Comprehensive Risk Assessment of Basic Services and Transport Infrastructure

101004830 - CRISIS - UCPM-2020-PP-AG

Cross-border risk assessment of basic services and transport infrastructure
Harmonized regional risk exposure model

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WP-4 | D4.1

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1. Introduction

In recent years, the improvement of disaster and emergency management through building a harmonized and efficient system for risk assessment of structures in the cross-border region has become increasingly popular. The CRISIS project specifically focuses on enhancing the cross-border cooperation and coordination in disaster risk management based on developed models and tools and raising public awareness and preparedness for disasters.

The main objective of this report is to present the activities carried out to create a harmonized regional risk exposure model for the basic services and transport infrastructure. The realized activities enable creation of a harmonized cross-border regional risk exposure model, which encompasses all relevant assets related to the basic services and transport infrastructure. A regional exposure database has been created based on contemporary practice and research compatible with the GEM Exposure Database (https://storage.globalquakemodel.org/what/physical-integrated-risk/exposure-database/). This database is specific enough to conduct numerical analysis and develop or select proper vulnerability functions.

A vital phase of this work package will be presented in D4.2 where the vulnerability assessment of the representative structural typology concerning the identified levels of seismicand landslide hazards will be presented. Several most probable and extreme risk scenarios will be defined and analyzed, as a crucial point of further analysis and management planning.

2. Methodology

Different countries, even neighboring ones, have different frameworks in which buildings for basic services and transport infrastructures as well as bridges are designed, built and maintained. Hence, they involve different institutions and employ different ways of gathering information on existing structures within their networks. Each of them may use different methods and systems for keeping records on their assets. Therefore, there is no readily available inventory which covers the entire stock of bridges and buildings for basic services in any of the CRISIS adjacent partner countries.

2.1. Buildings for basic services

To provide a set of tools and models for risk analysis for this project, the Global Earthquake Model (GEM) has been used. The purpose of the GEM Building Taxonomy is to describe and classify buildings in systematic and uniform manner. It is a key step towards assessing the seismic risk pertaining to buildings.

The Building Taxonomy data model is highly flexible and has the ability to represent building typologies using a shorthand form. This taxonomy was independently evaluated and tested by the Earthquake Engineering Research Institute (EERI), which received 217 TaxTreports from 49 countries, representing a wide range of building typologies, including single and multi-story buildings, reinforced and unreinforced masonry, confined masonry, concrete, steel, wood, and earthen buildings used for residential, commercial, industrial and educational occupancy [1].

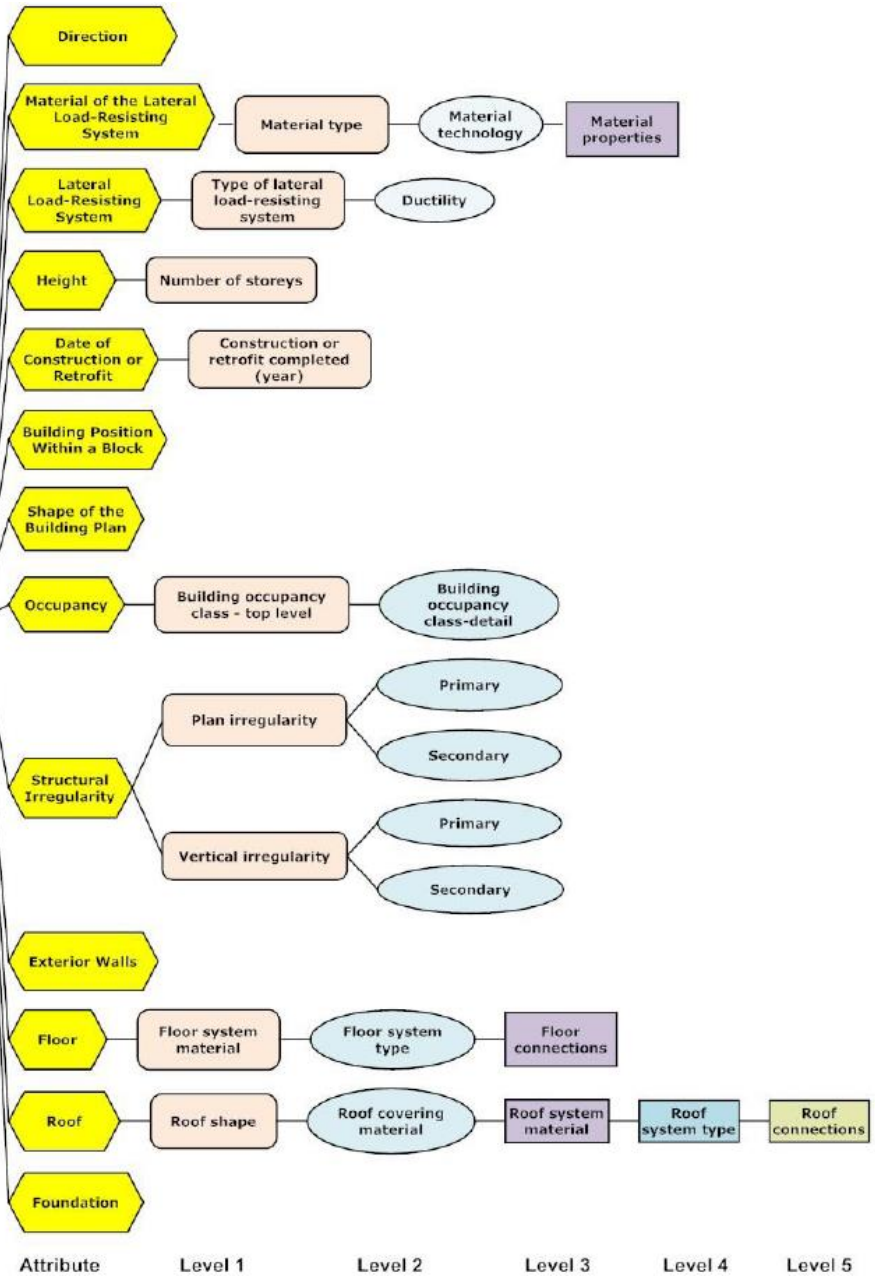

Figure 1. GEM Building Taxonomy v2.0: attributes and associated levels of detail [1]

The GEM Building Taxonomy describes a building or a building typology through 13 attributes which are associated with specific building characteristics that can potentially affect seismic performance:

1. **Direction** - this attribute is used to describe the orientation of building(s) with different lateral load resisting systems in two principal horizontal directions of the building plan which are perpendicular to one another.
2. **Material of the lateral load-resisting system** - e.g. "masonry" or "wood".
3. **Lateral load-resisting system** - the structural system that provides resistance against horizontal earthquake forces through vertical and horizontal structural components, e.g. "wall", "moment frame",etc.

4. **Height** - building height above ground in terms of number of storeys (e.g. a building is 3-storeys high); this attribute also includes information on number of basements (if present) and ground slope.
5. **Date of construction or retrofit** - identifies the year when the building construction was completed.
6. **Occupancy** - the type of activity (function) within the building; it is possible to describe a diverse range of occupancies - for example, residential occupancies include informal housing (slums) as well as high-rise apartment buildings.
7. **Building position within a block** - the position of a building within a block of buildings (e.g. "detached building" is not attached to any other building).
8. **Shape of the building plan** - e.g. L-shape, rectangular shape, etc.
9. **Structural irregularity** - a feature of a building's structural arrangement, such as one story significantly higher than other stories, an irregular building shape, or change of structural system or material that produces a known vulnerability during an earthquake. Examples: re-entrant corner, soft storey, etc. Recognizing the fact that a building can have more than one irregularity, the user is able to identify primary and secondary irregularity.
10. **Exterior walls** - material of exterior walls (building enclosure), e.g. "masonry", "glass", etc.
11. **Roof** - this attribute describes the roof shape, material of the roof covering, structural system supporting the roof covering, and roof-wall connection. For example, roof shape may be "pitched with gable ends", roof covering could be "tile", and roof system may be "wooden roof structure with light infill or covering".
12. **Floor** - describes floor material, floor system type, and floor-wall connection. For example, floor material may be "concrete", and the floor system may be "cast in-place beamless reinforced concrete slab".
13. **Foundation system** - that part of construction where the base of the building meets the ground. The foundation transmits loads from the building to the underlying soil. For example, a shallow foundation supports walls and columns in a building for hard soil conditions, and a deep foundation needs to be provided for buildings located in soft soil areas

Each attribute has been described by one or more levels Level 1, 2, 3, etc. Attributes and associated details included in the GEM Building Taxonomy are presented in Fig. 1.

To collect data for the basic services structures: schools and hospitals in the CRISIS project, GEM – Direct Observation Tool has been used [2]. This tool, which contains all these attribute levels leads to creation of a regional exposure model. This dataset contains specifically information related to structural characteristics and population data related to general basic services in different spatial resolutions. This geospatial exposure database will facilitate global earthquake risk and loss estimation through the GEM's OpenQuake platform.

2.2 Bridge structures

Within this project, a system for data collection has been determined to gather as much information as possible about the bridge network in each country and to gain enough insight into the bridge inventory and permit further modelling and risk assessment, as foreseen by the project.

