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Pregledni članak
Review article

UDK / *UDC*: 159.944-057.86
629.61.058.75

Primljeno / *Received:*
12. srpnja 2011. / *12th July 2011*
Odobreno / *Accepted:*
3. studenoga 2011. / *3rd November 2011*

ČIMBENICI UTJECAJA I METODE ODREĐIVANJA RADNOG OPTEREĆENJA VTS OPERATERA

INFLUENCE FACTORS AND METHODS FOR DETERMINING VTS OPERATOR'S WORKLOAD

SAŽETAK

Učinkovitost svakoga sustava čiji sastavni dio čini operativno osoblje ovisi o sposobnosti, uvježbanosti i organizaciji istih. Dobra organizacija rada osoblja te njihovog broja jest izuzetno bitna radi postizanja optimalnog radnog opterećenja, čime se povećava učinkovitost osobe, a smanjuje rizik pogrešaka u radnim postupcima. U radu se predstavlja organizacija osoblja VTS centra s pripadajućim odgovornostima te se navode čimbenici koji direktno i bitno utječu na radno opterećenje VTS operatera. Na temelju navedenog iznose se prijedlozi za optimizaciju određenih čimbenika utjecaja. U nastavku se navode metode određivanja razine radnog opterećenja osoblja, s naglaskom na subjektivne metode i objektivne metode mjerenjem fizioloških parametara. Primjenom tih metoda moguće je točnije odrediti optimalan broj operatera određenog VTS centra. Na temelju iznesenih metoda i primjera provedenih istraživanja u svijetu daju se prijedlozi pri korištenju i kombinaciji određenih metoda u istraživanju rada VTS tima.

Ključne riječi: *radno opterećenje, zamor, VTS osoblje*

SUMMARY

The effectiveness of any system, in which an integral part is the operational staff, depends on its abilities, skills and organization. Good organization of the tasks, personnel and their number is extremely important to achieve an optimal workload, thereby increasing the efficiency of the operator, and reduce the risk of errors in operating procedures. This paper presents the VTS Centre staff organization with the associated responsibilities and lists the main factors that directly and significantly affect the VTS operators' workload. Furthermore, the suggestions for optimizing the impact of certain factors are presented. The methods for determining the level of the staff workload are presented, with an emphasis on the subjective and objective methods by measuring physiological parameters. By applying these methods, it is possible to accurately determine the optimal number of operators in a VTS Centre. Based on the presented methods and research examples in the world, suggestions are given for the use and combination of specific methods for a VTS team workload researches.

Keywords: *workload, fatigue, VTS staff.*

1. UVOD

Služba nadzora i upravljanja pomorskim prometom (engl. Vessel Traffic Service – VTS) obavlja poslove praćenja, nadzora, upravljanja i organizacije pomorskog prometa određenog morskog područja, koje određuje nadležno ministarstvo obalne države. Učinkovitost i pouzdanost VTS službe u provođenju svih obveznih operacija, bez vremenskih prekida, ovisi o razini tehničkih rješenja i opreme na raspolaganju te o sposobnosti osoblja. Ključni dio osoblja za izvođenje operacija jesu VTS operateri, a njihova sposobnost ovisi o znanju, stručnosti i uvježbanosti, u koje treba neprekidno ulagati i redovito provjeravati.

Problem ovoga rada jest jedna od osnovnih činjenica koja može izuzetno negativno utjecati na općenitu sposobnost operatera za pouzdano izvođenje VTS operacija, a to je preveliko ili premalo radno opterećenje. Pod utjecajem jednog od krajnjih opterećenja operater može biti sklon pogreškama, što može dovesti do ozbiljnog povećanja rizika u pomorskom prometu.

Cilj rada jest identificirati čimbenike koji utječu na radno opterećenje operatera, iznijeti prijedloge za optimizaciju opterećenja te prikazati različite metode koje se mogu koristiti u istraživanju i procjeni trenutnog i općeg radnog opterećenja. Na temelju poznavanja čimbenika utjecaja, primijenjenih metoda i dobivenih rezultata moguće je dobiti smjernice za određivanje optimalnog broja aktivnih operatera u timu pojedinog VTS centra.

U ovome radu korištena je metoda analize prilikom navođenja čimbenika utjecaja na opterećenje, nakon kojih se predlažu moguća tehnička i organizacijska rješenja za optimizaciju opterećenja unutar VTS centra. Upotrijebljena je metoda deskripcije i kompilacije prilikom predstavljanja mogućih metoda različitih vrsta i pristupa za određivanje stupnja i uzroka radnog opterećenja te pripadajućih primjera dosadašnjih istraživanja u svijetu.

2. OSOBLJE VTS CENTRA

U VTS centrima osoblje se najčešće sastoji od VTS operatera (engl. Operators), VTS nadzornika (engl. Supervisors) i VTS upravitelja (engl. Manager), ovisno o veličini i složenosti područja nadziranja, vrste i razine pružanih

1. INTRODUCTION

Vessel Traffic Service (VTS) performs surveillance, management and organization of the maritime traffic in a specified area which determines the competent authority of the coastal State. The performance and reliability of the VTS in executing all mandatory operations without any interruptions, depends on technical solutions with the associated equipment available and the VTS staff skills. Staff key members for the conduct of operations are the VTS operators, and their ability depends on the knowledge, expertise and training, which should be continually invested into and regularly tested.

The problem of this paper is one of the basic facts that can affect very adversely the operator's general ability to perform VTS operations reliably, and that the workload is too high or too low. Under the influence of any extreme end of the workload, the operator can be liable to errors, which can lead to a significant increase of risks in maritime traffic.

The aim of this paper is to identify the factors that affect the operator's workload, introduce suggestions for optimizing the workload and display a variety of methods that can be used for the research and evaluation of the current and general workload. By knowing the influence factors, applied methods and the results obtained, it is possible to identify guidelines for determining the optimal number of active operators in a team of each VTS Centre.

In this paper, a method of analysis was used to identify the influence factors on the workload, after which possible technical and organizational solutions for the workload optimization within the VTS Centre are suggested. A method of description and compilation was used during the presentation of possible methods of various types and approaches to determine the level and causes of workload with the accompanying examples of similar researches carried out in the world.

2. VTS CENTRE STAFF

The VTS centre staff usually consists of VTS operators, a VTS supervisor and of a VTS manager, depending on the size and complexity of the surveyed area, types and levels of provided services, and traffic density. The competent au-

usluga, te gustoći prometa. Nadležna uprava za VTS centar, u Republici Hrvatskoj je Ministarstvo mora, prometa i infrastrukture koje je dužno utvrditi neophodan broj zaposlenika svih funkcija da bi centar mogao učinkovito ispunjavati svoju namjenu. Uprava je dužna pružiti zaposlenicima odgovarajuću i redovitu izobrazbu i uvježbavanje kako bi svoje zadatke odrađivali točno, sigurno i učinkovito. Nadalje, uprava je dužna jasno, nedvojbeno i detaljno predstaviti opise svih radnih mjesta, navesti odgovornosti i ovlasti. U nastavku su navedene osnovne odgovornosti uobičajenog dijela osoblja [5].

VTS operater jest ključna osoba u VTS centru, čija glavna funkcija jest izvršavanje svih VTS operacija. Radno mjesto operatera može uključivati:

- nadziranje i djelomice upravljanje pomorskim prometom,
- pružanje usluga informiranja i/ili navođenja brodova,
- komunikaciju i prikupljanje podataka o učesnicima u prometu,
- komunikaciju s ostalim institucijama, tijelima i osobama na kopnu,
- podršku sigurnosnim tijelima,
- sudjelovati u izmjeni informacija i nadzoru tijekom izvanrednih situacija na kopnu i moru,
- administrativne poslove po uputstvima VTS nadzornika ili upravitelja.

VTS nadzornik jest osoba koju uprava može postaviti u VTS centrima gdje radi više od jednog VTS operatera. Nadzornik jest odgovoran za upravljanje, koordinaciju i pružanje pomoći operaterima u smjeni za izvođenje VTS operacija. Iz navedenog je vidljivo da nadzornik treba imati dozvolu, znanje i vještinu kao i operateri za izvođenje svih VTS operacija te ih u slučaju potrebe može zamijeniti ili im pomoći. Osim navedenog može imati dužnost za:

- nadgledanje rada operatera,
- provjeru pridržavanja propisanih standarda osposobljenosti osoblja,
- provjeru pridržavanja propisane koordinacije između VTS centra i okolnih pravnih i fizičkih osoba koje su uključene u pomorski promet,

thority for the VTS[1] shall determine the necessary number of employees in all functions so that the Centre could effectively fulfill its purpose. The competent authority should provide to the employees an adequate and regular education and training so that they could perform their tasks accurately, safely and effectively. Furthermore, the competent authority should clearly, unambiguously and in detail present descriptions of all duties, specify the responsibilities and authority for each function. Hereafter are the basic responsibilities of the common VTS functions [5].

VTS operator is the key person in a VTS centre, whose main function is to execute all fundamental VTS operations. The operator's duties may include:

- monitoring and partly managing the maritime traffic,
- providing information and / or ship's guidance,
- communication and data collection on traffic participants,
- communication with other institutions, governmental bodies and persons ashore,
- support to the security institutions,
- participation in the exchange of information and monitoring during emergencies ashore and at sea,
- administrative and other duties upon VTS Supervisor or Manager directives.

The **VTS Supervisor** is a person which the Competent Authority can nominate in a VTS centre where more than one VTS operator works. The supervisor is responsible for managing, coordinating and assisting operators in the shift in their duty operations. From the above mentioned data, it is evident that the supervisor should have a license, knowledge and skills as well and should be an operator to perform all VTS operations, and, if necessary, replace or assist an operator in any specific duty. In addition to the above, a Supervisor may have a duty to:

- supervise the operators' work,
- verify compliance with the compulsory standards of staff training,

[1] In the Republic of Croatia the competent authority is the Ministry of Sea, Transport and Infrastructure.

- provjeru da pružane usluge VTS-a zadovoljavaju zahtjeve brodova i propise uprave,
- pružanje pomoći prilikom izobrazbe i uvježbavanja VTS operatera,
- obavljanje administrativnih poslova po uputstvima VTS upravitelja.

VTS upravitelj jest osoba koju uprava može postaviti za upravljanje i koordinaciju rada jednog ili više VTS centara. Ukoliko uprava odobrava, upravitelj može biti osoba koja nema dozvolu VTS operatera, ali mora imati znanje i vještinu voditi i koordinirati VTS centar. Radno mjesto operatera može uključivati:

- planiranje rada,
- upravljanje financijama i kadrom centra,
- administracija po uputstvima uprave,
- predstavljanje centra i odnosi s javnošću,
- koordinacija rada centra,
- provjera kvalitete pružanih usluga i operacija,
- provjera funkcionalnosti i dostatnosti svih resursa neophodnih za izvođenje VTS operacija,
- provoditi istragu u slučaju nezgode,
- prepoznavanje, razvijanje i predlaganje unapređenja pružanih usluga.

Osim navedenih radnih mjesta, u VTS centru može djelovati i osoblje drugih funkcija, primjerice osoblje za održavanje sustava, te tehnički i ostali pomoćnici.

3. UTJECAJ NA RADNO OPTEREĆENJE

Zamor se općenito može definirati kao smanjenje učinkovitosti, točnije po IMO MSC/Circ. 813 zamor jest smanjenje fizičke i/ili mentalne sposobnosti kao posljedica fizičke, mentalne ili emocionalne iscrpljenosti koja može narušiti gotovo sve sposobnosti, primjerice: snagu, brzinu, vrijeme reakcije, koordinaciju, donošenje odluka i ravnotežu.

Čimbenici koji se mogu identificirati da utječu na zamor osobe, mogu biti [9]:

- vrijeme spavanja i odmora
- biološki sat osobe

- verify compliance with the compulsory coordination between the VTS centre and the surrounding institutions and persons involved in the maritime traffic,
- ensure that services provided by the VTS meet the requirements of vessels at sea, and regulations of the Authority,
- provide assistance in the education and training of VTS operators,
- perform administrative and other tasks under the direction of the VTS Manager.

The **VTS manager** is a person which the Competent Authority can nominate to manage and coordinate the work of one or more VTS centres. If the Authority approves, the operator may be a person which does not hold the VTS operator's license, but must have the knowledge and skills to lead and coordinate the VTS Centre. The duties of the Manager may include:

- planning the work,
- financial and staff management,
- administration under the guidance of the Authority,
- representing one or more centers and public relations,
- coordination of all centers services,
- quality validation of the provided services and operations,
- validation of the functionality and sufficiency of all resources necessary to perform all VTS operations,
- accident investigation,
- identification, development and proposition on how to improve the provided services.

