ROAD INFRASTRUCTURE EXPENDITURES ON NATIONAL, REGIONAL AND COMMUNAL LEVEL IN AUSTRIA

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ABSTRACT

With budget restrictions and increasing need for cost control, life cycle costing analysis and asset management have gained importance for road authorities. Based on a comprehensive investigation of road infrastructure investments on national, regional and communal level from 2002 to 2008 in Austria a standardized expenditure framework is presented. Furthermore, the presented approach goes beyond the definition of a standardized set of benchmarks for annual costs of road infrastructures or average costs per unit for various road assets. Instead the cumulative probabilities of unit costs for different road assets are presented based on a thorough investigation of a vast number of projects. With the outcome of the research work, road authorities will be able to improve the benchmarking of their road expenditures. Furthermore a solid base for the prognosis of the necessary budgeting needs is provided in order to maintain the existing road network as well as to fund necessary further improvements. The developed methods were used in the assessment of the necessary road infrastructure expenditures for regional roads category B from 2007 to 2013 in Austria. Furthermore the findings of the research and the developed methods support an actualization of cost accounting, tolling and funding of road assets on every level.

KEY WORDS: Road infrastructure, budget, expenditures, benchmarking

1. LEGAL FRAMEWORK AND POLITICAL CONDITIONS

According to Federal Highway Act of 1971 roads have to be planned, build and maintained in a way that ensures a safe, easy and fluid flow of traffic. Furthermore the investments have to be economically efficient and should harm the environment as little as possible. Whether these goals are attainable has to be investigated at a very early stage at network level as part of a strategic environmental assessment according to Directive 42/2001/EG. At project level an environmental assessment with regard to all impacts during construction, maintenance, rehabilitation, and demolition has to be done for all mayor projects according to the Environmental Impact Assessment Act (2000) on the basis of Directive 85/337/EEC.

A consistent will of the legislature for a comprehensive assessment of road assets on the basis of a life cycle approach can therefore be considered as given for the whole European Union. In practice, however, due to limited budgets or not sufficient know how of the concept of life cycle costs often the initial investment costs are the only decision factor. Such a short term optimization of investment strategy may lead to the selection of unfavourable route or construction alternatives with high costs for maintenance and rehabilitation. The separation of responsibilities in different administrative departments, each with its own budget may also lead to cost savings in some departments, but not the life-cycle costs of the entire road system [1].

The incentive for planners and politicians alike to realize spectacular new projects, which are binding the necessary funds for operation and maintenance of the existing road network may result in higher life cycle costs. Furthermore, only in exceptional cases new megaprojects show significant revenues in well developed economies. A high budget pressure is also a strong incentive to cut necessary investments in maintenance and rehabilitation because road infrastructures usually are long lasting [2].

2. MANAGEMENT FRAMEWORK FOR ROAD ASSETS

Asset management in modern road authorities represents a comprehensive and structured approach to long-term management of all road assets with the goal to provide the best possible service for both road users and tax payers. In order to achieve that goal the needs of construction, operation maintenance and rehabilitation until deconstruction have to be considered already at the planning stage. With the concept in Fig.1, a continuous analysis and optimization during the life cycle is possible.

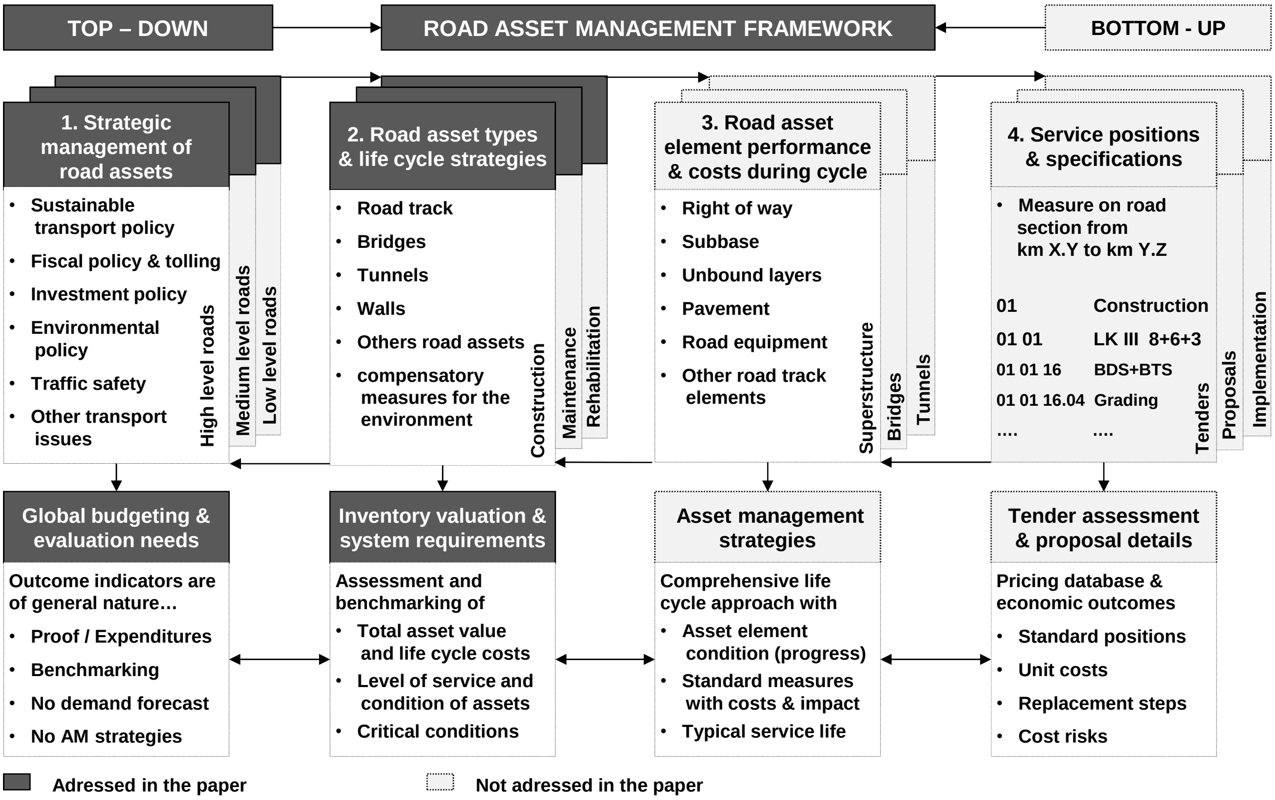


Fig.1: Asset management levels for road infrastructures „top down“ & „bottom up“

With the addressed "top down" approach existing budgets and expenditures per unit can be compared between road authorities. Furthermore investment and fiscal policy as well as tolling and other operational benchmarks can be assessed. Demand forecasting or asset management strategies are not feasible at this level, because actual expenditures do not necessarily have a connection to the actual budgeting needs. If individual assets (e.g. road tracks, bridges, tunnels) and the required expenditures at each phase during the life cycle are linked with their condition, the total asset value and budgeting needs can be estimated. A detailed planning of rehabilitation measures or an optimization of the life cycle however is only feasible at a more detailed level for each asset element. At project level the individual specifications and positions have to be considered and may be systematically assessed and compiled "bottom up".

3. INVESTING IN ROAD ASSET STRUCTURES

The well-developed and efficient transport infrastructure is a key to economic success in a single European market. The development of the regions and the resulting traffic due to this market has led to a concentration of the traffic growth on the high level transport network [3]. In response the highway network in the EU 27 has grown between 1990 and 2007 from 41.900 km to 65.100 km (+55%). The highway network in Austria has also grown +17% during this period [2], but was already well developed at this time. The road length per inhabitant 2007 for highways was 91% higher and for main or national roads 116% higher compared to the EU27 [Fig.2].