In this case, two categorizations of different type of data have been performed. The first categorization includes basic information on the structures - information on existence, location and overall length of the bridge. The second set of data includes information on the structural system and material of the bridge, as well as incomplete geometrical characteristics of the structural elements. This information has been used to classify the assets according to

the taxonomy scheme. In this project, the taxonomy used in the Infra-NAT project has been applied [3].

3. Regional risk exposure model

Presented further is a cross-border harmonized regional risk exposure model related to the targeted cross-border region between the three partner countries: N. Macedonia, Greece and Albania. A regional exposure database that has been created is based on contemporary practice and research [4]. This exposure model observes all relevant assets in the cross-border region related to the basic services and transport infrastructure.

In this study, schools, hospitals and bridges are taken into account. For the purposes of this project, only structures in larger populated areas related to border crossings and serving a larger number of users have been taken into account. It is considered that this type of structures will be the most beneficial in the period after any natural or human-induced hazard. Taking these structures into account, each neigbouring country in the region will be able to provide enhanced cross-border cooperation and coordination in disaster risk management.

Integrated cross-border region municipality map is presented in Fig. 2.

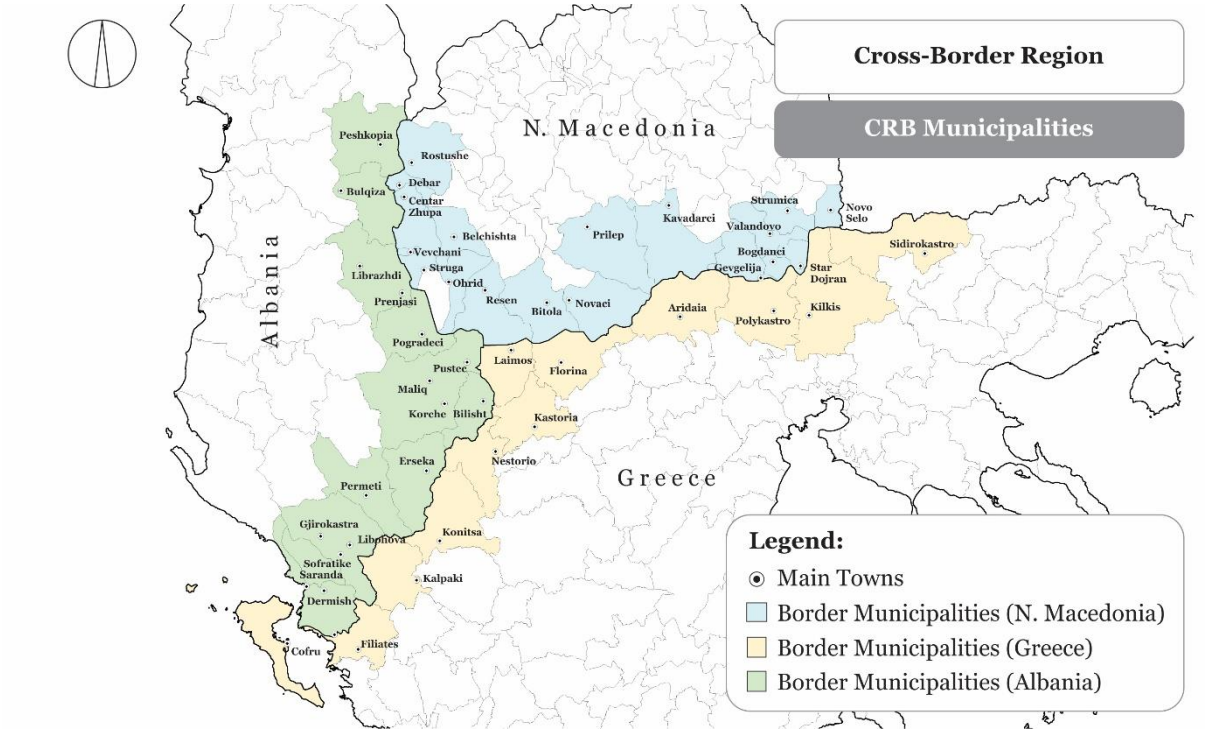

Figure 2. Integrated cross-border region; Main cities

The cross-border region that belongs to N. Macedonia (CBR-MKD), consists of 18 municipalities, the Greek cross-border region (CBR-GR), consists of 12 municipalities and the Albanian cross-border region near N. Macedonia and Greece consists of 17 municipalities. This region covers almost all the south-east and east part of Albania [4]. The region with the largest population is N. Macedonian.

3.1. Buildings for basic services

3.1.1 Schools

3.1.1.1 N Macedonia

To collect data regarding basic services of structures, for the needs of the project, a special form containing all data necessary to fill out the GEM Tool was prepared. These data shall further serve to create the risk and emergency management platform in WP5. The initial idea was to distribute this form through the regional centres of the Crisis Management Centre (CMC) in the cross border municipalities and people working in these centres to appoint persons who work in corresponding institutions (schools and hospitals) to provide data and fill out the forms, in which way, the collected data were to be transferred to the GEM tool. To explain data to be collected through the form, instructions were prepared additionally to present all questions and possible answers through pictures and examples.

Since the Crisis Management Centre is parter institutution in this project, and given that the objective of this project is improvement of the crisis management system for the purpose of more efficient response of the authorities managing emergency situations and catastrophes, a team from the Crisis Management Centre was engaged in upgrading their already existing module (http>//procena.cuk.gov.mk/) with data that are necessary in this project phase for regional risk exposure model harmonization.

The process of data acquisition was carried out in the already adopted way, through engagement of persons from the regional crisis management centres. In this way, the Crisis Management Centre acquired an improved system for evaluation of the endangerment of safety against all risks and hazards upgraded with data on schools and hospitals.

According to the State Statistical Office of the Republic of N. Macedonia [5], the total number of primary and secondary schools in the overall country territory is 1119 (979 primary schools +130 secondary schools). The review of the number of schools in the cross-border municipalities including all schools in the main towns and all schools in the remaining towns and smaller villages is shown in Table 1. The table clearly shows that there is a total of 322 schools in the considered region, 281 being primary schools and 41 being secondary schools.

Table 1. Primary and secondary schools by considered municipalities

#	Municipality	No. of primary schools	No. of secondary schools	Total no. of schools
1	Mavrovo i Rostuse	16	1	17
2	Debar	6	2	8
3	Centar Zupa	9	1	10
4	Struga	35	4	39
5	Vevcani	1	-	1
6	Debarca	11	-	11
7	Ohrid	18	4	22
8	Resen	21	1	22
9	Bitola	47	10	57
10	Novaci	9	-	9
11	Prilep	27	6	33

12	Kavadarci	12	4	16
13	Gevgelija	12	1	13
14	Valandovo	12	1	13
15	Bogdanci	4	1	5
16	Dojran	7	-	7
17	Strumica	23	5	28
18	Novo Selo	11	-	11
Total no.		**281**	**41**	**322**

As mentioned above, considered in the CRISIS project have been only structures located in larger populated areas related to border crossings for which corresponding data have been provided. The review of the number of considered schools per municipalities is displayed in Tab. 2 [6].

Table 2. Considered primary and secondary schools by municipalities in N. Macedonia

#	Municipality	No. of primary schools	No. of secondary schools	Total no. of schools
1	Mavrovo i Rostuse	0	1	1
2	Debar	2	1	3
3	Centar Zupa	1	0	1
4	Struga	2	1	3
5	Vevcani	1	0	1
6	Debarca	0	0	0
7	Ohrid	3	2	5
8	Resen	1	1	2
9	Bitola	7	0	7
10	Novaci	0	0	0
11	Prilep	6	1	7
12	Kavadarci	5	3	8
13	Gevgelija	4	1	5
14	Valandovo	3	0	3
15	Bogdanci	1	2	3
16	Dojran	1	0	1
17	Strumica	3	4	7
18	Novo Selo	0	0	0
Total no.		**40**	**17**	**57**

The location of the considered schools is shown in Fig. 3 [7].