In addition to the above-mentioned functions, the personnel in a VTS centre can perform other duties, such as system maintenance, technical assistance and other.

3. WORKLOAD IMPACTS

Fatigue can be generally defined as a decrease in efficiency, or by the IMO MSC/Circ. 813 fatigue is the decrease in physical and/or mental abilities as a result of physical, mental or emotional exhaustion, which can disrupt almost all capabilities, such as: strength, speed, reaction time, coordination, decision making and balance.

- psihološki i emocionalni čimbenici (strah, monotonija i dosada)
- zdravlje (dijete, bolesti)
- stres (vještine, znanje i uvježbanost za posao, osobni problemi i međusobni odnosi)
- utjecaj tvari (alkohol, lijekovi, kofein)
- godine starosti
- radno vrijeme (smjene)
- radno opterećenje (fizičko i mentalno).

Cilj ovoga rada jest identificirati čimbenike koji utječu na radno opterećenje operatera te metode prepoznavanja trenutne razine opterećenja. Iz toga razloga ostali čimbenici koji utječu na zamor osoba bit će zanemareni u nastavku.

3.1. Čimbenici utjecaja

Radno opterećenje osobe može se podijeliti na fizičko (engl. Physical Workload – PWL) i mentalno (engl. Mental Workload – MWL). Fizičko opterećenje jest mjerljiv udio fizičkih resursa koji se troše za vrijeme odrađivanja zadataka. Mentalno opterećenje jest razina sposobnosti mentalne obrade informacija za vrijeme odrađivanja zadataka [7].

S obzirom na raznolikost prometnog opterećenja pojedinog područja tijekom vremena, osobne psihofizičke sposobnosti svakoga pojedinog operatera i nizom drugih čimbenika, često je teško s pouzdanošću odrediti najpovoljniji broj VTS operatera jednoga centra. Uvođenjem određenog broja operatera neophodno je pratiti njihov rad, ponašanje i radno opterećenje nekom od poznatih metoda te po potrebi prilagoditi njihov broj i/ili prilagoditi neki od ključnih čimbenika opterećenja, ukoliko je to moguće. Prije same primjene metode određivanja opterećenja potrebno je identificirati čimbenike koji utječu na rad i psihofizičke sposobnosti operatera te ih pratiti kroz vrijeme.

Osnovni čimbenici s pomorskog stajališta koji utječu na radno opterećenje VTS operatera jesu:

- broj i značajke brodova na promatranom području
- složenost promatranog sektora.

Broj i značajke brodova primarno utječu na opterećenje, zato što su brodovi predmet nad-

The identified factors that affect the fatigue of individual persons may be [9]:

- time of sleep and rest,
- person's biological clock,
- psychological and emotional factors (fear, monotony and boredom),
- health (child, illness),
- stress (skills, knowledge and training for the job, personal issues and interpersonal relationships),
- the influence of substances (alcohol, drugs, caffeine),
- age,
- working hours (shift),
- workload (physical and mental).

The aim of this paper is to identify factors that affect the workload of operators, and the methods to detect the level of the workload. For this reason, other factors affecting the fatigue will be omitted hereafter.

3.1 Influence Factors

A person's workload can be divided into Physical Workload (PWL) and Mental Workload (MWL). Physical workload is a measurable share of physical resources which are consumed during the job performance. Mental workload can be expressed as the processing capacity during the job performance. [7]

Taking into account the diversity of the traffic load for each sector within the VTS area, over time, personal, psychological and physical abilities of each operator and many other factors are often difficult to reliably determine the optimal number of VTS operators within a centre. By engaging a certain number of operators, it is necessary to monitor their performance, behavior and workload using one or more known methods and, if necessary, adjust their number and/or adjust some of the key influence factors of workload if possible. Before the application of any method for determining the load level, it is necessary to identify the factors that affect the operator's work and psychophysical abilities and monitor them over time.

The main factors that affect the workload of VTS operators from the maritime point of view are:

zora VTS operatera. Za svaki nadzirani brod VTS operater provjerava i prati cijeli niz podataka, od kojih neke jednokratno, a neke gotovo neprekidno. Uobičajeno je da se jednokratno provjeravaju osnovni podaci o značajkama broda (identifikacijske oznake, država pripadnosti, dimenzije, vrsta tereta, luka odredišta i sl.) na ulazu u VTS područje. Većina tih podataka je dostupna putem automatskog identifikacijskog sustava (engl. Automtic Identification System – AIS) za brodove preko 300 BT-a u međunarodnoj plovidbi. Za sve ostale brodove i za one podatke koji nisu dostupni putem AIS-a, VTS operater je dužan uspostaviti radiokomunikacijski kontakt sa zapovjednikom ili časnikom broda putem VHF-a za prikupljanje podataka. S druge strane, podaci o brodu koji se gotovo neprekidno provjeravaju jesu oni dinamički, odnosno pozicija, brzina i kurs broda. Cilj neprekidnog nadzora jest motrenje da se spriječe opasnosti od sudara s drugim brodom i nasukanja, te pridržava li se Međunarodnih pravila za izbjegavanje sudara, propisanog plovidbenog puta – posebice u slučaju shema odvojene plovidbe, propisane brzine plovidbe (ukoliko postoji takvo ograničenje), izbjegavanja zabranjenih ili zaštićenih morskih područja i dr. Brod se motri sve do izlaska iz VTS područja ili do pristanka na vez luke odredišta.

Značajke svakoga broda mogu uvelike mijenjati opterećenje operatera, kao što su brzina broda (primjerice, nije isto pratiti brod čija je brzina 9 čvorova naspram broda čija je brzina 25 čvorova), teret (brod za generalni teret naspram tankera za prijevoz kemikalija), dimenzije (brod od 60 m naspram broda od 240 m) i sl. Brodovi velikih brzina, s opasnim teretom, ograničenih manevarskih sposobnosti, većim gazom ili dužinom zasigurno predstavljaju veći rizik u pomorskom prometu, što direktno utječe na opterećenje operatera [7].

Složenost promatranog sektora, odnosno područja VTS nadležnosti načelno određuje sljedeće:

- razvedenost obale, odnosno broj otoka, hridi i pličina,
- broj plovidbenih putova prilaznim lukama te njihova udaljenost od opasnih objekata ili pličina,
- broj i složenost shema odvojene plovidbe,
- mjesta križanja plovidbenih putova,
- the number and characteristics of ships in the VTS area,
- complexity of the VTS area.

The number and characteristics of ships are primarily affecting the load, because ships are subject to the VTS operator monitoring. For each monitored ship a VTS operator verifies and controls a whole range of data, some only once, and some almost continuously. Typically, the basic information about the ships characteristics are checked once at the entrance into a VTS area (identification, flag, size, type of cargo, port of destination, etc.). Most of these data are available via the Automatic Identification System (AIS) for ships over 300 GT engaged in international voyages. For all other ships and for those data that are not available through AIS, a VTS operator is required to establish a radio communication contact with the ship's captain or duty officer for data collection. On the other hand, data that are almost continuously monitored are dynamic, i.e. ship's position, speed and heading. The goal of a continuous monitoring is to prevent the ship's collision or grounding, and if the ship complies with the International Regulations for Preventing Collisions at Sea (COLREG), with the predetermined navigation routes – especially in the case of separation zones, with the predetermined speed limit (if any such restriction), with the avoidance of prohibited or protected marine areas and other. The ship is monitored until she leaves the VTS area or until she is berthed at the port of destination.

The characteristics of each ship can greatly change the operator's workload, like speed (for example, it is not the same to monitor the ship steaming 9 knots and the ship steaming 25 knots), cargo (general cargo ship compared to a chemical tanker), dimensions (ship of 60 m compared to a ship of 240 m) and so on. High-speed crafts, ships carrying dangerous cargo, ships with limited maneuverability, greater length or draft, certainly pose a greater risk to maritime traffic, which directly affects the load on operators [7].

The complexity level of the VTS area generally determines the following:

- indented coastline i.e. number of islands, reefs and shoals,
- the number of ship routes within the area and their distance from dangerous objects or shallow waters,

- konfiguracija sidrišta pred lukama,
- izloženost vjetru, valovima i morskim strujama (plovidba u zaštićenim ili područjima izloženim jakim utjecajem vanjskih sila),
- koncentracija ribarskih brodova, jahti i brodica nautičkog turizma (koji nemaju AIS sustav) te učestalost održavanja sportskih (regata, ronjenja) i drugih aktivnosti na moru.

Što je složenost područja veća to je brod izložen većem pomorskom riziku. Povećanim nadzorom nad složenim područjem, često se ukazuje potreba za izdavanjem većeg broja obavijesti i upozorenja brodovima, a time se direktno povećava i radna opterećenost operatera.

Ostali izuzetno bitni čimbenici koje treba uzeti u obzir te neprekidno ili periodično pratiti, a neke po potrebi i prilagoditi radnoj situaciji, jesu [4]:

- dužina dežurstva
- obvezne radne procedure
- uvjeti radne okoline
- vrste i obim pružanih usluga
- obim obveza izmjene informacija s ostalim VTS centrima i drugim službama
- tehnologija i oprema na raspolaganju
- komunikacija
- izvanredne okolnosti, nezgode i druge intervencije.

Na određivanje **dužine dežurstva** utječe niz drugih faktora koje je potrebno uzeti u obzir, a oni jesu: obim i gustoća pomorskog prometa određenog područja, složenost navigacijskih putova, obim radiokomunikacije, uobičajeni broj i obim pružanja navigacijskih savjeta i organizacijskih intervencija pomorskog prometa, zdravstvena ograničenja upotrebe opreme – posebice ekrana, uvjeti radne okoline i pravni propisi države.

Obvezne radne procedure svakoga centra moraju biti jasno određene i opisane. One se načelno dijele na unutarnje i vanjske. Unutarnje procedure se odnose na svakodnevno upravljanje VTS centrom, a vanjske procedure na svu interakciju s učesnicima u pomorskom prometu. Obje se mogu dijeliti na rutinske i izvanredne [6].

Rutinske unutarnje procedure jesu prikupljanje i arhiviranje raznih podataka iz pomorskog

- the number and complexity of the separation schemes,
- crossing of ship's waterways,
- configuration of anchorages,
- exposure to wind, waves and currents (navigation in protected areas or areas exposed to strong natural forces),
- concentration of fishing vessels, yachts and boats for nautical tourism (which generally do not have an installed AIS) and the frequency of sports (regattas, diving) and other sea activities

Ships are exposed to a higher navigation risk as the navigation area complexity increases. With a greater need of supervision in a complex area, it often indicates a need for a greater number of notices and warnings to the ships, and thus directly increases the workload of operators.

Other very important factors which should be taken into account, continuously or periodically monitored, and, if necessary, adjusted according to the work situation, are [4]:

- length of duty,
- mandatory operating procedures,
- working environment conditions,
- type and extent of provided services,
- extent of exchanging information with other VTS centres and other institutions,
- technology and equipment available,
- communication,
- emergencies, accidents and other interventions.

In determining the appropriate length of the shifts, many other factors should be taken into account, and they are: the volume and density of the maritime traffic of a specified area, the complexity of navigational routes, the extent of radio communications, the usual number and volume of provided navigational advices and organizational interventions within the traffic, health restrictions and recommendations on using the equipment – particularly the screens, working environment conditions and respective regulations by the state or Competitive Authority.

The **mandatory operating procedures** of each centre must be clearly defined and described. They are generally divided into internal and external ones. Internal procedures are

prometa i obavljenih komunikacija, održavanje i kalibracija opreme, održavanje publikacija i karti, interakcija s ostalim institucijama na kopnu, odnosi s javnošću, sigurnost podataka i osoblja, osposobljavanje osoblja i predaja smjene.

Izvanredne unutarnje procedure jesu propisani planovi u slučaju izvanrednih okolnosti prema kojima je potrebno redovito provoditi vježbe te ih primijeniti u slučaju stvarne opasnosti. One mogu biti procedure u slučaju otkazivanja dijela opreme VTS centra, požara ili poplave unutar ili neposredno uz centar, medicinska hitnoća ili sigurnosna prijetnja.

Rutinske vanjske procedure jesu komunikacija i izmjena podataka s brodovima prilikom najave dolaska, na ulasku u VTS područje, tijekom prolaska područjem, za vrijeme boravka na sidru i vezu, te na odlasku iz VTS područja.

Izvanredne vanjske procedure odnose se na izvanredne okolnosti učesnika pomorskog prometa tijekom kojih je VTS služba dužna odraditi određene radnje, provoditi dodatan nadzor i izmjenu informacija. Takve okolnosti na moru mogu biti sudar, udar, prevrnuće, potonuće, nasukanje, požar na brodu, čovjek u moru, zagađenje mora, određivanje mjesta ili luke zakloništa, medicinska hitnoća člana posade broda, sigurnosna prijetnja brodu te meteorološke ili oceanološke izvanredne situacije.

