IDENTIFIKACIJA I UPRAVLJANJE KRITIČNOM INFRASTRUKTUROM U ZONAMA PRUŽNIH PRELAZA
- STUDIJA SLUČAJA GRAD PRIJEDOR -

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Naučni rad

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Sažetak:

U radu je izvršena analiza bezbjednosnih rizika na kritičnoj infrastrukturi u zonama pružnih prelaza, sinteza problema, prijedlozi mjera, sa posebnim osvrtom na vanredne događaje na putnim prelazima, na području Grada Prijedor. Akcenat je stavljen na identifikaciju generatora bezbjednosnih rizika za kritičnu infrastrukturu kroz nedorečenu zakonsku regulativu koju treba promijeniti. U dijelu upravljanja identifikovanim bezbjednosnim rizicima, posebno je apostrofirana potreba za opštom primjenom standarda i direktive EN 2557/2022, kao i prilagođavanje nacionalne zakonske regulative u pogledu geometrije ose puta u odnosu na kolosjek, međusobne udaljenosti putnih prelaza i nagibi pristupnih puteva u odnosu na kolosjek. Vizuelni ambijent sa aspekta primenjenih zakonskih kriterijuma koje treba da ispuni pružno-putni prelaz, takođe je tertian u ovom istarživačkom radu. Navedeni elementi su neophodni za obezbjeđenje putnih prelaza sa sistemskim pristupom rješavanju problema, a koji zahtjeva investicije u cilju omogućavanja bezbjednog saobraćaja u uslovima povećanja brzine kretanja vozova na teritoriji grada Prijedora.

Ključne riječi: *kritična infrastruktura**,** rizici, bezbjednost, vanredni događaj, pružno putni prelazi.*

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1. Uvod

Prelaz puta preko željezničke pruge u nivou (putni prelaz ili putno-pružni prelaz) je četvorokraka raskrsnica preko kojeg se ukrštaju dva vida saobraćaja (drumski i željeznički). Tehničko-tehnološke i organizacione karakteristike željeznice odredile su joj prioritet kod ukrštanja u odnosu na drumski saobraćaj (od strane planera, organizatora i zakonodavaca), čime je i definisan način regulisanja saobraćaja preko prelaza.

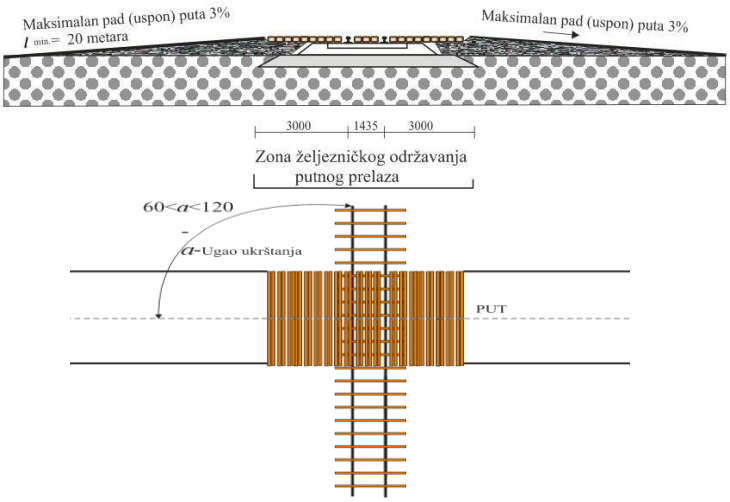
Željeznički saobraćaj (u kinematičkom smislu) s jedne strane je ograničen stepenom slobode kretanja, a sa druge strane (u dinamičkom smislu) generiše veliku kinetičku energiju prilikom kretanja što ima za posljedicu dugačak zaustavni put, a saobraćaj obavlja u kompozicijama voznih jedinica. Drumski saobraćaj se odlikuje većim stepenom slobode kretanja, pojedinačnim voznim jedinicama, manjom kinetičkom energijom, te kratkim zaustavnim putem.

Željeznički saobraćaj zahtjeva stroge režime tj. ispravnost i stabilnih i mobilnih kapaciteta u funkciji kompozicije, dok kod drumskog saobraćaja saobraćajnice po kojoj se kreću drumska vozila u kvalitetu variraju od običnog ruralnog puta do savremenog autoputa i vrlo su razgranate.

Kako bi se na sveobuhvatan način riješilo pitanje otpornosti subjekata koji su kritični za pravilno funkcionisanje unutrašnjeg transportnog sistema, EU Direktivom 2557/2022 uspostavlja se sveobuhvatan okvir koji se odnosi na otpornost kritičnih subjekata u pogledu svih opasnosti, bilo prirodnih ili uzrokovanih ljudskim djelovanjem, uzrokovanih slučajno ili namjerno [1], [10].

U skladu sa odredbama koje se odnose na kritičnu infrastrukturu kao i nacionalnih željezničkih propisa, ukrštanje željezničke pruge i puta mora se denivelisati u slučaju kada se na prelazu odvija intenzivan protok (preko 7000 vozila u danu) ili kada je preko pruge učestao saobraćaj (120 vozova na jednokolosiječnoj pruzi ili 240 vozova na dvokolosiječnoj pruzi). Učestalost vozova određuje željeznica, a protok drumskih vozila je direktno zavisan od pokretljivosti stanovništva, aktivnosti privrede i izbora puta od strane korisnika putne infrastructure [3].

Na Slici 1 šematski su prikazani osnovni elementi-propisani standardi kod projektovanja i izgradnje puta preko željezničke pruge u nivou.



Slika 1. *Prelaz puta preko željezničke pruge u primjeni propisanih standarda*

Na infrastrukturi željezničke korporacije u Republici Srpskoj postoji 278 prelaza puta preko željezničke pruge, od čega je u eksploataciji 259 prelaza.

U pogledu bezbjednosti, evidentan je sljedeći nivo osiguranja:

- Trougao preglednosti (259)
- Branici (18)
- Svjetlosno zvučna signalizacija (1)

Standard propisuje, da kod ukrštanja puta i pruge u nivou, drumska saobraćajnica bude u nivou sa GIŠ u dužini od 3 m od ose kolosjeka, poslije toga kolovoz puta ne smije imati veći nagib od 3 % na minimalnoj dužini od 20 metara i mora biti sa savremenim kolovozom. Takođe, ukrštanje mora biti pod uglom ne manjim od 60 stepeni i ne većim od 120 stepeni.

