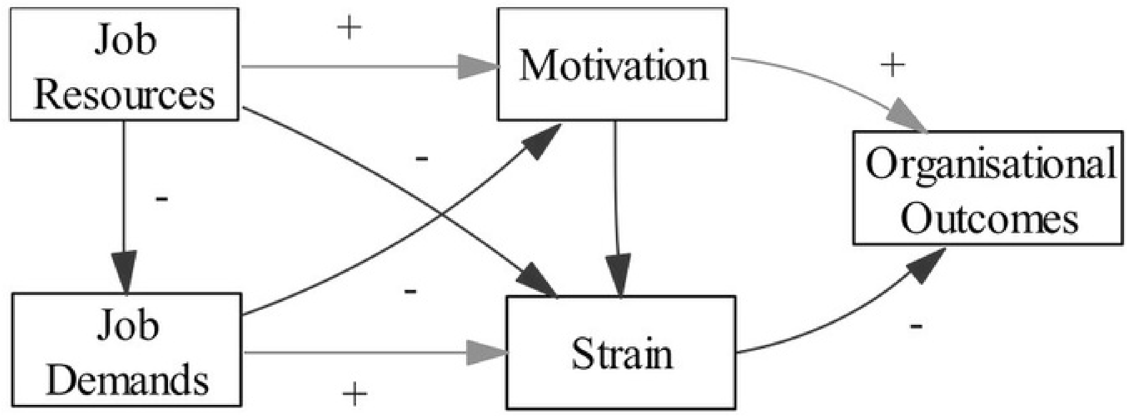


Figure 2: JD-R model adapted from Bakker and Demerouti (Demerouti, 2006)

JD-R model simplifies workplace complexity by categorizing factors mainly into demands and resources. It sometimes fails to fully capture the interplay of specific job characteristics that influence stress and motivation. JD-R approach falls short in addressing systematic workplace issue mainly during high crises and high-stress periods. (Llewellyn Ellardus van Zyl, 2025)

2.3.2 Person-Environment (P-E fit) Stress model The Person-Environment Fit Model was devised in 1966. The main theory this model purposes is that the stress occurs when there is poor fit between an individual and their environment. Environment here refers to the workplace while the person refers to the employee. The main concept is that misalignment between job demands and individual's personal abilities, preferences or resources lead to stress.

This model focuses on two primary factors: Individual person characteristics and environmental factors. First one revolves around the individual's skills, personality traits, needs, values and core competency. Second factor refers to work environments such as tasks, roles, work culture, organizational structure.

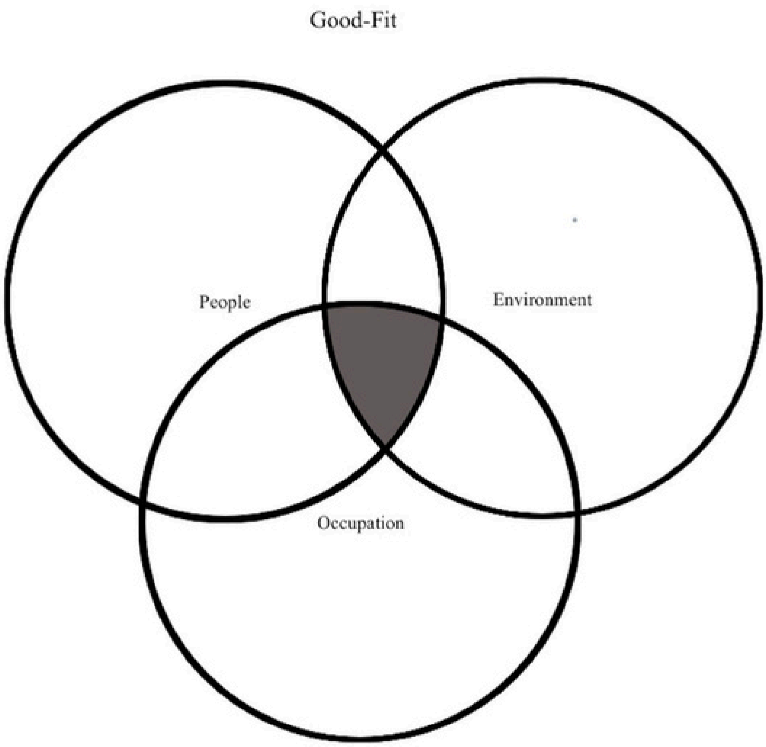


Figure 3: P-E fit model (Good fit)

One of the major shortcomings of Person-Environment fit model is its static assumption of fit. It treats compatibility of person and environment as relatively stable overlooking that both individual needs and work environment dynamically changes over the course of time. P-E fit models also lack differences between multiple type of fit such as Person- fit, Person-Organization fit.

2.3.3 Effort Reward Imbalance model The Effort-Reward Imbalance (ERI) model developed by Johannes Siegrist (1986), is
widely used theoretical framework. The Effort-Reward Imbalance framework argues that stress arises when employees invest substantial effort in their work but feel that pay,

recognition, or job security do not fairly compensate this input. In such condition, long term health and overall well-being of employee can decrease.

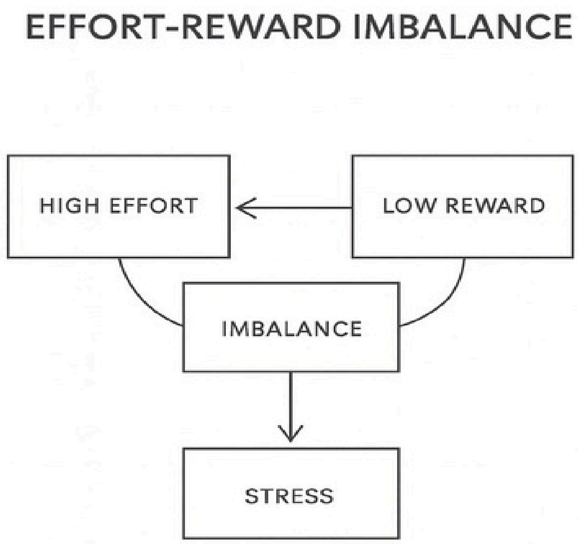


Figure 4: Schematic representation of ERI model (Siegrist, 1986)

(Natasja van Vegchela, 2005) explains that this model is based upon the premise that work related benefits depend upon a reverse relationship between job efforts and reward compensated at work.

ERI model is based on the norm of social reciprocity and includes three main components: effort (extrinsic job demands), reward (salary, esteem, job security) and commitment (a personal trait of excessive work-related commitment). According to this model, stress occurs when high cost of efforts is not met with adequate rewards, which can lead to negative consequences like poor health and burnout.

The ERI model has some limitations as it primarily focuses on effort-reward exchanges potentially overlooking other work factor like job control and social support which influence stress. It has narrow emphasis on rewards mainly in financial, esteem and job security domain which may not fully capture full spectrum of job stressors. Compared to

ERI model, the JDCS model offer a broader conceptualization of occupational stress by incorporating key three dimension: job demand, job flexibility and social backing. This makes JDCS framework better suited for analyzing complex workplace dynamics like Air traffic controlling environment.

2.3.4 JDCS Model The Job Demand Control (JDC) model was originally devised by Karasek in 1979 and improved by Johnson and Hall in 1988 to Job Demand Control Support (JDCS) Model. The JDC model, one of the most used models in research on the relationship between work and health. JDC model identifies two important aspects of work: job demands and job control. In 1980 Johnson and Hall added social aspect into the model resulting to job demand control support (JDCS) model. Social support is a central component of the expanded Job Demand Control Support model; it plays a critical buffering role in moderating the impact of high job demands on psychological strain. Strong supervisory and co-worker support experience lower stress levels even when exposed to high workload or time pressure. This addition know as buffer hypothesis suggests social support decreases the negative effect of demanding work environments by enhancing emotional resources, improving communication and facilitating collective problem solving.

Job demands refer to the workload and have been expressed in term of time pressure and role conflict. Job control often called as decision latitude refers to individuals' ability to control his/her work activities. Decision latitude includes two main components: skill discretion and decision authority. The JDCS adds social integration and states that social support moderates the negative impact of high strain. (Maes, 2010)

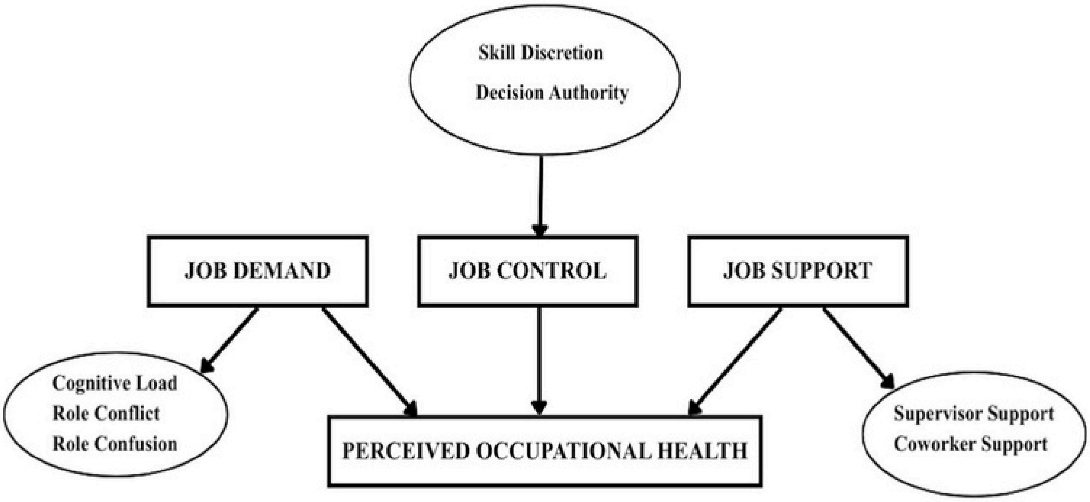


Figure 5: JDCS Stress Model (Johnson, 1988)

The core components for these models are:

Job Demand: Psychological stressors related to workload.

Job Control: Degree of decision authority and skill discretion workers must manage their task.

Social support: Emotional, informational and practical support from colleague and supervisors that can buffer stress effects.

The model's clarity and empirical validation over decades make it strong framework in capturing how environmental factors interact to influence employee's health. This usability in diverse population including high risk environment like Air Traffic Control makes JDCS model highly applicable where both demand, control and social support are crucial in predicting stress outcomes. (Igor Portoghese, 2020)

JDCS model is well suited for research requiring intervention development because its components are actionable: increasing job control or improving social support are practical strategies to reduce stress. Furthermore, this model has strong theoretical foundation and well-defined variables. It also aligns well with ergonomic and social support moderation roles in perceived stress among Air Traffic Controllers.

From human factors perspective, the three core JDCS components closely relates to key aspect of ATCOs intense job demand and performance in Air Traffic Control. Job demands reflect the cognitive workload, perceptual and temporal workload due continuous monitoring of air traffic, conflict detection and resolution, real-time sequencing and managing heterogeneous mix of traffic under time pressure. Job control captures the degree of procedural flexibility and autonomy ATCOs have in applying separation standards, making use of available gaps in arrival to stream for departures. Social support represents the team coordination, shared mental models and supervisory work during high-workload situations, encompassing both colleague collaboration across units and organizational backing in staffing, rostering and incident handling. Together these mappings demonstrate that the JDCS model operationalizes human factors construct in Air Traffic Controlling and makes it particularly suitable for analyzing stress in safety critical ATCO work.

2.4 Human factors perspective on TIA operational safety

Human Factors on Air Traffic Control focuses on synergy between humans, technology and the operational environment, with particular emphasis on workload, fatigue, situational awareness. SHELL(Software, Hardware, Environment, Liveware) model is conceptual model of human factors developed by Professor Edwards in 1972 and this model has been adopted by ICAO in DOC 9683 Human factors training manual. (ICAO, Human Factor Manual, 1998)

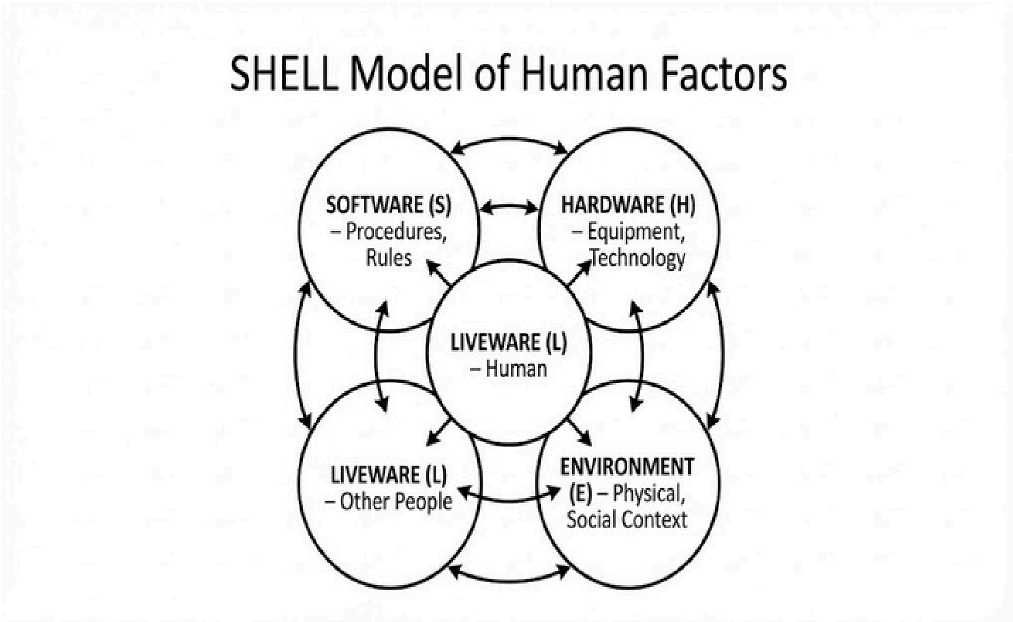


Figure 6: SHELL Model of Human Factors (ICAO DOC 9859)

The SHELL model components are:

1) Liveware (L): The central Human component.
2) Software (S): Rules, Procedures, Checklist, SOPs(Standard Operating Procedures)
3) Hardware (H): Equipment, Technology and Tools.
4) Environment (E): Physical (Noise, lighting, Weather, Social culture, Management).
5) Liveware (L): The interaction between other human being.

