TECHNO Science

INTERNATIONAL SCIENTIFIC JOURNAL OF TECHNICAL SCIENCES

EXTINGUISHING FIRES ON ELECTRIC VEHICLES

FIREFIGHTING INTERVENTIONS IN FIRES INVOLVING PHOTOVOLTAIC SYSTEMS AND BUILDINGS WITH SOLAR PANELS

FIRES IN ROAD TUNNELS

VOL 4 ISSUE 8
JULY 2026

University of Travnik
FACULTY OF TECHNICAL SCIENCES

TECHNO Science

INTERNATIONAL SCIENTIFIC JOURNAL OF TECHNICAL SCIENCES

University of Travnik
FACULTY OF TECHNICAL SCIENCES

TECHNO SCIENCE
International Scientific
Journal of
Technical Sciences
Vol. 4 Issue 8 July 2026
Print ISSN 2490-2330
e-ISSN 2490-2438
Catalogued in COBISS BH

Publisher
Faculty of Technical Sciences,
University of Travnik
Aleja konzula No. 5, Travnik,
Bosnia and Herzegovina

Print
FTS- odsjek GiD
Circulation: 300 copies

Communication
Faculty of Technical
Sciences,

University of Travnik Aleja
konzula No. 5, Travnik,
Bosnia and Herzegovina Tel/
fax: +387 30 540 876

GSM: +387 61 225 299

Email: info@fts.ba
technoscience@eftfts.edu.ba

Publishing
Techno Science publishes
twice a year in English with
Bosnian abstracts. Full
journal text available at
https://technoscience.ba/

Indexation
Indexation in international
databases is in progress.

TABLE OF CONTENTS

SADRŽAJ

DEAR READER,

The new issue of the Techno Science journal has arrived. We hope that we have met most of your expectations and fulfilled the commitments we announced in the previous editorial.

We have expanded and further internationalised our Techno Science family, and we are particularly pleased that, with each new issue, we are increasing the number of exceptional researchers who share their passion for scientific discovery and publication with us. This is also an opportunity to invite researchers and members of the academic community to actively participate in profiling and building such a demanding publication. We look forward to collaborating with new authors and reviewers, and are immensely grateful for all the suggestions from our readers aimed at enhancing the academic excellence of the journal.

We hope that reading these pages will inspire your own research – may the papers presented in this issue be not only a valuable source of information, but also a catalyst for academic dialogue, critical thinking, and new forms of collaboration.

This is also an opportunity to thank the entire team involved in the publication of Techno Science – each issue is a reflection of their knowledge, extraordinary efforts, dedication, and commitment

On behalf of those team efforts, I invite you to strengthen our academic bonds and celebrate knowledge – with this and all future issues of our/your Techno Science!

We wish you an insightful read.

Editor-in-Chief
Elvedin Bečić, PhD

DRAGI ČITATELJU,

pred Vama je novo izdanje časopisa Techno Science. Nadamo se da smo ispunili većinu Vaših očekivanja i vlastitih obaveza koje smo najavili u prethodnom uvodniku.

Širili smo i dodatno internacionalizirali našu Techno Science obitelj – posebno nas raduje što, sa svakim novim izdanjem, povećavamo broj iznimno kvalitetnih istraživača koji svoju strast za naučnim saznanjima i njihovom objavljivanju dijele sa nama. Ovo je, ujedno, i prilika da pozovemo istraživače, članice i članove akademske zajednice, da uzmu aktivno učešće u profiliranju i izgradnji ovako zahtjevne publikacije – unaprijed smo obradovani saradnjom se novim autorima, recenzentima, ali i iznimno zahvalni na svim prijedlozima čitatelja za unapređenje akademskog nivoa časopisa.

Nadamo se, da će čitanje ovih stranica, predstavljati i inspiraciju za Vaša vlastita istraživanja – neka Vam radovi prezentirani u ovom broju ne budu samo vrijedan izvor informacija, već i podsticaj za akademski dijalog, kritičko razmišljanje i nove oblike saradnje.

Ovo je prilika i da se zahvalim, kompletnom timu koji radi na realizaciji Techno Science – svaki broj predstavlja izraz njihovog znanja, vanrednih napora, posvećenosti i odricanja.

U ime tih timskih napora, pozivam Vas da jačamo naše akademske veze i slavimo znanje – ovim i svim narednim brojevima našeg/Vašeg Techno Sciencea!

Uživajte u čitanju!

Glavni urednik
doc.dr.sc. Elvedin Bečić

TECHNICAL AND ECONOMIC COMPARISON OF MONOLITHIC CONSTRUCTION AND THE COBIAX SYSTEM IN COMMERCIAL BUILDINGS

Berat Zejneli[1], Shinasi Zejneli[2], Engin Iljazi[3]

1. Laboratory for Testing Construction Materials, State University in Tetovo - RNM, IZIIS - Institute for Seismology at UKIM - University of Saint Cyril and Methodius in Skopje, North Macedonia
2. Faculty of Applied Sciences, Department of Concrete and Steel, State University of Tetovo – RNM, North Macedonia
3. International University-Vision, RNM, North Macedonia, University of Travnik, Bosnia and Herzegovina.

ABSTRACT

This paper presents a comparative analysis between conventional monolithic reinforced concrete construction and the COBIAX voided slab system used in commercial buildings. The study evaluates structural behaviour, construction efficiency, economic performance, and seismic response of both systems. Traditional monolithic construction is compared with modern reinforced concrete slabs incorporating recycled plastic void-forming elements.

The COBIAX system reduces concrete consumption and structural self-weight while maintaining the structural capacity and stiffness of the slab system. Reduction of dead load significantly improves seismic performance and enables optimisation of columns, foundations, and supporting elements.

The analysis was conducted according to Eurocode 2 and Eurocode 8 standards using conventional reinforced concrete design principles and verified engineering methods for voided slab systems.

The results demonstrate that the COBIAX system provides reduced construction costs, shorter execution time, improved sustainability, and better structural efficiency compared with conventional monolithic slabs. Furthermore, reduced slab thickness and lower material consumption allow larger spans and increased usable floor space.

Keywords: monolithic construction, reinforced concrete slabs, COBIAX system, voided slabs, structural efficiency, Eurocodes, commercial buildings

INTRODUCTION

Modern construction engineering continuously seeks methods for reducing structural weight, material consumption, and construction time while maintaining safety and durability. Reinforced concrete remains one of the most widely used construction materials due to its high compressive strength, durability, and adaptability in structural systems.

Traditional monolithic reinforced concrete slabs are widely applied in commercial and residential buildings. However, one of their major disadvantages is their significant self-weight, which increases seismic forces, material consumption, and foundation loads.

To overcome these limitations, innovative slab systems such as the COBIAX voided slab technology have been developed. The COBIAX system incorporates recycled plastic void formers within reinforced concrete slabs, replacing non-structural concrete in the neutral zone of the slab.

As a result, the slab weight is significantly reduced without negatively affecting structural performance. This allows larger spans, thinner slabs, reduced column dimensions, and more economical foundation systems.

In seismic regions, reduction of permanent loads is particularly important because seismic forces are directly proportional to structural mass. Therefore, lighter structural systems contribute to improved ductility and seismic resistance.

This paper presents a comparative technical and economic analysis between conventional monolithic construction and the COBIAX system in commercial buildings.

MONOLITHIC CONSTRUCTION SYSTEM

Monolithic construction systems are based on reinforced concrete frame structures consisting of foundations, columns, beams, slabs, and shear walls. These structural systems are constructed entirely on site using formwork, reinforcement, and cast-in-place concrete.

The execution process begins with earthworks and preparation of the foundation base. After excavation and soil compaction, a crushed stone layer is placed to improve load transfer and groundwater drainage.

The foundation slab is then constructed using reinforced concrete with dimensions determined through structural analysis. Basement walls and vertical structural elements are also executed in reinforced concrete.

The superstructure generally consists of:

• Reinforced concrete columns
• Beams
• Flat slabs
• Staircases
• Shear walls

The main advantage of monolithic construction is its simplicity and widespread application in engineering practice. However, this system has several disadvantages:

• High structural self-weight
• Increased seismic forces
• Greater concrete consumption
• Larger column and foundation dimensions
• Longer construction time

Because of these limitations, alternative slab technologies have become increasingly important in modern structural engineering.

Figure 1. *Conventional Reinforced Concrete Monolithic Slab System*

The COBIAX system is an innovative biaxial voided slab technology designed to reduce the self-weight of reinforced concrete slabs. The system uses hollow recycled plastic spheres or ellipsoidal modules positioned between upper and lower reinforcement layers. These void formers replace non-effective concrete in the central zone of the slab, where concrete contributes minimally to bending resistance.

The main objectives of the COBIAX system are:

• Reduction of concrete volume
• Reduction of slab self-weight
• Improvement of structural efficiency
• Reduction of seismic forces
• Larger structural spans
• Sustainable construction

The system allows bidirectional load transfer similarly to conventional solid slabs.

Two principal systems are commonly used:

Eco-Line System

• Spherical void formers
• Suitable for slab depths from 40 cm to 70 cm

Slim-Line System

• Flatter void formers
• Suitable for slab depths from 20 cm to 56 cm

The modules are placed between reinforcement layers according to the structural design plan.

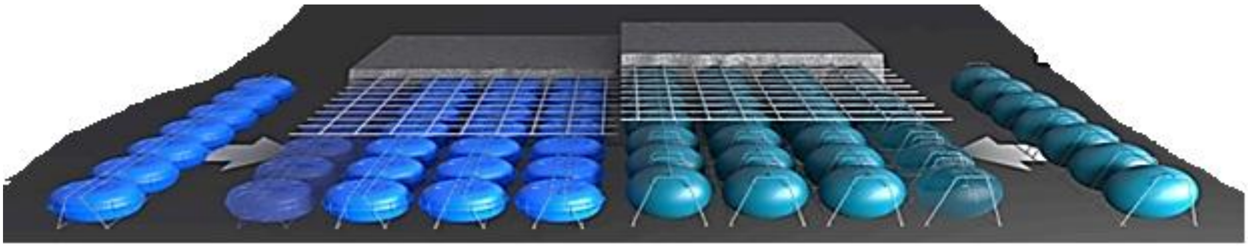


Figure 2. *COBIAX Eco-Line and Slim-Line Systems*

The structural analysis of COBIAX slabs can be performed using standard finite element software according to Eurocode regulations.

The design procedure includes:

1. Preliminary estimation of slab thickness
2. Selection of appropriate COBIAX modules
3. Determination of load reduction factors
4. Structural analysis considering reduced stiffness
5. Verification of punching shear zones
6. Final structural verification

Due to the reduction of concrete in the neutral zone, slab stiffness decreases only slightly, generally between 5% and 13%, while substantial weight reduction is achieved.

The system also enables the creation of solid zones around columns and supports where higher shear resistance is required.

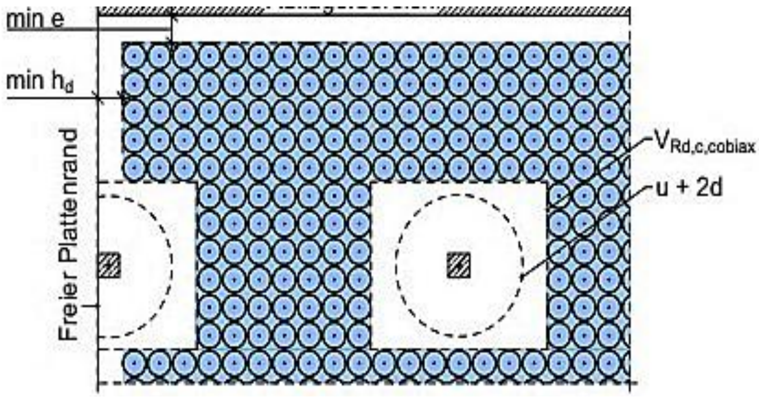


Figure 3. *Placement of COBIAX Modules Within Reinforced Concrete Slabs*

The use of recycled plastic void formers contributes significantly to environmental sustainability by reducing concrete consumption and lowering CO2 emissions.

COMPARISON BETWEEN MONOLITHIC AND COBIAX SYSTEMS

The main difference between conventional monolithic slabs and COBIAX slabs lies in the internal slab composition.

In monolithic slabs, the entire slab volume consists of solid reinforced concrete. In contrast, the COBIAX system removes non-structural concrete from the slab core and replaces it with lightweight void formers.

This reduction in concrete volume leads to several structural and economic advantages.

Structural Performance

The reduced self-weight decreases the total dead load acting on columns, beams, and foundations.
Consequently:

• Smaller structural elements can be designed
• Foundation dimensions can be reduced
• Seismic forces become lower
• Larger spans can be achieved
• Slab thickness can be reduced by approximately 5–10%

Despite the reduced concrete volume, the slab maintains adequate flexural stiffness and load-bearing capacity.
Construction Efficiency

The COBIAX system accelerates construction because:

• Less concrete is required
• Transportation loads are reduced

• Formwork demands are minimised
• Construction becomes more practical

The installation of modules is relatively simple and can be integrated into standard reinforced concrete construction procedures.

Environmental Benefits

The COBIAX system contributes to sustainable construction through:

• Reduced concrete usage
• Lower cement consumption
• Reduced CO2 emissions
• Use of 100% recycled plastic modules

Concrete production is one of the largest sources of global carbon emissions. Therefore, reducing concrete volume has significant environmental advantages.

Seismic Advantages

In seismic design, lower structural mass directly reduces earthquake forces.

Because the COBIAX system significantly reduces dead load, buildings demonstrate:

• Improved seismic behaviour
• Better ductility
• Reduced dynamic response
• Lower risk during earthquakes

These advantages make the system particularly suitable for seismic regions

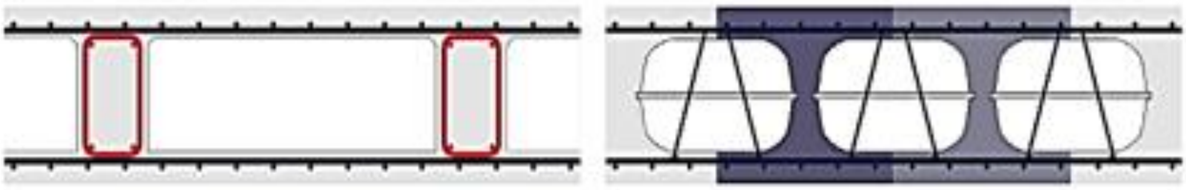


Figure 4. *Comparison Between Conventional Slabs and COBIAX Slabs*

COST ANALYSIS

Economic efficiency is one of the most important advantages of the COBIAX system. Although the initial cost of void formers increases slab production expenses, the overall project cost is reduced due to savings in:

• Concrete quantity
• Reinforcement requirements
• Foundation dimensions
• Transportation costs
• Construction time

The reduction in slab weight allows optimisation of the entire structural system.

According to the performed analysis, COBIAX slabs can reduce concrete consumption by approximately 25–30% compared with conventional monolithic slabs.

In the analysed case study:

• Conventional slabs required approximately 600 m3 of concrete
• COBIAX slabs required approximately 420 m3 of concrete

This represents a saving of approximately 180 m3 of concrete.

Additionally, approximately 1400 tons of CO2 emissions can be avoided through reduced material consumption.

Another advantage is the reduction in floor height due to flat slab construction without deep beams. This creates additional usable space and architectural flexibility.

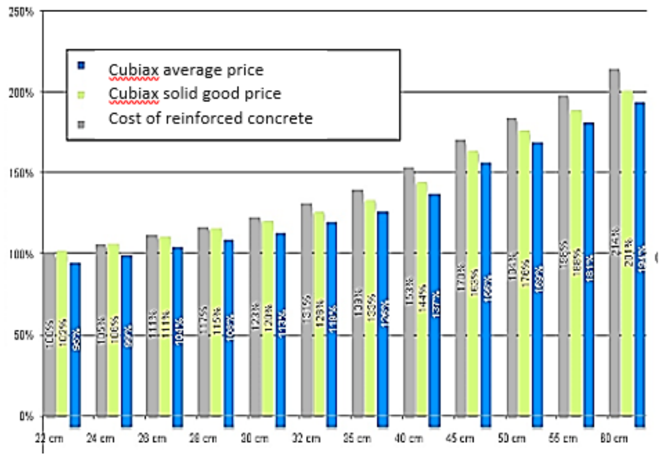


Figure 5. *Cost Comparison Between Conventional and COBIAX Slab Systems*

CONCLUSION

The conducted analysis demonstrates that the COBIAX system represents a highly efficient alternative to conventional monolithic reinforced concrete construction.

The system successfully reduces structural self-weight while maintaining the required structural safety, stiffness, and durability. Compared with conventional reinforced concrete slabs, the COBIAX system offers several important advantages:

• Reduced concrete consumption
• Lower structural dead load
• Improved seismic performance
• Faster construction process
• Reduced environmental impact
• Larger structural spans
• Lower foundation costs
• Greater architectural flexibility

The use of recycled plastic modules additionally contributes to sustainability and environmental protection. Based on the structural and economic analysis presented in this study, the COBIAX system can be considered a modern, sustainable, and economically justified solution for commercial buildings, particularly in regions exposed to seismic activity.

REFERENCES

1. Eurocode 2 – Design of concrete structures.
2. Eurocode 8 – Design of structures for earthquake resistance.
3. Cobiax international technical documentation.
4. Radić, J. Concrete structures and construction.
5. Omar, A. (2018). A state-of-the-art review on reinforced concrete voided slabs. ARPN Journal of Engineering and Applied Sciences, 13 (5).
6. Churakov, A. (2014). Biaxial hollow slab with innovative types of voids. Construction of Unique Buildings and Structures, 6 (21).
7. Prieto-Portar, L. A. (2008). The design of reinforced concrete slabs.
8. Taşkın, K., & Peker, K. (2014). Design factors and economical application of spherical voids in RC slabs.
9. Klein, D. (2007). Structural engineers, sustainability and LEED.
10. Cobiax USA voided slabs documentation.

TEHNIČKO-EKONOMSKO POREĐENJE MONOLITNE GRADNJE I SISTEMA COBIAX U POSLOVNIM ZGRADAMA

SAŽETAK

Ovaj rad prikazuje komparativnu analizu konvencionalne monolitne armiranobetonske gradnje i COBIAX sistema olakšanih ploča u poslovnim objektima. Studija analizira strukturno ponašanje, efikasnost gradnje, ekonomske performanse i seizmički odgovor oba sistema. Tradicionalna monolitna gradnja se poredi sa modernim armiranobetonskim pločama koje uključuju elemente za formiranje šupljina od reciklirane plastike.

COBIAX sistem smanjuje potrošnju betona i vlastitu težinu konstrukcije, dok istovremeno održava strukturni kapacitet i krutost sistema ploča. Smanjenje stalnog opterećenja značajno poboljšava seizmičke performanse i omogućuje optimizaciju stubova, temelja i potpornih elemenata.

Analiza je provedena u skladu sa Eurokod 2 i Eurokod 8 standardima korištenjem konvencionalnih principa projektovanja armiranobetonskih konstrukcija i verifikovanih inženjerskih metoda za sisteme olakšanih ploča.

Rezultati pokazuju da COBIAX sistem osigurava smanjene troškove izgradnje, kraću izvedbu radova, poboljšanu održivost i bolju strukturnu efikasnost u poređenju sa konvencionalnim monolitnim pločama. Nadalje, smanjena debljina ploče i manja potrošnja materijala omogućuju veće raspone i povećanu korisnu površinu poda.

Ključne riječi: monolitna gradnja, armiranobetonske ploče, COBIAX sistem, olakšane ploče, strukturna efikasnost, Eurokodovi, komercijalne zgrade

Correspondence to: Shinasi Zejneli
Faculty of Applied Sciences, Department of Concrete and Steel, State University of Tetovo – RNM, North Macedonia
E-mail: shinasi.zendeli@unite.edu.mk

THE EFFECT OF PARTICLE SIZE DISTRIBUTION ON THE EXPLOSIBILITY PARAMETERS OF SOY PROTEIN CONCENTRATES DUST

Mirsad Lišić

1. Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina

ABSTRACT

The paper presents the testing results of soy protein concentrate dust explosibility parameters, including maximum explosion pressure (pmax), maximum rate of explosion pressure rise ((dP/dt)max), and dust explosion severity index (Kst,max), as well as an analysis of the effect of dust particle size distribution on the examined parameters. Laboratory testing of explosibility parameters was carried out on three test samples with particle sizes of 125 µm, 75 µm, and 63 µm. The tests were performed in accordance with the international standard ISO/IEC 80079-20-2:2016. It was found that the 125 µm dust fraction had values of pmax = 6.7 bar and Kst,max = 110 bar·m/s. The 75 µm fraction had values of pmax = 7.0 bar and Kst,max = 137 bar·m/s. The 63 µm fraction had values of pmax = 7.1 bar and Kst,max = 132 bar·m/s.

Keywords: explosion pressure, maximum rate of pressure rise, explosion severity index, soy protein concentrates, particle size distribution

INTRODUCTION

Food industry facilities are often exposed to the risk of fires and explosions, as evidenced by a large number of combustible dust incidents occurring every year. An objective assessment of the potential hazard is difficult to achieve without detailed knowledge of the relevant parameters of the combustible dust used in a specific technological process. It should be emphasised that particle size distribution can significantly affect the explosibility and flammability parameters of dusts [4], [5].

In recent times, increasing attention has been paid to fire and explosion hazards of combustible dusts, which is evidenced by the development of standards covering this area as well as statistical monitoring of data on dust-related incidents. The data collected on combustible dust incidents for the period 2016–2019 in the USA indicate that, on average, 33.2 dust explosions, 29 injuries, and 3 fatalities occur annually [3]. Monitoring the frequency of fires and explosions according to dust type, industrial sector, and the type of equipment is of great importance for the implementation of effective preventive measures. Statistical data from the same source for the above-mentioned period indicate that wood processing products (sawdust, shavings, fibres, pellets) and food products (grain, flour, soy, rice, milk powder, seeds, fertilisers) account for an average of 60% of materials involved in combustible dust fires and explosions. The distribution of explosions and fires according to dust type and industrial sector is shown in Figures 1 and 2.