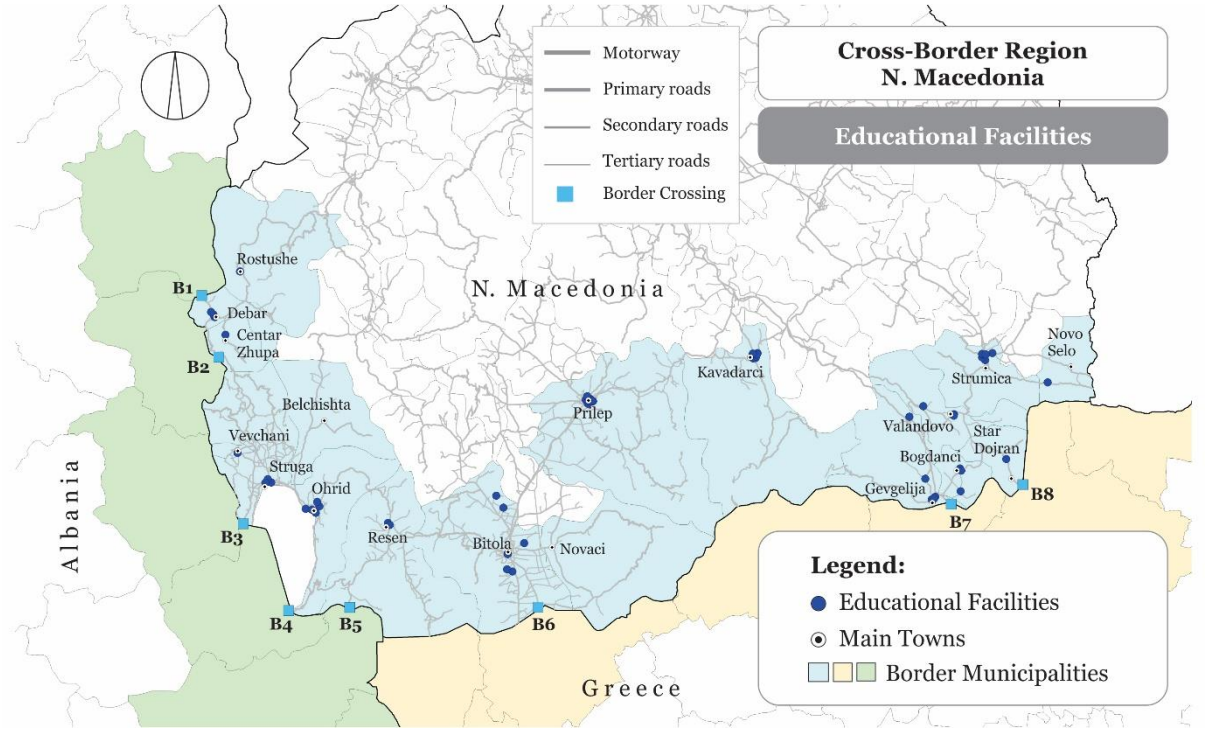

Figure 3. Location of the schools considered in this project

According to the material technology, most of the considered schools are constructed of cast-in-place concrete (CIP) accounting for 43.9% while 40.4% are constructed of fired clay solid bricks (CLBRS). A quite minor part of them are constructed by use of another masonry unit technology 3.5% (MO), whereas the remaining ones are constructed by use of an unknown technology involving stone 5.3%, (ST99), masonry 5.3%(MUN99) and concrete 1.8% (CT99)(Fig. 4 left).

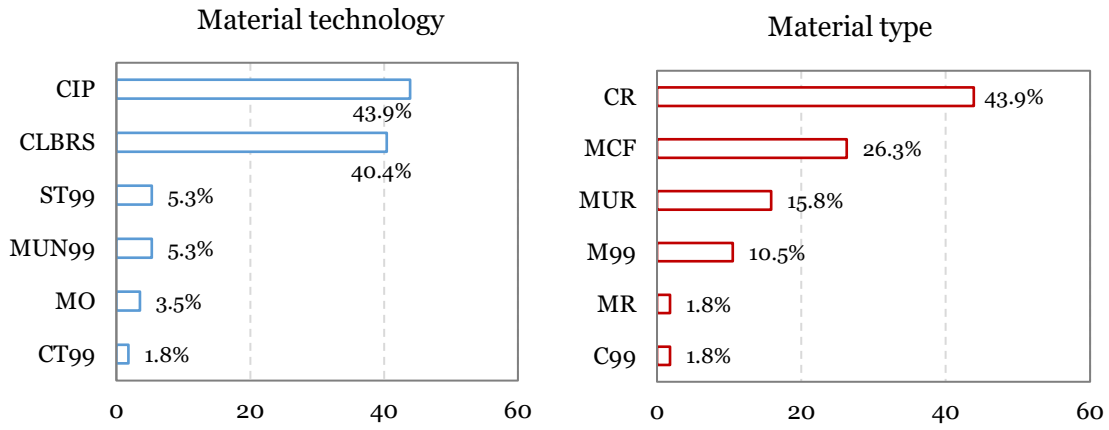

Figure 4. A percentage presentation of the considered schools in the cross-border region according to material technology (left) and material type (right)

A percentage presentation of the type of materials used for the schools is shown in Fig. 4 right. From this presentation and the presentation given above, it can be concluded that all structures constructed by use of the cast-in-place technology are constructed of reinforced concrete 43.9% (CR). Most of the structures constructed by use of the masonry technology are constructed of confined masonry 26.3 % (MCF) while the remaining ones are constructed of unreinforced masonry 15.8% (MUR). A quite smaller part are constructed of reinforced

masonry 1.8% (MR). The reinforcement is unknown in 10.8% of the masonry structures (M99), and 1.8% of the concrete structures (C99).
According to the number of storeys of the schools, most of them have two and three storeys above ground and have either one or none level below ground (Fig. 5).

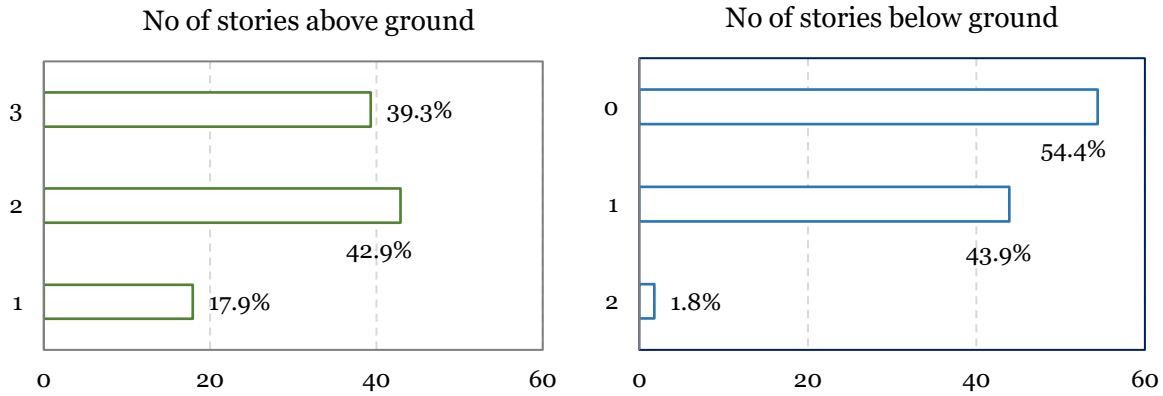

Figure 5. Percentage presentation of the considered schools in the cross-border region according to storeys above ground (left) and number of storeys below ground (right)

According to year of construction, the oldest school building of a primary school was built in Strumica in 1926, while the latest is the secondary school in Vevcani built in 2013.

Most of the school structures that have been considered in this database (60.7%) are built prior to the introduction of the seismic regulations. The remaining ones accounting for 39.3% of the buildings are designed and constructed according these codes.

The mean value of storey height of the buildings is 350 cm. In accordance with the data available, most of the structures are regular (62.8%), whereas 30.2% are irregular from structural aspect. The regularity of 7% of the structures is unknown.

3.1.1.2 Greece

According to the Hellenic School Network (https://www.sch.gr/), in the cross-border region there are 411 primary schools and 146 secondary schools, allocated in the twelve considered municipalities as shown in Table 3.

According to the Hellenic Statistical Authority, the total number of buildings used exclusively as schools in the cross-border region is 1174, while there are additional 88 buildings with mixed use, including that of schools (Table 4).

Table 3. Primary and secondary schools by considered municipalities in Greek cross-border region

#	Municipality	Primary Education Directorate Schools	Secondary Education Directorate Schools
1	Filiates	9	3
2	Konitsa	7	3
3	Pogoni	8	5
4	Florina	49	17
5	Kastoria	49	21
6	Nestorio	3	2

7	Prespes	2	1
8	Almopia	46	10
9	Kilkis	59	21
10	Paionia	28	11
11	Sintiki	32	10
12	Corfu	119	42
	Total no.	**411**	**146**

Table 4. Number of individual buildings used as schools by considered municipalities in Greek cross-border region

#	Municipality	No. of buildings exclusively used as schools	No. of buildings with mixed use incl. schools
1	Filiates	56	6
2	Konitsa	50	1
3	Pogoni	61	5
4	Florina	148	9
5	Kastoria	137	7
6	Nestorio	19	1
7	Prespes	25	0
8	Almopia	101	2
9	Kilkis	190	10
10	Paionia	104	6
11	Sintiki	71	4
12	Corfu	212	37
	Total no.	**1174**	**88**

As mentioned above, in the CRISIS project we have considered only critical structures located in the larger populated areas of the cross-border region. Table 5 lists the considered schools, while Figure 6 illustrates the spatial distribution of these schools. Mainly secondary schools were considered, as they are located in larger populated areas, they accommodate more students than primary schools and often act as shelters in cases of emergency such as earthquakes. Finally, Table 6 shows the main characteristics of the schools, such as the material type, the number of stories and the year of construction, which will be used for the vulnerability assessment.