The SHELL model focuses on relationship between these blocks and suggest a mismatch or breakdown of any component creates vulnerabilities and increases the risk of human error. It provides systematic way to analyse why things go wrong. SHELL model helps to improve safety to optimize the fit between people and their operational environment.

Classic ICAO identified ATC stressors can be organized along JDCS dimensions from human factors perspective as follows:

Table 2: Mapping of ICAO Identified ATC Stressors to JDCS Dimensions from a Human Factors lens

ICAO Identified ATC Stressors	**JDCS Dimension**	**Human-Factors Interpretation**
Traffic density, peak-hour overload, unforeseeable events	Job Demand	High cognitive workload, increased time pressure, and sustained real-time decision-making demands, leading to elevated mental workload and attentional strain.
Shift work, night duties, extended duty periods	Job Demand	Temporal workload and fatigue accumulation due to circadian rhythm disruption, negatively affecting vigilance, reaction time, and situational awareness.
Strict procedural compliance, limited flexibility in separation standards	Job Control	Reduced decision latitude and autonomy, constraining adaptive problem-solving and increasing reliance on rigid procedural execution under dynamic conditions.
Equipment limitations (radar coverage gaps, display organization, radio-telephony quality)	Job Control / Environmental Ergonomics	Inadequate human-machine interface support and suboptimal workstation ergonomics increase cognitive effort required to maintain safe operations.

In this study, SHELL 'Liveware-Liveware' interactions are operationalized through the social support construct of JDCS model, while 'Liveware-Environment' mismatches produce an elevated job demands and reduced decision latitude. SHELL model also provides a structural view of how TIA's software (procedures), hardware (CNS infrastructure), environment (terrain, weather, organizational culture) and liveware (ATCOs and pilots, ATCOs between different unit) interact while JDCS model translates these system features into psychosocial job characteristics experienced by ATCOs.

For example terrain-induced airspace constraints and single runway operation are E/H (Environment / Hardware) factor that elevate job demands. Strict ICAO procedures act as S (Software) factor that can limit job control and inter-unit coordination and supervisory represents L-L (Liveware-Liveware) interface that define the level of social support available.

(ICAO, Human factors guidelines for Air Traffic Management (ATM) System, 2000) suggests advanced ATM system should be designed as human-centred automation where technology supports rather than replace human, keeping human aspect for normal and abnormal operations. Early and proactive integration of human factors in specification, procurement and implementation is cost-effective strategy. ATCOs situational awareness in Air Traffic Controlling is broader than said, it includes awareness of traffic, weather condition, terrain and obstacles, CNS(Communication, Navigation and Surveillance) equipment, aircraft performance, condition and capacity of adjacent units. The design of traffic situation display should support situational awareness by providing updated information on traffic, weather, airport navigation aid automatically when any significant changes occurs.

Air Traffic Control is best explained as a socio-technical system in which ACTOs performance is shaped not only by individual capabilities, but by organizational policies, technologies, procedures, team dynamics and wider operation environment. Human factors guidance conceptualizes as complex socio-technical system within which human performance is always limited and enable by multiple layers including equipment design training, staffing, regulation, procedures and social work environment. Thus Air Traffic Control is treated as socio-contextual framework in which job demands, control, support and stress are embedded in broader layers of technology, procedures, culture, not reducible to individual single factor.

2.5 Integration of operational safety evidence from Tribhuvan International Airport safety report

Recent operational safety data from the TIA safety report 2024 further contextualizes the occupational stressful environment in Air Traffic Control domain at Tribhuvan International airport. According to the report, 102,729 domestic and 33,247 international flight movement is 2024 approaching pre-COVID traffic levels while operating with largely unchanged infrastructure and technological resources. The increased traffic density increases the job demand for ATCOs particularly in constrained airspace further characterized by mountainous terrain and single runway operations.

The analysis of hazard and occurrence is done in five areas which are threatening TIA safety significantly in 2024 and these are categorized as BIRD (Bird strikes), ADRM (Aerodrome Issue), NAV (Navigation), and MAC (Mid-Air Collisions) indicating strong emphasis on wildlife, runway safety, Air Traffic Control, navigation systems, and mid- air conflict prevention.

The safety report identifies ATM, MAC (loss of separation / AIRPROX), NAV, ADRM and BIRD occurrences as most important safety threat for 2024. Furthermore ATM, MAC and NAV event are associated with human performance limitations, particularly cognitive workload, time pressure and information processing capacity. In context of Tribhuvan International Airport theses data provides objective evidence that cognitively demanding operational conditions can coexist with elevated human performance risk. These reflects that safety risks are not solely due technical failures but are closely linked to human-system interface. Thus, occupational stress among ATCOs should be understood as a contributing human factor hazard that directly influence system safety, rather than as an isolated issue of individual well-being.

Table 3: Occurrence data from TIA safety report 2024

Occurrence Category	**Description**	**Number of Events**	**JDCS / Human-Factor Interpretation**
BIRD	Bird strike / near bird strike events	48	High vigilance demand, sustained attentional load
ATM	Air Traffic Management / CNS related occurrences	13	High cognitive workload, time pressure
ADRM	Aerodrome design, service, or functionality issues	11	Structural limitation on job control
NAV	Navigation-related occurrences	8	Mental workload, fatigue-related errors
MAC	Loss of separation / AIRPROX / TCAS alerts	7	Stress, situational awareness degradation

Out of reported safety occurrences, BIRD (48 events) presents single largest category. Prevention and management of bird strike requires continuous visual scanning, alertness and coordination thus increasing sustained situational awareness job demand on ATCOs. From JDCS perspective this contribute to chronic job demand particularly during peak traffic and seasonal bird activity.

A total of 28 occurrences (ATM=13, NAV=8, MAC=7) are directly related to air traffic management and navigation function which are cognitively intensive tasks. These events are recognized as indicators of:

- High mental demand
- Time pressure
- Reduces situational awareness under stress

The presence of 11 ADRM events highlight limitation related to aerodrome layout and infrastructure which decreases operational flexibility and force ATCOs to operate within rigid procedural constraints, thereby limiting job control.

The concentration of safety occurrence within cognitively intensive categories like ATM, NAV and MAC provides objective operational evidence that elevated job demand and constrained condition among ATCOs are not only perceived psychologically into stress but also reflected in measurable safety outcomes.

2.6 Application of JDCS in aviation

Application of JDCS in Air Traffic Controlling environment is very fitting as Air Traffic Controlling is characterized by continuous monitoring, processing information, multitasking, time pressure and high consequences of error. JDCS model states that when demands exceed an individual's coping capacity, stress increases. (Fawad Asif, 2018)

In Air Traffic Controlling high job demand includes:

1) Managing high density of traffic and peak hour overload
2) Maintaining utmost situational awareness
3) Time critical decision making
4) Environment stressor (Noise, shift work, fatigue, workplace ergonomics)

Job control (Decision Latitude)

Job control refers to level of autonomy and flexibility workers have over decision and task evaluation. In Air Traffic Controlling job control is limited because:

1) ATCOs must strictly follow ICAO- Standardized separation minima

2) Procedures are highly standardized.

3) Rules based decision making leave very less autonomy

4) Deviation can lead to safety risk

Low decision latitude increases strain when combined with high demands creating job strain category in JDCS model

Social support as a moderator

The JDCS model implies that workplace support from supervisors, peers and organizational setting can buffer the negative effect of high demand and low control. In Air Traffic Controlling social support may come from:

1) Team coordination between different ATC units (Tower, control and approach)

2) Supporting supervisor who encourage open communication.

3) Peer support during high workload situation.

4)Organization environment like rostering policies, debriefing and access to wellness program.

High social support in linked with lower perceived stress, improved performance and safer operation in ATC environment.

2.7 Literature and empirical studies

(Gautam, 2024) quantified a high prevalence of stress among ATCOs in Kathmandu, the study showed significant association of stress between day and night shift, sleep hours and alcohol consumption. High prevalence of moderate stress was depicted among Air Traffic Controllers of Kathmandu, Nepal and highlights the need of further extensive research in this area with the use of strong theoretical framework. This research work lacks strong theoretical framework such as JDCS model and fails to account for important psychosocial variable like job control and social support that influence occupational stress. Also, without moderating factors the finding cannot guide targeted interventions or fully explain why stress levels are high among the air traffic controllers.

(Lihua Tang, 2022) investigated how work-related stress contributes to burnout among civil aviation air traffic controllers. Using a cluster sampling approach, data were collected from 456 operational ATCOs. Occupational stress was assessed using two complementary instruments: the Job Content Questionnaire (JCQ), which captures demand-control characteristics and Effort-Reward Imbalance (ERI) questionnaire, which evaluates perceived imbalance between work input and returns. The finding from the study was there was high prevalence of burnout, with approximately 83.6 percent of respondents reporting burnout symptoms. The study further demonstrated a strong relationship between elevated occupational stress and burnout, indicating that sustained psychosocial stressors play huge role in reducing overall ATCOs well-being.

(Fatmawaty Mallapiang, 2022) in their thesis explored the contribution of qualitative workload, career development, and personal responsibility to work-related stress among air traffic control personnel. The study adopted a descriptive research design and took response from 67 ATC operators working at Sultan Hasanuddin International Airport, Makassar. Occupational stress was measured using Stress Diagnostic Survey (SDS) questionnaire. The finding from the study revealed that more than half of the participants (52.2%) experienced moderate level of work stress. Additionally, qualitative workload was predominantly rated as moderate by 71.6% of respondents, while perceptions of career development and personal responsibility were also largely within the moderate range, reported by 59.7% and 53.7% of participants respectively. These results suggest
that multiple psychosocial and organization factor jointly affect stress in ATC work environment.

(Usana García-Herrero, 2017) applied the Demand-Control-Social Support- Recognition framework to examine occupational stress among healthcare professionals. The study analyzed data from large international sample comprising 2211 healthcare worker across 35 countries. The finding from the study suggested that supervisory support played a more substantial role in reducing stress than general support from colleagues. In addition, sensitivity analysis demonstrated that recognition became particularly influential under condition characterized by job demands and limited control, where it significantly reduced stress levels. These results highlight the importance of managerial support and recognition as critical psychosocial resources in high-stress work environment.

(Atmaka, 2024) in their research work examined the interrelationship between fatigue, stress, and job satisfaction among air traffic controllers with special emphasis on psychological well-being. Using a quantitative research design data were collected with the means of standardized instruments including the Fatigue Assessment Scale (FAS) and the Karolinska Sleepiness Scale. The finding revealed that workload intensity and occupational stress were the primary drivers of fatigue, with stress level rising markedly during period of heavy air traffic. ATCOs reported higher levels of job satisfaction exhibited more effective coping strategies when dealing stress. Based on the outcomes, the study recommended improvements in shift scheduling, provision of adequate rest facilities, and access to psychological support services. Overall, the research highlights the critical role of fatigue and stress management in promoting overall job satisfaction and maintaining operational safety in air traffic control environments.

(Iqbal, 2012) investigated the impact of job stress on job satisfaction of employees and find out the drivers for the job stress adopted questionnaire-based survey approach for selected sample of Air traffic controllers of Pakistan civil aviation authority. A cluster sampling technique was used to survey 122 air traffic controllers (ATCOs), confirming a direct inverse relationship between occupational stress and job satisfaction.

