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IZAZOVI BUDUĆIH ISTRAŽIVANJA U OBLASTI INDUSTRIJSKE BEZBEDNOSTI

CHALLENGES OF FUTURE RESEARCH IN THE AREA OF INDUSTRIAL SAFETY

Originalni naučni rad / Original scientific paper
UDK /UDC: 614.8.084:6
331.45/.46:6
Rad primljen / Paper received: 03.10.2014

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Ključne reči
- industrijska bezbednost
- visokorizični sistemi
- ljudski faktor

Izvod

U današnjim turbulentnim uslovima poslovanja koje karakterišu ubrzan tehnološki razvoj „post-industrijskog“ društva, u kome nove tehnologije uzrokuju stvaranje novih rizika, upravljanje bezbednošću složenih tehno-socio-ekoloških sistema postaje imperativ održanja i opstanka. Kroz pregled tehnoloških otkrića, ali i talasa velikih tehnoloških i socioloških i ekoloških katastrofa, prikazani rad ukazuje na probleme budućih istraživanja u ovoj oblasti.

Keywords
- industrial safety
- high-risk systems
- human factor

Abstract

In today's turbulent business conditions, characterised by rapid technological development of a 'post industrial' society, in which new technologies result in new risks, safety management of complex techno-socio-ecological systems becomes imperative for sustainability and survival. This paper points out the problems related to future research in this area through a review of technological discoveries, and also waves of considerable technological, sociological and ecological disasters.

UVOD

Izučavanje bezbednosti je disciplina koja se razvija poslednjih 30 do 40 godina. Znanja o obezbeđenju bezbednosti očigledno postoje još od najranijih vremena čovekove istorije, ali se ona nije posebno izučavala. Posle II svetskog rata dolazi do tehnološkog razvoja koji je stvorio kompleksne sisteme. Napravljeni su interfejsi između čoveka i mašina u cilju automatizacije. Stvoreni se veliki privredni sistemi kojima je teško upravljati. U 80-tim godinama XX veka je centralna tema bezbednosti bila „normalnost akcidenata“.

VISOKORIZIČNI SISTEMI I TALAS KATASTROFALNIH DOGAĐAJA

Tokom XX veka stvorene su kategorije „visoko rizičnih sistema“: pomorski transport, brane, železnički transport, svemirske misije, hemijska postrojenja, DNA, avionski transport, hazardi od ratova, akcidenti vezani za nuklearna oružja, nuklearne elektrane, rudarstvo.

Slika 1. Hazardi na kraju XX veka

INTRODUCTION

Studying of safety is a discipline which has been in development in the last 30 to 40 years. Knowledge about providing safety apparently dates back to earliest times in mankind history, but it was never studied in detail. Technological advancement after World War II created complex systems. Interfaces between man and machine were designed for the purpose of automation. Large industrial systems which are difficult to manage were created. During the 80s of the last century, the central subject of safety was 'normality of accidents'.

HIGH RISK SYSTEMS AND WAVES OF CATASTROPHIC EVENTS

During the 20th century, categories of 'high risk systems' were defined, including: transport by sea, dams, railway transport, space missions, chemical plants, DNA, air transport, war hazards, nuclear weapon related accidents, nuclear plants, mining.

Figure 1. Hazards at the end of the XX century.

Kraj XX veka obeležio je veliki talas nesreća vezanih za tehnologiju i za ljudski faktor:

• Černobil (1986), nesreća prilikom probnog testiranja rezervnog postrojenja za snabdevanje električnom energijom. Radijacijom, koja se širila punih 10 dana, zagađene su obe zemljine hemisfere. To je najveća socio-ekonomska katastrofa u mirnodopskim uslovima, gde je 50% Ukrajine kontaminirano, 200.000 ljudi evakuisano i raseljeno, a 1,7 miliona ljudi bilo u direktnom kontaktu sa zračenjem.

• Nesreća na naftnoj platformi „Piper Alfa“ (1988) u Severnom moru. Uzrok nesreće je bila greška tehničara koji su zbog održavanja uklonili sigurnosne ventile što je dovelo do nagomilavanja tečnog gasa. Bilo je ukupno 100 ventila, a majstori su zaboravili da zamene samo jedan. Iste noći u 22 č. operater je pritisnuo dugme za pokretanje pumpi, tj. dugme za samouništenje. Tom prilikom je u eksploziji ubijeno 167 ljudi i samo 61 preživelo.

• Eksplozija spejs šatla „Čalenger“ 1986 u kojoj je nastradalo svih 7 članova posade. Šatl se raspao usled greške u konstrukciji.

• Nesreća u Bopalu 1984. godine u američkoj kompaniji „Junion karbajd Indija“ je najveća do sada zabeležena hemijska katastrofa u svetu i jedna od najpoznatijih ekoloških nesreća u ljudskoj istoriji. 40 tona otrovnog gasa isteklo je iz rezervoara i dospelo u vazduh. Zbog trovanja gasom nastradalo je oko 4000 ljudi.

