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ORIGINAL ARTICLE

Research of a Problem of Terrorist Attacks in the Metro (Subway, U-Bahn, Underground, MRT, Rapid Transit, Metrorail)

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Abstract This study considers the problem of protecting metros against terrorist attacks. We have collected statistics on all terrorist attacks committed in the metro since 1883, and we have analyzed the efficiency of technical security systems deployed at the metro. The analysis conducted showed that technical systems employed presently in metros cannot prevent bringing explosive devices of a certain type into the metro. Mathematical calculations make it possible to establish the assigned risk of delivering explosive devices of a certain type into metros. The research offers a possible way of increasing the level of security in the metro against the conveyance and use of explosive devices.

Keywords Metro · Subway · Terrorist attack on metro stations · Act of terrorism in the subway · Statistics on all terrorist attacks in the metro

1 Introduction

The terrorist attack in the Saint-Petersburg Metro (Russian Federation) committed on April 3rd 2017 showed the urgency of the problem of protecting metro systems from terrorist acts.

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The metro system is a critical and fundamental urban infrastructure (Deng et al. 2015). Numerous metro terrorist attacks expose the vulnerability of metro systems (Shvetsov 2015a).

The analysis showed that from 1883 to 2017, 39 terrorist attacks were committed in the metros of London, Paris, Moscow, Tokyo, New York, and other metros of the world. These terrorist attacks resulted in 745 fatalities and 8971 injuries.

Statistics of terrorist acts at metro systems around the world are shown in Tables 1, 2, and 3.

92.3% of terrorist attacks in the metro were committed with explosive devices (Table 3). This proves that potential terrorist threats committed with EDs constitute the major threat for metros. Other possible tools and ways of terrorist attacks are described in (Matsika et al. 2016; Shvetsov and Shvetsova 2017; Dietrich et al. 2017; Nehorayoff et al. 2016; Shvetsov et al. 2017b; Ackerman 2016).

Acts of terrorism committed in the metro resulted initially in equipping metro stations with technical security systems aimed at ensuring anti-terrorist security (Muratov 2015a; MMSS 2017).

Technical security systems are intended for detecting prohibited objects (including weapons and explosive devices) hidden under clothes and in the baggage of incoming passengers. According to the Moscow Metro Security Service, in 2016, the inspection of incoming passengers resulted in the detection of 77,000 prohibited objects including army hand grenades and antitank rocket launcher (MMSS 2017).

Technical security systems are deployed at the Security check zones located in the entrance halls between the entrances into metro stations and turnstiles.

Technical security systems deployed at the metro are structured in Table 4.

According to the information of the Saint-Petersburg Metro Security Service (Russian Federation) by April 3rd 2017, 95% of stations were equipped with the technical security systems listed in Table 4 (SPMSS 2017). However, this did not help to prevent the terrorist attack in the Saint-Petersburg Metro on April 3rd 2017.

To prevent new terrorist attacks, we need to investigate the reasons for the insufficient level of anti-terrorist security in the metro system even after equipping stations with technological security systems.

2 Literature Review

The literature review consists of a brief review of the historical highlights and research studies pertaining to terrorist attacks in the metro during the past 134 years.

Between 1885 and 2017, metro systems of 14 countries of the world have suffered 39 terrorist attacks (Tables 1, 2).

The terrorist attacks mentioned below exemplify the most notable of them:

July 7, 2005 London (UK): suicide bombers almost simultaneously put into action explosive devices in three metro trains between stations «Aldgate» and «Liverpool Street», «King's Cross» and «Russell Square», and near the station «Edgeware Road». As a result, 52 people died, and over 700 people were injured (Shvetsov et al. 2017a);