Uvjeti radne okoline VTS operatera određuju prikladnost radnog prostora za obavljanje procedura, a uključuju temperaturu, ventilaciju, osvjetljenje, buku, raspored radnih konzola, ergonomija sjedišta te dimenzije radnog prostora. Radni prostor bi trebao imati predviđeno mjesto za osobnu higijenu, konzumiranje jela i pića, odmor i nuždu. Dodatna pažnja treba se posvetiti dobroj izolaciji i smanjivanju vanjskih utjecaja koji mogu smanjiti koncentraciju, poput zvukova i osvjetljenja.

Vrste i obim pružanih usluga mogu znatno povećati radnu opterećenost operatera, posebice u zonama visoke gustoće prometa. Načelno, vrste usluga se mogu podijeliti na tri grupe, a to su Informacijska podrška, Plovidbeni savjeti i podrška brodovima u plovidbi te Organizacija plovidbe i upravljanje pomorskim prometom.

Informacijska podrška (engl. Information Service – IS) jest sustav dostavljanja obavijesti važnih za sigurnost plovidbe brodovima. Dostavljanje obavijesti obavlja se prema unaprijed objavljenom rasporedu, ili po zahtjevu broda

related to the daily management of the VTS centre, while the external procedures are related to all interaction with the participants in the maritime traffic. Both can be further divided into routine and emergency procedures [6].

Routine internal procedures include generally collecting and archiving different data of the maritime traffic and performed communications, maintenance and calibration of equipment, publication and chart corrections and updating, interactions with other institutions ashore, public relations, data and personnel security, staff training and shift handovers.

Internal emergency procedures are laid plans in the event of an emergency situation, by which exercises should be regularly conducted, and applied in the event of a real danger. They may include procedures in case of the VTS equipment failure, fire or flooding within or close to the centre, medical emergencies or security threats.

Routine external procedures include communication and information exchange with the ships announcing their port or area of arrival, upon entering the VTS area, transiting the area, during stay at anchor and berth, and, finally, on leaving the port and the VTS area.

External emergency procedures are related to the emergency situations of the participants in the maritime traffic, during which a VTS has its responsibilities, should conduct additional surveillance and information exchange. Emergency situations at sea could be a collision, impact, capsizing, sinking, grounding, fire on board, man over board, marine pollution, to determine a location or a port of refuge, medical emergencies for crew members, ship's security threats, and oceanographic and meteorological emergencies.

Work environment conditions determine the suitability of the VTS operator work space, including temperature, ventilation, lighting, noise, configuration of working consoles, seats ergonomics and workspace dimensions. The workspace should provide a place for personal hygiene, toilet, eating food and beverage and leisure. Additional attention should be paid to good insulation to minimize external influences that can reduce concentration, such as sound and lighting.

The **types and extent of the provided services** can significantly increase the workload on op-

koji se nalazi u području odgovornosti VTS-a. Dostavljanje obavijesti obavlja se korištenjem VHF sustava na predviđenim kanalima.

Plovidbeni savjeti i podrška brodovima u plovidbi (engl. Navigation Assistance Service – NAS) jesu savjeti, upute i obavijesti upućene jednom ili više brodovima koji zajedno plove nekim dijelom VTS područja, na njihov zahtjev. Cilj plovidbenih savjeta jest omogućiti zapovjedniku donošenje odluka kojima se sigurno i bez ugrožavanja ljudskih života ili okoline ostvaruju plovidbene zadaće. Savjeti i upute upućene zapovjedniku broda ne odnose se na okolnosti u kojima je ugrožena sigurnost broda, ljudi ili okoliša. Ova usluga zahtijeva znatnu vještinu i iskustvo, te za razliku od Informacijske podrške, zahtijeva neprekidno praćenje broda kojemu se usluga pruža. Ta činjenica može uzrokovati potrebu za dodatnim operaterom u VTS centru za obavljanje ostalih operacija na tome području.

Organizacija plovidbe i upravljanje pomorskim prometom (engl. Traffic Organization Service – TOS) jest skup obveznih uputa i dopuštenja kojima se zapovjednik broda obvezuje obaviti određenu radnju na zahtijevani način. Organizacija i upravljanje pomorskim prometom obavlja se sustavom dopuštenja (dopuštenje sidrenja, dopuštenje ulaska u VTS područje, dopuštenje isplovljenja i sl.). Izdanim uputama i dopuštenjima ne smije se odrediti način provedbe određene radnje već samo cilj koji se mora postići dok izvedba same radnje mora biti prepuštena zapovjedniku broda. Ova usluga traži od operatera dodatno vrijeme za planiranje kretanja brodova unutar područja promatranja.

Obveza izmjena informacija s ostalim VTS centrima i drugim službama može znatno utjecati na radno opterećenje operatera, posebice ukoliko su procedure javljanja nedovoljno organizirane. Druge službe su najčešće lučke kapetanije, centri za traganje i spašavanje, službe za sigurnost, operativni centri za izvanredna onečišćenja mora i sl. Izmjena informacija s ostalim VTS centrima, posebice susjednim s kojim se dijeli dio promatranog područja ili granica, treba biti uređena, standardizirana i funkcionalna, na način da se automatski razmjenjuju podaci o kretanju brodova i time rastereti obveza zapovjednika za prečestim i nepotrebnim javljanjem VTS centrima.

erators, particularly in areas of a high traffic density. Generally, the service types can be divided into three groups: Information Service (IS), Navigation Assistance Service (NAS) and Traffic Organization Service (TOS).

Information Service is a system to provide notices and warnings important for the safety of navigation. Notice and warning broadcasting shall be in accordance with the previously published schedule, or upon the ship's request which is in the VTS area. Broadcasting is usually done through a VHF system on the designated channels.

Navigation Assistance Service includes advices, instructions and information directed to one or more ships, sailing in the VTS area, at their request. The goal is to facilitate the master or duty officer to make decisions that are safe and without endangering human life, ship or the environment to perform navigational tasks. Advices and instructions addressed to the master of the ship do not apply to emergencies in which the safety of the crew, ship or the environment is compromised. This service requires considerable skills and experience, and unlike the Information Service, requires continuous monitoring of the ship to which the service is provided. This fact can be the cause for the need of an additional operator in the VTS centre to perform other operations.

Traffic Organization Service is a set of mandatory instructions and permits that commits the ship's master to carry out a specific task in the requested way. This Service is carried out by a system of permits (permit to anchor, permit to enter the VTS area, permit to leave the port, etc.). By issuing instructions and permits, only the objective which must be achieved must be clearly determined, while the performance and manner of action must be left to the ship's master. This service requires the operator's additional time for planning the ship's navigation and manoeuvring within the VTS area.

The **obligation to exchange information with adjacent VTS centres and other offices** can significantly affect the workload of the operator, particularly if the communication procedures are not adequately organized. Other offices or institutions are Port Authorities, Maritime Rescue Coordination centres, Security Institutions, Operational Centres for Marine Pollution and other. The exchange of information with other

Tehnologija i oprema na raspolaganju VTS operaterima može pozitivno ili negativno utjecati na radno opterećenje, ovisno o složenosti uporabe, održavanja, unapređivanja te stupnja automatizacije. Za pouzdano pružanje VTS usluga potreban je određeni stupanj redundancije sustava i senzora, posebice prilikom pružanja usluge plovidbenih savjeta i podrške brodovima u plovidbi, tijekom kojega je obvezno neprekidno praćenje broda.

Kombinacije i integracije određenih tehnologija, poput radara, AIS-a i sustava elektroničkih karata (engl. Electronic Chart Display and Information System – ECDIS) omogućuje znatno lakši nadzor i identifikaciju brodova na određenom području te upotrebu manjeg broja ekrana po operateru.

Komunikacija između VTS operatera i brodova unutar područja nadležnosti VTS centra je neophodna radi izmjene informacija raznih vrsta. Svaki razgovor s brodom operateru oduzima pažnju, trud i vrijeme. U slučaju veće gustoće prometa, na razgovore i javljanja može otpasti veći dio vremena radne smjene, posebice u slučaju loše organizacije i uslijed slabog poznavanja engleskog jezika i komunikacijskih fraza od strane zapovjednika ili časnika broda. Da bi se smanjila mogućnost nerazumijevanja i vrijeme razgovora, VHF radiokomunikaciju postupno zamjenjuje razmjena informacija pisanim putem, poput VHF DSC ili AIS sustavom poruka.

Osim s brodovima, operateri su dužni komunicirati i s ostalim pomorskim službama i institucijama na kopnu što se često odvija telefonski.

U slučaju nastanka **izvanredne okolnosti, nezgode ili druge intervencije** na moru, u luci ili unutar VTS centra tada radno opterećenje radne skupine naglo raste, ovisno o težini situacije. U takvim situacijama operateri često budu spriječeni obavljati obvezne radne procedure te postaju preopterećeni. VTS služba bi trebala imati poseban plan za hitnu organizaciju dodatnog ljudstva u takvim izvanrednim situacijama.

3.2. Prijedlozi optimizacije

Smanjenje radnog opterećenja može se postići utjecajem na neke od navedenih čimbenika, primjenom novih pristupa radnim obvezama i navikama, te uvođenjem nove i učinkovitije

VTS centres, especially with the adjacent ones to which a part of the jurisdiction area is shared, should be regulated, standardized and functional. This can be done by exchanging information about the maritime traffic automatically. This approach would disburden the ship's master of too frequent and unnecessary communication with VTS centres.

The **technology and equipment available** to the VTS operators can positively or negatively affect the workload, depending on the complexity of use, maintenance, updating procedures, and automation degree. To reliably provide all VTS services, the technical system and the associated sensors require a certain degree of redundancy, especially in providing Navigation Assistance Service during which a continuous and uninterrupted ship monitoring is essential.

The combination and integration of technologies, such as Radar, AIS and Electronic Chart Display and Information System (ECDIS) allows a much easier control and identification of ships in a particular area and the use of less screens per the operator console.

Communications between ships and the VTS operators includes the exchange of information of various kinds. Each conversation with the ship's officers requires the operator's attention, effort and time. In the case of a higher traffic density, the conversations and the reporting may take a greater part of the shift, especially in the case of poor organization, poor English language and Standard Marine Communication Phrases (SMCP) skills by the ship's officers. To reduce the possibility of misunderstanding and talk time, the VHF radio communication is gradually replaced by the text message information exchange, such as VHF DSC or AIS. Except with ships, the operators are required to communicate with other maritime authorities and institutions ashore, which is often done by telephone.

In the event of an emergency, accident or other interventions at sea, in port or within the VTS centre, the workload of the entire working team is growing rapidly, depending on the situation severity. In these situations, the operators are often overloaded and unable to carry out the required standard working procedures. The VTS should have an emergency plan for an immediate organization of additional manpower in such emergency situations.

tehnologije. Prijedlozi koji se mogu izdvojiti jesu:

- **Uvođenje *dinamičkog sektora*** u računalne aplikacije i organizaciju VTS centra. Primjenom automatizacije koja broji brodove u promatranom sektoru (putem akviziranih radarskih jeka i AIS oznaka brodova) moguće je odrediti maksimalni broj nadziranih brodova, odnosno gustoću prometa te kritična mjesta konvergencije pomorskog prometa. Na temelju tih podataka bilo bi moguće privremeno izmijeniti granice promatranog sektora pojedinog VTS operatera unutar jurisdikcije toga centra, te dio područja prebaciti na drugog, manje opterećenog operatera. Tim sustavom bi se mogla održavati ravnoteža u opterećenosti operatera te dinamički raspoređivati sektore područja s obzirom na trenutnu složenost prometa [11].
- **Automatsko emitiranje VTS obavijesti** i upozorenja koja su namijenjena za sve brodove u promatranom području, bi omogućilo rasterećivanje komunikacijskih obveza operatera. Takvo emitiranje je moguće organizirati putem AIS sustava i VHF-a. Obavijesti, upozorenja i upute za određeni brod i dalje se moraju pojedinačno davati nekim od komunikacijskih sredstava na raspolaganju.
- **Kombinacija i integracija radara, AIS-a i ECDIS-a** s pripadajućim alarmnim sustavima. Operateru je moguće znatno olakšati nadzor nad brodovima na način da mu se privuče pozornost za neku od radnji i opasnih ili nedopuštenih situacija, a one mogu biti:
  - » automatska akvizicija brodova na ulasku u VTS područje, te deakvizicija brodova na izlasku iz VTS područja ili dolaskom na vez;
  - » kontrola i statističko praćenje gustoće prometa promatranog područja;
  - » praćenjem i predviđanjem najbliže točke i vremena susreta dvaju brodova (engl. Closest Point of Approach – CPA i Time to Closest Point of Approach – TCPA) moguće je alarmirati operateru kritično mimoilaženje, odnosno moguću opasnost od sudara dvaju brodova;
  - » praćenjem i predviđanjem najbliže točke i vremena mimoilaženja broda od kopna, moguće je alarmirati operateru moguću opasnost od nasukanja brodova;