(Bader Alaydi, 2024) in their research using Job-Demand resource framework investigated 324 ATCOs across Saudi Arabia to determine the relationship between psychological demands and professional outcomes. The study identified three primary outcomes: first, a clear inverse relationship exists between mental workload and job performance. However, the research also highlighted two critical buffers: mindfulness and perceived social support both served to moderate this relationship, effectively weakening the negative impact of high workloads on workplace effectiveness. ATCOs who exhibited higher levels of mindfulness or reported robust social support were less susceptible to performance degradation typically linked with intense mental workloads.

(Iva Tomic, 2017) The study investigated how occupational stress and fatigue affect and produce human error within the aviation sector, with specific attention to air traffic control operations. Data were collected using structured questionnaires administered across multiple air traffic control units in China and Eastern Europe, yielding 73 valid responses. The analysis indicated that both stress and fatigue exert significant effect on ATCO job performance. Work pressure, fatigue, and shift work emerged as the most prominent stressors, reported by 58.9%, 60.3% and 76.7% of total respondents respectively. The finding further identified fatigue as the dominant risk factor, particularly in relation to night shift duties, which were associated with elevated physiological stress responses and reduced cognitive functioning. Overall, the study highlights critical area of concern and provides a valuable foundation for subsequent research aimed at mitigating human error in air traffic control.

(Hsiang Te Liu, 2018) in their study of 281 Taiwanese correctional officer used Job-Demand-Control-Support (JDCS) model and Structural Equation Modeling (SEM) to evaluate predictors of job satisfaction. The analysis revealed a dual impact: while social support acted as a significant positive predictor, factors such as job stress, intensive monitoring and high operational demand significantly eroded employee satisfaction.

(Marta Makara, 2020) in their research article did cross sectional study aimed to assess the level of perceived stress and occupational burnout in groups of Polish maritime navigators and air traffic controllers. They tested the model which linked occupational burnout, perceived stress and seniority. Methodology used was burnout questionnaire, PSS-10 and general self-efficacy scale. A significant occupational burnout was observed in group of controllers and navigators compared to equally emotionally burdening occupational group of polish firefighter. The assumption that person employed in special professional requirements as air traffic controllers and maritime navigator with a risk of strong, chronic emotional overload evaluate their life situation as less stressful than other employees was confirmed.

(Blanch, 2016) concluded the role of social support as a mediator helps the prevention of psychosocial stressors in the workplace and emphasized on improving social relationship at work. Two models considering support as a mediator variable in the explanation of job strain were assessed in the group of administrative and technical workers (N=281). The study concluded that effect of job control on job strain was fully mediated by social support from supervisors and coworkers.

(Peng Bai, 2024) in experimental study used an ATC performance evaluation system based on 8-item scoring framework with 25 indicators further assessing radiotelephony communication, flight progress strip, safety separation during simulated tower task. All ATCOs were tested under four working condition- Normal, fatigue, stress and combined fatigue and stress. Performance data were analyzed using multiple sample Kruskal-Wallis test for comparison. Controllers in fatigue and stress conditions showed significant declines in communication accuracy, timing, situational awareness and overall job performance effectiveness. The study concludes that fatigue and stress individually and especially combined have measurable, statistically significant impacts on operational ATCOs performance.

(Aristi Karagkouni, 2025) examined occupational well-being and job satisfaction among Air Traffic Controllers working with the Hellenic Air Navigation Service provider. Using cross-sectional quantitative approach, data were collected from 580 ATCOs across both operational and administrative roles through a comprehensive 196-item questionnaire. The survey covered demographic characteristics, working condition, occupational well- being, perceived Occupational Health and Safety (OHS), and overall job satisfaction. The results indicated that ATCOs who reported the presence of an established OHS system in their unit perceived higher levels of workplace safety and expressed greater job satisfaction. Moreover, autonomy related to work organization and break scheduling demonstrated a buffering effect, being associated with reduced stress and exhaustion and enhanced satisfaction, even though high workload and mental demands continued to be prominent source of stress.

(Aviation safety report, 2024)Overall global evidence demonstrated that high stress among ATCOs, but such research remains limited and almost absent in context of Nepal. While (Gautam, 2024) study quantified prevalence, it lacked a theoretical framework to explain the cause. It did not examine Job control and social support leaving critical gap in understanding why stress is high and how it can be mitigated.

(Diane B. Boivin, 2022) in their research article found that rotating shift schedules can lead to circadian misalignment as biological rhythms adapt poorly to changes in work hours. Finding from these studies showed disrupted melatonin production, sleep loss and internal clock desynchronization between central and peripheral clocks for individual working in shiftwork. For Air Traffic Controllers whose duties demands sustained situational awareness and rapid decision making, such circadian disruption may increase fatigue and reduce cognitive performance, potentially affecting operational safety during night and early morning shifts. (Maximilian Peukert, 2025) conducted research in Scandinavian Area Control Center using fatigue measurement in 74 operational staffs. The method used PVT-B (Psychomotor Vigilance Task) for objective measurement and SSS (Stanford Sleepiness Scale) for subjective measurement of fatigue. Morning shifts showed relatively stable subjective fatigue. Evening shift saw increasing fatigue towards the end of shift while night shift resulted in significantly higher fatigue levels both subjectively and objectively mainly due circadian rhythm effect rather than workload alone. These further highlights disruptive impact of circadian misalignment from shiftwork.

2.8 Measuring stress: The perceived Stress Scale (PSS-10)

The Perceived Stress Scale (PSS-10), developed by Sheldon Cohen in 1983, is one of the most applied instruments for measuring perceived stress. This tool consists of ten item questionnaire that capture how individuals evaluate and interpret stressful experiences in their daily lives. As a self-reported questionnaire, PSS-10 focuses on the extent to which respondents appraise their life situation as unpredictable, overwhelming, or stressful.

There are two subscales in PSS-10:

1) First one, Perceived helplessness focuses on (Items 1,2,3,6,9,10) measuring individual’s feeling about lack of control over their situation, and emotions.
2) Secondly, Measurement of Lack of self-efficacy (Items 4,5,7,8) measuring an individual’s perceived inability to handle the actual prevailing problem.

2.9 Contextual framework

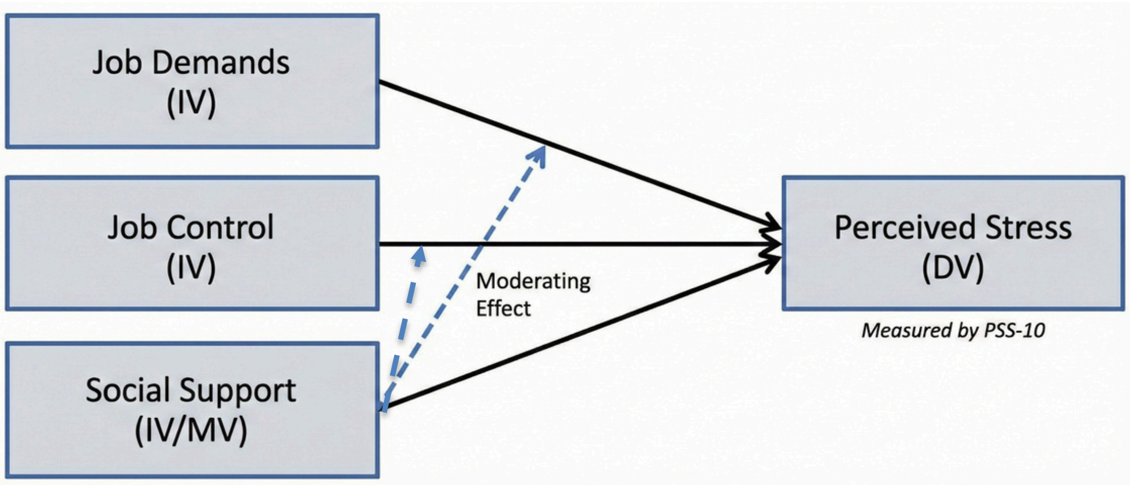


Figure 7: Conceptual framework based on JDCS model

The contextual framework for this study is grounded in Job-Demand-Control-Support (JDCS) model which proposes that occupational stress is influenced by interaction between job demand, job control and workplace social support.

Independent variables (IV's):

1) Job demands
2) Job control
3) Social support

Dependent Variable (DV):

1) Perceived Stress (Measured by PSS-10)

Moderating Variable (MV):

1) Social support moderates the relationship between job demand and perceived stress.
2) Social support moderates the relationship between job control and perceived stress.

The framework proposes that high demands combined with low overall job control leads to higher perceived stress among employees, measure here by perceived stress scale (PSS). Social support acts as a moderating variable in this framework meaning it influences the strength or direction of relationship between job demands/control and perceived stress. Specifically, higher social support social support is expected to buffer or reduce the negative impact of high job demands and low job control on perceived stress, thus improving occupational well-being.

2.10 Conceptual framework justification

The study incorporates the Job Demand Control Support (JDCS) model as primary theoretical framework and Perceived Stress Scale (PSS-10) as the outcome measure to assess occupational stress among ATCOs. The combination is theoretically robust, validated and well complemented to one other given the operational characteristics of air traffic control work.

The JDCS parameter (measured by Job Content Questionnaire) does not directly measure stress directly, instead it identifies workplace condition that predict stress. Thus, an outcome variable is necessary to quantify the actual stress level.

The PSS-10 fulfills this requirement by assessing:

- How unpredictable, uncontrollable, or overload ATCOs perceives their life to be,
- their ability to manage daily challenges
- Feeling of nervousness, overwhelm, or loss of control.

Using JDCS without PSS would help identify stressors but fails to reveal actual stress levels. Similarly, PSS without JDCS would measure stress but would not explain the contributory factors behind it. Thus, combination of these two tools allows research to achieve complete insight. Therefore, the use of JDCS framework together with PSS-10 is justified contextually and methodologically in this thesis.

2.11 Hypothesis formulation

Based on the theoretical framework of the Job Demand Control Support model and existing literature on occupational stress among air traffic controllers, the following hypotheses are proposed:

H1: Higher job demand experienced by air traffic controller at TIA are positively associated with higher levels of perceived occupational stress.

H2: Greater job control (Including decision latitude and skill discretion) among air traffic controllers at TIA is negatively associated with perceived occupational stress.

H3: Higher levels of social support from colleague and supervisors reduce perceived occupational stress among air traffic controllers in TIA.

H4: Social support moderates the relationship between job demands and perceived occupational stress such that the positive association between job demands and stress is weaker at higher levels of social supports.

H5: Social support moderates the relationship between job control and perceived occupational stress such that the negative association between job control and stress is weaker at higher levels of social supports.

These hypotheses will capture the direct effect of job demands, control and support on stress as well as the moderating effect of social support within the aviation occupational context where higher cognitive workload and responsibility are inherent stressors.

CHAPTER THREE: RESEARCH METHODOLOGY

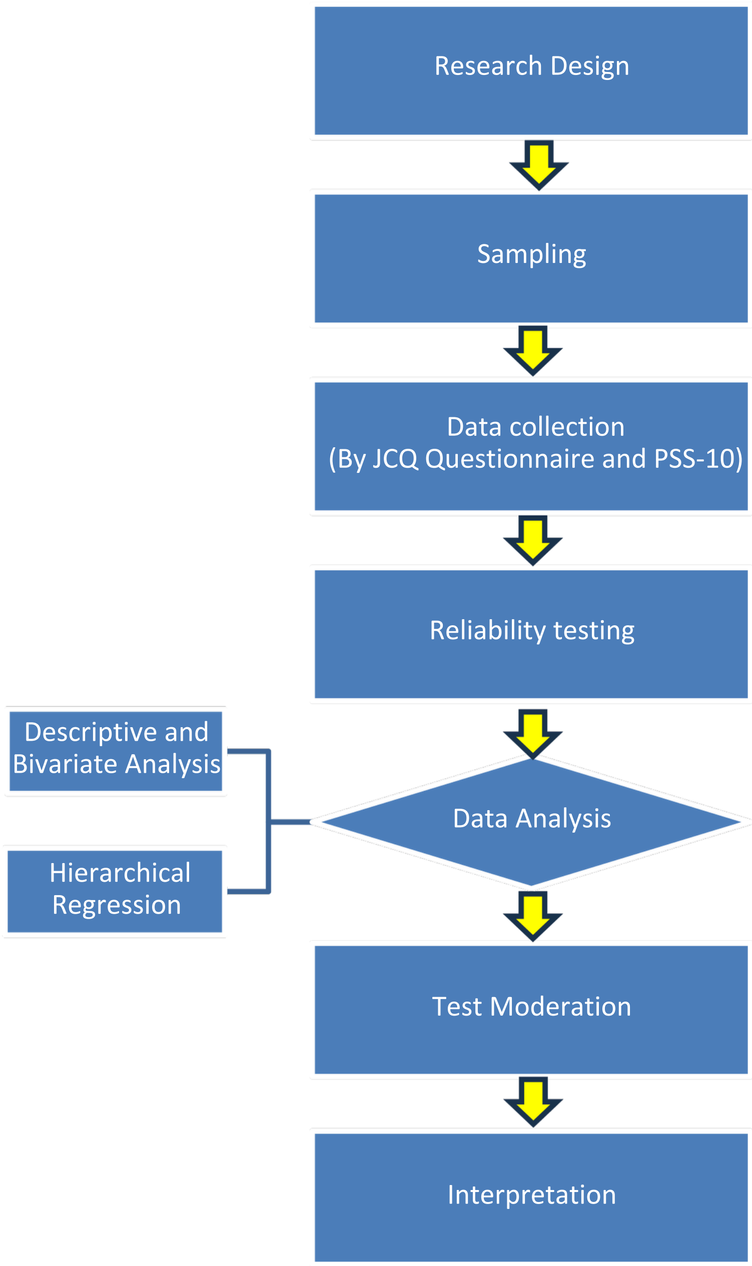


Figure 8: Methodology flowchart

3.1 Introduction

This chapter describes the research design, population, sampling strategy, data collection tools, procedures and analytical technique to be used in this thesis. Based on Job Demand-

Control- Support framework, this research uses a quantitative, cross-sectional correlational design to examine how job demands, job control, and social support influence perceived stress among Air Traffic Controllers at TIA.