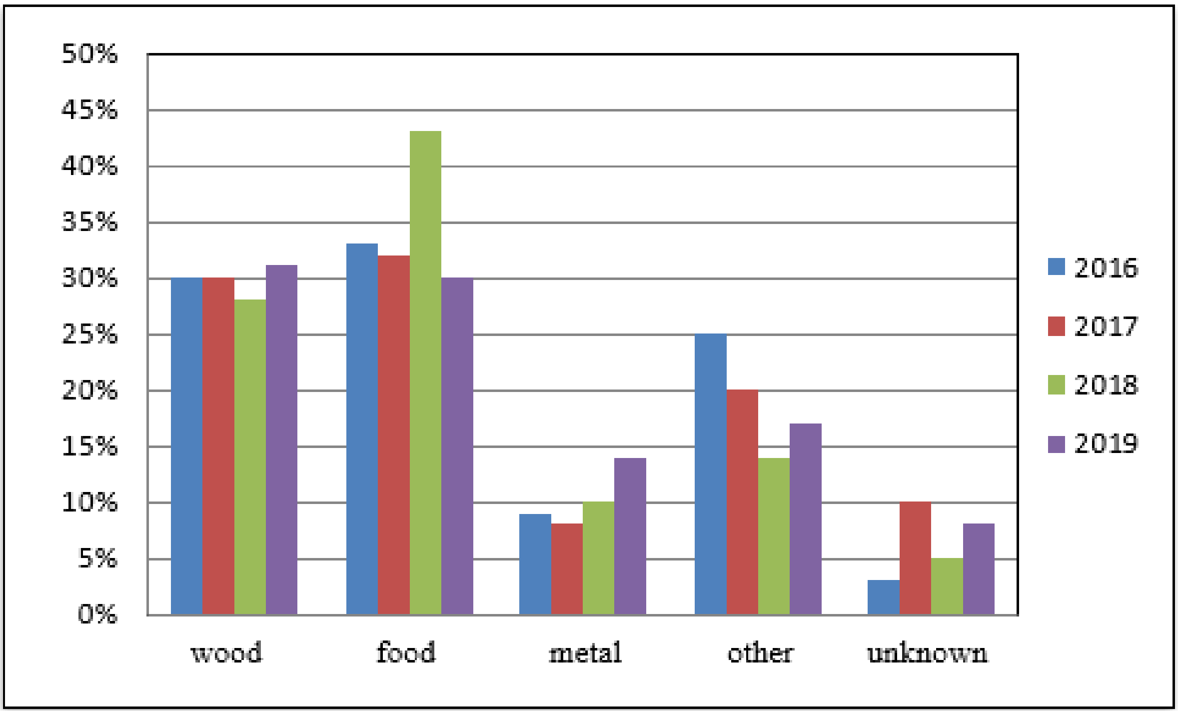


Figure 1. *Distribution of Explosions and Fires According to the Type of Combustible Dust*

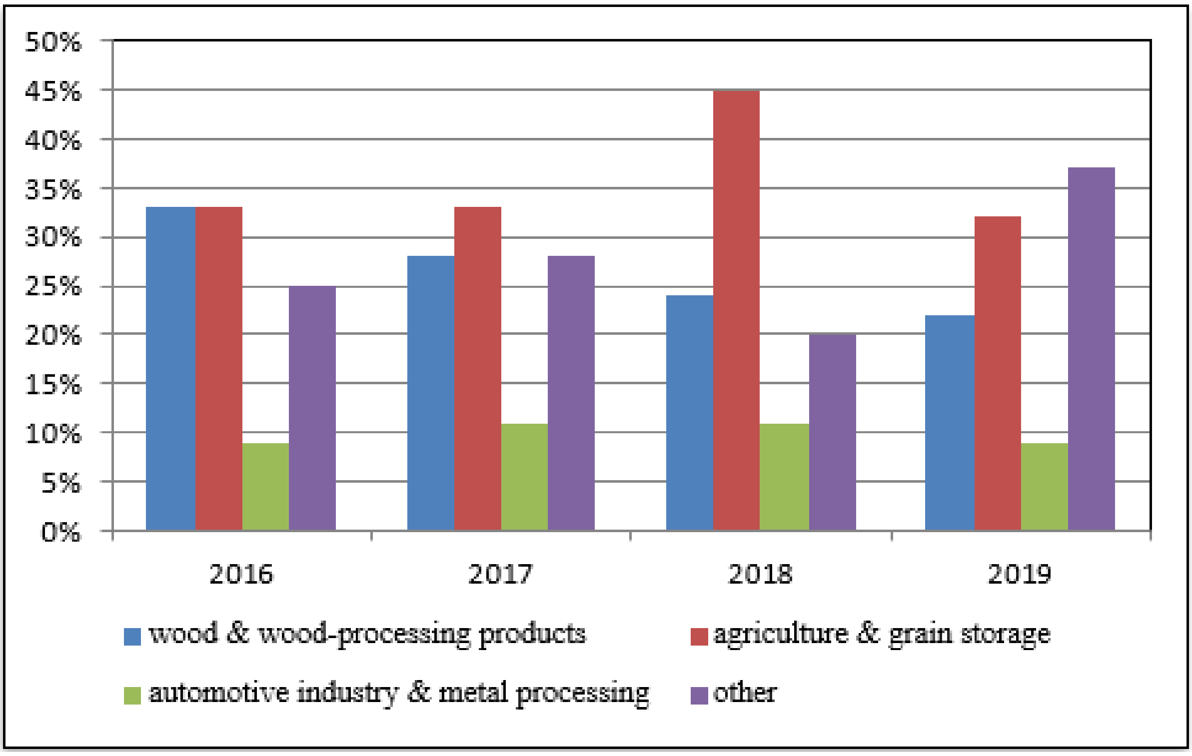


Figure 2. *Distribution of Explosions and Fires According to Industrial Sector*

It was found that the highest percentage of incidents in production processes is associated with dust collection equipment; however, this category shows the lowest proportion of recorded explosions compared to other types of equipment, as shown in Figure 3. The number of fatalities in incidents involving dust collectors is lower than in incidents involving other types of equipment, such as silos, elevators, conveyor belts, etc.

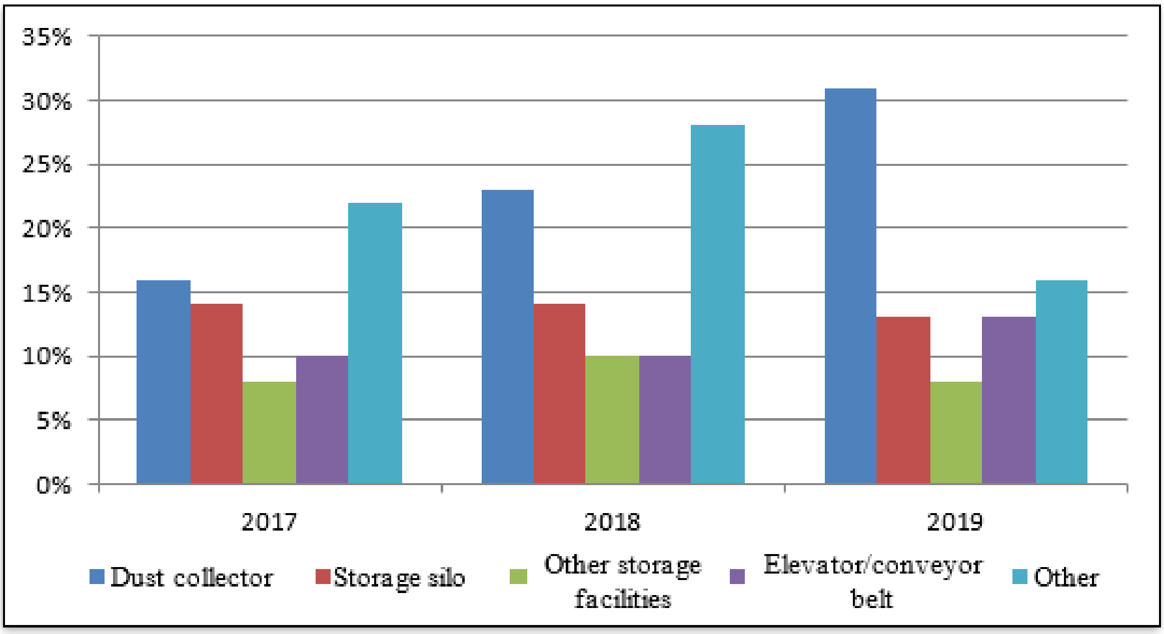


Figure 3. *Incidents Involving Combustible Dusts According to the Type of Equipment in the Production Process*

METHODOLOGY FOR TESTING EXPLOSION PARAMETERS

Knowledge of dust explosibility parameters is necessary for the design of industrial facilities, the correct selection and installation of electrical and mechanical equipment intended for use in potentially explosive atmospheres, the application of protective measures in such facilities, and the classification of hazardous areas.

The ISO/IEC 80079-20-2:2016 standard describes methods for testing combustible dusts and combustible dust layers for the purpose of their identification, in order to enable the classification of areas in which such materials are present [8]. The classification of areas containing combustible dusts is important for the proper selection and installation of electrical and mechanical equipment intended for use in such environments.

Testing of explosibility parameters was carried out in a spherical chamber with a volume of 20 dm^3, type KSEP 20 with accompanying equipment, manufactured by "Kühner" – Switzerland. The following parameters were measured: maximum pressure as a function of dust concentration (pmax), maximum rate of pressure rise as a function of dust concentration ((dP/dt)max), and ignition delay time (t1). The dust explosion was initiated using chemical igniters with a total energy of 10 kJ.

Table 1. *Explosibility Parameters and Standards According to Which They Were Determined [6] [7]*

Explosibility Parameter	Definition	Standard	Determination
p_{max}	Maximum explosion pressure (bar)	EN 14034-1:2004+A1:2011	Measurement of explosion pressure as a function of dust concentration in a 20 L test sphere
$(dp/dt)_{max}$	Maximum rate of pressure rise (bar/s)	EN 14034-2:2006+A1:2011	Testing of explosion severity in a test sphere, used for the calculation of the KSt value
K_{St}	Dust explosion severity index (bar·m/s)	EN 14034-2:2006+A1:2011	$(dp/dt)_{\max} \cdot V^{1/3} = const. = K_{St} = K_{\max}$

Prior to experimental testing, three test samples with particle sizes of 125 µm, 75 µm, and 63 µm were prepared by sieving on a vibrating sieve with standardised mesh sizes. The reason for preparing these samples was to investigate the "most unfavourable" case from the standpoint of explosion protection, since finer particles tend to react more violently than coarser ones. In addition, moisture, ash, and volatile matter contents were determined, as they also influence the tested parameters.

Testing of explosibility parameters was performed at dust concentrations of 125 g/m^3, 250 g/m^3, 500 g/m^3, 750 g/m^3, 1000 g/m^3, 1250 g/m^3, and 1500 g/m^3. After the initial test series, the concentration range near the observed maxima of pmax and (dP/dt)max was checked twice. The tests were repeated at the optimal concentration, as well as at the next lower and higher concentrations. The explosibility parameters were defined as the average values of the maximum values obtained from each series.

RESULTS AND ANALYSIS

The results of explosibility parameter testing for three particle size fractions of soy protein concentrates with an average moisture content of 6.17% m/m, ash content of 5.61% m/m, and volatile matter content of 83.33% m/m are presented in Table 2 and Figures 1, 2, and 3.

Table 2. *Explosibility Parameters of Soy Protein Concentrates*

Explosibility Parameters	Values		
	125 µm	75 µm	63 µm
Maximum explosion pressure, p_{max} *(bar)*	6.7	7.0	7.1
Maximum rate of pressure rise, *(dp/dt)*$_{max}$ *(bar/s)*	406	506	488
Explosion constant, $K_{st,max}$ *(m·bar/s)*	110	137	132
Ignition delay time of the explosive mixture, t_1 (ms)	72	47	42

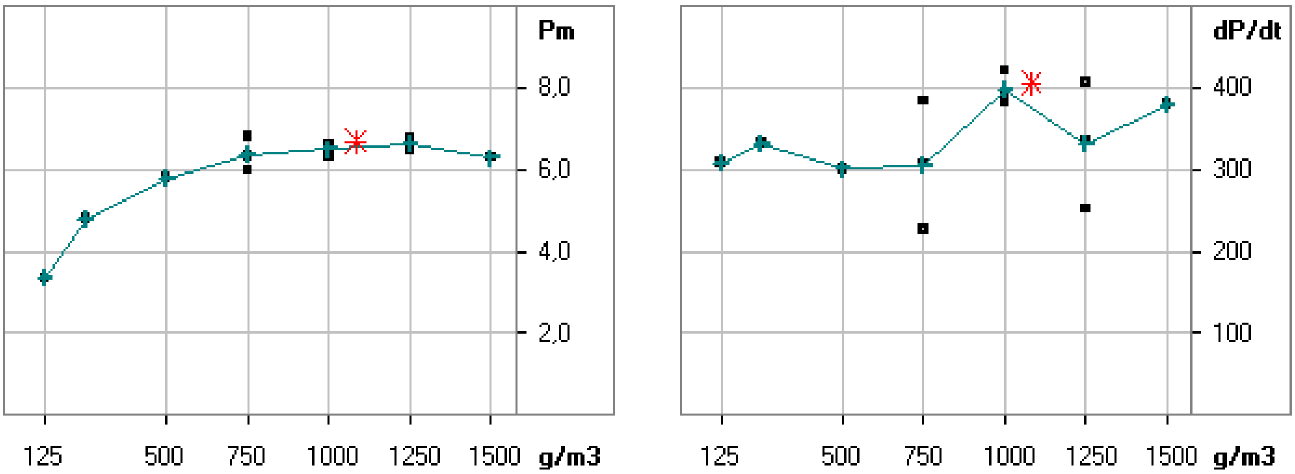


Figure 1. *Graphical Representation of the Increase in pmax and (dP/dt)max Depending on the Dust Concentration for a Particle Size Fraction of 125 µm*

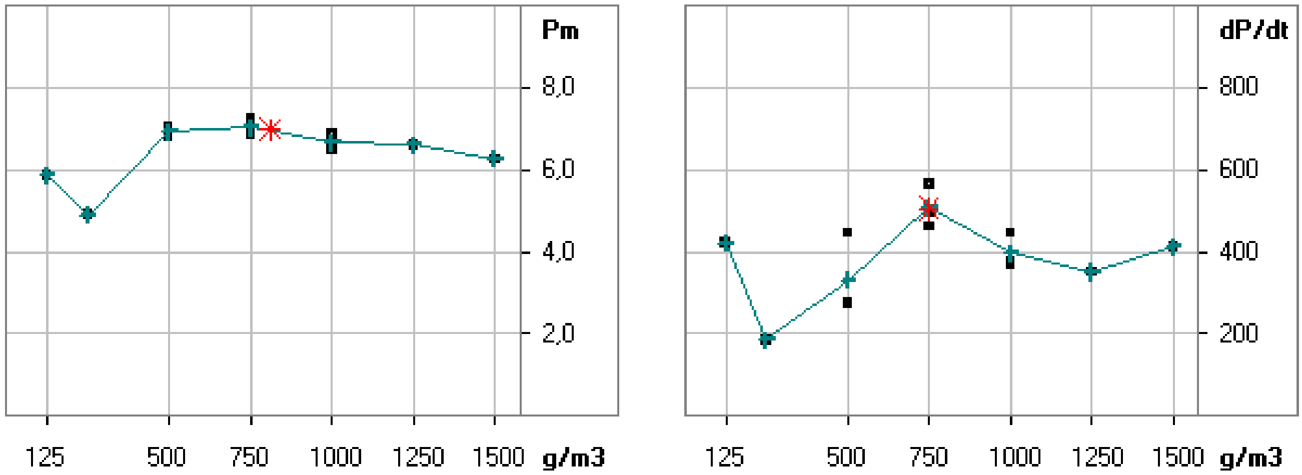


Figure 2. *Graphical Representation of the Increase in pmax and (dP/dt)max Depending on the Dust Concentration for a Particle Size Fraction of 75 µm*

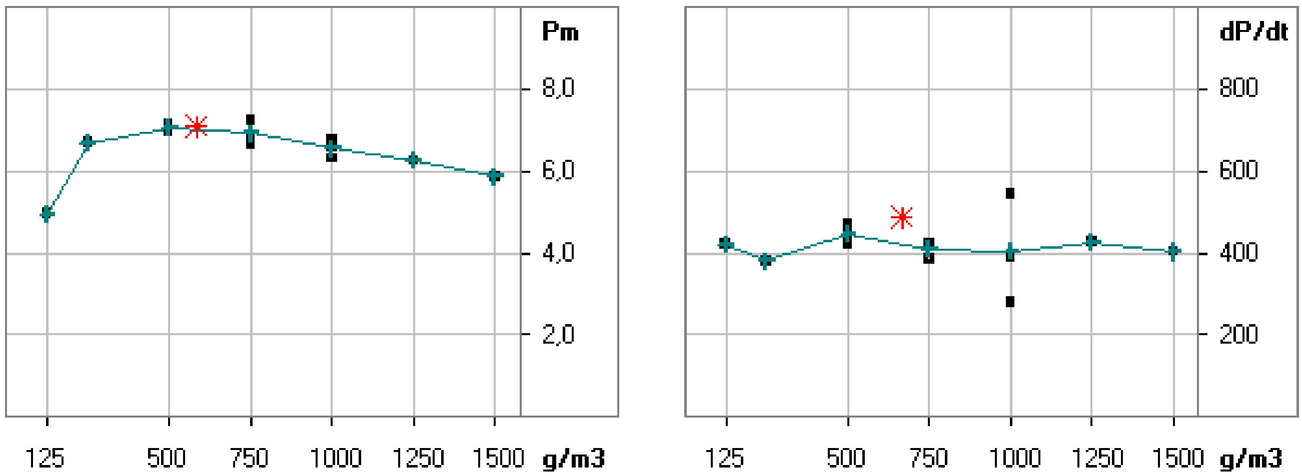


Figure 3. *Graphical Representation of the Increase in pmax and (dP/dt) max Depending on the Dust Concentration for a Particle Size Fraction of 63 µm*

Observing the graphical representations in Figures 1, 2, and 3, changes in the explosibility parameters with respect to the particle size distribution of the tested dusts are evident. The highest maximum explosion pressure was obtained for the 63 µm particle size fraction and amounts to 7.1 bar. The results of the study confirm the rule that the maximum explosion pressure and maximum rate of pressure rise are achieved at lower dust concentrations with decreasing particle size [5].

For the 125 µm particle size fraction of the tested dust, pmax = 6.7 bar and (dP/dt)max = 406 bar/s were obtained at a dust concentration between 1000 and 1250 g/m^3.

For the 75 µm particle size fraction, pmax = 7.0 bar was obtained at a dust concentration between 750 and 1000 g/m^3, while (dP/dt)max = 506 bar/s was obtained at a dust concentration of 750 g/m^3.

For the 63 µm particle size fraction, pmax = 7.1 bar and (dP/dt)max = 488 bar/s were obtained at a dust concentration between 500 and 750 g/m^3.

The ignition delay time of the explosive mixture for the 63 µm particle size fraction is the lowest and amounts to 42 ms, while for the 125 µm particle size fraction it is the highest and amounts to 72 ms. It was observed that the minimum ignition delay time for the tested 63 µm dust fraction occurs independently of the maximum explosion pressure and the maximum rate of explosion pressure rise, which is not the case for the other two tested samples. The highest value of the explosion constant is 137 m·bar/s, while the lowest is 100 m·bar/s. According to the explosion constant parameter (Kst,max), all three tested samples are classified into explosion class 1 (St1 < 200 m·bar/s), with weak or moderately explosive severity [1], [2].

CONCLUSION

The testing presented in this paper was carried out with the aim of obtaining relevant data on the effect of particle size distribution on the explosion parameters of soy protein concentrates for the "most unfavourable" cases from the standpoint of explosion protection. The value of the explosion constant together with the maximum explosion pressure is a measure of the explosion hazard that the tested soy protein concentrate dust introduces into the process, the knowledge of which is, among other things, necessary for the application of protective measures in plants and for the classification of hazardous areas.

Laboratory testing of explosibility parameters was carried out on three test samples with particle sizes of 125 µm, 75 µm, and 63 µm. It was found that with decreasing particle size of soy protein concentrates, the values of the explosion constant (max. 137 m·bar/s) and the explosion pressure (max. 7.1 bar) increase. The difference between the highest and lowest maximum explosion pressure is 0.4 bar, while the difference between the highest and lowest values of the explosion constant is 27 m·bar/s.

REFERENCES

1. Beck, H., Glienke, N., & Möhlmann, C. (1997, November). BIA report: Combustion and explosion characteristics of dusts. HVBG, Berufsgenossenschaftliches Institut für Arbeitssicherheit.
2. Barton, J. (2002). Dust Explosion: Prevention and Protection – A Practical Guide. Institution of Chemical Engineers (IChemE).
3. Dust Safety Science. (2019). Combustible Dust Incident Report. DustSafetyScience.com
4. Marković, J., Šišić, R., & Bajramović, K. (2017). Assessing the effectiveness of inertization of brown coal dust with limestone rock dust. Underground Mining Engineering, 31, 31-43. https://doi.org/10.5937/podrad1731031M
5. Mičević, S., Marković, J., Bajramović, K. (2004). Eksplozivnost prašine mrkog uglja u funkciji granulometrijskog sastava. Zbornik radova RGGF-a Tuzla, 29(1), 127–131.
6. Institute for Standardization of Bosnia and Herzegovina. (2011). BAS EN 14034-1:2004+A1:2011. Determination of explosion characteristics of dust clouds – Part 1: Determination of the maximum explosion pressure pmax of dust clouds. Sarajevo.
7. Institute for Standardization of Bosnia and Herzegovina. (2011). BAS EN 14034-2:2011. Determination of explosion characteristics of dust clouds – Part 2: Determination of the maximum rate of explosion pressure rise (dP/dt)max of dust clouds. Sarajevo
8. ISO/IEC 80079-20-2:2016: Explosive atmospheres. Part 20-2: Material characteristics — Combustible dusts test methods

UTICAJ GRANULOMETRIJSKOG SASTAVA NA PARAMETRE EKSPLOZIVNOSTI PRAŠINE SOJINIH PROTEINSKIH KONCENTRATA

SAŽETAK

Članak prikazuje rezultate ispitivanja parametara eksplozivnosti prašine sojinih proteinskih koncentrata: maksimalnog pritiska eksplozije (pmax), maksimalnog vremenskog porasta pritiska eksplozije (dp/dt)max, indeksa jačine eksplozije prašine (Kst,max) i analizu uticaja granulacije čestica prašine na ispitivane parametre. Laboratorijska ispitivanja parametara eksplozivnosti su izvršena na tri ispitna uzorka granulacije čestica 125 µm, 75 µm i 63 µm. Ispitivanja su provedena u skladu sa međunarodnom normom ISO/IEC 80079-20-2:2016. Ustanovljeno je da granulacija čestica ispitivane prašine 125 µm ima vrijednosti pmax= 6,7 bar i Kst,max = 110 bar·m/s. Granulacija čestica ispitivane prašine 75 µm ima vrijednosti pmax= 7,0 bar i Kst,max = 137 bar·m/s. Granulacija čestica ispitivane prašine 63 µm ima vrijednosti pmax = 7,1 bar i Kst,max = 132 bar·m/s.