Table 5. Considered schools by municipality

#	Municipality	No. of considered schools
1	Filiates	0
2	Konitsa	2
3	Pogoni	0
4	Florina	3
5	Kastoria	5

6	Nestorio	0
7	Prespes	0
8	Almopia	4
9	Kilkis	4
10	Paionia	1
11	Sintiki	0
12	Corfu	0
	Total no.	**19**

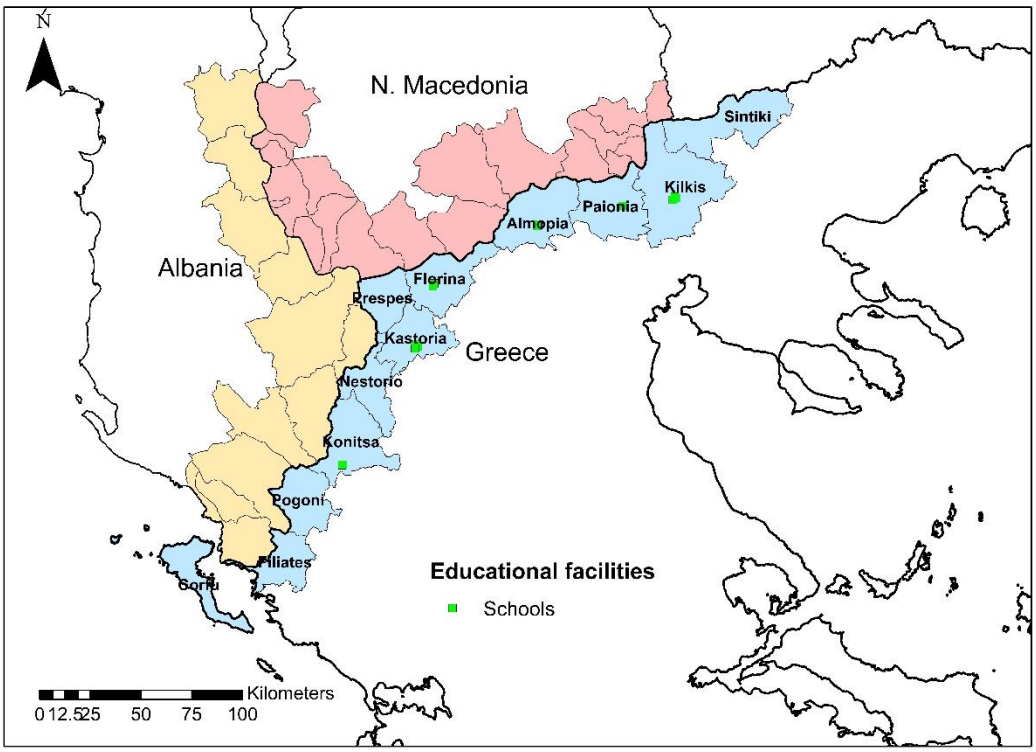

Figure 6. Location of the schools in the Greek part of the cross-border region considered in this project

Table 6. Main characteristics of considered schools

#	School Name	Municipality	Material	Number of storeys	Year of construction
1	Kastoria-2nd Junior High School	Kastoria	R/C	3	
2	Kastoria-1st High School	Kastoria	R/C	2	
3	Kastoria-3rd High School	Kastoria	R/C	2	
4	Kastoria-3rd Junior High School	Kastoria	R/C	2	
5	Kastoria-4th Junior High School	Kastoria	R/C	2	1996
6	Aridea- High School	Almopia	R/C	2	1996
7	Aridea-2nd Junior High School	Almopia	R/C	2	1979
8	Aridea- EPAL School	Almopia	R/C	2	1985
9	Aridea-Primary School	Almopia	R/C	2	> 1995
10	Kilkis 1st HighSchool	Kilkis	R/C	2	1990, 2010 (extension)
11	Kilkis 1st Junior High School	Kilkis	R/C	2	<1970
12	Kilkis 2nd Junior High School	Kilkis	R/C	2	<1970
13	Kilkis 2nd EPAL	Kilkis	R/C	3	1976

14	Florina 2nd High School	Florina	R/C	3	1995
15	Florina 2nd Junior High School	Florina	R/C	3	1995
16	Florina 3rd Junior High School	Florina	R/C	3	1979
17	Konitsa EPAL	Konitsa	R/C	1-2	
18	Konitsa High School	Konitsa	Masonry	2	
19	Polykastro High School	Paionia	R/C	2-3	1978

3.1.1.3 Albania

In the cross-border region there are 138 primary schools, 275 mixed primary and secondary schools, 343 secondary schools and 83 high schools, allocated in the seventeen considered municipalities as shown in Table 7.

Table 7. Schools by considered municipalities

No	**Municipality**	**Primary Schools**	**Secondary Schools/ Primary Schools**	**Secondary Schools**	**High Schools**	**Total**
1	Bulqize	4	23	32	4	**63**
2	Devoll	10	19	15	5	**49**
3	Diber	22	50	83	9	**164**
4	Dropull	0	1	5	2	**8**
5	Finiq	2	7	5	1	**15**
6	Gjirokaster	10	11	14	8	**43**
7	Kolonje	3	12	20	3	**38**
8	Konispol	4	4	3	1	**12**
9	Korce	15	30	19	12	**76**
10	Libohove	2	2	6	1	**11**
11	Librazhd	11	32	33	6	**82**
12	Maliq	14	23	27	8	**72**
13	Permet	3	5	22	2	**32**
14	Pogradec	23	33	27	11	**94**
15	Prrenjas	5	16	24	6	**51**
16	Pustec	3	4	1	1	**9**
17	Sarande	7	3	7	3	**20**
Total		**138**	**275**	**343**	**83**	**839**

The total number of schools considered for this project is 63 primary schools and 52 secondary schools. Table 8 lists the considered school for each municipality, while Figure 7 illustrates the spatial distribution of these schools.

Figure 7.Location of the schools considered in this project

Table 8.Considered primary and secondary schools by considered municipalities in Albanian cross-border region

No	Municipality	Primary Schools	Secondary Schools	Total
1	Bulqize	2	1	**3**
2	Devoll	1	2	**3**
3	Diber	7	4	**11**
4	Finiq	1	1	**2**
5	Gjirokaster	8	5	**13**
6	Kolonje	2	7	**9**
7	Konispol	2	0	**2**
8	Korce	13	9	**22**
9	Libohove	2	1	**3**
10	Librazhd	6	5	**11**
11	Maliq	4	4	**8**
12	Permet	3	8	**11**
13	Pogradec	6	1	**7**
14	Prrenjas	2	1	**3**
15	Sarande	4	3	**7**
	Total	**63**	**52**	**115**

The construction year and the number of storeys are given in the Fig. 8 and Fig. 9.

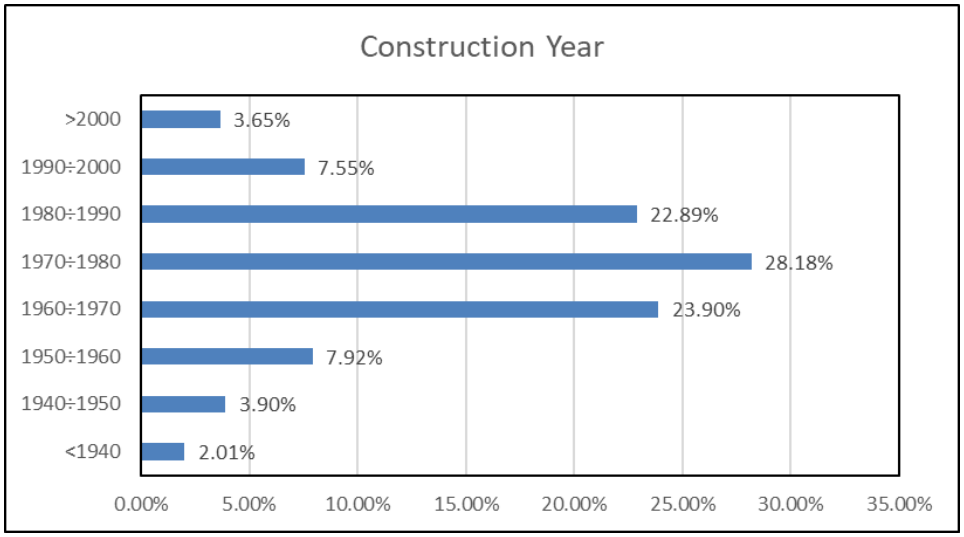

Figure 8 A percentage presentation of the considered schools in the Albanian cross-border region according to construction year

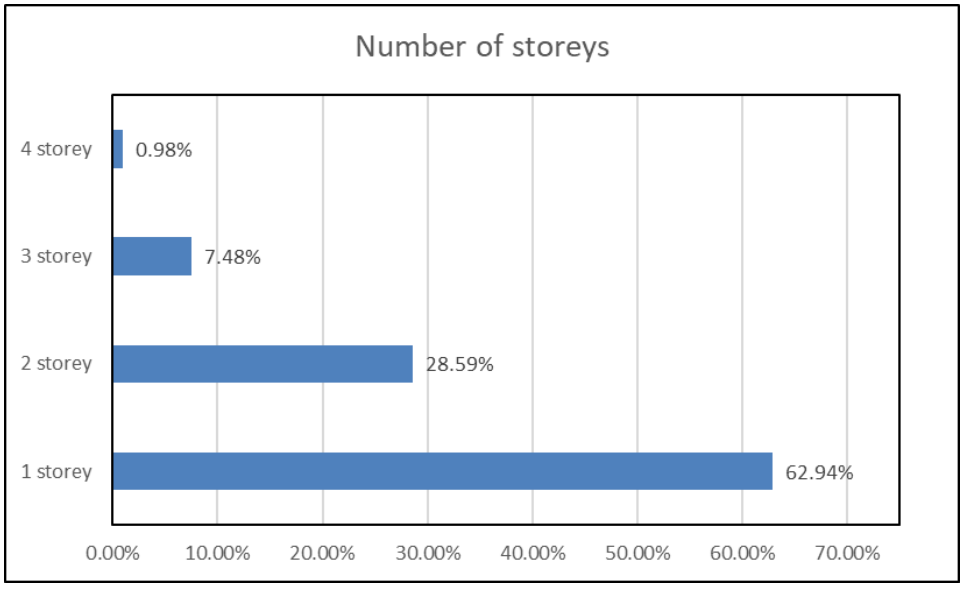

Figure 9 A percentage presentation of the considered schools in the Albanian cross-border region according to number of storeys

Fig. 10 and Fig. 11 given below show the information about the school's foundation condition and their external wall condition.

