A Review of Road Structure Data in Six European Countries

Ales Znidaric[1], Vikram Pakrashi[2], Eugene O'Brien[3], Alan O' Connor[4]

Abstract: The European Union has expanded significantly in recent years. Sustainable trade within the Union leading to economic growth to the benefit of the 'old' and 'new' member states is thus extremely important. The road infrastructure is strategic and vital to such development since an uneven transport infrastructure, in terms of capacity and condition, has the potential to reinforce uneven development trends and hinder economic convergence of old and new member states. Significantly, in the decades since their design and construction, loading conditions have significantly changed for many major highway infrastructure elements/networks due primarily to increased freight volumes and vehicle sizes. This coupled with the gradual deterioration of a significant number of highway structures, due to their age, and the absence of a pan-European assessment framework can be expected to affect the smooth functioning of the infrastructure in its as-built condition, through increased periods of reduced flow due to planned and unplanned interventions for repair/rehabilitation. This paper reports the findings of a survey regarding the current status of the highway infrastructure elements in six countries within the European Union as reported by the owners/operators. The countries surveyed include a cross section of *'existing'* older countries and *'new'* accession countries. The current situations for bridges, culverts, tunnels and retaining walls are reported along with their potential replacement costs. The findings act as a departure point for further studies in support of a Centralized and/or Synchronised EU approach to Infrastructure Maintenance Management. Information in the form presented in this paper is central to any future decision making frameworks in terms of trade route choice and operations, monetary investment, optimized maintenance, management and rehabilitation of the built infrastructure and the economic integration of the newly joined member states.

Proceedings of ICE **Keywords:** Infrastructure Planning, European Union (EU), Maintenance and Inspection

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1. Introduction

The European Union (EU) has expanded significantly in the decades since the Treaty of Rome in 1958. A recent and critical development has been the accession of ten new states in 2004 and a further two in 2007. These accessions have added 74 million people, 444 billion euro of extra Gross Domestic Product (GDP) and 738,573 square kilometres of land area[1,2]. It creates the largest single market for trade and investment in the world exceeding that of the United States and Japan combined. It is clearly important that intra-EU trade becomes sustainable and grows to the benefit of both the 'old' and 'new' member states. According to studies of the International Monetary Fund and the European Union itself, the gross and per capita GDP of many of the new states are lagging significantly behind the longer standing members[3]. The existing road infrastructure is strategic and vital to the trade and economic development of all of the member states. An uneven transport infrastructure has the potential to reinforce uneven development trends and hinder economic convergence of old and new member states. Previous European studies[4,5,6,7] have illustrated the importance of infrastructure maintenance management programmes. Central to such programmes is an understanding of the condition state of the infrastructural elements/networks and of the loading, of which freight loading is the most significant, to which it is subjected. In this regard, it is important to note that the loading conditions, especially the traffic loading, have significantly changed, in the decades since the formation of the Union, due to economic development and the construction of many major highway infrastructure elements. Additionally, the gradual deterioration of a significant number of highway structures[7], the absence of a pan-European assessment framework as well as a dearth of information on the condition of infrastructural elements/networks in some countries in the Union, has and can be expected to further affect the smooth functioning of the infrastructure in its as-built condition. Consequently, a well-organised infrastructure monitoring and infrastructure assessment framework is considered by the authors to be critical to achieve the goals of the Lisbon Agenda[8].

This paper reports the findings of a questionnaire based survey, as a part of the EU funded research project SAMARIS[4] regarding the status of the highway infrastructure elements in various countries within the EU/EFTA (European Free Trade Association) region. This includes both existing older countries and the new accession countries. The findings have been summarized in terms of the various infrastructural elements (bridges, culverts, tunnels and retaining walls), their distribution in various kinds of roads, construction materials, methods of construction and costs of replacement. These findings create the framework and act as a departure point for further studies in support of a Centralized Infrastructure Maintenance Management Programme (CIMMP). Such information, when used in a CIMMP, has the potential to significantly reduce the cost associated with sustaining a Union wide operable infrastructural network. It also aids in providing a route choice for the trading countries and in prioritizing the important new trade networks in the extended economic zones. The development of such a proactive framework enables the new member states to create an extended robust trade network involving key economic hubs leading towards integration of the economies. The uncertainty regarding infrastructural deficits is reduced for countries with such management programmes significantly. This, in turn, can attract prospective investors within the extended economic zones leading towards a long term and sustained investment associated with economic growth.

2. Infrastructure Information Survey

Under work package WP15 of SAMARIS, a questionnaire was sent to experts and research partners in various European countries to obtain information regarding the condition of their road structures. Significant information was received from Slovenia, Poland, Hungary, Czech Republic, Austria and Norway[9]. The first four of these countries joined the EU in 2004 while Austria joined the union in 1995. Norway is a founder member of the European Free Trade Association (EFTA) since 1960. While being outside of the EU, it supports free trade and cooperation. Thus, the countries selected provide a significant variation which reasonably covers the spectrum of the situation in Europe. The next section presents some selected data from the survey.

3. Results of the Survey

3.1 Bridges

Table 1 provides an overview of the existing road network system in the chosen countries, the distribution of bridges in them and the types of roads. Poland, being a large country, has a significantly longer length of roads than the others considered in this paper. However, the length of roads per unit area for the different countries is more or less comparable with the exception of Norway which is sparsely populated. As expected, the motorways comprise the least share whilst local roads comprise the largest share of the roads. The definition of regional or local roads varies from country to country and they are sometimes not distinguished separately. As a result, in some cases, they are marked as unknown. The minimum length beyond which a structure is considered to be a bridge in these countries varies from 2m to 5m. Short bridges, typically of length 10m or less, are the majority in most of the countries except for Poland where medium (10m to 100m) and long (greater than 100m) bridges are more common. Most of the bridges are situated on regional or local roads except for Slovenia and Austria where a significant number of bridges are situated on the motorway network.

Table 1. Distribution of Roads and Bridges in Various Countries.

