

# ASSESSMENT OF SOCIETAL VULNERABILITY IN CASE OF POWER FAILURE IN RAIL NETWORK

Michal Szatmári and Mária Lusková\*

University of Žilina, Faculty of Security Engineering  
Žilina, Slovakia

DOI: 10.7906/indecs.20.3.6  
Regular article

*Received:* 31 May 2021.  
*Accepted:* 31 December 2021.

## ABSTRACT

Vulnerability means the degree to which a reference object can withstand external or internal threats. The reference object can have a human, material character. The article will address the societal vulnerability due to a power failure in the rail network, and a specific event will be described in the form of a case study. Each part of the railway network, whether it be a depot, a station, a terminal, or others, is largely dependent on the supply of the electricity network to its functional elements in the system. To assess vulnerability, it should be quantified using available methods. Adequate measures must be taken to reduce vulnerability and a comprehensive protection system must be developed. These measures may be of organizational, methodological, or operational origin, but may also be a part of the system, such as subject protection, spatial protection, shell protection, or perimeter protection.

## KEY WORDS

social vulnerability, power failure, railway station

## CLASSIFICATION

JEL: L92, O18, R42

\*Corresponding author, *η*: [maria.luskova@fbi.uniza.sk](mailto:maria.luskova@fbi.uniza.sk); +421 41 513 6766;  
Univerzitna 8215/1, 010 26 Žilina, Slovakia

## INTRODUCTION

The railway station or the overall system of the railway network is dependent on the supply of electricity for the efficient functioning of most of the services and activities provided. Human resources can provide staff in the train set, for manual ticket sales, control of the operating rules of the object, but are unable to transport people and material by rail, process data on reservation tickets in the train set, monitor and detect unwanted persons who do not have verified access into specific rooms. In today's era of automation and technological advances, the company is much more vulnerable to the necessary condition of the necessary supply of electricity than in the past, when it was mainly the human factor that had to be considered.

The term vulnerability can be defined and examined from the point of several scientific fields. It is important to know the subject of the vulnerability study. Experts and authors have different definitions of vulnerability in their publications. Here are some examples:

- vulnerability can be understood as one of the characteristics of the environment, which is not unitedly defined, but it is assessed on the basis of various facts [1],
- the vulnerability of the advanced world is increased in particular by the growing complexity and interconnectedness of modern societies, the economic and technological systems of modern societies represent systems of nodes such as the city center and the connection between them, which can be a railway line or power lines, the interdependence of individual nodes and connections is so considerable that the failure of one can cause the collapse of the entire system [2],
- vulnerability generally means the property of any material object, technical device or social entity to lose the ability to perform its natural or established function as a result of external or internal threats of varying nature and intensity [3],
- the vulnerability of the object and the effect of the threat directly or indirectly condition the possibility of a greater risk [4],
- vulnerability is considered as a result of the interactions between physical (territorial) characteristics and the susceptibility and capacities of the socioeconomic system to adapt and cope with a specific hazard, expressed as a nondimensional index [5],
- vulnerability means a deficiency, weakness or condition of the analyzed asset, or entity, object, system, organization, region, or part thereof, that the threat may use to exert its adverse effects [6],
- vulnerability is the ability of a system and its components to accept hazard in the form of loss and damage [7],
- vulnerabilities are also represented by those parts of the object, or those elements of the protection system that do not provide the required degree of protection, they are a weak or easily overcome element, or create favorable conditions for attacking the object, increase the probability of an attack and its success [8].

In general, however, vulnerability is not a negative factor. Its negative impact will only be manifested if the threat uses the vulnerability of the reference object to achieve its goal. This means that the subject of research (material, people, resources, services, etc.) must be exposed to an existing or potential threat, which by its negative effect creates a causal chain of cause creating a possible consequence. The consequence of a negative event is already the overcoming of vulnerability.

## SOCIAL VULNERABILITY

The concept of vulnerability is originated from social sciences, and in the beginning it was almost exclusively used in the social sphere. In the article, the subject of research will be social vulnerability in the event of a power failure in the reference building of a railway station.