3.2 Optimization Recommendations

Reducing the workload can be achieved by influencing some of the mentioned factors, by the application of new approaches to work commitments and habits, and by introducing new and more efficient technologies. Recommendations that can be emphasized are:

- introduction of a *dynamic sector* in computer applications and VTS centre organization. Applying an automatic process which counts the number of ships in a sector (using radar and AIS), it is possible to determine the maximum allowed number of monitored ships and the critical convergence spots in maritime traffic. Based on these data, it is possible to temporarily change the boundaries of the VTS sector of each VTS operator within the entire VTS area, and a part of the sector area switch to another, less burdened operator. This system could maintain a balance among the operators' workload, and dynamically allocate area sectors giving the current traffic complexity 11];
- automatic broadcasting of information and warnings designated to all ships in the area of interest, would disburden the operator communications liability. Such broadcasts can be organized through the AIS and VHF. Notices, warnings and directions for a single selected ship have to be individually given through some of the communications systems available;
- combination and integration of Radar, AIS and ECDIS with associated automatic alarm systems. Ships monitoring can be greatly facilitated to the operator by drawing his attention to particular, dangerous or illegal actions and situations. This may be done by:
  - » automatic acquiring of ships entering the VTS area, and disacquiring ships leaving the VTS area or at berth;
  - » traffic density control and statistical monitoring of the observed area;
  - » monitoring and simulating the Closest Point of Approach (CPA) and Time to the Closest Point of Approach (TCPA) of two or more ships, it is possible to alert the operator about the critical ship's passing distance and potential collision danger;
  - » monitoring and simulating the CPA and TCPA of the ship from the coastline or

» uvođenjem i računalnim označavanjem zabranjenih ili zaštićenih zona na moru, moguće je odrediti alarm javljanja operateru za svaki ulazak i izlazak broda u neko od tih područja;

» automatskim računalnim praćenjem i zapisom brodskog puta moguće je provjeravati pridržava li se pojedini brod Pravila za izbjegavanje sudara, plovidbi shemom odvojene plovidbe, ograničenju brzine i sl.;

» alarmom sidrene pozicije, moguće je odrediti i nadzirati maksimalni lazni krug broda na sidrištu te odmah uočiti ukoliko dolazi do pretjeranog pomicanja broda uslijed oranja sidra ili drugih razloga;

- **upotrebom umreženih aplikacija** moguće je automatizirati obveznu izmjenu podataka VTS centra s drugim institucijama na kopnu te umanjiti ili ukinuti obveznu komunikaciju telefonom ili radiostanicom. Navedeno je korisno, primjerice, za izmjenu podataka s lučkom kapetanijom, peljarima, agentima i ostalim pravnim osobama glede najave dolaska i odlaska brodova, pozicije, vrste i količine tereta i dr.;
- **usavršavanje vježbom i izobrazbom** je neophodno za povećanje učinkovitosti rutinskih i izvanrednih procedura. Povećanjem razine znanja, iskustva i vještina operatera povećava se sigurnost, brzina i točnost izvođenja svih radnji, a time se i smanjuje radna optrećenost operatera.

Bitno je naglasiti da preveliki broj osoblja unutar VTS centra može također narušiti radnu učinkovitost, stvarajući dosadu i nezainteresiranost. Takva situacija sprječava operaterima sakupljanje neophodnog iskustava i razvijanje vještina te cijeli tim može postati neadekvatan za potrebe VTS službe.

Točan broj brodova koje jedan VTS operater može istovremeno promatrati tijekom određenog razdoblja jest teško odrediti, zbog djelovanja svih navedenih čimbenika, a da se taj podatak može koristiti općenito za različite VTS centre. Prilikom istraživanja radnog opterećenja u VTS centru New York preporučeno je da jedan operater može nadzirati do 14 brodova u 30 minuta [11]. Takav podatak može biti dobra preporuka za taj VTS centar u doba provođenja istraživanja. Bilo koji drugi VTS centar bi trebao provesti vlastito istraživanje s vlastitim operaterima za svoja područja nadležnosti i

shallow waters, it is possible to alert the operator about potential grounding;

» using computer monitoring of prohibited or protected areas at sea, it is possible to introduce the alarm signaling every ship's entrance and exit from these areas;

» using automatic monitoring and data recording of ships track, it is possible to check whether a certain ship does not comply with COLREG, separation schemes, speed limits, etc.;

» anchor position alarm, it is possible to determine and monitor the maximum ship's circle at anchor, and immediately see if there is an excessive movement of the ship due to dragging, or any other reasons;

- using applications through computer networks, it is possible to automate the necessary data exchange between the VTS Centre and other institutions ashore, reducing or eliminating the need to communicate by telephone or radio station. The above mentioned is useful, for example, for the data exchange with port authorities, pilots, agents, and other legal entities regarding ship's notices of arrival and departure, positions, cargo, draft, etc;
- education and training are necessary to increase the effectiveness of routine and emergency procedures. Increasing the operator's level of knowledge, experience and skills, it also increases the safety, speed and accuracy in task performance, and thus also reduces the operator's workload.

It should be noted that too many personnel within the VTS Centre can also impair work performance by creating boredom, monotony and lack of interest. This situation could prevent the operators in the acquisition of necessary experience and skills, leading the whole team to become inadequate for the needs of the VTS.

The exact number of ships that a single VTS operator can simultaneously monitor during a certain time period is difficult to determine, due to the effect of all the previously mentioned factors, especially to determine the exact number that could be used generally, i.e. for different VTS Centres. Upon the workload research in the VTS Centre New York, it was recommended that a single operator can monitor up to 14 ships in 30 minutes [11]. These information can be a good recommendation for that

ustvrditi je li broj zaposlenih preveliki ili premali, te može li se i na koji čimbenik utjecati da se poveća učinkovitost. Tijekom vremena istraživanje bi se trebalo ponoviti, kada se znatno promijeni bilo koji od prije navedenih bitnih čimbenika.

4. METODE ODREĐIVANJA RADNOG OPTEREĆENJA

Po definiciji radnog opterećenja, iz prethodnog poglavlja, moguće je odrediti tri osnovna stanja opterećenja osobe za vrijeme rada, odnosno smjene. Prvo stanje može označavati situaciju kada je sposobnost operatera znatno iznad postavljenih zahtjeva rada. Takva situacija može dovesti do dosađivanja, smanjene koncentracije i elana te uspavanosti operatera čime može biti sklon pogreškama.

Drugo stanje jest kada je izjednačena sposobnost operatera s postavljenim zahtjevima. Takvo postignuto stanje je optimalno za broj zaposlenih operatera u smjeni, za najbolju učinkovitost rada i koncentraciju te je vjerojatnost pogrešaka najmanja.

Treće stanje jest kada su postavljeni radni zahtjevi iznad sposobnosti operatera te ih nije u mogućnosti pravovremeno izvršavati, što uzrokuje smanjenu učinkovitost i sklonost pogreškama. Ukoliko se treće stanje redovito ponavlja ili dovoljno dugo traje može izazvati pojavu stresa kod operatera i općenito nezadovoljstvo s poslom. Navedenim se može definirati da je prihvatljivo, odnosno optimalno radno opterećenje operatera ona razina opterećenja koja mu omogućava sigurno i učinkovito upravljanje VTS sustavom [7].

Za odrediti stanje opterećenja osobe postoje razni pristupi i metode, koje se načelno mogu podijeliti u četiri skupine [1]:

- prva skupina jesu subjektivne metode procjene, koristeći različite upitnike, obrasce, ocjene i indekse koje promatrane osobe subjektivno i samostalno bilježe i određuju. Prednost subjektivnih metoda jest brzina dobivanja rezultata te činjenica da se ne koriste nikakvi uređaji i eksperimentalna oprema, osim papira i olovke ili jednostavne računalne aplikacije. Najveći nedostatak jest moguća neopravdana subjektivnost operatera koja može test učiniti nevjerodostojnim izvorom podataka;

specific VTS Centre at the time of research. Any other VTS centre should conduct its own research with its own operators for their jurisdiction area, to ascertain whether the number of employees is too great or too small. During the research, it could be determined whether any influence factor could be altered to increase efficiency. When a significant change appears in any of the foregoing important factors, a research should be repeated.

4. METHODS FOR WORKLOAD DETERMINATION

By workload definition in the previous chapter, it is possible to identify three main load conditions during the working time or shift. The first condition can indicate a situation when the operator's ability is significantly above the task requirements. A situation like that can lead to boredom, reduced concentration and enthusiasm, and the operator can be prone to errors.

The second condition is when the operator's ability is equal with the task requirements. This achieved condition is optimal to determine the appropriate number of employees, for the best work performance and concentration, and the risk for errors is the lowest.

The third condition is when the task requirements are beyond the operator's ability, without the possibility to perform them on time, which leads to a reduced efficiency and an increased risk of errors. If the third condition occurs regularly or lasts long enough, it can cause the appearance of stress and dissatisfaction with the job in general. Taking these facts into account, the acceptable or optimal VTS operator workload can be defined as a load level which enables a safe and efficient management of the VTS system [7].

To determine a person's load condition, there are various approaches and methods, which can be divided into four groups [1]:

- the first group are subjective assessment methods, using different questionnaires, forms, evaluations and indices which persons under observation self-determine and record subjectively and independently. The advantage of the subjective methods is the quickness of obtaining results and the fact that there is no use of any device or experimental equipment, other than paper and pencil or a simple computer application. The greatest disadvantage

- druga skupina jesu metode procjene kojima se uspoređuje ponašanje i učinkovitost promatrane osobe tijekom izvođenja rada;
- treća skupina jesu objektivne metode koje se temelje na fiziološkim mjerenjima promatranih osoba kao što su brzina pomaka oka, dilatacija zjenica oka, frekvencija treptanja oka, temperatura kože, galvanska reakcija kože, frekvencija otkucaja srca, krvni tlak, frekvencija udisaja i sl. Medicinski je utvrđeno da stres i emocionalna stanja ljudi utječu na promjene navedenih fizioloških mjerenja te se time može odrediti mentalna i fizička opterećenost osobe;
- četvrta skupina jesu metode kojima se kognitivna aktivnost osobe određuje na direktan način mjereći moždane signale.

Koristeći dostupnu literaturu na temu ispitivanja radnog opterećenja osoba na radnim mjestima kontrole prometa, vidljivo je da su najviše ispitivanja i eksperimenata prilagođena i provedena u zrakoplovnoj industriji, točnije na kontrolorima leta (engl. ATC – Air Traffic Controlers) i pilotima zrakoplova. U znatno manjoj mjeri su provođena ispitivanja na VTS operaterima, tako da je radno opterećenje tih ljudi još uvijek dosta neistraženo s obzirom na velike razlike u radnim uvjetima i složenosti nadziranog morskog područja. Navedeno je razumljivo s obzirom da je zrakoplovna industrija jedna od najbrže razvijanih zbog prirode transporta, velikih brzina zrakoplova i potencijalnih opasnosti od sudara u zraku ili zrakoplovnoj luci, padu zrakoplova i sl.

Zbog relativne sličnosti između radnih obveza kontrolora leta i VTS operatera, metode razvijene i korištene za potrebe zrakoplovne industrije, mogu biti korisne i za ispitivanje VTS operatera, ali uz svjesnost o specifičnim čimbenicima pomorskog prometa koji utječu na rad.

Od navedene četiri skupine metoda za procjenu opterećenja, najčešće korištene i najučinkovitije u dosadašnjim ispitivanjima su se pokazale metode iz prve skupine, odnosno subjektivne metode te metode iz treće skupine, odnosno objektivne metode mjerenjem promjena fizioloških parametara operatera. Zbog navedenog, u nastavku će se navesti kratki opis i primjena nekih metoda predstavnika tih dviju skupina.

is the possible unjustified operator's subjectivity which can make the method and research an unreliable source of information;

- the second group are the assessment methods which compare the behavior with efficiency of the observed person during task execution;
- the third group are objective methods based on physiological measurements of the observed persons, such as eye movement speed, eye pupil dilatation, eye blinking frequency, skin temperature, galvanic skin response, heart rate, blood pressure, breaths frequency, etc. It is medically proven that stress and emotional states affect the changes of these physiological measurements, and the knowing that the mental and physical load of any person can be determined;
- the fourth group are methods by which the cognitive activity of individuals is determined by a direct measurement of brain signals.