Ključne riječi: pritisak eksplozije, maksimalni vremenski porast pritiska, indeks jačine eksplozije, sojini proteinski koncentrati, granulacija čestica

Correspondence to: Mirsad Lišić
Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina
E-mail: mirsad.lisic@eftfts.edu.ba

FORTIFYING THE DIGITAL CLASSROOM: AI REVOLUTIONISING CYBERSECURITY IN GOOGLE WORKSPACE FOR EDUCATION

Haris Berkovac[1], Edina Berkovac[2], Selver Grabus[3]

1. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina; BH Telecom, Sarajevo, Bosnia and Herzegovina
2. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina
3. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina

ABSTRACT

As IT universities aggressively adopt Google Workspace for Education, the attack surface for cyber threats expands exponentially. Traditional security models, reliant on static rules and manual monitoring, prove inadequate against sophisticated phishing, credential theft, and data exfiltration attempts. This article explores the precise integration of Artificial Intelligence (AI) into Google's native security framework to create a proactive, adaptive defence mechanism. We examine how machine learning models analyse behavioural patterns, automate threat detection, and enforce zero-trust access controls within the Google for Education ecosystem. Through a case study at an IT university, we demonstrate an 85% reduction in incident response time and a 60% drop in successful phishing attempts. The piece concludes with actionable pro tips, future insights, and a roadmap for academic institutions seeking to harmonise high-tech learning with ironclad security.

Keywords: generative AI, computer science education, automated content generation, personalised learning, higher education, AI ethics, curriculum design, Workspace, Google, security

INTRODUCTION

The modern IT university is no longer a collection of physical classrooms, but a hybrid, always-on digital ecosystem. Google Workspace for Education (formerly G Suite) has become the backbone of this transformation, offering Gmail, Google Classroom, Drive, Meet, and collaborative documents. However, this very convenience breeds vulnerability.

The paradox: IT universities teach the next generation of defenders, yet their own infrastructure is a prime target for state-sponsored actors, ransomware gangs, and curious students probing for weaknesses. Traditional cybersecurity measures - firewalls, antivirus software, and periodic password changes - are reactive. They fail against zero-day exploits and polymorphic malware. Enter Artificial Intelligence. AI does not just follow rules; it learns the 'normal' rhythm of a university's digital traffic and flags anomalies in milliseconds.

This article dissects how AI specifically enhances Google Workspace for Education, transforming it from a simple productivity suite into an intelligent security sentinel.

AI IN ACTION ON GOOGLE FOR EDUCATION

The Threat Landscape Specific to IT Universities
IT universities present unique risks:

• High-Value Targets: Research on AI, quantum computing, and cryptography is lucrative for cybercriminals.

• Open Culture: Collaboration is encouraged, making strict access controls difficult.

• Credential Reuse: Students and faculty often reuse passwords across personal and institutional accounts.

How Google's AI-Layer Works

Google embeds AI not as an add-on, but as a fabric woven into Workspace. Key components include:

1. Context-Aware Access (CAA): AI analyses real-time signals: user location, device health, IP reputation, and typing patterns. If a professor in Seoul attempts to log in from a Tor browser in Moscow at 3 AM, AI blocks the access or enforces a strong challenge.

2. Gmail Phishing Detector (TensorFlow-based): Google's AI models scan billions of emails daily. For an IT university, this means detecting spear-phishing emails that use technical jargon (e.g., "Urgent: Your Git repository access token has expired") with 99.9% accuracy.

3. Drive Data Loss Prevention (DLP): AI-powered DLP scans documents in real-time. It can flag a student uploading a file named "AWS_Root_Keys.txt" or a researcher sharing a dataset with an external, non-approved collaborator.
4. Alert Centre Automation: Instead of 10,000 low-confidence alerts, AI correlates events. Example: A failed login + a new device enrolment + an email rule creation = one high-severity alert of a compromised account.

The Shift From Detection to Prediction

Traditional tools tell you what happened. AI tells you what will happen. By training models on historical breach data from global education sectors, Google's AI can predict which users are likely to click a malicious link next week based on their recent browsing patterns.

CASE STUDY: "TECHFORWARD UNIVERSITY" AI-DRIVEN RESILIENCE

Institution: A top-10 IT university with 15,000 students and 2,000 faculty.

Platform: Google Workspace for Education Plus.

Challenge: Over 120 account compromises in 6 months, primarily through Google Calendar invite phishing and fake Google Classroom assignment links.

Phase	Action	AI Feature Used	Outcome
Phase 1	Deployed Context-Aware Access	Risk score-based MFA (no MFA prompt if trusted device + location)	40% reduction in MFA fatigue attacks
Phase 2	Enabled AI-driven Gmail filtering	TensorFlow-based attachment sandboxing	Blocked 99.8% of malicious .pdfs
Phase 3	Activated Drive and Chat DLP	Pattern recognition for code commits & API keys	Detected 15 students sharing internal API keys externally

Table 1: *The AI Implementation (Phase 1-3)*

Results Over 12 Months

• Incident Response Time: From 4 hours to 35 minutes (85% reduction).
• Successful Phishing Compromises: Dropped from 120 to 12 (90% reduction).
• False Positives: AI reduced security team overhead by 70% (from 200 daily alerts to 60 actionable ones).
• Student Awareness: The university used AI-generated security reports to create personalised micro-training modules, improving click-through rates on training emails from 18% to 74%.

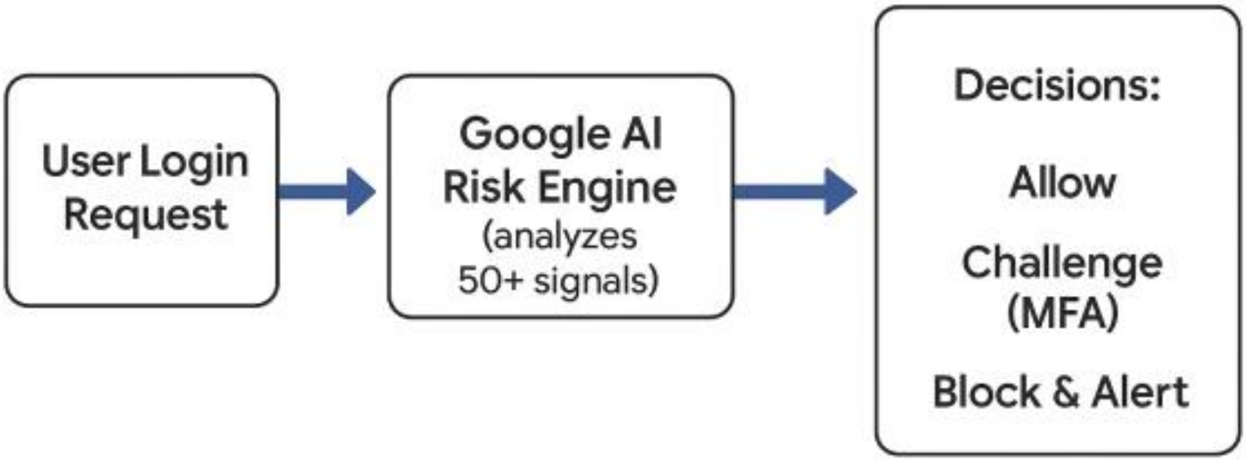
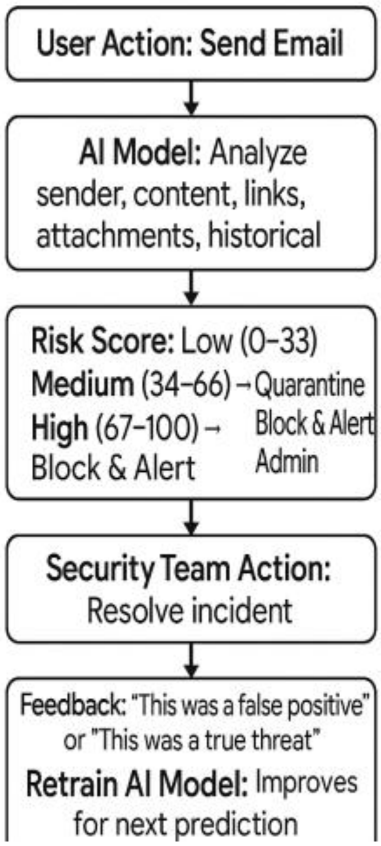


Diagram 1: *Risk Engine*

ADVANCED AI COUNTERMEASURES: BEYOND THE BASICS – A TECHNICAL DEEP DIVE

While the previous sections established the foundational role of AI in detecting known threats like phishing and credential theft, the modern IT university faces a more sinister reality: adaptive adversaries who use AI themselves. This chapter explores three advanced threat vectors - generative AI (GenAI) social engineering, living-off-the-land (LotL) attacks, and insider threat obfuscation- and details how Google's next-generation AI models counter them.

Diagram 2: *The AI Security Feedback Loop in Google Workspace*



The Rise of AI-Generated Spear-Phishing: When the Dean Sounds Like the Dean

Traditional phishing emails contain telltale signs: grammatical errors, mismatched URLs, or generic greetings. AI-powered attackers now use large language models (LLMs) to craft perfectly personalised emails in seconds.

The Attack Scenario: A threat actor scrapes a professor's public Google Scholar profile, LinkedIn activity, and recent tweets. An LLM generates an email that mimics the professor's writing style, references their ongoing research project, and asks a doctoral student to "review this shared Google Doc urgently." The document link leads to a fake Google login page that captures credentials.

Table 2: *How Google's AI Fights Back - Multi-Layered GenAI Defence*

Layer	AI Technology	How It Works Against AI-Generated Phishing
1. Sender Behaviour Analysis	Graph Neural Network (GNN)	Compares email metadata (send time, device, IP, typical send frequency) against the user's historical "graph." An AI-generated email from the dean at 2 AM from a new device is flagged even if the text is perfect.
2. Content Deep Inspection	Transformer-based detector (BERT fine-tuned on phishing)	Scans for subtle linguistic patterns unique to LLM-generated text (e.g., unusual verb tense consistency, over-politeness, lack of personal typos).
3. Link Dynamic Sandboxing	AI-powered URL isolation (Google Safe Browsing 2.0)	Clicks on links are rendered in a virtual container. AI observes if the destination page asks for credentials and spoofs Google's login UI. If yes, the link is globally blocked within minutes.
4. Real-Time User Risk Scoring	Federated learning across Google's education tenant	If 5 users in the same university report a similar email as suspicious, AI automatically demotes all similar emails from that sender pattern across the entire institution.

Quantitative Impact: In a 2024 Google internal study of education customers, these GenAI-specific layers reduced successful AI-generated phishing compromises by 96% compared to the previous generation of static filters.

Living-Off-the-Land (LotL) Attacks: When the Attacker Uses Google's Own Tools

LotL attacks are particularly insidious because they use legitimate Google Workspace features to move laterally, exfiltrate data, or maintain persistence. No malware is installed, so traditional antivirus sees nothing.
The Attack Scenario: A compromised faculty account (via previous phishing) does not download a backdoor. Instead, the attacker:

1. Creates a Google App Script that forwards all new emails from the "Research Grants" label to an external Gmail address.

2. Uses Google Drive's "Share with anyone with the link" to make a folder of source code publicly accessible.

3. Sets up a Google Calendar rule to automatically accept all meeting invites with a specific attendee (the attacker), allowing persistent recon.

Table 3: *How Google's AI Detects LotL Anomalies*

Normal Behaviour (Faculty Baseline)	Abnormal Behaviour (AI Flags)	AI Action
Creates 1-2 App Scripts per month	Creates 6 App Scripts in 1 hour, all with forwarding rules	Suspend scripts; alert admin
Shares 5 Drive folders externally per month	Shares 50 folders externally in 10 minutes	Auto-revoke external sharing; require re-verification
Creates 1 Calendar rule per week	Creates an "auto-accept all invites from unknown domain" rule	Block rule creation; log for investigation
Exports data via Google Takeout once per year	Initiates Takeout at 3 AM from a foreign IP	Require second admin approval

Traditional security rules would miss these actions because they are legitimate API calls. AI-based user and entity behaviour analytics (UEBA) establishes baselines and detects deviations.

Case Example - Real-World Prevention: A large IT university in Germany (anonymised) experienced a LotL attack where a compromised Ph.D. account began using Google Drive's built-in OCR to scan research documents and then shared them externally via a public link. Google's AI detected that the OCR usage volume had increased 400% compared to the student's historical pattern. Within 90 seconds, the AI auto-revoked all external sharing and forced a password reset. The attacker had exfiltrated only 3% of the intended data.

Insider Threat Obfuscation: When the User Is Valid but Malicious

The hardest threat to detect is a legitimate user who has gone rogue - a disgruntled researcher, a student selling exam answers, or an employee coerced by a foreign entity. Traditional security assumes valid credentials = valid user. AI flips this assumption.

Behavioural Scent Detection: Google's AI continuously computes an insider risk score based on subtle behavioural shifts. It does not rely on a single action but on a constellation of low-fidelity events that together indicate malice. Example Constellation (Insider Threat Pattern):

• Event A: User accesses a Drive folder they have not opened in 6 months (research on quantum encryption).

• Event B: User changes their Google Account recovery email to a personal ProtonMail address.

• Event C: User downloads a Google Doc as a .pdf at 11 PM on a Friday (outside normal hours).

Individually, each event is benign. Together, AI raises a high-fidelity alert with a plain-English explanation: "User appears to be staging data for exfiltration: unusual folder access + recovery email change + after-hours download + printing of sensitive material. Probability of malicious intent: 87 %. Recommend temporary access suspension."

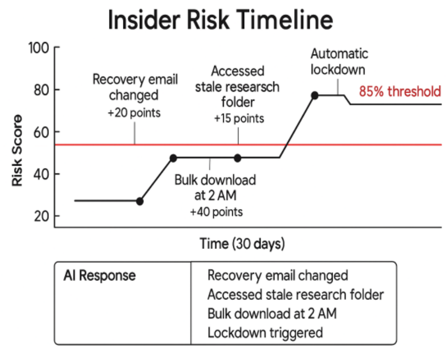
AI Mitigation Playbooks: Once the insider risk score crosses a configurable threshold (e.g., > 85%), Google's AI can execute automated, reversible actions:

1. Step 1 (Soft Restriction): Require the user to re-authenticate with MFA for any new sharing action.

2. Step 2 (Medium Restriction): Disable external sharing and download/print for that user only.

3. Step 3 (Hard Response): Lock the account, alert the security team via PagerDuty, and create a forensic snapshot of the user's recent activity.

Picture 1: *Insider Risk Timeline*



AI vs. AI: The Emerging Arms Race

We are entering an era where both attackers and defenders wield generative AI. Google's Security AI Workbench (powered by Sec-PaLM 2) is designed for this asymmetric fight. How Sec-PaLM 2 Outperforms Generic LLMs:

• Specialised Training: Trained on Google's vast telemetry (trillions of security events) plus public threat intelligence.

• Natural Language Investigation: An IT security admin can type: "Show me all accounts that shared a file externally from outside our campus IP range in the last hour, then had a failed login." The AI translates this into complex API queries and returns a table.

• Automated Remediation Summaries: After an incident, the AI generates a human-readable report.

The Offensive AI Threat: Attackers are already using AI to mutate malware signatures in real-time, bypassing static detections. Google's response is model cascading: a lightweight AI model runs on every email and file access (latency < 10ms). If it is uncertain, it escalates to a larger, slower, more accurate model. This cascading architecture maintains user experience while maximising detection depth.

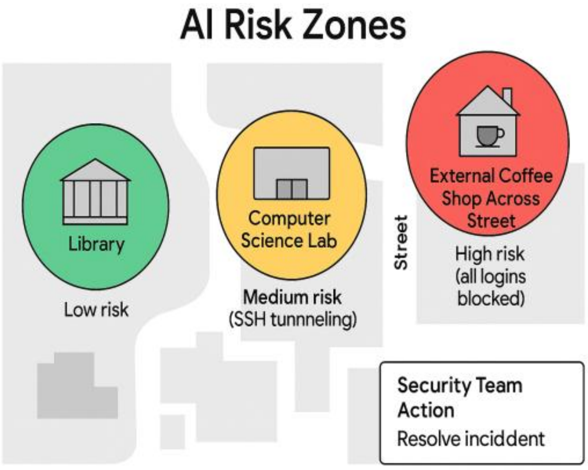
Implementation Roadmap for IT Universities: Moving From Reactive to Predictive

For an IT university currently using Google Workspace with basic security settings, here is a prioritised roadmap to adopt the advanced AI countermeasures described above.

Table 4: *Prioritised Roadmap*

Phase	Timeframe	AI Features to Enable	Expected Outcome
Phase 0: Foundation	Day 1	Mandatory MFA + Context-Aware Access (basic location/device)	Reduces commodity phishing by 80%
Phase 1: Detection	Week 1-2	AI-powered Gmail filtering + Drive DLP (standard rules)	Blocks 99% of known malware & sensitive data leaks
Phase 2: Behavioural	Week 3-4	UEBA for LotL detection (enable all anomaly alerts)	Detects compromised accounts within minutes, not days
Phase 3: Insider	Month 2	Insider risk scoring (requires change management & policy)	Flags malicious insiders before exfiltration
Phase 4: Predictive	Month 3-4	Sec-PaLM 2 Workbench + custom investigation playbooks	Security team resolves incidents in <15 minutes
Phase 5: Autonomous	Month 6+	Automated remediation (allow AI to quarantine, reset, notify)	90% of incidents fully automated; human reviews only complex cases

Picture 2: *All Risk Zones*



KEY TOOLS

Below are the specific AI-powered tools available within Google Workspace for Education Plus and their precise function.

Security Centre - Predictive risk scoring (User Risk, Device Risk) - Prioritising which compromised accounts to remediate first

Gmail Advanced Protection - AI-based attachment dynamic analysis - Blocking zero-day malware in classroom emails

Context-Aware Access - Attribute-based access control (location, device, group) - Allowing lab access only from campus IPs

Investigation Tool - Natural Language Processing (NLP) for log queries - Security admins asking: “Show me all logins from non-US IPs in last 24h”

Alert Centre - Correlation engine (clustering low signals into high alerts) - Detecting coordinated attacks (e.g., 50 failed logins across 50 accounts)

PRO TIPS FOR UNIVERSITY ADMINS

1. Start with User Risk, Not Device Risk: Students use personal devices. Configure AI to monitor who is accessing data, not just what device they use.

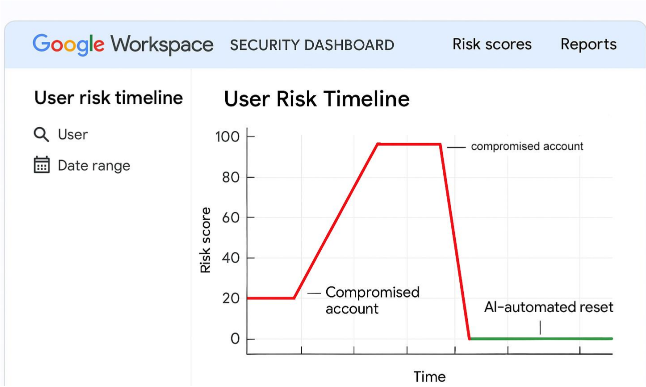
2. Train Your AI with Real Logs: For the first 30 days, run Google’s AI in “monitor only” mode. Feed it historical breach data to calibrate sensitivity for your unique academic environment.

3. Automate Remediation with Webhooks: Use Google Cloud Functions triggered by AI alerts to automatically move a compromised user to a “Lockdown” organisational unit (OU), resetting Drive sharing permissions.

4. Conduct Red-Team Exercises Against AI: Deliberately try to bypass Context-Aware Access (e.g., using a VPN). Learn where the AI gaps are.

5. Enable Gmail Log Search for Data Exfiltration: Look for patterns like “user sends email to personal Gmail with ‘backup’ in subject line.”

Picture 3: *Insider Risk Timeline*



CONCLUSION

For an IT university, cybersecurity is not a back-office function; it is a core academic and ethical responsibility. Google Workspace for Education, powered by its invisible AI layer, offers a transformative opportunity. No longer must security come at the cost of agility.

The evidence is clear: AI reduces response times from hours to minutes, slashes phishing success rates, and empowers overburdened security teams. However, technology alone is insufficient. IT universities must adopt a culture of continuous AI training, red-team testing, and ethical transparency.

REFERENCES

1. Cheung, A. C., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. Educational research review, 9, 88-113.

2. Drijvers, P. (2015). Digital technology in mathematics education: Why it works (or doesn't). In Selected regular lectures from the 12th international congress on mathematical education (pp. 135-151). Springer International Publishing doi:10.48550/arXiv.2506.05990

3. Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2014). Preparing for life in a digital age. In Preparing for life in a digital age.

4. Hemberger, T., & Konrad, S. (2021). Attitudes towards using digital technologies in education as an important factor in developing digital competence: The case of Slovenian student teachers. International Journal of Emerging Technologies in Learning, 16(4), 83–98.

5. Mittal, U., Sai, S., & Chamola., V. (2024). A comprehensive review on generative AI for education.

6. Rashid, F., Duong-Trung, N., Pinkwart, N. (2024). Generative AI in education: Technical foundations, applications, and challenges. doi:

7. 10.5772/intechopen.1005402

8. Shapiro, S. (2025). Exploring the impact of generative AI on education: Opportunities, challenges, and ethical considerations.

JAČANJE DIGITALNE UČIONICE: AI KAO REVOLUCIJA U KIBERNETIČKOJ SIGURNOSTI ZA GOOGLE WORKSPACE FOR EDUCATION

SAŽETAK
Kako IT univerziteti agresivno usvajaju Google Workspace for Education, površina napada za kibernetičke prijetnje se eksponencijalno širi. Tradicionalni sigurnosni modeli, koji se oslanjaju na statička pravila i ručno praćenje, pokazuju se neadekvatnim protiv sofisticiranog phishinga, krađe akreditiva i pokušaja eksfiltracije podataka. Ovaj rad istražuje preciznu integraciju umjetne inteligencije (AI) u Googleov izvorni sigurnosni okvir kako bi se stvorio proaktivan, prilagodljiv odbrambeni mehanizam. Ispitujemo kako modeli mašinskog učenja analiziraju obrasce ponašanja, automatizuju otkrivanje prijetnji i provode kontrole pristupa s nultom pouzdanošću unutar ekosistema Google for Education. Kroz studiju slučaja na IT univerzitetu, demonstriramo smanjenje vremena odgovora na incidente za 85% i pad od 60% uspješnih pokušaja phishinga. Članak se završava praktičnim savjetima, budućim uvidima i planom za akademske institucije koje žele uskladiti visokotehnološko učenje s nepokolebljivom sigurnošću.

