ASSESSMENT OF VULNERABILITY AND RISK OF LIFELINE SYSTEMS WITHIN THE FRAMEWORK OF THE RADIUS PROJECT FOR TASHKENT

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SUMMARY

Tashkent was one from 9 cities of case study selected by the Secretariat of the International Decade for Natural Disaster Reduction (IDNDR), United Nations launched in 1996 the RADIUS initiative (**R**isk **A**ssessment Tools for **Di**agnosis of **U**rban Areas against **S**eismic Disasters) with financial assistance from the Japanese Government . This paper describes an evaluation of a vulnerability both damage in lifeline systems and infrastructure of Tashkent carried out within the framework of implementation of IDNDR-RADIUS Initiative case study.

INTRODUCTION

Tashkent is one of the largest cities of Asia. It is the capital of the Republic of Uzbekistan, an important tourist centre of the region. It plays the important role in political, social, economic and cultural life of the country. The number of inhabitants is about 2,2 millions residents, occupied area – 362 square km. City is a large diversified industrial centre of Uzbekistan producing about 25% of industrial production of the country. The main branches are tractor construction and agricultural engineering, aircraft industry, electrotechnical engineering, metal working industry. Tashkent is located in region with a high level of seismicity (total number of earthquakes with intensity $4.0 < M < 7.5$ and macroseismic effect 6-7 ball on Tashkent territory since 1868 is 14, recurrence period of shocks with macroseismic effect for Tashkent: 6 ball - 20, 7 ball - 50, 8 ball - 100 years) and was exposed to influence of strong earthquakes already repeatedly in the past. Today seismic risk is higher than it was before.The problem of earthquake safety is a topical one for the city.

2. SOME CHARACTERISTICS OF LIFELINE SYSTEMS AND INFRASTRUCTURE OF TASHKENT

Vital activity of the city, especially for the recent 30 years, is provided with a complicated system of lifelines (Figure 1). To say the least there are in the city more than 3600 km of water-supply, 2300 km of sewerage system, 1600 km of heat-supply lines, 134 bridges of small, medium and large size, 20 large overbridges. Only for the recent 10 years 10 transport tunnels have been built. Total length of 30 pedestrian passages is more than 4 km. There are 30 km of engineering tunnels with diameter of 3.6 m and the subway. Total length of 3 lines of the subway will reach 50 km by 2000. Total length of main urban roads is 261 km, district roads - 1500 km.

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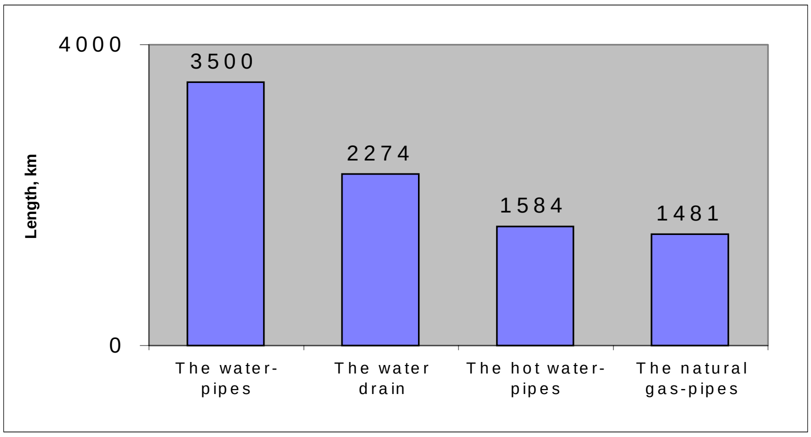

Figure 1: Length of underground communication on the territory of city

2.1 Water-supply system

Total volume of water- supply is 2457 thousand cubic meters a day, that is about one cubic meter per one citizen in average. The total water-supply system consists of 6 large water intakes, 86 pumping stations. Within the urban water-supply network there are 29867 wells and chambers, 30021 valves, 11506 fire hydrants. There are within the city 281 crossings with canals and ravines, 108 crossings with railways, 351 spillways. There are 105 crossings with operational subway lines and 38 with those under construction.

2.2 Sewerage system

There are on the territory of the city 6 large sewage water pumping stations. Within the urban networks and collectors there are 78 thousand wells and chambers, 30 emergency spillways, 40 artificial crossings of large diameters under railways and main roads, 48 crossings with subway lines.

2.3 Heat-supply

Heat supply system of the city of Tashkent consists of 12 heat centres, 130 small local boiler houses, 59 pumping stations providing with heat 70% of the population. An essential part of the heat supply system is presented by heat pipelines transferring heat as well as hot water to users - dwelling houses, administrative and industrial buildings and facilities.

