

IMPACTS OF THE FAILURE OF SELECTED TRANSPORT INFRASTRUCTURE ELEMENTS

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Summary: History provides many cases in which the failure of transport of food and other materials led to great loss of lives and turnovers in wars. Therefore, the transport infrastructure is one of the main infrastructures that create a critical infrastructure in the area. The object of monitoring are thus not only the immediate impacts of selected critical components, but the whole cascade of potential impacts at selected time intervals during the loss of functionality of transport system; the whole supply chain is influenced at failures of critical items. The research objective is to monitor and subsequently evaluate the severity of the consequences of failure of two selected elements of transport infrastructure. These are studied impacts on public assets in two cases of failure: the critical section of the busiest highway; and bus station in the centre of a large city.

Key words: critical infrastructure, modified method What, If, impacts of the transport infrastructure failure.

INTRODUCTION

The critical infrastructure is a set of mutually interconnected networks, i.e. the systems of various sectors of human system. An interconnection of systems means the mutual dependence. Therefore, in linkage with the safe critical infrastructure and with sustainable development potential there is necessary to solve several problems, namely safety of partial infrastructures and safety of a set of mutually dependent infrastructures. The critical infrastructure is thus important for the humans' security and development, it ensures the continuity of economic and social life of a state (territory) and provides a response to threats or disruption of basic living conditions, services and systems, the operation of which is vital for a functioning state (territory).

The critical infrastructure protection means protection of buildings and networks, i.e. mainly intersecting linear structures in the human system, which simply represent such structures in the technical area. The basic strategic approach for the protection of critical infrastructure is: nothing is absolutely safe, and elements and networks of critical infrastructure may fail sooner or later. Protection of critical infrastructure (and any infrastructure) is a process which takes into account all possible risks and threats and is aimed at ensuring the functions of elements, links and flows of critical infrastructure, so that their

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failure does not under any circumstances. Protection is therefore not possible without risk identification, analysis and assessment.

Protection of infrastructures and of critical infrastructure is provided by preventive and mitigation measures, by preparedness of components, resources, facilities and equipment to cope with the impact of disasters and targeted attacks on critical infrastructure, by ability to handle critical situations and to ensure rapid recovery. The concept of ensuring protection comes from the fact that every system has elements, links and flows that make up the critical points, which can easily cause the system failures either to fulfil the function to which it is addressed or to significantly contribute to such non-function (their vulnerability significantly contributes to the vulnerability of the system). Principles of strategic management for critical infrastructure security recommend procedure based on a vulnerability assessment system derived from concept that the risk is equal (1) to a loss of functionality if following disasters occur: technological accidents (internal) of critical elements links and flows in the system (e.g., defects, aging, lack of maintenance); errors or control system failure, human errors, natural disasters or technological accidents (external) of another system, terrorist or criminal attack or act of war.

High-quality transport infrastructure and a wide range of transport services is a prerequisite for a healthy economic, social and environmental development of the region. Therefore, the area of transport and transport infrastructure is monitored in the annual statistical yearbooks and is one of the most important areas of EU aid. If infrastructure has to effectively assist the economic and social development, it must be built in advance, and must be functional.

The transport infrastructure has many critical spots that include the elements, objects and nets. In paper we only concentrate to two dissimilar elements with aim to show how to determine real impacts of their failure. In further paragraphs we concentrate to the road transport. Roads are divided into the following categories: highways (freeways); roads; local communications; purpose-built communication. Critical situations are divided by scope on:

- local, the subject of which are usually local roads, public authorities and their organization and their organizational units and equipment designed for their maintenance and renewal,
- regional, the subject of which are generally Class I and II roads, their administrative offices and organizations and their organizational units and equipment designed for their maintenance and renewal,
- national, the subject of which are usually national primary roads and highways, their administrative offices and organizations and their organizational units and equipment designed for their maintenance and renewal.

Given the fact that the critical situation on roads usually occurs due to external factors, their indications will depend on the type and extent of the initial threat or occurrence of a critical situation (e.g. due to flooding). Critical situations are solved by administrators.

To evaluation of the impact of critical situation should be based on specific local conditions and particularly on specific transportation needs of the territory. Each road transport has its reason and purpose: emergency (ambulances, fire-fighters, police, emergency

services for accidents, gas, water, electricity, etc.); supply (food, drinking water, medicines, various products, etc.); ensuring the availability of transport services for schools, offices, courts, medical facilities and employment; technological transport of raw materials, intermediate products and finished products; work and business trips; leisure (entertainment, culture, sports, recreation, etc.); extraordinary transportation (evacuation of persons, animals or property, removing the effects of natural or technological disasters), etc.