Ključne riječi: generativna umjetna inteligencija, informatičko obrazovanje, automatsko kreiranje sadržaja, personalizovano učenje, visoko obrazovanje, etika umjetne inteligencije, izrada nastavnog plana i programa, Workspace, Google, sigurnost

Correspondence to: Haris Berkovac
Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina; BH Telecom, Sarajevo, Bosnia and Herzegovina
E-mail: haris.berkovac@eftfts.edu.ba

COMPARATIVE STUDY OF STEEL PRIMARY BEAMS FOR DIFFERENT SPANS

Berat Zejneli[1], Shinasi Zejneli[2], Meryem Kaprol[3]

1. Laboratory for Testing Construction Materials, State University in Tetovo - RNM, IZIIS - Institute for Seismology at UKIM - University of Saint Cyril and Methodius in Skopje, North Macedonia
2. Faculty of Applied Sciences, Department of Concrete and Steel, State University of Tetovo – RNM, North Macedonia
3. International University-Vision, RNM, North Macedonia, University of Travnik, Bosnia and Herzegovina.

ABSTRACT

The aim of this study is to perform a comparative analysis of steel primary beams with different cross-sections and truss systems for various spans and roof slopes. The analysis includes six structural solutions: I-section, H-section, rectangular hollow section (☐), circular hollow section (○), constant-depth truss, and variable-depth truss. The research was conducted for spans ranging from 8 m to 44 m and roof slopes from 0° to 20°, using Tower 8 software and S235 structural steel.

The results demonstrated that the I-section is the most efficient among solid profiles in almost all analysed combinations. The H-section achieves similar performance for larger spans, while hollow sections exhibit weaker behaviour as the span increases. Constant-depth trusses provide the lowest deflections and deformations for spans greater than 12 m. Variable-depth trusses show strong dependence on roof slope and become efficient only at higher slope angles.

Keywords: steel beam, cross-section, truss, Tower 8, S235, roof slope

INTRODUCTION

Steel is one of the most important structural materials for large-span buildings, such as industrial halls, warehouses, sports facilities, and agricultural structures. The selection of the primary load-bearing system directly affects the economy of the structure, material consumption, and deformation behaviour.

In roof systems, the primary structural members can be designed either as solid steel sections or as truss systems. The most commonly used profiles are I and H sections, while rectangular and circular hollow sections are used for specific structural and architectural requirements. For large spans, trusses are frequently applied because of their efficient material distribution and reduced structural weight. The objective of this study is to perform a parametric comparison of different steel primary beam systems in order to determine the most efficient structural solution for various spans and roof slope angles.

RESEARCH METHODOLOGY

The analysis was carried out using Tower 8 (Radimpex) structural analysis software based on a linear-elastic model. Structural steel grade S235 was adopted as the construction material.

The following parameters were considered:

• spans: 8 m, 12 m, 16 m, 20 m, 24 m, 28 m, 32 m, 36 m, 40 m, and 44 m,

- roof slopes: 0°, 5°, 10°, 15°, and 20°,
- loading cases: 6 kN/m^2 and 12 kN/m^2,
- boundary conditions: simply supported and fixed-end beams.

Six types of structural systems were analysed:

1. I-section,
2. H-section,
3. rectangular hollow section,
4. circular hollow section,
5. constant-depth truss,
6. variable-depth truss.

For each structural configuration, the following values were calculated:

- normal stresses (σ), $\sigma = M/W + N/A$
- relative deflections (δ), $\delta = k \cdot qL^4/(EI)$

The results were normalised by adopting the I-section as the reference value (σ = 1.000 and δ = 1.000).

Boundary Conditions of Supports

In this topic, two support boundary conditions are analysed: simple (pin/roller) support and fixed (encastre) support. In the case of simple support, the beam is free to rotate at the support, the bending moment at the ends is zero, and the maximum bending moment occurs at mid-span ($M\_max = qL^2/8$, $\delta\_max = 5qL^4/384EI$). In the case of fixed support, rotation at the support is restrained, negative moments are generated at the ends, and the maximum positive moment at mid-span is smaller ($M\_max = qL^2/12$ at the ends, $\delta\_max = qL^4/384EI$ — five times smaller than in the case of simple support).

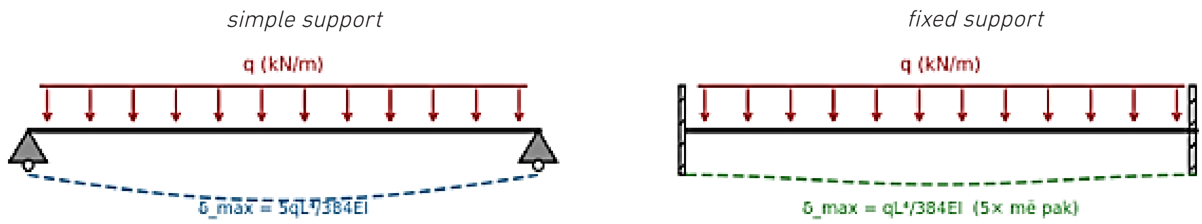


Figure 2.1 *— Beam Under Uniform Load With Free Support (Left) and With Embedment (Right), With the Corresponding Deformation Shapes.*

In practice, boundary conditions are realised through the structural details of the beam connections to columns or other supports. Figure 2.2 shows two types of real structural connections: a simple connection and a rigid connection.

Figure 2.2 — Two Types of Structural Connections: A Simple Connection (Left) With an Angle Plate That Allows Free Rotation and Transmits Only Shear Forces; and a Rigid Connection (Centre, Orange) With Bolted Top and Bottom Plates That Also Transmits Bending Moments. Source: Simpson Strong-Tie.

Types of Cross-Sections for Steel Beams

The industrial production of structural steel offers a wide range of standardised profiles (Figure 2.4). In this topic, four main families of full profiles (I-profile, H-profile, rectangular profile, circular profile/tube) and two types of trusses are compared, which are presented in detail below.

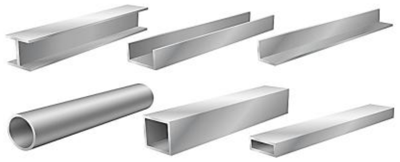


Figure 2.3 *— Common Types of Standardised Steel Profiles. In This Topic, the I-Profile (Top Left) and Circular, Square and Rectangular Profiles (Bottom) are Studied. U and L Profiles are not the Subject of This Paper.*

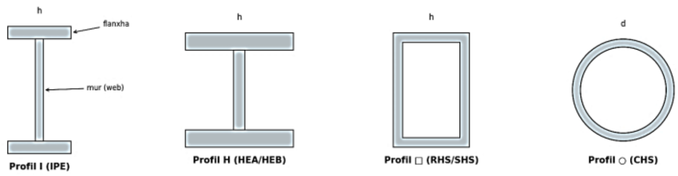


Figure 2.4 *— Schematic of the Four Complete Cross-Sections Analysed: I-Profile, H-Profile, □-Profile (Rectangular) and ○-Profile (Circular/Tube).*

THEORETICAL BACKGROUND

The behaviour of steel beams under vertical loading depends primarily on:

• span length,
• moment of inertia of the cross-section,
• section modulus,
• support conditions,
• roof slope angle.

Beams with higher moments of inertia exhibit smaller deformations, while increasing the span significantly increases beam deflections.

I-sections provide a highly efficient strength-to-weight ratio due to their large moment of inertia in the principal bending direction. H-sections provide greater stability but also higher self-weight. Hollow sections exhibit improved torsional resistance but lower efficiency for large spans.

Truss systems utilise greater structural depth to reduce bending deformations and are therefore suitable for large-span structures.

RESULTS AND ANALYSIS

Horizontal Beams (0°)

For horizontal beams, the I-section provides the best performance among the solid profiles. The H-section exhibits larger deformations, particularly for shorter spans. Hollow sections become significantly less efficient as the span increases.

The constant-depth truss demonstrates the best overall performance in terms of deflections and deformations. For spans greater than 12 m, its deflections are 25–67% lower than those of the I-section.

Roof Slope of 5°

With the introduction of a 5° roof slope, the differences between the I and H sections become smaller. For larger spans, the H-section achieves almost identical results to the I-section.

The variable-depth truss becomes more efficient and shows smaller deformations than the solid profiles for spans greater than 20 m.

Roof Slope of 10°

At a roof slope of 10°, the variable-depth truss exhibits the poorest behaviour. Deflections become significantly larger than those of the I-section due to insufficient structural depth.

The constant-depth truss continues to provide the best overall performance.

Roof Slopes of 15° and 20°

At higher roof slopes, the variable-depth truss becomes considerably more efficient. For spans between 36 m and 44 m, its performance becomes equal to or better than that of the I-section.

The constant-depth truss remains the most efficient system in terms of deformation control, especially for large spans.

DISCUSSION

The results confirm that the selection of the beam type primarily depends on the span length and roof slope.

For small and medium spans, the I-section represents the most rational solution due to its low weight and favourable mechanical properties. The H-section may be applied when additional structural stability is required.

Hollow sections demonstrate acceptable behaviour for smaller spans; however, their efficiency decreases as the span increases.

For large spans, truss systems provide significantly better performance than solid sections. The constant-depth truss exhibits the smallest deformations in almost all analysed combinations. The variable-depth truss becomes justified only at higher roof slopes.

CONCLUSION

Based on the performed analysis, the following conclusions can be drawn:

1. The I-section represents the most efficient solid structural solution in the majority of analysed cases.
2. The H-section achieves performance similar to the I-section for large spans.
3. Hollow sections exhibit weaker performance as the span increases.
4. The constant-depth truss provides the smallest deformations and the best overall results for spans greater than 12 m.
5. The variable-depth truss strongly depends on roof slope and becomes efficient only at roof slopes of 15° and 20°.
6. For small spans, solid sections are more economical than truss systems.

The obtained results may serve as a basis for selecting optimal structural systems in the design of steel halls and large-span buildings.

REFERENCES

1. Timoshenko, S. P., & Gere, J. M. Theory of elastic stability. McGraw-Hill.
2. EN 1993-1-1: Eurocode 3 — Design of steel structures.
3. EN 10025-2: Structural steels.
4. SCI Steel building design — Blue book.
5. Tata Steel Europe — Structural hollow sections.
6. Radimpex software. Tower 8 User Manual.
7. SkyCiv Engineering. Truss vs beam: Structural comparison.
8. Shanmugasundaram, K. Parametric study on structural steel beams.
9. Sulayman, A. Comparative study between wide flange and cellular beams.
10. IRJET. Standardization of industrial steel roof truss sections.

KOMPARATIVNA STUDIJA ČELIČNIH GLAVNIH GREDA ZA RAZLIČITE RASPONE

SAŽETAK

Cilj ove studije je izvršiti komparativnu analizu čeličnih glavnih greda različitih poprečnih presjeka i rešetkastih sistema za različite raspone i nagibe krova. Analiza uključuje šest konstrukcijskih rješenja: I-profil, H-profil, pravokutni šuplji profil (☐), kružni šuplji profil (O), rešetka konstantne dubine i rešetka promjenjive dubine. Istraživanje je provedeno za raspone od 8 m do 44 m i nagibe krova od 0° do 20°, korištenjem softvera Tower 8 i konstrukcijskog čelika S235.

Rezultati su pokazali da je I-profil najefikasniji među punim profilima u gotovo svim analiziranim kombinacijama. H-profil postiže slične performanse za veće raspone, dok šuplji profili pokazuju slabije ponašanje s povećanjem raspona. Rešetke konstantne dubine pružaju najmanje otklone i deformacije za raspone veće od 12 m. Rešetke promjenjive dubine pokazuju snažnu ovisnost o nagibu krova i postaju efikasne tek pri većim uglovima nagiba.

Ključne riječi: čelična greda, poprečni presjek, rešetka, Tower 8, S235, nagib krova.

Correspondence to: Shinasi Zejneli
Faculty of Applied Sciences, Department of Concrete and Steel, State University of Tetovo – RNM, North Macedonia
E-mail: shinasi.zendeli@unite.edu.mk

EXTINGUISHING FIRES ON ELECTRIC VEHICLES

Aleksandar Majstorović[1], Mladen Todić[2], Tihomir Latinović[3]

1. Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina
2. Faculty of Mechanical Engineering, University of Banja Luka, Bosnia and Herzegovina
3. Faculty of Information Technology, University “VITEZ”, Bosnia and Herzegovina

ABSTRACT

We are witnessing a time in which the lack of energy sources (various types of fossil fuels) is felt, which is caused by irrational consumption, but also the impossibility of using and distributing crude oil or natural gas (as the leading energy sources) due to the consequences of war, which are felt in all types of industry, especially in the automotive industry. Naturally, in the last few years, this has affected the development and expansion of both passenger and cargo electric vehicles, which are primarily presented as more environmentally friendly and technologically advanced, compared to conventional vehicles. With the introduction of electric-powered vehicles into use, their shortcomings have started to manifest when compared to conventional vehicles both in terms of supplying electricity and in terms of fire protection, i.e., fire extinguishing.

Keywords: electric vehicles - classification, charging, deficiency, firefighting

INTRODUCTION

Due to the increasing environmental awareness and the “green focus,” which primarily aims to reduce pollution and improve air quality in large cities caused by exhaust emissions from motor vehicles worldwide, there is an idea for complete electrification of mobility (full adoption of electric cars) in the European Union. Additionally, there are plans to completely cease the production of gasoline and diesel engines by the end of 2035. Leading global passenger car manufacturers, such as the German automaker BMW, have announced the cessation of gasoline and diesel engine production at their central European facility based in Munich, starting as early as 2024. However, engine production will continue in facilities located in Austria and the United Kingdom. Recently, the Swedish automaker Volvo also joined this trend by completely discontinuing diesel engine production for passenger cars, which they had been producing continuously for 45 years. Volvo’s plan is to produce only electric vehicles by 2030. Meanwhile, the management of the world’s largest car manufacturer, Toyota, has announced that diesel engines will remain in use for several more years.

In the Netherlands, a significant problem has recently emerged due to the mass use and charging of electric vehicles during specific time periods (between 5 PM and 8 PM). This has led to frequent disruptions in the electricity supply to major cities (such as Utrecht, Rotterdam, Amsterdam, and The Hague) due to overloading of both low-voltage and high-voltage grids.

HISTORY OF ELECTRIC VEHICLES

The first electric vehicle, characterised by limited range and a speed of 12 km/h, appeared back in 1839 (credited to Robert Anderson). It used non-rechargeable primary energy cells. In 1861, Otto Nikolaus constructed the first internal combustion engine as an alternative to steam engines. By 1864, he began serial production of internal combustion engines ICE[11] [11]. Another notable electric vehicle was designed by our renowned inventor and scientist, Nikola Tesla, in 1931. He modified a standard Pierce-Arrow automobile by replacing its ICE with an electric motor. This vehicle operated based on wireless transmission of electrical energy and is believed to have reached a maximum speed of 144 km/h.

[1] Hereafter referred to as ICE

TYPES OF ELECTRIC VEHICLES

Electric vehicles can be categorised into four groups:

1. **Hybrid Electric Vehicle** (HEV[21]): HEVs have both an internal combustion engine (ICE) and an electric motor. The ICE is used for driving and charging the battery, while the electric motor reduces CO2 emissions or enhances ICE performance during driving. The HEV battery is not charged from an external power source; instead, it relies solely on regenerative braking to recover energy.

2. **Plug-In Hybrid Electric Vehicle** (PHEV[3]): PHEVs also have both an ICE and an electric motor, similar to HEVs. However, PHEVs offer two operating modes:

- **Pure electric mode**: In this mode, both the electric motor and battery provide energy to the vehicle.

- **Hybrid mode**: Both the ICE and electric motor are utilised.

This type of vehicle uses an ICE engine and an electric motor in a similar way as an HEV, the difference being that electric propulsion[4] is the main driving force. The ICE engine is used for driving and charging the battery, and is supplied with fuel from the tank, while the electric motor is used to reduce CO2 emissions or to increase the performance of the ICE engine while driving, and supplies electricity from the battery. The PHEV battery can be charged from an external power source and by recuperating the electrical energy obtained by deceleration or braking.

3. **Battery Electric Vehicle** (BEV[5]) – fully electric vehicles that are powered exclusively by an electric motor from a battery power source. The battery is charged from an external power source (electrical network), and its power is transferred to one or more electric motors of direct current or alternating current, which are characterised by high torque and at lower speeds. These vehicles have DC to AC converters, while the range of these vehicles depends solely on the battery capacity. By decelerating or braking, the electric motor/motors recover electrical energy, i.e., charge the battery.

4. Electric Vehicle With Fuel Cells (Fuel Cell Electric Vehicle, FCEV[6]; Fuel Cell Electric Vehicle, FCEV) - use “fuel cell technology” to produce electricity through a chemical reaction by combining hydrogen (from the vehicle’s tank) and oxygen (from the air), where electricity is generated to start the electric motor and water, which is discharged from the car through the exhaust pipes.

According to their configuration, electric vehicles, compared to vehicles with ICE engines, are much more flexible in terms of the simplicity of the mechanical systems because the electric motor is their only moving part, while the power supply is made possible by connecting batteries that can be placed in different places in the vehicle provided that there is an electrical connection between them, and due to the very nature of flexibility, different types of configuration are possible, for example: front- or rear-wheel drive, all-wheel drive, etc. [1, 2].

BATTERIES FOR ELECTRIC VEHICLES

The range of electric vehicles is determined by the capacity of the batteries, which depends on the vehicle’s load, terrain configuration, driving style, and power consumers. Several types of batteries are used in operation. Previously, lead-acid, NiCd, and NiMH (nickel-metal hydride) batteries were used, while lithium-based batteries such as LiS (lithium-sulphur), LiCoO2 (lithium-cobalt-oxide), LiMnO2 (lithium-polymer), and LiFePO4 (lithium-ion-phosphate) are used nowadays. Li-ion batteries have proven to be the best in practice due to their capacity and very good energy retention, characterised by a self-discharge of 1-5% per month (which is 15% less compared to NiMH batteries). However, their tendency to overheat is their main drawback.

The Chinese battery manufacturer for electric vehicles, BYD, has developed a new generation of LiFePO4 (lithium-ion-phosphate) batteries, which are smaller in size and weight. Compared to previous batteries of the same type, they are cheaper to produce, and the range of electric vehicles has increased to 1000 km.

Lithium (from Greek lithos - stone), chemical symbol Li, is the lightest of all known metals (alkaline metal), and due to its reactivity, it is not found in its elemental state in nature. It is stable in dry air at room temperature for a long time, slowly reacting to form lithium nitride[71], while in moist air, it oxidises very quickly, creating lithium hydroxide[8]. Like all alkaline metals, in contact with moisture on the skin, it can cause severe burns due to corrosion, which clearly indicates the dangers and harmfulness it can cause.

[2] Hereafter reffered to as HEV
[3] Hereafter reffered to as PHEV
[4] Propulsion (lat. propulsus – pushed forward) a device that takes over the power of a drive device (in this case an electric motor), [15]
[5] Hereafter referred to as BEV
[6] Hereafter referred to as FCEV

[7]a compound of lithium and nitrogen Li3N
[8]Hydroxides - compounds in which hydroxide anions are present, and bases or alkalis are aqueous solutions of hydroxides

FIRES IN ELECTRIC VEHICLES

In comparison to ICE vehicles, extinguishing fires in electric vehicles presents several types of dangers, such as toxic and explosive products (hydrogen fluoride, hydrogen chloride, hydrogen cyanide), thermal and light emissions from the combustion of lithium batteries, chemical reactions caused by water penetration into lithium battery casings, and the danger of high-voltage system shocks (ranging from 400 to 650 V depending on the manufacturer).

Fires in electric vehicles can occur due to:

- Cracking of lithium battery casings due to mechanical damage and short circuits caused by traffic accidents or mishaps.

- Charging batteries with too strong or too weak currents, leading to rapid heating of the batteries and their ignition.

- Discharging batteries with too strong currents, heating them up and leading to their ignition.

FIRE EXTINGUISHING TACTICS FOR ELECTRIC VEHICLES

When extinguishing fires, firefighters must use protective equipment (protective clothing, footwear and, insulating devices at a distance of 15 m from the vehicle). Since there is no adequate tactic for extinguishing this type of fire in our region, it is necessary to apply developed tactical models and approaches of French and American firefighters, which are based on two modes of extinguishment:

1. If the fire has not reached the electric batteries, an offensive attack is recommended, applying extinguishing tactics as for ICE vehicles.

2. If the fire has reached the electric batteries, a defensive attack is recommended.

PROCEDURES FOR EXTINGUISHING FIRES ON ELECTRIC VEHICLES

Considering that a fire in an electric vehicle can occur on the battery itself or can spread to the battery from the rest of the vehicle, and that batteries can react differently when burning or exposed to heat, firefighters are prescribed the following procedures:

• Extinguishing fires on electric vehicles with water does not pose a danger to firefighters;

• Inspection of the extinguished battery with a thermal imaging camera is necessary due to the possibility of reignition within a few hours to 24 hours;

• The burning of the battery is accompanied by the sound of rushing air, intense white smoke, sparking, and a constant flame;

• Batteries are located in an insulated housing, and it is impossible to reach the seat of the fire with extinguishing agents, which is why a large amount of water is needed for extinguishing (up to 15,000 litres), so a water supply must be planned;

• After extinguishing a fire on batteries, it is necessary to continue cooling them to prevent reignition;

• It is forbidden to remove the cover of the electric battery housing due to the possibility of high-voltage electric shock;

• During extinguishing, use the available equipment from fire vehicles;

• Electric and hybrid equipment does not require special extinguishing equipment.

FIRE EXTINGUISHING AGENTS FOR ELECTRIC VEHICLES

The primary agents for extinguishing fires are water, foam, and powder. In the case of electric vehicles, water is mainly used until the fire reaches the electric batteries, after which foam and powder are utilised.

