



SLEEPINESS IN BRAZILIAN AVIATION: A PROBLEM-SOLVING APPROACH

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Abstract

Excessive Daytime Sleepiness - (EDS) can have a negative impact on performance, memory and attention, increasing the risk of accidents, including air accidents. It is a condition that, when diagnosed and treated, can significantly reduce these risks. By using the Soft Systems Methodology approach, the main relevant systems, the necessary transformations, and the strategic human activity systems were identified to promote culturally viable and desirable changes in the systemic context. As a concrete result, strategic actions were proposed for each identified transformation, which, if implemented, have the potential to minimize the risks of air accidents resulting from EDS. Finally, control criteria were established that provide a clear roadmap for the implementation and evaluation of the success of these transformations. The supersystem developed in this study presents a systematic and robust approach to addressing the complex and multifaceted issue of fatigue and sleepiness management in aviation.

Keywords: Excessive daytime sleepiness, Fatigue, Soft Systems Methodology, SSM, Problem structuring

1. Introduction

Sleep is an essential physiological process that allows the body to renew its physical and mental capacities, reaching higher levels of consciousness. On the other hand, when sleep is not restorative, individuals may not adequately recover their self-control skills and may exhibit unsafe behaviors. [1] Chronic sleep disorders result in Excessive Daytime Sleepiness (EDS), which is a cause of fatigue in the crew [2, 3]. EDS occurs when there is a reduction in the number of hours of sleep compared to the recommended levels, which can reduce alertness, attention, concentration, memory, and decision-making, increasing the risk of accidents, including air accidents [4, 5]. This condition can be caused by sleep deprivation or by sleep-related disorders, such as Obstructive Sleep Apnea Syndrome (OSAS) [6]. OSAS is the most prevalent sleep disorder, affecting 2% to 26% of the population [7]. It is estimated that 80% of people with moderate to severe sleep apnea are not diagnosed and, consequently, are not being treated [8]. EDS is a disease that, when diagnosed and treated, can significantly reduce the risk of accidents [9]. This condition can be diagnosed by subjective and objective means. Subjective methods are mainly screening questionnaires, such as the Karolinska Sleepiness Scale and the STOP-Bang Questionnaire [2]. The International Civil Aviation Organization (ICAO) suggested, in 2019, the screening of all pilots for the risk of sleep apnea, through the application of the STOP-Bang questionnaire [10]. In Brazil, all military personnel, including airmen and air traffic controllers, undergo Periodic Health Inspections (INSPSAU) for the purpose of assessing psychophysical fitness for the adequate performance of the mission [11, 12]. However, there is currently no legislation for the screening of OSAS and EDS in civil and military aviation in Brazil [13]. The absence of legislation for the screening of obstructive sleep apnea and Excessive Daytime Sleepiness in civil and military aviation represents a significant risk. Without clear and mandatory guidelines for the screening of these conditions, affected individuals may not be identified or treated adequately, which can lead to reduced performance, errors, and ultimately, air accidents.

This study aims to structure the problem in the context of the Brazilian Air Force, more specifically in airmen and Air Traffic Controllers (ATC), with the aim of proposing measures to minimize the risks of air accidents resulting from Excessive Daytime Sleepiness. An adapted version of the Soft Systems Methodology (SSM) was used as a problem structuring method. The SSM was developed by Checkland with the aim of applying systems engineering principles to complex and wicked problems, seeking to redesign systems [14]. In this approach, participants build conceptual models for each system view and compare them with reality, promoting discussions about culturally viable and systemically desirable changes [15].

This article is organized as follows: section 2 presents the SSM methodology and how it is applied to the context of EDS in aviation. Section 3 details the application of the methodology, including the construction of the Rich Picture, the identification of Relevant Systems, Transformation Tables, the strategic actions proposed for each transformation, the control criteria, and the development of the supersystem. Finally, section 4 concludes the article, highlighting the applicability of SSM to address complex and multifaceted issues such as the management of fatigue and sleepiness in aviation.