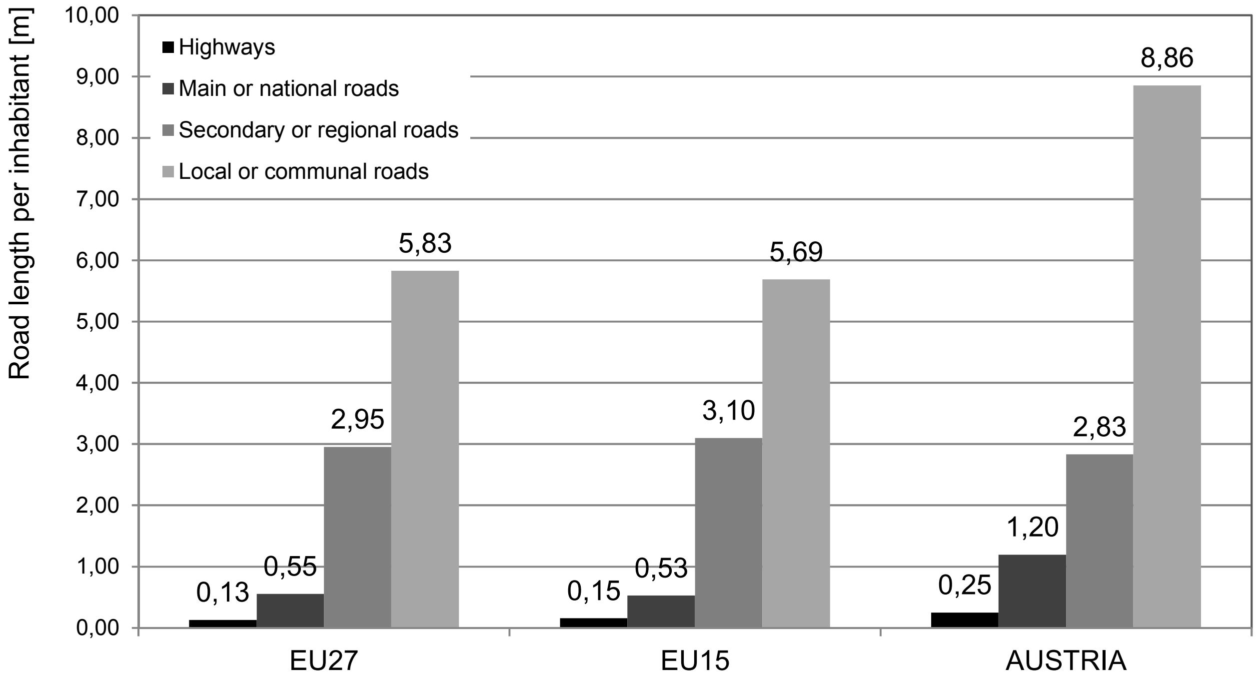


Fig.2: Road length per inhabitant for all level of roads 2007 (EU27, EU15, AT)

Deficient transport systems with limited capacity or reliability may produce economic costs due to reduced opportunities, time losses from congestion and resulting environmental damages. With new transport projects (e.g. roads) existing bottlenecks may be removed resulting in better accessibility to markets, investments, employment, and recreational activities. Whether the resulting internal and external costs for such projects outweigh the benefits has to be assessed individually. In general an efficient transport infrastructure has provided economic and social opportunities with benefits for the economy [4]. Among other factors the division of labour and economy of scale allowed a substantial growth of the gross domestic product (GDP) in the EU27 of +54% and in Austria of +99% from 1990 to 2007. The accessibility of regions (NUTS3) and the gross domestic product was found to be related with a coefficient of determination of 0.29 (linear model). Furthermore large agglomerations are benefitting above average compared to rural regions from high level transport networks [5].

If the transport infrastructure is already well developed, the marginal costs for further extension of transport infrastructure tend to outweigh the benefits due to a progressive increase of costs for a further gain of accessibility. In addition the necessary amount of civil structures (e.g. bridges, tunnels) and measures to compensate negative environmental impacts grow accordingly. Thus an optimal transport infrastructure for each region exists considering all costs and benefits in an LCC - approach.

Austria has a rather large network of 2.144 km of highways and expressways that are maintained by a private company (ASFINAG) held by the Republic. Due to the mountainous topography and a permitted speed of up to 130 kph a high amount of bridges (7,6%) and tunnels (7,3%) in the layout of these roads was necessary. The regional road network is maintained by nine federal states and consists of category B roads with a length of 9.994 km and category L roads with lower importance and a length of 23.673 km. Due to the comparably lower permitted speed (50 to 100 kph) and safety standards a better adaption to the topography is possible resulting in a significant smaller amount of civil structures. The lowest level of public roads with a length of approximately 74.000 km is maintained by 2.357 communities. With most of the communities located on flat land or valleys and a permitted speed of 30 to 50 kph only a small amount of bridges and almost no tunnels exist on this network level (Fig. 3).

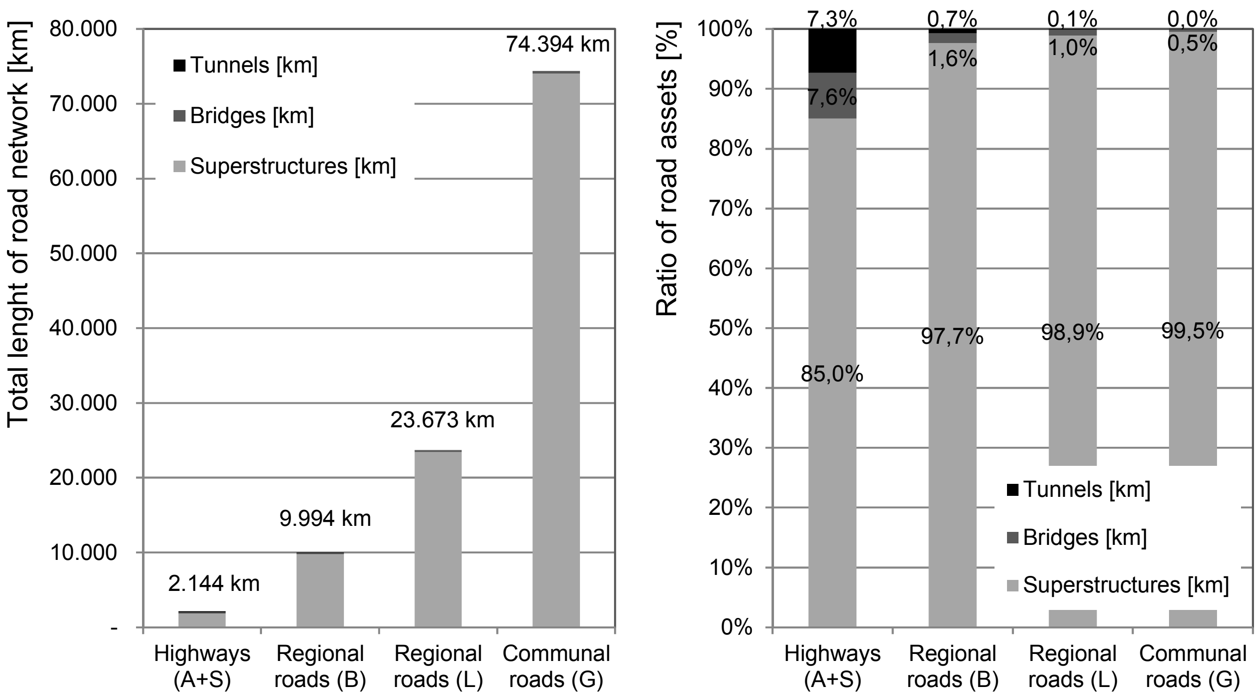


Fig.3: Total length of road network and ratio of road assets 2010 (AT)