In a deliberate fire caused for experimental purposes by DEKRA[91] on a Lithium-ion battery vehicle to test the effectiveness of extinguishing agents, the first signs of burning due to a short circuit and damage to the electric battery appeared after eight minutes. This was accompanied by visible deformations on the battery casing, release of toxic gases, the appearance of a bright flame (up to 2 metres long), and the spraying of a small amount of aluminium (within a 2-metre diameter), while the measured temperature on the electric battery was 750° C.

• **Water**: The effectiveness of water as an extinguishing agent for electric vehicle batteries during the initial extinguishing was proven within a 40-second interval, using approximately 70 litres of water. After 140 seconds, self-ignition occurred, consuming about 200 litres of water, with the extinguishing interval lasting 4 minutes. To completely extinguish the electric battery, approximately 500 litres of

[9] DEKRA - Deutsche Kraftfahrzeug-Überwachu-ngs-Verein e.V. (German Motor Vehicle Monitoring Association) was founded in 1925 in Berlin and is focused primarily on car safety. More recently, it has been engaged in the testing and certification of electric vehicles.

water were used over a 17-minute interval. After extinguishing, the electric battery was submerged in a water pool and continued to release smoke bubbles for the next three hours, indicating that due to water extinguishing, the electric battery began to reheat, leading to its reignition. It was found that it could reignite within 24 to 48 hours.

• **F-500**: An additive (not foam) that is added to water to reduce its surface tension for more efficient penetration into the pores of the combustible material. It is used as a fire extinguishing agent with a cooling effect, a wetting agent, and for controlling the release of hazardous liquids and gases, with possible dosages of 1%, 3%, and 6%. During the extinguishing of fires on electric vehicle batteries, its effective properties were demonstrated by rapidly removing heat, neutralising combustion and reducing flame intensity and evaporation, thereby increasing visibility. A specially designed nozzle (turbo nozzle with a self-mixer) set to a water flow of 75 litres and an additive dosage of 1% was used, with the flame disappearing after just 14 seconds and 15 litres of the mixture used. To completely extinguish the electric battery, approximately 80 litres of the mixture were consumed, and unlike water, the battery temperature did not rise during or after extinguishment.

• **Firesorb**: It is also an additive mixed with water when extinguishing fires on electric vehicle batteries, characterised by forming a gel that adheres to the combustible surface, rapidly removing heat, and significantly reducing the rate of water evaporation, thus decreasing its consumption. Water from a hydrant was used for extinguishing, with a Z2 mixer and an additive dosage of 1.8%, with the flame disappearing after just 6 seconds and 40 litres of the mixture used. To completely extinguish the electric battery, approximately 120 litres of the mixture were consumed, and like with F-500, the battery temperature did not increase during or after extinguishment.

FIRE SUPPRESSION EQUIPMENT FOR ELECTRIC VEHICLES

For extinguishing fires in electric vehicles, the usual firefighting equipment available to fire brigades can be used, but attention must be paid to the extinguishing agents. Recently, several models of fire suppression equipment specifically designed for electric vehicles have emerged, including:

1. **Fire Blanket** (VLITEX Fire Blanket): This fire blanket is designed to prevent the inflow of air, suppress flames, and contain toxic products until safe extinguishing begins or until the vehicle can be safely moved after fire suppression. The blanket's base is made of glass fibres coated on both sides with a layer of silicone. It is reusable and can withstand temperatures up to 1100° C for 50 hours. It can be used on all vehicle models, including off-road vehicles and motorcycles.

2. **Low-Pressure Water Mist System** (VLITEX SprayJet HV): This system consists of interconnected low-pressure nozzles. It efficiently generates a water mist to dissipate heat from the fuel material and cool it down. Additionally, it helps displace air from the combustion zone. The system is suitable for installation in hard-to-reach areas, such as underneath vehicles (for cooling electric vehicle batteries, braking systems, etc.) using an adiabatic process. It has proven to be highly effective in practice.

3. **Emergency Plug**: In critical situations, the emergency plug connects to the vehicle's charging socket and simulates the charging process. This automatically shifts the electric vehicle's transmission to the "P" position (activating the electric brake), preventing sudden movement. Integrated LEDs in the plug housing indicate whether the vehicle is deactivated.

CONCLUSION

Environmentally friendly, electric-powered vehicles (BEVs) do not produce harmful products from the operation of their engines, such as CO or CO_2, nor soot particles, nor do they make noise like ICE engines, and they do not make any sound when idle. Based on research, as well as experience from practice, it can be said that this type of vehicle does contribute to environmental pollution to some extent, given that the increase in their number in some European countries has also increased the production of electrical energy (operation of thermal power plants), while electricity produced from "renewable" energy sources for this type of vehicle is insufficient and negligible. Additionally, the movement of these vehicles, under the effect of friction, wears out the tires, as well as in vehicles with auto and diesel engines, which continues to pollute the environment with small rubber particles, since those in electric vehicles wear out faster due to greater mass and torque, compared to ICE engines.

Of course, when braking, electric vehicles, as well as vehicles with ICE engines, use the same braking systems, in which, due to the increase in friction during braking, brake linings made of plastics (Bakelite)[101] and asbestos[11] wear out, which pollutes the environment with microplastics. and asbestos fibres, pollutants that are very dangerous for health.

Chinese companies, under the slogan "Electricity is cheaper than oil", lowered the prices of the electric cars they produce in order to be as competitive as possible on the European market, which will put an additional burden on the power systems of the European Union countries [17]. Although electricity is a cheaper energy source than oil, electric vehicles are still more expensive than vehicles with ICE engines.

[10] Bakelite - a type of plastic with very wide application, is obtained from a crystalline mass of phenol and formaldehyde gas.
[11] Asbestos – natural fibrous mineral, resistant to high temperatures. Asbestos fibres are very dangerous for human and animal health, causing malignant diseases.

Some German political parties advocate an analysis that would prove the advantages, but also the disadvantages, of ceasing the production of ICE engines, noting that customers still have difficulty accepting electric cars and that the infrastructure for charging electric vehicles is inadequate, which resulted in a decline of electric car sales in Germany and influenced the reduction of the ambitious goals of the Mercedes manufacturer, [5].

Information comes from the Stellantis group that the mass of batteries in electric cars represents a significant obstacle in increasing environmental protection, and that in the next decade, efforts will be made to reduce the mass of batteries in electric cars by up to 50%. The very method of obtaining lithium for batteries, taking into account its extraction from the earth's crust, up to chemical processing and negative consequences during use, also contributes to the adverse effect on environmental protection [4]. Batteries for electric vehicles, as well as other types of electric batteries, lose their capacity over time or after a certain number of charging and discharging cycles, and their range and reliability in exploitation decrease, which indicates the need for their replacement. Bearing in mind the toxicity of lithium, as well as other components (electrolytes) that make up an electric battery, the methods and places of their proper disposal, as well as the possibility of recycling, must be seriously approached, which would avoid additional pollution of the environment that is already damaged by a large number of pollutants in our area.

Fires on electric vehicles, i.e., fire products caused by the burning of lithium batteries and insulation on the electrical installations of electrically powered vehicles are major pollutants, as extinguishing them also consumes large amounts of water that pours onto the surrounding terrain or into the storm water sewerage. Additionally, these fires should be approached carefully, knowing that the tactics for extinguishing this type of vehicle (if the electric battery is on fire) are different from the usual tactics for extinguishing vehicles with ICE engines.

Water, as the most widespread, cheapest, and most frequently used means of extinguishing fires, is not recommended as a means of extinguishing batteries on electric vehicles due to its interaction with lithium, resulting in increased burning intensity, but should only be used as a means of cooling (battery or other electronic vehicle components). For extinguishing fires on electric vehicle batteries, use water only with the addition of additives such as F-55 or Fire-sorb.

Special attention should be paid in accidental situations during technical interventions (traffic accidents or accidents) or fires in which at least one electric vehicle was involved, and emphasis should be placed on turning off the main switch (if possible) due to the interruption of the vehicle's supply of high-voltage electricity with additional securing of the vehicle with stabilisation blocks in order to avoid its sudden start.

Regular training of firefighters should indicate that they never touch, damage or cut the orange high-voltage cables, which are normally located in well-secured and protected parts of the vehicle, and that when intervening on this type of vehicle, they must wear protective equipment, including equipment for protection against electrical energy shocks. They should also be educated on electric vehicle firefighting and regularly informed about innovations on non-electric vehicles, as well as the method of application and effectiveness of both existing and new means of extinguishing fires on them. Unfortunately, many firefighting units in the territory of Republika Srpska and the Federation of Bosnia and Herzegovina are not in the financial capacity to purchase the above-mentioned and very effective means, but are forced to extinguish this type of fire with the most commonly used means - water.

REFERENCES

Books and scientific and professional sources:

1. D. Knezevic. (2023). Research on the experience and training of firefighters for intervention on electric and hybrid vehicles. Final paper, Karlovac University of applied Sciences. Karlovac.

2. M. Saric. (2020). Electric vehicle fire. Final paper. Karlovac University of applied Sciences. Karlovac.

3. M. Sipus. (2018). Extinguishing electric car fires. Firefighting and fire management. Zagreb.

Other sources:

4. https://autoblog.rs/blog/auto/vesti/2024/04/ 06/masa-baterija-u-automobilima-mora-biti-prepolo-vljena [Retrieved 7 April 2024].

5. https://www.b92.net/automobili/aktuelno/ 11 698/veleobrt-sada-bi-da-ukinu-zabranu-di-zelasa-i-be-nzinaca-u-eu/vest [Retrieved 7 April 2024].

6. https://autorepublika.com/2024/04/03/toy-ota-veruje-da-je-i-dalje-dug-zivot-pred-dizelmotorom/?fbclid=IwAR0gFe0OfcBkJlZW4XynXsn1KqCsOShFtvhc68MrMJIjViESb_pmkvLb9jY [Retrieved 6 April 2024].

7. https://hr.fluorined-chemical.com/fireexti-nguishing-agent/f-500-foam-fireextinguishing-agent.html [Retrieved 16 April 2024].
8. https://www.jutarnji.hr/autoklub/aktualno/ elektricna-mreza-na-rubu-kolapsa-ova-zemlja-eu-u-obz-ir-uzima-izbacivanje-elektricnih-auta-iz-gradova-15440928 [Retrieved 26 March 2024].
9. https://www.klprotektion.hr/proizvod/eme-rgency-plug-h1/ [Retrieved 17 April 2024].
10. https://revijahak.hr/2021/10/25/dolaze-el-ektricna-vozila-bmw-uskoro-prestaje-s-proi-zvodnjom-benzinskih-i-dizelskih-motora-u-glavnom-pogonu/ [Retrieved 26 March 2024].
11. https://smart-ri.hr/znate-li-da-je-prvo-ele-ktricno-vozilo-proizvedeno-prije-vise-od-100-godina/ [Retrieved 11 March 2024].
12. https://smartlife.mondo.rs/e-zivot/mobi-lnost/a53942/byd-blade-baterija-1000km-bez-punjenja.ht-ml [Retrieved 28 March 2024].
13. https://srpskainfo.com/kraj-jedne-ere-vo-lvo-dizel-otisao-u-istoriju-otkrijte-sta-ce-sve-djani-proi-zvoditi-u-narednih-6-godina/ [Retrieved 28 March 2024].
14. https://sr.wikipedia.org/wiki/Litijum, [Retrieved 9 April 2024].
15. https://tehnicki.lzmk.hr/clanak/propulzija-elektricna, [Retrieved 8 April 2024].
16. https://www.telegraf.rs/auto/auto-vesti/ 3364889-nikola-tesla-elektricni-automobil; [Retrieved 5 April 2024].
17. https://ubrzanje.telegraf.rs/nauka-i-privre-da/3865796-pojeftinili-kineski-elektricni-auto-mobili-a-prodaja-skocila-za-skoro-50-odsto-evo-cime-su-se-vodili, [Retrieved 4 April 2024].
18. https://www.vecernji.hr/barkod/stellantis-postao-cetvrta-auto-grupacija-na-svijetu-s-godisnjom-prodajom-vise-od-8-milijuna-vozila-1467833, [Retrieved 4 April 2024].
19. https://vlitex.fr/en/, [Retrieved 17 April 2024].

GAŠENJE POŽARA NA ELEKTRIČNIM VOZILIMA

SAŽETAK

Svjedoci smo vremena u kojem se osjeti nedostatak energenata (razne vrste fosilnih goriva) koji je prouzrokovan neracionalnom potrošnjom, ali i nemogućnosti korištenja i distribucije sirove nafte ili zemnog gasa (kao vodećih energenata) zbog posljedica ratnih dejstava koje se osjete u svim vidovima industrije, a naročito u autoindustriji. Naravno, ovo je u posljednjih nekoliko godina uticalo na razvoj i ekspanziju električnih vozila, kako putničkih tako i teretnih, koja su prezentovana prvenstveno kao ekološka i tehnološki naprednija u odnosu na konvencionalna vozila. Uvođenjem u upotrebu vozila na električni pogon, počeli su se ispoljavati i njihovi nedostaci u odnosu na konvencionalna vozila, kako u pogledu opskrbljivanja električnom energijom tako i u pogledu zaštite od požara, odnosno gašenja požara na istim.

Ključne riječi: električna vozila – podjela, punjenje, nedostaci, gašenje požara

Correspondence to: Aleksandar Majstorović
Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina
E-mail: aleksandar.majstorovic@eftfts.edu.ba

THE ADAPTIVE ENGINEER: AI TRANSFORMING GRADUATE IT EDUCATION FOR MASTER'S-LEVEL EXCELLENCE

Haris Berkovac[1], Edina Berkovac[2], Selver Grabus[3]

1. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina; BH Telecom, Sarajevo, Bosnia and Herzegovina
2. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina
3. Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina

ABSTRACT

Graduate studies in information technology (master's level) occupy a critical middle ground: students must bridge the gap between undergraduate fundamentals and cutting-edge industry practice, often while working part-time or changing careers. Traditional cohort-based, lecture-heavy models fail to accommodate diverse entry skill levels, accelerated industry demands, and the need for hands-on project portfolios. This article explores how artificial intelligence (AI) is fundamentally improving learning quality for IT graduate students through personalised adaptive learning pathways, intelligent code review and debugging assistants, AI-generated practice problems and case studies, and automated project feedback loops. Through a case study of a 12-month master's programme in cybersecurity and AI that deployed an AI-augmented learning platform, we demonstrate a 35% improvement in concept mastery, a 50% reduction in instructor grading time, and a 28% increase in job placement within 3 months of graduation. The article concludes with pro tips, key tools, and a roadmap for graduate programme directors seeking to embed AI responsibly into their curricula.

Keywords: AI, computer science education, automated content generation, personalised learning, higher education, AI ethics, master's, education

INTRODUCTION

The Master of Science in Information Technology (MSIT) and its specialised variants (Cybersecurity, Data Science, Cloud Computing, AI Engineering) are among the fastest-growing graduate degrees worldwide. Enrolment has increased by over 40% in the last five years as professionals seek to upskill or pivot into tech.

The Challenge of Heterogeneity: Entering graduate IT cohorts are wildly diverse. Some students come from rigorous computer science undergraduate programmes; others from bootcamps or non-technical fields (e.g., finance, biology). Some are full-time students; others are working professionals balancing evening classes.

The Quality Gap: Traditional graduate pedagogy - the 3-hour lecture, the midterm exam, the semester-long group project- was designed for a more homogeneous, full-time residential student body. It struggles with:

• Pacing mismatches: Advanced students are bored; struggling students are lost.

• Feedback delays: Students wait weeks for graded assignments, missing the learning window.

• Real-world relevance: Curricula lag behind industry tools (e.g., Kubernetes, LangChain, Snowflake) by 12–18 months.

The AI Solution: Artificial intelligence enables a shift from a one-size-fits-all model to a dynamic, personalised, competency-based model. For graduate IT students - who are digitally native and career-focused - AI tools act as an always-available tutor, code reviewer, project scaffolder, and career coach. This article demonstrates precisely how.

AI ENHANCING GRADUATE IT LEARNING

The Core Frictions in Graduate IT Education

Table 1: *The Core Frictions*

Friction Point	Manifestation in Graduate IT Programmes	Traditional Mitigation (Inadequate)
Skill heterogeneity	Some students have never used Git; others have industry CI/CD experience	Remedial bootcamp (week 0) – too generic
Feedback velocity	Assignment submitted Friday; grade returned Thursday (6 days later)	Teaching assistant office hours (undersubscribed)
Conceptual abstraction	Understanding distributed consensus (Paxos/Raft) from slides only	Textbook diagrams – static, non-interactive
Project scaffolding	"Build a full-stack app" – no guidance on architecture choices	Sample projects (copied, not learned)
Career relevance	Learning legacy frameworks while industry demands new ones	Occasional guest lectures (surface-level)

Core AI Capabilities for Graduate IT Learning

For master's-level IT students, AI is not about replacing the instructor but about unblocking the student continuously.

Adaptive Prerequisite Remediation

Before a course on "Applied Machine Learning," an AI system (e.g., a customised Moodle or Canvas plugin) assesses each student's Python, statistics, and linear algebra skills. It then generates personalised micro-modules:

• Student A (CS background): Skips Python review, gets advanced NumPy optimisation.

• Student B (career-changer): Gets interactive Python exercises with instant feedback.

• Result: The entire cohort arrives at Week 2 with the same foundational baseline.

Intelligent Code Review Assistant

Graduate IT courses heavily feature programming assignments. An AI-powered code reviewer (integrated into GitHub

Classroom or similar) provides instant, structured feedback:

• Correctness: "Your sorting algorithm fails on negative numbers."

• Efficiency: "This nested loop is $O(n^2)$. Could you use a hash map for $O(n)$?"

• Style: “Variable name ‘x’ is unclear; use ‘user_input’ instead.”

• Security: “You’re constructing SQL queries with string concatenation-risk of injection.”

Dynamic Problem Generation

Instead of a static problem set, an AI generates infinite practice problems at varying difficulty. For a course on “Network Security”:

• Easy: “Identify the vulnerability in this short firewall rule snippet.”

• Medium: “Given this PCAP file, describe the attack pattern.”

• Hard: “Design a detection rule for a novel zero-day exploiting CVE-2024-XXXX.”

Students cannot simply memorise answers; they must apply reasoning each time.

AI-Moderated Project Sprint Reviews

For semester-long team projects (e.g., “Build a CI/CD pipeline for a microservices app”), an AI agent integrated into Slack or Discord:

• Asks daily check-in questions: “What blockers did you encounter? Rate your progress 1-5.”

• Provides just-in-time resources: “You mentioned Docker networking issues. Here is a 5-minute tutorial on bridge vs. host mode.”

• Detects struggling teams: If a team reports low progress for three consecutive days, the AI alerts the instructor for human intervention.

Personalised Career-Skill Alignment

The AI analyses job descriptions from the student’s target roles (e.g., “Cloud Security Engineer” or “ML Ops”) and maps them to the graduate curriculum. It then recommends:

• Elective courses.

• Side projects to fill gaps.

• Specific AI-generated practice interviews.

Quantifying “Improved Quality” for Graduate IT

Diagram 1: *A Flowchart*

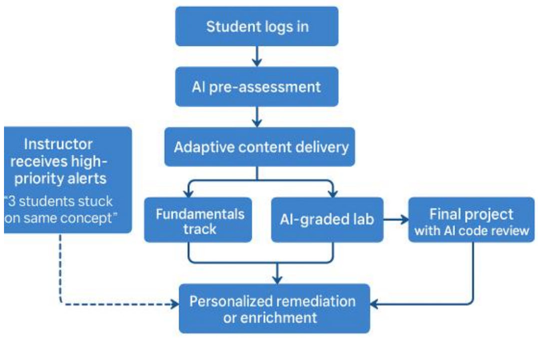


Table 2: *Quantifying “Improved Quality” for Graduate IT*

Dimension	Traditional Graduate Course	AI-Augmented Graduate Course
Concept mastery (post-test)	68% average	82% average
Time instructor spends on grading	15 hours/week (for 60 students)	4 hours/week (auto-grading + AI first-pass)
Student "stuck" duration	2.5 days (waiting for email reply)	15 minutes (AI chatbot or instant review)

Assignment plagiarism rate	12% (students share code)	2% (unique generated problems per student)
Job placement within 3 months	65%	85%

CASE STUDY: "MERIDIAN GRADUATE SCHOOL" – AI-FIRST MSIT PROGRAMME

Institution: A fictional private university with a 12-month, 36-credit Master of Science in Information Technology (concentrations in Cybersecurity, Cloud Computing, and AI Engineering).

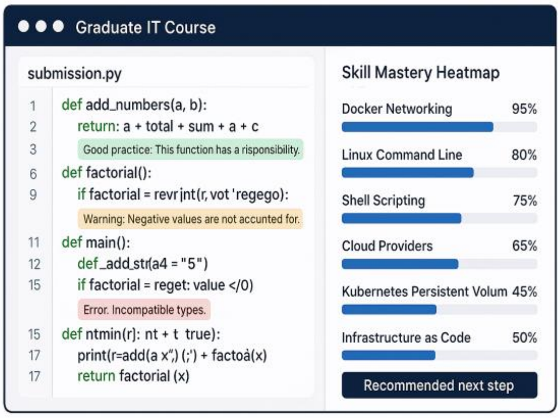
Enrolment: 180 students per cohort (60 per concentration).

Challenge: High heterogeneity (40% non-CS undergraduates), instructor burnout from grading, and a 68% job placement rate at graduation.

Table 3: *AI Implementation Over 12 Months*

Phase	Action	AI Tool Deployed	Measured Outcome
Pre-course (Week -2)	Adaptive skills assessment and remediation	Custom Canvas LTI + GPT-4 tutor	All students reached 80% baseline in Python, Git, SQL
Weekly (Core)	AI code review on all programming assignments	GitHub Copilot + CodeRabbit (automated PR comments)	90% of code feedback delivered within 5 minutes
Weekly (Theory)	Dynamic multiple-choice and short answer generation	Quizlet AI + Instructor-edited bank	Exam cheating attempts dropped by 85%
Project-based (Sprints)	AI project coach (Slack bot)	Custom LangChain agent + course content RAG	Instructor intervention needed only for 15% of teams (vs. 60% before)
Capstone (Final term)	AI resume and interview prep	Yoodli (speech AI) + VMock (resume AI)	Job placement at graduation: 82% (up from 68%)

Picture 1: *A Dashboard Screenshot From a Graduate IT Course*



BEYOND THE BOT: ADVANCED AI PEDAGOGIES AND ASSESSMENT INTEGRITY FOR GRADUATE IT

While the previous chapters established the core AI tools for personalised learning, code review, and career alignment, a deeper transformation is unfolding. This chapter explores three advanced dimensions of AI-augmented graduate education: AI-mediated collaborative learning, integrity-preserving assessment design, and the AI fluency curriculum-skills that graduate IT programmes must teach to remain relevant. We conclude with a strategic roadmap for programme-wide AI adoption and a frank discussion of risks.