• Ekološka katastrofa 1989. kad je tanker „Ekson Valdez“ u more nedaleko od obala Aljaske ispustio oko 42 miliona litara sirove nafte.

• U eksploziji u naftno-hemijskom kompleksu u Lionu 1987. je nastradalo nekoliko radnika i napravljena je velika materijalna šteta. Do nesreće je došlo kada je tim tehničara preselio električni kabl, spajajući generator struje za zavarivanje sa unutrašnjošću rezervoara.

INDUSTRIJSKA BEZBEDNOST

Generički modeli industrijske bezbednosti su razvijeni 80-tih i 90-tih godina XX veka. Savremeno doba karakterišu nove ekonomske paradigme, informacione tehnologije, kompeticija u ceni i brzini transporta, zahtevi za proširenjem asortimana usluga „post-industrijskog“ društva, privatizacija kompanija i razvoj državnih regulativa, globalno tržište, novi socijalni pokreti (feminizam, ekologija, održivost). Sve to utiče na upravljanje bezbednošću savremenih industrijskih sistema i zahteva da istraživanja bezbednosti prate transformaciju današnjeg sveta: globalizacija, ekologija, tehnologija i nove skale katastrofa, novi koncepti rada.

Globalizacija je oblikovala nova operativna ograničenja u visokorizičnim industrijama. Ekološka svest je rastuće prisutna u poslovnom razvijenom svetu, a čovek je izložen nizu opasnosti uključujući i antropički.

Cilj budućih istraživanja bezbednosti je kontinuirano obezbeđenje i unapređenje bezbednosti kroz adaptaciju pravila i procedura bezbednosti. Aspekti istraživanja bezbednosti se odnose na:

- Metodologije istraživanja
- Tehnologija
- Organizacija
- Izazovi vezani za ljudski faktor

The end of the 20th century was marked by a large wave of accidents related to technology and the human factor:

• Chernobyl (1986), a disaster that occurred during the testing of the backup facility for supplying electric energy. Radiation, which spread over a period of 10 days, polluted both hemispheres of the earth. This was the largest socio-economical disaster in peacetime, where 50% of Ukraine was contaminated, 200 000 people were evacuated, and 1.7 million people came under direct contact with radiation.

• 'Piper Alpha' oil platform disaster (1988) in the North Sea. The cause was an error made by technicians who removed safety valves for maintenance purposes, which lead to the accumulation of liquid gas. There was a total of 100 valves, and the technicians forgot to replace just one. At 22 h the same night, the operator pressed the button that activates the pumps, i.e. the 'self-destruction' button. The resulting explosion killed 167 people with only 61 survivors.

• Explosion of space shuttle 'Challenger' in 1986, in which all 7 crew members died. The shuttle fell apart due to structural flaw.

• Accident in Bopal in 1984 in an American company 'Union Carbide India' is the largest chemical disaster in the world so far, and one of the most well known ecological disasters in mankind history. Forty tons of toxic gas leaked from the tank into the air. Around 4000 people died due to gas poisoning.

• Ecological disaster in 1989 when the tanker 'Exxon Valdez' leaked around 42 million litres of crude oil into the sea near the Alaskan coast.

• In the oil-chemical complex in Lyon, in 1987, a number of workers were killed and considerable material damage was made by an explosion. The accident occurred when a team of technicians moved an electric cable by connecting the welding station generator with the inside of the tank.

INDUSTRIAL SAFETY

Generic models of industrial safety were developed in the 80s and 90s. Modern age is characterised by new economic paradigms, information technologies, competition in price and transport speed, demands for expanded range of services of a 'post-industrial' society, privatisation of companies and development of state regulations, global market, new social movements (feminism, ecology, sustainability). All of the above affects the safety management of modern industrial systems and demands that safety research follows transformation of the modern world: globalisation, ecology, technology, new disaster scale and work concepts.

Globalisation shaped new operative constraints in high risk industries. Ecological awareness has an increasing presence in the developed business world, whereas man is exposed to a number of hazards, including anthropic ones.

The goal of future safety research is the continued providing and improvement of safety through adapting of safety rules and procedures which should accommodate the changes in all areas. Aspects of safety research are related to:

- Research methodologies
- Technology
- Organisation
- Challenges related to human factor

METODOLOGIJE ISTRAŽIVANJA

Bezbednost je dinamički „ne događaj“ jer je cilj procene i odlučivanja da se neželjeni događaj ne desi. Postavlja se pitanje: Kojim metodama i na koji način analizirati i procenjivati „ne događaj“.

ORGANIZACIONI IZAZOVI

Organizacioni izazovi se odnose na turbulentno kompleksno okruženje i svet koji se menja što predviđanja čini teškim. Samostalni bezbednosni sistemi postaju integrisani bezbednosni sistemi. Izbor ključnih pokazatelja uspeha treba da poveže upravljanje bezbednošću sa poslovnim upravljanjem. Upravljanje bezbednošću treba da je uvek prisutno u upravljanju poslovnim sistemom pri čemu treba odrediti ekonomsku vrednost bezbednosti (preko studija slučaja i podsticaja vezanih za bezbednost). Objekti istraživanja bezbednosti su: ljudski faktor, pouzdanost i bezbedni inženjering, visoko pouzdane organizacije, kognitivni inženjering, interakcija ljudi i mašina, prirodno donošenje odluka, bezbednosna kultura, učenje iz nesreća i istraživanja, percepcija rizika i regulacija.