Table 1 Terrorist attacks at metros of the world

Data, City, Country	Place of terrorist attack	Terrorist tool	Injuries	Fatalities
30-10-1883, London, UK	Station "Praed Street" ("Paddington") Station "Westminster Bridge"	Explosive device (ED)	40	0
20-01-1885, London, UK	Station "Gower Street" ("Euston Square")	ED	0	0
26-04-1897, London, UK	Station "Aldersgate Street" ("Barbican")	ED	60	1
04-02-1939, London, UK	Station "Tottenham Court Road" Station "Leicester Square"	ED	2	0
26-07-1939, London, UK	Station "Victoria Station" Station "King's Cross"	ED	7	1
15-03-1976, London, UK	Station "West Ham"	ED	10	1
16-03-1976, London, UK	Station "Wood Green"	ED	1	0
08-02-1977, Moscow, Russian Federation	Between stations "Izmailovskaya" and "Pervomaiskaya"	ED	37	7
23-12-1991, London, UK	Station "Harrow-on-the-Hill" Station "Neasden"	ED	0	0
23-02-1992, London, UK	Station "London Bridge"	ED	29	0
03-02-1993, London, UK	Station "South Kensington"	ED	0	0
19-03-1994, Baku, Azerbaijan	Station "20 January"	ED	49	14
03-07-1994, Baku, Azerbaijan	Between stations "28 May" and "Ganjlik"	ED	58	13
15-12-1994, New York, USA	Metro train	ED	2	0
21-12-1994, New York, USA	Station "Fulton Street Station"	ED	48	0
20-03-1995, Tokyo, Japan	Five metro trains	Toxic substance (TS)	6300	13
25-07-1995, Paris, France	Station "Saint-Michel"	ED	117	8
17-08-1995, Paris, France	Station "Charles de Gaulle-Etoile"	ED	17	0
06-10-1995, Paris, France	Station "Maison Blanche"	ED	13	0
17-10-1995, Paris, France	Between stations "Orsay Museum" and "Saint-Michel"	ED	29	0
28-10-1995, Baku, Azerbaijan	Between stations "Ulduz" and "Narimanova"	ED	300	289
11-06-1996, Moscow, Russian Federation	Between stations "Tul'akaya" and "Nagatinskaya"	ED	16	4
03-12-1996, Paris, France	Station "Port-Royal"	ED	92	4
29-10-1997, Tbilisi, Georgia	Station "Didube"	ED	0	1

Table 1 continued

Data, City, Country	Place of terrorist attack	Terrorist tool	Injuries	Fatalities
01-01-1998, Moscow, Russian Federation	Station "Tret'yakovskaya"	ED	3	0
08-08-2000, Moscow, Russian Federation	Underground crossing under the "Pushkin Square"	ED	118	13
27-07-2000, Düsseldorf, Germany	Station "Wehrhahn"	ED	10	0
05-02-2001, Moscow, Russian Federation	Station "Belorusskaya-Koltsevaya"	ED	20	0
04-09-2001, Montreal, Canada	Station "Berri"	TS	45	0
12-05-202, Milan, Italy	Station "Duomo"	ED	0	0
18-02-2003, Taegu, South Korea	Station "Jungangno"	Combustible fluid (CF)	151	192
06-02-2004, Moscow, Russian Federation	Between metro stations "Avtozavodskaya" and "Paveletskaya"	ED	250	42
31-08-2004, Moscow, Russian Federation	Station "Rizhskaya"	ED	46	10
07-07-2005, London, UK	Between stations "«Aldgate» and "Liverpool Street"	ED	700	52
	Between stations "King's Cross" and "Russell Square"			
	Station "Edware Road"			
29-03-2010, Moscow, Russian Federation	Station "Lubyanka"	ED	88	41
	Station "Park Kultury"			
11-04-2011, Minsk, Belarus	Station "Oktyabr'skaya"	ED	203	15
14-07-2014, Santiago, Chile	Station "Los Dominicos"	ED	0	0
22-03-2016, Brussels, Belgium	Station "Maalbeek"	ED	70	14
03-04-2017, Saint-Petersburg, Russian Federation	Between stations "Technological institute" and "Sennaya Square"	ED	40	10
Totals			8971	745

On March 29, 2010, in Moscow (Russian Federation): two terrorist acts were committed: female suicide bombers exploded two explosive devices at the stations of the Moscow metro «Lubyanka» and «Park Kultury», 41 persons were killed and 88 injured (Dikanova 2010);

On April 11, 2011, in Minsk (Belorus), an explosive device was exploded at the metro station "Oktyabr'skaya". The explosive capacity of the explosive devices was equal to approximately 5 kg of TNT, and was filled with armature, nails, and metallic balls. 15 people were killed, and 203 were injured (Krupnye terroristicheskie akty 2013).

Table 2 Terrorist attacks at metros, statistics on countries

Country	Number of attacks	% of total
UK	11	28.2
Russian Federation	9	23.0
France	5	12.8
Azerbaijan	3	7.6
USA	2	5.1
Japan	1	2.5
Georgia	1	2.5
Germany	1	2.5
Canada	1	2.5
Italy	1	2.5
South Korea	1	2.5
Belarus	1	2.5
Chile	1	2.5
Belgium	1	2.5
Totals	39	100

Table 3 Terrorist tools employed in metros

Terrorist tools	Number of attacks	% of total
Explosive device (ED)	36	92.3
Toxic substance (TS)	2	5.1
Combustible fluid (CF)	1	2.5
Totals	39	100

The public transportation system appears to have become a preferred target of terrorists because of the potential for disruption, destruction, and the possibility of escape of the perpetrator(s), due to the size, openness, accessibility, lack of passenger identification, and the number of people such transportation systems carry (Jenkins 2001). Terrorist attacks on the public transportation system are described in (Colliard 2015; Bruyelle et al. 2014; Borrion et al. 2014; Edwards et al. 2016; Johnstone 2011; Lockey et al. 2005; Fiumara 2015; Hunter and Lambert 2016; O'Neill et al. 2013; Setola et al. 2015; Jenkins 2004; Polunsky 2015, 2017; Wilson et al. 2007; Tripathi and Borrion 2016; Starita and Scaparra 2017; Lievin et al. 2013).