		Slovenia	**Poland**	**Hungary**	**Czech Republic**	**Norway**	**Austria**
Total Road Length	**km**	20138	370297	135555	55711	91825	106011
Road Length/ km^2	**km**	0.99	1.184	1.457	0.706	0.238	1.264
Motorway	**%**	2	unknown	unknown	1	1	2
National Roads	**%**	6	5	22	11	29	9
Regional Roads	**%**	23	8	unknown	88	29	unknown
Local Roads	**%**	69	87	78	unknown	41	89
Number of Bridges		2095	29041	6059	16536	16140	28149
Average Road Length/ Bridge	**km**	9.6	12.75	22.37	3.37	5.69	3.77
Bridges on Motorway	**%**	34.8	0.3	2.7	unknown	unknown	15.6
Bridges on National Roads	**%**	17.7	12	11.7	19.6	63.9	25.4
Bridges on Regional Roads	**%**	47.5	12	31.3	76.3	36.1	35.3
Bridges on Local Roads	**%**	unknown	75.8	54.3	unknown	unknown	23.8
Superstructure Length <10m	**%**	45	6	69	69	59	55
Superstructure Length 10m-100m	**%**	45	54	30	29	35	40
Superstructure Length >100m	**%**	10	40	2	2	7	5
Span Length <10m	**%**	55	37	75	72	62	54
Span Length 10m to 100m	**%**	44	63	25	27	33	40
Span Length >100m	**%**	1	0	0	0	5	6

Figure 1(a) shows the number of bridges built in various countries over a period of more than one hundred years. It is important to note that the majority of bridges have been built in the post-war period from 1945 to 1965. The loading conditions in many of these bridges have thus changed significantly whilst many of the structures considered may be expected to have undergone a significant amount of deterioration. Information regarding the bridge stock is only partial and an assessment framework for these bridges is considered to be very important in the new countries for the establishment of *'safe'* infrastructure to facilitate intra-EU trade. The growth of bridge deck area over time (Figure 1(b)) fluctuates somewhat for most of the countries. While it is apparent that all six countries have built extensively in the post-war period, there was little addition to the

Norwegian and Austrian stocks between 1966 and 1980. This was addressed in Norway in the 1981 to 1990 period and in Austria since then.

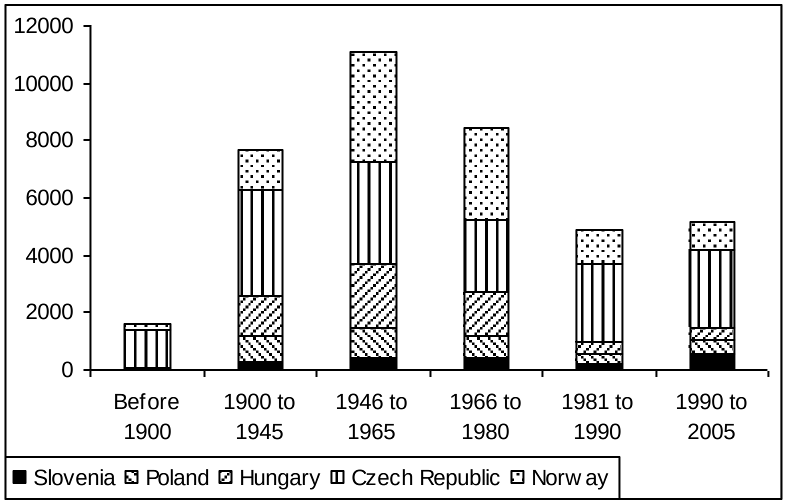

Figure 1(a). Number of bridges built at various times.

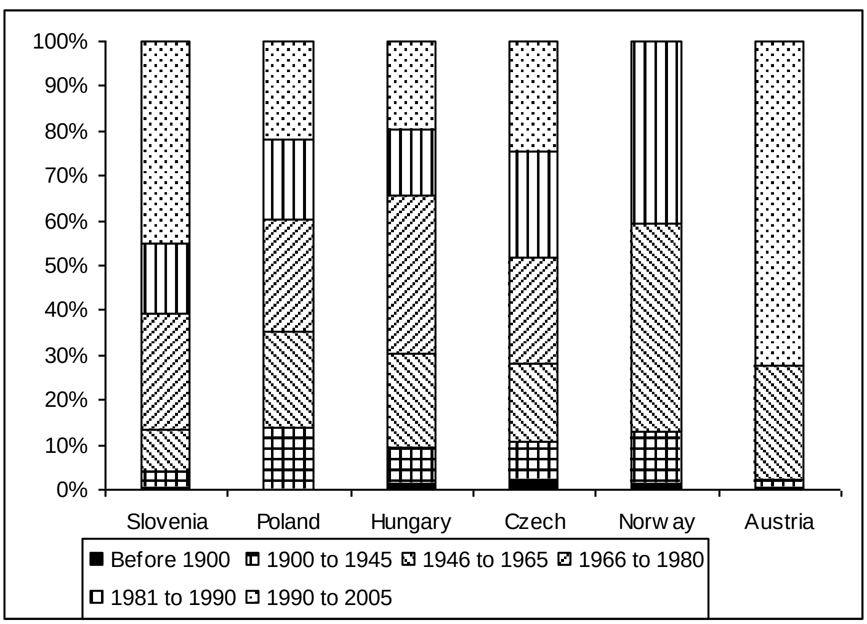

Figure 1(b). Growth of bridge deck area over time expressed as a percentage of national stock.

Figures 2(a) and 2(b) present the distributions of the various types of bridges by their numbers and deck area respectively. There are clear differences in preferences between countries. Austria is seen to have the highest number of arch bridges, suspension bridges, beam and slab bridges and cable stayed bridges. Slab and box girder bridges form the majority of the bridge stock in the Czech Republic. Movable and other types of bridges are mostly found in Norway. However, Norway has significantly more deck area than Austria in terms of suspension bridges and the Czech Republic in terms of box girder bridges.