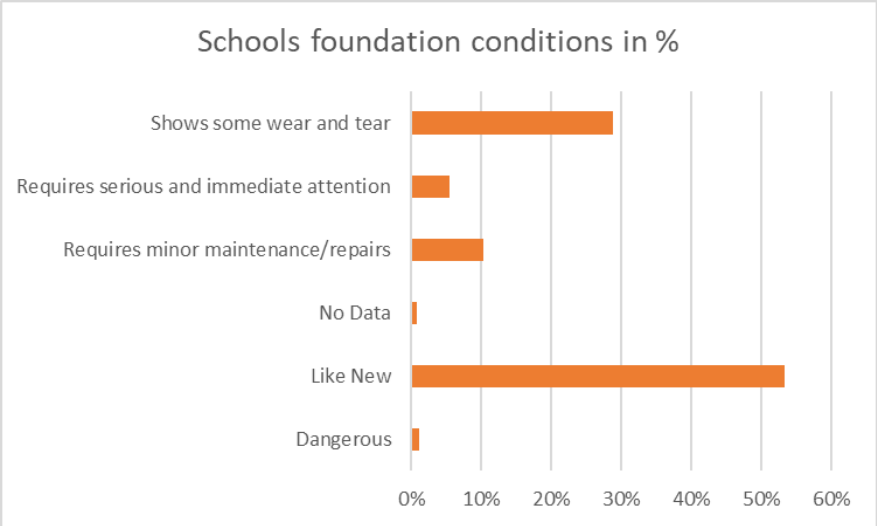

Figure 10 A percentage presentation of the considered schools in the Albanian cross-border region according the foundation conditions

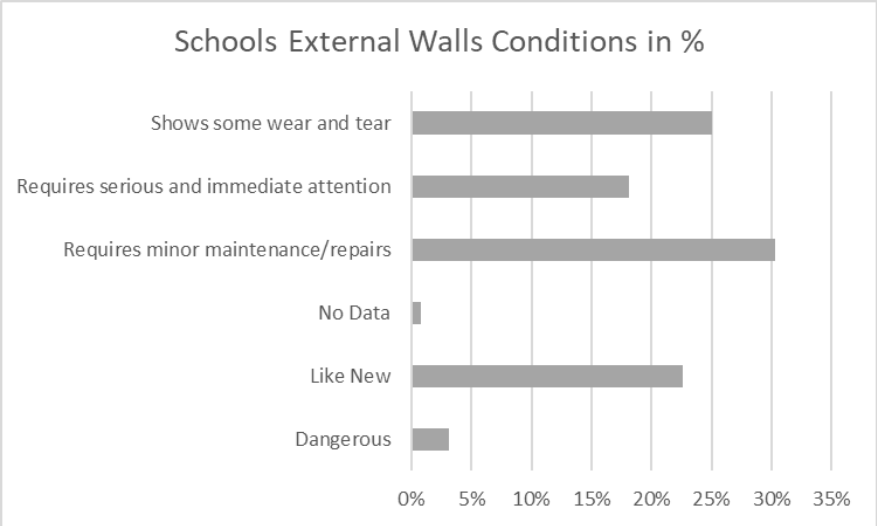

Figure 11 A percentage presentation of the considered schools in the Albanian cross-border region according the external walls conditions

3.1.2 Hospitals

3.1.2.1 N Macedonia

The same procedure for collecting data for the schools is used for the hospitals (see part 3.1.1).

The buildings for basic services considered in this project have been health care buildings representing: general hospitals, clinics, special hospitals and health care centres, i.e., those health care structures that can provide corresponding care and hospitalization of the injured. The review of the number of these structures per municipalities is shown in Table 9.

Table 9. Selected health-care facilities per related municipalities

#	Municipality	General hospitals	Clinics	Special hospitals	Health care centres	Total
1	Mavrovo i Rostuse	-	-	-	1	1
2	Debar	1	-	-	-	1
3	Centar Zupa	-	-	-	-	-
4	Struga	1	-	1	-	2
5	Vevcani	-	-	-	1	2*
6	Debarca	-	-	-	-	-
7	Ohrid	1	-	2	1	4
8	Resen	-	-	1	1	2
9	Bitola	-	1	-	1	2
10	Novaci	-	-	-	-	-
11	Prilep	2	-	-	1	2
12	Kavadarci	1	-	-	1	2
13	Gevgelija	1	-	1	-	2
14	Valandovo	-	-	-	1	1
15	Bogdanci	-	-	-	-	-
16	Dojran	-	-	-	-	-
17	Strumica	1	-	-	-	1
18	Novo Selo	-	-	-	-	-
Total no.		**7**	**1**	**5**	**8**	**21**

* The health care centre in Vevcani is accommodated in two structures: old and new.

Due to limited access to design documentation, i.e., precise data on some of these structures, for the purposes of this investigation, data on only a certain number of these have been provided. Namely, there were data on a total of 16 health care buildings. Their distribution per municipalities is shown in Tab. 10.

Table 10. Hospitals by considered municipalities

#	Municipality	Total no.of hospitals
1	Mavrovo i Rostuse	-
2	Debar	1
3	Centar Zupa	-
4	Struga	3
5	Vevcani	2
6	Debarca	
7	Ohrid	1
8	Resen	2
9	Bitola	1
10	Novaci	-
11	Prilep	-
12	Kavadarci	2
13	Gevgelija	2

14	Valandovo	1
15	Bogdanci	-
16	Dojran	
17	Strumica	1
18	Novo Selo	-
	Total no.	**16**

The presentation of the location of the considered health care structures is given in Fig. 12.

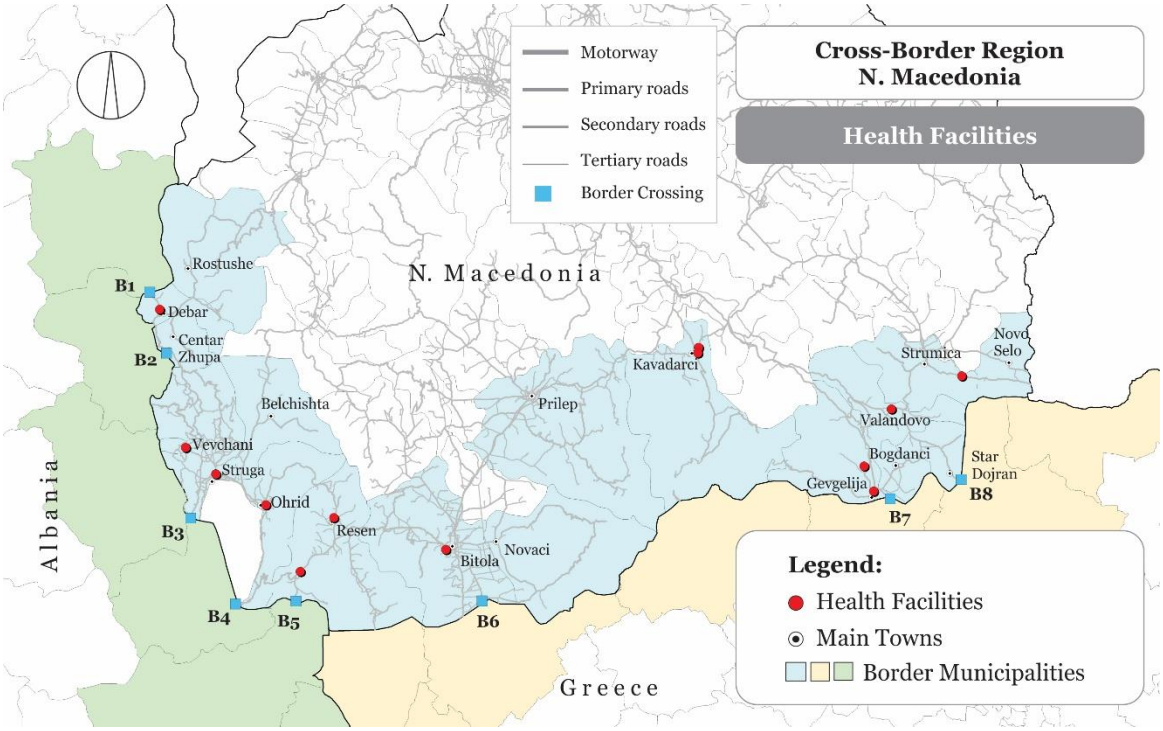

Figure 12. Location of the health facilities that have been taken into account with this project

Most of the health care structures for which data have been provided are constructed by use of reinforced concrete (CR) 68.8%, approximately 13% are constructed of masonry with unknown reinforcement (M99), 6.3% are constructed of unreinforced cement masonry (MUR) and the same percentage are constructed of reinforced masonry (MR) and concrete with unknown reinforcement (C99), Fig. 13.