3.2 Research design

A quantitative, cross-sectional, correlational research design was adopted for this study as this approach is appropriate because:

1) It allows the measurement of Job demands, Job control, social support and Perceived stress using numerical scales.
2) It supports hypothesis testing through correlations, regression and moderation analysis.
3) It is suitable for exploring relationship among multiple workplace variables.

3.3 Population and study site

The targeted population includes all licensed ATCOs working in the major ATC units of TIA and they are:

1) Area control center (ACC)
2) Approach Control Unit (APP)
3) Aerodrome Control Tower (TWR)

3.4 Sample size

According to ANSLRD (Air Navigation Services Licensing and Rating Division) total number of ATCOs at TIA ATS operation is 69. Given the small and finite population of licensed ATCOs at TIA, a census approach was adopted to maximize statistical power and reduce sampling bias, which is appropriate for regression analysis with multiple predictors. Census sampling minimizes sampling error and maximizes representativeness for small, definable population.

Response rate

Sample size for this study was determined using (Cochran, 1977) formula with Finite Population Correction (FPC) as study population is finite and known. During the data collection period, the total number of licensed Air Traffic Controllers (ATCOs) in Air Traffic Services operations at Tribhuvan International Airport was 69.

Cochran's initial formula for estimating sample size for large populations is given by:

$$n_0 = \frac{Z^2 \cdot p \cdot (1-p)}{e^2}$$

where Z represents the Z-value corresponding to a 95% confidence level (1.96), p is the estimated proportion of the attribute present in the population (assumed as 0.5 for maximum variability), and e is the margin of error (0.05). Substituting these values yields an initial sample size of 384.

Since the target population was finite ($N = 69$), Finite Population Correction was applied using the following formula:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Applying the correction resulted in a required minimum sample size of approximately 59 respondents. In the present study, 58 valid questionnaires were obtained, yielding a response rate of approximately 84%. Given the census based approach, high response rate, and minimal difference between the required and achieved sample size, the final sample is considered statistically adequate and methodologically sound for regression and moderation analyses.

3.5 Data collection instruments

Four sections of structured instruments were used and listed in appendix section.

3.5.1 Job Demand Scale

Adapted from the Job Content Questionnaire (JCQ). It Assesses workload, cognitive demand, time pressure and complexity.

Scale: 5-point Likert (1= Strongly Disagree, 5= Strongly Agree)

3.5.2 Job Control Scale

Adapted from JCQ. Measures decision latitude, skill discretion and autonomy within the ATC environment

Scale: 5-point Likert (1= Strongly Disagree, 5= Strongly Agree)

3.5.3 Social Support Scale

Assesses the degree of peer and supervisory support and team coordination.

Serves both as an independent variable and as a moderator.

Scale: 5-point Likert (1= Strongly Disagree, 5= Strongly Agree)

3.5.4 Perceived Stress Scale (PSS-10)

A globally validated 10-item scale measuring perceived stress in recent one month.

- Score range from 0 to 40.
- Four items are reverse coded (ITEM 4, ITEM 5, ITEM 7, ITEM 8)
- Higher scores indicate higher stress.

Scale: (0 = Never, 1 = Almost Never, 2= Sometimes, 3= Fairly often, 4= Very often)

3.5.5 Demographic and Work-related Information

This includes:

- Age
- Gender
- Years of ATC experience
- Monthly Working hours
- Working ATC unit

3.6 Data analysis techniques

The data collected through the structured questionnaires were coded and entered into IBM SPSS statistics version 31.0.1.0 and Microsoft Excel for analysis.

3.6.1 Data screening and reliability analysis

Before testing the hypothesis, the dataset was screened for missing values and outliers. Given the census approach (N=69) minimizing the data loss is critical. Any incomplete response is reviewed to determine if they should be excluded.

Reliability analysis is conducted to assess the internal consistency of four parameters scale used in survey:

- Ø Job demand scale
- Ø Job control scale
- Ø Social support scale
- Ø Perceived Stress scale

Cronbach's alpha coefficients are calculated for each scale. A coefficient value of alpha above 0.70 is considered acceptable, indicating that each item in each scale has consistently measured underlying construct.

3.6.2 Descriptive and Correlational Analysis

Descriptive analysis (Mean and standard deviation) is computed to summarize the demographic profile and levels of stress, demand and support perceived by TIA ATCOs.

A Pearson correlation matrix is generated to examine the initial bivariate relationships between the variables, specifically testing hypothesis H1, H2 and H3 (direct association)

3.6.3 Hierarchical regression and moderation analysis

To test hypothesis H4 and H5, that social support moderates the relationship between demand and perceived stress and social support moderates relationship between job control and perceived stress, a hierarchical multiple regression analysis is performed. This technique allows for the isolation of interaction effect after controlling for other variables.

3.7 Pilot testing

A pilot study was conducted among 3 ATCOs not included in the final sample to identify ambiguous wording. Average survey completion time was also calculated. Also, survey was fine tuned to validate item relevance to TIA context. Some minor modifications were made based on pilot feedback.

3.8 Ethical Considerations

Following were the ethical considerations:

- Informed consent was obtained from all participants.
- Participation was voluntary with option to withdraw anytime
- Data were stored securely and used solely for academic purposes.
- Formal approval obtained from CAAN.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Demographic Profile of Respondents

A total of 58 air traffic controllers (ATCOs) from Tribhuvan International Airport participated in the study. The table below presents the demographic profile of the respondents.

Table 4: Demographic profile of ATCOs

Variable	Category	Frequency(n)	Percentage(%)
Gender	Male Female	35	60.3
	25-31 32-39	23	39.7
Age Group	40-45 46-52	5	8.6
	53-58 TWR	28	48.3
	only TWR,	10	17.2
	APP	11	19.0
	ACC	4	6.9
	Day	21	36.2
Working ATC unit	Morning and Rotating	37	63.8
Working Shift	40-50 hours	3	5.2
		1	1.7
		54	93.1
Average Working Hours (Weekly)		33	56.9
	less than 40 hours	5	8.6
	more than 50 hours	20	34.5

Gender

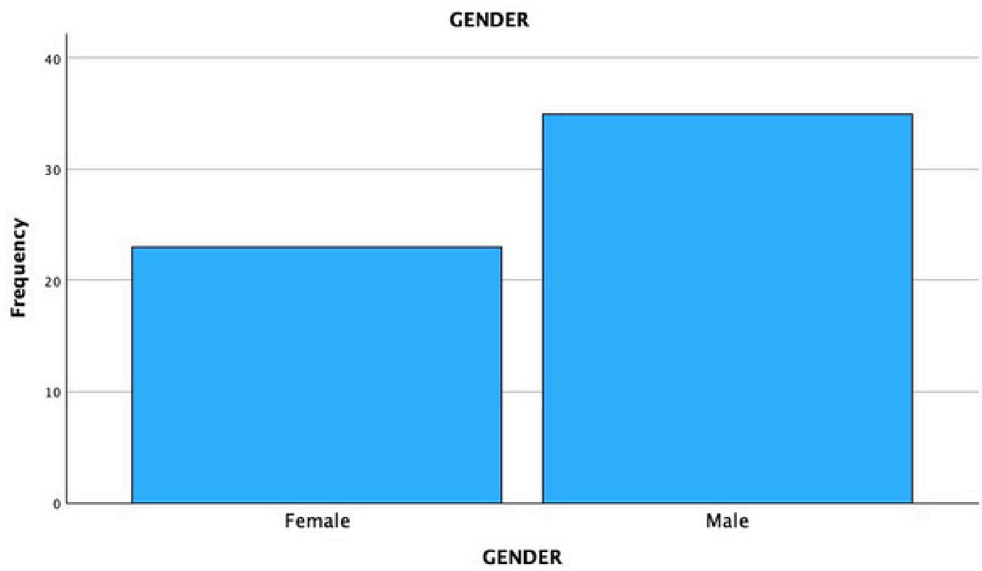


Figure 9: Distribution of gender among ATCOs

The sample consist of 60.3% Male(n=35) and 39.7% Female (n=23) participants. This reflects the gender distribution of ATC workforce where male controllers outnumber female controllers.

Age Group

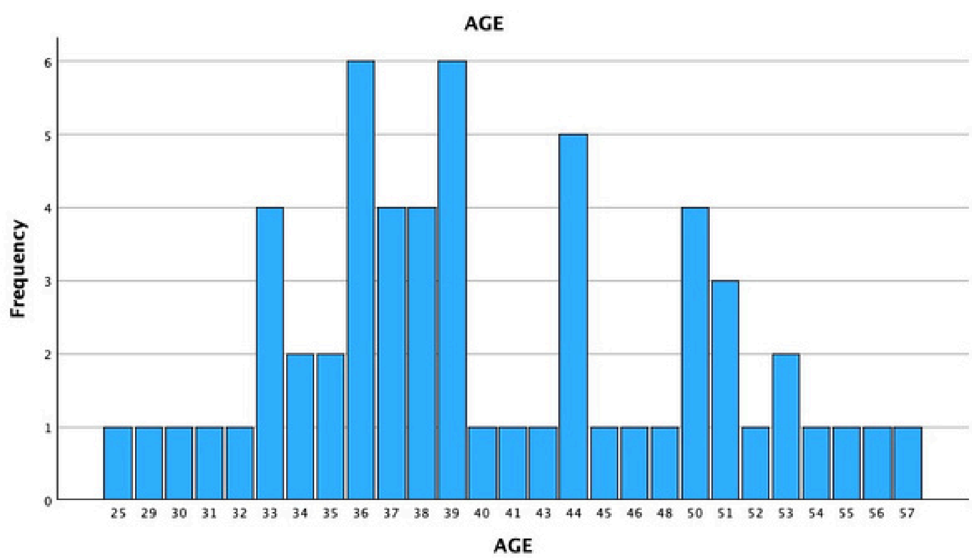


Figure 10: Distribution of Age in ATCOs

Most ATCOs were in 32-39 age group (48.3%), followed by those aged 46-53 (19%) and 39-46 years (17.2%). Only 8.6 % belonged to the youngest category (25-32 years), and 6.9% were aged 52-58 years. This distribution indicates that ATC workforce at TIA is predominantly mid-career with balanced mix of operational maturity and experience. The mean age of 41.09 years (SD=7.747). The standard deviation of 7.747 indicates a moderate spread of ages, showing mix of both younger and older controller within the operational environment.

Working ATC unit

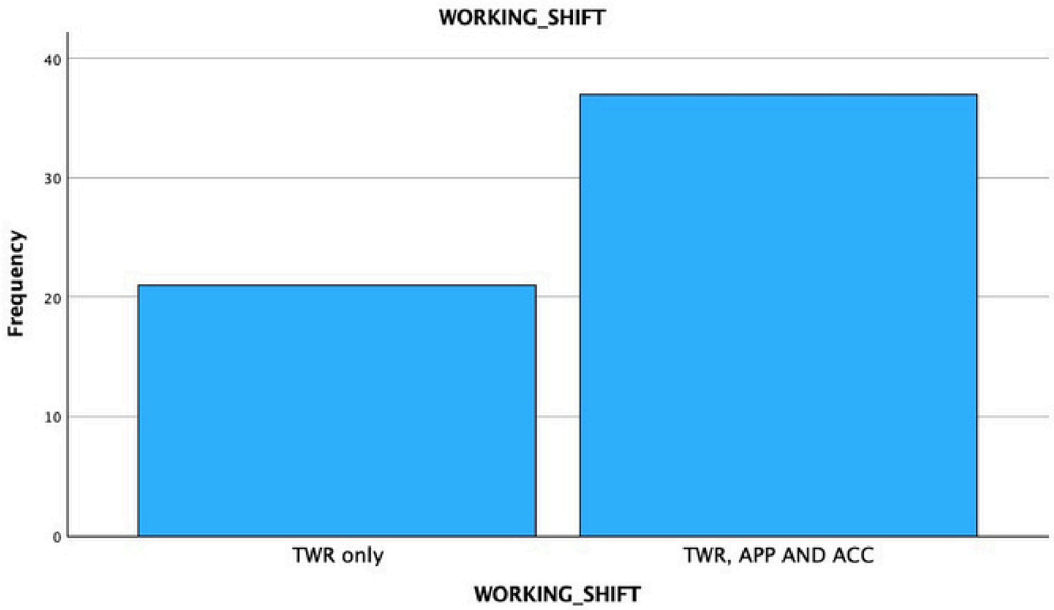


Figure 11: Distribution of working position among ATCOs

A total of 36.2%(n=21) of ATCOs worked exclusively in the Tower (TWR), while 63.8% (n=37) were involved across TWR, APP and ACC units. This ensures the data captures perspective from all ATC operational section of TIA including both aerodrome and radar environment.