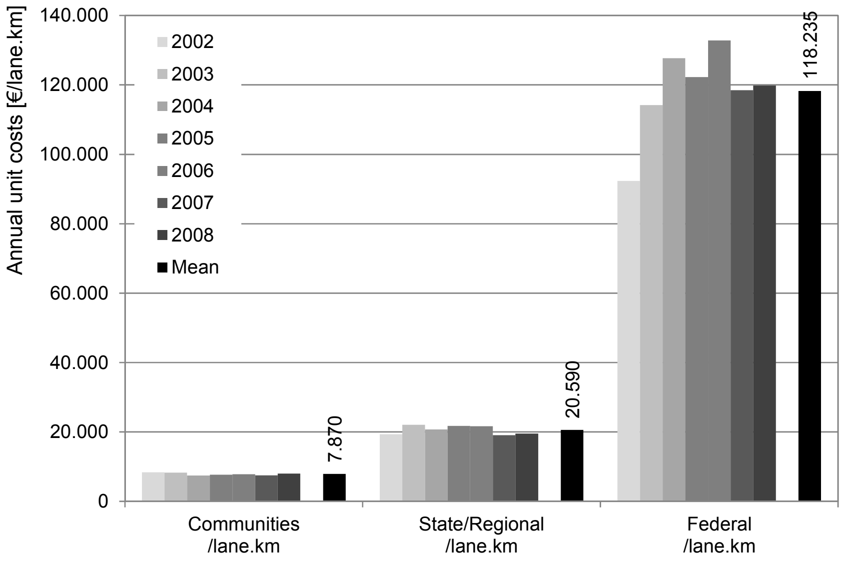
4. ACTUAL EXPENDITURES FOR ROAD ASSETS

From 2002 to 2008 an average of about 1,17 billion euros per year (price level 2010) are invested by the ASFINAG for highways and expressways (corresponds to 1.6% of the federal budget). Applied to the network with a length of 2.144 km or 10.400 lane kilometre, the average annual expenses add up to approximately 118.000 € per lane kilometres. This amount is split with 59% on new construction and expansion, 24% for rehabilitation, 14% for maintenance & operation and 3% for other expenditures. The high proportion of new construction expenditures reflects the network expansion from 1.999 km (2002) to 2.104 km (2008) and afore mentioned high unit costs (Fig.4).

The nine federal states in Austria spend around 1,49 billion € per year (representing 3,9% of the state budgets) for regional roads category B and L. With a length of 72.000 lane kilometres the annual expenditures 20.600 € per lane kilometre are a fraction of those for highways and motorways. These expenditures are split in a third each for operation, maintenance and new construction. On this road network level the investments are concentrated mainly on the expansion of bottlenecks and increasing rehabilitation needs.

The road expenditures of the 2.357 communities with a total of 1,17 billion € per year amounts to an average of 10,6% of the communal budgets, or about 7.900 € per lane kilometre (all prices 2010). The distribution of costs can be roughly estimated with about 50% for maintenance & operation, 40 % for rehabilitation and 10 % for new construction. Due to the fact that 64% of the community income (743 € per capita) results from shares per head, peripheral communities with aging population and migration as well as a deterioration of communal infrastructures will run into huge financial problems.

Total unit expenditures for road assets on all levels of roads from 2002 to 2008 (prices 2010)



	Communities (2002-2008)	Regions (2002-2008)**	Asfinag (Federal) 2002-2008
Annual road expenditures (OH+AOH 61 - prices 2010)*	€ 1.170.000.000	€ 1.491.000.000	€ 1.225.000.000
Percent of the (federal, provincial, municipal) budgets	10,6%	3,9%	1,6%
Kilometer or lanes	148.000	72.400	10.300
Annual unit costs per lane kilometer***	7.900 €	20.600 €	118.200 €
Percent initial construction expenditures	10%	33%	59%
Percent rehabilitation expenditures	40%	33%	24%
Percent maintenance expenditures	50%	33%	14%
Percent other expenditures	-	-	3%
Expenditure ratio	1	3	15
Total traffic ratio cars*	1	4	40
Total traffic ratio trucks*	1	5	27

*Variations possible **Regionalization of road category B in 2002 *** No direct comparison possible due to different amount of civil structures and lane w idth

Fig.4: Unit costs and average expenditures for road assets from 2002 to 2008 (AT)

5. DEVELOPMENT, STRUCTURE AND AGE OF ROAD ASSETS

A key aspect of a asset management of road infrastructures is an asset inventory with condition and age of the asset types. While age profiles of road assets cannot be translated directly to the condition and performance they give a good overview of the age and development of the road assets. Together with condition indicators master functions for the deterioration average service lives can be determined. Based on the resulting stochastic distribution of service lives it is not possible to predict which asset or asset element will fail but it is possible to predict a replacement rate on network level. The cost accounting for road assets in Austria and Germany is based on such concepts (perpetual inventory method PIM). With this approach a rough approximation of expected costs and necessary revenues (e.g. tolling, taxation) is possible [6;7].

The provided age profiles in this paper are based on a complete inventory count for the indicated road network and asset type and are presented as cumulative distributions. The first plans for a highway network in Austria appeared around 1920 with initial construction starting 1938 in Salzburg. The main part of the highway network (around 60%) was constructed in the time period between 1970 and 1990 (median = 1980). The age distribution of highway bridges is steeper with more than 80% of the bridges being constructed between 1970 and 1990 (median = 1980). Most of the highway tunnels were constructed as single-tube tunnels in a first wave between 1975 and 1995 with a second tube added after several tunnel incidents between 1999 and 2001 (median = 1989). The age of asphalt pavements (median = 1989) and wearing course (median = 2001) is significantly shorter while sub base and track can be assumed with an age distribution between initial construction and bridge construction (Fig.5;6).

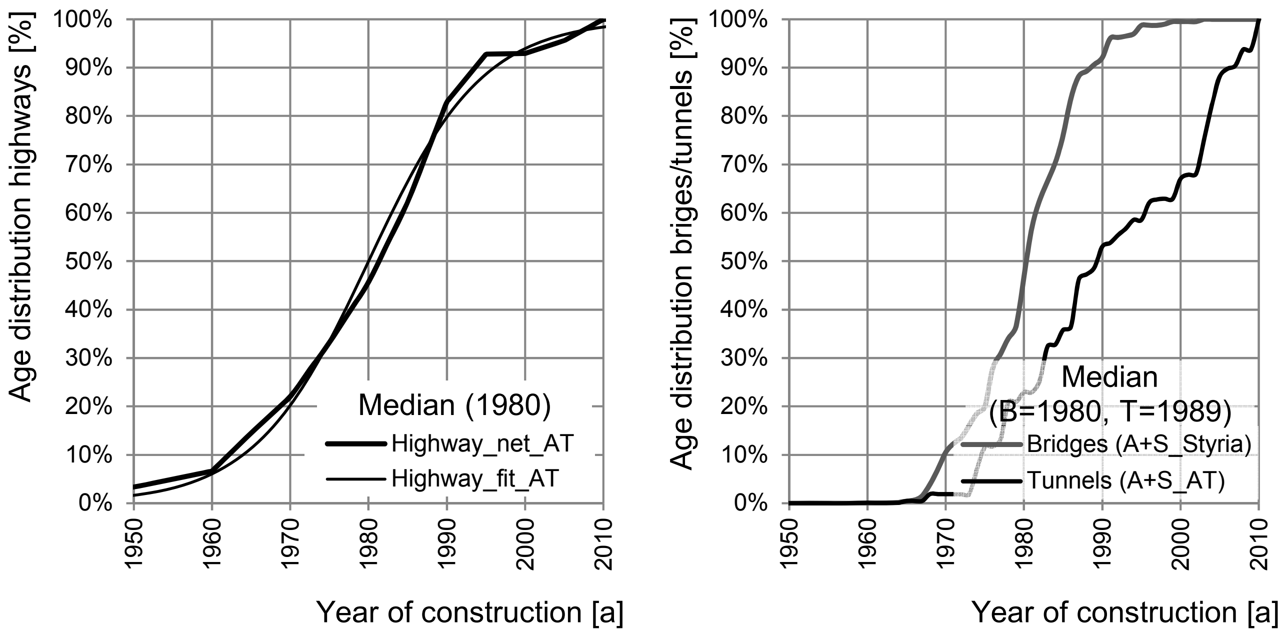


Fig.5: Development and age of highway network, bridges and tunnels 2010 (AT/Styria)