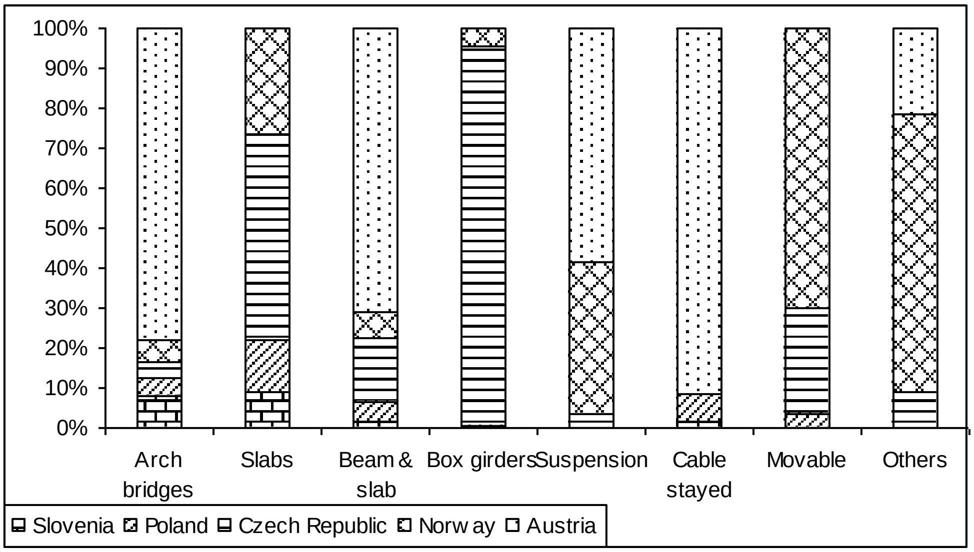

Figure 2(a). Type of construction of bridges expressed as a percentage of total number of national stock.

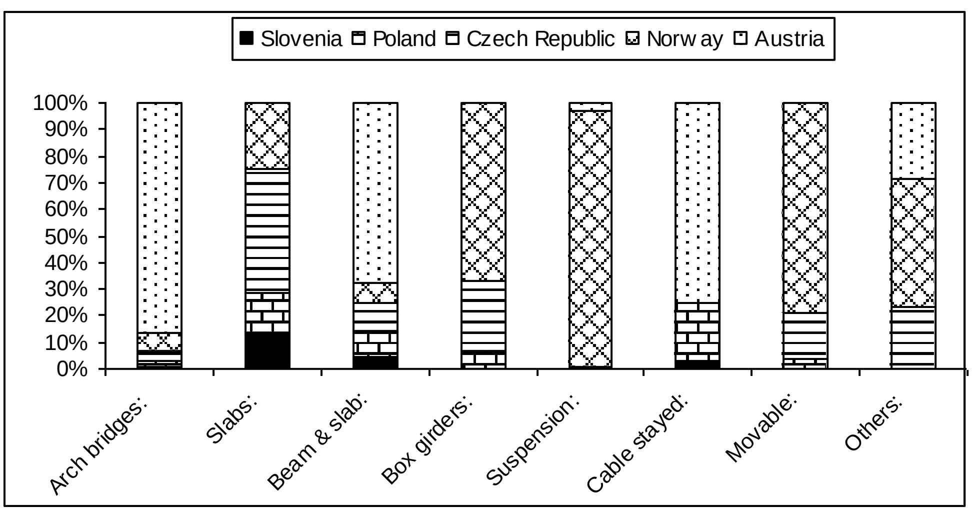

Figure 2(b). Type of construction of bridges expressed as a percentage of total deck area of national stock.

Bridges made of reinforced concrete comprise about two-thirds of the entire bridge stock for all the countries. This is followed by prestressed concrete, masonry and steel. The findings are the same both in terms of numbers and deck area. Apart from Hungary, no other country reported reinforced polymer bridges. Figure 3 shows the distribution of the bridges in terms of the material of construction used. In interpreting Figure 3 it is noted that RC = Reinforced Concrete, PC = Prestressed Concrete and FRP = Fibre Reinforced Polymer. The total replacement cost for the bridge stock reported has been estimated to range from €1.12 billion for Slovenia (lowest) to €29 billion for Austria (highest). All prices have been reported in the year 2006. A comparison between Poland and the Czech Republic in terms of the replacement costs of bridges for various types of road (Figure 4) show that the costs are comparable for national roads. However, replacement of bridges in motorways or regional roads is significantly more expensive in Czech Republic.

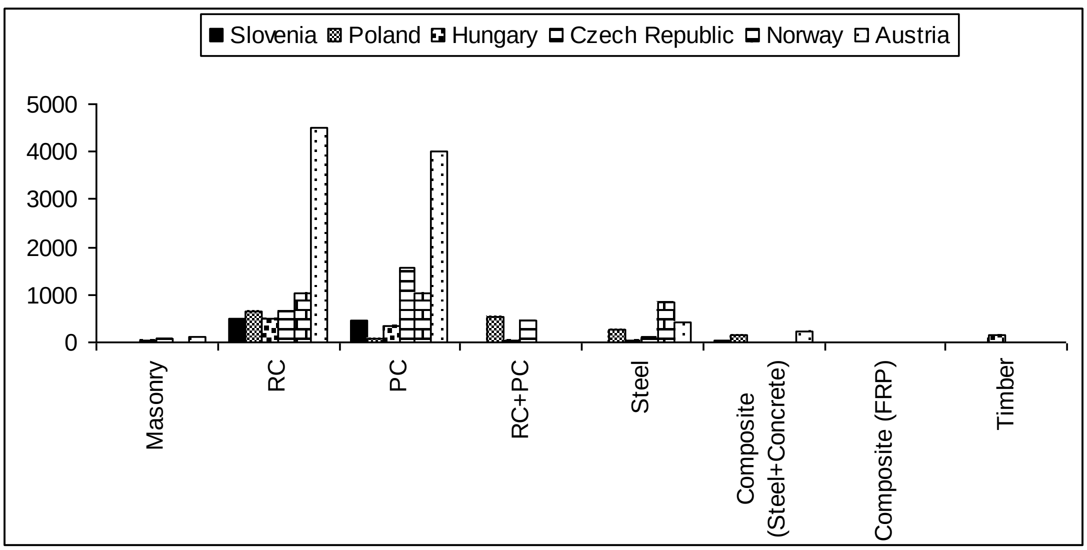

Figure 3. Distribution of number of bridges based on material of construction.