Postojeća regulative na željeznici, regulativa koja uređuje oblast javnih puteva, te propisi iz domena prostornog uređenja, definišu saobraćaj u zoni prelaska puta preko željezničke pruge, na sljedeći način [11], [12]:

- Ukrštanje željezničke pruge i puta, određivanje mjesta na kojima se može izvesti ukrštanje pruge i puta i utvrđivanje mjera koje se moraju preduzeti radi obezbjeđenja odvijanja saobraćaja na putnim prelazima propisuje se zavisno od protoka i gustine saobraćaja, preglednosti željezničke pruge, brzine vožnje na pruzi i putu, i od drugih mjesnih uslova koji su od značaja za bezbjednost saobraćaja.
- Ukrštanje željezničke pruge i autoputa i ukrštanje pruge i puta u

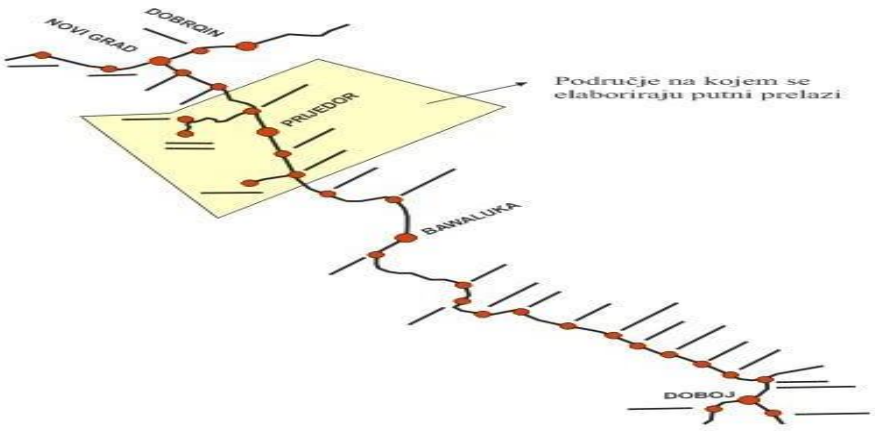
staničnom prostoru između ulaznih, odnosno izlaznih skretnica, od kojih počinju stanični kolosjeci, ne može biti u istom nivou.

- Ukrštanje željezničke pruge i puta koji nema svojstvo autoputa ne može biti u istom nivou ako je saobraćaj motornih vozila na putu vrlo gust ili ako je željeznički saobraćaj na pruzi učestao i ako to zahtjevaju posebni uslovi na mjestu ukrštanja pruge i puta, i drugi razlozi bezbjednosti željezničkog saobraćaja.
- Minimalno rastojanje između dva putna prelaza ne može biti manje od 1000 metara, odnosno izuzetno 700 metara.
- Nekategorisane puteve potrebno je preusmjeriti na najbliži javni put, a ako to nije moguće treba ih međusobno povezati i izvesti ukrštanje na jednom mjestu. Mjesto ukrštanja određuju u konkretnom slučaju željeznička korporacija i lokalna uprava.
- Putni prelaz je sastavni dio pruge sa obje strane kolosjeka u širini od 3 metra od ose kolosjeka sa produžetkom ukrštajućeg puta od 20 metara čiji nagib ne smije biti veći od 3%. Dio prelazne pruge i ukrštajući put u dužini od 3 metra od ose kolosjeka obavezni su održavati željeznička korporacija, a ostali dio upravljač puta, i lokalna uprava na čijoj se teritoriji nalazi putni prelaz.

2. Podaci o putnim prelazima

Upravljač željezničkog saobraćaja na prugama Republike Srpske, "ŽRS" AD Doboj, je sačinio Elaborat o evidenciji i stanju prelaza puta preko željezničke pruge. Na dionici pruge (Doboj)- Niševići-Svodna-(Novi Grad) počev od stacionaže pruge Doboj-Novi Grad km 128+714 do km 165+350, Omarska-Tomašica i Brezičani-Ljubija na teritoriji Grada Prijedor nalaze se 63 pružno-putna prelaza u nivou (željezničke pruge i drumskih saobraćajnica), i to 34 ukrštanja na pruzi (Doboj)-Niševići-Svodna-(Novi Grad), 10 ukrštanja na pruzi Omarska-Tomašica i 19 ukrštaja na pruzi Brezičani-Ljubija [2].

Na Slici 2 šematski je prikazana pruga Doboj-Novi Grad gdje se na osjenčenom dijelu analiziraju putni prelazi na teritoriji lokalne zajednice Grada Prijedora.



Slika 2: *Disperzija prelaza pute preko željezničke pruge, na relaciji Doboj-Novi Grad, sa apostrofiranjem na teritoriju Grada Prijedora*

Drumski saobraćaj na ovim putnim prelazima je u rasponu od slabog inteziteta do umjerenog i jakog inteziteta, prelaz na tzv. „trinaesta“. Iz navedenog, lako se zaključuje da postoji neopravdano veliki broj prelaza koji značajno umanjuju kvalitet pruge i njen rang upoređujući je sa ostalim savremenim prugama okruženja. Neophodno je preduzeti odgovarajuće mjere redukovanja i osiguranja putnih prelaza koje bi se sprovele u skladu sa zakonskim propisima, primjenjujući saobraćajne, građevinske, urbanističke i ekonomske kriterijume.

Postojeće stanje putnih prelaza posmatrano je kroz sledeće karakteristike:

A. Analitičko prezentovanje
B. Disperzija putnih prelaza
C. Bezbjednost saobraćaja na prelazu puta preko željezničke pruge
D. Vizuelno i šematsko prezentovanje (preko fotografija i šema)

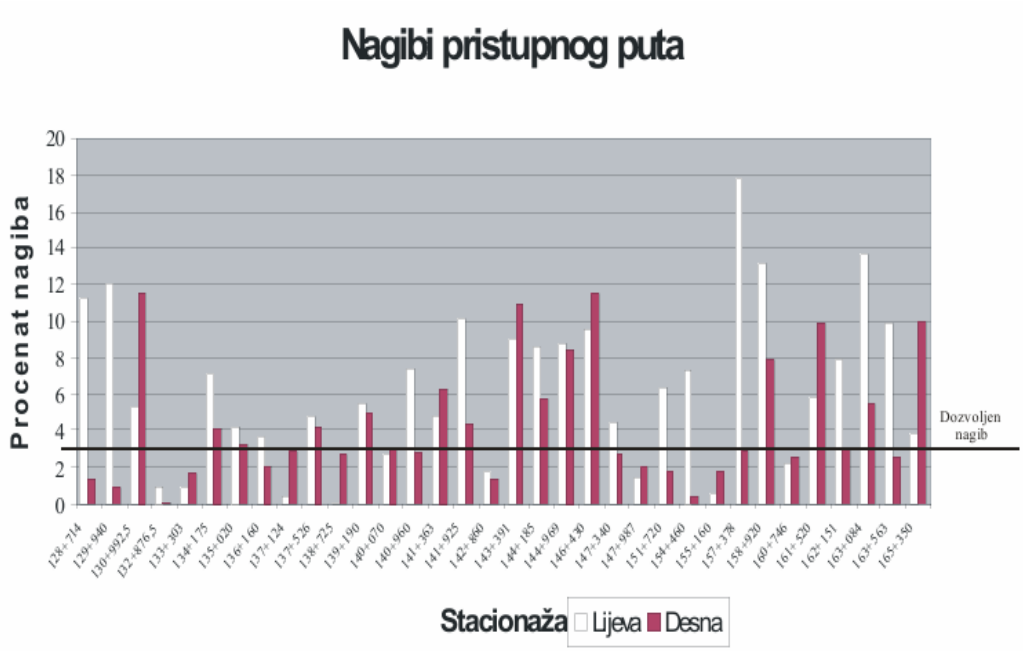
2.1 Analitička prezentacija

Na području Grada Prijedor postoje 54 putna prelaza, od čega su 33 putna prelaza zaštićena saobraćajnim znakovima na pristupnom putu („Andrejin krst“ i „znak zabrane“ STOP) i trouglom preglednosti, 2 putna prelaza, pored saobraćajnih znakova na putu, zaštićena su i branikom kojom se rukuje ručno i 19 neosiguranih putnih prelaza, na pruzi Brezičani – Ljubija, koja su van eksploatacije.