LJUDSKI FAKTOR

Teško je predvideti rizik od ljudskog faktora: ljudi greše, može se desiti da su neuspešni u izvršenju operacije, ili zdravstveni poremećaj dok rade. Teško je proceniti i mogućnosti koje su rezultat jedinstvenosti ljudskih sposobnosti.

Treba istraživati psihosocijalne hazarde na radnom mestu, kao i kompetentnost, vođstvo, osnaživanje, socijalni kapital i socijalni marketing. Veliki problem su interpersonalni odnosi i nejasnoće u razumevanje zbog nedorečenosti, dvosmislenosti, nejednake težine određenih pojmova u različitim kulturama u multikulturalnim organizacijama.

U visokorizičnim sistemima je važno građenje kulture bezbednosti, što predstavlja dugoročan, kontinuiran proces. Tokom radikalnih promena sa aspekta bezbednosti izuzetno je važno proučiti hazarde uzrokovane verovanjima i mentalnim sklopovima kako individualnim, tako i kolektivnim.

ODRAZ ISTRAŽIVANJA BEZBEDNOSTI NA PRIVREDNE SUBJEKTE

Bezbednost je uvek vezana za vreme. Vremenska dimenzija zahteva dinamičku definiciju bezbednosti.

Još jedan problem vezan za bezbednost je: Kako ocenjivati vodeće (ili pozitivne) indikatore bezbednosti (ako nema incidenata i nesreća)?

Treba naći nove paradigme za probleme u kojima se javljaju kontradiktorni i promenljivi zahtevi; čije rešenje je često teško prepoznati zbog složene međuzavisnosti problema koji zahtevaju rešenja koja će obezbediti rešenja za upravljanje neočekivanim, otpornost u doba neizvesnosti i visoku pouzdanost organizacije.

To zahteva proširivanje naučnih objekata istraživanja, „otporan inženjering“ i nove pristupe u upravljanju rizikom. Što se tiče bezbednosnih procedura u privrednim subjektima, opšta je slika da danas imamo suviše birokratskih procedura i „papirologije“ u vezi upravljanja rizikom, što ponekad ima kontra efekat koji se manifestuje smanjenjem bezbednosti.

RESEARCH METHODOLOGY

Safety is a dynamic ‘non-event’ since the purpose of assessment and decision making is to ensure that the unwanted event does not occur. This raises the question: In which way and by which methods can ‘non-event’ be analysed.

ORGANISATIONAL CHALLENGES

Organisational challenges are related to the turbulent complex environment and the ever-changing world, which makes predictions difficult. Individual safety systems become integrated. The selection of key indicators of success should connect safety management with business management. Safety management should always be present in business system management, wherein the economic value of safety needs to be determined (by using case studies and incentives related to safety). Aspects of safety research include: human factor, reliability and safe engineering, highly reliable organisations, cognitive engineering, interaction between man and machine, natural decision making, safety culture, learning from accidents and research, risk perception and regulation.

HUMAN FACTOR

It is difficult to predict the human factor risk: people make mistakes, may not succeed in performing an operation, or may experience health conditions at work. It is difficult to evaluate possibilities in uniqueness of human capabilities.

Research should include psychosocial hazards at the workplace, as well as competence, leadership, strengthening, social capital and social marketing. A huge problem lies in interpersonal relationships and uncertainties in understanding due to ambiguities, unequal weight of certain terms in different cultures within multicultural organisations.

In high risk systems, building of a safety culture is important, and represents a long-term, continued process. During radical changes, it is of great importance for the safety aspect to study hazards caused by beliefs and mindsets, both individual and collective.

REFLECTION OF SAFETY RESEARCH ON INDUSTRIAL SUBJECTS

Safety is always related to time. The time dimension demands a dynamic definition of safety.

Another problem related to safety is: How to evaluate leading (or positive) safety indicators (in case there are no incidents or accidents)?

There is a need to find new paradigms for problems which involve contradictory and variable demands; whose solution is often hard to identify due to complex correlations that require solutions that will enable managing of unexpected events, resistance during uncertain times and high organisation reliability.

This requires the expansion of scientific research objects, ‘resistant engineering’ and new approaches to risk management. As for safety procedures in industrial subjects, there is a general impression that today we have too many bureaucratic procedures and ‘paperwork’ related to risk management that sometimes has counter-productive effects manifested in reduced safety.

TEHNOLOGIJA, ORGANIZACIJA I IZAZOVI VEZANI ZA LJUDSKI FAKTOR

Model dat na sl. 2 prikazuje dve grupe problema:

1. Normalni problemi koji su se dešavali u praksi i za koje postoji iskustvo u njihovom rešavanju.
2. Opasni i standardnim tehnikama i procedurama nerešivi problemi koji su takvi bilo zbog svoje kompleksnosti i hitnosti u rešavanju bilo zbog nestrukturiranosti i novih opasnosti.