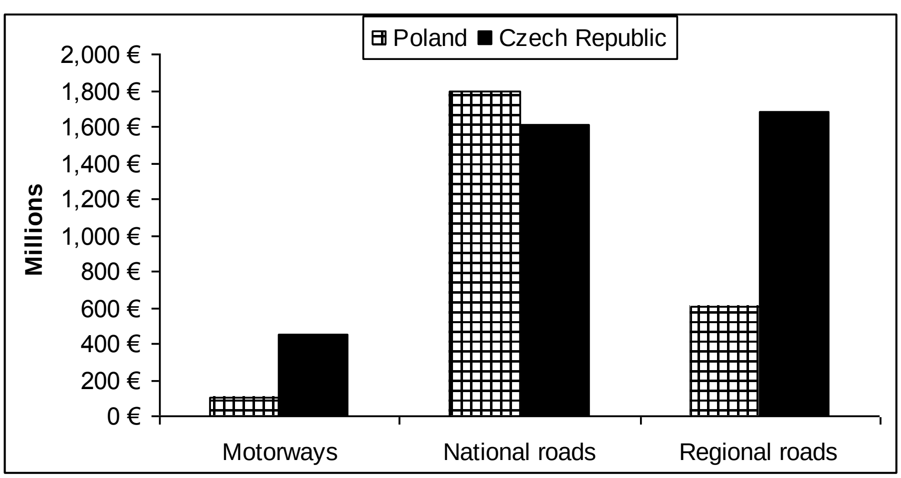

Figure 4. Replacement costs of bridges on various types of road.

Data on the investment in bridges, i.e. new build + maintenance, with respect to time, as a % of the total investment in infrastructure provision, is available for the Czech Republic (Figure 5). The investment is fairly uniform with time, except for the last fourteen years which shows a sharp decline. This trend is significant as it demonstrates a reduction in investment for a deteriorating network subjected to increasing loads and volumes of freight traffic, in effect it is the converse of what should be expected to provide an efficient, safe and operable network. The maximum investment period coincides with the time when most of the bridges where built (1946 to 1965). The annual costs per square meter of bridge area were reported to be very high for Poland and Slovenia in comparison with the other countries. A comparison between the total annual costs of infrastructure management for Slovenia, Poland and the Czech Republic (Figure 6) shows that the costs are ranked according to the total number of bridges present in the country).

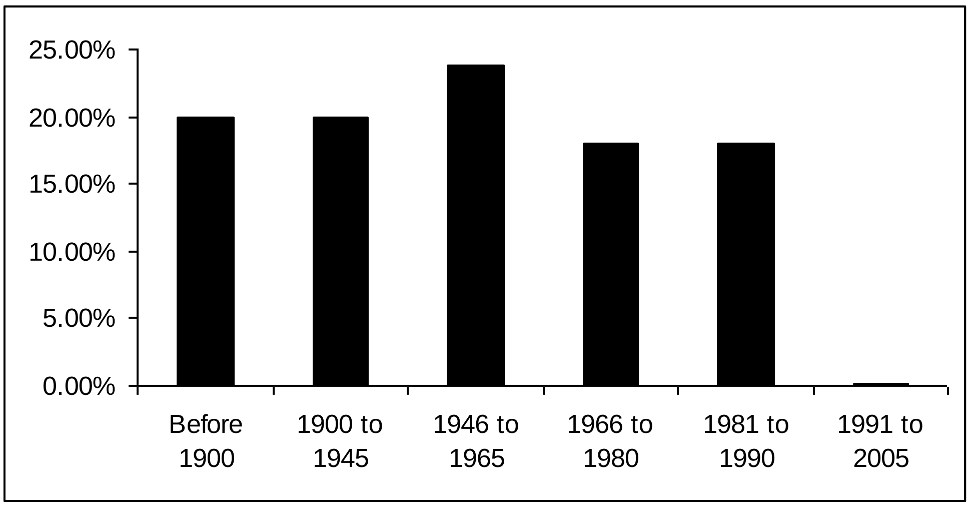

Figure 5. Investment in Bridges over time in the Czech Republic expressed as a percentage of total investment.

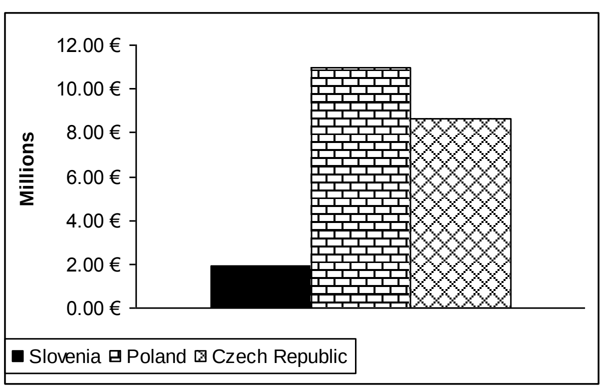

Figure 6. Total Annual Management Costs for Bridges.

3.2 Culverts

Inadequate information on culverts is available for most of the countries. Norway considers a culvert to be a bridge; hence data for culverts usually gets combined with data for the bridge stock. Figure 7 presents the information on culverts for Poland. Most of the culverts are made of concrete or precast concrete both in terms of numbers and total length. The rate of construction of culverts over time has been varied. However, a significant growth in numbers is noted since 1946. The Czech Republic has reported the replacement costs per square meter for concrete, precast concrete and corrugated steel to be €857, €367 and €350 respectively (cost reported in 2006). The total replacement costs for all culverts were estimated to be in the range €36 million to €106 million for Slovenia and Poland respectively.