Using the available literature on the subject of human workload in traffic control workplaces, it is evident that most tests and researches were adapted and implemented in the aviation industry, or more specifically, on the Air Traffic Controllers (ATC) and aircraft pilots. In a much lesser extent tests on the VTS operators were conducted. Because of that the workload of these professionals is still quite unexplored due to the differences in the working conditions and the complexity of the marine areas. These facts are understandable, given that the aviation industry is one of the fastest developed due to the nature of transport, aircraft's high speed, and the potential risk of collisions in the air or at the airport, aircraft crashes, etc.

Because of some relative similarities between the workload of the air traffic controllers and the VTS operators, methods developed and used for the aviation industry can be useful for testing the VTS operators. Doing that, a researcher must be aware of the specific maritime traffic factors which affect the work.

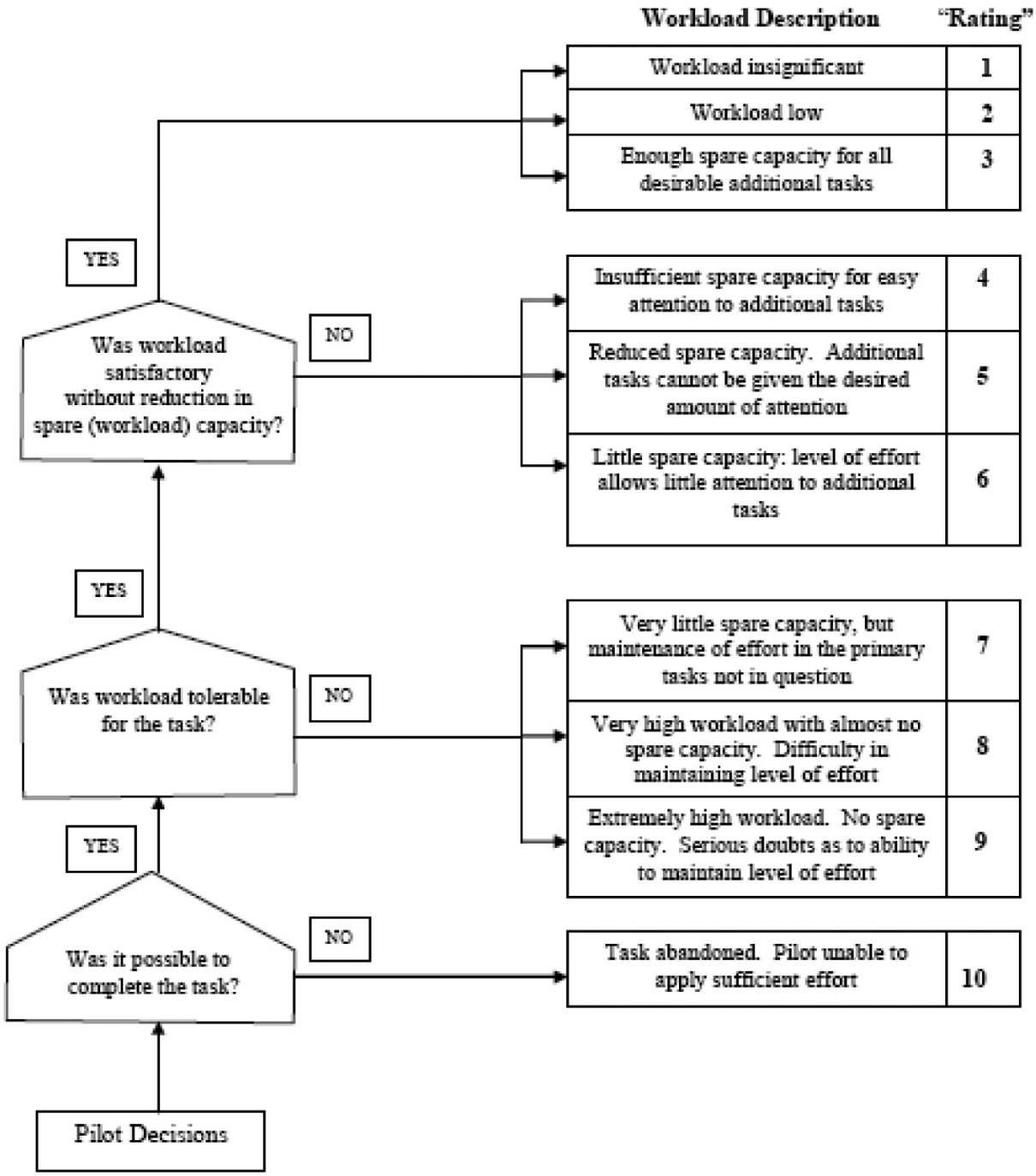
Of the above mentioned four main groups of methods, the most commonly used ones and the most effective in the previously conducted researches have proven the methods from the first group i.e. subjective methods, and the third group i.e. objective methods measuring changes in physiological parameters. Therefore, a brief description and application of some of the methods representing these two groups follows.

4.1. Subjektivne metode

Bedfordova skala (Roscoe and Ellis, 1990) jest jednodimenzionalna procjena mentalnog opterećenja kreirana za pilote zrakoplova. Na jednostavnom principu slijeda pitanja sama promatrana osoba određuje razinu svoje rezer-

4.1 Subjective Methods

Bedford Scale (Roscoe and Ellis, 1990) is a one-dimensional assessment of the mental workload created for aircraft pilots. Using simple questionnaire, an observed person determines by itself the level of spare ability to per-



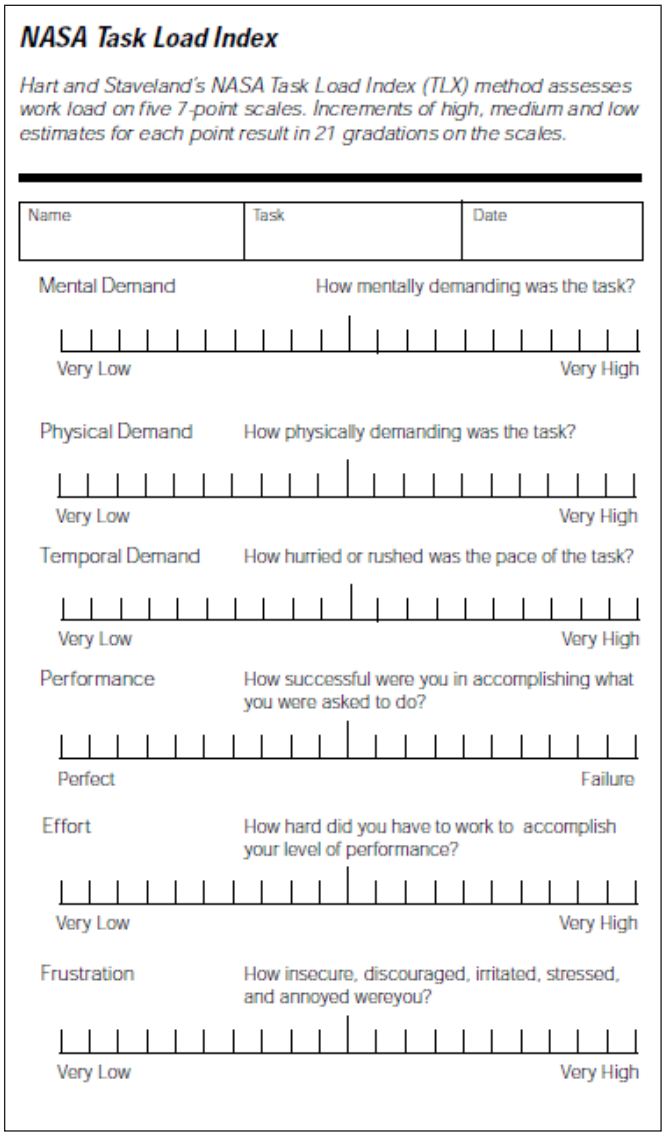
Slika 1. Bedfordova skala radnog opterećenja
Figure 1 *Bedford workload scale*

Izvor: Stanton, N. A., et al., Human factors methods – a practical guide for engeneering and design, Ashgate Publishing Limited, 2005 / *Source: Stanton, N. A., et al., Human factors methods – a practical guide for engineering and design, Ashgate Publishing Limited, Great Britain, 2005.*

Level	Workload Heading	Spare Capacity	Description
5	Excessive	None	Behind on tasks; loosing track of the full picture.
4	High	Very Little	Non-essential tasks suffering. Could not work at this level very long.
3	Comfordable Busy Pace	Some	All tasks well in hand. Busy but stimulating pace could keep going continuously at this level.
2	Relaxed	Ample	More than enough time for all tasks. Active on ATC task less than 50% of the time.
1	Under-Utilised	Very Much	Nothing to do. Rather boring.

Slika 2. ISA skala radnog opterećenja
***Figure 2** ISA workload scale*

Source: Stanton, N. A., et al., Human factors methods – a practical guide for engineering and design, Ashgate Publishing Limited, Great Britain, 2005. / *Izvor: Stanton, N. A., et al., Human factors methods – a practical guide for engeneering and design, Ashgate Publishing Limited, 2005.*



Slika 3. NASA TLX skala
***Figure 3** NASA TLX scale*

Izvor / *Source*: http://human-factors.arc.nasa.gov

vne sposobnosti za obavljanje postavljenih radnih zahtjeva. Skala je podijeljena na 10 razina, od 1 koja označava zanemarivo opterećenje, do 10 koja označava preveliko opterećenje i nemogućnost izvršavanja zadatka (Slika 1). Skala se zbog jednostavnosti primjene može ispunjavati i za vrijeme postavljenog radnog zahtjeva [10].

ISA – *Instantaneous Self-Assessment* jest vrlo jednostavna metoda kojom promatrana osoba može procijeniti svoju radnu opterećenost tijekom izvršavanja radnih zadataka. Metoda je razvijena 1992. godine u početku za ocjenjivanje mentalne opterećenosti kontrolora zračnog prometa. ISA metodom subjekt je potaknut u pravilnim vremenskim razmacima (uobičajeno svakih nekoliko minuta) samostalno, ocjenom od 1 do 5 procijeniti svoju opterećenost (Slika 2). Ocjena 1 označava nezauzetost i veliku količinu rezervne sposobnosti izvršavanja zadataka, a ocjena 5 označava izuzetnu opterećenost bez rezervne sposobnosti izvršavanja zadataka [10].

NASA TLX – *Task Load Index* (Hart i Staveland, 1988) jest metoda za određivanje mentalnog opterećenja putem višedimenzionalne skale. Skala se sastoji od 6 dimenzija, odnosno vrsta opterećenja (Slika 3) da bi se ustanovila dijagnoza o prirodi i udjelu svake vrste koje utječu na cjelokupnu opterećenost osobe [10]. Dimenzije, odnosno vrste opterećenja jesu:

- mentalni zahtjevi – kolika je potrebna mentalna aktivnost poput razmišljanja, odluka, računanja, je li zahtjev kompleksan ili jednostavan i sl.;
- fizički zahtjevi – kolika je potrebna fizička aktivnost, brzina, spretnost i sl.;
- vremenski zahtjevi – pritisak roka izvršenja, tempo rada;
- učinkovitost – subjektivno mišljenje o osobnoj učinkovitosti i zadovoljstvu;
- trud – koliko je truda trebalo utrošiti za rad (mentalno i fizički);
- frustracija – ocjena između nesigurnosti, obeshrabljenja, iritacije, stresa i dosade naspram sigurnosti, zadovoljstva, opuštenosti i spokoja.

NASA TLX je najčešće korištena subjektivna metoda za određivanje mentalne opterećenosti u više područja, poput vojnog i civilnog zrakoplovstva, kontrolnim centrima zrakoplovnog prometa, kontrolnim centrima nuklearnih elektrana te cestovnom prometu.