Posmatrajući i analizirajući pojedine karakteristika putnih prelaza uočava se da se radi o nižem nivou sigurnosti putnih prelaza, sa sljedećim karakteristikama:

- Trouglovi preglednosti na većini putnih prelaza nisu obezbjeđeni;
- Ukrštanje se obezbjeđuje preko drvenih pragova;
- Ugao ukrštanja puta i pruge preko 3 prelaza je veći od dozvoljenog;
- Nagibi puta su nestandardni, jer značajno premašuju 3% (Grafik 1).

Na Grafiku 1 prikazani su nagibi pristupnog puta u zonama prelaska puta preko željezničke pruge u nivou na teritoriji Grada Prijedora.



Grafik 1. *Grafički prikaz nagiba pristupnih puteva*

Na Grafiku 1 je očigledno je da su nagibi pristupnog puta na većem dijelu prelaza veći od dozvoljenih 3 % što značajno ugrožava bezbjednost saobraćaja na prelazima naročito u zimskom preiodu.

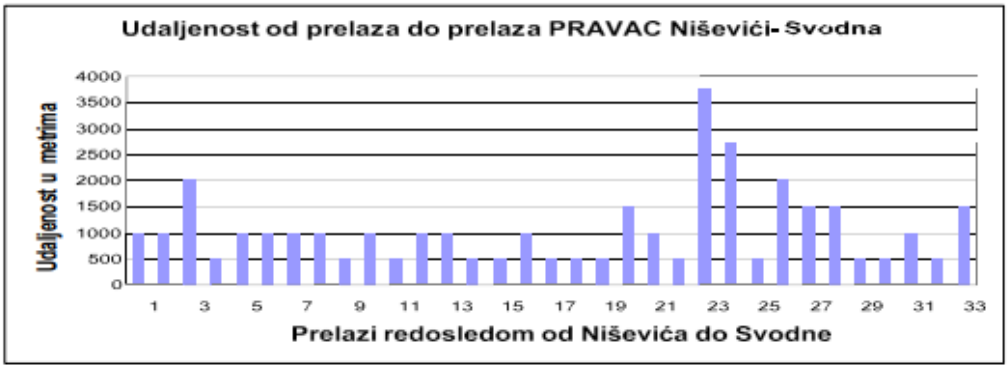
Takođe, evidentna su nepovoljna stanja, koja usložnjavaju situaciju u smislu bezbjednosti i kvaliteta saobraćaja, u formi:

- Kod velikog broja putnih prelaza, pri izgradnji, nisu poštovani Zakonom propisani uslovi (nedostaje tehnička dokumenatacija).
- Ne postoje ozvaničena podzakonska akta kojima se detaljnije definišu uslovi projektovanja, građenja i načina održavanja putnih prelaza.

- Postoji određeni broj prelaza na kojima je učestalost udesa značajno veće nego na ostalim prelazima, što ukazuje na potrebu za iznalaženjem boljih tehničkih rješenja i obezbjeđenje dodatnih materijalnih sredstava.
- U našoj zemlji nema dovoljno licenciranih preduzeća za opremanje prelaza niti je jasno definisan tehnički pregled i predaja u eksploataciju (saobraćaj) prelaza, u skladu sa Zakonom.
- Kod manjeg broja prelaza nisu ispunjeni jedan ili više Zakonom propisanih uslova (trougao preglednosti, ugao ukrštanja, nagib nivelete puta u dužini od 20 metara od ose kolosjeka, međusobna udaljenost mnogo manja od Zakonom propisane i dr.). Nameće se potreba za otklanjanjem značajnih nedostataka i usmjeravanje dva ili više javnih puteva na zajedničko mjesto ukrštanja, odnosno usmjeravanjem nekategorisanih puteva na javne puteve.
- Ako ne postoje uslovi da se ispoštuju zakonske norme, prelazi se moraju zatvoriti, nakon što se građanima omogući alternativni pristup objektima stanovanja.

2.2 Disperzija putnih prelaza

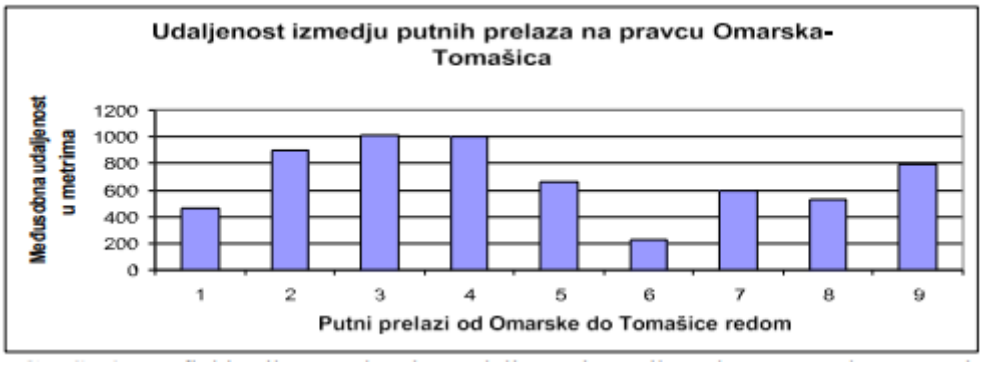
Na dionici Ništevići-Svodna, samo 12 prelaza ima međusobnu udaljenost veću od 1000 metara. Neki od prelaza (Grafik 2) su međusobno udaljeni manje od 500 metara, što je za konkretan nivo ranga pruge nedopustivo



Grafik 2. *Grafički prikaz međusobne udaljenosti putnih prelaza Ništevići-Svodna*

Evidentan je i mali broj putnih prelaza na međusobnoj udaljenosti većoj od 1000 metara. Zanemarljiv je broj prelaza na međusobnoj udaljenosti od 2000 metara (samo 3) što je veoma zabrinjavajuće.

Pruga Omarska-Tomašica (Grafik 3) je u još kompleksnijoj situaciji. Međusobne udaljenosti ne prelaze 1000 metara. Kao što se sa grafika može vidjeti postoje prelazi čija je međusobna udaljenost nešto više od 200 metara.



Grafik 3. *Grafički prikaz međusobne udaljenosti putnih prelaza Omarska-Tomašica*

Slična je situacija i na pruzi Brezičani-Ljubija, na kojoj su samo 4 prelaza na međusobnoj udaljenost većoj od 1000 metara

Grafik 4. *Grafički prikaz međusobne udaljenosti putnih prelaza Brezičani-Ljubija*

2.3 Bezbjednost saobraćaja na prelazu puta preko željezničke pruge

Pod pojmom vanrednog događaja, smatra se događaj zbog kojeg je nastala najmanje jedna od sljedećih posljedica: smrt, teža ozljeda, materijalna šteta, prekid saobraćaja, ugrožavanje ili otežavanje željezničkog saobraćaja.