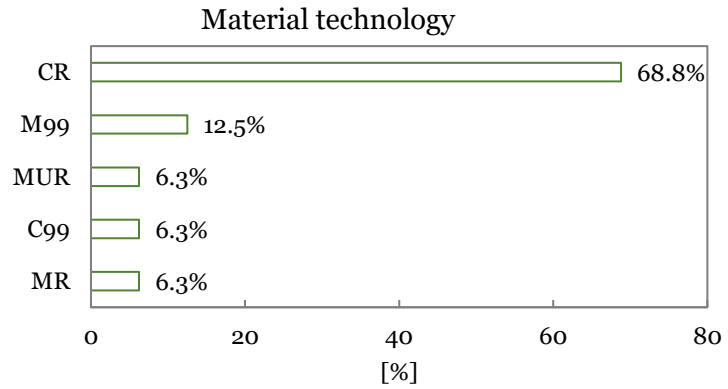

Figure 13. Percentage presentation of the considered health care structures in the N. Macedonian cross-border region according to material technology

According to number of storeys above and below ground, half of the health care structures have 2 levels above ground and 1 level below ground (Fig. 14).

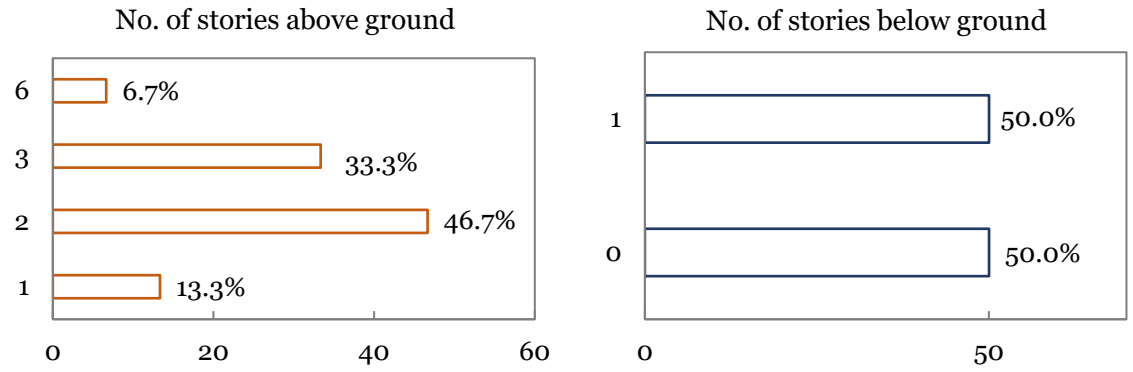

Figure 14. Percentage presentation of the considered health care buildings in the cross-border region according to number of storeys above and below ground

Unlike school buildings, health care buildings in the considered region are somewhat older, the oldest building being built in 1925, while the latest being built in 1989. More than 85% of the considered hospitals are built prior to the introduction of the seismic regulations (1981). The remaining ones 14.3% are designed and constructed according these codes.

According to data available on these structures, most of them are regular from structural aspect.

The shown presentations are based on data provided on a limited number of structures. There are no data on the remaining ones.

3.1.2.2 Greece

According to the Hellenic Statistical Authority, the total number of buildings used exclusively as hospitals or clinics in the cross-border region is 92, while there are additional 87 buildings with mixed use, including that of hospitals/clinics (Table 11).

Table 11. Number of individual buildings used as hospitals/clinics by considered municipalities in Greece region

#	Municipality	No. of buildings exclusively used as hospitals/clinics	No. of buildings with mixed use incl. hospitals/clinics
1	Filiates	2	0
2	Konitsa	2	0
3	Pogoni	2	0
4	Florina	3	0
5	Kastoria	9	2
6	Nestorio	1	0
7	Prespes	2	0
8	Almopia	8	1
9	Kilkis	28	12
10	Paionia	7	0
11	Sintiki	9	0

12	Corfu	19	2
	Total no.	**92**	**17**

As mentioned above, in CRISIS project we have considered only critical structures located in larger populated areas of the cross-border region. A total of 7 healthcare facilities including hospitals and health centers were considered. Table 12 lists the considered healthcare facilities, while Figure 15 illustrates the spatial distribution of these buildings.

Table 12. Main characteristics of considered healthcare facilities

#	Healthcare facility	Municipality	Material	Number of storeys	Year of construction
1	Kastoria- Hospital	Kastoria	R/C	3	1971
2	Florina- Hospital	Florina	R/C	2	1938
3	Florina- Hospital	Florina	R/C	2-4	>1986
4	Aridea- Medical Center	Almopia	R/C	2	
5	Polykastro- Medical Center	Paionia	R/C	1	
6	Konitsa Medical Center	Konitsa	Masonry, R/C (extension)	2	1995, 1988 (extension)
7	Kilkis Hospital	Kilkis	R/C	2?	1937, 1959, 2011

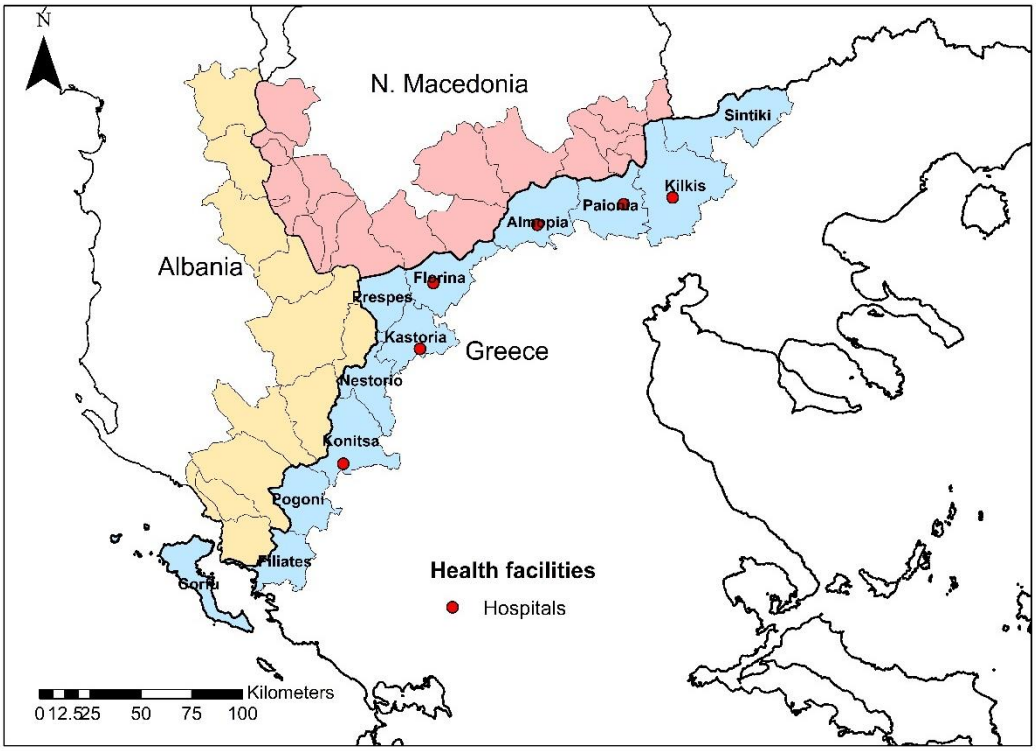

Figure 15. Location of the healthcare facilities in the Greek part of the cross-border region considered in this project

3.1.2.3 Albania

Figure 16 illustrates the spatial distribution of the healthcare facilities considered in this project.

These facilities have mostly 3 and 4 storeys, and their structure is made of a combined masonry and RC system, in order to create relatively large spaces.

Figure 16. Location of the healthcare facilities in the Albanian part of the cross-border region considered in this project

3.2 Bridges

3.2.1 N Macedonia

For the purposes of this project, a database on bridges situated along the main roads within the cross-border region with Albania and Greece has been created. A total of 165 bridges have been considered. Their locations are shown in Fig. 17. For some of these bridges, complete data have been available, while for some of them, there have been only basic data. Most of the bridges are situated along roads running to the border crossings on these two countries.