Following can occur in road transportation: restrictions or total closures of traffic on some roads, damaged bridges and road body; the slowing or stopping at the expense of maintenance, renewal, the slowing or stopping of the construction program. In other fields it is followed by the slowdown or cessation of other activities in the national economy.

Generally each transport infrastructure is composed of several different items that are essential for its function, important objects and networks are those that make up the linear structure of the area (3, 4). Objects of monitoring are:

- critical stretch of the busiest Czech highway,
- Bus station that is one of the basic elements of transport infrastructure. The implications of failure of the selected section of the public assets, not only immediate impact, but the whole cascade of potential impacts at selected time intervals.

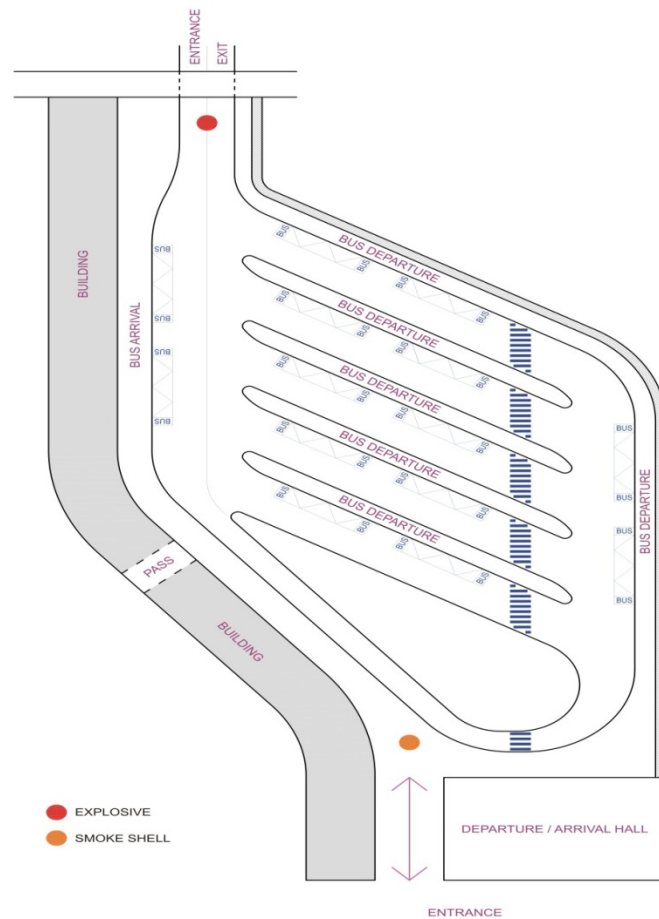
1. DATA USED FOR RESEARCH

There were performed two independent researches that are described as follows:

1. The impact investigation focused on the line element of transport infrastructure, stretch of highway was chosen, located in Vysocina County, which contains 34 kilometres of D1 highway. In terms of infrastructure, protection of the line elements is the hardest one (2, 3), because these are long stretches, the maintenance and repairs of which are time and resources consuming, and physical protection is almost impossible.
2. Based on a study of a terrorist attack in London in 2005 and a fire at Prague Florenc Central Bus Station (4) situational analysis was carried out on plans of large Czech bus stations with international transport. It was found out that there are large bus stations, which have only one entrance and exit for buses (Figure 1) and therefore research focused on the impact of the explosion where indicated.

In both cases there were used data on sites obtained from the documentation given in land-use plans and from the professional walk downs of selected sites. By expert judgement based on more than 30 years' experience the vulnerable items were found. In investigation the attention was just concentrated to these vulnerable places.

The data on impacts of followed items' failures were obtained by brainstorming; the group of 12 students of CVUT in Prague, Faculty of Transportation was selected and educated by way that their knowledge was concentrated to the unified understanding the infrastructure failure process and the integral safety. Their outputs were reviewed by experts who have knowledge and experience from responses to objects' failures.



Source: Authors

Fig. 1 - Scheme of situation

2. THE METHOD OF INVESTIGATION

To determine the cascade of impacts on public assets associated with the malfunction of selected sections of D1 highway or bus station, the modified method What, If (5) was used with aim to identify the impacts on protected assets at times 0h, 3h, 6h, 24h, 3 days and 14 days (0h is the beginning of loss of function):

1. Possible impacts on the human lives and health.
2. Possible impacts on the human security.
3. Possible impacts on the property.
4. Potential impacts on public welfare.
5. Possible impacts on the environment.
6. Possible impacts on infrastructure and technology: supplies of energy (electricity, heat, gas); water supply; sewerage; the transport network; cyber infrastructure (communication and information networks); banking and financial sector; emergency services (police, fire-fighters, paramedics); basic services in the area (food supply, waste disposal, social services, funeral services), industry and agriculture; and state and local authorities.