2.4 Gas-supply

Gas supply system of the city presents a complex of 3 gas distributing stations, 49 controlling stations of high pressure, 18 pumping stations, more than 100 controlling stations of medium pressure. For gas lines steel pipes are used of diameter from 57 to 1020 mm

2.5 Power-supply

The city is supplied with electric power from 5 internal sources (Tashkent hydroelectric station, Tashkent thermal power station, 4 urban hydrous, 9 substations 220/110/10 and 62 substations 110/35/10) and 3 external sources (Charvak, Syrdarya and Novoangren electric stations), 124 distributing stations apply a voltage to 3200 transformers, connected with each other with more than 5000 underground cables and 2500 aerial cables. Main large facilities have loop networks from different power sources to maintain the continuity of supply. Main cable lines were put into operation during the period of 1950-1970 years and most of those lines have been deteriorated. About 50% of underground lines and transformers were put into operation before 1966 and 35-40% of them was constructed without antiseismic measures.
It was found that seismic influence of intensity IX would produce the following unrecoverable losses: substations 15%, transformers 50%, aerial cables 100% and about 15000 punctures along the cable routes.

2.6 The Subway

The disposition of Tashkent in a seismic active zone with loess soils having hydro-consolidation properties and high level of underground water has motivated the choice of certain design solutions destined for withstanding seismic influence. The main conditions of assuring of the seismic stability were constructive solutions providing braces in longitudinal and transverse directions. Using open-cut technique of construction of subway tunnels the whole-section casing with damping braces was first applied for the Tashkent subway. To provide uniform distribution of load on the bed of loess soils the foundation was designed in the form of monolithic reinforced concrete plate - station tray. Special anti-seismic measures were taken as well as against sinking There are two anti-seismic joints along the length of stations.

2.7 Bridges

There are 134 bridges on the territory of the city, 17 of which were built before 1947, 30 during the period of 1947-1966, 87 after 1966. Results of investigations show that 17 of 47 bridges built before 1966 have rather vulnerable points and they are subject to destruction under seismic excitation of intensity IX. The handling ability of many bridges and overbridges does not meet intensive road traffic. Approaches to bridges do not provide proper drainage and often supports are found to be bare, resulting in defects of bearing structures.

2.8 Pedestrian underpasses and transport tunnels

Construction of pedestrian underpasses has been activated for recent years because of construction of highways and the subway. Underpasses those serve as entrance to the underground stations is designed seismic resistant along with other station structures. As for other pedestrian underpasses not connected with the subway, as materials of interview show, they are seismically vulnerable. Tunnels received wide extension for recent years. They are designed using seismic considerations, but workmanship quality often does not meet proper requirements.

2.9 Engineering tunnels (collectors)

To improve laying of engineering lines (water, gas, heat, power supply) for recent 25-30 years about 30 km of tunnels have been constructed. They have circular cross-section with diameter of 3.6 m. Tunnels are assembled of 8 blocks mounted over stud bolts. Anti-seismic braces for these blocks have not been considered in the design. Engineering tunnels of shallow laying run through loess soils having hydro-consolidation properties. Investigations conducted show that in case of seismic influence of intensity IX about 30% of engineering tunnels would be damaged.

2.11 Urban roads

There is more than 2000 km of urban roads. Automobile roads are situated on plain places. After 1966 earthquake damages to roads did not take place in fact. Some cases of cracking of roadway covering did not influence on the vital activity of the city. However there were side effects at places of crossings with ruptured pipelines, where large parts of roads subsided. That is why at the places of crossings should be provided additional jackets to prevent possible leakage of liquids and safeguard the roads.

3. DAMAGEABILITY AND VULNERABILITY OF LIFELINE SYSTEM AND INFRASTRUCTURE ELEMENTS

The issues of seismic vulnerability are drawing attention especially for recent years as far as growth of cities is related with development and complication of lifeline systems. For the city of Tashkent this question became as a topical after the earthquake of 1966. That time a detailed collection of information about damages to lifelines and their consequent analysis was implemented with the purpose to determine character and criteria of damageability of different underground structures mainly pipelines with different characteristics. On the Figure 2 a graph is shown presenting specific breakage ratio for water-supply systems for the period of 70 years for Tashkent.