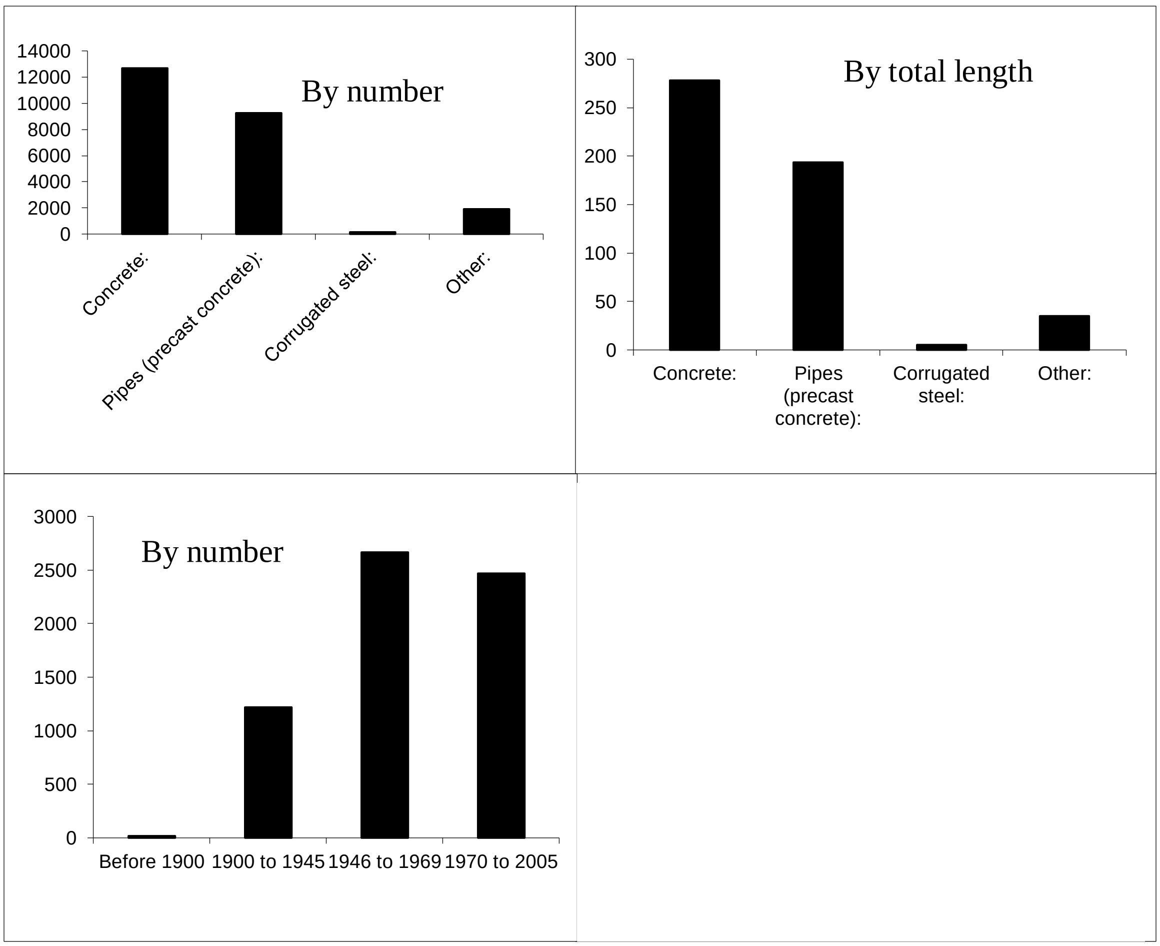

Figure 7. Distribution of culverts in Poland by material of construction and over time.

3.3 Retaining Walls

The data collected for the various countries centers around the bridge stock. In contrast, questions regarding retaining walls elicited little response. The only available information was from the Czech Republic. Most retaining walls are situated on regional roads. Gravity walls are the most common form of construction. Dry-stone and improved dry-stone are the most common materials for construction followed by plain and reinforced concrete.

3.4 Tunnels

Excluding Norway, which has about one thousand tunnels on their national road network, Austria, Slovenia and Czech Republic have a modest numbers of tunnels. The average length of tunnels varies from about 500m to 900m for Norway, Austria and Slovenia. The distribution, by number and length, in Slovenia, the Czech Republic and Austria on various types of road, is presented in Table 2. The growth in tunnel construction has been significant and about 70% of those reported have been built in the last 35 years. Interestingly, in the post-war period when the construction of bridges and culverts was significant, tunnel construction was quite low (Figure 8). About 89% tunnels of Slovenia are ventilated followed by Austria (70%) and Norway (57%). Nearly all the tunnels are bored or cut-and-cover type. The replacement costs are estimated to be ranging from €7 to €9 million (reported in 2006) per km length.

Table 2. Distribution of Tunnels in Various Countries

	Unit	**Slovenia**	**Czech Republic**	**Austria**
Total	Number	37	15	320
Motorway	Number	14	3	181
National Roads	Number	13	9	84
Regional Roads	Number	10	3	55
Local Roads	Number	0	0	0
Motorway	km	11.46	0.9	204
National Roads	km	0.9	3.98	51
Regional Roads	km	1.946	0.08	32
Local Roads	km	0	0	0
Unidirectional	Number	24	4	0
Bidirectional	Number	13	11	0
Unidirectional	km	6.386	1	206
Bidirectional	km	7.92	4	81

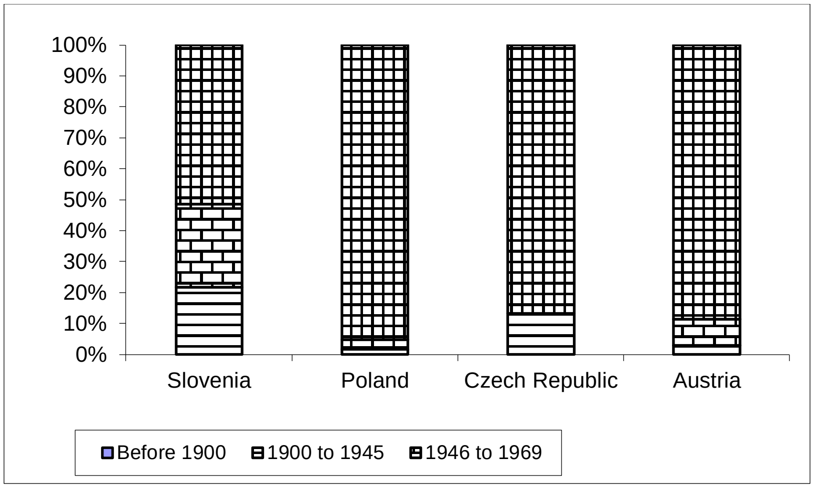

Figure 8. Distribution of number of tunnels constructed over time.