From the time of 3h secondary effects are observed that are associated with the interconnection between the assets of the human system.

3. IMPACTS OF FAILURE OF THE SELECTED SECTION OF THE D1 ON PUBLIC ASSETS

Scenario of emergency situation caused by the collapse of a highway bridge in Velke Mezirici is according to (6) as follows:

- 0h - the collapse of the highway bridge at Velke Mezirici, direct damage to persons, property, environment and infrastructure, located under the bridge and its surroundings, loss or damage to persons or property that were on the bridge, the destruction of critical infrastructure, the traffic accidents in both directions, one of the problem is damage of important railway being under the bridge,
- 0h10m - arrival of the Integrated Rescue System (IRS) to D1 and to the affected area and start of response work, including setting up crisis teams in communities located near the affected area,
- 3h - panic and confusion in the area under the bridge, i.e., in area of direct damage to people, property, environment and infrastructure located under the bridge and its surroundings; meetings of emergency crews and security councils of municipalities with extended powers, of neighbouring regions Vysocina and Southern Moravia, and of state, preparation of supporting response with material, technical and financial aid, information in the media,
- 6h - evacuation of people, property preservation and restoration of infrastructure activities, which are located under the bridge and its surroundings; arrival of technology and expertise of the Armed Forces and the civilian companies to provide a replacement bridge, deepening problems in the surrounding villages, the definition of pass routes, diverting congestions on surrounding roads,
- 24h - stabilization and preparation of the draft for restoration of damaged areas, a complete closure of the D1 section between 104th and 153rd kilometre, increased traffic volume within a radius of 40 kilometres from the monitored point.
- 3 days - the preparation of recovery of the affected area, closed section D1, bridge replacement and efforts to re-launch,
- 14 days - restoration of the affected area under the bridge and help of municipalities, counties and the state to affected people, stabilization operations in the surrounding villages, the distribution of automobile traffic; start of work on the final restoration of the bridge.

The results of the investigation, the effects of failure of the selected section D1 on protected assets are in Tables 1 to 6 (6).

Tab. 1 - Impacts on human assets at the time of 0h

Protected asset	Impacts
The lives and health of humans	Injury and death of direct participants in the accident which caused the bridge failure. Direct losses and damage to lives and health of people who are under the bridge and its surroundings. Limited population movements due to increased dust.

Human security	Stress and shock of direct participants and eyewitnesses of the accident. Nervousness of drivers in the starting jam. Panic and loss of safety for people in the area of direct damage.
Property	Property damage at direct participants such as cars crash, highway damage, damage to buildings under the bridge. The possibility of injury or death of animals in the area under the bridge and possibly related to traffic accidents (e.g. transport of farm animals - if the vehicle is part of the accident). Damage of important railway being under the bridge.
Public welfare	Shock, despair at people in the area of direct damage.
Environment	Increased dust. Pollution of the river. Broken trees in the area under the bridge.
Infrastructures and technologies	Interruption of power lines under the bridge and the subsequent power cuts throughout the neighbourhood. Damage of important railway being under the bridge.
	The emergence of congestions in the vicinity of the accident. Interruption of traffic on road No. 360 in the fall of the bridge.

Source: Authors

Tab. 2 - Impacts on human assets at the time of 3h after the loss of functionality

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Finding the wounded and victims in the rubble in the area of direct damage under the bridge. In winter there is hypothermia accident, injured have a lack of fluids.	Other injuries and human deaths due to accidents in the caused by traffic jams. Lack of alternative accommodation for people whom fallen bridge damaged or destroyed dwelling.
Human security	Fear, shock, panic and loss of security in the area of direct damage.	Fear about the future in area of direct damage. The activities of criminal elements.
Property	Damage to property (vehicles, cargo, real estate) as a result of accidents in the secondary jams.	Loss of property caused by thieves. Destruction of property in the area of direct damage under the bridge due to domino effects, such as fires.
Public welfare	Fear among people.	Nervousness from loss of comfort due to increased traffic volumes.
Environment	Generation of waste and contamination of components due to redevelopment work.	Increasing contamination of components and quantities of waste.
Infrastructures and technologies	The continuing power failure.	Installation of alternative sources of electricity.
	Interruption of traffic on road No. 360 caused by the fall of the bridge. Damage of important railway being under the bridge.	Increased traffic on surrounding roads. Interruption of public transport and goods transport by N - S railway.
	High load of telecommunications network.	
	Lack of personnel and material in hospitals, hospitals at full capacity. Time delays in the treatment of injuries.	Lack of staff, beds and medicines.
	Possible delay in supply.	Possible damage to perishable goods.