In security terminology, vulnerability is assessed semi-quantitatively, qualitatively and quantitatively. These methods consist of a verbal description, a numerical description, or a combination [8].

Social vulnerability is a complex issue that needs to be assessed from a variety of perspectives. A correct and objective assessment of social vulnerability requires answers to three questions [9]:

1. Who is vulnerable? The question aims to identify social actors.
2. What makes them vulnerable? The answer is to identify the phenomena and events that can cause existential problems for social actors or social systems.
3. Why are they vulnerable? In this case, we identify the root causes that predispose to exposure to negative phenomena and events [9].

Social vulnerability is a phenomenon difficult to measure, so groups of social indicators will be used to assess the level of social vulnerability. Usually, the variability of the fact being examined cannot be described with one indicator, and therefore whole groups of indicators are used, and the interpretation of the obtained data is then based on the combination of data found by the indicators. Social indicators are easily identifiable indicators that make it possible to examine or measure phenomena and processes in the social environment. They represent a complex usually created using quantitative methods, which provide data on the characteristics of social life. They have a dynamic character, change over time, they are the result of interactions between social actors and reveal some basic features of social reality. In general, the most commonly used indicators are derived from official statistics and are therefore used to assess the level of development of a company [9].

## CASE STUDY

The authors will examine the possible situation of a power failure at a railway station in the Slovak Republic. As the number of passengers by ZSSK railway transport in the Slovak Republic has tended to increase in the last 4 years (Table 1), it is necessary for passenger transport, as one of the railway transport services, to be as reliable as possible without the loss of trust of customers.

**Table 1.** Railway passenger transport statistics in the Slovak Republic by ZSSK for the period 2016-2019 [11].

Year	Number of passengers in millions
2016	65,61
2017	72,47
2018	73,81
2019	77,36

Disturbances in the electric power supply can originate from natural disasters, adverse weather, technical failures, human errors, labor conflicts, sabotage, terrorism, and acts of war. A disturbance has its starting point in an initiating event, i.e. a threat or hazard that is materialized [10].

In terms of time, we assume that a significant part of the electricity infrastructure has been damaged by extreme natural events. Resumption of electricity supply will be possible after a few days to weeks, unless a replacement solution is implemented, either in the form of construction of a replacement line at the site of the damage, or by the transport and installation of backup transformers in the affected substations. For the purpose of social vulnerability

assessment, the following scenarios and events have been determined, which may affect the reference object according to Table 2, where the risk carrier will be a natural disaster in the contribution and the scenario will always result in long-term power failure at the railway station.

**Table 2.** The natural factor causing the event with potential scenario.

<b>Event</b>	<b>Scenario</b>
Earthquake	Electrical equipment will lose its stability and power lines will be damaged.
Flood	The area in which the railway station is located is flooded.
	There will be flooding and short circuits in the server room of the railway station.
Landslide	The slope loses its long-term stability and falls apart, which damages the energy supply.
Wind spout	The wind will cause considerable damage to the power lines.

In Table 3, the social actors have been identified, as well as the kind of social phenomenon that makes them vulnerable, and why they are vulnerable in the potential event of a long-term power outage that affects them at a railway station.

**Table 3.** Who is vulnerable, what makes them vulnerable and why they are vulnerable.

<b>Who is vulnerable?</b>	<b>What makes them vulnerable?</b>	<b>Why are they vulnerable?</b>
Passengers reliant on rail transport	Impossibility to travel to work	Limited on the possibility of traveling by other means of transport
Unemployed	Penury	Education and qualifications
Children	Stress	Limited transportation options on the places
Seniors	Impossibility travel to the doctor	Social status
Persons with disabilities	Criminality	Disability

Passengers reliant on rail transport (do not own a car, do not have a driver’s license, etc.) in the event of a power failure, for example do not have the possibility to use another type of transport to the place of work or to a greater distance, so their options are limited. During a long outage and the impossibility to travel to work, they could lose their jobs.