Načini njihovog rešavanja su predloženi za pojedine kategorije. Tako se problemi koji su opasni, kompleksni i hitni rešavaju pokušajima na bazi intuicije, inteligencije i prethodnog znanja, a kompleksni „normalni problemi“ za čije rešavanje ima dovoljno vremena na bazi zdravorazumskog zaključivanja i stručne analize.

Slika 2. Model rešavanja normalnih i opasnih problema sistema

Nove tehnologije, kao što su informacione i komunikacione tehnologije, nanotehnologija, roboti, veštačka inteligencija, „sintička biologija“, novi vidovi interakcije čoveka i mašina, energija vetra, sunca (sl. 1), donose nove hazarde koje treba eliminisati ili smanjiti.

SAVREMENI TEHNOLOŠKI HAZARDI I DRUGI TALAS KATASTROFA

Tehnološki razvoj i nove tehnologije generišu nove rizike. Slika 3 prikazuje hazarde savremenog društva.

Slika 3. Novi hazardi

TECHNOLOGY, ORGANISATION AND CHALLENGES RELATED TO THE HUMAN FACTOR

Model given in Fig. 2 shows two groups of problems:

1. Normal problems that occurred in practice and for which there is experience in solving them.
2. Dangerous problems that cannot be solved by using standard techniques and procedures, due to either their complexity and urgency in solving or their non-structuring and new hazards.

The ways of solving such problems are suggested for individual categories. In this way, dangerous, complex and urgent problems are solved by attempts based on intuition, intelligence and previous knowledge, whereas complex 'normal problems' with enough time to solve are solved based on common sense conclusions and expert analysis.

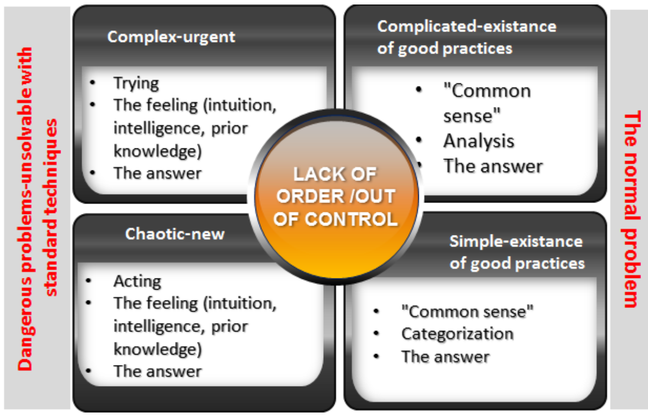


Figure 2. Model for solving normal and dangerous system problems.

New technologies, such as information and communication, nanotechnology, robots, artificial intelligence, 'synthetic biology', new forms of interaction between man and machine, wind and sun energy (Fig. 1), bring new hazards which need to be eliminated or mitigated.

MODERN TECHNOLOGICAL HAZADRS AND SECOND WAVE OF DISASTERS

Technological development and new technologies generate new risks. Figure 3 shows the hazards of modern society.

Figure 3. New hazards.

NOVI PRISTUPI U ISTRAŽIVANJU BEZBEDNOSTI

Kontinuirano se traže nove paradigme za probleme u kojima se javljaju kontradiktorni i promenljivi zahtevi; čije rešenje je često teško prepoznati zbog složene međuzavisnosti problema. Visoko rizični sistemi pokušavaju da budu visoko pouzdani i da uspeju da izbegnu katastrofe u okruženju u kojem se mogu očekivati nesreće zbog faktora rizika i kompleksnosti. Pri tome se proširuju objekti istraživanja i u sfere koje nisu bile predmet istraživanja nauke, a cilj je otporan inženjering i adekvatno upravljanje rizikom.

Iz primenjenih istraživanja poznata je važnost znanja koje se može pretvoriti u akciju i važnost implementacije znanja. Treba naglasiti da postoji jaz između znanja i njegove implementacije. Tabela 1 daje pregled naučnih i praktičnih podataka u svim sferama, pa i u sferi bezbednosti. Može se videti da naučni podaci daju više opštih znanja koja nisu uvek praktično primenjiva i mogu biti baza za praktičnu primenu. Često se dešava da problemi i rešenja iz prakse vezana za neki lokalni sistem bude povod i prethodnica naučnim istraživanjima.

Tabela 1. Razlike između teorijskih i praktičnih istraživanja, /5/

Naučni podaci	Praktični podaci
Bazirano na eksperimentalnim istraživanjima (npr. Random kontrolisani eksperimenti)	Bazirani na praktičnim eksperimentima ili učenju iz iskustva (npr. „studije slučaja“)
Bazirani na teoriji	Bazirani na praksi
Nisu uvek praktično primenjivi	Nemaju uvek teorijski prizvuk
Univerzalno znanje	Znanje vezano za lokalni sistem i određeni kontekst
Može biti baza za praktičnu primenu	Ovo znanje često prethodi naučnim istraživanjima i saznanjima
Jednostavan i kompleksan sadržaj	Kompleksan i haotičan sadržaj
Visoko vrednovano za istraživače	Visoko vrednovano za praktičare

Kod istraživanja problema bezbednosti postoji dobra primena razvoja povezanih i podržavajućih naučnih disciplina.