Prevention and preparedness of risks in transportation systems are crucial for homeland security and require, among other things, a proper analysis of the vulnerabilities of the assets, a clear awareness of criticalities, possible countermeasures, and adequate methods to design, scale, and optimize the protection (De Cillis et al. 2013).

With almost 200 metro systems worldwide, and hundreds of millions of passengers carried annually (Ackerman 2016), underground or metro systems by their open-access nature are at risk from terrorist attack. Such concentrations of

Table 4 Technical security systems deployed at the metro

Engineering and technical facilities; systems for complete passenger flow screening and monitoring	Engineering and technical facilities and systems for partial (selective) passenger flow screening	Engineering and technical facilities and systems for disarming suspected explosives
Radiation monitoring equipment	Stationary X-ray screening baggage inspection systems of conveyer and non-conveyer types	Radio suppression systems for radio-controlled explosive devices
Metal detector gates	Stationary X-ray screening systems for individual inspection of passengers	Explosion-proof containers
Video surveillance system	Transportable detectors of explosives and illicit substances using tagged neutron technology	
	Hand-portable metal detectors	
	Portable X-ray television systems	
	Portable explosive vapor detectors	

people in contained environments make the systems especially vulnerable to attack through the use of explosives and improved explosive devices (Ashby et al. 2017).

One of the primary aims of terrorists is to terrorize people; therefore, the Metro system used by almost every city resident has become a priority object for attacks. Terrorist attacks in the metro plants fear in human hearts that next time, they can be killed in the next terrorist act. People will remember this threat every time they come down into the metro (Shvetsov 2015b).

The major terrorist tool for committing attacks in the metro is explosive devices (Shvetsov et al. 2017a). Explosive devices are the most common method of carrying out terrorist attacks not only in metros but also on railways (Standberg 2013; Strandh 2017). An example of this is the terrorist attack committed on the morning of 11th March 2004, when ten explosions took place in four commuter trains in Madrid, Spain (Larcher et al. 2015). This terrorist method is the most destructive compared to other methods such as armed assaults, subversive activities, or arson (O'Neill et al. 2012). Bombs are relatively easy and cheap to construct, with detailed instructions on how to build various forms of explosives readily available online (Weimann 2004), and can injure enough people to overwhelm the security resources in many communities (DePalma et al. 2005; Larcher et al. 2015). Types of EDs employed in metros and the ways of introducing them are described in (Shvetsov et al. 2017a).

3 Methodology

The reasons for the insufficient level of anti-terrorist security in metro systems can be revealed by the assessment of the efficiency of the technological security systems installed at metro stations' entrance halls and by calculation of the percentage of risks of bringing EDs into metro which these systems allow.

Methodologies used for the assessment of terrorist hazards and applicable to metro are described in the research work «Risk assessment methodology (RAMPART Methodology)» (Matsika et al. 2016).

- RAMCAP Plus: An all hazards' resilience oriented RAM, focusing on decreasing the vulnerability by identifying critical threats and scenarios, and increasing the system's resilience (ASME-ITI 2009).
- NSRAM: The focus of the Network Security Risk Assessment modelling (NSRAM) methodology is to determine the interconnected system response to different types of incidents and accidents (IIIA 2015).
- FAIR: Factor Analysis of IT and Information Risk (FAIR) is a framework for creating and maintaining a threat-modelled information risk framework (Optical Risk 2014).
- SEST-RAM: Developed through the EC SECURESTATION project (Soehnchen and Barcanescu 2014).
- FAIT: This tool was developed in the US by the National Infrastructure Simulation and Analysis Center to support DHS by determining the significance and the interdependencies of the US critical infrastructures (Kelic et al. 2008).
- RAND Methodology: Scenario-based qualitative RA cost-effective evaluation. The scope of the work is the railway sector and terrorist threats (Ortiz et al. 2008).

Detailed study of the described methodologies has shown that these methodologies cannot be applied to assess the efficiency of technical security systems installed at metro stations' entrance halls and to calculate the risk of bringing EDs into metro permitted by these systems.

This analysis can be performed by two stages:

Stage One—development of a model for anti-terrorist protection of metro (the model will help assess the efficiency of the technical security systems installed at metro stations' entrance halls);

Stage Two—mathematical calculation of the risks of bringing ED into metro (the calculation will allow us to determine the percentage of the risk of bringing ED permitted by the technical security systems).

3.1 Stage One—Development of the Model of Anti-terrorist Protection of Metro Systems

The development of the model includes Unit 1 that describes different types of EDs (that can be brought into metro) and Unit 2 that describes technical systems (for detecting EDs). Subsequently guidelines simulate connections between Units 1 and 2 that show what ED type is detected by a certain technical security system.

