Human Factors and Workload in Air Traffic Control Operations - A Review of Literature

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ABSTRACT

Purpose: The present paper focuses on the review of concepts, theories and empirical underpinnings of human factor in Air traffic control through literature studies primarily in the light of mental work load. This paper reviews what is currently known about workload, particularly from the field of ATC. One of the few areas of almost universal agreement in the literature on ATC complexity is that complexity plays a major role in driving controller workload.

Design/methodology/approach: Workload in ATC is generally mental, as opposed to physical, in nature. The paper will therefore briefly review what is known about mental workload.

Findings: The findings of the paper implicitly point out that workload factor include mental work load, ATC Task Load Factors and ATC Operator Factors. Workload in ATC is generally mental, as opposed to physical, in nature. Task load i.e., the demand imposed by the ATC task itself is generally distinguished from workload i.e., the controller’s subjective experience of that demand. The link between ATC task load and workload is a causative (albeit indirect) one, that is influenced by a number of internal factors.

Originality/value: Based on literature review of 25 empirical articles, the paper makes Managerial implications that the workload factor include mental workload, ATC Task Load Factors and ATC Operator Factors. All researchers are sanguine that the relationship between task load and perceived workload can ever be adequately expressed.

Key Words: Mental Work Load, ATC Task Load Factors, ATC Operator Factors.

1. INTRODUCTION

The most prevalent theme echoed in the literature on traffic management centres was that each centre is unique. Generally speaking, two types of centres exist: (1) very new centres and (2) legacy centres. The legacy centres generally started smaller in size and staffing, lower in technology, and more specific in their mission since they were created for more immediate needs. One good example is the centre in New York City. Its initial purpose was to control the signal timing throughout the city and monitor the tunnels leading to Manhattan Island for incidents. Currently, under the 1996 Federal Highway Administration’s Model Deployment Initiative, the New York legacy traffic management centres are evolving to provide travelers with real-time travel information by integrating of information provided by 14 different area agencies. Legacy traffic management centres are often faced with the challenge of taking on new roles and responsibilities, causing the need to increase in size and staffing. Whereas before these centres operated independently, they now need to develop liaises of communication and partnership agreements with other agencies. Finally, one of the most critical problems faced by legacy centres is dealing with evolutionary technology upgrades. The technology used to monitor older sections of the roadway may be completely different than the technology used to monitor the newer roadway sections.

ATC involves a wide array of equipment, operational procedures, and many thousands of personnel in a variety of occupational categories. It is difficult to conceptualize the system as a whole and to discuss human factors problems relating to the entire man-machine system at one time without other difficulties intruding. The principal among these difficulties is the fact that the system is an ever changing mixture of men and machines. At the present time, many en route and terminal facilities are being equipped with new NAS Stage A and ARTS 111 hardware and software. However, much of the air traffic for the next few years will continue to operate within the context of older ATC systems. Consequently, for a substantial period into the future, there will be a mix comprised of manual, semi automated, and fully automated operations for performing many of the most important functions. Thus, highly specific recommendations concerning studies to be conducted of particular panels and displays, operational procedures, communications techniques, and the like, would be inappropriate in a report of this type. Furthermore, FAA personnel (particularly those at NAFEC) have an excellent on-going program for conducting such studies and the developing recommendations and concerning specific man-machine interface problems. It seems likely that those who are close to the operational situation on a day-to-day basis can most effectively identify, study, and recommend solutions to these highly specific human factors problems.
2. STATEMENT OF PROBLEM

This paper reviews what is currently known about mental workload, particularly from the field of ATC. One of the few areas of almost universal agreement in the literature on ATC complexity is that complexity plays a major role in driving controller workload. Workload in ATC is generally mental, as opposed to physical, in nature. The paper will therefore briefly review what is known about mental workload.

3. OBJECTIVE OF THE PAPER

The vast complexity and the diffused nature of the air traffic control systems makes it necessary to adopt some organizing structure in order to obtain an overview for considering the system as a whole. The main objective of the paper is to review the underpinning of human factors in ATC in mental workload perspectives.

4. LITERATURE REVIEW

A. Mental Workload

Interest in defining and developing metrics of mental workload has grown dramatically since the mid-1970s (Sanders & McCormick, 1987; Wickens, 1980). Most attempts to define mental workload have grown by way of analogy out of the concept of physical workload (Meshkati, Hancock & Rahimi, 1990).