Unemployed people often cannot afford road transport due to their financial prospect of approaching penury. They often rely on rail transport. In addition, they may be vulnerable to their lack of education and qualifications, making it very difficult for them to find a job that would lead them to a better economic and social situation. They often have only limited opportunities in employment, such as a part time job, seasonal employment agreement or occasional temporary job offers without long-term stable employment. Due to a long-term power outage at the railway station, they could lose the possibility of their work potential where it could be used.

Children may have the usual way of going to school or certain places by rail. In the event of a long-term power outage and a necessary change in the usual way, they can be affected by a sudden, unusual situation which can make them anxious. As children cannot drive a car, they have limited means of transport without the help of another person holding a driving license and a car or an alternative to public transport.

Seniors have a higher incidence of health problems and diseases than the younger generations. Many seniors have no one to transport them during the day to a larger city for a medical examination, and therefore, often use rail transport. A power failure at a railway station and the cessation of the operation of a long-term interval may lead to the cancellation of their original intention to receive medical assistance on a given date. This could cause potential future health problems or failure to obtain the necessary medication for their health problems. Their social status as people who are often reliant on the help of doctors makes them socially vulnerable actors.

Persons with disabilities due to a power outage at a railway station will potentially be forced to use another form of passenger transport. These people usually cannot afford to spend money on a taxi service and must therefore use other passenger transport options. Boarding places, for example public transport, are not necessarily in close proximity to a railway station, therefore these people are sometimes forced to cross sites which could be considered as crime magnets [12]. Potential attackers can see them as an easy target, as they have a predisposition to be unable to defend themselves as a disabled person against a robbery or violent attack.

For the purpose of assessing social vulnerability in the event of a power failure at the reference object of the railway station, the following three indicators have been determined, which contain their specific characteristics.

To assess social vulnerability, the Social Vulnerability Index (SVI) will be used, which will be calculated from the indicators and their specific characteristics of selected social actors. As mentioned in the second chapter, vulnerability can be assessed by various methods, and here the quantitative point method has been chosen. Point 1 means the minimum social vulnerability and, conversely, the highest point in the range of scoring is the maximum vulnerability. The individual indicators with their characteristics can be found in Tables 4-6. In Table 4, the age criterion intentionally varies by gender.

**Table 4.** Socio-structural evaluation.

Indicators	Point evaluation					
	Male			Female		
	1	2	3	1	2	3
<b>Age</b>	≤ 29	30-59	60+	≤ 19	20-49	50+
<b>Health Condition</b>	Healthy	Health problems	Half invalid / Invalid	Healthy	Light health problem	Half invalid / Invalid
<b>Qualification / Education</b>	Without qualifications / -	High School (HS)	University (U)	Without qualifications / -	High School (HS)	University (U)
<b>Type of family</b>	Complete / Incomplete	2 members and more	Solo	Complete / Incomplete	2 members and more	Solo

**Table 5.** Socio-economic evaluation.

Indicators	Point evaluation					
	1	2	3	4	5	6
<b>Employment</b>	Public administration	Private sector	Part-time job	Agreement on performance of work	Temporary job	Without work
<b>Source of income</b>	State	Businessman	Self employed	Reward for a specific work	Occasional income	State benefit / Pension / -
<b>Income size (SR conditions)</b>	$\geq 1500$ €	1499 - 1000 €	999 - 750 €	749 - 500 €	Living wage	Under level of living wage
<b>Housing conditions</b>	Own house	Own flat	Long term lease	Short term lease	Family	Hostel

**Table 6.** Socio-urban evaluation.

Indicators	Point evaluation			
	1	2	3	4
<b>Size of residence</b>	Regional capital	District town	Village	Sparsely populated areas
<b>Distance of residence</b>	$\geq 120$ km	$\geq 100$ km	$\geq 80$ km	$\geq 60$ km

For a comprehensive assessment of social vulnerability, we will use the Social Vulnerability Index (SVI), which was calculated according to the relationship [13]:

$$SVI = \sum_{i=1}^n p_i/n, \quad (1)$$

where  $p_i$  is the point evaluation of the characteristics of the indicator,  $n$  is the number of indicators.