Working Shift

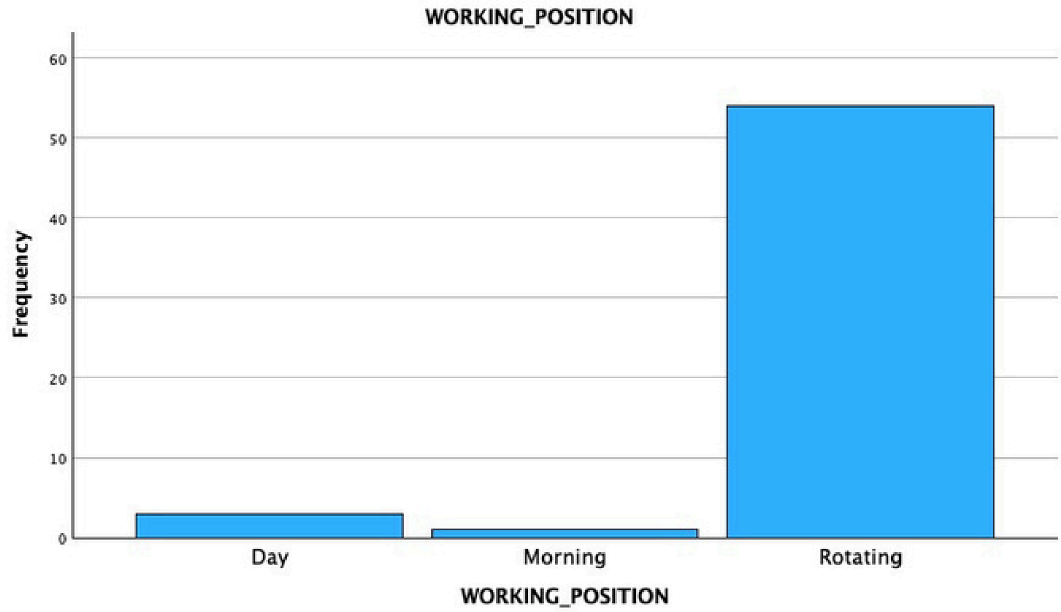


Figure 12: Distribution of working shift among ATCOs

The majority of ATCOs (93.1%) reported being on rotating shifts, consistent with standard ATC duty roster. This also highlights a key stress-related element of ATC work: irregular shift cycle.

Average weekly working hours

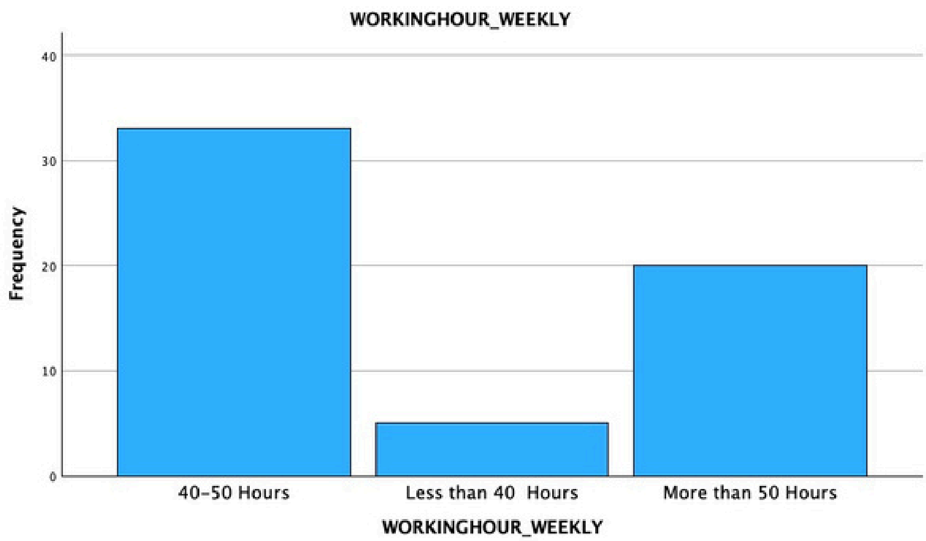


Figure 13: Working hours weekly

More than half of the ATCOs (56.9%) reported working 40-50 hours per week, while 34.5% worked more than 50 hours a week. Only 8.6% worked less than 40 hours. This shows that sizeable portion of ATCOs exceed standard workload which could risk elevated job demand and fatigue.

Experience

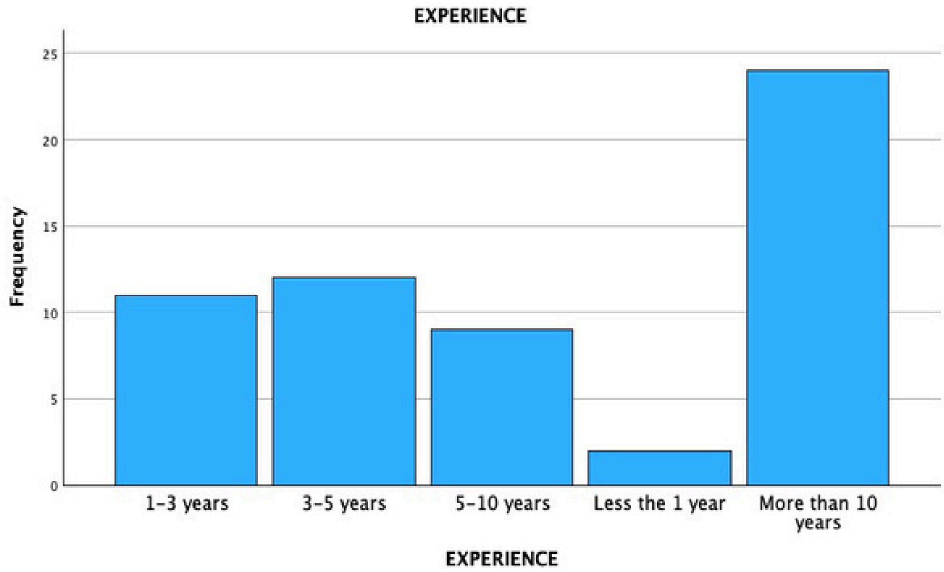


Figure 14: Distribution of working experience among ATCOs

The working experience graph from ATCOs shows the population is heavily skewed toward high experience, with largest proportion having more than 10 years of experience. The large number of highly experience shows potential for leadership, mentorship and supervisorship.

4.2 Reliability Analysis (Cronbach's alpha)

For the measurement of internal consistencies of measure scale used in the questionnaire Cronbach's alpha value are calculated. Cronbach's alpha value of 0.70 or above is considered acceptable, while 0.80 or higher indicates good reliability for social science research. Cronbach's alpha is calculated as

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2}\right)$$

where k represents the number of items, σ^2_i represents item variance, and σ^2_t represents the variance of the total score.

The reliability results for each variables Job demand, Job control, social support and perceived stress scale are presented in the table 5 below:

Table 5: Cronbach's alpha value

Variable	**Number of Items**	**Cronbach's Alpha(α)**	**Reliability Level**
Job Demand (JD)	7	0.847	Good
Job Control (JC)	7	0.859	Good
Social Support (SS)	6	0.935	Excellent
Perceived Stress Scale (PSS)	10	0.881	Good

Overall, the high reliability values across all the constructs confirm that the instruments used in this study are psychometrically sound, stable and appropriate for subsequent statistical analysis such as correlation and regression.

4.3 Descriptive Statistics (Mean, SD)

Table 6: Mean and Standard deviation for JD, JC, SS and PSS

VARIABLES	**N**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Job Demand (JD)	58	1	5	3.9187	0.71158
Job Control (JC)	58	1.71	5	3.7241	0.65376
Social Support (SS)	58	1.33	5	3.4885	0.87128
Perceived Stress Scale (PSS)	58	0.5	3	1.7345	0.64958

Mean scores were interpreted using standard Likert-scale classification, where values between 3.67-5.00 indicate high levels, 2.34-3.66 indicate moderate levels, and 1.00-2.33 indicate low levels.

4.3.1 Job Demand

The job Demand score is relatively high indicating that ATCOs perceive a high level of workload, time pressure, and cognitive demand in their daily operations. The Standard deviation of 0.71 reflects moderate variation among respondents meaning most ATCOs experience similar level of elevated demands.

4.3.2 Social Support

The mean social support score indicates a moderate level of support from supervisor and colleague. The relatively high Standard deviation (0.87) suggests a wide variation meaning some ATCOs feel highly supported while other experience limited support which may influence stress as predicted by JDCS model

4.3.3 Job Control

Job control shows a moderately high mean value indicating ATCOs generally perceive good levels of decision latitude and skill discretion although slightly lower than perceived job demand. This aligns with specialized high responsibility nature of ATC job.

4.3.4 Perceived Stress

For descriptive interpretation, total PSS score was categorized into commonly applied cut-offs: 0-13 = low stress, 14-26 = moderate stress, and 27-40 = High stress. Perceived stress values are reported as mean item scores; higher values indicate higher stress and correspond proportionally to total PSS-10 scores. Mean item score (average per item) was 1.73, corresponding to a total estimated stress score of 17.3 among ATCOs at TIA. Given the high job demands reported. Minimum 0.5 and maximum 3 show variation meaning some controllers experience minimal stress while other experience high stress levels. The SD of 0.65 reflects moderate variation.

Table 7: Distribution of Stress levels (N=58)

Stress Category	Frequency	Percentage
Low Stress	19	32.80%
Moderate Stress	32	55.20%
High Stress	7	12.10%

Most respondents (55.2%) falls under the moderate stress category. However, 12.1 % of respondents experience high stress which is operationally concerning in safety critical professions such as air traffic control. And even a small high stress subgroup is operationally significant in Air traffic controlling as individual performance failures can have systemic safety consequences. Variability in perceived stress suggests difference in coping capacity, job control and job support mechanism.

The results indicate that ATCOs at Tribhuvan International Airport experience moderate levels of perceived stress which is comparable to findings reported in both regional and international studies. (Gautam, 2024) reported moderate to high stress levels among ATCOs in Kathmandu particularly among those exposed with rotating shift. Similarly, (Marta Makara, 2020) in their Polish study, the mean PSS-10 score among air traffic controllers was 13.75 ± 6.89 indicating predominantly low to moderate stress in that population. While very few studies publish PSS score for ATCOs specifically, we can compare to general adult normative scores from large samples. (Kristie M. Harris, 2023) in their research in U.S community sample, the average PSS-10 score was 13.08 ± 8.09. In contrast the present study sample demonstrated moderate stress levels overall, suggesting relatively greater perceived stress among ATCOs in Nepalese context.

Stress Analysis by Gender

Table 8: Stress scoredistribution by gender

Gender	Mean Stress	SD	N
Male	16.20	5.74	35
Female	19.09	7.29	23

An independent samples t-test was conducted to examine gender differences in total perceived stress score among ATCOs. Male ATCOs (N=35) reported lower mean stress score (M = 16.20, SD= 5.74) compared to female ATCOs (N=23, M=19.09, SD=7.29). However, the difference was not statistically significant, t (56) = -1.68, p = 0.098 (two tailed).

Stress Analysis by Work Experience

Perceived Stress level was analyzed across different experience groups as tabulated below:

Table 9: Stress level distribution among experience group

Experience Level	**Mean Stress Score**	**Standard Deviation**	**N**
Less than 1 year	9.5	0.71	2
1–3 years 3–5	20.82	6.94	11
years 5–10 years	16.08	6.39	12
More than 10	22.56	4.95	9
years	15.08	5.26	24

The results show a non-linear relationship between experience group and stress. Controllers with 5-10 years of experience reported the highest stress levels followed by those in 1–3-year category. This pattern suggests that stress peaks during mid-career stages where operational responsibility and task complexity increase by full autonomy and coping mechanism may not be fully developed.

Stress Analysis by Shift Pattern (Operational Risk Insight)

Table 10: Stress score by working shift pattern

Shift Type	Mean Stress	SD	N
Rotating	17.74	6.44	54
Day	12.67	6.35	3
Morning	10	-	1

Although samples are mostly associated with rotating shift confirming with work nature of air traffic controlling, rotating shifts are associated with higher level of stress which is consistent with:

Circadian rhythm disruption, fatigue accumulation and reduced recovery time. Rotating shift system introduces temporal misalignment between human cognitive capacity and operational demand, increasing stress.