Vanredni događaji na putnim prelazima na području koje pokriva željeznička korporacija u petogodišnjem vremenskom period [4], [9], predstaljeni su u Tabeli

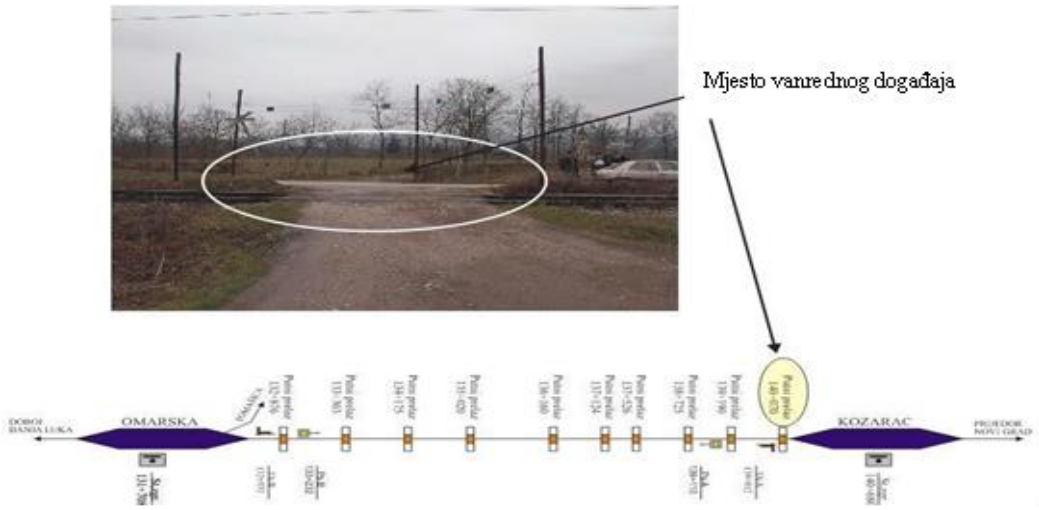
Tabela 1. *Pregled vanrednih događaja na PP u RS i na području Grada Prijedor u periodu 5 godina*

R.br.	VREMENSKI PERIOD	1.god		2.god		3.god		4.god		5.god		Ukupno	
		ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD
1	Vanredni događaj na PP	25	3	14	1	20	4	22	3	20	1	101	12
2	Smrtno stradalo lice		-		-	6	-	2	1	3	-	11	1
3	Teže ozlijeđeno lice	4	-	6	3	4	1	9	2	3	-	26	6
4	Prekid saobraćaja (h)	3	2	13	1	36	6	24	5	19	-	124	14
5	Materijalna šteta	24	-	14	1	20	4	20	3	20	-	100	8

Evidentno je da prelazi puta preko željezničke pruge na teritoriji lokalne zajednice Grada Prijedora, značajno učestvuju u dijelu ukupnog broja vanrednih događaja (12 %), teže ozlijeđenih je 6 od ukupno 26 koliko je u Republici Srpskoj evidentirano u posmatranom periodu. Evidentirano je i 14 prekida željezničkog saobraćaja, na teritoriji lokalne zajednice.

Ako se tome dodaju niske brzine saobraćanja vozova, tada se može zaključiti da je izuzetno nizak kvalitet prevoza, u direktnoj vezi sa bezbjednosnim ciljevima, koji se mogu postići samo niskim brzinama u eksploataciji željezničkog saobraćaja.

Na Slici 3 prikazan je jedan od fotografisanih prelaza puta preko željezničke pruge, koji može poslužiti kao reprezent stanja prelaza na teritoriji Grada Prijedora.



Slika 3. *Karakterističan prelaz puta preko željezničke pruge na teritoriji Grada Prijedor*

3. Metodologija rješavanja bezbjednosnog problema

U cilju podizanja nivoa bezbijednosti saobraćaja u zonama prelaza puta preko željezničke pruge u nivou, potrebno je utvrditi metodološki pristup rangiranja kriterija koji utiču na donošenje menadžerskih odluka, posebno kada je u pitanju podizanje nivoa maksimalnih brzina vozova [5], [6], [7].

S tim u vezi, obaveza upravljača puta i upravljača željezničkog saobraćaja, je da prije donošenja odluke (rekonstrukcija, modernizacija, investicije. itd.), utvrde sljedeća stanja:

1. Parametre toka drumskog saobraćaja preko preko željezničke pruge:
   - Protok vozila
   - Gustinu toka
   - Brzine
   - Vrijeme putovanja-prelaska vozila u toku
   - Jedinično vrijeme putovanja-prelaska vozila u toku
   - Vremenske intervale slijeđenja vozila u toku
   - Rastojanje sleđenja vozila u toku
2. Vidljivost na putnom prelazu:
   - Dobra
   - Djelomična i
   - Ograničena
3. Položaj putnog prelaza:
   - PP u stanici, i
   - PP na otvorenoj pruzi
4. Broj kolosjeka na putnom prelazu
5. Broj i karakter vanrednih događaja na konkretnom putnom prelazu
6. Geološki, građevinski, urbanistički i zakonski uslovi, i
7. Ekonomski pokazatelji.

Izabrani kriterijumi su fizički parametri koji imaju presudan uticaj na nivo osiguranja prelaza puta preko željezničke pruge, i poslužiće u svakom pojedinačnom slučaju kao osnov za određivanje vrste osiguranja putnih prelaza. Na osnovu navedenih kriterijuma vrši se rangiranje prelaza, u cilju utvrđivanja prioriteta u projektovanju i modernizaciji prelaza. U konkretnom

slučaju na bazi ustanovljenih kriterija, potrebno je utvrditi optimalan broj prelaza, iste projektovati u funkciji tehničko-trehnoloških i ekonomskih kriterija, te za svaki pojedinačni tvrditi nivo sigurnosti prelaza.

4. Zaključak

Veliki broj prelaza puta preko željezničke pruge na teritoriji Grada Prijedora, u najvećem broju slučajeva nisu urbanističko-građevinski legalizovani odnosno nisu projektovani i izvedeni u skladu sa propisima i standardima. Nastali su u vremenu nelegalne gradnje određenih gradskih naselja, koja nisu prethodno usklađena sa prostorno-planskim aktima lokalne zajednice.

U fazi legalizacije navedenih naselja, vršena je "sanacija" pojedinačnih objekata stanovanja, a da projekat saobraćajnog rješenja, posebno prelaska puta preko željezničke pruge nije rađen, čime se ostavila mogućnost građanima da pojedinačno ili grupno rješavaju problem, suprotno građevinskim ili saobraćajnim standardima, a pogotovo izostankom primjene directive EU 2557/2022 kojom se regulišu odnosi prema kritičnoj infrastrukturi.
Kako ne postoji mogućnost zatvaranja pojedinih prelaza, prije nego što se građanima ne omogući alternativni pristup objektima stanovanja, neophodno je ustanoviti sljedeće periode aktivnosti:

- Kratkoročni periodi, koje podrazumjevaju bolje obezbjeđenje postojećih prelaza, sa pozicije saobraćajne signalizacije (vertikalna, svjetlosna, zvučna), trougla preglednosti i stvaranja baze podataka za buduća planiranja redukovanja putnih prelaza, kako bi se došlo do zadovoljavajućih rješenja u budućnosti.