AI-Mediated Collaborative Learning: From Group Work to Intelligent Teaming

Traditional group projects in graduate IT suffer from well-known pathologies: social loafing, uneven skill distribution, coordination overhead, and schedule conflicts. AI can restructure collaboration into something far more effective: intelligent teaming.

AI as Team Synthesiser

Instead of each team member working in silos, an AI agent (integrated into Slack, Discord, or Microsoft Teams) actively facilitates collaboration:

Table 4: *Collaboration*

Function	AI Action	Student Benefit
Meeting summarisation	Listens to 30-minute voice discussion (opt-in); generates bulleted summary with action items and owners	No one misses decisions; accountability is clear
Code conflict resolution	When two students push conflicting changes to a shared repo, AI suggests a merge strategy and highlights which lines conflict	Reduces debugging time by 60%
Idea clustering	AI ingests all team members' brainstorming notes and groups similar ideas, surfacing unique contributions	Ensures all voices are heard, even quiet members
Workload balancing	AI analyses commit history and Slack activity; flags if one member is doing 80% of the work	Instructor can intervene before resentment builds

Case Example - The Silent Contributor: In a graduate cloud computing course, a non-native English speaker rarely spoke in team meetings. The AI meeting summariser detected that her text chat contributions contained high-quality architectural insights. The AI flagged this to the instructor, who then restructured the team to assign her the role of "architecture document lead." Her engagement and team satisfaction both improved dramatically.

Cross-Team Intelligence Sharing

AI can anonymise and aggregate learnings across multiple project teams, creating a collective intelligence that benefits the entire cohort. How It Works: After each sprint, each team submits a 200-word "lessons learned" to an AI system. The AI:

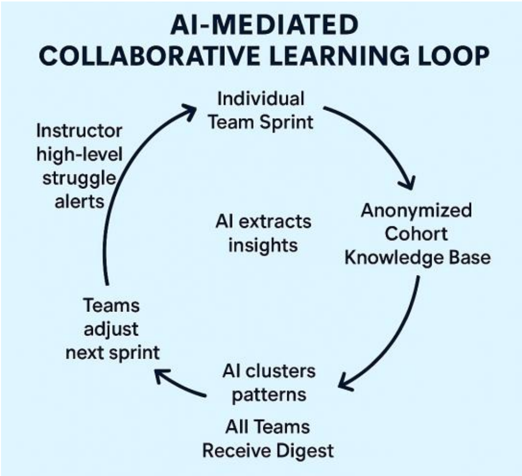
1. Extracts recurring patterns (e.g., "3 teams struggled with Docker volume mounting").

2. Anonymises the source.

3. Generates a "cohort insights" digest distributed to all teams.

Result: The instructor does not need to repeat the same explanation five times. Students learn from each other's mistakes at scale. The AI also identifies topics where the entire cohort is struggling, triggering a just-in-time mini-lecture.

Diagram 2: *AI-Mediated Collaborative Learning LoopCourse*



Integrity-Preserving Assessment Design: Beyond Plagiarism Detection

The rise of generative AI has created an existential panic in graduate education: "If ChatGPT can write the essay or solve the coding problem, what is the value of the degree?" The answer is not to ban AI (impossible) but to redesign assessment for the AI era.

The Shift from Product to Process

Traditional assessment evaluates the final artefact (code, paper, solution). AI can now generate that artefact trivially. The new paradigm evaluates the process - the student's journey of verification, critique, and iteration.

Table 5: *AI-Resilient Assignment Types:*

Assignment Type	Traditional Version	AI-Resilient Version	How AI Is Used Legitimately
Code assignment	"Implement quicksort"	"Fix the bugs in this AI-generated quicksort, then explain why each fix was needed"	Student critiques AI output
System design	"Design a URL shortener"	"You are given three AI-generated designs. Evaluate each against these five criteria. Defend your choice."	Student evaluates and compares

Literature review	"Summarise 10 papers"	"Run these 5 papers through an AI summariser. Identify two factual errors in the AI summary using citations from the original papers."	Student verifies AI output
Security analysis	"Find vulnerabilities in this code"	"You are an AI red team. Generate 5 prompts that would trick an LLM into revealing API keys. Then explain why each works."	Student generates adversarial inputs

The "AI Use Disclosure" as a Graded Deliverable

Rather than hiding AI use, graduate programmes should require explicit disclosure and reflection. A sample assignment component:

AI Use Statement (10% of grade): For each major deliverable, submit a 150-word section answering:

1. Which AI tools did you use (e.g., ChatGPT, Copilot, Claude)?

2. For which specific tasks (e.g., debugging, outlining, code generation)?

3. What did you change from the AI's output? Why?

4. What did you learn from the interaction that you would not have learned alone?

Outcome: Students become conscious rather than covert AI users. They develop metacognitive skills essential for professional life, where AI is a standard tool.

AI-Assisted Proctoring and Its Limits

Remote proctoring tools (Honorlock, Proctorio, Respondus) use AI to monitor eye movement, room sounds, and browser activity. Their effectiveness is debated, and they raise significant privacy concerns.

Table 6: *Balanced Recommendation for Graduate IT:*

Scenario	Proctoring Approach	Rationale
Low-stakes quiz (practice, 5% of grade)	No proctoring; open-AI but time-limited	Encourages learning, not policing
Moderate-stakes exam (20% of grade)	AI proctoring (optional; students can opt for in-person instead)	Balances integrity with flexibility
High-stakes final (40% of grade)	In-person, proctored, no devices (written or locked-down lab machines)	Preserves degree credibility
Capstone defence (100% of final project)	Oral examination (virtual or in-person) with faculty committee	Tests genuine understanding

The AI Fluency Curriculum: Teaching Graduate IT Students to Work With, Not Against, AI

Graduate IT students will enter workplaces where AI is ubiquitous. Yet most programmes currently teach AI only as a subject (e.g., machine learning) rather than as a tool for all subjects. Every graduate should exit with AI fluency - the ability to strategically deploy AI across the software development lifecycle.

A One-Credit "AI for Engineers" Module

Graduate programmes should integrate a compulsory, one-credit module (approximately 15 hours) into the first semester.

Outcome: After 8 weeks, every graduate student, regardless of specialisation, can leverage AI effectively, safely, and ethically.

Table 7: *Structure*

Week	Topic	Hands-On Activity
1	Prompt engineering patterns (zero-shot, few-shot, chain-of-thought)	Student writes prompts to solve 5 distinct coding problems
2	Retrieval-augmented generation (RAG) for technical Q&A	Student builds a RAG bot on a set of course PDFs
3	Code generation: strengths and blind spots	Student compares Copilot, ChatGPT, and Claude on the same task
4	Debugging with AI	Student gives an AI a buggy program; critiques the AI's diagnosis
5	AI for documentation and testing	Student uses AI to generate docstrings and unit tests
6	Security risks: prompt injection, data leakage, model poisoning	Student successfully executes a prompt injection on a test model
7	Ethics: bias, privacy, energy	Student calculates carbon footprint of training a small model
8	Final project: AI-augmented development workflow	Student documents their personal AI toolchain for a mini-project

Implementation Roadmap for Graduate Programme Directors

Moving from pilot to programme-wide AI integration requires strategic planning. Below is a prioritised roadmap.

Critical Success Factors:
• Faculty development, not mandate: Faculty who fear AI will resist. Provide stipends, release time, and peer mentoring.

• Student involvement: Create an "AI for Learning" student advisory board. They will surface misuse issues and effective practices **faster than** any monitoring tool.

• Transparency with employers: Publish a "Graduate AI Competencies" document to employers.

Picture 2: *Dashboard Screenshot*

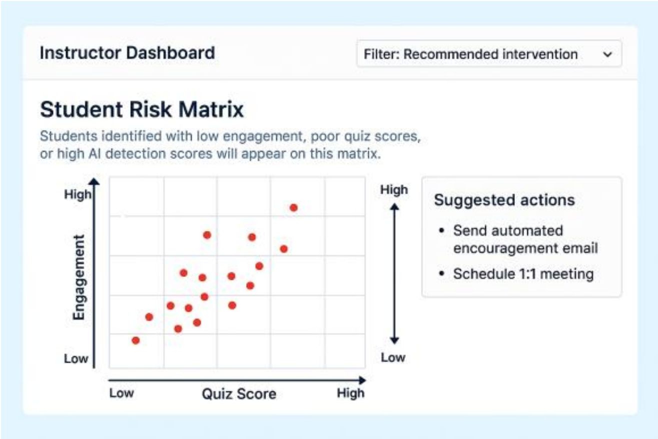
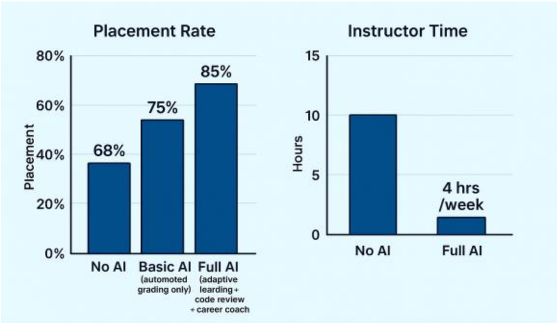


Table 8: *Traditional vs. AI-Augmented Graduate IT Course (Weekly Snapshot)*

Day	Traditional Course	AI-Augmented Course	AI Contribution
Monday	3-hour lecture (student attention drops after 30 min)	1-hour lecture (recorded) + 2 hours of interactive AI tutor exercises	AI identifies confusion points; adapts pacing
Tuesday	Students read textbook chapter	Students complete AI-generated practice set (unique per student)	Dynamic difficulty adjustment
Wednesday	TA office hours (2 hours, 10 students attend)	24/7 AI chat + TA office hours (attendance optional)	AI answers 80% of questions instantly
Thursday	Work on programming assignment (silent struggle)	Work on assignment + AI code reviewer gives instant feedback	Inline comments on each commit
Friday	Submit assignment (no feedback until next week)	Submit final; immediate auto-score + detailed rubric	Full grading done in < 5 minutes
Weekend	Students forget material	AI spaced-repetition flashcards (5 minutes/day)	Retention optimised

Picture 3: *A Bar Chart Comparing Three Cohorts*



THE DOUBLE DIVIDEND: BETTER STUDENT OUTCOMES AND LOWER CULTY LOAD

CONCLUSION

Graduate IT education stands at a pivotal moment. The demand for skilled professionals has never been higher, yet traditional programmes struggle with heterogeneity, feedback delays, and relevance gaps. Artificial intelligence offers a proven, scalable solution.

When deployed thoughtfully, AI does not devalue the graduate degree, it enhances it. Students receive personalised, instant feedback. Instructors are liberated from mechanical grading to focus on mentorship and design. Curricula become dynamic, shifting with industry needs. And graduates emerge not just with theoretical knowledge but with verified, granular competencies that employers trust.

REFERENCES

1. Awouda, A. (2024). Bloom's IoT taxonomy towards an effective industry 4.0 education.
2. Boustani, N., & Sidani, D. (2025). Leveraging ICT and generative AI in higher education for sustainable development: The case of a Lebanese private university.
3. Faccia, A., Ridon, M., et al. (2025). Advancements and challenges of generative AI in higher educational content creation. A technical perspective.
4. Mittal, U., Sai, S., & Chamola., V. (2024). A comprehensive review on generative AI for education.
5. Rashid, F., Duong-Trung, N., & Pinkwart, N. (2024). Generative AI in education: Technical foundations, applications, and challenges.
6. Shapiro, S. (2025). Exploring the impact of generative AI on education: Opportunities, challenges, and ethical considerations.
7. Veluru, C. (2024). The impact of generative AI on content curation and content advancements in education and training,
8. Vieriu, A., & Petrea, G. (2025). The impact of artificial intelligence (AI) on students' academic development.

SNALAŽLJIVI INŽENJER: KAKO UMJETNA INTELIGENCIJA TRANSFORMIŠE POSTDIPLOMSKO IT OBRAZOVANJE ZA IZVRSNOST NA MASTER NIVOU

SAŽETAK

Postdiplomski studij informacionih tehnologija (master nivo) zauzima kritičnu sredinu: studenti moraju premostiti jaz između osnova dodiplomskog studija i najsavremenije prakse u industriji, i to često dok rade honorarno ili mijenjaju karijeru. Tradicionalni modeli zasnovani na kohortama, preopterećeni predavanjima, ne uspijevaju da prilagode različite nivoe početnih vještina, ubrzane zahtjeve industrije i potrebu za praktičnim projektnim portfolijima. Ovaj rad istražuje kako umjetna inteligencija (AI) suštinski poboljšava kvalitet učenja za studente postdiplomskih studija IT-a kroz personalizovane prilagodljive puteve učenja, inteligentne asistente za pregled koda i otklanjanje grešaka, praktične probleme i studije slučaja generisane putem AI-a, te automatizovane petlje povratnih informacija projekta. Kroz studiju slučaja 12-mjesečnog master programa iz kibernetičke sigurnosti i AI-a koji je implementirao platformu za učenje proširenu putem AI-a, demonstriramo 35% poboljšanje u savladavanju koncepata, 50% smanjenje vremena ocjenjivanja instruktora i 28% povećanje zapošljavanja u roku od 3 mjeseca od diplomiranja. Članak se završava profesionalnim savjetima, ključnim alatima i planom za voditelje postdiplomskih programa koji žele odgovorno ugraditi AI u svoje nastavne planove i programe.

Ključne riječi: AI, informatičko obrazovanje, automatsko kreiranje sadržaja, personalizovano učenje, visoko obrazovanje, etika umjetne inteligencije, master, obrazovanje

Correspondence to: Haris Berkovac
Faculty of Technical Studies, University of Travnik, Travnik, Bosnia and Herzegovina; BH Telecom, Sarajevo, Bosnia and Herzegovina
E-mail: haris.berkovac@eftfts.edu.ba

APPLICATION OF UNMANNED AERIAL VEHICLES AND DIGITAL TOOLS IN DAMAGE ASSESSMENT AND CRISIS MANAGEMENT SUPPORT

Stjepan Draganić[1], Aleksandar Ljubljanović[2], Danijela Dežić[3], Vedran Gongeta[4]

1. Ministry of Internal Affairs, Department of Civil Protection, Vukovar, Republic of Croatia
2. Ministry of Internal Affairs, Department of Civil Protection, Osijek, Republic of Croatia
3. Ministry of Internal Affairs, Department of Civil Protection, Vukovar, Republic of Croatia
4. Ministry of Internal Affairs, Police Directorate, Vinkovci, Republic of Croatia

ABSTRACT

The paper presents the application of unmanned aerial vehicles (UAVs) and digital tools in assessing damage after a storm in the area of the Municipality of Bošnjaci, Vukovar-Srijem County, Republic of Croatia. The Civil Protection Directorate conducted aerial photography of the affected area the day after the storm and again twenty days later. Approximately 1,250 residential buildings were photographed using orthophoto techniques, while public buildings were documented using photogrammetry and 3D modelling.

The aim of the paper is to demonstrate the possibilities of using UAVs in rapid damage assessment, creating digital records and supporting decision-making during crisis management. The advantages of this approach are analysed through the data collection rate, increased operational personnel safety, documentation accuracy and the ability to compare the situation before and after rehabilitation. Emphasis is placed on the integration of geospatial data and digital technologies into the civil protection system for more efficient planning and coordination of activities in the field.

Keywords: unmanned aerial vehicles, orthophoto, 3D modelling

INTRODUCTION

Digital transformation has significantly changed the way in which crisis management, risk assessment, and the execution of protection and rescue activities have been carried out in recent years. The development of unmanned aerial vehicles (UAVs), geospatial technologies, digital records and tools based on artificial intelligence have enabled faster data collection, more precise analysis of the situation on the ground, and more efficient decision-making in emergency situations. The particular importance of such technology comes to the fore during natural disasters and major accidents when it is necessary to assess the extent of damage in a very short time, ensure the safety of operational forces, and coordinate a large number of participants in the civil protection system. Climate change, the increasing frequency of extreme weather events, and the growing complexity of crisis situations further emphasise the need to modernise the protection and rescue system. In such circumstances, traditional damage assessment methods are often insufficient due to the slow data collection rate, limited terrain availability and increased risk for operational personnel. This is precisely why modern civil protection systems are increasingly using digital technologies that enable the rapid processing of large amounts of data, the creation of orthophoto images, 3D models, and digital databases for the needs of crisis management. An example of such an approach was recorded after the storm and hailstorm that hit the area of the Municipality of Bošnjaci in the Vukovar-Srijem County, Republic of Croatia, on 1 July 2024. The disaster caused extensive damage to residential and commercial buildings, infrastructure and agricultural areas, and required the urgent activation of the civil protection system and the coordinated action of numerous operational forces. Immediately after the event, aerial photography of the affected area was carried out using unmanned aerial vehicles, during which orthophoto images and 3D models of the buildings were created for precise damage assessment and rehabilitation planning. The Civil Protection Directorate conducted a systematic digital recording of the situation on the ground, including the recording of approximately 1,250 residential buildings, while public buildings were documented with photogrammetry and 3D models. The obtained data enabled a comparison of the situation immediately after the storm and during the rehabilitation process, which significantly improved the coordination of the activities carried out by the operational forces, the assessment of priorities, and the transparency of the reconstruction process. In addition to the technical aspect, the application of digital tools and UAVs has also played an important role in the field of safety and health at work. The use of aerial photography has reduced the need for operational personnel to be exposed to dangerous and difficult-to-reach areas, especially during inspections of damaged roofs, infrastructure, and the power grid. In this way, digital technologies have contributed to reducing the risk of injury, faster hazard assessment, and more efficient planning of protective measures in the field. The aim of this paper is to present the possibilities of using unmanned aerial vehicles, digital records, and modern analytical tools in damage assessment and support for crisis management after natural disasters. Special emphasis is placed on the integration of geospatial data, digital documentation and the possibilities of applying artificial intelligence in data processing in order to increase the efficiency of the civil protection system, the safety of operational personnel, and the improvement of the decision-making process in crisis situations. The paper is based on experiences and activities carried out during the recovery from the consequences of a storm in the area of the Municipality of Bošnjaci, Vukovar-Srijem County, Republic of Croatia, and presents concrete examples of the use of UAV technology, orthophotography, 3D modelling, and digital data analysis as part of a modern approach to managing crisis events in the digital age.

EQUIPMENT USED IN THE INTERVENTION

Drone DJI Matrice 300 RTK Technical Characteristics

The DJI Matrice 300 RTK is a professional drone designed for civil protection operations, infrastructure inspections, search and rescue, and crisis management. The main technical characteristics include:

-Maximum flight time: up to 55 minutes
-Maximum range of signal transmission: up to 15 km
-Maximum flight speed: approximately 82 km/h
-Weather resistance: IP45 protection against rain and dust
- Operating temperature: from -20 °C to +50 °C
- Maximum flight height: 7000 m
- Positioning system: RTK (Real Time Kinematic) for high precision navigation and mapping
- Six-fold sensor system for avoiding obstacles (vision + infrared sensors)
- Ability to carry multiple payloads at the same time
- Redundant control and power systems to increase flight safety
- AI functions for automatic object tracking and mission planning

Camera Zenmuse H20T

DJI Zenmuse H20T is a multi-sensor camera developed for security, civil protection, and technical inspection operations.
The system includes:
- 20 MP zoom camera
- 23× optical zoom
- 200× maximum hybrid zoom
- 12 MP wide-angle camera
- Radiometric thermal camera with a resolution of 640 × 512 px
- Laser rangefinder with a range of up to 1200 m
Key capabilities:
- detection of thermal anomalies,
- inspection of damaged facilities,
- search for people,
- night operations,
- precise marking of locations,
- documentation of damage from the air.
The thermal camera is particularly useful during:
- fires,
- technical interventions,
-inspection of electrical infrastructure,
- search and rescue,
- assessment of building safety after disasters.

Control and Transmission System

The DJI Matrice 300 RTK uses the advanced DJI OcuSync Enterprise data transmission system.
System features:
- three-channel 1080p real-time video transmission,
- automatic switching between 2.4 GHz and 5.8 GHz frequencies,
- AES-256 data transfer encryption,
- ability to work with two control stations,
- support for controlling multiple cameras simultaneously,
- integration with GIS and cartographic systems.
The control station enables:
- autonomous mission planning,
- RTK navigation,
- telemetry data display,
- sensor and camera management,
-automatic mapping and photogrammetry.

Operational Capabilities

The DJI Matrice 300 RTK system, equipped with the Zenmuse H20T camera, enables a wide range of operational activities in the fields of civil protection and crisis management:
-rapid reconnaissance of affected areas,
-damage assessment following natural disasters,
-creation of orthophotos,
-3D modelling of structures and terrain,
-thermal inspection of infrastructure,
-search and rescue operations,
-monitoring of post-disaster recovery efforts,
-surveillance of fire sites and critical infrastructure,
-support for decision-making in crisis situations,
-reduction of operational personnel exposure to hazardous areas.
In civil protection operations, the system enables:
-faster data collection,
-more precise damage recording,
-improved coordination of operational forces,
-safer fieldwork,
-digital archiving and comparison of conditions before and after recovery.