2. Method

This section describes the detailed design of the study, which includes the application of the Soft Systems Methodology [16]. The article uses this methodology to deal with a complex and problematic context, involving multiple actors and conflicting values. The methodology is adapted following the configuration proposed by Ion Georgiou [17, 18], composed of three phases: diagrammatic description of the situation, identification of problems and necessary transformations, and creation of systemic models to operationalize the desired changes (Fig. 1). In Phase 1, focus on the context and knowledge production, a Rich Figure is drawn that offers a diagrammatic description of the problem under consideration. This figure provides essential information for analyzes 1, 2 and 3, assisting in the identification of the necessary transformations to improve the situation. Phase 2 aims to identify the necessary transformations to make the solution of the problem viable. According to the four transformation rules of the methodology, inputs are stipulated and represent the definition of the problem and outputs would be indicators for its solution. In Phase 3, systemic planning, each transformation is contextualized within a CATWOE (English acronym for Costumer, Actors, Transformation, Weltanschauung, Owner, and Environment restriction). From this contextualization, the transformations are expressed as formal statements of intent, through root definitions. Based on the CATWOE and its root definitions, a Human Activity System (HAS) is designed to guide the realization of the outputs stipulated in each transformation. Once the corresponding HASs have been designed for all transformations, they are interconnected to form a systemic action plan, called a supersystem (Fig. 1) [17, 18].

3. SSM implementation

A. Phase I - Description of the Situation

In this first phase of the methodology, what is known about the problem situation will be contextualized.

- 1: Rich Figure:
Through the Rich Figure, it was possible to identify several relevant systems. Of these, two will be evaluated: Health Inspection with failures and Flight Activity, both marked with a dashed orange line in the Rich Figure (Fig. 2).
- 2: Analyses 1 and 3 - Actors and Power Relations: The actors evaluated in this study were: ICAO (International Civil Aviation Organization), ANAC (National Civil Aviation Agency), CO-MAER (Aeronautics Command), COMGEP (General Personnel Command), CENIPA (Aeronautical Accident Investigation and Prevention Center), DECEA1 e DECEA2 (Department of Airspace Control), DIRSA (Health Directorate), CINDACTA (Integrated Air Defense and Air Traffic Control Center), JSS (Superior Health Board), DMI (Integrated Medicine Division) of DIRSA, JES (SPECIAL HEALTH BOARDS), CAIS (Comprehensive Health Care Center), ATM (Air Traffic Controller), Aircrew and users.

		Soft System Methodology (SSM) Decision-Making Model					
		Objective	Focus		Tool		Output
Phase	1	Knowledge Production	Diagrammatic Analysis	Players	Analysis 1	Rich Pictures	Knowledge Database
				Socio-Cultural Dynamics	Analysis 2		
				Power	Analysis 3		
	2	Knowledge Application	Transformations		SSM Transformation Rules		Application Database
			Contextualization of Transformations		CATWOE		
			Planning Statements		Root definition		
	3	Systemic Planning	Control Criteria	Individual Systems Planning	Individual Human Activity Systems	Effectiveness Efficiency Efficacy Ethicality Elegance	Systems Database
				Integrated Systems Planning	Supersystem		

Figure 1 – Reconfigured SSM [18]

Table 1 shows the power dynamics between the actors involved, with numbers in parentheses indicating their level of power and influence. The scale ranges from 1 to 6, with 1 being the highest level of power and influence and 6 being the lowest level. Thus, ICAO (1), for example, has the greatest capacity for influence, being able to converge international standards. On the other hand, the Aircrew and the User (6) have the lowest level of power. This power dynamic is crucial to understanding how transformations can be implemented and who has the capacity to drive them.

- 3: Analysis 2 - Socio-cultural Analysis:

Analysis 2 provides a tool to examine the political, religious, ethical, aesthetic, cultural, historical, economic, ecological, and social influences that affect the problem situation [17].

- Politics:

In the context of air traffic, pressure for low costs and efficiency can increase ATM fatigue. A military culture that prioritizes strength and resilience over well-being can discourage the proper approach to fatigue in health inspections.

- Religion:

In air traffic, religious rituals can affect the availability of controllers and religious holidays can change the flow of air traffic. In the military context, religions that value self-care and rest can promote a more proactive stance in addressing fatigue.

- Ethics:

In air traffic management, ethics implies a duty to care for the health and safety of controllers, preventing them from becoming excessively tired. In the military context, ethics involves respecting the autonomy of military personnel, allowing them to express concerns and make informed decisions about their well-being. This requires creating an environment where military personnel feel comfortable communicating fatigue and seeking support when needed.