The model helps us to determine:

- What types of EDs are detected by the systems for complete passenger flow screening;

- What types of EDs are detected by the systems for partial passenger flow screening. When only partial inspection is used, there is a risk of bringing EDs into metro.

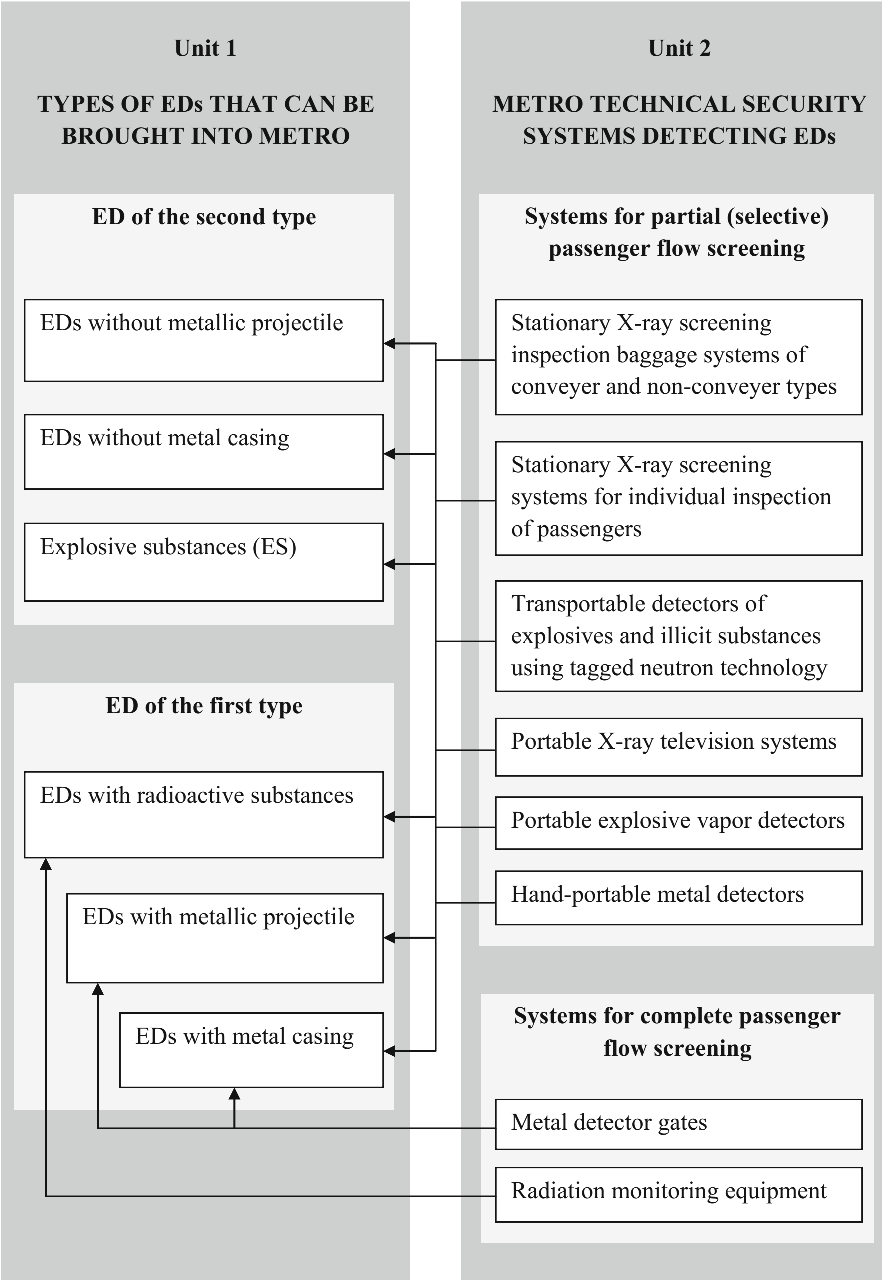


Fig. 1 Model of metro counter-terrorist protection

The authors have formed a model of metro counter-terrorist protection (Fig. 1) that shows what technical security systems identify specific types of EDs when the latter are brought into the metro.

3.1.1 Results

As a result, the developed model of metro anti-terrorist protection shows that:

(1) the security systems ensure complete inspection of the entire incoming passenger flow for:

- EDs with metal casings, EDs containing metallic projectiles, and EDs containing radioactive substances (hereinafter—EDs of the first type);

(2) the security systems ensure only partial inspection of the incoming passenger flow for:

- explosive substances, EDs without metal casings, EDs containing no metallic projectiles, and EDs containing no radioactive substances (hereinafter—EDs of the second type).

The security systems ensure only partial inspection of the incoming passenger flow for EDs of the second type. Therefore, the risk of bringing an ED of the second type into the metro remains.