Source: Authors

Tab. 3 - Impacts on human assets at the time of 6h after the loss of functionality

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Evacuation of people who are located under the bridge and its surroundings. Fatigue of people in cars, exhaustion due to dehydration and lack of medicines, the possibility of hypothermia in the winter. Lack of food people in the towers. The growing problem with liquids.	Occurrence of accidents due to driver fatigue. Injuries due to increased traffic on surrounding roads. Extension of time travel. Deepening problems with increased traffic volume. The persistence of the problem.
Human security	Loss of safety for people in the directly affected area under the bridge. Deepening of stress for drivers and people living in municipalities at diversion roads.	The emergence of conflicts and injuries. The activities of criminal elements.
Property	Damages to cargo costs due to standing in a jam.	Damage to property in the area directly affected by the debris of the bridge due to domino effects.
Public welfare	Restrictions on social life, the persistence of anxiety and conflict. Loss of security.	The activities of criminal elements.
Environment	Deterioration of air quality in the alternate routes, noise and vibration. In the case of an accident with a release of water pollutants potential threat to surface and groundwater and soil.	Further contamination of components and other waste in the area directly under the bridge.
Infrastructures and technologies	The continuing power failure.	Replacement power supplies do not cover all needs. Interruption of heat supply and gas due to lack of electricity directly in damaged area.
	The emergence of threats to drinking water supplies in disaster areas in case of release of hazardous substances.	Interruption of water supply due to lack of electricity directly to the damaged area.
	The capacity of the raids and exits on the highway is exhausted Problems on important railway being under the bridge.	Increasing pressure on alternate routes. Interruption of traffic on Highway No. 360th. Interruption of public transport and goods transport by N - S railway.
	Use of alternate routes.	Overloading of tour routes, traffic control failures in the villages at detour routes.
	Delays in supply, manufacturing plants supply constraints	Extension of delivery dates.

Source: Authors

Tab. 4 - Impacts on human assets at the time of 24 hours after the loss of functionality

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Injuries due to increased traffic on surrounding roads. Comfort due to reduced congestion, long time arrivals.	As a result of increased traffic intensity threat to public health communities on alternate routes. The power failure affects the lack of food and drink (fridge leak).
Human security	Nervousness of drivers, passengers and interested citizens.	Increase in crime activities.
Property	Damage to private property on the alternate routes.	Damage caused by domino effects.
Public welfare	Impaired access to schools, employment, hospitals and offices.	Lack of food - people's dissatisfaction.
Environment	Contamination of components, quantities of waste	Accumulation of waste and contamination from the response works i.e., the necessary technical work.
Infrastructures and technologies	Workaround for D1. Insufficient capacity of alternate routes.	Insufficient capacity of alternative sources of electricity and the resulting lack of supply capacity of water, heat and gas.
	Increasing demands on staff to control traffic in towns on alternate route.	Interruption of water supply due to lack of electricity directly to the damaged area.
	Problems on important railway being under the bridge.	Interruption of public transport and goods transport by N - S railway.
	Many current problems for public administration.	Lack of resources for recovery. Lack of qualified experts to determine appropriate response measures and activities.
	Delayed supply of people and production companies (just-in-time, kanban).	Decrease in production due to lack of raw materials or parts.

Source: Authors

Tab. 5 - Impacts on human assets at the time of 3 days after the loss of functionality

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Injuries due to increased traffic on surrounding roads. Reduction of comfort due to the increase of truck traffic in small towns. There is still a problem.	Problems in the supply of food, water and medicines. Respiratory difficulties. Deterioration of health due to mental problems.
Human security	Growth of psychological damage in people with loss of home and people living at alternate routes.	Criminal activities.
Property	The possibility of disruption of building structures (e.g. sites) on alternate routes due to increased trucking traffic.	Mass thievery
Public welfare	Impaired accessibility persists.	People from the damaged area will

		begin to understand the consequences of the situation and fear for the future.
Environment	Contamination of components, quantities of waste	Damaged forest and ruined fields (possibly with crop) under the fallen bridge.
Infrastructures and technologies	Persistent increased traffic intensity.	Problems with restoring electricity supply, drinking water, gas and heating in the area under the bridge.
	Problems on important railway being under the bridge.	Interruption of public transport and goods transport by N - S railway.
	Public administration overwhelmed with problems	Public administration lacks the resources, and power.
	Persistent delays in supply, increasing the volume and frequency of supply.	Highly affected businesses end their activity.