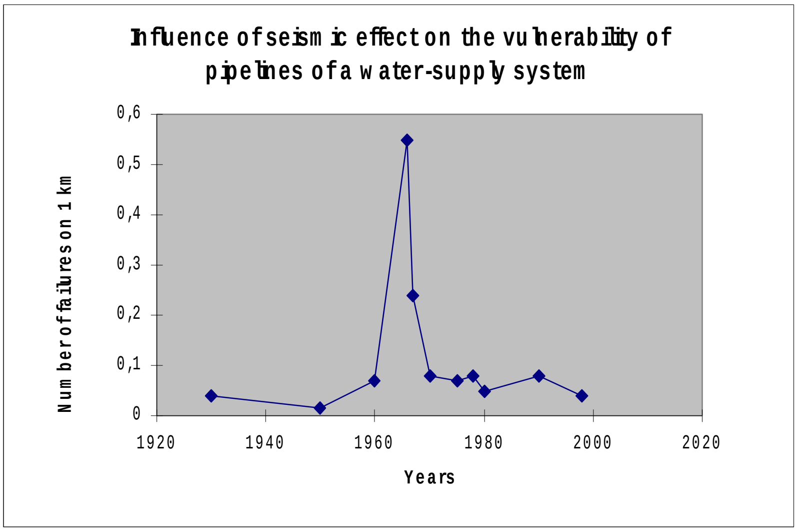

Figure 2: Influence of seismic effect on the vulnerability of pipelines of a water-supply system

It was found that damages to pipelines occurred mainly in the following:

- at places close to sharp turns, intersections through the rivers and ravines, and also at complicated junctions;
- at places of rigid junctions (using flanges and welding);
- at places of laying of pipelines in water-saturated soft soils having distinctive physical and mechanical properties;
- because of unsatisfactory quality of construction and non-observing building rules and standards.

Vulnerability depends on:

- depth of the underground pipelines
- diameter and material of pipelines
- fluid pressure of liquid in the pipeline
- type of junction;
- service life and maintaining conditions

On the base of the study of factual damage data from Tashkent earthquake and its aftershocks, numerous data from other earthquakes around the world and as result of calculations, we obtained relationships between specific breakage ratio for lifelines and seismic intensity. For these purposes all pipelines were classified into three categories A, B and C:

- А – socket-pipes of ceramic and concrete materials in lines without pressure;
- Б - socket-pipes of cast iron and reinforced concrete elements in lines without pressure;
- В – steel and reinforced concrete pipes in lines with pressure.

For each of the categories a graph presenting specific breakage ratio (vulnerability) versus seismic intensity was constructed as shown on Figure 3.

Damage grades of pipelines was classified in the following manner:

- **Minor to slight damage.** Non-considerable hairline cracks in sandy or asbestos stuffing of pipe coupling which have no influence on the regime of serviceability.
- **Moderate damage.** Deformation of joints of socket-pipes and breakage in pressure pipelines. Cracks in plaster of brick wells and chambers. Sometimes cracks in joints of reinforced concrete pipes. Mortar falls from the joints.
- **Heavy damage.** Bulging out joints of bell-mouthed cast iron joints and cracks in ceramic pipes, circular cracks in joints of concrete and reinforced concrete pipes collectors. Breakages in pressure pipelines causing to cutting off the damaged units. Cracks in walls of the wells and chambers, constructed of blocks and prefabricated elements. Cracks in siphons. Shear of ceramic pipes at places of their connection to inspection chambers. Disruption of gate valves on pressure pipelines.
- **Destruction.** Considerable number of breakage of ceramic, cast iron and asbestos pipes. Circular cracks in reinforced concrete pressure pipelines, longitudinal and cross cracks in walls of brick collectors, some

disruptions of joints of asbestos and steel pipelines. Damage to siphons and steel reducers. Deformations in structural elements of wells and chambers. Vertical shear of ceramic pipes oriented perpendicular to main pipeline, chipping-off parts of bell-mouthed joints. Considerable damage to gate valves and fittings.

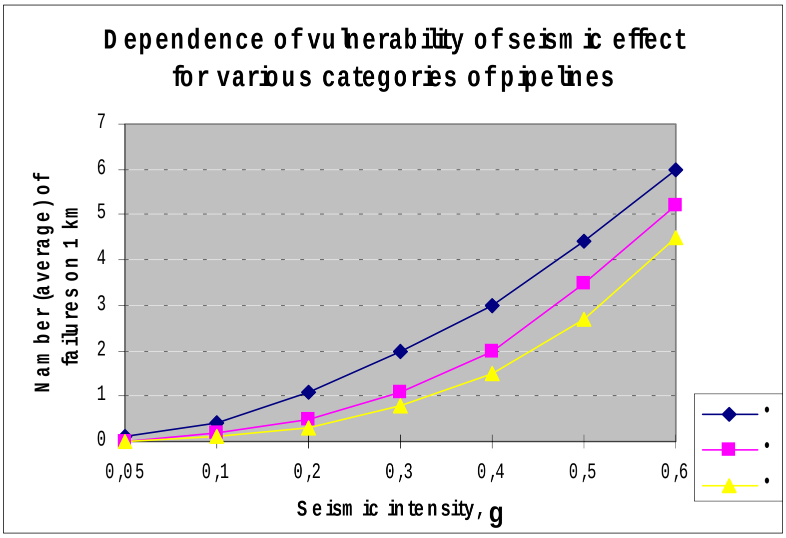

Figure 3: Dependence of vulnerability of seismic effect for various categories of pipelines