3.2 Stage Two—Mathematical Calculation of the Risks of Delivering EDs Into the Metro

A mathematical calculation of the percentage of the risk caused by bringing EDs of second type into the metro allowed by the technical security systems can be implemented by the following formula:

$$X = 100 - \frac{Y_2}{Y_1} \cdot 100, \tag{1}$$

where: X is the risk of bringing an ED of second type into the metro; Y_1 is the number of incoming passengers; Y_2 is the number of passengers who have passed additional (selective) screening.

3.2.1 Results

The experimental calculations using formula (1) were implemented by the example of the Moscow metro where all stations had already been equipped with the technical security systems listed in Table 4 [according to the information provided by the Moscow Metro Security Service (MMSS 2017)].

Given the source data are as follows:

Y_1 (the number of incoming passengers) is 6.9 mln people per day (Metrobits "World Metro Database" 2017);

Y_2 [the number of passengers who have passed additional (selective) screening] is 130 thousand people per day (MMSS 2017; Muratov 2015b),

having calculated according to the formula (1), we received the following results:

X (risk of bringing an ED of second type into the metro) equals 98.1%.

Calculations of the probability of bringing EDs of the second type into the metro (98.1% in accordance with formula 1) point to the main problem in the anti-terrorist protection of the metro. This problem is the low efficiency of the deployed technical security systems. These systems do not allow for inspection of the entire incoming passenger traffic for EDs of the second type and allow the risk of bringing in EDs of the second type which creates a hazard of committing new terrorist attacks.

4 Discussion

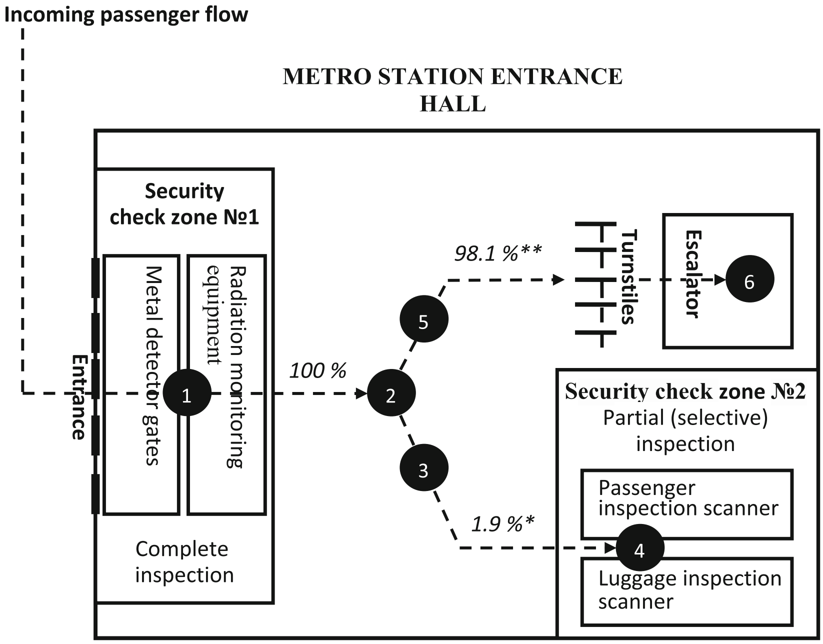
The partial (selective) inspection of incoming passengers for the purposes of detection of EDs of the second type creating a hazard of committing new terrorist attacks is explained by the fact that due to the tremendous passenger, traffic technical security systems deployed at the metro do not ensure complete inspection. Passenger traffic at the metro stations reaches:

- 9.0 million people per day (Tokyo metro) (Metrobits "World Metro Database" 2017);
- 6.9 million people per day (Moscow metro) (Metrobits "World Metro Database" 2017);
- 4.7 million people per day (New York metro) (Metrobits "World Metro Database" 2017).

The high metro passenger traffic makes it impossible for the deployed technical security systems to inspect the entire incoming passenger flow. For instance, the measurements of the incoming passenger traffic at the Moscow metro station "Bykhino" showed that between 8.00 a.m. and 8.15 a.m. (rush hour), the incoming passenger traffic reaches 6 persons per second. However, the inspection time at the booth of the X-ray inspection system "X-Scan" is 5 s; in addition, a certain time is required for the person to enter and exit the booth, which on the whole requires 15–20 s per person per check, which makes it technically impossible for the metro security service to screen all incoming passengers for having an ED of the second type with them.

The scheme of introducing EDs in the metro (Fig. 2) shows the portion of passengers not inspected for EDs of the second type freely entering the metro and consequently able to bring EDs of the second type into the metro.