The lack of a clear definition is reflected in the disagreement over appropriate metrics of mental workload. It seems generally agreed that mental workload is not a unitary, but a multi-dimensional concept (Leplat, 1978; Moray, 1979; Kramer, 1991), that taps both the difficulty of a task and the effort (both physical and mental) brought to bear (Gopher & Donchin, 1986). It therefore represents an interaction between task and operator, that can vary for different task-operator combinations (Leplat, 1978). Such factors as time pressure, noise, stress, and distraction can all influence the ‘human costs’ of performing a given task (Hancock & Chignell, 1988; Jorna, 1993). Aptitude, skill, experience, operating behaviours, and personality traits have all been cited as determinants of subjective workload in ATC (Bisseret, 1971; Sperandio, 1978). Clearly, the same given task might represent a reasonable amount of workload for an experienced operator, yet overtax a novice. The distinction is generally made between task load (the objective demands of a task) and workload (the subjective demand experienced in the performance of a task). Inherent in the notion of mental workload has been the concept that the human operator has a limited capacity to process information. Information processing models of the 1950s grew out of the field of communications engineering. Experiments into “dichotic listening” by Colin Cherry in the early 1950s demonstrated the difficulty humans have in dividing attention. In what has been termed the “cocktail party phenomenon,” people are able to attend to only one source of information, unless some salient stimulus—such as their own name—is broadcast. The notion of channel capacity was adopted to explain limitations of the information processing system.

Based on mounting evidence, theories of attention have been significantly refined over the years. The 1970s saw the emergence of “resource models” of attention, which postulate that all cognitive processes demand resources that are available only in limited supply. Whereas channel theories had assumed a structural bottleneck in information processing, resource models held that limitations were functional, in the form of attention or effort (Sanders, 1979). If task demands exceed available resources, performance declines. Conversely, if task demands fall short of supply, then the amount of residual resource provides a measure of spare mental capacity. Perhaps the most widely accepted current model of human attention is the Multiple Resources model, as proposed by Wickens (1980). According to this model, tasks differ on the basis of demands they place in terms of: input modality (visual versus auditory); data input code (spatial versus verbal); and response type (manual versus verbal) characteristics.

According to this multiple resource model, the degree of interference between two tasks can be characterized by the tasks’ compatibility along the dimensions outlined above. This model has proven useful in predicting what sorts of tasks (do they rely on spatial or verbal information? Do they require verbal or manual response? Is information auditory or visual?) will interfere with one another. Further, workload in this model is the demand that tasks place on a limited supply of attention resource.

B. ATC Task Load Factors

Task load (i.e., the demand imposed by the ATC task itself) is generally distinguished from workload (i.e., the controller’s subjective experience of that demand). A number of studies have attempted to identify traffic-related workload factors for ATC. Of many prospective task load indices, the number-of-aircraft-under-control (i.e., traffic load) has shown the clearest predictive relationship to workload measures (Hurst & Rose, 1978; Stein, 1985). As with complexity, traffic density does not appear to fully capture workload. Some of the other (airspace-related) ATC task load factors include:

- Sector flow organization (Arad, 1964);
- Number of traffic problems (Kalsbeek, 1976);
- Number of flight altitude transitions (Cardosi & Murphy, 1995);
- Mean airspeed (Hurst & Rose, 1978);
- Sector area (Arad, 1964);
Airspace factors are clearly not the only contributors to ATC task load. Such other considerations as the ATC position (e.g., oceanic versus terminal (Wickens, Mavor & McGee, 1997)), and the controller interface (including both the visual display and the data entry system) are critical in determining a controller’s task load. They do not always do so, however, in predictable or beneficial ways. As research from other domains has demonstrated, a system’s interface itself can impose additional task demands. For instance, automated tools can have the unintended effect of raising task load (Selcon, 1990; Kirlik, 1993). The potential for such situations appears increasingly likely as more sophisticated “advisory” types of decision aids emerge within ATC. By presenting the controller the additional tasks of (1) considering the system’s advice, and (2) comparing the system’s solutions to those he/she must continue to generate (if he/she is to remain “in the loop”), such decision aiding automation might paradoxically force an additional task upon the controller (Hilburn & Jorna, 2001 depicted a simplified schematic of the relationship between ATC task load and controller workload. Though many other factors e.g., time pressure, motivation, efforts are omitted in his research. The literature review also revealed a number of compensatory cognitive strategies that controllers use in accommodating changes in complexity and workload.

5. CONCLUSION

The enormous complexity and the diffused nature of the air traffic control systems makes it necessary to adopt some organizing structure in order to obtain an overview for considering the system as a whole. The paper was review on the workload factors task factor. All researchers are sanguine that the relationship between task load and perceived workload can ever be adequately expressed. And it has been found a simplified schematic of the relationship between ATC task load and controller workload. The literature review revealed a number of compensatory cognitive strategies that controllers use in accommodating changes in complexity and workload.

6. SCOPE FOR FURTHER RESEARCH

However, this study takes in to account some of the major aspects of workload and task load factors but still there is much more to do in this field of study. This study is limited to workload and task load factors and its effect on ATC. Though various studies have shown a strong relationship between complexity factors and controller workload but this aspect has not been undertaken in the study. Many other factors (e.g., time pressure, motivation, effort) are omitted from this study.

REFERENCES


Complexity Factors. DOT/FAA/CT-TN03/14. Atlantic City, New Jersey: FAA.


Leroux, M. (1993). The PATS cooperative tools. In The proceedings of the scientific seminar on