The calculated values of the social vulnerability index can be included in Table 7, with the final assessment of social vulnerability for a given social actor and the characteristics of individual indicators. For social actors, Table 3 was used again, where an expert estimation determined 20

**Table 7.** Scope of social vulnerability index.

SVI	Assessment of social vulnerability
0-1,19	Low vulnerability
1,2-2,19	Medium vulnerability
2,2-3,19	High vulnerability
3,2-4,4	Very high vulnerability

possible alternatives or groups of communities using rail transport with their social indicators and characteristics. The minimum score is therefore 10 points for the indicators set, while the maximum score is 44 points.

As a critical threshold for social vulnerability, an unacceptable threshold of 2,2 has been set, which, according to the scope that has been chosen, represents a large and very high vulnerability. Overcoming the critical vulnerability threshold means that the negative consequence of a potential natural threat caused by a long-term power outage can have a serious impact, whether financially, socially or indirectly on the health of the social actors. The resulting values of the Social Vulnerability Index (SVI) from Table 8 can be compared with the acceptable threshold values of the range of the Social Vulnerability Index in Table 7.

In Table 8, following abbreviations have been used for indicators:

- socio-structural: S = Sex Male/Female, A = Age, HC = Health condition, Q = Education / qualification, ToF = Type of family,
- socio-economic: E = Employment, SoI = Source of income, IS = Income size, HS = Housing conditions,
- socio-urban: SoR = Size of residence; DoR = Distance of residence.

**Table 8.**Final assessment of social vulnerability (continued on p.274).

Social actors	Passengers reliant on rail transport												Σ	SVI
	S	A	HC	Q	ToF	E	SoI	IS	HS	SoR	DoR			
Unemployed	M	19	Healthy	HS	Complete	Private sector	Reward for a	≥ 1500 €	Long term	Regional capital	≥ 60 km	21	2,1	
	M	59	Health problem	-	Solo	Temporary job	Occasional	999 - 750 €	Long term	District town	≥ 60 km	31	3,1	
	F	22	Healthy	HS	Complete	Agreement on	Businessman	749 - 500 €	Short term	Regional capital	≥ 60 km	25	2,5	
	F	48	Healthy	-	2 member	Public administ	State	1499 - 1000 €	Own house	Regional capital	≥ 80 km	17	1,7	
	F	37	Health problem	U	Solo	Agreement on	Reward for a	999 - 750 €	Long term	District town	≥ 60 km	28	2,8	
	M	27	Healthy	HS	Solo	Without work	State benefit	Living wage	Hostel	Regional capital	≥ 60 km	35	3,5	
Passengers reliant on rail transport	M	54	Healthy	HS	2 member	Public administ	State	≥ 1500 €	Own flat	District town	≥ 120 km	15	1,5	
	F	37	Health problem	U	Solo	Agreement on	Reward for a	999 - 750 €	Long term	District town	≥ 60 km	28	2,8	
	F	48	Healthy	-	2 member	Public administ	State	1499 - 1000 €	Own house	Regional capital	≥ 80 km	17	1,7	
	M	27	Healthy	HS	Solo	Without work	State benefit	Living wage	Hostel	Regional capital	≥ 60 km	35	3,5	