The scheme of bringing EDs into the metro (Fig. 2) and calculation according to the formula (1) showed that the inadequacies of the metro technical security systems are the reasons for insufficient level of anti-terrorist security in metro and require upgrading. The Metro needs equipping with additional technical security system



Key:

1 – detection of ED of first type;

2 – distribution of passengers by security service specialists of the metro;

3 – specific partial selection of passengers from the passenger flow for screening with scanners and directing a passenger to scanner screening;

4 – detection of ED of second type;

5 – free passage of passengers into the metro without scanner screening;

6 – bringing EDs of the second type in the metro.

** % of passengers additionally (selectively) inspected (Muratov 2015b);*

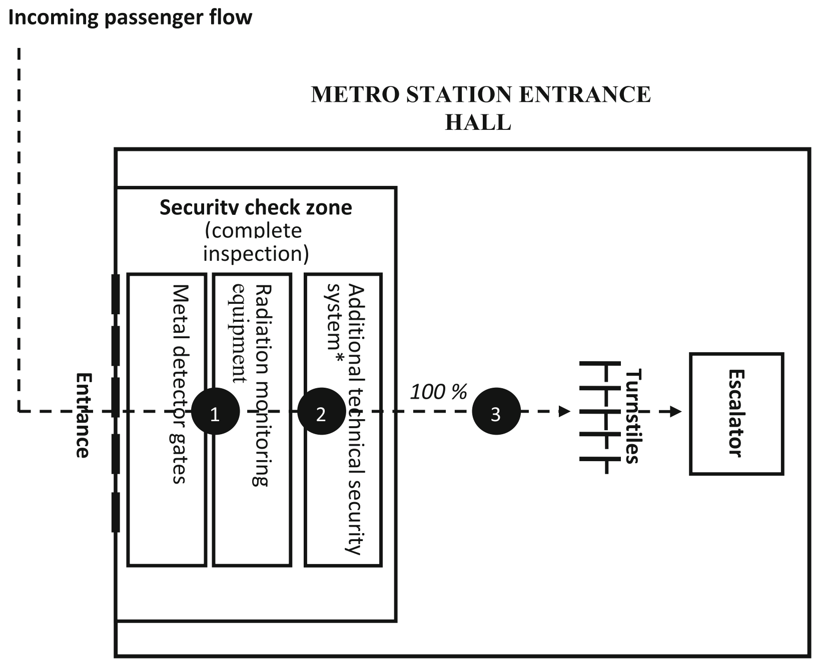
*** % of passengers without additional (selective) inspection (Muratov 2015b).*

Fig. 2 Scheme of bringing EDs in the metro

capable of 100% inspection of incoming passengers for the presence of EDs of the second type.

To equip the metro with a system capable of 100% inspection of newly chosen passengers for the presence of EDs of the second type, we need to determine the handling capacity which this system must ensure.

A handling capacity of not more than 0.16 s per person on the move was determined on the basis of statistic data on passenger traffic at the metro station “Vykhino” (Moscow Metro) which has one of the highest possible rates of passenger flow among all metro stations of the world (170,000 passengers per day (Muratov 2015a). Measurements of the incoming passenger traffic at this station showed that between 8.00 a.m. and 8.15 a.m. (rush hour), the incoming passenger traffic reaches 6 persons per second.



Key:

1 – detection of EDs of the first type and weapons;

2 – detection of EDs of the second type;

3 – passage of passengers into the metro.

** system capable of 100% inspection of passengers of the metro for the presence of EDs of the second type that have a handling capacity of no more than 0.16 sec per person on the move.*

Fig. 3 Scheme of screening incoming passengers that ensures 100% detection of weapons, EDs of the first and the second types

Equipping metros with additional technical security systems that have a preliminary calculated handling capacity according to this scheme will work in practice for the screening of incoming passengers (Fig. 3) to ensure 100% detection of EDs of the first and the second types.

Scheme for the screening of incoming passengers (Fig. 3) will resolve the problem of the insufficient level of anti-terrorist security in metros. This conclusion is supported by the research (Barkakati et al. 2010).

5 Directions for Future Research

This research can be developed further in two directions:

- the elaboration of technical security system capable of 100% inspection of passengers of the metro for the presence of EDs of the second type due to its handling capacity of not more than 0.16 s per person on the move;
- this research can also serve as a basis for the development of the Strategy for protection against terrorist attacks in the metro (further on in this paper—Strategy). The Strategy must offer a complex of organizational measures and methodologies and technologies aimed at the protection against terrorist attacks in the metro. The Strategy must be universal and applicable to a metro system of any country of the world; it can be developed by an international consortium consisting of research organizations dealing with the sphere of transport security.

The development of the Strategy may be financed by an interested party (for example, an international organization like the United Nations Security Council Counter-Terrorism Committee (CTC 2017) or governmental authorities like the Transportation Security Administration (USA) (TSA 2017).

After it has been developed, the Strategy will become an international roadmap for protection of metro against terrorist attacks.