Stress analysis by Working Position

Working position was classified into two group. To examine the stress effect across operational role, mean stress score was analyzed based on respondent's primary unit or position.

Table 11: Stress score across working position

Primary Unit / Position	Mean Stress Score	Standard Deviation	N
TWR only	17.81	7.47	21
TWR, APP and ACC	17.08	5.96	37

The results indicate perceived stress levels are moderate to high in both operational groups with mean stress score exceeding 17 in each category.

From human factors viewpoint tower-only controllers are exposed to high intensity, time critical decision-making particularly during peak traffic period involving take-offs, landing and ground movement coordination. These tasks demand continuous watch, rapid communication and immediate error rectification which can elevate perceived stress. Conversely controllers operating across multiple units (TWR, APP and ACC) experience broader task variety and higher overall system complexity but may benefits from larger procedural familiarity, task rotation which can reduce perceived stress despite higher cognitive demands. Although different Air traffic Control positions impose slightly different kind of workloads, the analysis shows that stress remains consistent across the unit indicating that stress in Air traffic controlling is systematic rather than position specific and must be addressed through organizational and ergonomic interventions.

4.4 Correlational Analysis

Pearson's correlation analysis was conducted to examine the bivariate relationship among Job Demand (JD), Job Control (JC), Social Support (SS), and Perceived Stress (PSS). The correlational coefficients are presented below in the table:

Table 12: Correlational relationship between the variables

S.N.	**Variable Pair**	**r-value**	**p-value**	**Strength & Direction**	**Significance**
1	Job Demand (JD) ↔ Job Control (JC) Job	0.064	0.633	Very weak positive	Not significant
2	Demand (JD) ↔ Social Support (SS) Job	-0.274	0.037	Weak negative	Significant
3	Demand (JD) ↔ Perceived Stress (PSS)	0.359	0.006	Moderate positive	Significant
4	Job Control (JC) ↔ Social Support (SS)	0.466	<0.001	Moderate positive	Significant
5	Job Control (JC) ↔ Perceived Stress (PSS)	-0.446	<0.001	Moderate negative	Significant
6	Social Support (SS) ↔ Perceived Stress (PSS)	-0.719	<0.001	Strong negative	Highly significant

Bivariate relations with stress

Job demand is moderately and positively correlated with PSS ($r = 0.359$, $P=0.006$), indicating that air traffic controllers who are experiencing higher job demands report higher perceived stress.

Social Support ($r = -0.719$, $p<0.001$) and Job Control ($r = -.446$, $p<0.001$) are both negatively related to PSS showing greater social support and greater decision latitude are each associated with substantially lower stress at bivariate level.

4.4 Regression analysis

This section analyzes regression models used to test the core assumption of Job Demand Control Support (JDCS) model in the context of air traffic controllers in Nepal. Perceived Stress (PSS) was used as dependent variable, while Job Demand (JD), Job Control (JC) and Social Support (SS) are used as independent variable.

The analysis was conducted in two different stages:

Main effect of JD, JC and SS on Stress

The multiple regression model assessed the predictive effects of Job demand (JD), Job control (JC) and Social Support (SS) on perceived stress (PSS) among ATCOs

The regression model examining the effects of Job Demand, Job Control, and Social Support on Perceived Stress among Air Traffic Controllers was statistically significant, $F(3,54) = 24.245$, $p < .001$. The predictors together accounted for 57.4% of the variance in stress ($R^2 = .574$), with an adjusted R^2 of .550, indicating that the model is both strong and stable. The high correlation coefficient ($R = .758$) suggests that the combination of JD, JC, and SS is strongly related to perceived stress, confirming the relevance of the JDCS model in the ATC work environment.

This is notably higher than previously reported values in occupational stress research. (Bruin, 2006) in JDCS model of workforce study reported explained variances of approximately 34%-40% for psychological strain outcomes across gender groups indicating substantially smaller explanatory power. In another study (Majid Bagheri

Hossein Abadi, 2021) among Iranian nurses reported that JDCS predictors explained 42% of the variance ($R^2 = 0.49$) which is comparable to variance in present study.

The comparatively higher explained variance in the current study may reflect the highly structured and standardized nature of air traffic control work where job demand, decision discretion and social support are more uniformly experienced across other professional settings.

Interpretation of coefficients table

Job Demand (JD) → Stress

- Job Demand significantly predicted higher stress levels ($\beta = .215$, $p = .028$), reflects sustained cognitive workload and temporal pressure which in human factors are increased attention tunnelling, fatigue accumulation and error susceptibility in safety critical operations.

Job Control (JC) → Stress

- Job control has a negative effect meaning more autonomy reduces stress. The result is marginally non-significant ($\beta = –.195$, $P= 0.064$)

Social Support (SS) → Stress

- Social Support emerged as the strongest predictor of perceived stress ($\beta = –.570$, $p < .001$). High level of support from coworker and supervisor support greatly reduced stress level among ATCOs.

Moderation Testing

M1: Moderation effect of social support (SS) on relationship between Job Demand (JD) and perceived stress (PSS).

Model 1A: Main effects model

- Job Demand (JD_C)
- Social Support (SS_C)

Model fit:

- $R = .739$
- $R^2 = .546$
- Adjusted $R^2 = .529$
- $F(2, 55) = 33.04$, $p < .001$

Model 1 explained 54.6% of the variance in perceived stress, indicating strong and statistically significantly relationship between Job Demand, Social Support, and Stress among air traffic controllers.

Table 13: coefficients table for mean centered variable

Predictor	**B**	**β**	**p-value**	**Interpretation**
JD_C	0.159	0.174	0.071	Positive but marginally non-significant
SS_C	-0.501	-0.672	< .001	Strong, significant negative effect

Social support is the dominant predictor of stress. Higher social support substantially lowers perceived stress.

After adding the moderation effect (SS XJD), change statistics are presented as below:

- $\Delta R^2 = .003$
- F-change = 0.367
- P = 0.547

Table 14: coefficient table for moderation effect

Predictor	**β**	**p-value**	**Interpretation**
JD_C	0.184	0.061	Still marginal
SS_C	-0.655	< .001	Remains strongly significant
Moderation(SS × JD)	-0.058	0.547	Not significant

Mean centering was applied to the independent variables before creating interaction term to reduce multicollinearity and improve coefficient interpretability in the moderation analysis.

The results indicate that the relationship between job demand and perceived stress is not significantly moderated by social support, suggesting that social support functions primarily as direct factor rather than buffering mechanism in this sample.

Hierarchical regression analysis revealed that job demand and social support together explained a substantial portion of variance in perceived stress among air traffic controllers. Social support emerged as a strong and statistically significant negative predictor of stress, while job demand showed a positive but marginal effect. The addition of the interaction term did not significantly improve the model, indicating absence of moderation effect. These finding suggest that social support operates as a direct stress- reducing factor rather than buffering mechanism, highlighting the importance of organizational and peer support system in high-demand, safety critical work environment. Multi collinearity was assessed using VIF (Variance Inflation Factor), tolerance and collinearity diagnostics, where all indicated that no multicollinearity issues in the regression models.

M2: Moderation effect of social support (SS) on relationship between Job Control (JC) and perceived stress (PSS).

This tests if social support moderates the effect of job control on perceived stress, consistent with the buffering hypothesis of Job Demand Control Support (JDCS) model.

Model 1B (Main effect only)

Model fit

- $R = .730$
- $R^2 = .533$
- Adjusted $R^2 = .516$
- $F(2,55) = 31.444$, $p < .001$

Job control and social support jointly explained 53.3% of the variance in perceived stress, indicating a strong and statistically significant main-effect model.

Table 15: coefficient table of JD_C and SS_C

Predictor	**β**	**p-value**	**Meaning**
JC_C	-0.142	0.178	Not significant
SS_C	-0.653	< .001	Strong, significant

Social support directly reduces stress. Job control does not significantly predict stress in isolation. A hierarchical moderated regression was conducted with perceived stress as the dependent variable and mean-centered job control (JC_C), mean centered social support (SS_C), and their interaction term (JC_C × SS_C)

After adding the moderating variable (SS × JC), change variables are as follow:

- $R = .793$
- $R^2 = .629$
- Adjusted $R^2 = .609$
- $\Delta R^2 = .096$
- F-change $(1,54) = 13.977$, $p < .001$

Collinearity diagnostics (Condition indices < 2, VIF = 1.026) indicated no problem in multicollinearity among predictors.

Table 16: coefficient table after moderation

Predictor	**β**	**t**	**p-value**
JC_C	-0.141	-1.509	0.137
SS_C	-0.604	-6.382	< .001
Moderation (SS × JC)	0.314	3.739	< .001

For further understanding the model the relationship can be represented by following regression equation:

$$\text{Perceived stress} = b + (-0.141)\,JC + (-0.604)\,SS + (0.314)\,(JC \times SS)$$

Adding the moderation term increased variance by 9.6%. Hierarchical analysis revealed that social support significantly moderates the relationship between job control and perceived stress, The interaction between job control and social support was statistically significant and accounted for substantial increase in explained variance. This indicates that social support moderates the relationship between job control and perceived stress.

Overall, the findings confirmed that occupational stress among ATCOs at TIA is shaped by the interaction of high job demands, constrained operational control, and variable social support. These results provide a coherent empirical foundation for conclusion and organizational recommendations presented in next chapter.

4.5 Summary of Key Findings

This thesis examined occupational stress among Air Traffic Controllers (ATCOs) stationed at Tribhuvan International Airport using Job-Demand-Control-Support (JDCS) theoretical framework. With the use of census-based survey of 58 ATCOs (84% response rate), the research investigated how job demands, job control, and social support influence perceived stress levels in unique operational context of TIA.

The findings confirm that occupational stress among ATCOs at TIA is not an individual issue but a systematic outcome of high job demand, constrained operational control and variability in social support. The JDCS framework demonstrated strong explanatory power in this safety-critical aviation environment.

4.5.1 Hypothesis Testing Summary

H1: Job Demands and Perceived Stress (Supported)

The study confirmed that higher job demands are significantly associated with elevated perceived stress ($r = 0.359$, $p = 0.006$ and $\beta = 0.215$, $p = 0.028$). ATCOs at TIA experience substantial workload pressure, with a mean job demand score of 3.92 (SD = 0.71) reflecting the high cognitive workload, time pressure and complexity inherent in managing heterogenous traffic. From a human-factors perspective, sustained high demand increases mental workload, fatigue accumulation, and vulnerability to performance deterioration.

H2: Job Control and Perceived Stress (Supported)

The negative relationship between job control and perceived stress was confirmed ($r = -0.446$, $p<0.001$). However, in multivariate regression this effect became marginally non-significant ($\beta = -0.195$, $p = 0.064$) suggesting that job control's influence on stress may be partially mediated or suppressed by other factors, particularly social support. This finding aligns with the constrained operational environment of Air Traffic Controlling in TIA where ICAO procedures and other TIA operational limitation reduce ATCOs decision latitude.

H3: Social Support and Perceived Stress (Strongly Supported)

Social support emerged as the strongest predictor of reduced stress ($r = -0.719$, $p < 0.001$; $\beta = -0.570$, $p < 0.001$). This finding underscores the critical buffering role of supervisory and peer support in high stress, safety critical environment. ATCOs who perceived higher levels of team coordination and organizational support reported substantially lower stress levels. This finding highlights the critical role of teamwork, supervisory support, and organizational dynamics in maintaining psychological resilience in safety-critical operations.

H4: Social support as Moderator of Job Demand Stress Relationship (Not supported)

Contrary to the buffering hypothesis of JDCS model, social support did not significantly moderate the relationship between job demand and perceived stress ($\beta = -0.058$, $p = 0.547$; $\Delta R^2 = 0.003$). The absence of significant moderation suggests that certain operational job demands at TIA- such as traffic density and terrain constraints are inherently non-negotiable. This suggests that in TIA context social support function primarily as a direct stress reducing factor rather than a buffer against high demands.

H5: Social Support as Moderator of Job Control – Stress Relationship (Supported)

A significant interaction effect was found between job control and social support in predicting stress ($\beta = 0.314$, $p < 0.001$; $\Delta R^2 = 0.096$). This 9.6% increase in explained variance indicates that the job control-stress relationship is significantly moderated by social support. The positive coefficient suggests a complex interaction: the protective effect of job control on stress may be most pronounced when social support is lower, while high social support may compensate for limited control.

At lower levels of social support, higher job control is associated with lower stress, however at high support, the marginal benefit of additional control diminishes, consistent with the idea that supportive social climate can compensate for limited autonomy,

4.5.2 Demographic and Work-Related Patterns

Gender Differences: Female ATCOs reported higher mean stress score (Mean Stress Level = 19.00, SD = 7.29) compared to male ATCOs (Mean Stress Level = 16.2, SD = 5.74) with greater variability. This finding warrants organizational attention to potential differential experiences, workplace dynamics or coping resources availability across the genders.