4. EVALUATION OF LOSSES FROM SCENARIO EARTHQUAKE

Estimations of damages to lifelines resulting from the scenario earthquake were obtained on the base of using the scenario map of seismic intensity distribution, prepared by the Institute of Seismology of Uzbek Academy and taking into consideration localisation of lifeline networks on the territory of the city. Specific breakage level and damage to elements of lifeline systems were calculated and damage maps were compiled for water-supply system , sewerage system , heat-supply system , gas-supply system and infrastructure of automobile roads, bridges, tunnels, subway . The indexes of a vulnerability of lifeline pipes are shown in Table 1 for zones with various seismic intensity from scenario earthquake.

Table 1: Indexes of vulnerability of lifeline pipes

Name of the lifeline systems	Vulnerability (number of breakage's per 1 km)			
	VI (MSK)	VII (MSK)	VIII (MSK)	IX (MSK)
Water supply	0.0-0.2	0.2-0.5	0.5-2.0	2.0-5.0
Sewerage system	0.0-0.4	0.4-1.1	1.1-3.1	3.1-6.0
Gas supply system	0.0-0.1	0.1-0.3	0.3-1.5	1.5-4.5
Heat supply system	0.0-0.2	0.2-0.4	0.4-1.6	1.6-4.5

The map of distribution of damages of the infrastructure elements (highways, bridges, tunnels, subway) from scenario earthquake is shown as an example on Figure 4 .