- Aesthetics:

Air traffic organizations face the challenge of dealing with fatigue as a potential threat to their safety image. In the armed forces, the projection of an image of strength and resilience can discourage the expression of health problems, leading to underreporting of fatigue.

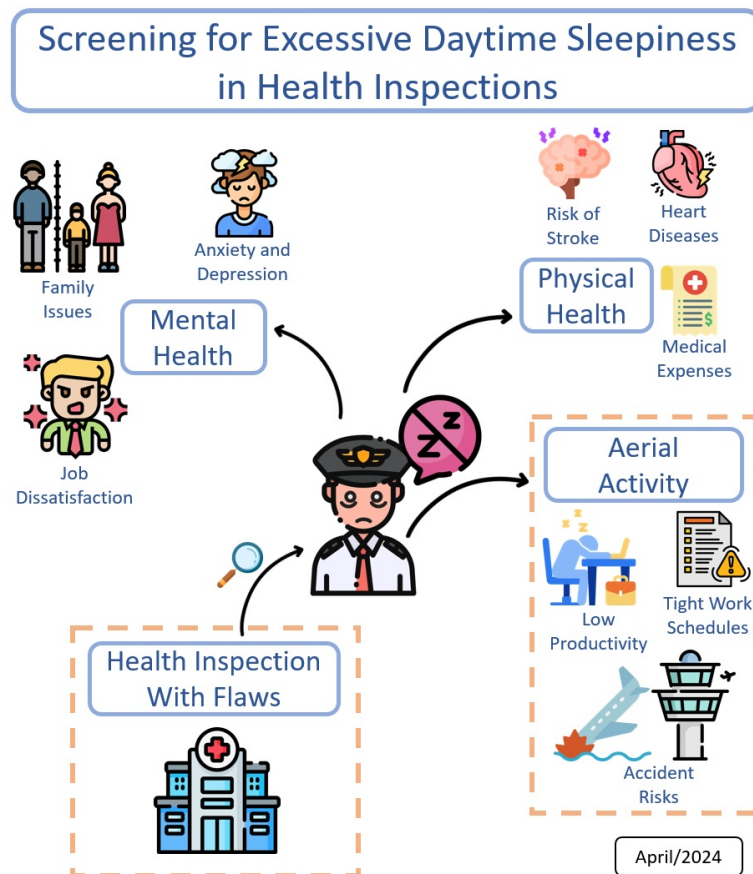


Figure 2 – Rich Figure

- Cultural:

In air traffic, the perception of fatigue can range from a weakness to a real health issue, influencing the likelihood of controllers reporting fatigue. In military culture, the stigma surrounding mental and physical health problems can cause military personnel to hesitate to report fatigue problems during health inspections.

- Historical:

Historically, the growth of the aviation industry has led to periods where the demand for qualified controllers exceeded the supply, resulting in increased fatigue. In the military environment, there has been an evolution in the attention given to mental health. While in the past the focus was mainly on physical illnesses, today there is a growing recognition of the importance of issues such as fatigue.

- Economic:

The economic health of an organization or country directly affects the salaries and benefits of ATMs, causing high turnover of personnel and increased workload for the remaining controllers. In the military context, the budget of an institution can determine the funding available for health, thus affecting the ability to identify and adequately treat fatigue.

- Ecological:

In the context of air traffic, the quality of the physical work environment, such as lighting, temperature, and noise levels, can have a determining impact on fatigue. In the military context, extreme conditions of temperature, altitude, and humidity in which military personnel may operate are factors that predispose to fatigue.

- Social:

Table 1 – POWER DYNAMICS

Agents	Influence Capacity
ICAO (1)	Converge international standards. Influences ANAC and COMAER
ANAC (2)	Develop, implement, and maintain the Specific Operational Safety Program - ANAC. Develop requirements for the issuance of aeronautical medical certificates. Influences COMGEP, CENIPA, DECEA, and DIRSA.
COMAER (2)	Develop, implement, and maintain the Specific Operational Safety Program - COMAER. Approve modifications to established physical fitness evaluation requirements and disability-causing diseases. Influences ANAC and units subordinate to COMAER.
COMGEP (3)	Approve and submit to COMAER modifications to established physical fitness evaluation requirements and disability-causing diseases. Influences units subordinate to COMAER.
CENIPA (3)	Investigate aeronautical accidents and incidents. Influences ANAC and DECEA.
DECEA1 (3)	Regulate and supervise air navigation service providers. Influences CINDACTA, airmen, ATM, and users.
DECEA2 (3)	Plan, coordinate, control, supervise, and standardize operational activities. Influences CINDACTA, airmen, ATM, and users.
DIRSA (3)	Draft and submit modifications to established physical fitness evaluation requirements and disability-causing diseases. Influences JSS, DMI, JES, and CAIS.
CINDACTA (4)	Provide air traffic control and telecommunications services for COMAER in the Southeast region. Influences airmen, ATM, and users.
JSS (4)	Highest instance medical-legal link in the Aeronautics Health System within COMAER. Influences JES.
DMI (4)	Propose modifications to the characteristics and functioning of the Center for Integral Health Care. Influences CAIS.
JES (5)	Inspect airmen and air traffic controllers. Influences airmen.
CAIS (5)	Provide comprehensive, continuous, and coordinated medical care. Influences airmen.
ATM (5)	Perform airspace control and management. Influences airmen and users.
Airmen (6)	Perform specific functions onboard aircraft.
User (6)	Direct user of the air traffic control and management service.

In the case of ATMs, the expectation of long working hours can contribute to fatigue. In the military context, society's expectations of the role of the military in defending the country can

lead to an intense workload and stressful conditions, intensifying fatigue.

After the socio-cultural analyzes, 3 "worldviews" (Weltanschauung) were extracted from them. 1st: Air traffic control service providers must actively manage risks with the potential to impact operational safety; 2nd: A Health Inspection that includes sleepiness screening, in accordance with ICAO Standards and Recommended Practices; 3rd: An organization with robust protocols for integrating diseases diagnosed in the Health Inspection into its care treatment.

B. Phase 2 - Identification of Transformations

In Phase 2 of this study, 2 transformations were identified for the Relevant System "Health Inspection with Failures" and 1 transformation for the Relevant System "Air Activity". The transformations are listed in Table 2.

Table 2 – TRANSFORMATIONS

T	Input		Output
T1	Absence of protocols for the perception and management of fatigue and sleepiness	→	Existence of protocols for the perception and management of fatigue and sleepiness
T2	Absence of protocols for sleepiness screening during Health Inspections	→	Presence of protocols for sleepiness screening during Health Inspections
T3	Low integration between disease detection at Health Inspections and its subsequent medical treatment	→	High integration between disease detection at Health Inspections and their treatment in care

C. Phase 3 - Systemic Planning

In Phase 3, systemic plans were created to implement the necessary transformations. This included the development of the CATWOE and the root definitions derived from them, as described in Tables 3, 4, 5.

Table 3 – CATWOE OF T1

Customers (C)	Airlines, airport administrators, and civil aviation users
Actors (A)	Integrated Air Traffic Control and Air Defense Centers
Transformation (T)	Absence of protocols for the perception and management of fatigue and sleepiness → Existence of protocols for the perception and management of fatigue and sleepiness
Weltanschauung (W)	Air navigation service providers are required to proactively manage risks that could potentially affect operational safety
Owner (O)	Department of Airspace Control
Environment restriction (E)	Hierarchical structure, resistant organizational context, cultural/social aspects that exacerbate symptoms

Table 4 – CATWOE OF T2

Customers (C)	Airmen and Air Traffic Controllers
Actors (A)	Superior Health Board (JSS)
Transformation (T)	Absence of protocols for sleepiness screening during Health Inspections → Presence of protocols for sleepiness screening during Health Inspections
Weltanschauung (W)	A Health Inspection that includes sleepiness screening, in accordance with ICAO Standards and Recommended Practices
Owner (O)	DIRSA, COMGEP
Environmental Restrictions (E)	Hierarchical structure, resistant organizational context, increased inspection costs

Table 5 – CATWOE OF T3

Customers (C)	Airmen and Air Traffic Controllers
Actors (A)	Integrated Medicine Division of DIRSA
Transformation (T)	Low integration between disease detection at Health Inspections and its subsequent care → High integration between disease detection at Health Inspections and its subsequent care
Weltanschauung (W)	An organization with robust protocols for integrating diseases diagnosed at Health Inspections into subsequent care
Owner (O)	DIRSA, COMGEP
Environmental Restrictions (E)	Hierarchical structure, restricted budget, and limited human resources

1) Root Definition for Transformation 1:

A system that serves airlines, airport operators and civil aviation users, operated by Integrated Air Defense and Air Traffic Control Centers, must establish protocols for the management of fatigue and drowsiness in order to actively manage the risks with the potential to impact operational safety, which belongs to the Department of Airspace Control and operates under a hierarchical structure, a resistant organizational context and with cultural/social aspects that potentiate the symptoms.