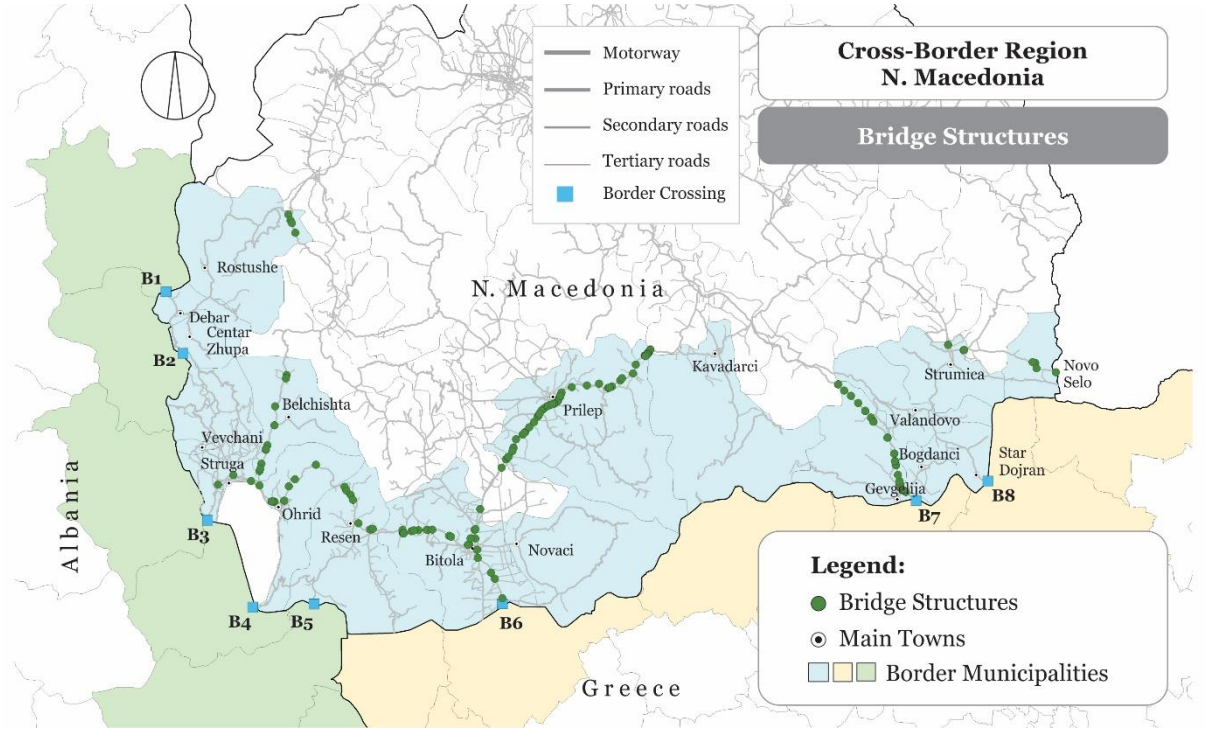

Figure 17. Location of the bridges considered within this project

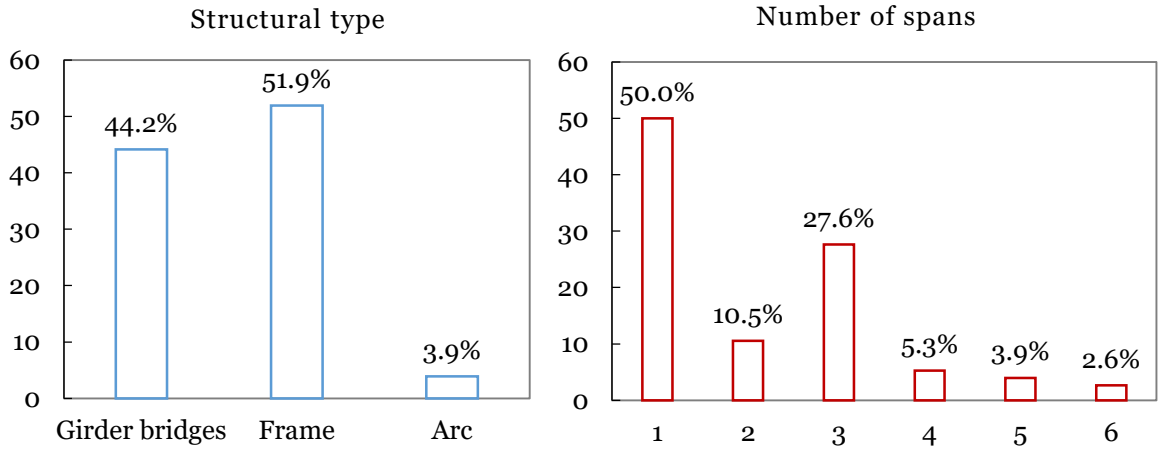

Figure 18. Percentage presentation of number of bridges from the aspect of structural type (let) and number of spans (right)

For most of these bridges, there are basic data on the material of which they are constructed, total length, number of spans and structural system. According to type of structural system,

the most frequently found bridge types in this region are bridges with frame structural system, then bridges with a girder system (with beam and slab main girders), while arch bridges account for the least number of bridges (Fig. 18 left).

As to the number of spans of structures for which there are data, half of them have 1 span, about 28% have 3 spans, while the greatest number of spans in this region is 6 (Fig. 18 right).

The number of bridges in cross-border municipalities is shown in Tab. 13.

Table 13. Number of bridges by municipalities

#	Municipality	Total no.
1	Mavrovo i Rostuse	4
2	Debar	-
3	Centar Zupa	-
4	Struga	3
5	Vevcani	-
6	Debarca	11
7	Ohrid	12
8	Resen	7
9	Bitola	26
10	Novaci	-
11	Prilep	42
12	Kavadarci	17
13	Gevgelija	36
14	Valandovo	-
15	Bogdanci	-
16	Dojran	-
17	Strumica	3
18	Novo Selo	4
	Total no.	**165**

3.2.2 Greece

In the context of CRISIS project, all the bridges inside the cross-border area of interest were identified. Furthermore, an on-site investigation of the most critical bridges related to this project was performed. While a large number of bridges exists, only a certain number spans along the main road network that connects the neighboring countries.

To illustrate the importance of the bridges with respect to their relationship with the main road network, the following terminology is used:

- (M): main, a bridge that is located on the main road that connects two countries,
- (S): secondary, a bridge that crosses the road network, i.e. it extends over or under the main road,
- (O): outside, a bridge that is outside the road network of interest.

In general, most of the bridges are constructed as single-span, frame structures, while reinforced concrete is the most used material. On the contrary, only a few multi-span or arched bridges exist. A total of 385 bridges are considered in this research project, while main (M) and secondary (S) bridges were thoroughly surveyed, on-site, in the context of CRISIS project.

In particular, sixteen main (M) bridges were reported (Table 1414):

Table 14. Main bridges (M) in Greece region

#	Latitude	Longitude	Material	Total length	Height	Spans	Span length
1	39.910496	20.365309	RC	15.00	8.00	1	15.00
2	39.909162	20.372037	RC	22.00	8.00	1	20.00
3	39.896614	20.543840	RC	150.00	20.00	5	30.00
4	40.18719	20.8009	RC	210.00	5.50	6	35.00
5	40.236049	20.872800	RC	100.00	4.50	3	33.00
6	41.101861	22.566405	RC	10.00	4.00	1	10.00
7	41.104180	22.563422	RC	10.00	4.00	1	10.00
8	41.114239	22.555528	RC	10.00	4.00	1	10.00
9	40.5933019	21.0656523	RC	12.00	4.50	1	12.00
10	40.5832178	21.0633739	RC	10.00	4.00	1	10.00
11	40.5664639	21.0666642	RC	11.00	4.50	1	11.00
12	40.5636362	21.0737621	RC	6.50	4.00	1	6.50
13	40.8941373	21.433287	RC	10.00	4.50	1	10.00
14	40.8559241	21.4328478	RC	7.50	4.50	1	7.50
15	40.835644	21.4369079	RC	5.00	4.00	1	5.00
16	41.0333558	22.608754	RC	5.00	4.00	1	5.00

In addition, nine secondary bridges cross the main road network. Both main (M) and secondary (S) bridges, as well as all the other bridges (O) reported in the region of interest, are shown in Figure 1919.

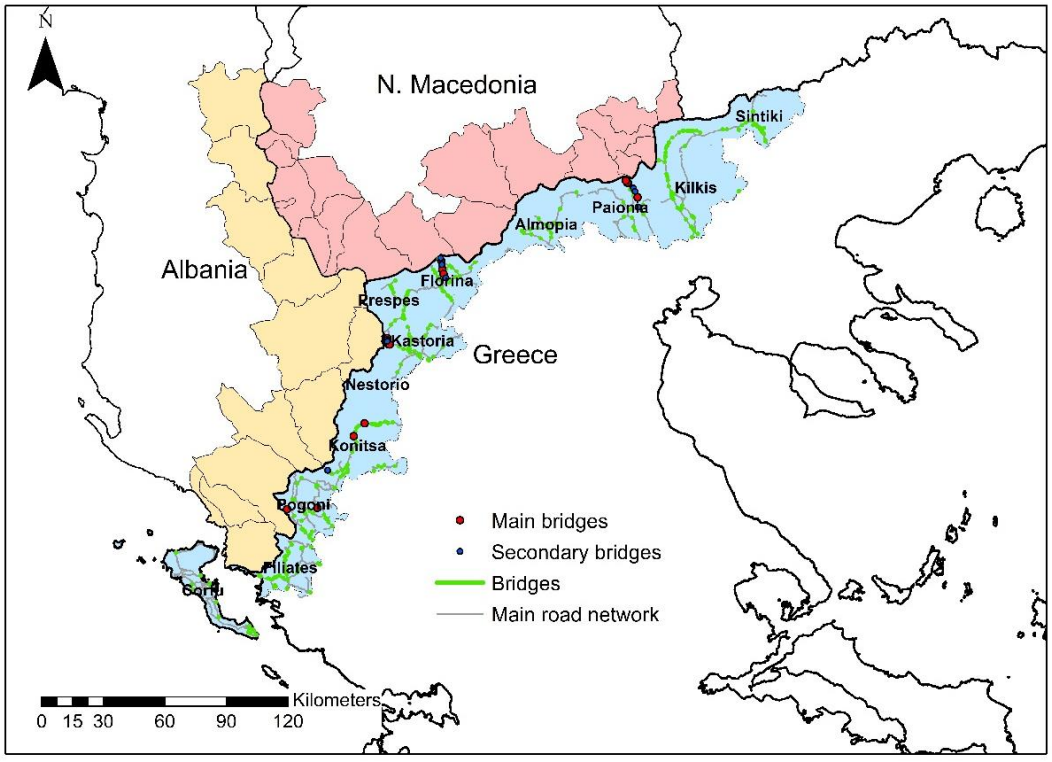

Figure 19. Location of the bridges considered; Greek part

3.2.3 Albania

For the purposes of this project, a database on bridges situated along the main roads within the cross-border region with North Macedonia and Greece has been created. A total of 191 bridges have been considered. Their locations are shown in Fig. 20. For these bridges basic data have been available. Most of the bridges are situated along roads running to the border crossings on these two countries.