Persons with disabilities				Seniors				Children					
F	F	M	M	F	F	M	M	F	F	M	M	F	F
33	52	45	37	67	65	74	69	14	13	16	12	47	
Half invalid	Health problem	Invalid	Health problem	Health problem	Half invalid	Invalid	Health problem	Health problem	Healthy	Healthy	Healthy	Healthy	Healthy
-	HS	HS	U	-	HS	U	HS	-	-	SŠ	-	U	
Incomplete	2 member	Incomplete	Solo	Solo	Complete	Solo	Solo	Complete	Incomplete	Complete	Incomplete	Solo	
Without work	Part-time job	Private sector	Private sector	Without work	Brigády	Without work	Public administ	Without work	Without work	Temporary job	Without work	Agreement on	
State benefit	Businessman	Self employe	Businessman	Pension	Occasional	Pension	State	-	-	Occasional	-	Occasional	
Living wage	1499 - 1000 €	≥ 1500 €	≥ 1500 €	749 - 500 €	749 - 500 €	749 - 500 €	Nad 1500 €	Under level of	Under level of	999 - 750 €	Under level of	749-500 € brutto	
Long term lease	Own flat	Family	Own house	Own flat	Own house	Own flat	Own house	Family	Family	Family	Family	Long term	
Regional capital	Regional capital	Village	District town	Regional capital	Sparsely populate	District town	Village	Sparsely populate	Village	District town	Regional capital	Regional capital	
≥ 60 km	≥ 120 km	Do 80 km	≥ 100 km	≥ 80 km	≥ 100 km	≥ 80 km	Do 120 km	≥ 80 km	≥ 100 km	≥ 80 km	≥ 80 km	≥ 60 km	
34	20	26	18	31	31	33	19	37	33	29	32	28	
<b>3,4</b>	<b>2</b>	<b>2,6</b>	<b>1,8</b>	<b>3,1</b>	<b>3,1</b>	<b>3,3</b>	<b>1,9</b>	<b>3,7</b>	<b>3,3</b>	<b>2,9</b>	<b>3,2</b>	<b>2,8</b>	



## EXAMPLE OF SVI COMPUTATION

A healthy passenger 54-year-old man reliant on rail transport with a high school education has a family of two members. He works in the public administration and receives a payment from the state over € 1500. He is also the owner of a flat. He lives in a district town located within 120 km from the place of power failure at the railway station.

Socio-structural evaluation according to Table 4: 2, 1, 2, 2.

Socio-economic evaluation according to Table 5: 1, 1, 1, 2.

Socio-urban evaluation according to Table 6: 2, 1.

Rated indicators added will give the value  $p_i$ :  $2 + 1 + 2 + 2 + 1 + 1 + 1 + 2 + 2 + 1 = 15$ .

The number of our social indicators is marked as  $n$  equal to 10. In the last step, these values can be used in the following formula to find out the final value of the social vulnerability for the social actor:

$$SVI = \sum_{i=1}^n p_i/n, \frac{15}{10} = 1,5. \quad (2)$$

The remaining values of the social vulnerability for all social actors were calculated in the same way.

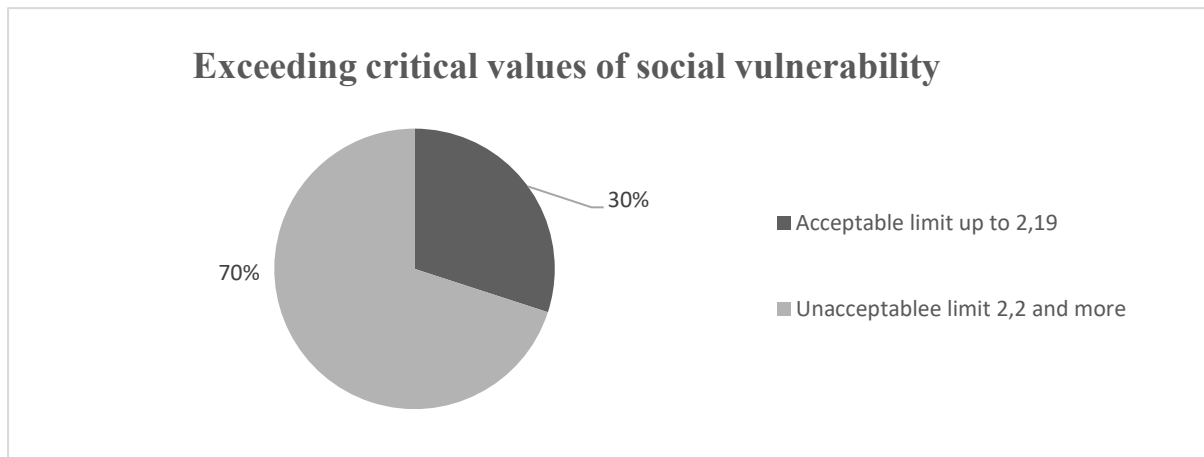


Figure 1. Resulted ratio exceeding critical values of the social vulnerability of our social actors.