4. Conclusions

This paper presents a synopsis of the responses of various infrastructure owners/managers, from a cross section of European countries, to questions on road structures. The importance of the information lies in the fact that a number of these countries have joined the European Union in recent years and the existing condition of their infrastructure is important for the maintaining/enhancing/developing intra-EU trade and consequently in driving economic development. Information on infrastructural components other than bridges is poor. A large number of bridge and culverts were constructed during the post-war period of 1946 to 1969 suggesting that it is important to rate them according to their present condition state, allowing for deterioration, and under current traffic loading conditions. Although the replacement costs of the infrastructural elements are extremely high and the management costs have to be prioritized due to limited budgets, few management systems, in the opinion of the authors, consider economic aspects in the assessment and prioritization of remedial actions. Going forward then, in terms of EU investment through structural funds etc., there appears to be considerable scope for enhanced maintenance management optimization/prioritization/ synchronisation processes on a trans EU existing/prioritised/planned transportation network level rather than on an project by project level.

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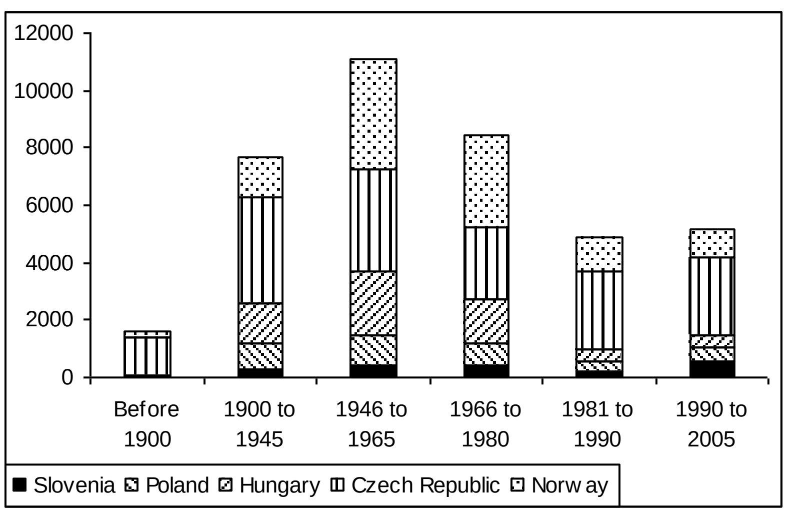

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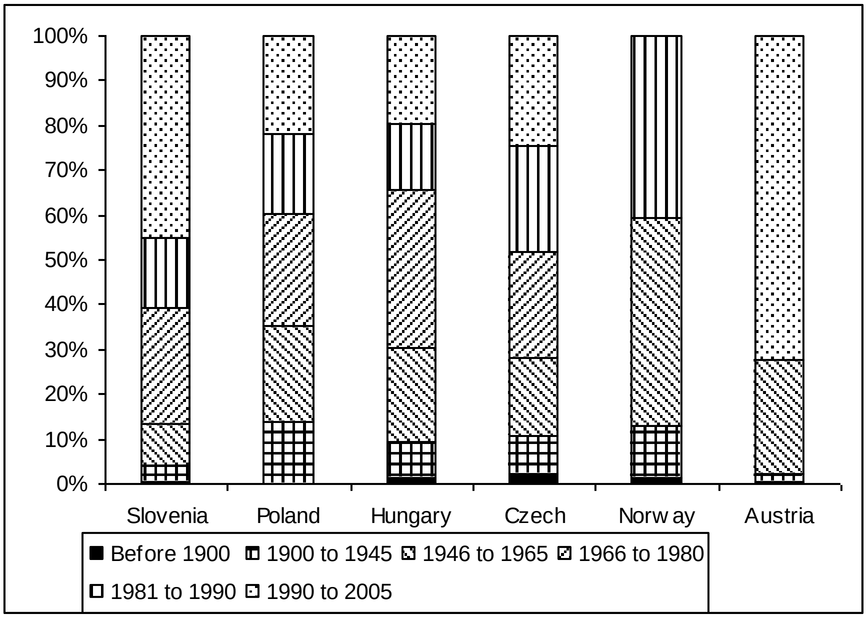

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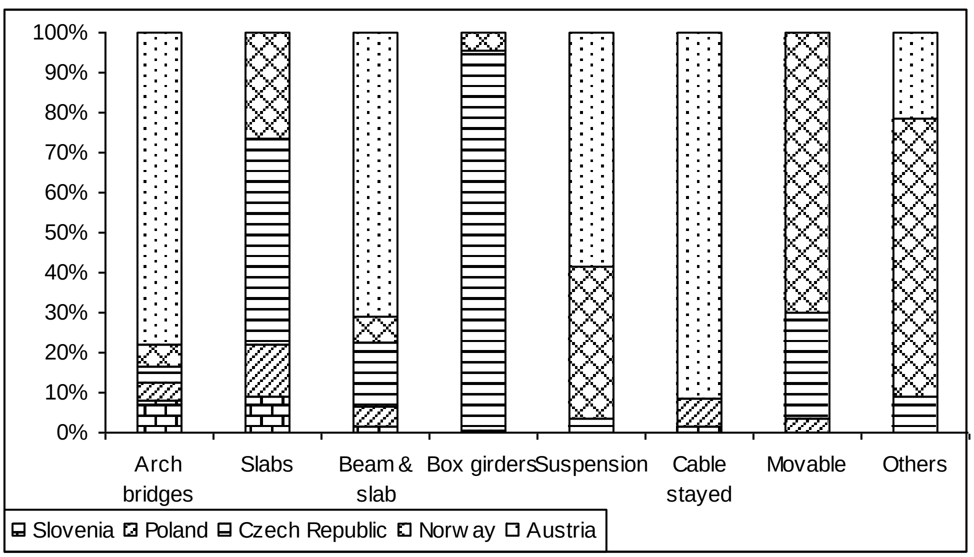
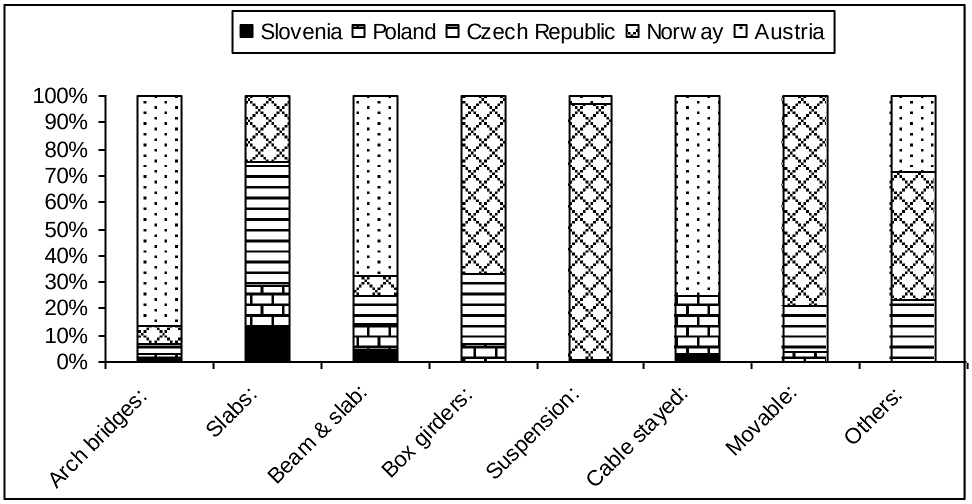