Globalni katastrofalni rizici su oni koji mogu da nanesu smrt i razaranje na globalnom nivou. U ljudskoj istoriji, ratovi i kuga su to učinili više puta, kao i pogrešne ideologije koje su obeležile neko doba. Naučnici su napravili listu takvih rizika, /4/:
- Prirodne katastrofe
- Kolapsirajuća zvezda
- Smrtonosni udar komete ili meteora
- Erupcija supervulkana
- Neprijateljski vanzemaljski uticaj
- Prirodna pandemija
- Antropičke katastrofe
- Fizički eksperimenti
- Klimatske katastrofe
- Sveopšti rat
- Superinteligentne mašine
- Genetski stvoreni organizmi

Svedoci smo ekstremnih klimatskih promena koje jako utiču na kritičnu infrastrukturu i visokorizične sisteme.

NEW APPROACHES TO SAFETY RESEARCH

There is a continuous need to find new paradigms for problems involving contradictory and variable demands; whose solution is often hard to identify due to complex correlations between problems. High risk systems try to be highly reliable and to avoid disasters in an environment where accidents can be expected due to risk factors and complexity. Thereby, research objects are expanded into spheres which were not the subject of research, for the purpose of resistant engineering and adequate risk management.

Known from the applied research is the importance of knowledge which can be converted into actions and knowledge implementation. It should be pointed out that there is a gap between knowledge and its implementation. Table 1 shows the review of scientific and practical data in all spheres, including safety. It can be seen that scientific data provide more general knowledge which may not always be practically applicable and may be used as a base for such application. More often than not, practical problems and solutions related to a local system become the incentive for and predecessor to scientific research.

Table 1. Differences between theoretical and practical research, /5/

Scientific data	Practical data
Based on experimental research (e.g. Random controlled experiments)	Based on practical experiments or learning from experience (e.g. case studies)
Based on theory	Based on practice
Not always practically applicable	No theoretical tones
Universal knowledge	Knowledge related to local systems and specific context
May be used a base for practical application	This knowledge often precedes scientific research and conclusions
Simple and complex contents	Complex and chaotic content
Highly valuable to researchers	Highly valuable to practitioners

Present in safety problem research is a good application of development of connected and supporting scientific disciplines.

Global catastrophic risks are those that can result in death and destruction on a global level. In mankind history, wars and plague did that multiple times, as well as wrong ideologies that marked a certain age. Scientists have created a list of such risks, /4/:
- Natural disasters
- Collapsing star
- Fatal comet or meteor impact
- Supervolcano eruption
- Hostile alien influence
- Natural pandemic
- Anthropic disasters
- Physical experiments
- Climate disasters
- Global war
- Super-intelligent machines
- Genetically engineered organisms

We are witnessing extreme climate changes that heavily affect the critical infrastructure and high risk systems.

Zbog toga se razvijaju novi koncepti upravljanja i u proceni bezbednosti visokorizičnih sistema uvodi nova terminologija: otpornost, kompleksnost, novi rizici, konstruktivizam.

Čovečanstvo je imalo i drugi talas katastrofa u visokorizičnim sistemima početkom XXI veka:

• *Space Shuttle Columbia* (2003) se raspao nad Teksasom i Luizijanom, kada je ušao u zemljinu atmosferu i tom prilikom je poginulo je svih sedam članova posade.

• Eksplozija u rafineriji, *Texas City* (2005), kada je oblak ugljovodonične pare eksplodirao pri procesu izomerizacije u jedinici BP rafinerije. Poginulo je 15 radnika, a povređeno više od 170.

• Bansfild - veliki požar u petom najvećem skladištu naftnih proizvoda u Velikoj Britaniji, sa kapacitetom od oko 60 miliona litara goriva. Povređeno je 43.

• Nesreća Er Fransovog putničkog aviona Erbas 330-203 koji je poleteo sa aerodroma Galeao u Rio de Žaneiru u Brazilu, i uputio se prema aerodromu Šarl de Gol u Parizu u Francuskoj. Avion je nestao nad Atlantskim okeanom 1. juna 2009. godine, sa 216 putnika i 12 članova posade.

• Eksplozije i potonuće naftne platforme *Deepwater Horizon* (2010) u Meksičkom zalivu. Poginulo je 11, a podvodne kamere su otkrile da iz cevi curi nafta i gas na dnu okeana, oko 42 km od obale Luizijane. To je najgora nesreća ove vrste u američkoj istoriji.