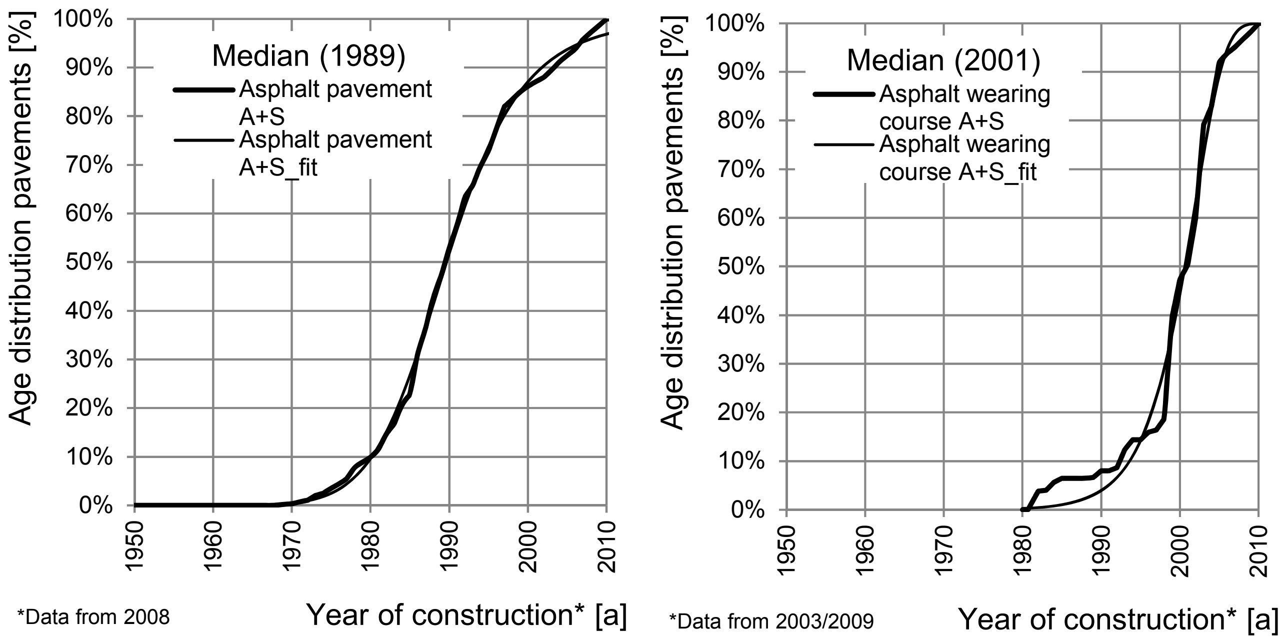


Fig.6: Age of asphalt pavement & wearing course on highways 2010 (AT)

Considering existing regulations (e.g. safety requirements for tunnels RL 2004/54/EG), necessary technical equipment (e.g. max. length of bailey bridges as replacement during replacement), and cost functions the length distribution of bridges and tunnels is an important factor. 70% of 4.000 highway bridges are shorter than 50 m. However, if the bridge area is considered these bridges amount only to 26% of the total bridge area of 5,4 million square meters. The number of important tunnels according to EU – regulations with a length of more than 500 m on highways amounts to 70% of all tunnels or more than 95% of tunnel length (Fig. 7). In comparison the bridges and tunnels on regional roads are significantly older (median = 1973/1976) and shorter (Fig. 8). On regional roads category B 89% of all bridges are shorter than 50 m (category L=95%). If the bridge area is considered these short bridges amount to 41% of the total bridge area (L=69%).

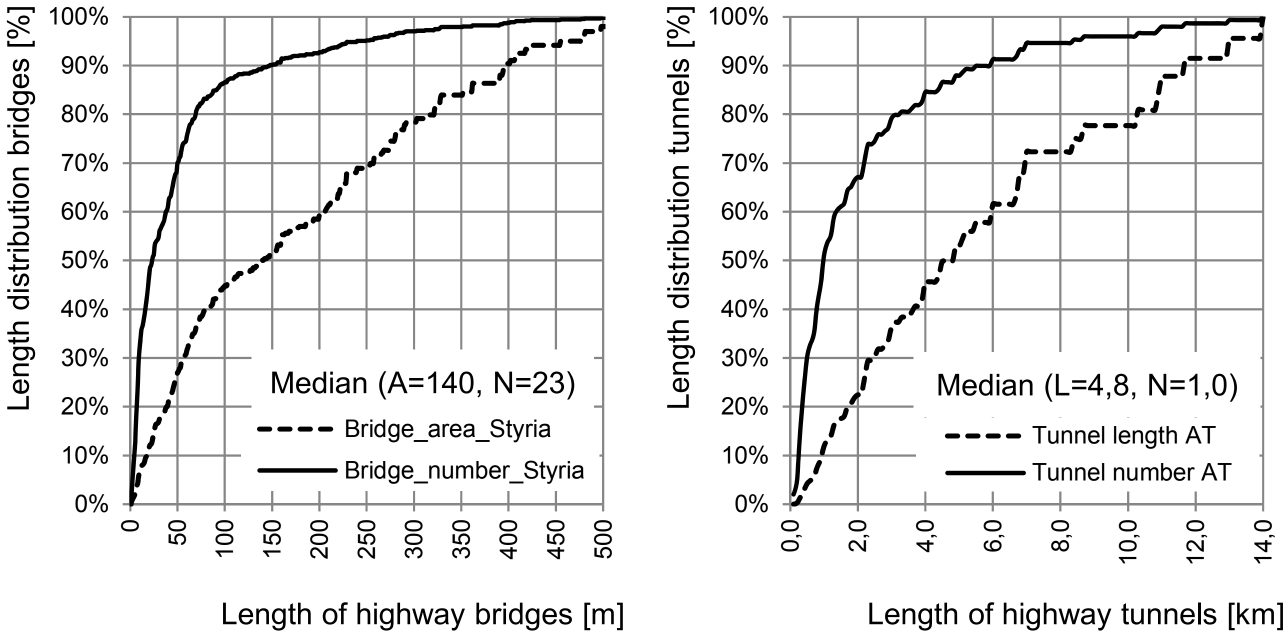


Fig.7: Length distribution of highway bridges and tunnels 2010 (AT/Styria)