- Srednjoročni periodi, koje podrazumjevaju potrebu izrade prostorno-planske dokumentacije u cilju vršenja eksproprijacije zemljišta u zaštitnom pojasu pruge, kako bi se stvorili uslovi za gradnju "sabirne" saobraćajnice, koje bi prethodile aktivnostima smanjenja odnosno redukovanja broja prelaza puta preko željezničke pruge.

- Dugoročni periodi, koje podrazumjevaju utvrđivanje minimalno potrebnog broja prelaza i lociranje istih u prostoru, izrada tehničke dokumentacije, izgradnja i opremanje prelaza primjenom ITS – automatsko regulisanje saobraćaja na prelazu puta preko željezničke pruge, sa bezbjendosne distance kretanja šinskog vozila. Takođe, donošenje nacionalnog zakonskog okvira koji tertira kritičnu infrastrukturu i definiše subjekte odgovorne za upravljanje istom.

LITERATURA

[1] Brunner, E. M., Suter, M.“International Critical Information Infrastructure Protection Handbook”, Center for Security Studies, ETH Zurich, 2009

[2] Dakić, B.“ Elaborat o putnim prelazima na ŽRS", Republička uprava za inspekcije poslove Republike Srpske, Banja Luka. 2008

[3] Đuričić, R., Bošković, B., Rosić, S.”European concept of railway safety”, Faculty of Transportation, Doboj, 2017

[4] DG-ECHO,”European Emergency Response Capacity”, Directorate-General for European Civil Protection and Humanitarian Aid Operations, 2015

[5] European Railway Agency (ERA), Railway Safety Management System, Version 1, 2010

[6] Kadić, A.”MOGUĆNOST FORMIRANJA HRVATSKOG TIMA STRUKTURNIH INŽENJERA UNUTAR EUROPSKOG KAPACITETA ZA ODGOVOR NA HITNE SITUACIJE (EERC)”, ZiS Journal 4(2), pp 94-108, 2024

[7] Kalač, S., Hodžić, J. and Lukač, D.”Improvement of the Safety System in the Railway Infrastructure of Montenegro”, TTTP 5(2), pp 57-63, 2020

[8] Railway Safety Directive 49/2004 / EC, European Commission, 2004

[9] Živojević, E. & Baručija, A.”KORIŠTENJE GEO-BIM PLATFORME ZA UPRAVLJANJE U KRIZNIM SITUACIJAMA I NA KRITIČNOJ INFRASTRUKTURI”, ZiS Journal 4(1), pp 94- 101, 2024

[10] https://eur-lex.europa.eu/eli/dir/2022/2557/oj/eng

[11] https://putevirs.com/korisnik/dokumenti/Zakon_o_javnim_putevima.pdf

[12] https://vladars.rs/sr-SP Cyrl/Vlada/Ministarstva/msv/pravniiadministrativniokvir/PublishingImages/Pages/default/ЗаконожељезницамаРепубликеСрпскеСлужбенигласник РепубликеСрпске-број2019-17

IDENTIFICATION AND MANAGEMENT OF CRITICAL INFRASTRUCTURE IN RAILWAY CROSSING AREAS - CASE STUDY CITY OF PRIJEDOR -

DOI: *10.70329/2744-2403.2025.5.10.1*

Scientific article

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ABSTRACT:

The paper analyzes safety risks in critical infrastructure in the areas of railway crossings, synthesizes problems, proposes measures, with special emphasis on emergency events at railway crossings in the area of the city of Prijedor. Emphasis is placed on identifying generators of safety risks for critical infrastructure through incomplete legal regulations that need to be changed. In the part of managing identified safety risks, the need for general application of standards and directives EN 2557/2022 is particularly emphasized, as well as the adjustment of national legal regulations regarding the geometry of the road axis in relation to the track, the mutual distance of railway-road crossings and the slopes of access roads in relation to the track, which is also emphasized in this paper. The visual environment from the aspect of the applied legal criteria that a railway-road crossing should meet is tertiary in this research manuscript. The above elements are necessary for securing railway-road crossings with a systematic approach to solving problems, which requires investments in order to enable safe traffic in conditions of increasing train speeds in the territory of the city of Prijedor.

Key words*: critical infrastructure, risks, safety, emergency, railway crossings.*

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1. Introduction

A level crossing (road-rail crossing) represents a four-legged intersection where two types of traffic intersect: road and rail. The technical, technological, and organizational characteristics of the railway have determined its priority at intersections compared to road traffic (by planners, organizers, and legislators), thereby defining the method of regulating traffic at the crossing.

Railway traffic, in a kinematic sense, is on one hand limited by the degree of freedom of movement, while on the other hand, in a dynamic sense, it generates significant kinetic energy during motion, resulting in a long stopping distance, and traffic occurs in compositions of rolling stock units. Road traffic is characterized by a higher degree of freedom of movement, individual vehicles, lower kinetic energy, and a shorter stopping distance.

Railway traffic requires strict regimes, i.e., the reliability and stability of both mobile and fixed capacities according to the composition of rolling stock units, whereas in road traffic, the roads on which vehicles move vary in quality—from ordinary rural roads to modern highways—and are highly branched.

To comprehensively address the resilience of entities critical to the proper functioning of the internal transport system, EU Directive 2557/2022 establishes a comprehensive framework concerning the resilience of critical entities against all types of hazards, whether of natural origin or caused by human activity, accidentally or intentionally [1], [10].

In accordance with provisions relating to critical infrastructure as well as national railway regulations, the intersection of a railway line and a road must be grade-separated in cases where the crossing experiences intensive traffic flow (over 7,000 vehicles per day) or when rail traffic is frequent (120 trains on a single-track line or 240 trains on a double-track line). Train frequency is determined by the railway, while road traffic flow depends on population mobility, economic activity, and the route choice of road infrastructure users [3].

Figure 1 schematically presents the basic elements and prescribed standards for the design and construction of a road at a level railway crossing.

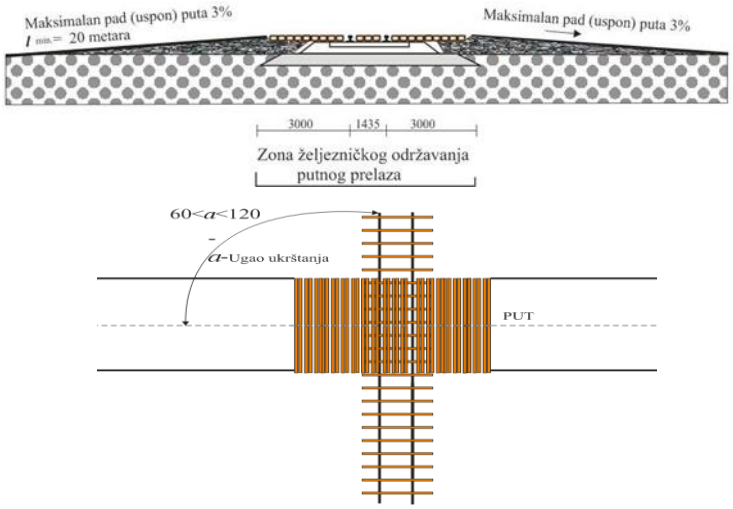

Figure 1. *Road crossing over a railway track in accordance with the prescribed standards*

On the railway infrastructure of the Railway Corporation in the Republic of Srpska, there are 278 level crossings, of which 259 are currently in operation.