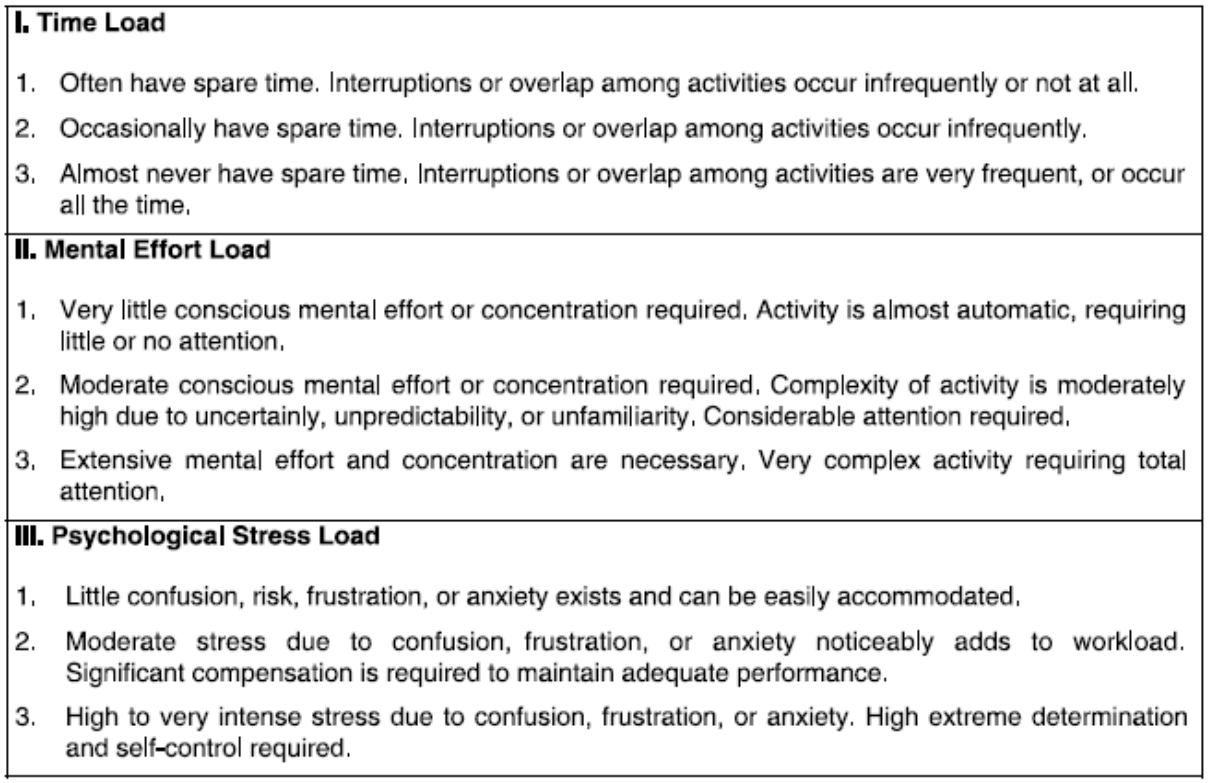
form the given task requirements. The scale is divided into 10 levels i.e. ratings, from 1, indicating an insignificant workload, to 10 that indicates a too high workload and inability to perform the task (Figure 1). Because of its simplicity the test can be used while performing duties [10].

ISA – Instantaneous Self Assessment is a very simple method by which the observed person can self evaluate the workload while performing its duties. It was developed in 1992 to evaluate the mental workload of air traffic controllers. By using the ISA method, the observed person is stimulated at regular intervals (usually every few minutes) to independently self-assess its workload using 1 to 5 levels (Figure 2). Level 1 indicates an under-utilized workload and a large amount of spare capacity to carry out tasks, on the other hand, level 5 indicates an excessive workload with no spare capacity to carry out tasks [10].

NASA TLX – Task Load Index (Hart and Staveland, 1988.) is a method for determining the mental workload using a multi-dimensional scale. The scale consists of 6 dimensions (Figure 3) to diagnose the nature and proportion of each type of load which impacts on the whole person's workload [10]. The dimensions of the load are:

- mental demands – how much mental activity the person needed (thinking, decision making, calculation, was the requirement complex or simple, etc);
- physical demands – how much physical activity the person needed (speed, agility, etc.);
- temporal demand – pressure due to the execution of the time limit or work pace;
- performance – the subjective opinion of a personal performance and satisfaction;
- effort – how much effort was required (mentally and physically);
- frustration – rating between uncertainty, discouragement, irritation, stress and boredom versus security, pleasure, relaxation and tranquility.

NASA TLX is the most commonly used subjective method for determining the mental workload in several areas, such as military and civil aviation, air traffic control centres, nuclear power plant control centres and road traffic.



I. Time Load

1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interruptions or overlap among activities occur infrequently.
3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

II. Mental Effort Load

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainly, unpredictability, or unfamiliarity. Considerable attention required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

III. Psychological Stress Load

1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.
2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration, or anxiety. High extreme determination and self-control required.

Slika 4. SWAT skala čimbenika opterećenja
Figure 4 *SWAT workload scale*

Izvor: Stanton, N. A., et al., Human factors methods – a practical guide for engeneering and design, Ashgate Publishing Limited, 2005. / *Source: Stanton, N. A., et al., Human factors methods – a practical guide for engineering and design, Ashgate Publishing Limited, Great Britain, 2005.*

SWAT – *Subjective Workload Assessment Technique* (Reid i Nygren, 1988), odnosno subjektivna tehnika procjene radnog opterećenja jest višedimenzionalna metoda kojom se određuje opterećenje subjekta analizom tri čimbenika: vremensko opterećenje, mentalni trud i psihološki stres. Svaki čimbenik ima tri razine koje subjekt samostalno određuje nakon obavljena zadatka (Slika 4). Metoda je kreirana u početku za procjenu opterećenja pilota i posade zrakoplova te uz NASA TLX metodu jedna je od najčešće korištenih za tu namjenu [10].

MACE – *Malvern Capacity Estimate* (Goillau i Kelly, 1996) jest metoda za jednostavnu i brzu procjenu maksimalnog kapaciteta opterećenosti osobe. Kreirana je za kontrolore zrakoplovnog prometa koji samostalno ocjenjuju svoj kapacitet nadziranja broja zrakoplova. MACE se ispunjava i primjenjuje na kraju radnog zadatka i dobivaju se rezultati maksimalnog kapaciteta osobe za nadzor određenog broja zrakoplova na sat. Metoda je namijenjena za upotrebu tijekom simulacijskih vježbi.

SWAT – Subjective Workload Assessment Technique (Reid and Nygren, 1988) is a multidimensional method which determines the load on the subject by the analysis of three factors: time load, mental effort load and psychological stress load. The observed person individually and subjectively rates each factor upon the completed task by choosing one of the three offered levels (Figure 4). Initially, the method was designed to assess the workload of aircraft pilots and crew, and it is one of the most commonly used for this purpose next to the NASA TLX method [10].

MACE – Malvern Capacity Estimate (Goillau and Kelly, 1996.) is a method for a rapid and simple estimation of a person's maximum load capacity. It is designed primarily for air traffic controllers who independently assess their capacity to monitor a certain number of aircrafts. MACE is used, filled up and implemented after task completion, and the given results have shown the maximum capacity i.e. capacity of monitored aircrafts per hour. The

Pored navedenih postoji još niz drugih subjektivnih metoda koje se koriste za dodatna istraživanja te radne i psihološke procjene kako pojedinaca tako i cjelokupnog tima neke organizacije. Ova skupina metoda često se provode i kao kontrolne metode za usporedbu s rezultatima ostalih istraživanja.

4.2. Objektivne metode mjerenjem fizioloških parametara

Po učestalosti korištenja, druga velika skupina jesu objektivne metode kojima se mjerenjem uočavaju i bilježe promjene fizioloških parametara osobe uslijed pojave stresa, mijenjanja emocionalnog stanja ili opterećenja. Međutim, treba znati koje fiziološke vrijednosti daju točnije podatke i čije promjene su jasnije vidljive u kratkim vremenskim intervalima tijekom promatranja, odnosno eksperimentiranja. Jedne od češće korištenih takvih metoda jesu praćenje promjena sljedećih parametara:

- **potencijal kože** – može se mjeriti samoljepljivim Ag/AgCl elektrodama. Elektrode se obično postave na ruku promatrane osobe. Aktivna elektroda se može postaviti na hipotenar (uzvisinu na prednjoj strani dlana koju čine mišići koji kontroliraju mali prst) nedominantne ruke, a referentna elektroda se može postaviti 10 cm dalje na ručni zglob;
- **provodljivost kože** – može se mjeriti 50 mm^2 Ag/AgCl elektrodama postavljene na drugi članak kažiprsta i prstenjaka nedominantne ruke. Potencijal se može mjeriti istosmjernom strujom od 15 μA;
- **protok krvi u koži** – može se mjeriti neinvazivnim senzorima, poput Hematron senzora, koji se može postaviti na palčanu uzvisinu na dlanu nedominantne ruke. Aktivni dio Hematron senzora koji dira kožu sastoji se od mjernog i referentnog dijela. Mjeri se temperaturna razlika između ta dva dijela, na način da centralni inercijski grijač održava uvijek temperaturnu razliku od 2 stupnja Celzija između centralnog i perifernog dijela. Veličina i oblik grijača je takva da se temperaturno polje širi samo kapilarnom mrežom u koži. Mjerna snaga utrošena na održavanje razlike temperature ovisi o protoku krvi u kapilarama koja odnosi toplinu;
- **temperatura kože** – može se mjeriti osjetljivim termorezistorima koji se obično postav-

method is intended for use during simulation exercises.

In addition to these methods there are a number of other subjective methods used for additional research, physical and psychological assessment for individuals and entire teams of an organization. The methods from this group are often used as control methods for comparing the result with other studies and researches.

4.2 Objective Methods Measuring Physiological Parameters

By using frequency, in the second large group there are objective methods used to measure and record the changes in physiological parameters of a person due to effects of stress, emotional state or workload. However, it should be known which physiological values provide more accurate data and whose changes are clearly visible or detectable during the short time observation periods. Objective methods include monitoring of changes in the following parameters:

- **skin potential** – can be measured by self-adhesive Ag/AgCl electrodes. Electrodes are usually placed on the observed person's hand. The active electrode can be placed on the hypothenar (eminence on the palm, which are the muscles that control the little finger) of the non-dominant hand, and the reference electrode can be placed 10 cm further on the wrist;
- **skin conductance** – can be measured by 50mm^2 Ag/AgCl electrodes placed on the index and ring finger of the non-dominant hand. The potential can be measured by the direct current of 15 μA;
- **skin blood flow** – can be measured by noninvasive sensors, such as Hematron sensors, which can be placed on the thenar eminence of the non-dominant hand. The active part of the Hematron sensor that touches the skin consists of measuring and reference part. The temperature difference is measured between the two parts, in a way that the central inertial heater always maintains a 2 degrees Celsius temperature difference between the central and peripheral part. The size and shape of the heater is such that the temperature field expands only through the skin capillary network. The measured power spent on maintaining

ljaju na unutrašnju stranu dlana nedominantne ruke;

- **frekvencija srca** – može se mjeriti elektrodama postavljenim na prsima u razini srca. Derivacijski signal kao interval između dva uzastopna R vala elektrokardiograma (ECG) elektronski se obrađuje i prikazuje kao frekvencija srca;
- **pomaci oka** – mogu se mjeriti s EMR senzorom (engl. Eye Mark Recorder) kojim je moguće definirati i pratiti točke fiksacije i vrijeme fiksacije oka. Ovom metodom se može utvrditi na koje informacije, sudionike u prometu i situacije operater pridodaje najviše pažnje tijekom radnog vremena [8]. Moguća je i primjena aplikacija koja uz praćenje pomaka oka, bilježi vrijeme trajanja treptaja i brzinu pomaka oka, za koje je istraživanjima dokazano da se oba parametra smanjuju tijekom povećanja mentalnog opterećenja. Nasuprot tome, promjer zjenice se povećava s povećanjem kognitivnih zahtjeva [2]. Prednost prikupljanja podataka o pomacima oka operatera jest što je osim vremena nastupanja većeg opterećenja moguće definirati što je operater gledao kada je opterećenje nastupilo.

5. PRIMJERI PROVEDENIH ISTRAŽIVANJA OPTEREĆENJA

U nastavku slijede primjeri provedenih istraživanja i eksperimentiranja na ATC i VTS operaterima te komentari na dobivene rezultate i uočene čimbenike koji utječu na radno opterećenje.

5.1. Ispitivanje praćenjem frekvencije srca

Broj otkucaja srca zdrave odrasle osobe kreće se između 60 i 140 puta u minuti, ovisno odmara li se osoba ili fizički napreže, odnosno je li opuštena ili pod stresom. Frekvencija srca jest pojam koji opisuje frekvenciju kardijalnog ciklusa, tj. određuje broj srčanih kontrakcija u minuti. Varijabilnost frekvencija srca (engl. Hart Rate Variability – HRV) jest varijacija u vremenu između dvaju sukcesivnih otkucaja srca (R-R interval između dvaju vrhova vala otkucaja srca). Granične vrijednosti R-R intervala jesu niska frekvencija (engl. Low Frequency – LF) od 0,04 – 0,15 Hz te visoka frekvencija (engl. High Frequency – HF) od 0,15 – 0,40 Hz.

the temperature difference depends on the blood flow in the capillaries;

- **superficial skin temperature** – can be measured by sensitive thermistor which is usually placed on the inner side of the palm of the non-dominant hand;
- **heart rate** – can be measured by electrodes placed in the precordial position. Derivation signals as the interval between two successive R waves of the electrocardiogram (ECG) are electronically processed and displayed as a heart rate;
- **eye movements** – can be measured with the Eye Mark Recorder (EMR) sensor that can be used to define and monitor the point and time of eye fixation. Using this method it can be determined on which data, traffic participants and situation, the operator pays the most attention during the working hours [8]. It is possible to use an application which beside the eye movements monitoring records the blinking duration and the speed of the eye movement, which is proven in researches that both parameters are reduced during the increased mental workload. On the other hand, the pupil diameter increases with higher cognitive demands [2]. The advantage of collecting data about the operator's eye movements beside defining the time of the high workload occurrence, it can be defined what was the operator looking at that exact time i.e. the cause of the workload.