• Nesreća u nuklearnoj centrali Fukušima 1 obuhvata seriju nuklearnih nesreća i otkazivanje uređaja u nuklearnoj elektrani Fukušima 1, kod grada Okuma (Japan), koje su nastale kao posledica katastrofalnog zemljotresa u Japanu 11. marta 2011. godine. 30.000 ljudi je učestvovalo u otklanjanju posledica nesreće. Povećanje učestalosti obolevanja kod njih se nastavlja, jer su oštećeni geni u celini. Naredne generacije će nositi pečat zbog ove katastrofe.

• Nestanak aviona Malejža erlajnsa 2014. godine, koji je leteo iz Kuala Lumpura za Peking. Poginulo je 239 putnika i članova posade.

• Nesreća Boinga 777 malezijske aviokompanije, koji je leteo na liniji Amsterdam-Kuala Lumpur, dogodila se 17. jula 2014. godine u Donjecku, na istoku Ukrajine. U avionu se nalazilo 283 putnika i 15 članova posade.

• Avion Erbas A 320 nemačke kompanije Džerman vings srušio se 24. marta 2015. godine sa 150 putnika i članova posade na jugu Francuske, između opština Dinj i Barselonet, 100 kilometara severno od Nice. Nije bilo preživelih.

Analiza ovih rizika je pokazala da se standardizacijom (pri čemu se standardi kontinuirano preispituju, proveravaju i poboljšavaju) i uvođenjem mehanizama za upravljanje rizikom, težište problema upravljanja bezbednošću pomerilo sa samo tehnološkog i na područje ljudskog faktora. Čovek sa svojim sposobnostima, ograničenjima, emocijama i stanjima nije samo racionalno biće i njegovo ponašanje je teško standardizovati. Zato je teško predvideti ponašanja učesnika u procesu koji u sebi sadrži rizik, a često i vrednovanje parametara procesa nije jednoznačno. Idealno bi bilo kada bi ponašanje ljudi bilo uvek u granicama dozvoljenih odstupanja i samim tim predvidivo.

Praksa pokazuje da nije uvek tako. Čovek u savremenom društvu je izložen velikom zahtevima, često je u stanju stresa

Due to this, new concepts for management are developed and new terms are introduced into evaluation of safety of high risk systems: resistance, complexity, new risks, and constructivism.

Mankind suffered a second wave of disasters in high risk systems at the beginning of the 21st century:

• Space Shuttle Columbia (2003) fell apart above Texas and Louisiana, upon entering the atmosphere and all seven crew members died on that occasion.

• Explosion in the Texas City refinery (2005) when a cloud of hydrocarbon vapour exploded during the isomerisation process in a unit within the BP refinery. Fifteen workers were killed and more than 170 were injured.

• Buncefield - a great fire in the fifth largest oil product storage in the UK, with a capacity of 60 million litres of fuel - 43 injured.

• The accident involving Air France airliner Airbus 330-203 which took off from airport Galeao in Rio de Janeiro in Brazil, on its way to Charles de Gaulle airport in Paris,. The airplane disappeared above the Atlantic Ocean on June 1st, 2009, along with 216 passengers and 12 crew members.

• Explosions and sinking of the oil platform 'Deepwater Horizon' (2010) in the Gulf of Mexico, 11 people killed, underwater cameras revealed that there was oil and gas leaking, about 42 km from Louisiana shore. This was the worst disaster of this kind in American history.

• Disaster in Fukushima 1 nuclear plant involved a series of nuclear accidents and failures of devices, near the town of Okuma (Japan) which were caused by a catastrophic earthquake in Japan on March 11, 2011. 30 000 people were involved in removing consequences. An increase in disease frequency continues, since human genes have been damaged as a whole. Upcoming generations will still bear the marks of this disaster.

• Disappearance of the Malaysia Airlines airplane, 2014, which was flying from Kuala Lumpur to Beijing. 239 passengers and crew members were killed.

• The crash of Malaysia Airlines Boeing 777 which was flying from Amsterdam to Kuala Lumpur took place on July 17, 2014 in Donetsk, eastern Ukraine. On board the plane were 283 passengers and 15 crew members.

• Airplane Airbus A 320 of 'German wings' crashed on March 24, 2015, along with 150 passengers and crew members in southern France, between the municipalities of Digne and Barcelonnette, 100 km north of Nice, with no survivors.

Analysis of these risks had shown that standardisation (wherein standards are continually re-evaluated, checked and improved) and introduction of mechanisms for risk management moves the focus of safety management problems from a purely technological to an area that involves human factor as well. A human being, with its capabilities, limitations, emotions and states is not just rational, so its behaviour is difficult to standardize. Hence it is hard to predict the behaviour of participants in a process that involves risks, and often evaluating process parameters is not unambiguous. It would be ideal if human behaviour was always within allowed limits and thus predictable.

Practice has shown that this is not always the case. People in modern society are subjected to a large number of zbog izloženosti ogromnoj količini informacija, hitnosti u odlučivanju, problema sa kojima se nosi u svakodnevnom životu i to povećava njegovu ranjivost.

Sem ljudskog faktora, klimatske i druge promene vezane za životnu sredinu dovele su do razvijanja svesti o neophodnosti zaštite životne sredine, pa je zbog toga i ova dimenzija postala cilj proučavanja bezbednosti rizika sistema.