Regarding safety, the following levels of protection are recorded:

- Sight triangle (259)
- Barriers (18)
- Light and sound signaling (1)

The standard prescribes that at a level crossing of a road and railway, the roadway must be level with the track gauge for a length of 3 m from the track centerline; beyond this, the road surface must not have a gradient greater than 3% over a minimum length of 20 meters and must be equipped with a modern pavement. Furthermore, the crossing must be at an angle of no less than 60 degrees and no more than 120 degrees.

Existing railway regulations, regulations governing public roads, and spatial planning regulations define traffic in the zone of a level railway crossing as follows [11], [12]:

- The intersection of a railway and a road, determination of locations where such crossings may be constructed, and the measures that must be taken to ensure safe traffic at level crossings are prescribed depending on

traffic flow and density, railway visibility, speed on the railway and the road, and other local conditions relevant to traffic safety.

- The intersection of a railway and a highway, as well as the intersection of a railway and a road within station areas between entry and exit switches, from which station tracks originate, must not be at the same level.
- The intersection of a railway and a road that is not classified as a highway must not be at the same level if motor vehicle traffic on the road is very heavy, if rail traffic is frequent, or if special conditions at the crossing site or other railway safety reasons require it.
- The minimum distance between two level crossings must not be less than 1,000 meters, or exceptionally 700 meters.
- Unclassified roads must be redirected to the nearest public road; if this is not possible, they should be connected to each other and the crossing constructed at a single location. The crossing location in each specific case is determined by the railway corporation and the local authority.
- The level crossing is considered an integral part of the railway on both sides of the track for a width of 3 meters from the track centerline, with an extension of the intersecting road for 20 meters, the gradient of which must not exceed 3%. The portion of the crossing within 3 meters from the track centerline is to be maintained by the railway corporation, while the remaining section is the responsibility of the road authority and the local administration in whose territory the crossing is located.

2. Data on Level Crossings

The railway traffic operator on the railways of the Republic of Srpska, "ŽRS" AD Doboj, prepared a Report on the Records and Condition of Road-Rail Crossings. On the railway section (Doboj)–Niševići–Svodna–(Novi Grad), from the Doboj–Novi Grad track kilometer 128+714 to km 165+350, as well as Omarska–Tomašica and Brezičani–Ljubija within the territory of the City of Prijedor, there are 63 level crossings (railway and road intersections), including 34 crossings on the (Doboj)–Niševići–Svodna–(Novi Grad) line, 10 crossings on the Omarska–Tomašica line, and 19 crossings on the Brezičani–Ljubija line [2].

Figure 2 schematically presents the Doboj–Novi Grad railway, where the shaded section highlights the level crossings analyzed within the territory of the local community of the City of Prijedor.

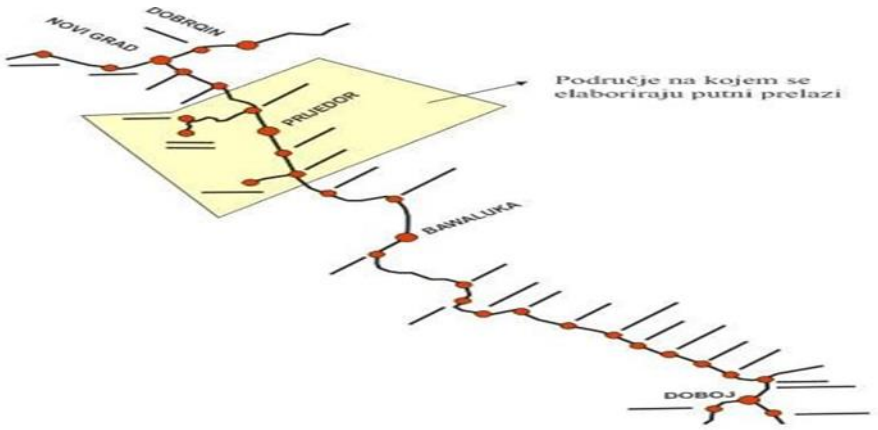

Figure 2: *Distribution of road-rail level crossings along the Doboj–Novi Grad route, highlighting the territory of the City of Prijedor*

Road traffic at these level crossings ranges from low to moderate and high intensity, with one crossing classified as "thirteenth." From this, it can be easily concluded that there is an unjustifiably large number of crossings, which significantly reduces the quality of the railway and its classification compared to other modern railways in the region. It is necessary to implement appropriate measures to reduce and secure level crossings in accordance with legal regulations, applying traffic, construction, urban planning, and economic criteria.

The current state of level crossings has been considered through the following characteristics:
A. Analytical presentation
B. Distribution of level crossings
C. Traffic safety at road-rail crossings
D. Visual and schematic presentation (through photographs and diagrams)

2.1 Analytical Presentation

In the territory of the City of Prijedor, there are 54 level crossings, of which 33 are protected by traffic signs on the access road ("Andrejin cross" and "STOP" sign) and a sight triangle, 2 crossings are additionally protected by a manually operated barrier, and 19 crossings on the Brezičani–Ljubija line are unsecured and out of operation.

Observing and analyzing the individual characteristics of the level crossings, it is evident that they represent a lower level of safety, with the following characteristics:

- Sight triangles are not provided at most level crossings;
- Intersections are secured with wooden sleepers;
- The crossing angle of the road and railway at 3 crossings exceeds the permitted limit;
- Road gradients are non-standard, significantly exceeding 3% (Figure 1).

Figure 1 shows the gradients of access roads in the zones of level railway crossings within the territory of the City of Prijedor.