DIGITAL TOOLS USED TO PROCESS IMAGES

Agisoft Metashape Professional – A Program for Processing Orthophoto Images and Creating 3D Models

Digital technologies have played an increasingly important role in the civil protection system in recent years, especially in the field of damage assessment, creating digital records, and supporting crisis management. After natural disasters and major accidents, it is necessary to collect accurate data on the situation on the ground in a very short time, assess the extent of the damage, and enable effective coordination of operational forces. In such situations, photogrammetric programs for processing aerial images and creating three-dimensional spatial models play an important role. Agisoft Metashape Professional is a professional software for processing digital photos and creating orthophoto maps, point clouds, and 3D models of objects and terrain. The program allows processing a large number of photos taken from the air and their automatic linking and georeferencing. Based on overlapping photos, the software generates precise geospatial data that can be used for damage assessment, rehabilitation planning, and analysis of the situation on the ground. The data processing process begins with loading the photos and their automatic alignment. The program recognises common points in the photos and determines the position of the cameras and the basic geometry of the scene. After that, a dense point cloud is generated, which represents a detailed three-dimensional view of the objects and terrain. Based on the point cloud, a 3D model with high-resolution textures is created, as well as orthophoto images that enable precise measurements and damage analysis. The special value of the program is reflected in the ability to create geometrically corrected orthophoto images of high precision. Such images enable the measurement of areas, distances and volumes and the precise recording of damage to objects and infrastructure. The obtained data can be integrated into GIS systems and used for operational planning, the creation of situational views, and keeping digital records during crisis situations. The application of the program is particularly important during natural disasters, such as storms, floods, fires, and earthquakes, when it is necessary to quickly collect and precisely process a large amount of data from difficult-to-reach areas. In the case of the storm that hit the Bošnjaci Municipality in Vukovar-Srijem County, Republic of Croatia, on 1 July 2024, a systematic aerial survey of the affected area was carried out to assess the damage and monitor the rehabilitation of the consequences. The obtained data were processed in the Agisoft Metashape Professional program and were used to create orthophoto images and 3D models of damaged objects. Digital processing enabled precise recording of damage to residential and public buildings, comparison of the state before and after rehabilitation, and better coordination of operational activities in the field. In this way, the process of damage assessment and decision-making was significantly accelerated, while at the same time, the safety of operational personnel was increased because the need for direct access to dangerous and unstable objects was reduced. The program also enables long-term storage of digital data, which is important for the needs of documenting events, analysing the effectiveness of rehabilitation, and planning future preventive measures. The integration of photogrammetry, orthophoto technology, and 3D modelling represents an important step towards the modernisation of the civil protection system and more efficient crisis management in the digital age. The application of Agisoft Metashape Professional shows how modern digital tools can significantly improve damage assessment, information management, and coordination of operational forces during emergency events. Such an approach enables faster, safer and more precise decision-making and contributes to the development of a modern and technologically advanced protection and rescue system.

Basic Functions of the Program

Agisoft Metashape Professional enables:
-creation of high-resolution orthophoto maps,
- generation of 3D models of objects and terrain,
- creation of a digital surface model (DSM),
- creation of a digital terrain model (DTM),
- georeferencing of data using GPS/RTK coordinates,
- measurement of distances, areas, and volumes,
- classification of point clouds,
- export of data to GIS and CAD systems.

APPLICATION OF UAV IN RECORDING THE AFFECTED AREA AFTER A STORM

The day after a strong storm hit the area of the Municipality of Bošnjaci, aerial recording activities using unmanned aerial vehicles (UAV systems) were carried out with the aim of quickly assessing the damage, collecting spatial data, and supporting crisis management. The activities were carried out by the State Civil Protection Intervention Unit Osijek in cooperation with the local field coordinator (head of the Vukovar Civil Protection Service), who provided logistical and operational support during the implementation of the task.

Two operators of the State Civil Protection Intervention Unit Osijek were sent to the field with two unmanned systems, with the work organisation adjusted to the size and complexity of the affected area. In order to more efficiently perform aerial photography, the area of the Municipality of Bošnjaci was divided into six sectors, and the flight altitude was determined. Two operational teams were formed that operated in parallel, with each team responsible for photographing pre-defined sectors. This method of work enabled a significant reduction in the time required for data collection and better coordination of activities in the field. Logistics preparation was of particular importance in the implementation of the activities. The vehicle in which the operators arrived in the field was equipped with a gasoline generator, which enabled continuous power supply of the equipment with electricity. This ensured the conditions for continuous operation of unmanned systems, battery charging, and data processing in the field without the need for interruptions or additional equipment relocation. Such self-sufficiency of the operational team proved to be extremely important in conditions when part of the infrastructure in the affected area was damaged or out of function.
During the operation, special attention was paid to public facilities. 3D models were created for municipal buildings, a school, a kindergarten, a museum, a church, a cemetery, and other important infrastructure using the photogrammetry method. Based on a large number of overlapping photographs, three-dimensional models of the facilities and the surrounding area were created, which enabled a detailed overview of the degree of damage, structural stability and accessibility of the locations. Such models represent an important tool for further damage analysis, rehabilitation planning and documentation of the consequences of the disaster. The remaining part of the settlement was photographed using the orthophoto technique. The orthophoto images enabled the creation of precise, high-resolution georeferenced images of the area, on which damage to roofs, roads, economic buildings, and vegetation is clearly visible. The obtained data was used to quickly assess the extent of the damage and create situational images necessary for the civil protection headquarters and other operational services involved in the rehabilitation of the damage caused by the storm.
The total duration of the aerial photography operation was approximately four hours. In a relatively short time, a large amount of spatial data was collected, which enabled a detailed overview of the affected area without the need for a long tour of the field. The use of UAVs has proven to be extremely effective in situations of natural disasters because it allows for rapid data collection, increases the safety of operational forces, and provides a quality basis for decision-making during crisis management. This intervention confirms that the use of unmanned aerial vehicles, with good organisation of operational teams and appropriate logistical support, is an important tool of the modern civil protection system in assessing damage and managing the consequences of natural disasters. After 20 days of rehabilitation to eliminate the consequences of the hailstorm, the terrain was re-recorded in same way as it was recorded the first time so that the recordings could be compared with the initial state. The recordings were handed over to the municipality for use and are a permanent and indelible trace of the complex event.

Orthophoto and 3D Modelling

After conducting UAV imaging of the affected area, orthophoto images and 3D models of the settlement were created using specialised digital tools for spatial data processing. Orthophoto images enabled a precise overview of all objects and surfaces from the air with the possibility of detailed recording of damage to roofs, commercial buildings, roads, and agricultural areas. At the same time, 3D models were created for public facilities, which enabled a more detailed analysis of the damage and planning of rehabilitation activities. The obtained spatial data represented an important support for civil protection headquarters, local government units, and expert services during damage assessment and decision-making. The application of orthophoto and 3D technology significantly accelerated the process of data collection, increased the accuracy of damage assessment, and ensured a quality documentation basis for reporting, reconstruction planning, and monitoring the progress of rehabilitation in the field.

DATA PROCESSING AND ANALYSIS

After completing the field imaging with unmanned aerial vehicles, the collected photographs were processed in the Agisoft Metashape Professional program, one of the leading tools for photogrammetric spatial data processing. The program enables the automatic connection of a large number of recordings and the creation of precise high-resolution digital models of the space.

During data processing, the first step is to align and georeference the photos using GPS/RTK coordinates, ensuring the spatial accuracy of the results. Based on the processed images, orthophoto maps, digital surface models (DSM), digital terrain models (DTM) and three-dimensional models of objects and areas affected by storms are created. The products thus obtained allow for a detailed overview of damage to buildings, transport infrastructure, agricultural areas, and other spatial elements. An additional advantage of the system is the ability to precisely measure distances, areas, and volumes, as well as classify point clouds for easier separation of individual objects or types of damage. The final data can be exported to GIS and CAD systems, making them available to civil protection headquarters, local government units, and expert services for further analysis, damage assessment, rehabilitation planning, and decision-making during crisis management. The use of such digital tools significantly increases the speed, accuracy, and efficiency of the damage assessment process compared to classic field visit methods.

CONCLUSION

The storm accompanied by hail that hit the Municipality of Bošnjaci on 1 July 2024, posed an extremely demanding challenge for the civil protection system and required rapid data collection, damage assessment, and coordination of a large number of operational forces. In such circumstances, the use of unmanned aerial vehicles (UAVs) and digital tools has proven to be an effective solution that significantly improves the processes of crisis management and assessment of the consequences of natural disasters. The conducted UAV imaging enabled systematic and comprehensive documentation of the affected area in a very short time. The division of the settlement into six sectors and the engagement of two UAV teams of the State Intervention Unit of Civil Protection Osijek enabled the imaging of the entire area of the municipality in approximately four hours. The collected data was processed in the Agisoft Metashape Professional program, where high-resolution orthophoto maps, digital surface models, and three-dimensional representations of public buildings were created. Such products enabled a detailed overview of damage to residential and commercial buildings, infrastructure, and public buildings, and provided a quality basis for making operational decisions. The special value of the application of UAV technology is reflected in the ability to quickly collect large amounts of spatial data with significantly less human resource involvement. While the classic damage assessment required the engagement of 75 civil engineers and 20 municipal employees over eight working days to assess damage to residential buildings, with an additional sixteen days to record damage to commercial buildings, agricultural land, and movable property, UAV enabled obtaining a complete overview of the situation during the first day after the disaster itself. This resulted in significant savings in time, human capacity and organisational resources, and reduced the impact of subjective assessment present in traditional methods of assessing damage. From the aspect of occupational safety, the use of unmanned aerial vehicles represents an important contribution to the safety of operational personnel. Instead of entering potentially dangerous areas with damaged buildings, unstable structures, or compromised infrastructure, the assessment of the situation can be carried out remotely, thereby reducing the exposure of workers to risks and increasing the overall safety of intervention activities. This approach is in line with modern principles of risk management and occupational health protection, which emphasise the application of technologies to reduce direct exposure to hazards. The resulting digital products have proven to be extremely useful for the work of civil protection headquarters at all levels of management. Orthophoto images and 3D models have enabled a more precise assessment of priorities, more efficient planning of remediation activities, better allocation of resources and better quality communication between local governments, operational forces, and state institutions. An additional advantage is the possibility of permanent data archiving, their subsequent analysis and comparison of the situation before and after the implementation of remediation measures, which creates a valuable knowledge base for future interventions and assessments. The results of the presented case study confirm that the integration of UAVs, photogrammetric methods and geospatial information systems represents a significant step towards the digital transformation of the civil protection system. Such an approach increases operational efficiency, shortens reaction time, improves the quality of damage assessment, and contributes to safer work of all intervention participants. At the same time, it enables the creation of reliable spatial databases that can serve the needs of planning, prevention, education, and development of local communities' resilience to future disasters. Based on the executed activities, it can be concluded that unmanned aerial vehicles and digital tools no longer represent only technological support for classical work methods, but are becoming one of the key elements of the modern disaster management system. Their further integration into the operational procedures of the civil protection of the Republic of Croatia, along with continuous training of operators and the development of standardised application methodologies, represents an important direction for the future development of the protection and rescue system and increasing the safety of the population and operational forces in emergency situations.

REFERENCES

1. Agisoft. (2024). Metashape Professional User Manual. Agisoft LLC.
2. DJI. (2024). Matrix 300 RTK User Manual. DJI Technology Co., Ltd.
3. DJI. (2024). Zenmuse H20 Series User Guide. DJI Technology Co., Ltd.
4. European Union Aviation Safety Agency (EASA). (2019). Commission Implementing Regulation (EU) 2019/947 on the rules and procedures for the operation of unmanned aircraft.
5. European Union Aviation Safety Agency (EASA). (2019). Commission Delegated Regulation (EU) 2019/945 on unmanned aircraft systems.
6. Federal Emergency Management Agency (FEMA). (2021). Damage Assessment Operations Manual.
7. International Civil Aviation Organization (ICAO). (2023). Manual on Remotely Piloted Aircraft Systems (RPAS).
8. International Federation of Red Cross and Red Crescent Societies (IFRC). (2022). World Disasters Report 2022.
9. ISO. (2018). ISO 45001: Occupational Health and Safety Management Systems.
10. OECD. (2023). Building Resilient Infrastructure for the Future.
11. United Nations Office for Disaster Risk Reduction (UNDRR). (2023). Global Assessment Report on Disaster Risk Reduction 2023.
12. Law on Civil Protection System. Official Gazette 82/15, 118/18, 31/20, 20/21 and 114/22.
13. Law on Mitigation and Elimination of the Consequences of Natural Disasters. Official Gazette 16/19.
14. Instructions on how to operate and use unmanned aerial vehicles within the Directorate of Civil Protection (Ministry of Internal Affairs of the Republic of Croatia, RCZ, January 2023).

PRIMJENA BESPILOTNIH LETJELICA I DIGITALNIH ALATA U PROCJENI ŠTETA I PODRŠCI KRIZNOM UPRAVLJANJU

SAŽETAK

Rad prikazuje primjenu bespilotnih letjelica (UAV) i digitalnih alata u procjeni šteta nakon olujnog nevremena na području Općine Bošnjaci, Vukovarsko-srijemske županije, Republika Hrvatska. Ravnateljstvo civilne zaštite provelo je zračno snimanje pogođenog područja dan nakon nevremena te ponovno nakon dvadeset dana. Ortofoto tehnikom snimljeno je približno 1250 stambenih objekata, dok su javni objekti dokumentovani korištenjem fotogrametrije i 3D modeliranja.

Cilj rada je prikazati mogućnosti primjene UAV-a u brzoj procjeni šteta, izradi digitalnih evidencija i podršci donošenju odluka tokom kriznog upravljanja. Analiziraju se prednosti ovakvog pristupa kroz brzinu prikupljanja podataka, povećanu sigurnost operativnog osoblja, preciznost dokumentovanja te mogućnost poređenja stanja prije i nakon sanacije. Naglasak je stavljen na integraciju geoprostornih podataka i digitalnih tehnologija u sistem civilne zaštite radi učinkovitijeg planiranja i koordinacije aktivnosti na terenu.

Ključne riječi: bespilotne letjelice, ortofoto, 3D modeliranje

Correspondence to: Stjepan Draganić
Ministry of Internal Affairs, Department of Civil Protection, Vukovar, Republic of Croatia
E-mail: sdraganic2@mup.hr

FIREFIGHTING INTERVENTIONS IN FIRES INVOLVING PHOTOVOLTAIC SYSTEMS AND BUILDINGS WITH SOLAR PANELS

Muharem Čupina

1. Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina

ABSTRACT

The development and increasing use of photovoltaic systems on residential, public and industrial buildings create new challenges in the field of fire protection and firefighting interventions. The aim of this paper is to analyse the specific characteristics of fires involving buildings equipped with solar panels, identify the main risks faced by firefighters during interventions, and present basic safety procedures and preventive measures that contribute to more efficient and safer fire suppression. The purpose of the paper is to emphasise the importance of professional firefighter training and proper design of photovoltaic systems in order to reduce the risk of fire occurrence and spread. The paper will use a review and analysis of available scientific and professional literature. The literature analysis shows that fires in photovoltaic systems most commonly occur due to electrical faults, improper installations, inadequate maintenance, and arc faults. Fires involving buildings equipped with solar panels require a specific approach by firefighting units due to particular electrical and structural risks.

Keywords: photovoltaic systems, fire, firefighting interventions, solar panels, fire protection

INTRODUCTION

The use of renewable energy sources has experienced significant growth worldwide in recent years, with photovoltaic (PV) systems occupying a particularly important position among them. The development of solar technology has enabled the widespread installation of solar panels on residential, commercial, industrial, and public buildings. In addition to numerous benefits, such as reducing greenhouse gas emissions and improving energy efficiency, the increasing number of installed photovoltaic systems has introduced new challenges in the field of fire protection and firefighter safety.

Fires involving buildings equipped with solar panels differ from conventional fires due to the presence of electrical energy generated by photovoltaic modules as long as they are exposed to sunlight. As a result, certain parts of the system may remain energised even after the main power supply of the building has been disconnected, increasing the risk of electric shock during firefighting operations (Piantedosi et al., 2016). Such circumstances require a specialised approach by fire departments and the implementation of specific safety procedures.

In Bosnia and Herzegovina, the solar energy sector has experienced rapid development in recent years. An increasing number of households and businesses are investing in photovoltaic systems, which raises the likelihood that firefighters will encounter buildings equipped with solar panels during emergency interventions.

RESEARCH PROBLEM AND OBJECTIVE

The research problem addressed in this paper concerns the specific hazards that arise during firefighting operations involving buildings equipped with photovoltaic systems. Unlike conventional electrical installations, solar panels represent a continuous source of electrical energy during daylight hours, which may endanger firefighter safety and complicate firefighting activities.

The aim of this paper is to analyse the most common causes of fires in photovoltaic systems, identify the risks faced by firefighters during interventions, and present recommended protective measures and safety procedures. A particular objective is to emphasise the importance of firefighter training and the application of modern technical solutions to reduce the risk of injuries and material losses.

RESEARCH METHODOLOGY

This study applies a literature review and analysis methodology focusing on scientific and professional publications related to photovoltaic system fires and firefighter safety. International reports, firefighter training manuals, scientific articles, and technical guidelines issued by relevant fire protection organisations were analysed.

Special attention was given to documents published by the International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS), research concerning the safety of building-integrated photovoltaic systems, and professional guidelines intended for fire services. Through content analysis, the most common causes of fires, characteristic intervention risks, and recommended preventive measures were identified.

RESULTS AND DISCUSSION

The analysis of available scientific and professional literature indicates that photovoltaic systems, although considered a reliable and environmentally friendly source of energy, introduce specific fire safety challenges that may influence both fire occurrence and firefighting operations. The reviewed studies show that most fires associated with photovoltaic systems are not caused by the solar panels themselves but rather by electrical failures, improper installation practices, inadequate maintenance, and damage to electrical components.

Causes of Fires in Photovoltaic Systems

According to Romosios, Vasilikou, and Choulakis (2018), the most common causes of fires in photovoltaic systems are faulty electrical connections, poorly executed installations, inverter malfunctions, and electrical arc faults. Arc faults represent one of the most dangerous phenomena in photovoltaic systems because they generate extremely high temperatures that can reach several thousand degrees Celsius, which is sufficient to ignite surrounding combustible materials. Buildings where solar panels are installed on roofs constructed from combustible materials or equipped with heat-sensitive insulation are particularly vulnerable.

Zamrazilova (2024) points out that an additional challenge is posed by Building Integrated Photovoltaic (BIPV) systems, where photovoltaic modules simultaneously function as building components and electricity generators. In the event of a fire, such systems may accelerate fire spread through roof and façade structures, thereby increasing risks to building occupants and emergency responders.

Research further indicates that improper system installation significantly increases the likelihood of fire occurrence. Poorly executed electrical connections, low-quality connectors, damaged cables, and inadequate surge protection are among the most common technical deficiencies leading to overheating and fire development. Meacham et al. (2012) emphasise that the growing number of photovoltaic installations requires continuous improvement of fire safety standards in order to reduce the risk of incidents.

Risks to Firefighters During Interventions

The reviewed literature confirms that fires involving photovoltaic systems present unique challenges for firefighting units. The primary hazard arises from the fact that solar panels continue generating electricity whenever exposed to sunlight. Unlike conventional electrical installations, where disconnecting the power supply eliminates the risk of electric shock, components of photovoltaic systems may remain energised even after the building's main power switch has been turned off.

According to the IEA-PVPS report (Namikawa, 2017), the most significant risks to firefighters include electric shock, arc flash incidents, falls from rooftops, restricted movement on buildings, and structural collapse caused by fire damage. A particular challenge is that solar panels are often installed on rooftops, where they may obstruct firefighter access and complicate roof ventilation procedures.

An additional hazard is the high direct current (DC) voltage generated by photovoltaic systems. According to firefighter safety guidelines, some systems can produce up to 1,500 V DC, representing a serious threat to the life and health of emergency responders. Even when current levels are limited, such voltages can result in severe injuries or fatalities due to electric shock.

Piantedosi et al. (2016) emphasise that special attention should be given to cables and connection points between photovoltaic modules, as these locations are most susceptible to damage and arc fault occurrence. During firefighting operations, all conductors should be assumed to be energised until proven otherwise.

In addition to electrical hazards, firefighters are exposed to chemical risks. During the combustion of photovoltaic modules, harmful substances may be released, posing potential respiratory hazards. Therefore, international guidelines recommend the mandatory use of a self-contained breathing apparatus (SCBA) during interventions involving solar panel installations.

Safety Procedures and Preventive Measures

The reviewed literature indicates that risks during firefighting operations can be significantly reduced through the implementation of appropriate safety procedures. The first step involves promptly identifying the presence of a photovoltaic system on the affected building. Consequently, international standards recommend clear labelling of buildings, electrical cabinets, and major system components to ensure that firefighters are immediately aware of the additional hazards upon arrival.

Namikawa (2017) states that access corridors between rows of rooftop panels should be provided to allow firefighters safe access to fire locations. The installation of rapid shutdown systems is also recommended, as these systems reduce voltage levels in certain parts of the installation and thereby improve intervention safety.

When extinguishing fires, the use of fog or spray water streams is recommended while maintaining prescribed safety distances from electrical components. Direct solid water streams may increase the risk of electric shock and are therefore not recommended near energised system components.

Regular maintenance also plays a crucial role in fire prevention. Periodic inspections of electrical connections, cable conditions, protective devices, and thermal imaging assessments can help identify faults at an early stage and prevent fire occurrence.

Situation and Challenges in Bosnia and Herzegovina

The solar energy sector in Bosnia and Herzegovina has experienced considerable growth in recent years. Rising electricity prices, improved technology availability, and renewable energy policies have contributed to the increasing number of photovoltaic systems installed on residential, commercial, and industrial buildings.

However, the analysis of available literature and professional practice indicates that the development of photovoltaic systems has not been fully accompanied by the development of specialised firefighting procedures. Most fire departments in Bosnia and Herzegovina still lack dedicated operational guidelines for fires involving solar panel installations. Furthermore, specialised training programmes in this field remain limited.

Considering the anticipated growth of solar power installations, firefighters are expected to encounter photovoltaic systems more frequently during future interventions. Therefore, it is necessary to develop national guidelines based on international best practices, improve firefighter training programmes, and strengthen cooperation between system designers, electrical engineers, installers, and fire protection services.

The findings of this analysis confirm that proper system design, regular maintenance, the implementation of modern protective technologies, and continuous firefighter education are key factors in reducing fire risks and improving the safety of firefighting operations involving photovoltaic systems.

CONCLUSION

Fires involving photovoltaic systems represent a specific challenge for firefighting units due to the presence of electrical energy, the risk of electric shock, and restricted access to fire locations. Unlike conventional electrical installations, photovoltaic systems can continue generating electricity when exposed to sunlight, even after the main power supply has been disconnected. This characteristic significantly increases operational risks and requires firefighters to apply specialised tactics and safety procedures during emergency interventions.

The literature review revealed that the most common causes of fires in photovoltaic systems are electrical faults, improper installation practices, damaged electrical connections, inadequate maintenance, inverter failures, and arc fault occurrences. These factors can lead to overheating of system components and ignition of surrounding combustible materials, particularly in rooftop installations and building-integrated photovoltaic systems. The findings also indicate that the growing number of photovoltaic installations worldwide is accompanied by an increased need for effective fire prevention strategies and improved operational preparedness.

The analysis also highlights the importance of continuous firefighter education and specialised training programmes focused on photovoltaic technologies. As solar energy systems become more common, fire departments must adapt their operational procedures and develop the necessary technical knowledge to respond safely and effectively to such incidents. Cooperation between firefighters, engineers, installers, and regulatory authorities is essential for improving overall fire safety standards.