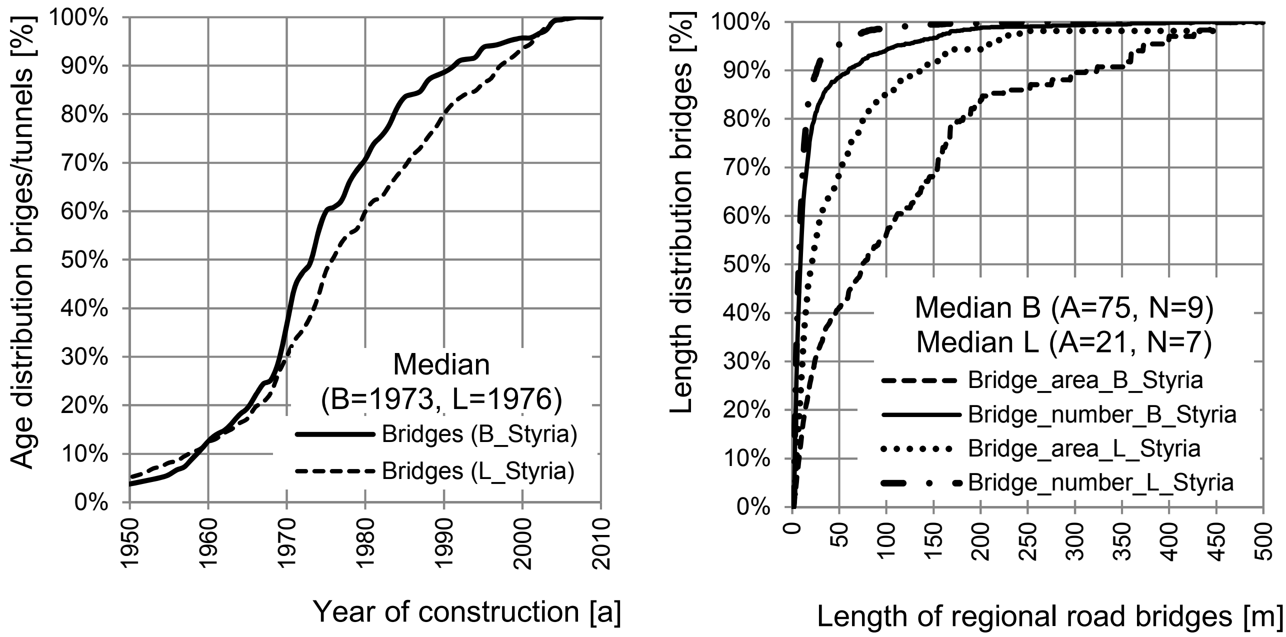


Fig.8: Age and length distribution of bridges on regional roads 2010 (Styria)

6. INITIAL INVESTMENT COSTS OF ROAD ASSETS

To account for uncertainties of costs the unit costs of realized projects or assets can be compared "top down". This cost distributions include all realized cost risks of the analysed projects and are therefore an ideal basis for a plausibility test of detailed calculations "bottom up" of individual projects. In Fig.9, the distributions of the construction costs of new projects for regional roads (median = 400 €/m^2), highways and motorways (median = 1.130 €/m^2) are presented. These unit costs include engineering works (without taxes) of entire road sections in Austria & Germany. Furthermore the construction cost distributions of bridges (median = 1.600 €/m^2) and tunnels (median = 2.360 €/m^2) are given. The probability distributions of the unit costs are modelled based on a log-normal distribution. Together with the distribution of the service lives and standard cycles for typical road assets the financial needs on project level as well as network level can be estimated.

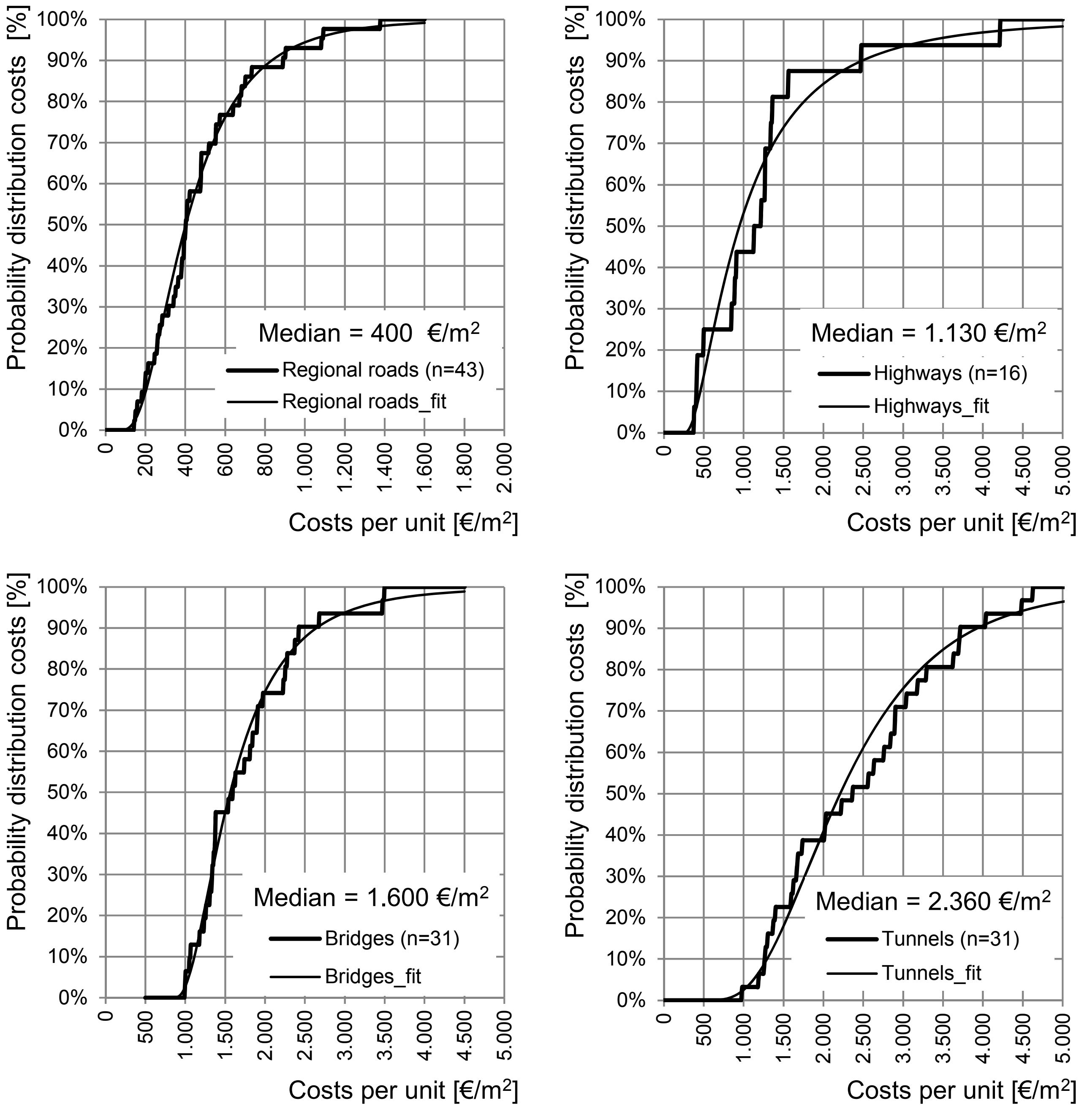


Fig.9: Cost distribution of the adjusted unit costs of road construction projects with all structures as well as individual assets (e.g. bridges and tunnels) with prices as of 2010 (no taxes)

7. A SIMPLE LCC – APPROACH FOR ROAD ASSETS

The presented life cycles for road superstructures, bridges and tunnels are based on a framework of aggregated, standardized measures and service lives on road asset element level. The annual unit costs of bridges in this example are 12 times higher and 17 times higher for tunnels than the costs of superstructures (Fig. 10). The annual unit costs allow an estimation of the average annual investment needs of new assets during their service life (Method 1).