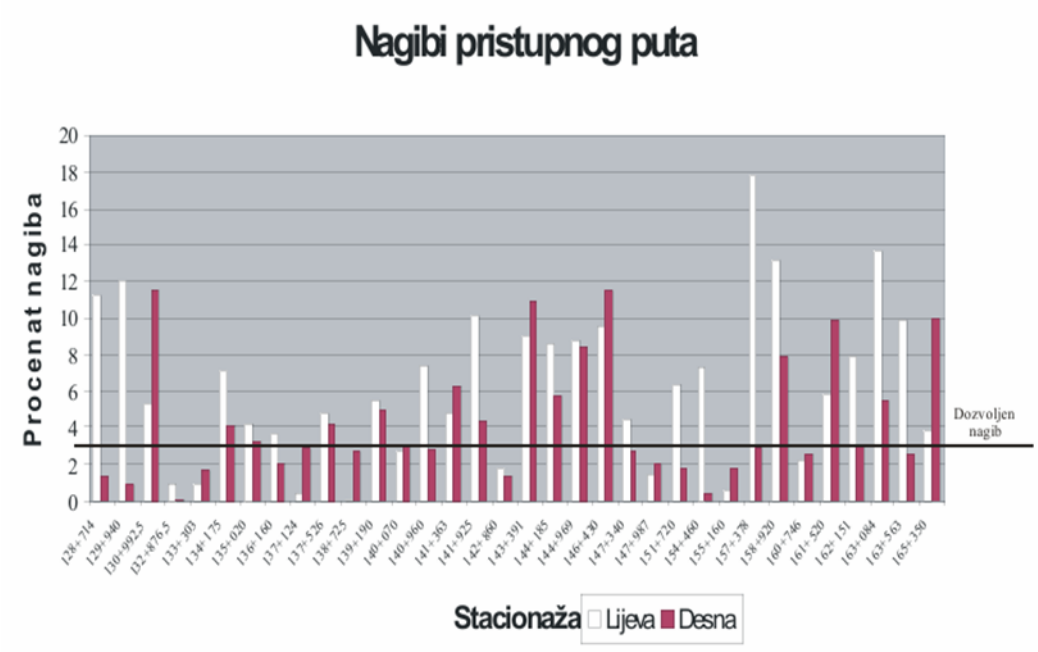

Figure 1. *Graphical representation of access road gradients*

In Figure 1, it is evident that the gradients of the access roads at most crossings exceed the permissible 3%, significantly compromising traffic safety at the crossings, especially during the winter period.

Furthermore, unfavorable conditions are apparent, complicating the situation in terms of traffic safety and quality, as follows:

- At a large number of level crossings, construction did not comply with legally prescribed conditions (technical documentation is missing).
- There are no officially enacted subordinate regulations that define in detail the conditions for designing, constructing, and maintaining level crossings.
- A certain number of crossings exhibit a significantly higher frequency of accidents compared to others, indicating the need for better technical solutions and the provision of additional material resources.
- In our country, there are insufficient licensed companies for equipping crossings, and the technical inspection and commissioning (traffic operation) of crossings in accordance with the Law are not clearly defined.
- At a smaller number of crossings, one or more legally prescribed conditions are not met (sight triangle, crossing angle, road gradient over 20 meters from the track centerline, minimum distance between crossings significantly shorter than legally required, etc.). This necessitates the elimination of major deficiencies and the direction of two or more public roads to a common crossing point, or the rerouting of unclassified roads to public roads.
- If it is not possible to comply with legal standards, crossings must be closed after providing residents with alternative access to their properties.

2.2 Distribution of Level Crossings

On the Ništevići–Svodna section, only 12 crossings are spaced more than 1,000 meters apart. Some crossings (Figure 2) are located less than 500 meters from each other, which is unacceptable for this specific railway classification.

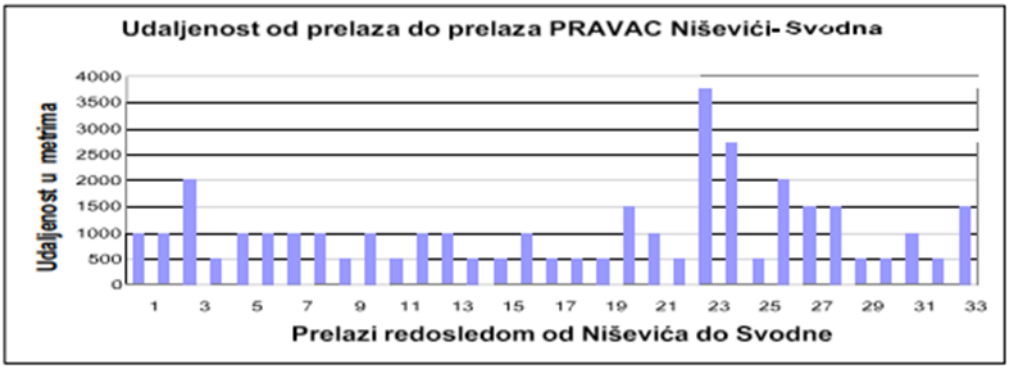

Figure 2. *Graphical representation of the spacing between level crossings on the Ništevići–Svodna section*

A small number of level crossings are spaced more than 1,000 meters apart, and the number of crossings with a spacing of 2,000 meters is negligible (only 3), which is highly concerning.

The Omarska–Tomašica railway (Figure 3) presents an even more complex situation. The distances between crossings do not exceed 1,000 meters. As shown in the figure, there are crossings with a spacing of just over 200 meters.

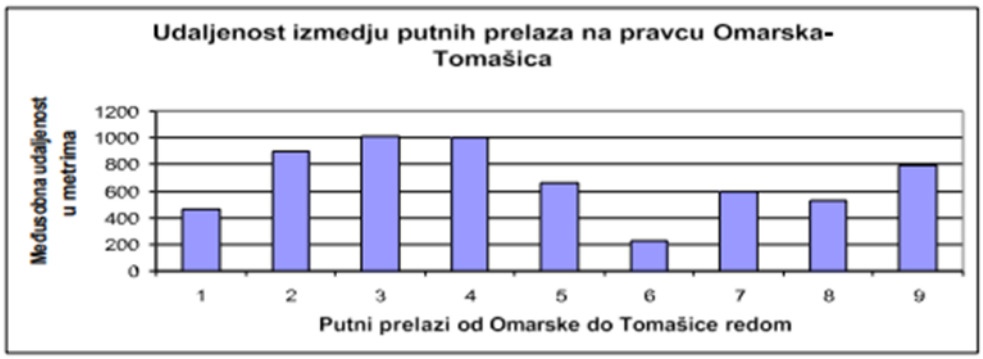

Figure 3. *Graphical representation of the spacing between level crossings on the Omarska–Tomašica section*

2.3 Traffic Safety at Road-Rail Level Crossings

An extraordinary event is defined as an incident that results in at least one of the following consequences: death, serious injury, material damage, traffic disruption, or endangerment or obstruction of railway operations. Extraordinary events at level crossings within the area covered by the railway corporation over a five-year period [4], [9] are presented in the Table.

Table 1*. Overview of extraordinary events at level crossings in the RS and in the territory of the City of Prijedor over a 5-year period*

S. num	TIME PERIOD	1. year		2. years		3. years		4. years		5. years		Total	
		ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD	ŽRS	PD
1	Emergency event on PP	25	3	14	1	20	4	22	3	20	1	101	12
2	Fatality		-		-	6	-	2	1	3	-	11	1
3	Severely injured	4	-	6	3	4	1	9	2	3	-	26	6
4	Traffic interruption (h)	3	2	13	1	36	6	24	5	19	-	124	14
5	Material damage	24	-	14	1	20	4	20	3	20	-	100	8

It is evident that level crossings within the territory of the local community of the City of Prijedor account for a significant portion of the total number of extraordinary events (12%), with 6 of the 26 serious injuries recorded in the Republic of Srpska during the observed period occurring there. Additionally, 14 railway traffic disruptions were recorded within the local community.