Source: Authors

Tab. 6 - Impacts on human assets at the time of 14 days after the loss of functionality

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Suicides of unstable people in directly affected area. Lack of sleep for people at alternate routes.	Lack of food, drink and medicines due to the replacement operation of infrastructures.
Human security	Fear about the future among people in directly affected area.	Psychiatric disorders in affected persons. Criminal activities.
Property	Demolition of highly damaged buildings in the area directly affected. Damage to buildings and other property on the alternate routes.	Thievery
Public welfare	Complaints and requesting reimbursement for damage.	Requirements for determination of the new bypass routes and fast commissioning D1.
Environment	Problems with waste from the rubble, response and technical work associated with the replacement solution.	Slow removal of waste and debris due to lack of finances
Infrastructures and technologies	Highly inflated transportation on alternate routes.	The deterioration of the technical condition of the road on alternate routes.
	Problems on important railway being under the bridge.	Interruption of public transport and long-term deviation of goods transport – substitute for the N - S railway.
	Large recovery demands on the financial sector.	Inadequate or delayed recovery of the affected area.
	Higher demands on the work of public administration.	Possible failures of public administration.

Source: Authors

From tables 1 - 6 it is evident that the impacts of failure are very significant and that the longer the loss of functionality, the greater the economic loss and damage to people and the environment. It is true that public administration is prepared to some extent because there are diversion routes for D1 in the Vysocina region, which lead by the Class I roads (61 km) by road and Class II. road (77 km). According to the survey, which is given in (6), if the failure exceeds 14 days, capacity of bypass routes cannot serve as replacement of the broken section in the long term and also affects damage to public assets in the neighbourhood. This means that the solution of long-term outage of the monitored D1 section must be taken throughout the eastern part of the Czech Republic, i.e. not enough to take action at the regional level.

4. IMPACTS OF EXPLOSION AND SMOKE ON BUS STATION ON PUBLIC ASSETS

Impacts of explosion and smoke at bus station as identified by the examination (4) are given in Tables 7 to 8.

Tab. 7 - Immediate impacts of explosions and smoke on public assets

Protected asset	Impacts
The lives and health of humans	Loss of life and injury.
Human security	Stress, shock, disorientation.
Property	Damage to buildings, vehicles and personal belongings of direct participants in the explosion. Damage to commercial premises and equipment. Possible death of animals (dogs, cats) accompanying passengers.
Public welfare	Panic
Environment	Contamination of air as a result of an explosion. Damage to the ground. Leakage and fire of fluids from damaged buses.
Infrastructures and technologies	Disturbance of water pipelines, electricity power lines and other networks at the station and its surroundings.
	Blocking of entrances and exits of buses from and to the bus station.
	Restrictions on transport in the vicinity

Source: Authors

Tab. 8 - Impacts of explosion and smoke on public assets after 3h after the explosion

Protected asset	Impacts	
	Primary	Secondary
The lives and health of humans	Harm to rescuers.	Injury caused by power, water, gas failure, and the effects of fumes from the explosion.
Human security	Stress, shock	Fear of ability to reach destination
Property	Falls of the buildings due to static distortion	Occurrence of fires
Public welfare	Panic	Fear among people
Environment		Air pollution due to burning fluids. Increased dust. Contamination of groundwater.
Infrastructures and technologies	Lack of buses for transportation.	Overload of nearby stations. Failures in successions of the transport network.

	<p>Failure of public transport. The emergence of issues such as: carrier does not transport passengers to where they wanted operator of the bus station prohibits carriers departure / arrival, even though they paid a fee for using the bus station etc.</p>	<p>The pressure of passengers on transport companies (refund to pay the fare of the original ticket price, identification of replacement transports).</p>
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Source: Authors

The facts listed in Tables 7 and 8 show that the effects of loss of functionality of the basic element of transport infrastructure, such as bus stations, are very important and greatly affect the social and economic life of the city and its surroundings.

CONCLUSION

The above facts show that the impacts of loss of function of important sections of D1 are very significant. The investigation also showed that specific level of impact depends on the nature and characteristics of the transport network, i.e. it is highly site specific. A similar result was obtained also in other parts of the transport infrastructure, i.e. bus station. It is necessary to identify bottlenecks and take such measures ensuring that disruption of transport services does not exceed the tolerable limit and that impacts on protected assets were acceptable.

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