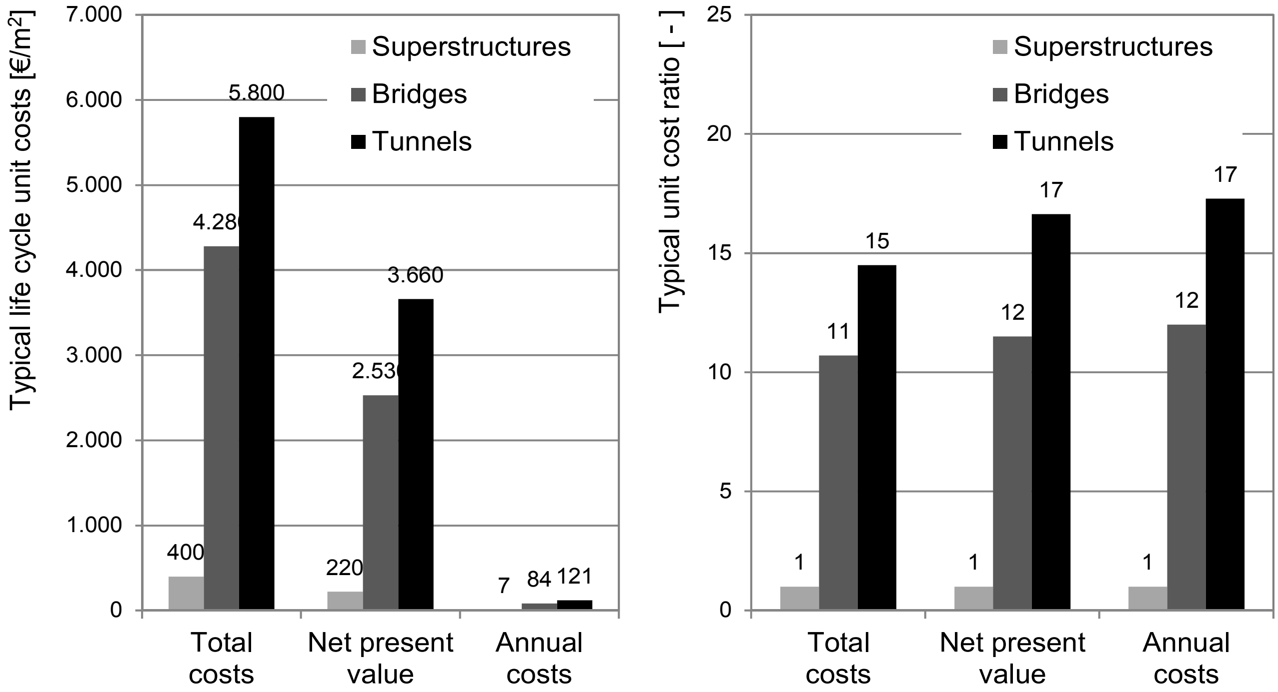


Fig.10: Typical life cycle unit costs and cost ratio of road assets on regional roads 2010 (AT)

To determine the current financial requirements for an existing road network this method is not suitable. For this task the amount of sections in a specific condition linked with the standardized life cycles have to be considered. The actual budgeting need is the result of the amount of assets in a specific condition multiplied with the annual costs of perpetual standardized life cycles starting with the appropriate measure for this condition (Method 2).

For the comparison of future investment needs of road assets, construction or route alternatives on project level a life cycle factor based on standardized life cycles can be used. The life cycle factor represents the ratio of the net present value during the service life (including initial investment, repair work, demolition and capital costs) and the amount of the initial construction investment itself (LCC - factor ≥ 1). This factor and the underlying cost development (Fig. 11) allows a fast forward estimation of the life cycle costs based on the cost estimate for the initial construction (Method 3) [8].

For a fast forward prediction of the road expenditures on road network level the age distribution of road assets can be combined with perpetual standardized life cycles. For each year a new standardized life cycle has to be started and the resulting costs have to be multiplied with the amount of road asset types that were built in that specific year. The superposition of all costs for existing road assets in a specific year is a good approximation of the necessary budget. For road networks that were built in a short time period compared to their service life the necessary expenditures occur in form of waves (Method 4). These waves subside after a few cycles if the stochastic distribution of service lives is considered.

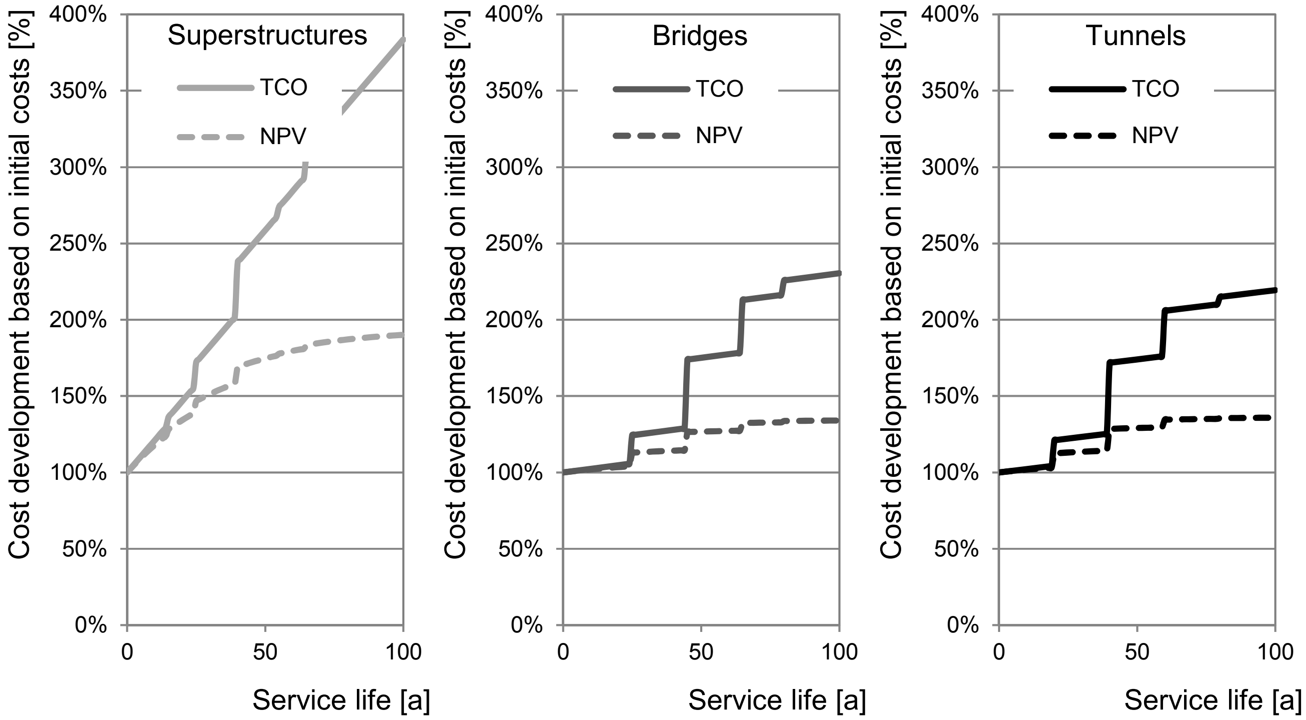


Fig.11: Normalized life cycles based on initial costs on road asset type level calculated with an interest rate of 3% and an average economic service life of 80 years (AT)

8. SIMPLE LCC – APPROACH ON NETWORK LEVEL

As an example the development of road expenditures for highways and regional roads category B is calculated based on the presented amount of road assets, standardized life cycles, and age distributions (Method 4). The amount of generalized measures for superstructures, bridges and tunnels is estimated without consideration of the distribution of service lives. Furthermore other road assets (e.g. noise barriers, dams, walls) as well as the actual condition are not accounted for. Due to these simplifications the resulting expenditures are only a reflection of the underlying ageing processes and general investment trends and are given as a relative number based on the calculated investment needs of 2010.