Experience- Stress Trajectory: The nonlinear relationship between experience and stress revealed that mid-career controllers (5-10 years) reported highest stress levels (M = 22.56, SD =4.95). This pattern suggests a critical period where operational responsibility and task complexity peak before full autonomy and mature coping mechanism develop.

Shift Work: There are three working shifts allocated in Tribhuvan International Airport for ATCOs. Most ATCOs (93.1 %) are working in rotating shift with shift changes every two days. High stress, circadian rhythm disruption, fatigue accumulation, and reduced recovery time associated with irregular work schedules as found out by (Diane B. Boivin, 2022) and (Maximilian Peukert, 2025).

Workload: One third of respondents (34.5%) reported working more than 50 hours per week increasing fatigue risk a finding presented in TIA safety report 2024 which documents 28 ATM/NAV/MAC related safety occurrences linked to human performance limitations.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion Based on Research Objectives

5.1.1 Conclusion Based on the General Objective

The general objective of this thesis was to analyze occupational stress experienced by Air Traffic Controllers at Tribhuvan International Airport using the Job-Demand-Control-Support (JDCS) model. The finding confirmed that ATCOs at TIA experience moderate to high levels of occupational stress mainly driven by high job demands combined with constrained job control. The JDCS framework was found to be effective in explaining stress in Nepalese air traffic control environment accounting for 62.9% of the variance in perceived stress, thereby validating its applicability in a highly safety critical aviation environment.

5.1.2 Conclusion Based on Specific Objective 1 (To assess the level of job demands, job control and social support among ATCOs)

The finding in this thesis revealed that job demands were high among ATCOs with mean score of 3.92 (SD=0.71) at TIA reflecting workload, time pressure and sustained cognitive effort. Job control was perceived at a moderate level (Mean=3.72, SD=0.65) signaling limited decision latitude due to strict procedures, airspace constraints, and infrastructure limitations. Social support was also reported as moderate level (Mean= 3.49, SD=0.87), with noticeable variation among ATCOs suggesting inconsistent availability of supervisory and peer support across operational units.

5.1.3 Conclusion with Respect to Specific Objective 2 (Relationship between JDCS variables and perceived stress)

The relationship analysis demonstrated that job demands were positively and significantly associated with perceived stress ($r = 0.359$, $p < 0.01$), confirming that increasing workload and time pressure elevated stress levels among ATCOs. Job control exhibited a moderate negative relationship with perceived stress ($r = 0.446$, $p<0.001$), indicating that higher decision latitude and skill discretion are linked with reduced stress. Similarly social support showed a significant negative association with perceived stress.

These findings collectively support JDCS conceptual framework that high demand increases stress while job control and social support act as mitigating resources.

5.1.4 Conclusion Based on Specific objective 3 (Moderating role of social support)

The hierarchical regression analysis confirmed that social support did not moderate the job demand-stress relationship ($\Delta R^2=0.003$, $p=0.547$) but significantly moderated job control-stress relationship ($\Delta R^2=0.096$, $p<0.001$, $\beta=0.314$). High social support partially compensated for limited control, reducing stress among ATCOs.

5.1.5 Conclusion Based on Specific Objective 4 (To analyze stress variation based on demographic variables)

Demographic analysis revealed that 55.2% of ATCOs experienced moderate stress, while 12.1% reported high stress, which is operationally significant given the safety critical nature of air traffic control. Gender based differences in perceived stress were observed with female ATCOs reporting higher mean stress scores in comparison to male counterparts. Stress levels varied across experience group with mid-career ATCOs (5-10 years of experience) exhibiting the highest stress levels, suggesting increased responsibility and workload during this phase. Most ATCOs were found to be working in rotating shift compared to fixed shift highlighting the influence of circadian disruption and fatigue on occupational stress at TIA.

5.1.6 Model Fit and Explained Variance

The full JDCS model explained 57.4% of variance in perceived stress ($R^2 = 0.574$, $F(3,54) = 24.245$, $p < 0.001$), demonstrating strong predictive validity. The addition of the social support x job control interaction term increased explained variance to 62.9% ($R^2 = 0.629$), confirming the model’s robustness in ATC context of Nepal.

5.2 Theoretical Contribution

This study reframes occupational stress not as individual vulnerability but as a system-level signal indicating misalignment between job demands, human cognitive limits and operational resources.

5.2.1 Validation of JDCS Model in South Asian Aviation Context

This study represents first systematic application to use multivariate regression to test JDCS moderation hypothesis in the Nepalese ANSP context, addressing a significant geographical and contextual gap in occupational stress literature. While previous studies (Gautam, 2024) quantified stress prevalence, this thesis makes advancement on those studies by:

- Establishing the theoretical mechanism through which job demands, control and support influence stress.
- Demonstrating that the JDCS model, developed primarily in Western contexts, retains predictive validity in South Asian aviation environment.
- Provide empirical support for 4 of 5 hypotheses derived from JDCS theory.

5.2.2 Integration with Aviation Safety Science

The triangulation of JDCS findings with operational safety data from the TIA safety report 2024 provides a compelling Human Factors narrative:

- 28 cognitively intensive safety occurrences (ATM, NAV, MAC) correlate with high reported job demands and stress.
- Infrastructure limitation (ADRM occurrences) objectively constrains job control.
- The concentration of incidents in attention demanding categories (BIRD: 48 event) reflects sustained vigilance demands.

By empirically connecting ATCO stress, JDCS variables and occurrences categories, this study contributes to aviation human-factor science by showing how psychosocial risk factors and safety performance indicators can be integrated within a single socio-technical framework for Tribhuvan International airport. Furthermore, this integration demonstrates that occupational stress is not merely a well-being issue but has important safety implication aligning with ICAO and ILO emphasis on human factors in aviation safety.

5.3 Practical Implications and Recommendations

Based on the findings, recommendations are proposed at organizational, technological, ergonomic, and policy levels.

5.3.1 Organizational-Level Interventions

Enhance Social Support Structures

TIA management should prioritize:

1) Formalized Peer Support Programs: Establish structured mentoring systems pairing experienced ATCOs with mid-career ATCOs (5-10 years) who showed highest stress levels.
2) Supervisory Training: Develop leadership development programs focusing on transformational leadership, emotional intelligence and stress recognition for supervisors.
3) Team Coordination Workshops: Regular simulation based excercises emphasizing inter-unit coordination to strengthen collegial bonds.
4) Create confidential feedback mechanism (safety culture survey, stress debriefing sessions) to facilitate dialogue between ATCOs of TIA and management.

Workload management and Roster Optimization

To address high job demands (M=3.92) and high duty hours (34.5% working > 50 hours/week):

1) Workload Monitoring system: Implement real-time workload assessment tools e.g NASA-TLX during peak traffic period to identify overload conditions.
2) Dynamic Rostering: Develop evidence-based shift schedules that minimize circadian disruption, adequate recovery time and limit consecutive night shifts,
3) Fatigue Risk Management System (FRMS) should be data-driven using local operational data rather than using generic templates.
4) Strategic Staffing: Increase controller workforce to reduce per-controller workload, particularly during peak traffic seasons.

Job Control Enhancement

While the operational constraints limits autonomy, incremental improvements are possible:

1) Participatory Decision making: Involve ATCOs in procedural review, roster design and workplace ergonomics decisions.
2) Skill Discretion Development: Provide advanced training in non-routine scenarios (Emergency procedures, adverse weather operation) to increase ATCOs problem solving capacity.
3) Flexible Break Scheduling: Allow ATCOs greater autonomy in timing short break during low traffic periods.
4) Input on Technology Adoption: Engage ATCOs in CNS(Communication, Navigation and Surveillance) infrastructure upgrade planning to ensure user-centric design adoption.

5.3.2 Infrastructure and Technological Interventions

Upgrade CNS infrastructure

The TIA safety report documented 8 NAV related occurrences and 13 ATM incidents, reflecting technological limitations. Priority investments should include:

1) Precision Approach System: Install ILS (Instrument Landing System) to reduce weather related operational pressure.
2) Enhanced Radar Coverage: Extend radar surveillance to STOL sectors to improve situational awareness and reduce cognitive workload.
3) Digital Communication system : Transition from analog R/T to Controller Pilot Data Link Communication (CPDLC) to reduce repetitive voice communication workload.

Airspace and procedural Optimization

1) Airspace redesign: Collaborate with ICAO, and Aviation experts to optimize arrival/departure routes that maximize usable airspace with terrain constraints.

2) Segregated Helicopter Routes: Establish dedicated VFR helicopter routes to reduce randomness and conflict potential with fixed-wing traffic.
3) Further sectorization of kathmandu TIA (Terminal Control Area) and fully implement ATFM (Air Traffic Flow Management) System to ensure maximum utilization of declared capacity of TIA.
4) AMAN(Arrival Manager) to optimize arrival sequencing and spacing. DMAN (Departure Manager) to optimize departure flow and runway usage.
5) Establishment of separate ATC Clearance Delivery unit to reduce workload of surface movement controller in Aerodrome Control Tower.

5.3.4 Occupational Health and wellness program

1) Regular stress screening: Conduct regular stress screening using validated tools like PSS-10 or similar tools semi-annually to identify at risk individuals early which to be part of proactive human-factor program.

2) Psychological Counselling Service: Provide confidential access to occupational psychologist specializing in safety critical professions.

3) Stress Management Training: Conduct workshop on evidence based coping strategies (mindfulness, cognitive reframing, time management)

5.3.5 Policy and Regulatory Recommendations

National ATC well-Being Policy

TIA management should develop a comprehensive policy framework addressing:

1) Maximum duty hours: Enforce strict limits aligned with ICAO standards and fatigue science
2) Just culture Implementation: Adopt non-punitive reporting systems that encourages disclosure of stress related performance issue.

Continuous Monitoring and Research

1) Longitudinal stress monitoring: Establish annual occupational health survey to track trends and intervention effectiveness.

5.4 Future Research Direction

1) Future research should employ longitudinal designs to track how stress levels change with seasonal traffic variations in Nepal.

2) Incorporating physiological markers (e.g. cortisol levels or heart rate variability) would provide a more objective measure of the stress experience during high density traffic.

3) Extend the study to include ATCOs from other Nepali airport to improve generalizability and compare stress profile across different operational environments.

4) Explore qualitative perspectives (Interviews/focus group) to capture deeper experiential insights into occupational stress.

REFERENCES

Gautam, K. (2024). Stress-related factors and their correlation among Air Traffic Controllers of Kathmandu, Nepal. *Janaki Medical College Journal of Medical Sciences*, 25-31.

Lihua Tang, L. F. (2022). Study on the Relationship between Occupational Stress and Job Burnout of Air Traffic Controllers of Civil Aviation . *Industrial Engineering and Innovation Management* , 61-67.

Bader Alaydi, S.-I. N. (2024). Mitigating the Negative Effect of Air Traffic Controller Mental Workload on Job Performance: The Role of Mindfulness and Social Work Support. *Safety*.

Costa, P. G. (1996). *Occupationalstress and stress prevention in air traffic control.* International Labour Office.

Usana García-Herrero, J. R.-G. (2017). The Influence of Recognition and Social Support on European Health Professionals' Occupational Stress: A Demands-Control-Social Support-Recognition Bayesian Network Model. *BioMed Research International*.

Atmaka, E. W. (2024). Fatigue, Stress, and Job Satisfaction in the Air Traffic Controller (ATC) Work. *Indonesian Journal of Interdisciplinary Research in Science and Technology (MARCOPOLO*, 1461-1474.

Iva Tomic, J. L. (2017). Strategies to Overcome Fatigue in Air Traffic Control Based on Stress Management. *The International Journal of Engineering and Science (IJES)*, 48-57.

Iqbal, M. (2012). Impact of Job Stress on Job Satisfaction among Air Traffic Controllers of Civil Aviation Authority: An Empirical Study from Pakistan. *International Journal of Human Resource Studies*, 53-70.

Hsiang Te Liu, H. H. (2018). The Causal Model Analysis of Job Demand-Control-Support, Job Stress, And Job Satisfaction: The Samples From Correctional Officers in Taiwan. *CNU Journal of Higher Education*, 42-54.

Maes, M. V. (2010). The Job Demand-Control (-Support) Model and psychological well-being: A review of 20 years of empirical research. *Work & Stress*.

Fawad Asif, U. J. (2018). The Job Demand-Control-Support Model and Employee Wellbeing: A Meta-Analysis of Previous Research. *Pakistan Journal of Psychological Research*, 203-221.

Llewellyn Ellardus van Zyl, M. A. (2025). Cracks in the JD-R model? The failure of strengths use, job crafting, and home-work spillover to support wellbeing during COVID-19. *Frontier in Psychology*.

Igor Portoghese, M. G. (2020). Job Demand-Control-Support Latent Profiles and Their Relationships with Interpersonal Stressors, Job Burnout, and Intrinsic Work Motivation. *International Journal of Environmental Research and Public Health*.