5. EXAMPLES OF PERFORMED WORKLOAD RESEARCHES

The following are examples of the research and experimentation on the ATC and VTS operators as well as comments on the obtained results and identified factors which affect the workload.

5.1 Heart Rate Monitoring

The heart rate of healthy adults ranges between 60 and 140 times per minute, depending on whether the person is resting or under physical strain i.e. whether it is relaxed or under stress. Heart rate is a term that describes the frequency of a cardiac cycle, which determines the number of heart contractions per minute. Heart rate variability (HRV) is the variation in

Niskom frekvencijom određuje se indeks simpatičkog i parasimpatičkog živčanog sustava koji kontroliraju frekvenciju srca. Visokom frekvencijom određuje se indeks parasimpatičkog tona [7].

Mjerenja navedenih podataka bilježi se pomoću monitora frekvencije srca (engl. Heart Rate Monitor – HRM). Oprema se sastoji od mjernih senzora na zapešću i prsima te pripadajuće programske podrške.

Primjer studije istraživanja mentalnog opterećenja VTS operatera putem frekvencije srca na operaterima Turkish Straits VTS (TSVTS) Istanbul Strait [7], obuhvaća sljedeće:

- određivanje fluktuacije otkucaja srca i LF/HF odnosa svakog operatera osobno. Tijekom određivanja povećanja i smanjenja jačine i frekvencije otkucaja srca uspoređuju se istovremeni radni zahtjevi, događaji i karakteristike broda uključenog u događaj;
- opća procjena osobe i radnog kolektiva radi određivanja zajedničkog ponašanja i razmjene informacija s obzirom na događaje i karakteristike broda uključenog u događaj;
- procjena osobe s obzirom na radni sektor područja nadležnosti (gustoća prometa, pravila plovidbe, radni zahtjevi, pružane usluge, itd.);
- procjena osobe s obzirom na dnevnu razliku doba smjene, radne uvjete u centru te meteorološke i oceanološke prilike.

Rezultati istraživanja doveli su do sljedećih zaključaka:

- mentalno radno opterećenje najveće je na početku preuzete smjene, prvih 2−3 minute, tijekom prilagodbe, namještanja monitora, analiziranja stanja prometa i sl.;
- mentalno opterećenje je općenito najviše u trenucima praćenja pomorskog prometa u usporedbi s ostalim radnim zadacima;
- utvrđena je donja granica značajnog mentalnog opterećenja, koja iznosi 90 otkucaja u minuti. Povećan broj otkucaja, tj. iznad te granice označava značajno opterećenje operatera;
- nije utvrđena ovisnost fizičke predispozicije osobe s fluktuacijama frekvencija srca tijekom rada VTS operatera;
- utvrđeno je da brodovi duži od 150 m, kao i tankeri, brodovi za ukapljeni plin i opasan te-

time between two successive heart beats (R-R interval between two wave peaks of the heart rate). The limiting values of the R-R intervals are the Low frequency (LF) from 0.04 to 0.15 Hz, and the High frequency (HF) from 0.15 to 0.40 Hz. The Low frequency determines the index of the sympathetic and parasympathetic nervous system which controls the heart frequency. The High frequency determines the index of the parasympathetic tone [7].

Measurements of these data are recorded using a Heart Rate Monitor (HRM). The equipment consists of a measuring sensor at the wrist and chest, with the associated software.

An example of the mental load research studies on the Turkish Straits VTS operators (TSVTS-Istanbul Strait) using heart rate recordings [7], includes the following:

- determination of the heart rate and LF / HF relations fluctuations of each operator. While determining variations in the intensity and frequency of heart beats, tasks, events and ship characteristics involved in the events are compared at the sane time;
- general assessment of each person and the whole team to determine the common behavior and information exchange flow with regard to the events and ship characteristics involved in the events;
- operator assessment with regard to the sector of the VTS area (traffic density, navigation regulations, operating requirements, services provided, etc.);
- operator assessment with regard to the daily difference of shift times, working conditions in the centre;
- meteorological and oceanographic conditions.
- The research results have led to the following conclusions:
- mental workload is highest at the beginning of the shift, the first 2-3 minutes, during adjustment, console setting, traffic conditions analysis, etc.;
- generally, mental workload is highest during maritime traffic monitoring in comparison with all other routine tasks;
- a lower limit of significant mental workload is determined, which is 90 heart beats per minute. The heart rate above this limit indica-

ret te brodovi s ukrcanim peljarem utječu na povećanje opterećenja;

- u slučaju postavljenog pitanja treće osobe ka operateru nije zabilježen porast opterećenja, međutim ukoliko sam promatrani operater postavi pitanje opterećenje poraste;
- opterećenje je u porastu u slučajevima davanja savjeta ili instrukcija brodovima;
- promatrani sektori područja nadležnosti utječu na opterećenje, koje je znatno povećano u sektorima veće gustoće prometa, s mjestima križanja kursova te brojnijom komunikacijom s brodovima.

Načelno, čimbenici koji značajnije utječu na rad srca te mentalno opterećenje operatera moguće je sažeti na: specifikacije brodova, promatrani sektor, gustoća prometa, prisutnost peljara, komunikacijske vještine zapovjednika ili časnika broda te umor operatera.

5.2. Oslikavanje mozga optičkim senzorima

Za oslikavanje mozga, odnosno praćenje aktivnosti mozga postoje razne metode poput magnetne rezonance (fMRI), pozitronske emisijske tomografije (PET) i magnetne encefalografije (MEG). Navedene metode su skupe, vrlo osjetljive na pomicanje promatrane osobe i invazivne na zdravlje. Razvojem optičkih senzora danas se češće koristi infracrvena spektroskopija (eng. Functional near-infrared spectroscopy – fNIR) kao neinvazivna metoda kojom se mjeri promjena koncentracije oksigeniranog hemoglobina (oxy-Hb) i deoksigeniranog hemoglobina (deoxy-Hb) u moždanom korteksu. Time se mogu mjeriti i pratiti kognitivne aktivnosti osobe vezane za hemodinamičke promjene u mozgu. fNIR tehnologija i oprema je sigurna, nije skupa u odnosu na prethodne metode, relativno mala i lako prenosiva. Oprema se sastoji od savitljive podloge s izvorima svjetlosnih valova, optičkim senzorima kao receptorima te prateće programske podrške na računalu. Valovi se emitiraju na dužini od 730 nm i 850 nm.

Primjerom studije mentalnog opterećenja kontrolora leta, u sklopu istraživanja na FAA's Wiliam J.Hughes Technical Center, korištenjem fNIR-a utvrđeno je da je fNIR tehnologija pogodna za takva testiranja [1]. Postavljanjem fNIR senzorske podloge na čelo promatranih kontrolora leta pratile su se hemodinamičke promjene u prefrontalnom korteksu. Cijelo

tes a significant mental workload on the operator;

- a person's physical predisposition dependence to heart rate fluctuations during the VTS operator's work is not determined;
- it was found that ships longer than 150 m, as well as tankers, liquefied natural gas carriers, ships with dangerous cargo and pilots onboard affect the increase of the workload;
- in case of questions set by a third party to the operator, no workload increase was recorded, but if the observed operator had a question, the workload increased;
- the workload increased while providing advices or instructions to ships;
- VTS sector characteristics affect the load, which was significantly increased on sectors of a higher traffic density, more waterway crossing points, and numerous communications with ships.

Generally, factors that significantly affect the operator's heart rate and mental workload can be summarized as: ship specification, VTS sector, traffic density, pilot presence onboard, the communication skills of the ship's master or officer and operator's fatigue.

5.2 Brian Imaging Using Optical Sensors

For brain imaging i.e. brain activity monitoring, there are various methods such as magnetic resonance imaging (MRI), positron emission tomography (PET) and magneto-encephalography (MEG). These methods are expensive, highly sensitive to the observed person's movement and invasive to health. With optical sensors development, now are more commonly in use the Functional Near-Infrared Spectroscopy (FNIRS) as a noninvasive method used to measure variations in oxygenated hemoglobin concentration (oxy-HB) and deoxygenated hemoglobin (deoxy-HB) in cerebral cortex. By using FNIRS, person's cognitive activities related to the hemo-dynamic changes in the brain can be measured and monitored. The FNIRS technology and equipment is safe, inexpensive as compared to the previous methods, relatively small and portable. The equipment consists of a flexible pad with light sources, optical sensors as receptors and associated software on a computer. The emitting light wave's length is 730 nm and 850 nm.

istraživanje ovom metodom je zbog malih dimenzija opreme bila provedena na radnom mjestu kontrolora, a ne u laboratoriju. Istraživanjem jest utvrđeno da su promjene u oksigenaciji krvi u prefrontalnom korteksu povezane s kognitivnim radnim opterećenjem kontrolora. Nadalje, utvrđeno je da tekstualni komunikacijski procesi na računalu zahtijevaju znatno manju moždanu aktivnost nego glasovni komunikacijski procesi korištenjem pripadajuće telekomunikacijske opreme. Rezultate fNIR istraživanja potvrdile su subjektivne ocjene operatera za osobno radno opterećenje putem kontrolnih upitnika [1].

5.3. Usporedba subjektivnih i objektivnih metoda – indeks opterećenja

U sljedećem primjeru je vidljiv spoj subjektivnih i objektivnih metoda za određivanje indeksa vrednovanja mentalnog opterećenja osoba [3]. Cilj studije jest određivanje mentalnog opterećenja kontrolora leta tijekom stvarnih radnih operacija promatranjem i usporedbom stvarnog broja nadziranih zrakoplova i predloženog indeksa opterećenja DI (engl. Demand Index). Operaterima je mjereno čak pet vegetativnih varijabli: potencijal i provodljivost kože, protok krvi i temperatura kože, te frekvencija srca. Tim mjerenjima se želi ukazati na istovremene varijacije radnog opterećenja i neurovegetativnih fizioloških parametara. Metode procjene se mogu sažeti na:

1. mjerenje varijacija autonomne fiziološke aktivnosti operatera kroz radno vrijeme,
2. usporedba korelacije između varijacija autonomne aktivnosti s DI indeksom s jedne strane te brojem zrakoplova kao drugim objektivnim indeksom s druge strane,
3. usporedba DI indeksa i ocjena subjektivne metode NASA-TLX testa.

Za vrijeme nadzora zračnog prometa tri situacije su prepoznate i bitno utječu na DI indeks:

- nadzor prometa – zadatak kontrolora jest nadzirati primljene podatke svakog zrakoplova da ne prelaze standardne mjere sigurnosti, poput vertikalne i lateralne separacije;
- radarska kontrola – svim zrakoplovima kojima je odredište ista zrakoplovna luka kontrolor je dužan davati upute glede regulacije prometa te nadzirati usmjerenje i sigurnosnu udaljenost od prethodnog zrakoplova;

By the example of the mental workload study of air traffic controllers, as a part of the research on the FAA's William J. Hughes Technical Center, by using FNIRS, it was found that the FNIRS technology is suitable for such testing [1]. Setting the FNIRS sensor pad on the observed air traffic controller's forehead, the hemo-dynamic changes in the prefrontal cortex were monitored. The whole research was conducted in the ATC workplace, and not in the lab, due to the small dimensions of the equipment. By research it was found that blood oxygenation changes in the prefrontal cortex are associated with the cognitive workload of a controller. Furthermore, it was found that text communication processes on a computer require significantly less brain activity than voice communication processes using associated telecommunications equipment. FNIRS research results were confirmed by the operator's subjective workload assessments using control questionnaires [1].

5.3 Comparison of Subjective and Objective Methods – Workload Index

In the following example, a synthesis of the subjective and objective methods for determining the index of a person's mental load evaluation is visible [3]. The aim of the study is to determine the mental workload of air traffic controllers during real working operations by observing and comparing the actual number of monitored aircrafts and the proposed Demand Index (DI). Even five negative variables were measured on the operator: skin potential and conductance, blood flow, skin temperature and heart rate. By these measurements the intention was to indicate the simultaneous variation of workload and neurovegetative physiological parameters. The assessment methods can be summarized to:

1. measuring the autonomic physiological activity variation of the operator through the hours of operation,
2. comparison of the correlation between the autonomic activity variation and Demand Index on one hand, and the number of aircrafts as another objective index on the other hand,
3. comparison of the Demand Index and NASA-TLX test evaluation as a subjective control method.