The projected expenditures for highways in Austria (Method 4) vary depending on the assumed service life for the cycle of asset types. A key finding of the model for highways is a developing reinvestment wave with more than 200% of the estimated actual investment needs for 2010. Based on a realistic scenario with the selected service life of 70 years for the standardized life cycles the reinvestment wave should arrive between 2030 and 2040 (Fig. 12). If the assumed necessary maintenance and rehabilitation investments are not conducted in time it is also possible that the life cycle is shortened and the wave will arrive a few years earlier. With an assumed extended service life due to an optimized asset management and timing of preventive maintenance and rehabilitation measures the necessary reinvestments increase significantly slower. If the stochastic distribution of service lives is considered, the reinvestment waves of investment will be flattened compared to the presented calculations. The main driving factors for the high reinvestment wave on highways are bridge assets. From the viewpoint of a safe and fluid flow of transport this is a very demanding challenge due to the fact that an entire route may be blocked if bridges need to be closed.

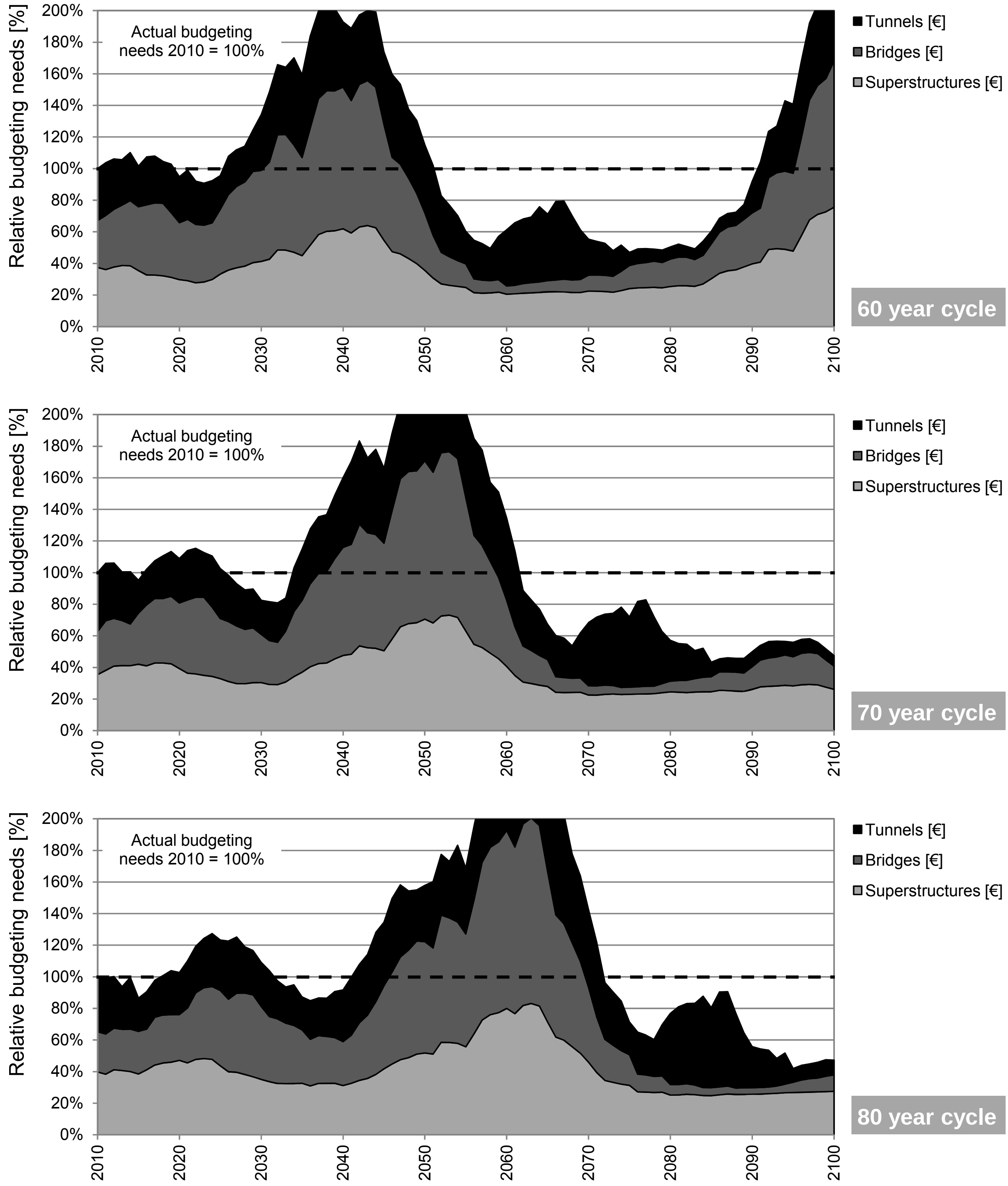


Fig.12: Relative life cycle costs for highway assets in Austria from 2010 to 2100 based on expected budgeting needs 2010 (cycle = 60; 70; 80 years)

The predicted reinvestment wave for regional roads based on a realistic selected service life of 80 years shows a comparably lower reinvestment wave arriving around 2040 under the assumption that all necessary prior reinvestments have taken place. Responsible for this development is the broader distribution of the age structure of road assets and the relatively low share of civil structures in comparison to highways. If the necessary maintenance and rehabilitation measures are delayed or deferred, the reinvestment wave is expected to be much steeper and will arrive earlier (Fig. 13).