Considering the low train operating speeds, it can be concluded that the quality of transport is extremely low, directly related to safety objectives, which can only be achieved through low speeds in railway operations.

Figure 3 shows one of the photographed level crossings, which can serve as a representative example of the condition of crossings within the territory of the City of Prijedor.

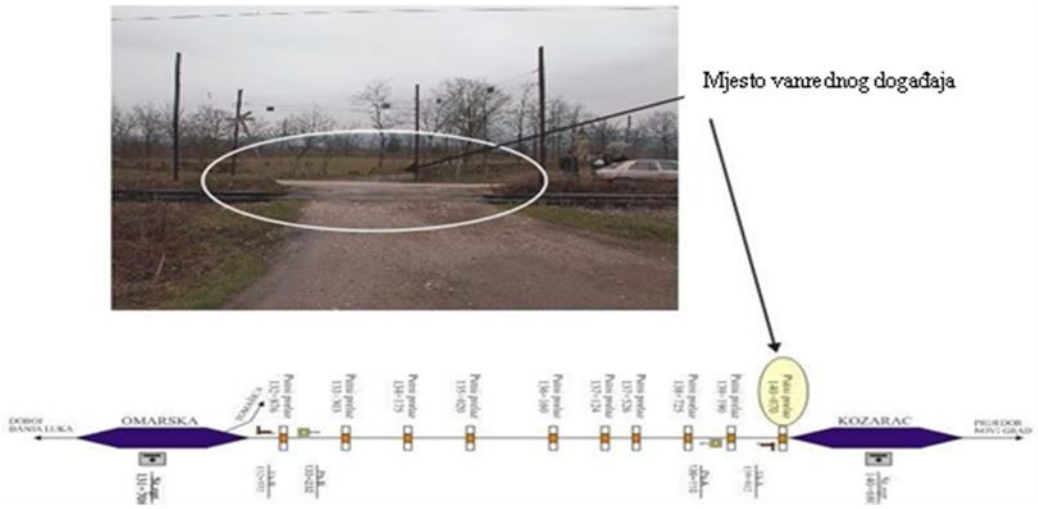

Figure 3. *Representative road-rail level crossing in the territory of the City of Prijedor*

3. Methodology for Addressing the Safety Issue

In order to increase traffic safety in the zones of level road-rail crossings, it is necessary to establish a methodological approach for ranking the criteria that influence managerial decision-making, particularly regarding the increase of maximum train speeds [5], [6], [7].

In this context, the responsibility of the road operator and the railway traffic operator is to determine the following conditions before making decisions (reconstruction, modernization, investments, etc.):

1. **Parameters of road traffic flow over the railway crossing:**

    - Vehicle flow
    - Traffic density
    - Speeds
    - Travel time of vehicles crossing
    - Unit travel time of vehicles crossing
    - Time intervals between successive vehicles
    - Vehicle spacing during crossing

2. **Visibility at the level crossing:**

- Good
- Partial
- Limited

3. **Position of the level crossing:**

- Crossing within a station
- Crossing on an open track

4. **Number of tracks at the level crossing**
5. **Number and nature of extraordinary events at the specific crossing**
6. **Geological, construction, urban planning, and legal conditions**
7. **Economic indicators**

The selected criteria are physical parameters that have a decisive impact on the safety level of a road-rail crossing and will serve in each individual case as the basis for determining the type of crossing protection. Based on these criteria, crossings are ranked to establish priorities in the design and modernization of crossings. In the specific case, it is necessary to determine the optimal number of crossings, design them according to technical, technological, and economic criteria, and assert the safety level for each individual crossing.

4. Conclusion

A large number of road-rail level crossings within the territory of the City of Prijedor, in most cases, are not urbanistically or constructionally legalized, meaning they were not designed and executed in accordance with regulations and standards. They emerged during a period of illegal construction of certain urban settlements, which were not previously aligned with the spatial planning acts of the local community.

During the legalization phase of these settlements, individual residential buildings were "remedied," but traffic planning, particularly the design of road-rail crossings, was not carried out. This allowed residents to address the issue individually or collectively, contrary to construction and traffic standards, and especially without the application of EU Directive 2557/2022, which regulates relations concerning critical infrastructure.

Since it is not possible to close individual crossings before providing residents with alternative access to their properties, the following activity periods need to be established:

- **Short-term periods**, involving better securing of existing crossings through traffic signage (vertical, light, and sound signals), sight triangles, and creating a database for future planning of level crossing reduction to achieve satisfactory solutions in the future.
- **Medium-term periods**, involving the preparation of spatial planning documentation for the expropriation of land within the railway protective zone, creating conditions for the construction of "collector" roads, which would precede activities aimed at reducing the number of road-rail level crossings.
- **Long-term periods**, involving the determination of the minimally required number of crossings and their spatial location, preparation of technical documentation, construction, and equipping of crossings using ITS – automatic traffic control at the road-rail crossing, ensuring safe train movement distances. Additionally, this includes the adoption of a national legal framework that regulates critical infrastructure and defines the entities responsible for its management.

LITERATURE

[1] Brunner, E. M., Suter, M.“International Critical Information Infrastructure Protection Handbook”, Center for Security Studies, ETH Zurich, 2009

[2] Dakić, B.“ Elaborat o putnim prelazima na ŽRS", Republička uprava za inspekcije poslove Republike Srpske, Banja Luka. 2008

[3] Đuričić, R., Bošković, B., Rosić, S.”European concept of railway safety”, Faculty of Transportation, Doboj, 2017

[4] DG-ECHO,”European Emergency Response Capacity”, Directorate-General for European Civil Protection and Humanitarian Aid Operations, 2015

[5] European Railway Agency (ERA), Railway Safety Management System, Version 1, 2010

[6] Kadić, A.”MOGUĆNOST FORMIRANJA HRVATSKOG TIMA STRUKTURNIH INŽENJERA UNUTAR EUROPSKOG KAPACITETA ZA ODGOVOR NA HITNE SITUACIJE (EERC)”, ZiS Journal 4(2), pp 94-108, 2024

[7] Kalač, S., Hodžić, J. and Lukač, D.”Improvement of the Safety System in the Railway Infrastructure of Montenegro”, TTTP 5(2), pp 57-63, 2020

[8] Railway Safety Directive 49/2004 / EC, European Commission, 2004

[9] Živojević, E. & Baručija, A.”KORIŠTENJE GEO-BIM PLATFORME ZA UPRAVLJANJE U KRIZNIM SITUACIJAMA I NA KRITIČNOJ INFRASTRUKTURI”, ZiS Journal 4(1), pp 94- 101, 2024

[10] https://eur-lex.europa.eu/eli/dir/2022/2557/oj/eng

[11] https://putevirs.com/korisnik/dokumenti/Zakon_o_javnim_putevima.pdf

[12] https://vladars.rs/sr-SP Cyrl/Vlada/Ministarstva/msv/pravniiadministrativniokvir/PublishingImages/Pages/default/ЗаконожељезницамаРепубликеСрпскеСлужбенигласник РепубликеСрпске-број2019-17