6 Practical Application of the Results of the Research

The results we obtained can be employed by an interested party (for example, Metro Security Service (MMSS 2017), or governmental authorities like the Transportation Security Administration (USA) (TSA 2017) for the development of programs for protection against terrorist attacks in the metro.

References

Ackerman G (2016) Comparative analysis of VNSA complex engineering efforts. J Strat Secur 9(1):119–133

Ashby M, Bowers K, Borrion H, Fujiyama T (2017) The when and where of an emerging crime type: the example of metal theft from the railway network of Great Britain. Secur J 30(1):1–23
ASME-ITI (2009) All-hazards risk and resilience. Prioritizing critical infrastructures using the RAMCAP Plus SM approach. ASME Innovative Technologies Institute, LLC. ISBN: 978-0-7918-0287-8. Available on http://files.asme.org/ASMEITI/RAMCAP/17978.pdf
Barkakati N, Maurer D, Bowser A, Stattel A (2010) Explosives detection technologies to protect passenger rail. Report to Congressional Committees, GAO-10-898. US Government Accountability Office, Washington
Borrion H, Tripathi K, Chen P, Moon S (2014) Threat detection: a framework for security architects and designers of metropolitan rail systems. Urb Plan Transp Res 2(1):173–194
Bruyelle J-L, O'Neill C, El-Koursi E, Hamelin F, Sartori N, Khoudour L (2014) Improving the resilience of metro vehicle and passengers for an effective emergency response to terrorist attacks. Saf Sci 62:37–45
Colliard J (2015) Towards integrated railway protection. In: Setola R, Sforza A, Vittorini V, Pragliola C (eds) Railway infrastructure security. Part of the topics in safety, risk, reliability and quality, book series (TSRQ), vol 27. Springer, Cham, pp 13–24
CTC (2017) Official website of the United Nations Security Council Counter-Terrorism Committee. Retrieved from http://research.un.org/en/counter-terrorism
De Cillis F, De Maggio MC, Pragliola C, Setola R (2013) Analysis of criminal and terrorist related episodes in railway infrastructure scenarios. J Homel Secur Emerg Manag 10(2):1–30
Deng Y, Li O, Lu Y (2015) A research on subway physical vulnerability based on network theory and FMECA. Saf Sci 80:127–134
DePalma RG, Burris D, Champion HR, Hodgson M (2005) Blast injuries. N Engl J Med 352:335–342
Dietrich B, Iff S, Profelt J et al (2017) Development of a local air surveillance system for security purposes: design and core characteristics. Eur J Secur Res. doi:10.1007/s41125-017-0015-7
Dikanova TA (2010) To the issue of preventing terrorism on transport. Bull Acad RF Prosec Gen Off 3(17):49–56
Edwards FL, Goodrich DC, Griffith J (2016) Emergency management training for transportation agencies. Mineta Transportation Institute Report. Mineta Transportation Institute, San Jose, pp 12–70
Fiumara F (2015) The railway security: methodologies and instruments for protecting a critical infrastructure. In: Setola R, Sforza A, Vittorini V, Pragliola C (eds) Railway infrastructure security. Topics in safety, risk, reliability and quality, book series (TSRQ), vol 27. Springer, Cham, pp 25–63
Hunter JA, Lambert JR (2016) Do we feel safer today? The impact of smiling customer service on airline safety perception post 9–11. J Transp Secur 9(1–2):35–56
IIIA (2015) NSRAM Infrastructure Modeling Tool. Institute for Infrastructure and Information Assurance (IIIA). Retrieved from http://www.jmu.edu/iiia/wm_library/Network_Security_Risk_Assessment_Modeling_(NSRAM)2.pdf
Jenkins B (2001) Protecting public surface transportation against terrorism and serious crime: an executive overview. Mineta Transportation Institute, San Jose
Jenkins B (2004) Terrorism and the security of public surface transportation. RAND Corporation, Santa Monica
Johnstone B (2011) New strategies to protect America: terrorism and mass transit after London and Madrid. Center for American Progress, Washington. Retrieved from https://cdn.americanprogress.org/wpcontent/uploads/kf/TRANSIT_SECURITY.PDF
Kelic A, Warren DE, Phillips LR (2008) Cyber and Physical Infrastructure Interdependencies. SANDIA REPORT
Krupnye terroristicheskie akty v mire v 2000–2003 gg (2013) [Major terrorist acts in the world in 2000–2013] [RIA «Novosti» web-site]. Retrieved from https://ria.ru/spravka/20110819/420149164.html
Larcher M, Forsberg R, Björnstig U, Holgersson A, Solomos G (2015) Effectiveness of finite-element modeling of damage and injuries for explosions inside trains. J Transp Saf Secur 8(1):83–100
Lievin BA, Bugaev AS, Ivashov SI, Razevig VV (2013) Distantly piloted aircrafts and the track security. World Transp Transp 11(2):152–157
Lockey D, MacKenzie R, Redhead J, Wise D, Harris T, Weaver A, Hines K, Davies G (2005) London bombings July 2005: immediate pre-hospital medical response. Resuscitation 66(2):9–12