Figure 2(a)



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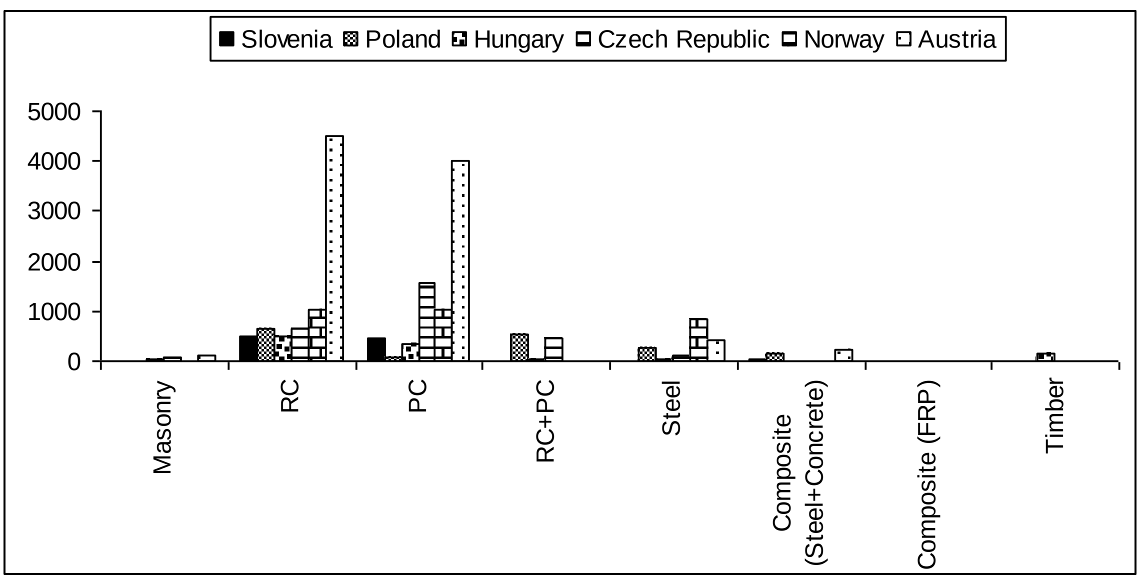
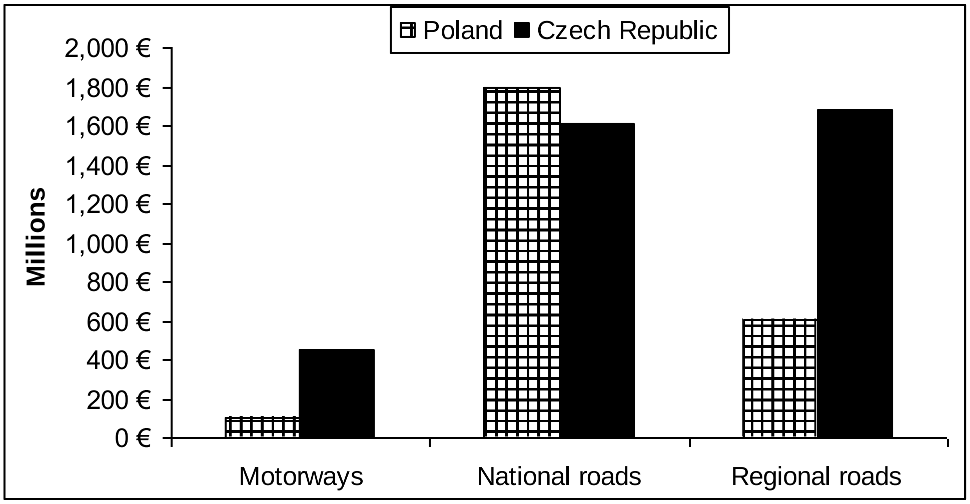


Figure 3



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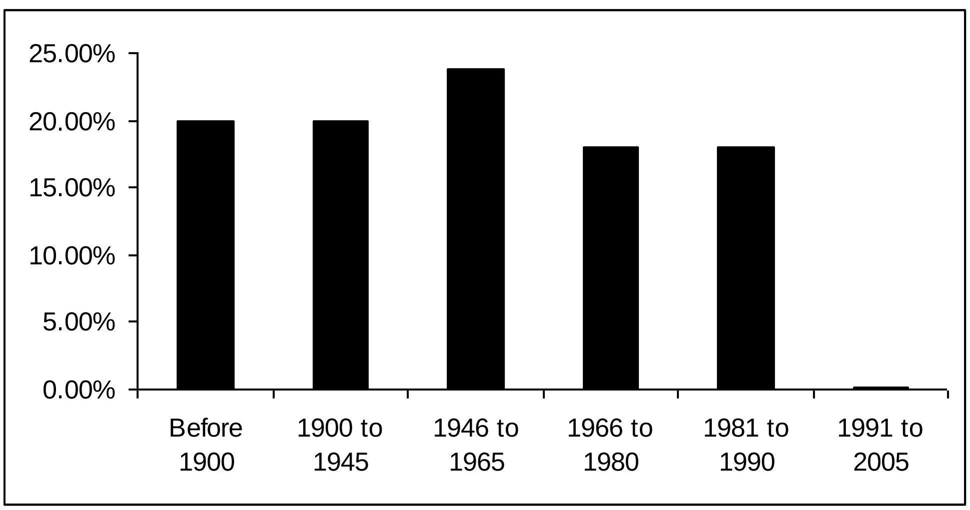