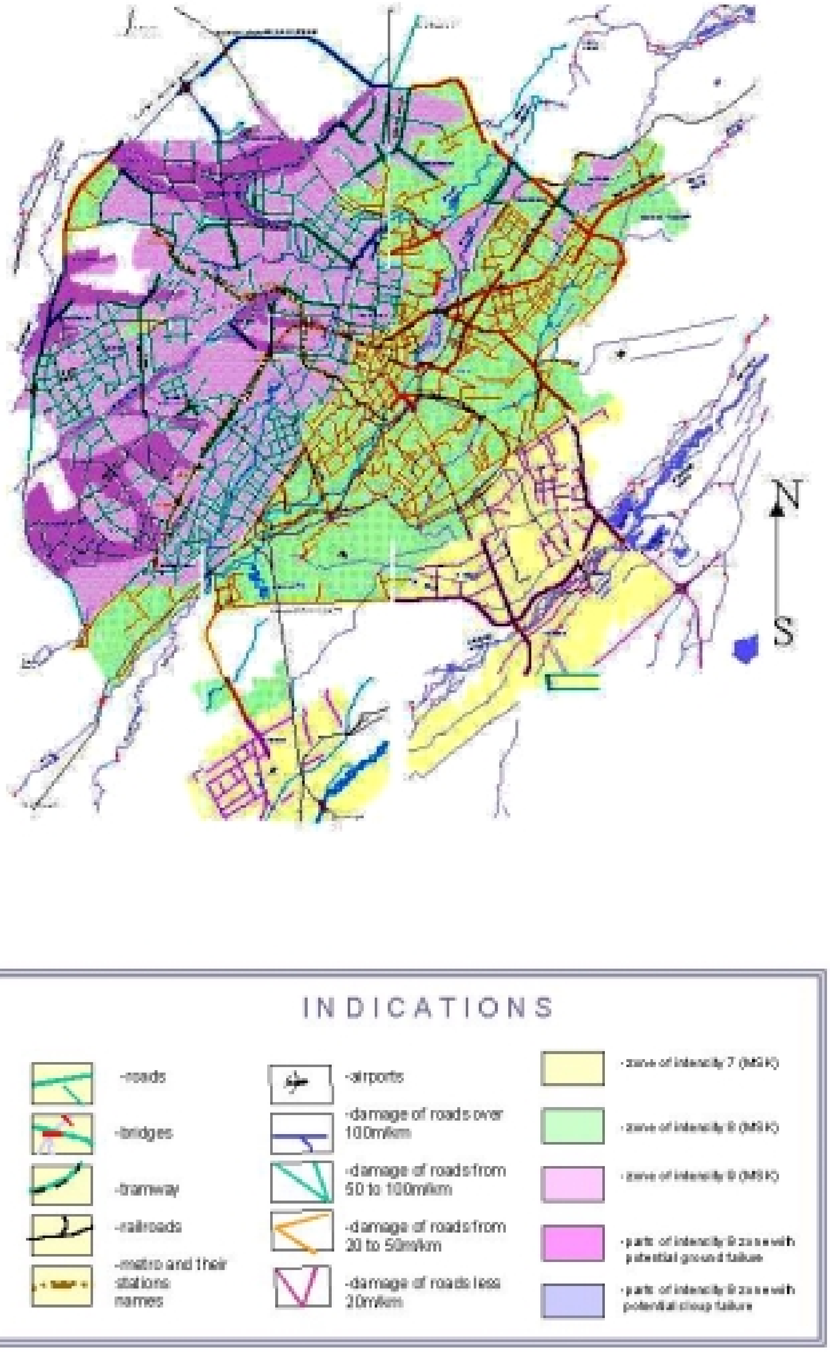

Figure 4: The map of Tashkent infrastructure elements

It was compiled by T.Rashidov, V.Kryghenkov, V.Omeljanenko, T.Abdullaev, A.Ishankhodjaev, M.Kuzmin, E.Kuzmina

In view of lack of data there have not been taken into account possible losses from the scenario earthquake from such units as airport, railway stations and terminals, tram and trolley-bus lines, heat-centres and some other urban elements, damage to which may cause additional losses about $US230 million. For positions from 1 to 4 of the Table 2, taking account transition to national currency and extremely low rate of basic funds fixed at the level of 1991, a coefficient 5 was applied. Thus, total losses for lifeline systems and infrastructure from the scenario earthquake are estimated as equal to US$ one billion.

Table 2: Integrated table of estimated losses both of lifelines and infrastructure elements

NN	Lifelines and infrastructures	Calculated losses US$
1.	Water-supply - pipelines; - facilities and equipment	 110.0 20.0
2.	Sewerage: - pipelines; - equipment	 80.0 13.0
3.	Heat-supply: - pipelines; - facilities and equipment	 55.0 45.0
4.	Gas-supply: - pipelines; - facilities and equipment	 65.0 1.5
5.	Power supply	231.0
6.	Subway	15.0
7.	Bridges, tunnels, inter-crossings	78.6
8.	Automobile roads	17.4
9.	Overbridges	5.6
10.	Underpasses	8.4
11.	Engineering collectors	24.6
	TOTAL	**770.1**

Received results regarding to vulnerability of lifeline systems were used by City Emergency Department for development of the plan of actions at probable earthquake. The risk management plan for Tashkent include the following initiatives regarding to vulnerability reduction of lifeline systems :

Energy, gas, heat, water supply, and sewerage

- To make the total inventory of the energy, gas, water, heat supply networks, sewerage, buildings, equipment, gas-distributive stations, and all pumping station
- Substitution of all air-lines of energy, gas, heat supply by the underground ones with regard for antiseismic measures
- Improvement of seismic stability of underground networks by substitution of old underground lines
- Improvement of seismic stability and safety of places of crossing of engineering networks with the most important constructions (metro, bridges, tunnels, overbridges, pedestrian passages, etc.)
- Improvement of new energy supply lines
- Improvement of seismic stability of substations, pumping stations in the system of energy, gas, heat, water supply
- Improvement of seismic stability of the heat networks and reduction of heat waste
- Reduction of risk and losses in the lifelines caused by the secondary sources of disasters (fire, floods, explosions, etc.)
- Complex of scientific and experimental studies of the ground conditions for laying of engineering communications with maintenance of seismic precautionary measures
- Substantiation and creation of research centre for underground life-line systems of Tashkent

Metro, bridges, overbridges, tunnels, pedestrian passages

- Improvement of seismic stability of the Tashkent metro
- Improvement of seismic stability of the engineering manifolds constructed for laying of engineering communications
- Enhance the responsibility for infringement of the norms of seismostability when constructing unique underground constructions and communications

- Improvement of seismic stability of pedestrian passages and typification of their designs
- Take the constant control of large-scale constructions and their elements

The developed initiatives entered in the action plan should covered 3 stages of the event expected:

- before the earthquake: a long period of development of the society. During this period it is necessary to prepare for future scenario earthquake reducing seismic vulnerability of the city;

- right away after the earthquake: a short-term period (no more than 1 month) during which the most necessary measures for emergency liquidation should be taken;

- after the earthquake: a long period lasting few years and connected with elimination of the scenario earthquake consequences.

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