Matsika E, O'Neill C, Battista U, Khosravi M, Laporte A, Munoz E (2016) Development of risk assessment specifications for analysing terrorist attacks vulnerability on metro and light rail systems. Transp Res Proced 14:1345–1354

Metrobits "World Metro Database" (2017) [Online]. Available: http://mic-ro.com/metro/table.html

MMSS (2017) Moscow Metro Security Service. Official website of the Moscow metro. Retrieved from http://mosmetro.ru/about/structure/security/

Muratov VP (2015a) Novyy uroven bezopasnosti sozdadut v moskovskom metro k 2020 g. [New security level will be formed in the Moscow subway by 2020]. Regional news agency of the Moscow region. Retrieved from http://riamo.ru/government_interview/20150211/608705532.html

Muratov VP (2015b) News agency of the Moscow. The security service of Moscow Metro daily reveals to 200 dangerous subjects. Retrieved from http://www.mskagency.ru/materials/2517870

Nehorayoff A, Benjamin A, Smith D (2016) Aum Shinrikyo's nuclear and chemical weapons development efforts. J Strat Secur 9(1):35–48

O'Neill C, Robinson A, Ingleton S (2012) Mitigating the effects of firebombs and blast attacks on metro systems. Proced Soc Behav Sci 48:3518–3527

O'Neill C, Robinson AM, Santiago A (2013) Metro vehicle blast testing: mitigating the effects of terrorist attacks on metro vehicles. In: 10th World Congress on Railway Research. Sydney, Australia

Optical Risk (2014) Factor analysis of information risk methodology brochure. Available at http://www.optimalrisk.com/Cyber-Security/FAIRMethodology

Ortiz DS, Weatherford BA, Greenberg MD, Ecola L (2008) Improving the safety and security of freight and passenger rail in Pennsylvania. RAND Corporation

Polunsky S (2015) Texas should adopt homeland security standards for high-speed rail. Chds Theses: Executive summaries. Homeland Security Affairs. Retrieved from https://www.hsaj.org/articles/9298

Polunsky SM (2017) Homeland security and Texas' high-speed rail. J Transp Secur. doi:10.1007/s12198-017-0180-y

Setola R, Sforza A, Vittorini V, Pragliola C (2015) Railway infrastructure security. Topics in safety, risk, reliability and quality, book series (TSRQ), vol 27. Springer, Cham

Shvetsov AV (2015a) Underground railway transport safety. Proc Petersburg Transp Univ 4(45):72–77

Shvetsov A (2015b) Aspects of transport security of the Moscow metro. Transp Bus Rus 4(119):147–149

Shvetsov AV, Shvetsova SV (2017) Protection of high-speed trains against bomb-carrying unmanned aerial vehicles. J Transp Secur. doi:10.1007/s12198-017-0182-9

Shvetsov A, Shvetsova S, Kozyrev VA et al (2017a) The "car-bomb" as a terrorist tool at metro stations, railway terminals and airports. J Transp Secur 10(1–2):31–43

Shvetsov AV, Sharov SV, Shvetsova SV (2017b) Method of protection of pedestrian zones against the terrorist attacks made by means of cars including off-road vehicles and trucks. Eur J Secur Res. doi:10.1007/s41125-017-0018-4

Soehnchen A, Barcanescu M (2014) Risk assessment tool for public transport. Transport Research Arena, Paris

SPMSS (2017) Saint-Petersburg Metro Security Service. Official website of the Saint-Petersburg Metro. Retrieved from http://www.metro.spb.ru/transpsft.html

Standberg V (2013) Rail bound traffic—a prime target for contemporary terrorist attacks. J Transp Secur 6(3):271–286

Starita S, Scaparra MP (2017) Passenger railway network protection: a model with variable post-disruption demand service. J Oper Res Soc. doi:10.1057/s41274-017-0255-y

Strandh V (2017) Exploring vulnerabilities in preparedness: rail bound traffic and terrorist attacks. J Transp Secur. doi:10.1007/s12198-017-0178-5

Tripathi K, Borrion H (2016) Safe, secure or punctual? A simulator study of train driver response to reports of explosives on a metro train. Secur J 29(1):87–105

TSA (2017) Transportation Security Administration. Official website of the Department of Homeland Security. Retrieved from https://www.tsa.gov

Weimann G (2004) http://www.terror.net: How modern terrorism uses the Internet. (Special Report 116). United States Institute of Peace. Retrieved from http://www.usip.org/sites/default/files/sr116.pdf

Wilson J, Jackson B, Eisman M, Steinberg P, Riley J (2007) Securing America_s passenger-rail systems. RAND Corporation, Santa Monica