Natasja van Vegchela, J. d. (2005). Reviewing the effort–reward imbalance model:drawing up the balance of 45 empirical studies*Social Science &Medicine* , 1117–1131.

Blanch, A. (2016). Social support as a mediator between job control and psychological strain. *Social Science & Medicine*, 148-155.

Peng Bai, Y. C. (2024). Research on the influence of bad working state on air traffic control effect based on multi-independent sample Kruskal-Wallis test. *Journal of Air Transport Management*.

ICAO. (1998). *Human Factor Manual.* International Civil Aviation Organization.

ICAO. (2000). *HumanfactorsguidelinesforAirTraffic Management (ATM) System.* International Civil Aviation Organization.

Marta Makara, S. M.-M. (2020). An Exploration of Perceived Stress, Burnout Syndrome, and Self-Efficacy in a Group of Polish Air Traffic Controllers and Maritime Navigators: Similarities and Differences. *International Journal of Environmental Research and Public Health*.

Aristi Karagkouni, S. Z. (2025). Assessment of Occupational Health and Safety Performance in Air Traffic Control: An Empirical Investigation of Stress and Well-Being. *Safety*.

Fatmawaty Mallapiang, A. W. (2022). Description of Qualitative workload, carreer development and personal responsibility toward the risk of work stress operators on Air Traffic Controller (ATC). *Hospital Management Studies Journal (Homes Journal)*.

Demerouti, B. (2006). The Job Demands-Resources model: state of the art. *Journal of Managerial Psychology*.

ICAO. (2018, 15th edition). *ICAO Annex 11, Air Traffic Services.* International Civil Aviation Organization.

Kristie M. Harris, A. E. (2023). The Perceived Stress Scale as a Measure of Stress: Decomposing Score Variance in Longitudinal Behavioral Medicine Studies. *Annals of Behavioral Medicine*, 846-854.

(2024). *Aviation safety report.* Civil Aviation Authority of Nepal.

Cochran, W. G. (1977). *Sampling Techniques.* JOHN WILEY & SONS.

Diane B. Boivin, P. B. (2022). Disturbance of the Circadian System in Shift Work and Its Health Impact. *Journal of Biological Rhythms*, 3-28.

Maximilian Peukert, L. C. (2025). Subjective and objective fatigue dynamics in air traffic control. *Ind Health*, 431-442.

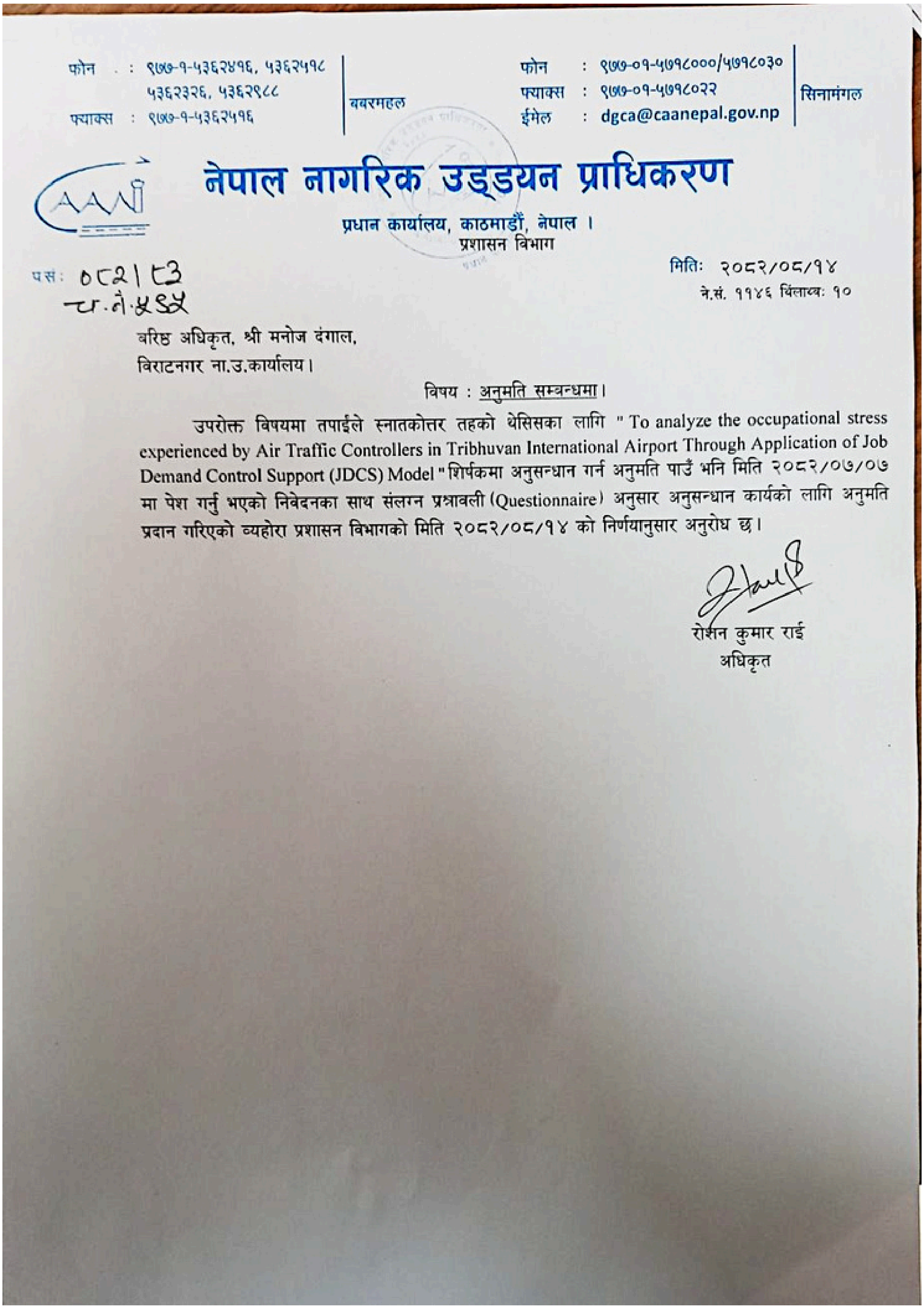
Christopher D. Wickens, W. S. (2022). *Engineering Pyschology and Human Performance* . New York, NY 10158: Routledge .

Reason, J. (1997). *Managing the Risks of Organizational Accidents.* New York: Routledge.

Bruin, G. P. (2006). The Job Demand Control Model of Job Strain across Gender. *SA Journal of Industrial Psychology*, 66-73.

Majid Bagheri Hossein Abadi, E. T. (2021). Relationships Between Job Satisfaction and Job Demand, Job Control, Social Support, and Depression in Iranian Nurses. *The Journal of Nursing Research* .

APPENDIX-A (PERMISSION FROM CAAN)



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फोन : ९७७-०१-४७१८०००/४७१८०३०
फ्याक्स : ९७७-०१-४७१८०२२
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प्रशासन विभाग

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बरिष्ठ अधिकृत, श्री मनोज दंगाल,
विराटनगर ना.उ.कार्यालय।

विषय : <u>अनुमति सम्बन्धमा</u>।

उपरोक्त विषयमा तपाईले स्नातकोत्तर तहको थेसिसका लागि " To analyze the occupational stress experienced by Air Traffic Controllers in Tribhuvan International Airport Through Application of Job Demand Control Support (JDCS) Model " शिर्षकमा अनुसन्धान गर्न अनुमति पाउँ भनि मिति २०८२/०७/०७ मा पेश गर्नु भएको निवेदनका साथ संलग्न प्रश्नावली (Questionnaire) अनुसार अनुसन्धान कार्यको लागि अनुमति प्रदान गरिएको व्यहोरा प्रशासन विभागको मिति २०८२/०८/१४ को निर्णयानुसार अनुरोध छ।

रोशन कुमार राई
अधिकृत

APPENDIX-B (QUESTIONNAIRE USED IN THESIS)

Occupational Stress Among Air Traffic Controllers in Nepal: An Application of the Job Demand Control Support (JDCS) Model - A case study in Tribhuvan International Airport

Dear Participant,

This survey is part of a study on how **Job demand, Job control and support affect stress among air traffic controllers**. Your honest feedback will help identify ways to improve comfort, safety, and performance in ATC workspaces.

It takes only **8-10 minutes**, and your responses will remain **completely confidential**.

Thank you for your valuable time and support!

Instructions:

• Please answer all questions as honestly as possible. There are no right or wrong answers.

• Unless otherwise stated, use the response scale shown at the start of each section.

* Indicates required question

1. Consent & Participation • *

Purpose: This study examines dob demand, job control, job support and their relationship with stress among air traffic controllers.

• Time required: Around 8-10 minutes.
• Risks: None anticipated.
• Voluntary & Anonymous: Participation is voluntary and identity will remain Anonymous.
• Data Use: Results will be used for academic purposes.

I confirm that I am 18+ years old and consent to participate

Check all that apply.

☐ Yes

DEMOGRAPHIC SECTION

2. D1. Age (years) *

3. D2. Gender (optional) *

Mark only one oval.

- ⬭ Male
- ⬭ Female
- ⬭ Other

4. D3. Years of ATC experience in TIA (years) *

Mark only one oval.

- ⬭ Less the 1 year
- ⬭ 1-3 years
- ⬭ 3-5 years
- ⬭ 5-10 years
- ⬭ More than 10 years

5. D4. Primary unit/position : *

Mark only one oval.

- ⬭ TWR only
- ⬭ TWR, APP AND ACC

6. D5. Typical duty shift pattern: *

Mark only one oval.

- Morning
- Day
- Night
- Rotating

7. D6. Average weekly duty hours

Mark only one oval.

- Less than 40 Hours
- 40-50 Hours
- More than 50 Hours

Job Demand Section

Response Scales

Agreement scale:

1 = Strongly disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly agree

8. Job Demand Section *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
My job requires working very fast.	⬭	⬭	⬭	⬭	⬭
My job requires working very hard.	⬭	⬭	⬭	⬭	⬭
I am often required to maintain a high level of concentration for long periods.	⬭	⬭	⬭	⬭	⬭
I have too much work to do in too little time.	⬭	⬭	⬭	⬭	⬭
The traffic load during peak hours is overwhelming.	⬭	⬭	⬭	⬭	⬭
I face frequent unexpected situations requiring rapid decision-making.	⬭	⬭	⬭	⬭	⬭
I experience high mental pressure while managing aircraft.	⬭	⬭	⬭	⬭	⬭

9. Job Control Section *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
My job requires me to be creative in solving problems.	⬭	⬭	⬭	⬭	⬭
My job requires a high level of skill and expertise.	⬭	⬭	⬭	⬭	⬭
I have the opportunity to learn new things at work.	⬭	⬭	⬭	⬭	⬭
I am able to use my skills fully during ATC operations.	⬭	⬭	⬭	⬭	⬭
I have a lot of say about what happens on my job.	⬭	⬭	⬭	⬭	⬭
I can decide how to carry out my tasks.	⬭	⬭	⬭	⬭	⬭
I feel I have control over important decisions in my work.	⬭	⬭	⬭	⬭	⬭

Social support

Agreement scale
1 = Strongly disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly agree

10. Social Support *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
My supervisors are concerned about the welfare of ATCO's.					
I receive useful feedback from my supervisors.					
My supervisors help me when I face difficulties.					
My colleagues are friendly and supportive.					
I can rely on my colleagues when I encounter problems.					
There is a good sense of teamwork among ATCOs..					

11. Perceived stress test

Mark only one oval per row.

	Never	Almost never	Sometimes	Fairly often	Very often
In the last month, how often have you been upset because of something unexpected?	⬭	⬭	⬭	⬭	⬭
In the last month, how often have you felt unable to control important things in your life?	⬭	⬭	⬭	⬭	⬭
In the last month, how often have you felt nervous and stressed?	⬭	⬭	⬭	⬭	⬭
In the last month, how often have you felt confident about your ability to handle personal problems?	⬭	⬭	⬭	⬭	⬭
In the last month, how often have you felt that things were going your way?	⬭	⬭	⬭	⬭	⬭
In the last month, how often have you found	⬭	⬭	⬭	⬭	⬭

you could not cope with all the things you had to do?					
In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
In the last month, how often have you felt on top of things?	○	○	○	○	○
In the last month, how often have you been angered because of things that were outside your control?	○	○	○	○	○
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

12. OE1. For Stress reduction, if you could change one aspect of your workstation, environment, or system, what would it be and why?

APPENDIX-C (PLAGIARISM REPORT)

Manoj Dangal

Occupational Stress and Human Factors Among Air Traffic Controllers at Tribhuvan International Airport: An Application ...

Tribhuvan University

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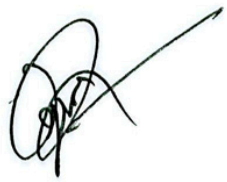

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