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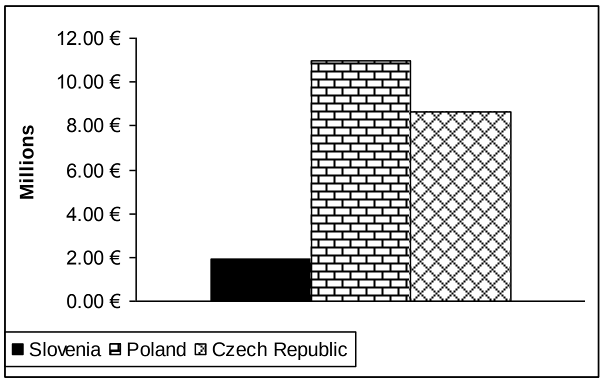
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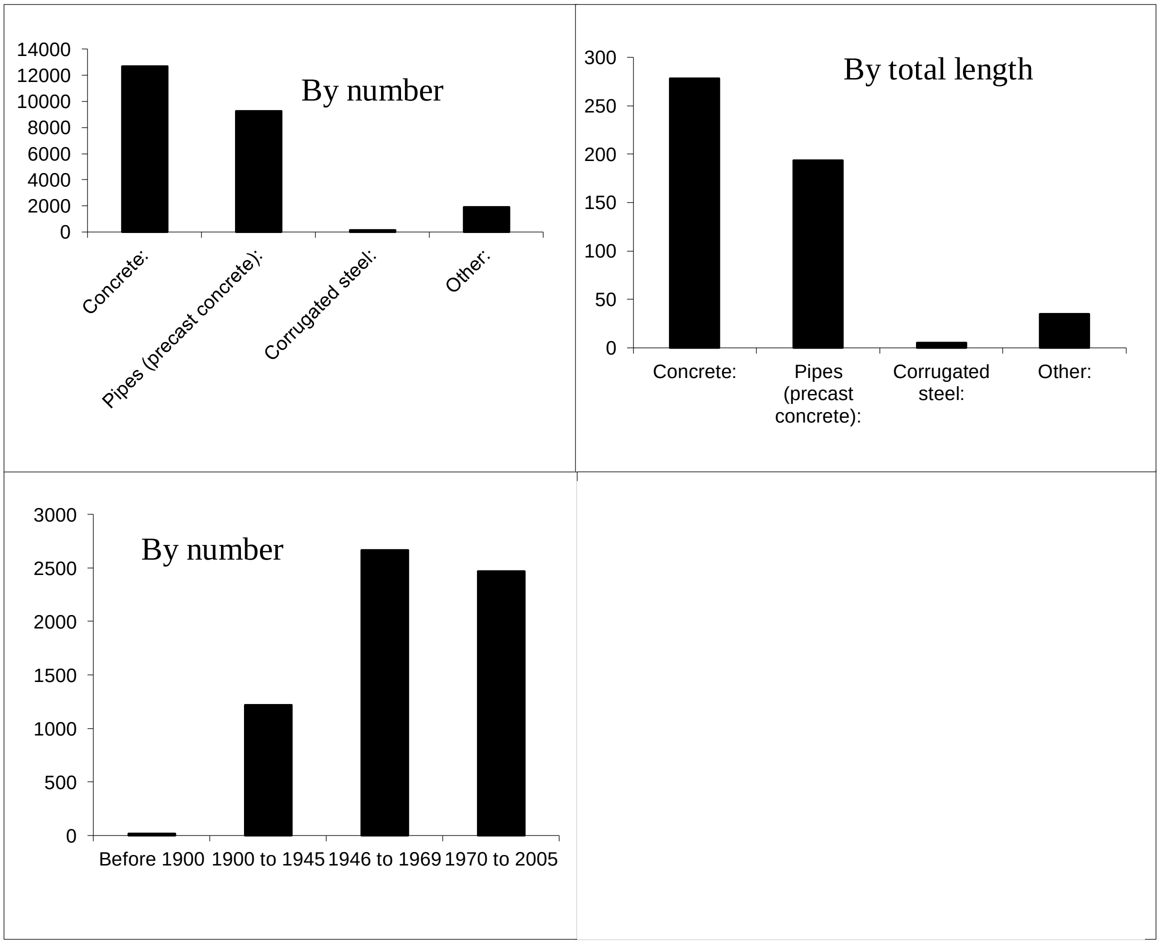
Figure 6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Corrugated steel:
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Concrete:
Pipes (precast concrete):
Corrugated steel:
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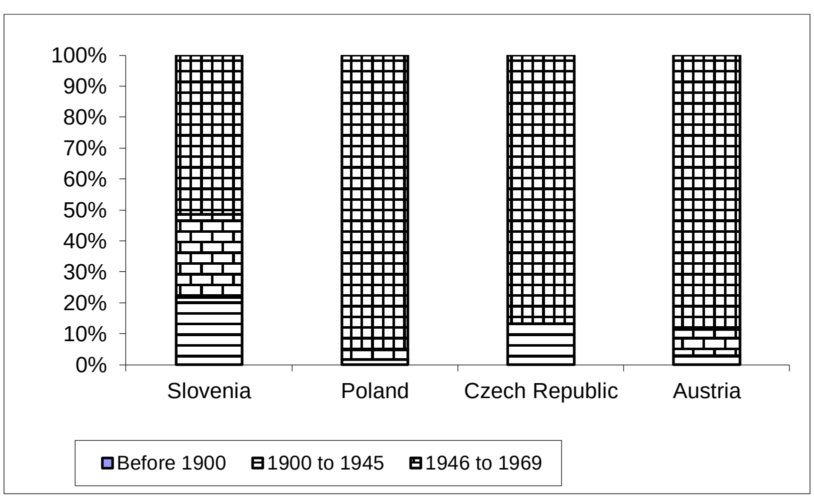
By number
Before 1900
1900 to 1945
1946 to 1969
1970 to 2005

Figure 7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Slovenia
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Figure 8

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