2) Root Definition for Transformation 2:

A system that serves aircrew and air traffic controllers, operated by the Higher Health Board, must establish protocols for sleepiness screening in Health Inspections in order to have a sleepiness screening, in accordance with ICAO Standards and Recommended Practices, which belongs to DIRSA and COMGEP and operates under a hierarchical structure, a resistant organizational context and increased inspection costs.

3) Root Definition for Transformation 3:

A system that serves aircrew and air traffic controllers, operated by the DIRSA Integrated Medicine Division, must optimize the integration between disease detection in the Health Inspection and its care treatment in order to have robust protocols for this integration, which belongs to DIRSA and COMGEP and operates under a resistant organizational context, restricted budget and limited human

resources.

From the root definitions, sets of activities were created that result in the output of each transformation, called Human Activity Systems (HAS) [17].

4) Human Activity System for Transformation 1:

The first HAS incorporates part of the recommendations provided in the guide for fatigue management in air services [19], as recommended by ICAO (Fig. 3). The proposal was prepared from the perspective of DECEA [20].

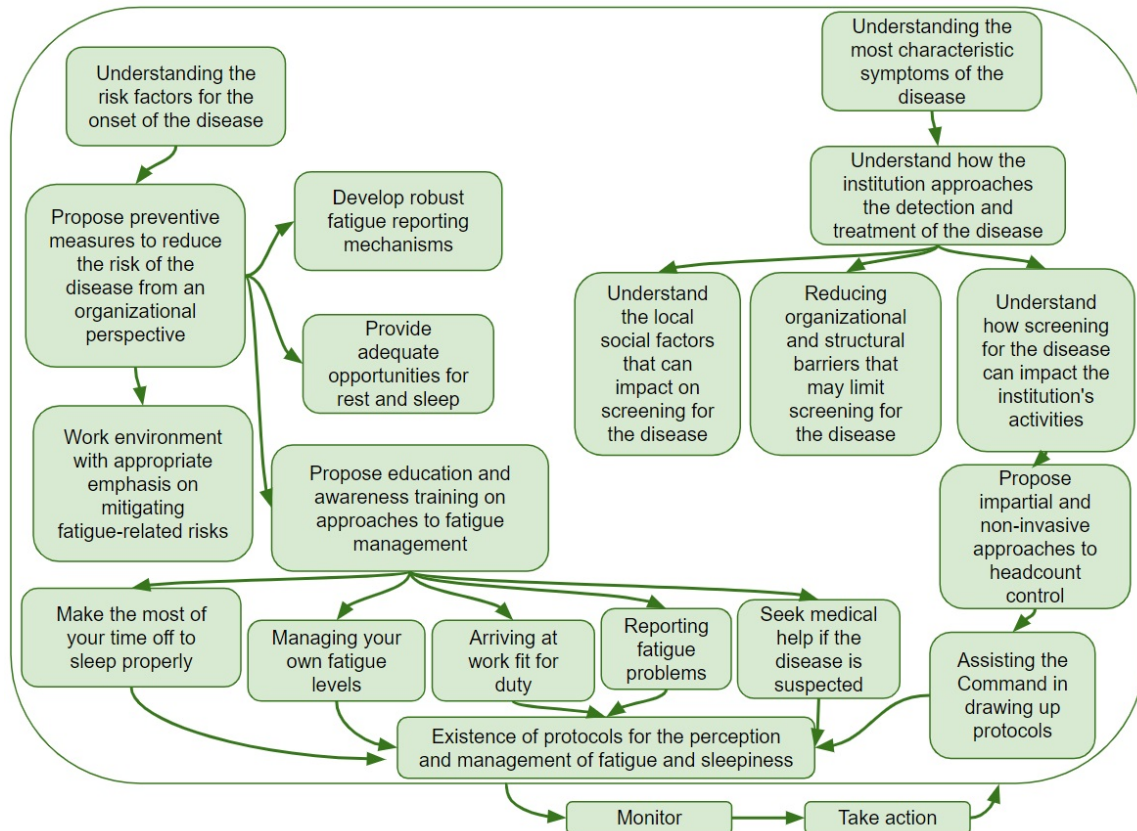


Figure 3 – HAS Transformations T1

Regarding control criteria, in terms of effectiveness, a reduction in fatigue-related absenteeism is expected. However, this goal should be achieved with the least possible increase in human resources in order to be efficient. The system will be effective if there is a gradual reduction in fatigue-related absenteeism.

In terms of ethics, the protocols are implemented in accordance with national health authorities and ICAO recommendations. Regarding elegance, the positive image of the institution as an air navigation service provider is reinforced.

5) Human Activities System for Transformation 2:

The second HAS encompasses research and understanding of techniques to track EDS in Health Inspections, as well as proposes the creation of legislation on the subject (Fig. 4). For Transformation 2, effectiveness should be evaluated by the quality of research and the capacity of the proposed techniques to track EDS in Health Inspections. Efficiency should consider the optimal use of resources in conducting research and formulating legislation. Effectiveness can be measured by the contribution of tracking techniques and new legislation to EDS mitigation. Ethics must ensure that the research and proposed legislation respect ethical principles, including privacy and the rights of those inspected. Finally, elegance evaluates whether the tracking techniques and legislation are presented in a clear, understandable, and aesthetically satisfactory manner.

6) Human Activities System for Transformation 3:

The third HAS aims to raise awareness among doctors and those inspected about fatigue, as well as proposes actions to strengthen the relationship between diagnosis and treatment (Fig. 5). For Trans-