Given the increasing number of photovoltaic systems in Bosnia and Herzegovina, additional efforts are needed to strengthen the regulatory framework, develop national operational guidelines, and expand firefighter training programmes. Future activities should focus on harmonising local regulations with international best practices, promoting preventive maintenance, and improving awareness of photovoltaic fire risks among both professionals and system owners. Such measures would contribute to a higher level of safety, reduce potential fire losses, and ensure effective protection of people, property, and the environment in the context of the growing use of renewable energy technologies.

REFERENCES

1. Meacham, B., Poole, B., Echeverria, J., & Cheng, R. (2012). Fire safety challenges of green buildings. Fire Protection Research Foundation.
2. Namikawa, S. (2017). Photovoltaics and firefighters' operations: Best practices in selected countries (IEA-PVPS T12-09:2017). International Energy Agency Photovoltaic Power Systems Programme.
3. Piantedosi, M., Granato, T., & Hausman, N. (2016). Solar photovoltaic (PV) fire safety training. Clean Energy States Alliance.
4. Romosios, G., Vasilikou, A., & Choulakis, S. (2018). Fires in solar power systems and firefighter safety – A review. In SafeKozani 2018 Proceedings: 5th International Conference on Civil Protection & New Technology (pp. 22–27). SafeGreece.
5. Zamrazilova, M. (2024). Fire safety of building integrated photovoltaic systems—State of the art. Journal of Infrastructure, Policy and Development, 8(6), 3601. https://doi.org/10.24294/jipd.v8i6.3601

VATROGASNE INTERVENCIJE KOD POŽARA NA FOTONAPONSKIM SISTEMIMA I OBJEKTIMA SA SOLARNIM PANELIMA

SAŽETAK

Razvoj i sve šira primjena fotonaponskih sistema na stambenim, javnim i industrijskim objektima donosi nove izazove u oblasti zaštite od požara i vatrogasnih intervencija. Cilj rada je analizirati specifičnosti požara na objektima sa solarnim panelima, identifikovati glavne rizike za vatrogasce tokom intervencije te prikazati osnovne sigurnosne procedure i preventivne mjere koje doprinose efikasnijem i sigurnijem gašenju požara. Svrha rada je ukazati na značaj stručne obuke vatrogasaca i pravilnog projektovanja fotonaponskih sistema radi smanjenja opasnosti od nastanka i širenja požara. U radu će biti korištena metoda pregleda i analize dostupne naučne i stručne literature. Analiza literature pokazuje da požari na fotonaponskim sistemima najčešće nastaju usljed električnih kvarova, neispravnih instalacija, lošeg održavanja i pojave lučnih kvarova. Požari na objektima sa solarnim panelima zahtijevaju poseban pristup vatrogasnih jedinica zbog specifičnih električnih i konstrukcijskih rizika.

Ključne riječi: fotonaponski sistemi, požar, vatrogasne intervencije, solarni paneli, zaštita od požara

Correspondence to: Muharem Čupina
Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina
E-mail: muharem.cupina@ftt.edu.ba

FIRES IN ROAD TUNNELS

Melisa Sidran[1], Alden Palo[1]

1. Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina

ABSTRACT

Road tunnel fires are among the most critical safety challenges in modern transport systems due to space constraints, extreme heat, and difficult evacuation. This paper analyses key risk factors and technical solutions for fire prevention and suppression in tunnel infrastructure. The study examines fire development phases, the role of intelligent detection systems (such as linear heat detectors), and the importance of integrated management via control centres. A particular emphasis is placed on a modern safety challenge: the presence of electric vehicles in tunnel traffic. In conclusion, it is highlighted that tunnel safety depends on the synergy of advanced infrastructure, precisely defined firefighting protocols, and the continuous training of operational forces.

Keywords: fire protection, road tunnels, electric vehicles, lithium-ion batteries, detection systems, firefighting tactics

INTRODUCTION

While tunnels are vital components of modern transportation networks, they present significant safety risks, with fires posing the most critical threat due to confined spaces and limited evacuation options. This paper examines the specific characteristics of tunnel fires, the essential safety and detection infrastructure, and the pivotal role of control centres in effective incident management. By analysing standardised firefighting procedures and reflecting on the catastrophic 1999 Mont Blanc tunnel fire, this study highlights the necessity of integrating advanced technological systems with strategic operational planning to minimise risk and enhance safety.

TUNNEL FIRE CHARACTERISTICS

A fire in a tunnel has specific characteristics that make it extremely dangerous compared to fires in open spaces. The enclosed space, limited ventilation, high concentration of flammable materials, and restricted access for emergency services make a tunnel fire one of the most complex safety challenges.

Fire Development and Spread

Since the distance between the tunnel ceiling and the burning material is relatively small, flames in the centre of the fire quickly reach the ceiling. Thermal energy then transfers to the structure or is transported via smoke gases in the airflow direction. The energy transferred to the ceiling and the energy of hot gases emit thermal radiation back towards the burning material, which accelerates heating of the condensed phase and contributes to faster fire development. Fire development in an enclosed space can be divided into the following phases: ignition phase, growth phase, flashover, fully developed phase, and decay/extinguishment phase.
The temperature of a tunnel fire can exceed 1,000°C, while smoke spreads at speeds greater than 10 m/s, significantly complicating evacuation and intervention (Ingason et al., 2015).

Causes of Fire

The most common causes of fires in road tunnels include traffic accidents and vehicle collisions, engine or electrical installation failures, overheating and ignition of tires or brakes, improper transport of flammable materials, and human negligence and violation of regulations. Analysis of European Union data shows that over 60% of tunnel fires occur as a result of traffic accidents involving heavy goods vehicles or buses (Evans, 2016).

Electric Vehicles as Special Fire Causes

Electric vehicles (EVs) introduce a new risk dimension due to lithium-ion batteries which can enter thermal runaway – exponential temperature increase leading to self-sustaining combustion that does not require oxygen, making standard suppression methods ineffective.

In the specific environment of tunnels, EV fires present critical dangers due to two key factors: emission of toxic gases (combustion of electrolyte releases high concentrations of hydrogen fluoride, hydrocyanic acid, and other toxic compounds) and extreme temperatures with re-ignition risk exceeding 1000°C (Sturk et al., 2019;

Doughty & Roth, 2012).

Consequences of Fire

The consequences of a tunnel fire are multiple – from human casualties and material damage to prolonged tunnel closures and traffic disruption. Smoke and heat waves represent the greatest threat to life, as the majority of tunnel fatalities are caused by asphyxiation before being reached by flames. High temperatures can damage concrete linings and safety installations, leading to costly and lengthy repairs (Gaggero & Salvo, 2015).

SAFETY ELEMENTS IN TUNNELS

Tunnel Lighting

Tunnel lighting must cover normal operation, power failure and emergency evacuation scenarios. Backup power provides autonomous supply for up to two hours. Traffic signals at both entrances must switch to red immediately upon detector activation (Pravilnik o sustavima za dojavu požara, 1999).

Ventilation System

The ventilation system plays a key role in controlling the spread of smoke and heat waves. The control centre manages longitudinal and transverse ventilation, regulates airflow speed and direction to remove smoke from evacuation corridors, and creates smoke barriers to enable passenger evacuation and firefighter access.

Ventilation is mandatory in tunnels longer than 1 km with traffic exceeding 2,000 vehicles per lane per day, and consists of fire-resistant ceilings, axial-diagonal fans, motorised louvres every 75–100 m, and reversible fans for longer tunnels.

Water Supply and Hydrant Network

Every tunnel must have a sufficient water supply secured through hydrants. Hydrants must be placed near portals and along the tunnel at distances not exceeding 150 m. Pressure must be at least 6 bar and no more than 12 bar.

Video Surveillance

Video systems in tunnels must enable identification of stopped vehicles and smoke appearance. The monitoring system must allow the control centre to continuously monitor traffic throughout the entire tunnel. In the event of an emergency, the control centre screen automatically switches to the camera nearest the incident.

Fire Detection and Alarm Systems

Modern tunnel fire detection prioritises temperature sensors over optical smoke detection, as the latter is prone to errors from environmental contamination.

Linear Heat Detectors

These are the most reliable systems due to their resistance to false alarms and environmental interference. They consist of a sensor cable capable of early fire detection. The MHD 535 model is considered the industry leader, responding 50% faster than competitors even under high airflow. These systems are categorised as:

• **Integral:** React to temperature rise along the entire length.
• **Non-integral:** React to temperature rise at specific localised points.

Light Beam Detectors

These utilise a transmitter and receiver on opposite sides of the tunnel. Smoke interrupts the beam, triggering an alarm. They are particularly effective for high-heat fires that produce minimal smoke.

Additional Systems

Beyond automatic sensors, tunnels utilise manual alarm points for drivers and passengers. The complete fire alarm infrastructure integrates a central control unit, automatic/manual sensors, and alarm notification devices.

THE CONTROL CENTRE'S ROLE IN FIRE MANAGEMENT

The control centre is the hub for monitoring and managing all tunnel safety systems, including ventilation, lighting, fire detection, video surveillance, and communication.

Organisation and Functions

The operational room utilises monitoring systems (CCTV, SCADA, ITS) to communicate with emergency services, drivers, and staff. In the event of a fire, the centre detects the incident, activates safety protocols, coordinates evacuation, monitors the situation, and handles documentation.

Emergency Coordination

The SCADA system allows for real-time technical monitoring. Effective coordination with emergency services, supported by regular training, ensures compliance with NFPA 502 standards.

FIREFIGHTING IN TUNNELS

Extinguishment

Tunnels of certain length must have, alongside all preventive measures, a service with appropriate equipment: rapid vehicles with sufficient means (water, foam, powder), hydraulic tools, isolated air-line breathing apparatus, infrared cameras, and radio communication. Empirical data on time consumption in long tunnels: approach with breathing apparatus every 100 m – 5 minutes; laying C-hose every 100 m – 10 minutes; rescue of casualties every 100 m – 15 minutes.

Evacuation

Evacuation of endangered persons requires additional construction measures: construction of two tunnel tubes with one-way traffic, construction of a service tunnel alongside the main traffic tube, construction of vertical pedestrian exits to open space, and construction of vertical shafts. Requirements include: evacuation time 5–10 minutes, movement speed up to 1.5 m/s, maximum air temperature tolerable by an unprotected person 80°C for up to 15 minutes, and minimum visibility for evacuation of 7.0–15.0 metres.

Tactical Approach

In tunnel fire conditions, there is no established, accepted rule for tactical approach. Operations must not be undertaken with insufficient personnel, as they quickly become exhausted due to the mandatory use of breathing and heat protection equipment. The type of tactical operation is determined by the fire location in the tunnel – frontal approach is the only feasible option if it is possible to reach the fire source directly.

EV Firefighting Tactics in Tunnel Environment

The firefighting tactics for electric vehicles in tunnels differ significantly from standard procedures due to the specifics of battery systems. The basic tactical goal is not only suppressing visible flames, but breaking the thermal runaway chain within the battery pack. The tactical approach is divided into three key phases:

(1) Offensive cooling with large quantities of water: Unlike conventional fires where foam or powder can be used, water is essential for EVs. Modern protocols recommend specialised nozzles (Fognails or Battery Extinguishing System Units) that penetrate the battery casing and inject water directly between cells.

(2) Smoke layer control and ventilation: Due to extreme smoke toxicity, tactics must be synchronised with the tunnel's longitudinal or transverse ventilation system to maintain 'critical velocity' and prevent backlayering.

(3) Safe removal and immersion: After localisation, the vehicle must be promptly removed from the tunnel, as re-ignition risk persists for up to 24 hours. The safest method uses specialised mobile water containers (RedBox systems) in which the vehicle is submerged (NFPA, 2020; Euro NCAP & CTIF, 2021).

CASE STUDY: MONT BLANC TUNNEL FIRE (1999)

The 1999 Mont Blanc tunnel fire is one of Europe's greatest traffic disasters, claiming 39 lives and serving as a critical turning point for tunnel safety standards.

The Incident

The fire began on 24 March 1999, when a cargo truck carrying flour and margarine caught fire. Despite attempts to extinguish it, the flames spread rapidly. Due to delayed traffic warnings, numerous vehicles were trapped inside. Poor communication between French and Italian rescue services caused the fire to burn for 53 hours, resulting in severe damage that closed the tunnel for three years and required nearly half a billion euros for repairs.

Incident Outcome

Following this tragedy and the subsequent Gotthard tunnel disaster (2001), the EU established mandatory safety standards through Directive 2004/54/EU to prevent similar catastrophes.

CONCLUSION

Fires in road tunnels represent one of the most critical safety challenges in the modern transport system. The specifics of the tunnel as an enclosed space, where temperatures can exceed 1,000°C and smoke spreads at speeds greater than 10 m/s, require flawless coordination between technical systems and human factors.

Linear temperature detectors enable rapid fire positioning with minimal false alarms. A growing challenge is posed by electric vehicles, requiring a tactical shift towards offensive battery cooling to prevent thermal runaway.

The analysis of the Mont Blanc tunnel case study serves as a reminder of the catastrophic consequences of inadequate integration and the importance of strict safety protocols. Achieving maximum safety in tunnels is not the result of a single measure, but the synergy of advanced infrastructure, specialised tunnel firefighting vehicles, and continuous personnel training. Implementation of international standards, with adaptation to local legislation, represents the only path towards minimising risks and efficient incident management in tunnel environments.

REFERENCES

1. Doughty, D. H., & Roth, E. P. (2012). A general discussion of Li-Ion battery safety. The Electrochemical Society Interface, 21(2), 37–44.
2. Euro NCAP & CTIF. (2021). Euro NCAP rescue sheet: Guidelines for firefighting operations.
3. European Committee for Standardization. (2016). EN 50575: Fire performance of construction products – Reaction to fire.
4. Evans, D. (2016). Tunnel fire safety. Elsevier.
5. Fire-fightingtruck.com. (n.d.). Double cabin tunnel rescue firefighting truck specialized vehicle. Retrieved from https://www.fire-fightingtruck.com
6. Gaggero, L., & Salvo, L. (2015). Fire safety in road tunnels. Springer.
7. Ingason, H., Li, Y. Z., & Lönnermark, A. (2015). Tunnel fire dynamics. Springer Science & Business Media.
8. National Fire Protection Association (NFPA). (2020). Emergency response guide for electric vehicles and hybrid electric vehicles. Quincy, MA: NFPA.
9. National Fire Protection Association (NFPA). (2022). NFPA 502: Standard for road tunnels, bridges, and other limited access highways. Quincy, MA: NFPA.
10. Pravilnik o sustavima za dojavu požara [Regulation on fire detection and fire alarm systems]. (1999). Narodne novine, 56/1999.
11. Sidran, M. (2025). Uloga kontrolnog centra u upravljanju požarom u cestovnom tunelu [The Role of the Control Centre in Road Tunnel Fire Management] [Seminar paper]. Faculty of Technical Sciences, University of Travnik.
12. Državna vatrogasna škola. (2024). Vatrogasna taktika [Firefighting tactics]. Retrieved from https://dvskola.hr/wp-content/uploads/2024/10/Vatrogasna-taktika.pdf
13. Stipić, K. (2023). Vatrodojavni sustavi u kriznim situacijama požara u tunelima [Fire alarm systems in tunnel fire emergency situations] [Final thesis]. Veleučilište Velika Gorica.
14. Sturk, D., et al. (2019). Fire tests on e-vehicle battery packs and full-scale vehicles (Report 2019:54). RISE Research Institutes of Sweden.
15. Zhang, H., et al. (2020). Emergency response coordination in tunnel fires. Safety Science, 121, 1–10.

POŽARI U CESTOVNIM TUNELIMA

SAŽETAK

Požari u tunelima predstavljaju ozbiljan sigurnosni izazov u modernim transportnim sistemima zbog ograničenog prostora, izuzetno visoke temperature i teške evakuacije. Ovaj rad analizira ključne faktore rizika i tehnička rješenja za prevenciju i gašenje požara u tunelima. Ispituju se faze razvoja požara, uloga inteligentnih sistema detekcije (poput linearnih sistema detekcije toplote) i značaj integrisanog upravljanja putem kontrolnih centara. Posebno se fokusira na savremeni sigurnosni izazov: prisustvo električnih vozila u tunelskom saobraćaju. Zaključuje se da sigurnost u tunelu zavisi od sinergije napredne infrastrukture, preciznih protokola gašenja požara i kontinuirane edukacije operativnih snaga.

Ključne riječi: zaštita od požara, cestovni tuneli, električna vozila, litij-ionske baterije, sistemi detekcije, vatrogasna taktika

Correspondence to: Alden Palo
Faculty of Technical Studies, University of Travnik, Bosnia and Herzegovina
E-mail: mr.alden.palo@gmail.com

INSTRUCTIONS FOR AUTHORS

The aim and purpose of the journal

Techno Science is an international scientific journal from the area of technical sciences. It is published twice a year.

General provisions

Each paper is evaluated, so that it corresponds to the intention of the journal, and then reviewed. The authors are responsible for the content and ethics of everything written in the paper. The authors can be requested to give a specific statement that the paper has not been published in another publication. Techno Science does not question the authors' copyright over the published papers, but preserves the right of distribution in accordance with the legal provisions, and without further consultation with the authors, with which the authors agree when submitting the paper. Authors are not entitled to re-release/reprint the paper, apart from a copy of the printed journal. It is necessary to include the corresponding author's information, his or her e-mail address and the institutional e-mail address.

Preparation of attachments

It is recommended that the authors keep the structure of the journal, including: the Abstract, Introduction, Problem and Aim, Methods, Results, Discussion, Conclusion and References. This recommendation does not bind the authors but helps ease the publishing process and understanding of the subject matter. The attachments are not limited in size, but should not exceed 7 pages in the journal. The text font is Times New Roman 11 pt with 1.15 line spacing, created in two columns. The expected size of the paper is 12 000 (exceptionally 14 000) characters without tables and images. All tables should be standardised (e.g. MS Excel), and the images, photographs and other illustrations should be in a vector format or a high quality printing resolution (600 dpi). Before printing, the journal has the right to edit the illustration. In such instances, the author will be consulted or informed via e-mail.

References

The reference list, as well as other forms of text formatting, will be accepted if they are made in accordance with the APA standard (American Psychological Association) and translated into English with an indication of the original language in the brackets. The attachment is sent exclusively in electronic form (e-mail, CD, disc, etc.)

Language used in the attachments

Techno Science publishes papers in English with abstracts in Bosnian. The abstract is delivered in Bosnian and English.

Note

Attachments that do not meet the requirements, or need to be consulted upon, will be returned to the author with a warning containing the actions that need to be undertaken.

Delivery address for the attachments

Techno Science - Faculty of Technical Studies, University of Travnik
Aleja Konzula 5, Travnik, Bosnia and Herzegovina
E-mail: technoscience@eftfts.edu.ba

Publication of the journal

The journal is published in printed and electronic form. The electronic version is available at
the website: https://technoscience.ba/

UPUTE AUTORIMA RADOVA

Cilj i svrha časopisa

Techno Science je međunarodni naučni časopis iz oblasti tehničkih nauka. Izdaje se dva puta godišnje.

Opće odredbe

Svaki rad se ocjenjuje u odnosu na to da li odgovara namjeri časopisa, a zatim se recenzira. Autori su odgovorni za sadržaj i etiku svega što se nalazi u radu. Od autora se može tražiti da daju konkretnu izjavu da djelo nije objavljeno u drugoj publikaciji. Techno Science ne prejudicira autorska prava autora objavljenih radova, ali zadržava pravo distribucije u skladu sa zakonskim odredbama, a bez daljnjih konsultacija sa autorima, sa čime se autori saglase prilikom slanja rada. Autori nemaju pravo na ponovno izdavanje/reprint, osim jednog primjerka štampanog časopisa. Potrebno je dostaviti podatke autora za korespondenciju, njegov e-mail i institucionalni e-mail.

Priprema priloga

Preporučuje se da autori zadrže strukturu časopisa koja uključuje: sažetak, uvod, problem i cilj, metode, rezultate, diskusiju, zaključak i literaturu. Ova preporuka ne obavezuje autore, ali pomaže na putu lakšeg razumijevanja materijala i publikacije. Prilozi nisu ograničeni u veličini, ali ne bi trebali prelaziti 7 stranica u časopisu. Font teksta je Times New Roman 11 pt, prored je 1,15 kreiran u 2 kolone. Očekivana veličina je 12 000 karaktera bez tabela i slika (izuzetno može biti 14 000 karaktera). Sve tabele treba da budu standardizovane (npr. MS Excel), a slike, fotografije i druge ilustracije treba da budu u vektorskom formatu ili rezoluciji koja obezbjeđuje kvalitetnu štampu (600 dpi). Časopis ima pravo uređivanja ilustracije prije štampe, o čemu konsultuje ili obavještava autora putem e-maila.

Liste referenci

Liste referenci, kao i drugi oblici oblikovanja teksta, biti će prihvaćeni ako su napravljeni po APA standardu (American Psychological Association), prevedeni na engleski jezik sa naznakom originalnog jezika u zagradama. Prilog se šalje isključivo u elektronskom obliku (e-mail, CD, disk itd.).

Jezik priloga

Techno Science objavljuje radove na engleskom jeziku sa sažetkom na bosanskom jeziku. Sažetak se dostavlja na bosanskom i engleskom jeziku.

Napomena

Prilozi koji ne ispunjavaju uslove ili ako je za njih potrebna dodatna konsultacija biti će vraćeni autoru uz upozorenje o radnjama koje treba preduzeti.

Adrese za dostavu priloga

Techno Science – Fakultet za tehničke studije, Univerzitet u Travniku
Aleja konzula 5, Travnik, Bosna i Hercegovina
E-mail: technoscience@eftfts.edu.ba

Objava časopisa

Časopis izlazi u štampanom i elektronskom obliku. Elektronska verzija je dostupna na web adresi: https://technoscience.ba/


Univerzitet u Travniku
University of Travnik
AKREDITOVAN
Fakultet za tehničke studije
I ciklus
Dodiplomski studij
II ciklus
Master studij
III ciklus
Doktorski studij
Načini studiranja
Redovan, Vanredan, Učenje na daljinu (DL)
SIGURNOST I ZAŠTITA NA RADU I ZAŠTITA OD POŽARA 3+2, 4+1
INŽENJERSKA INFORMATIKA 3+2, 4+1
TEKSTILNO INŽENJERSTVO I MODNI DIZAJN 3+2, 4+1
GRAFIČKI DIZAJN I MULTIMEDIJA 3+2, 4+1
GRAĐEVINA 3+2, 4+1
ARHITEKTURA 3+2, 4+1