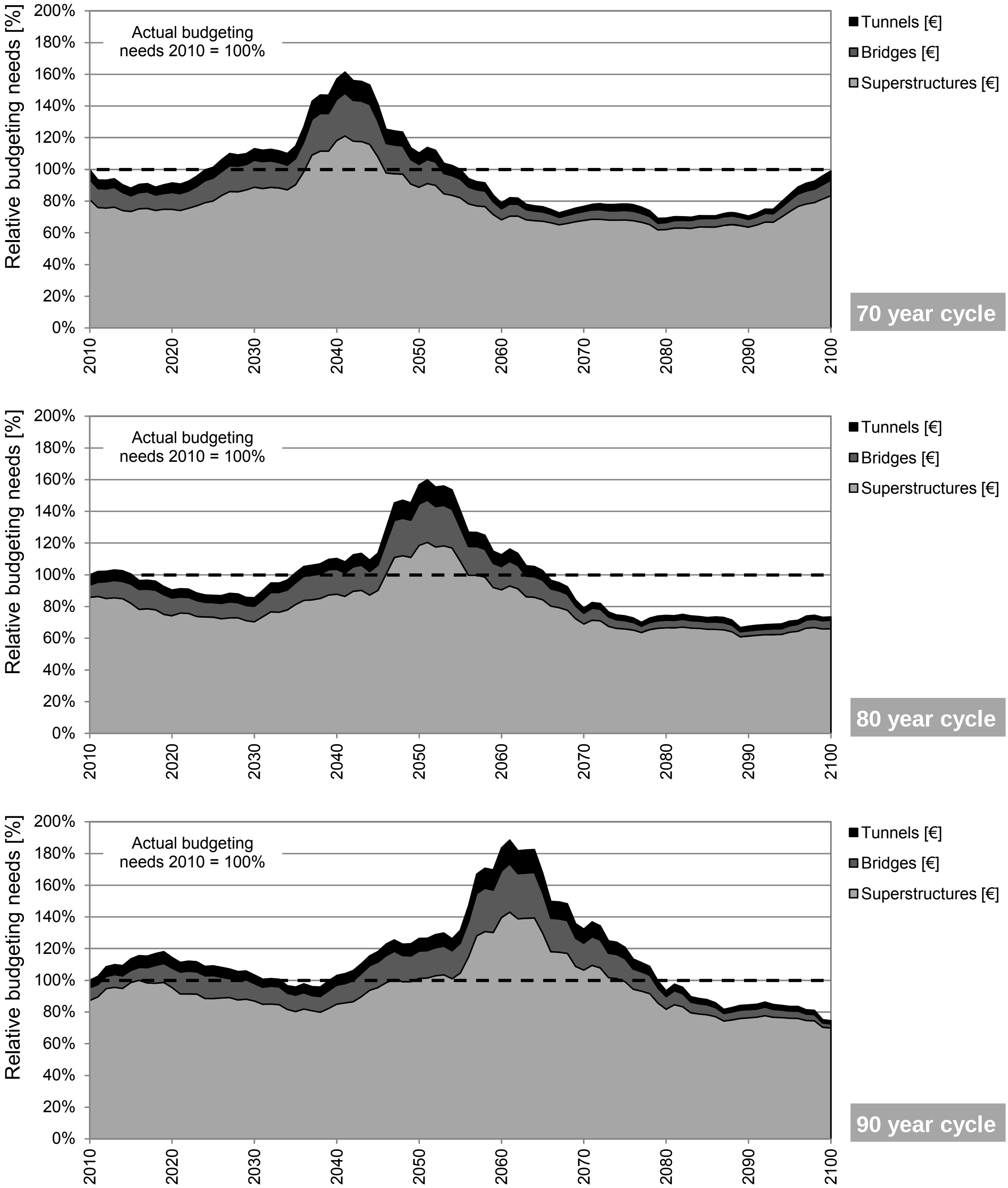


Fig.13: Relative life cycle costs for regional road assets (B) in Austria from 2010 to 2100 based on expected budgeting needs 2010 (cycle = 70; 80; 90 years)

The predicted average expenditures from 2010 to 2020 for highways based on a realistic service life of 70 years will be 15% higher if the cycle is shortened to 60 years and will be 18% lower if the cycle may be extended up to 80 years (Method 4). The calculation based on annual costs shows a similar tendency (Method 1). If the results of both methods are compared it becomes clear that the budgeting needs in the considered period are below average due to the relative young age of the road assets on highways in Austria.

The predicted average expenditures for regional roads category B with a realistic service life of 80 years shows no significant variation due to extended or shortened service life from 2010 to 2020 (Method 4). Based on the average annual costs (Method 4) a small decrease of expenditures can be observed. The reason for the low variation of expenditures may be found in a wide age distribution of the road assets in this category, the low amount of civil structures and the dominance of running costs in the considered period (Fig. 14).

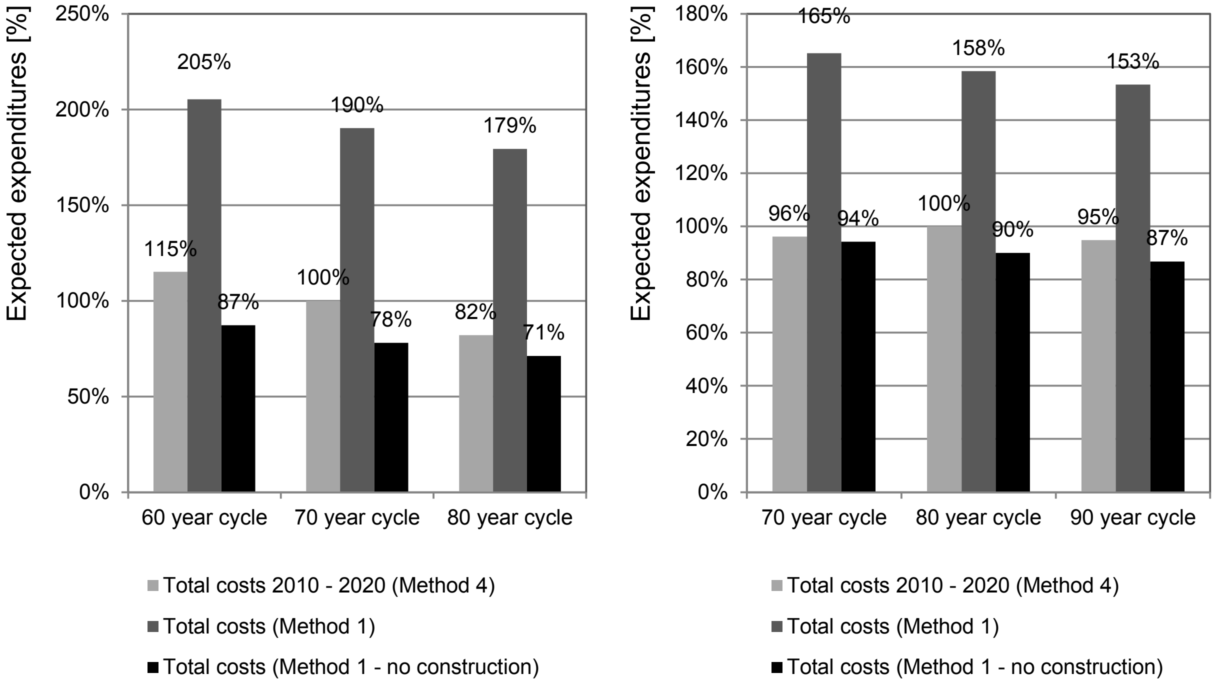


Fig.14: Comparison of predicted average expenditures from 2010 to 2020 (Method 4) with the average annual costs based on the standardized life cycle (Method 1)

9. SUMMARY AND OUTLOOK

For the strategic management of road assets the questions of the necessary funding for a sustainable transport policy compared to investments in other public sectors have to be answered. Furthermore a proof of necessary expenditures to maintain and operate existing road assets has to be provided together with a comprehensive benchmarking. With the presented standardized expenditure framework and the key figures from the investigation of road asset age and investments on national, regional and communal level this question can be answered.

The tasks to determine the budgeting needs and optimized life cycle strategies are addressed on road asset type level based several methods together with the age distribution of the existing assets as well as standardized life cycles. The findings of the research provide substantial data and methods for an actualization of cost accounting, tolling and funding of road assets. With the presented methods an allocation of budgets for asset types and all necessary tasks during the life cycle on network level is also possible.

The application of the presented methods on highways and regional roads allowed an estimation of the expected budgeting needs from 2010 to 2100. Based on a realistic scenario a developing reinvestment wave with more than 200% of the estimated actual investment needs should arrive between 2030 and 2040. The main driving factors for the high reinvestment wave on highways are bridge assets. This will be this is a very demanding challenge due to the fact that an entire route may be blocked if bridges need to be closed. The predicted reinvestment wave on regional roads will be much lower due to a wider age distribution and a lower amount of civil structures.

The presented framework addresses the tasks of an asset management for road assets "top down" from a strategic point of view as well as "bottom up" from the view of individual assets and measures on projects level. In this paper selected findings of the "top down" approach are presented. With the provided data and methods an actualization of road costing accounting and expected expenditures are supported. Further research on all levels of the presented framework will provide additional insights for these tasks

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