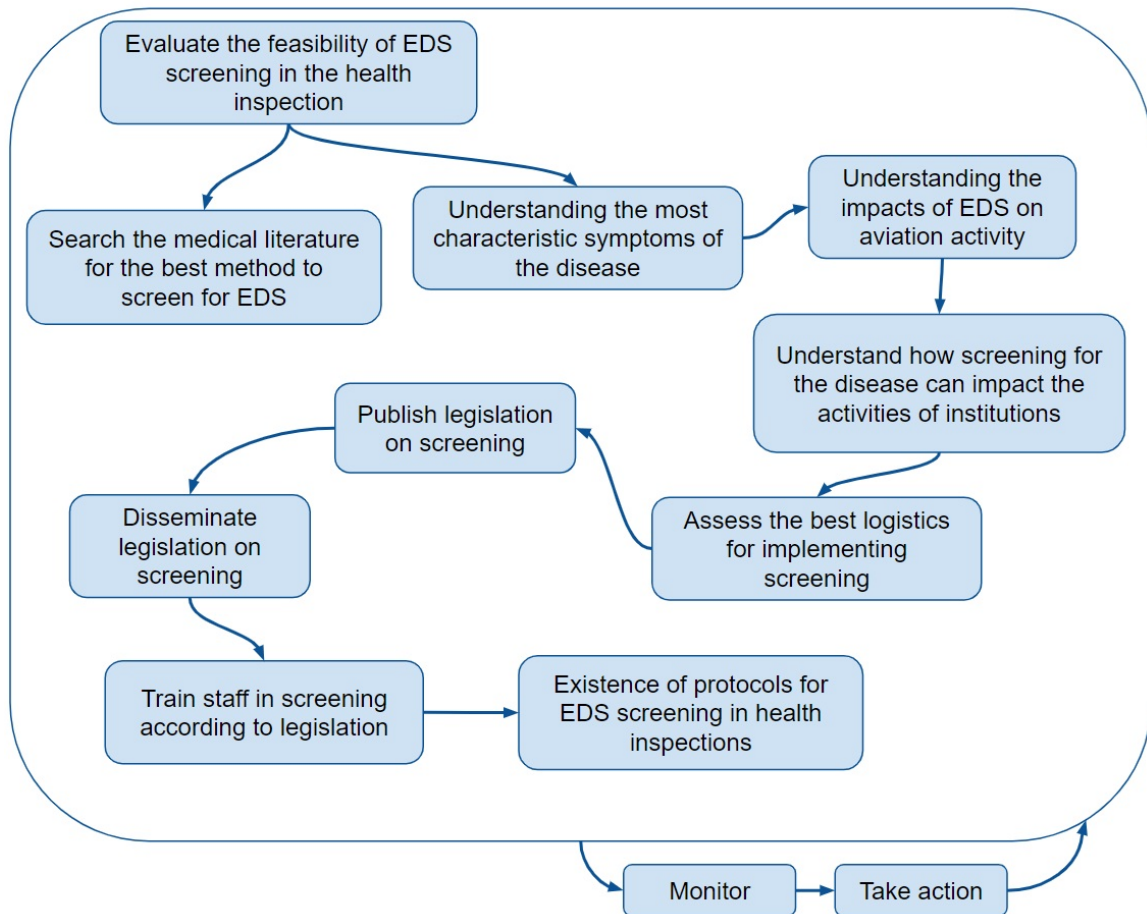


Figure 4 – HAS Transformations T2

formation 3, effectiveness should measure the success of awareness-raising activities on fatigue and the improvement of the relationship between diagnosis and treatment. Efficiency should evaluate the optimization of resources in these activities. Effectiveness should be measured by the contribution of these actions to the identification and treatment of EDS. Ethical principles, including the privacy and rights of individuals, must be respected during activities. Finally, elegance should evaluate whether these activities are presented in a clear, understandable, and aesthetically satisfactory manner.

7) Supersystem:

The last planning stage of the SSM is the connection of all HAS into a single system, called the supersystem. This is the tool that should be able to solve the problem situation in question [17]. The developed supersystem is presented in (Fig. 6). For the Supersystem, effectiveness should measure the success of the activities developed by HAS 1, 2 and 3 in tracking, treating EDS in Military Health inspections and its organizational management. Efficiency should evaluate whether the Brazilian Air Force - (FAB) financial resources are being well applied to address the EDS problem. Effectiveness should be measured by the contribution of the activities in resolving the problem situation. In relation to ethics, care must be taken with the privacy of those involved in data collection for EDS tracking. Finally, elegance aims to evaluate whether the implemented activities are concise and easily understood.

4. Main Conclusions

This study presented a systematic application of the Soft Systems Methodology to address the complex issue of fatigue and drowsiness in aviation. Through the three phases of SSM application, we identified stakeholders, explored the problem situation, and developed a comprehensive supersystem to address the identified issues. The Human Activity Systems proposed for each transformation suggest strategic and operational actions that, if implemented, have the potential to address the issue in