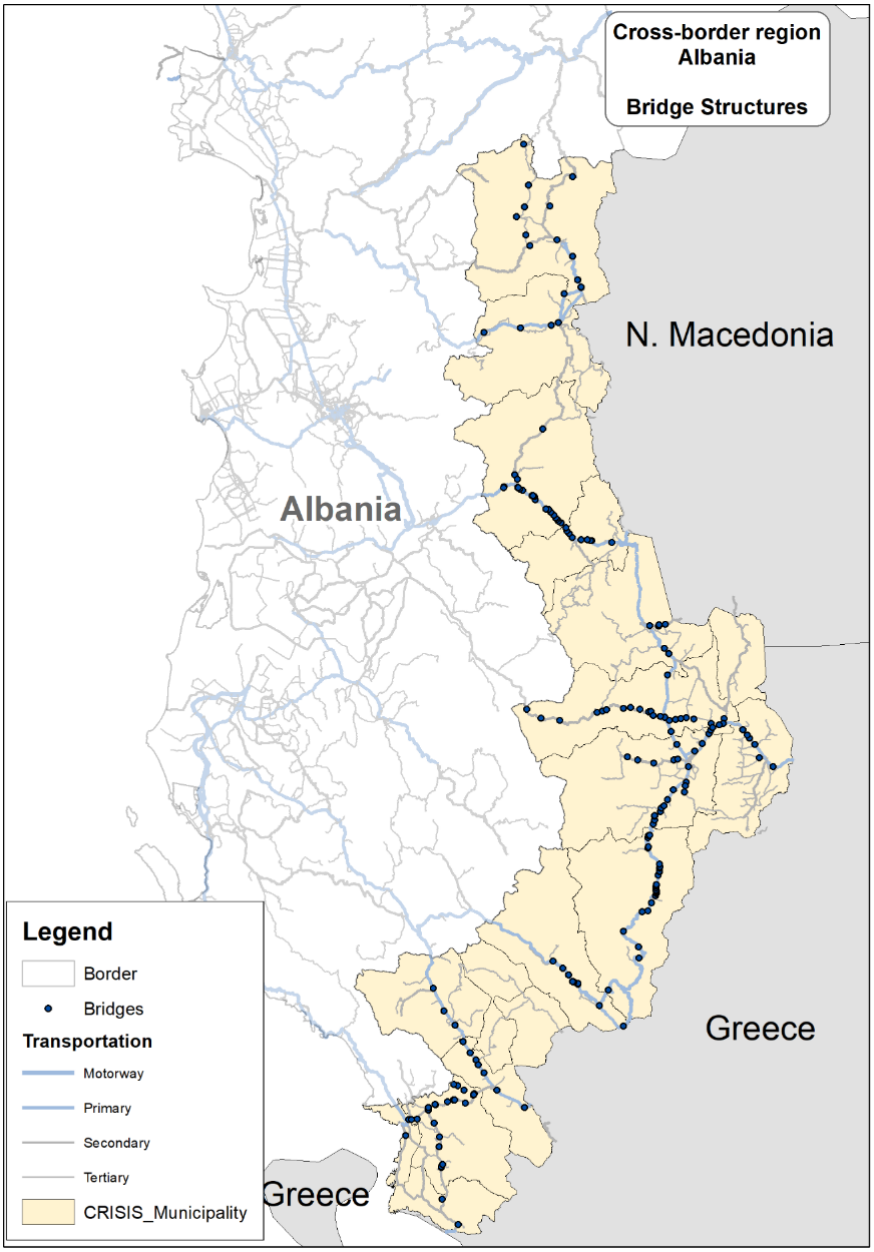

Figure 20. Location of the bridges considered within this project

For most of these bridges, there are basic data on the material of which they are constructed, total length, number of spans and structural system. According to type of structural system, the most frequently found bridge types in this region are bridges with a girder system (with

beam and slab main girders), then bridges with frame structural system and pre-fabricated truss bridge account for the least number of bridges (Fig. 21 left).

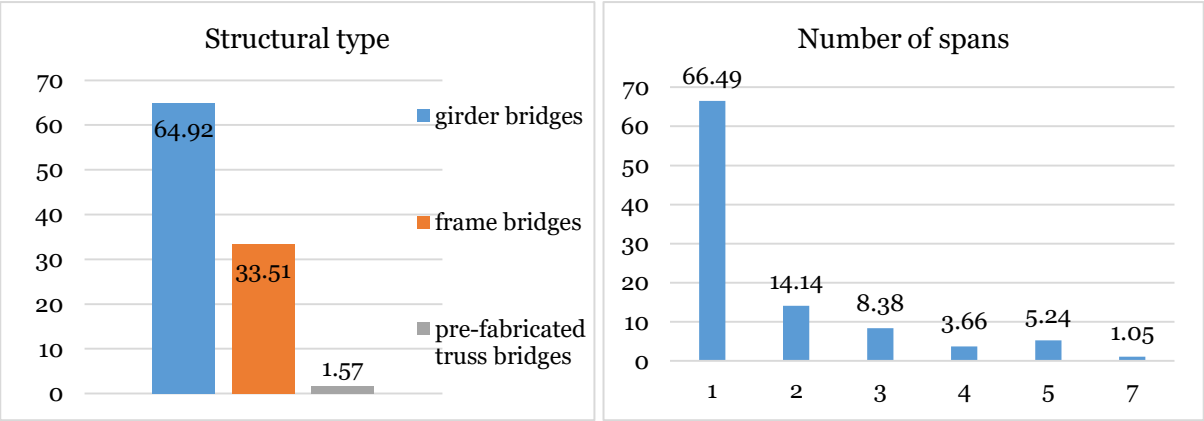

Figure 21. Percentage presentation of number of bridges from the aspect of structural type (let) and number of spans (right)

As to the number of spans of structures, for which there are data, more then half of them (67%) have 1 span, about 15% have 2 spans, 8.38% have 3 span, 3.66 % 4 span, 5.24 % have 5 span, while the greatest number of spans in this region is 7 (Fig. 21 right).

The number of bridges in cross-border municipalities is shown in Tab. 15.

Table 15. Number of bridges by municipalities

#	Municipality	Total no.
1	Maliq	16
2	Bulqize	4
3	Dropull	7
4	Diber	11
5	Finiq	11
6	Konispol	1
7	Maliq	3
8	Korce	20
9	Devoll	2
10	Pogradec	2
11	Permet	1
12	Librazhd	23
13	Gjirokaster	38
14	Prrenjas	9
15	Permet	8
16	Kolonje	29
17	Maliq	1
18	Diber	5
	Total no.	**191**

4. Summary

The following points can be made to summarise the harmonized risk exposure model of basic services and transport infrastructures:

- For the cross-border region among the countries – participants in this project, a harmonization of the exposure model has been made for educational structures, health care structures and bridges as part of the transport infrastructure by use of the GEM taxonomy.
- In this project, only structures in larger cities related to cross-border areas sand serving a larger number of users have been considered. This holds for all countries –partners in the project.
- From the cross-border region, in the territory of N. Macedonia, a total of 57 schools out of which 40 primary and 17 secondary schools have been included.
- A total of 15 health care structures from the cross-border region of the territory of N. Macedonia have been analyzed.
- For the purposes of this project, a data base on bridges situated along main roads within the frames of the cross-border region has been created. From the territory of N. Macedonia, a total of 165 bridges along main roads leading to border crossings on the neighbouring countries Albania and Greece have been considered.
- For Greece, a total number of 19 schools, 7 healt-care facilities and 16 bridges were assessed.
- A database on bridges situated along main roads within the frames of the cross-border region has been created. From the territory of Albania, a total of 191 bridges along main roads leading to border crossings on the neighbouring countries N. Macedonia and Greece have been considered
- For the considered cross border region between N.Macedonia, Greece and Albania, total number of 191 school buildings (57 in N. Macedonia; 19 in Greece and 115 in Albania), 46 health care structures (16 in N. Macedonia, 17 in Greece and 13 in Albania), and 741 bridges (165 in N. Macedonia, 385 in Greece, and 191 in Albania) are observed.

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