Pri tome se bezbednost može proučavati iz više perspektiva: filozofski pristup, analitički i preko grafičkih modela.

Filozofski pristup

Ovim pristupom se bavi nauka. Ideja je da nauka treba kontinualno da proizvodi više merljivih rezultata. Pri tome se misli na usku fokusiranost na nauku o bezbednosti i rešenja koja se odnose na probleme. Ovde se postavlja pitanje kako definisati rezultat? Da li je objavljen naučni rad sa rezultatom? Ili broj (ili kvalitet) u radu ponuđenih rešenja vezanih za bezbednost?

Filozofski pristup, kroz prizmu pozitivističke epistemologije, bavi se istraživanjem sledećih ideja:
- Znanje može dobiti samo na jedan pravi način
- Nauka je vrednosno neutralna
- Istraživač može istraživati sistem ako je van njega, tj. bez uticaja na njega
- Istraživanje kauzalnih zakona koji se pretpostave i zatim testiraju kao hipoteze.

Analitički pristup

Analitički pristup se bazira na činjenici da je globalizacija oblikovala nova operativna ograničenja u visokorizičnim industrijama:
- Ekološka svest je rastuće prisutna u poslovno razvijenom svetu, a čovek je izložen nizu opasnosti.
- Svedoci smo ekstremnih klimatskih promena koje jako utiču na kritičnu infrastrukturu i visokorizične sisteme.
- Razvijaju se novi koncepti i terminologija: otpornost, kompleksnost, novi rizici, konstruktivizam, upravljanje.
- Imali smo i imamo talase katastrofa u visokorizičnim sistemima.
- Objekt posmatranja se kretao od tehnoloških, preko sociotehnoloških do ekosociotehnoloških sistema.

Grafički modeli

Anatomija incidenta na sl. 2 pokazuje transformaciju normalnih uslova rada koji uz neočekivani događaj prelaze u nenormalne uslove rada. Ukoliko tada dođe do propusta u kontroli ili analiza mogućih hazarda nije predvidela takav scenario, dolazi do gubitka kontrole nad radnim procesom. U slučaju da je odbrana sistema nedovoljna ili je nema uopšte, dolazi do nesreće sa posledicama koje ona izaziva.

Grafički model „švajcarskog sira“ koji je dao Džejms Rizon o *sastavu* nesrećnog događaja je jednostavan i koristan način razmišljanja o tome kako se greške mogu dogoditi, čak i kada postoji više slojeva *odbrane*. U slici datoj kao ilustracija modela, *slojevi* odbrane sistema uspešne misije helikoptera su: trening, održavanje i kontrola opreme, metereološki uslovi u dozvoljenim granicama i poštovanje procedura.

demands and are often in a state of stress by being exposed to a large amount of information, urgency in decision making and problems encountered in everyday life.

Apart from the human factor, climate and other changes related to environment, lead to developing of an awareness of necessity of environmental protection, so this dimension also became the goal of studying of risk system safety.

Thus safety can be studied from multiple perspectives: philosophical approach, analytically and by graphic models.

Philosophical approach

This is the scientific approach. The idea is that science should continually produce multiple measurable results. This refers to a close focus on science about safety and solutions related to the problems. Here the question that is asked is how to define the result? Was this result published as a scientific paper? Or the number (or quality) of safety solutions offered in the paper?

The philosophical approach through a prism of positivistic epistemology is involved in research of following ideas:
- Knowledge can be obtained in only one real way
- Science is valuably neutral
- The researcher may research a system if they are outside of it, i.e. are not influencing it in any way
- Research of causal laws which are first assumed and then tested as hypotheses.

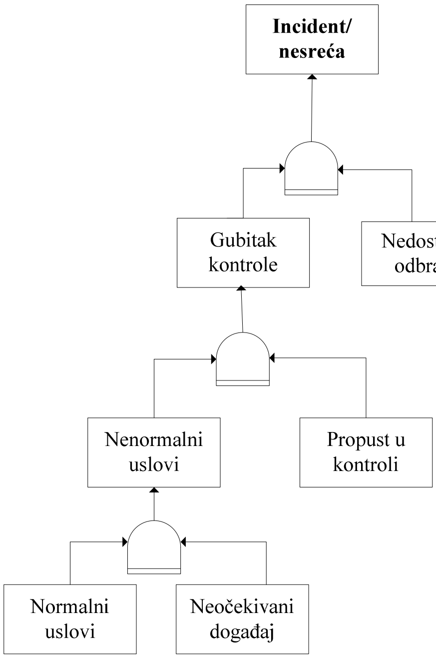
Analytical approach

The analytical approach is based on the fact that globalisation has shaped new operational constraints in high risk industries:
- Ecological awareness is ever more present in the developed business world, so man is exposed to a series of hazards.
- We are witnessing extreme climate changes which heavily affect the critical infrastructure and high risk systems
- New concepts and terminology are developed: resistance, complexity, new risks, constructivism and management.
- We also experienced waves of disasters in high risk systems.
- The observed object moved from technologic through socio-technologic to eco-socio-technologic systems.