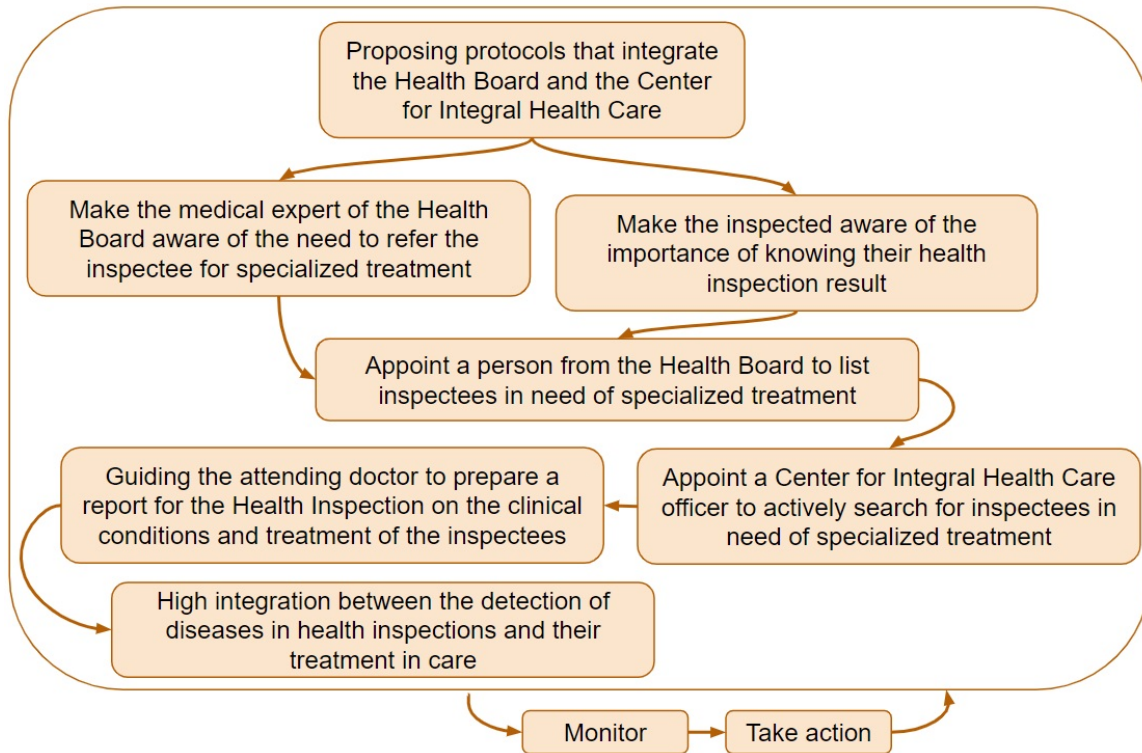


Figure 5 – HAS Transformations T3

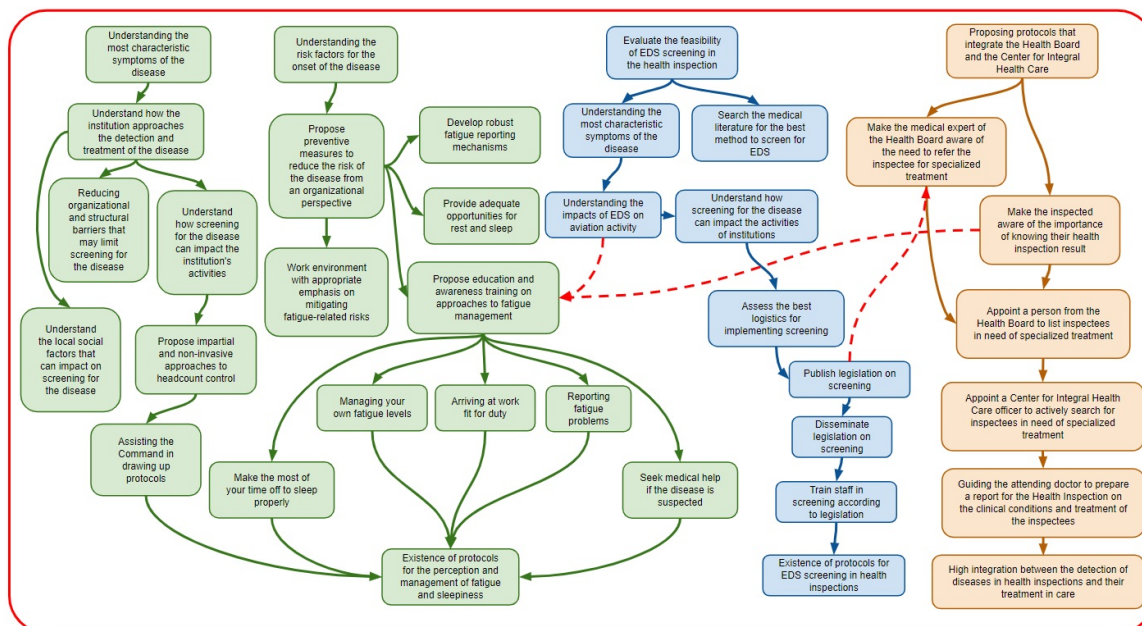


Figure 6 – Supersystem

a comprehensive manner. The strategies proposed for the Relevant Air Activity System propose measures for fatigue management in the air traffic controller's organizational environment. The strategies for the Relevant Health Inspection with Failures System suggest measures for the implementation of robust legislation and protocols for the tracking of excessive daytime sleepiness in inspections. Still in this system, strategies are proposed to optimize the integration between diseases diagnosed in health inspections and their outpatient treatment. The root definitions and control criteria established provide a clear roadmap for the implementation and evaluation of the success of these transformations. Although the focus of this study is the aviation environment, the methodology used can be applied to a variety of other complex problem situations. Therefore, we hope that this study not only

contributes to the improvement of fatigue management in aviation, but also inspires the application of SSM in other contexts.

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