## CONCLUSION

The results show that out of the 20 different types of social actors selected, the number exceeding the critical threshold of social vulnerability (Figure 1) represents 70 %, that is 14 of the total number, while at the same time 30 %, that is 6 social actors do not pass that threshold. Therefore, it has been found that the impact of a power failure due to a natural factor can endanger a significant part of the examined population. According to the results, the most socially vulnerable groups are children, the elderly and the unemployed, as together up to 10 potentially vulnerable social actors from these groups would have difficulties in continuing their activities, usual transport practices, finances, health, etc. From this result it is possible to conclude that in the event of a power failure, there may be a significant halt or even a decrease in the number of passengers using rail transport. The state, regional self-governing bodies or private investors could support other forms of public transport in the given locality, and this way, in the competition for customers using passenger transport services, they could threaten the vision and goal of the largest passenger railway carrier, ZSSK in Slovakia to transport up to 1 billion people a year by 2030. In addition to the various negative social impacts of this potential natural threat that prevents the supply of electricity and functionality in a certain section of the rail transport, escalating CO2 emissions can also be assumed, due to the increase in passenger car traffic, which would also damage the environment.

## ACKNOWLEDGMENT

This work has been supported by VEGA grant No. 1/0371/19 named “Societal vulnerability assessment due to failure of important systems and services in electricity sector” and the FP7 project No. 608166 “Risk Analysis of Infrastructure Networks in response to extreme weather”.

## REFERENCES

- [1] Gallina, V., et al.: *A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment*. Journal of Environmental Management **168**, 123-132, 2016, <http://dx.doi.org/10.1016/j.jenvman.2015.11.011>,
- [2] Hofreiter, L.: *The security environment of today's world*. In Slovak. Radim Bačuvčík-VerBuM, Zlín, 2016,
- [3] Hofreiter, L. and Halaj, M.: *The factors for security assessment of the organization*. <http://trilobit.fai.utb.cz/Data/Articles/PDF/66af11db-13d3-4636-a5c0-ca209fe40287.pdf>, accessed 15<sup>th</sup> March 2020,
- [4] Erasim, E. and Karagiannis D.: *Security in information systems*. In German. vdf Hochschulverlag AG an der ETH Zürich, Vienna, 2002,
- [5] Paron, P.; Baldassarre G. and Shroder, J.F.: *Hydro-Meteorological Hazards, Risks, and Disasters*. Elsevier, Amsterdam, 2018,
- [6] Cardona, O.D. and Carreño M.L.: *Updating the Indicators of Disaster Risk and Risk Management for the Americas*. Journal of Integrated Disaster Risk Management **1**(1), 27-47, 2011, <http://dx.doi.org/10.5595/idrim.2011.0014>,
- [7] Blišťanová, M.: *Vulnerability assessment as part of environmental analysis*. Metes Proceedings of the International Conference, Bratislava, 2017,
- [8] Hofreiter, L.: *Facilities security management*. In Slovak. Žilinská univerzita v Žiline/EDIS, Žilina, 2015,
- [9] Hofreiter, L. and Byrtusová, A.: *Security indicators*. In Slovak. Radim Bačuvčík-VerBuM, Zlín, 2016,
- [10] Murray, A.T. and Grubestic, T.H.: *Critical Infrastructure Reliability and Vulnerability*. Springer, Berlin, 2007, <http://dx.doi.org/10.1007/978-3-540-68056-7>,
- [11] ZSSK: *A number of modified roads*. In Slovak. <https://www.zssk.sk/vysledky>, accessed 25<sup>th</sup> March 2020,
- [12] Ivor, J.: *Criminology as part of a trust policy*. In Slovak. Leges, s. r. o., Praha, 2018,
- [13] Armas, J. and Gavriş A.: *Social vulnerability assessment using spatial multi-criteria analysis (SEVI model) and the Social Vulnerability Index (SoVI model) - A case study for Bucharest, Romania*. Natural Hazards and Earth System Sciences **13**(6), 1481-1499, 2013, <http://dx.doi.org/10.5194/nhess-13-1481-2013>.