- opasnost od sudara – u slučaju da se predvide preklapanja zrakoplovnih ruta ispod minimalnih sigurnosnih udaljenosti, kontrolor je dužan dati upute za izmjenu određene rute.

Smatra se da radno opterećenje raste od prve (nadzora) do treće situacije (opasnost od sudara) te se time i pridodaje ocjena od 1, 2 i 3,5. DI indeks se računa tijekom radnog vremena svakih 10 sekundi, a dobiva se zbrojem broja nadziranih zrakoplova (N) i izračunatog radnog opterećenja na temelju situacije između svakog promatranog para zrakoplova.

Konačni DI se računa:

$$DI=\Sigma DI(j) \text{ uz uvjet } 1 \leq j \leq N . \quad (1)$$

Uz predloženu formulu autora studije, tijekom eksperimenta određeno je pet razina opterećenja: razina 1 s $DI \leq 2,5$ kada se može pojaviti dosada i smanjena budnost, razina 2 s $2,5 \leq DI \leq 5,5$ koja se smatra standardnim radnim opterećenjem, zatim razina 3 s $5,5 \leq DI \leq 9,5$ koja označava osrednje povišenim opterećenjem, razina 4 s $9,5 \leq DI \leq 14$ koja označava visoku opterećenost, te razina 5 kada je $DI \geq 14$ koja označava previsoku i rizičnu opterećenost.

Uz DI računanje, kod pet fizioloških parametara svake osobe uočene su sljedeće promjene: temperatura i protok krvi kože smanjuju se kako se radno opterećenje povećava, te nasuprot tome, provodljivost i potencijal kože, te frekvencija srca raste kako se povećava radno opterećenje.

Rezultati mjerenja i promatranja su doveli do sljedećih činjenica i zaključaka [3]:

- povećanjem objektivnog opterećenja (veći broj zrakoplova ili DI indeks) osobe se smatraju *aktiviranima* kada fiziološki parametri ukazuju na povećanje stupnja napetosti. Nasuprot tome, kada fiziološki parametri ukazuju na smanjenje stupnja napetosti, osobe se smatraju u stanju *opuštanja.* U konačnici, osobe se smatraju u *stabilnom stanju* kada nema promjena u fiziološkim parametrima;
- pokazano je da je postotak aktivacije osoba veći promatrajući DI indeks nego isključivo broj zrakoplova, što ukazuje da broj zrakoplova ne mora nužno povećati radno opterećenje i nije dostatan kao jedini parametar za određivanje opterećenja;

During the air traffic control, three situations were identified that significantly affect the DI index:

- traffic monitoring – the controller task is to monitor the received data of each aircraft that they not exceed the standard security measures, such as the vertical and lateral separation;
- radar control – to all aircrafts with the same destination airport, a controller is required to give instructions regarding traffic regulation and monitor the direction and distance from the preceding aircraft;
- collision risk – if the aircraft courses are crossing or overlapping the below minimum safety distance, a controller is required to give instructions to pilots to change one or both courses.

It is believed that the workload increases from the first (monitoring) to the third situation (collision risk) and thus adds a level of 1, 2 and 3.5. The DI index is calculated during the work time every 10 seconds, and it is obtained by the sum of the number of monitored aircrafts (N) and the calculated workload based on the situation between each observed pair of aircrafts.

Final DI is calculated:

$$DI=\Sigma DI(j) \text{ , with: } 1 \leq j \leq N \quad (1)$$

With the formula proposed by the authors, during the experiment, five levels of workload are determined: level 1 with $DI \leq 2.5$ when boredom and decreased alertness can appear, level 2 with $2.5 \leq DI \leq 5.5$, which is considered to be a standard workload, then level 3 with $5.5 \leq DI \leq 9.5$, which indicates a moderately high workload, level 4 with $9.5 \leq DI \leq 14$, which indicates a high workload, and level 5 when the $DI \geq 14$ indicates an excessive workload. Experimenting DI calculations, the observed five physiological parameters showed on each person the following changes: the temperature and skin blood flow decrease as the workload increases, and on the other hand, the skin conductance, skin potential and heart rate increase as the workload increases.

The measurements and observations results have led to the following facts and conclusions [3]:

- provodljivost i potencijal kože te frekvencija srca su u većoj korelaciji s DI indeksom, brojem zrakoplova i subjektivnih ocjenjivanja. Nasuprot tome, termovaskularne varijable (protok krvi i temperatura kože) su bile u znatno manjoj korelaciji, a time i nepouzdan izvor za određivanje trenutnog opterećenja osobe;
- DI indeks je u jasnoj korelaciji sa NASA-TLX subjektivnim samoocjenjivanjem operatera.

6. ZAKLJUČAK

U gotovo svakom radnom okruženju, pa tako i u VTS centrima, može doći do povremenog porasta ili smanjenja radnog opterećenja, što se smatra normalnim situacijama te prosječno dobro uvježbane i organizirane osobe mogu to relativno lako podnijeti. Međutim, ukoliko se neka od krajnosti opterećenja, preveliko ili premalo, redovito pojavljuje ili neprekidno traje tijekom radnog vremena, može imati vrlo negativan utjecaj na radnu sposobnost i učinkovitost osobe.

Preveliko opterećenje, može dovesti do zamora osobe koja naglo gubi koncentraciju, osoba namjerno skraćuje ili preskače propisane postupke te vremenski ne stiže obaviti obvezne radnje. Nasuprot tome, premalo opterećenje dovodi do uspavanosti i dosade te jednako tako do gubitka koncentracije. U oba slučaja VTS operater jest podložan pogreškama čija posljedica može biti ozbiljno povećanje rizika u pomorskom prometu. Osim podložnosti pogreškama, operateri u krajnjim stanjima opterećenosti mogu izgubiti motivaciju za daljnjim usavršavanjem i napredovanjem što dovodi do općeg nezadovoljstva i interesa za radnim mjestom.

Prilikom određivanja stupnja opterećenosti i optimalnog broja aktivnih operatera, bitno je poznavati prednosti i nedostatke, odnosno ograničenja pojedine metode. Da bi se umanjila pogreška, odnosno povećala pouzdanost dobivenih rezultata, pokazalo se korisno kombinirati dvije ili više metoda različitih vrsta. Najučestalije kombinacije među provedenim istraživanjima do sada su usporedbe dobivenih rezultata mjerenjem promjena fizioloških parametara ili moždane aktivnosti operatera s jednom ili više subjektivnih metoda. Korištenje samo subjektivne metode može biti nepouzda-

- by increasing the objective load (greater number of aircrafts or DI index) the controllers are considered *activated* when physiological parameters indicate an increase in the tension degree. As opposed, when the physiological parameters indicate a decrease in the tension degree, controllers are considered to be in a state of *relaxation*. Ultimately, controllers are considered to be in a *stable condition* when there are no changes in physiological parameters,
- it is shown that the percentage of *activated* controllers is greater observing the DI index, than just the number of aircrafts, which indicates that the greater number of aircrafts does not necessarily increase the workload, and it is not sufficient as the sole parameter for determining the workload,
- skin conductance, skin potential, and the heart rate are more correlated with the DI index, the number of aircrafts and subjective assessments. As opposed, thermo-vascular variables (skin blood flow and superficial skin temperature) were much less correlated, and therefore unreliable source for determining the person's current workload,
- DI index is clearly correlated with the NASA-TLX subjective self-assessment.

6. CONCLUSION

In almost every workplace, including the VTS centres, there may be an occasional increase or decrease in the workload, which is considered as a normal occurrence, and the average well-trained and organized persons can relatively easy handle it. However, if some of the extreme workload, too high or too low, appear regularly or last continuously during the shifts, it can have a very negative impact on the operator's working ability and efficiency.

Too high workload can lead to fatigue when the person suddenly loses concentration and the person could intentionally shorten or skip the mandatory procedures and could not manage to finish the required actions on time. As opposed, no workload leads to lethargy and boredom, and also to a loss of concentration. In both cases, the VTS operator is subject to errors which may cause a serious risk increase in maritime traffic. In addition, operators in the extreme states of workloads may lose the moti-

no, posebice u centrima s malim uzorkom, odnosno malim brojem zaposlenih operatera, jer osobni pristup poslu i subjektivno poimanje opterećenja može biti vrlo različito. Provođenje ispitivanja se može vršiti tijekom vježbanja u VTS simulatorima ili u normalnoj radnoj okolini, što je vjerodostojnije.

S detaljno identificiranim čimbenicima i primjenom odabranih metoda za određivanje stupnja opterećenosti, svaki VTS centar bi trebao provoditi istraživanje na svojem VTS timu, da se dobije uvid je li organizacija dobra, je li broj zaposlenika optimalan te treba li posvetiti pažnju određenim čimbenicima koji znatno narušavaju učinkovitost centra. Na određene čimbenike se može relativno jednostavno utjecati jer su organizacijskog karaktera, primjerice raspodjela nadziranih sektora, dužina dežurstva, obvezne radne procedure i obim pružanih usluga. Ostali čimbenici poput uvjeta radne okoline, tehnologije i oprema na raspolaganju te komunikacije mogu zahtijevati i nova znatna ulaganja sredstava da bi se postupci centra unaprijedili.

Unutar VTS tima, može se pokazati izuzetno korisno imati ili povremeno angažirati VTS instruktora s osnovnom funkcijom uvježbavanja i pružanja dodatne izobrazbe operaterima, čime se učinkovitije sakuplja neophodno iskustvo i vještina.

vation for further development and promotion, leading to general discontent and losing interest in profession.

When determining the level of the workload and the optimal number of active operators, it is important to know the advantages, disadvantages and limitations of each method. In order to reduce the error possibility and to increase reliability of the results, it is shown useful to combine two or more methods of different approaches. The most common methods combination is a comparison between the results obtained by measuring the changes in the physiological parameters or the operator's brain activity with one or more subjective methods. Using only subjective methods can be unreliable, especially in centres with a small pattern i.e. a small number of employed operators, because the personal approach to work and the subjective perception of load may be very different. Testing can be performed during training in the VTS simulators or in the normal operating environment, what is more authentic.

With the precisely identified influence factors and selected methods application for determining the workload level, each VTS centre should conduct a research on its own VTS team, to gain an insight into whether the organization is proper, whether the operator number is optimal, and whether is needed to pay attention to certain factors that significantly impair the work effectiveness. Certain factors can be relatively easily controlled because they are of an organizational nature, such as the VTS sector distribution, length of shifts, mandatory operating procedures and provided services. Other factors, such as working environment conditions, technology and equipment available and communications, may require new and substantial investments of resources to enhance the processes.

Within the VTS team, it would be extremely useful to have, or occasionally to engage, a VTS instructor with the basic function of conducting additional training and education of all operators, thus effectively providing such a necessary experience and skills.

LITERATURA / REFERENCES

[1] Ayaz, H., et al., Cognitive Workload Assessment of Air Traffic Controllers Using Optical Brain Imaging Sensors, Advances in Understanding Human Performance: Neuroergonomics, Human Factors Design, and Special Populations, CRC Press, Taylor & Francis Group, 2010.

[2] Ahlstrom, U., An Eye for the Air Traffic Controller Workload, Journal of the TRF, 46 (2007), 3.

[3] Collet, C., et al., Subjective Aspects of Mental Workload in Air-Traffic Control, Performance et Innovation des IHM, Toulouse, 2010.

[4] IALA Guideline No. 1045 On Staffing Levels at VTS Centres, 1st ed., France, 2005.

[5] IALA Vessel Traffic Services Manual, 4th ed., France, 2008.

[6] IALA Recommendation V-127 On Operational Procedures for Vessel Traffic Services, 1st ed., 2004.

[7] Kum, S., et al., Mental Workload of the VTS Operators by Utilising Heart Rate, Transnav 2007 – The 7th International Navigational Symposium on Marine Navigation and Safety of Sea Transportation, Gdynia, 2007.

[8] Kum, S., et al., VTS Operators' Eye Movements, World Maritime Excellence, Odesa National Maritime Academy, Odesa, 2007.

[9] MSC/Circ.1014, Guidelines on Fatigue, London, International Maritime Organization, 2001.

[10] Stanton, N. A., et al., Human Factors Methods – A Practical Guide for Engeneering and Design, Ashgate Publishing Limited, 2005.

[11] Workload of the VTS Sector Operator and Implications for Task Design, U.S. Coast Guard Research and Development Center, Groton, 1994.

[12] http://human-factors.arc.nasa.gov