Graphic models

Anatomy of the incident in Fig. 2 shows the transformation of normal working conditions which transform into abnormal working conditions due to an unexpected event. In case there are control oversights or scenarios that were not predicted by the possible hazard analysis, control over the work process is lost. In case the system defence is insufficient or there is none, accidents will occur with the resulting consequences.

Graphical model known as the ‘Swiss cheese’, given by James Reason, about the *composition* of an accidental event represents a simple and useful way of considering how error can occur, even when there are multiple layers of *defence*. In the figure given as model illustration, *layers* of a defence system for a successful helicopter mission are: training, equipment maintenance and control, meteorological conditions within the allowed limits and compliance with procedures.



Slika 4. Trajektorija nesreće, /5/

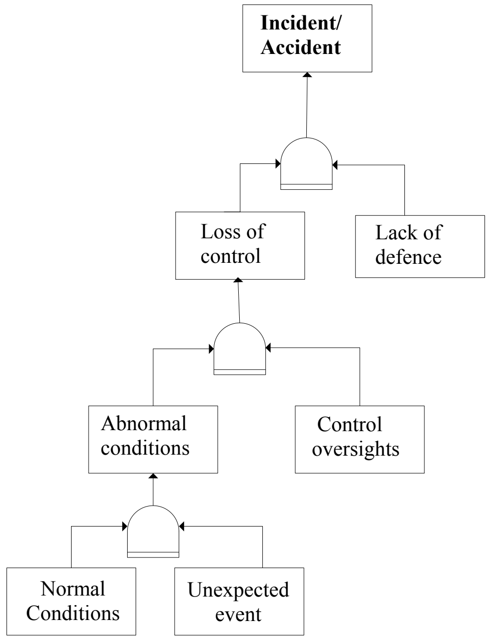
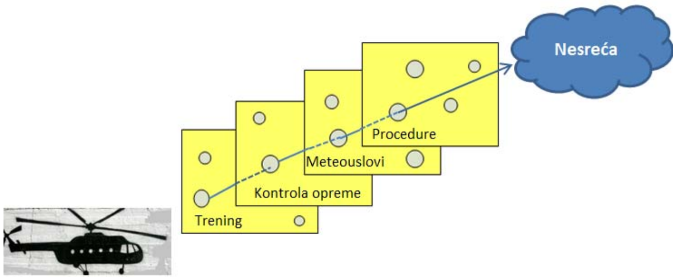


Figure 4. Scheme of incidence, /5/.



Slika 5. Nesreća prikazana preko modela švajcarskog sira

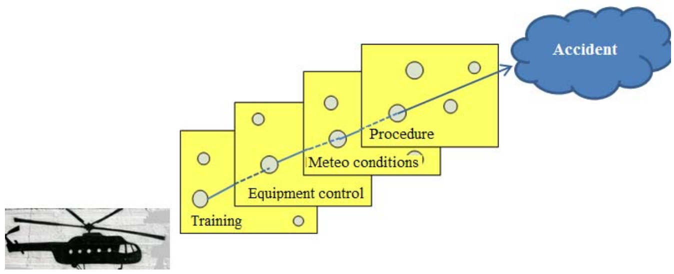


Figure 5. Accident shown by Swiss cheese model.

ZAKLJUČAK

Tehnološki razvoj generiše nove rizike, pa stoga upravljanje rizikom mora da prati razvoj novih tehnologija.

Predmet proučavanja rizika u početku su bili samo tehnološki sistemi, pa su se uključivanjem ljudskog faktora posmatrali socio-tehnološki sistemi, a danas sa rastom svesti o neophodnosti očuvanja životne sredine rizik posmatra eko-socio-tehnološke sisteme.

Upravljanje rizicima ne može se više bazirati samo na odgovorima na prošle nesreće, već mora biti sve više proaktivno. Pri tom se mora primenjivati prilagodljiva strategija zasnovana na zatvorenoj povratnoj sprezi, na bazi merenja ili posmatranja nivoa sigurnosti u sadašnjem trenutku i eksplicitno formulisanog nivoa ciljne sigurnosti. Zbog ljudske fleksibilnosti i kreativne intelektualne sposobnosti, postoji određeni potencijal za takvo adaptivno upravljanje (ljudi su vrlo važan izvor sigurnosti, ne samo izvor greške).

CONCLUSION

Technological development generates new risks; thus risk management must follow new technology developments.

The subject of studying risks initially only included technological systems, and with the inclusion of the human factor, socio-technologic systems were observed, whereas today, with increasing awareness of the necessity for environmental protection, risk is related to eco-socio-technologic systems.

Risk management cannot be based on response to past accidents alone anymore, but now must be increasingly proactive. Whereby, an adaptable strategy based on a closed feedback loop and measuring or monitoring of current safety levels needs to be applied, taking into account the explicitly formulated level of desired safety. Due to human flexibility and creative intellectual capability, there is a certain potential for such adaptive management (people are a very important source of safety, not just errors).

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