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D-A-CH research project "Technical asset value assessment within asset management" (TAniA) - Using asset valuation as a key performance indicator in asset management

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Abstract

The main objective of TAniA – technical asset value assessment within asset management – is the development and practical approach of a calculation procedure for a technical, condition-based asset value and a reconstruction value of road infrastructure assets. It should be a part of a sustainable life-cycle solution as basis for a strategic and technical decision process. TAniA enables to close existing gaps in the actual assessment and decision processes. It extends the existing life cycle approaches, considering the requirements of a holistic and sustainable solution. The project offers an overall solution, which could be implemented into the decision processes of road administrations without intensive additional effort.

Keywords: asset management; asset valuation; performance indicators; maintenance strategies; socioeconomic and financial sustainability; multimodal transport governance.

1. Overview and motivation

The asset value of road infrastructure assets (pavements, bridges, tunnels) can be a decisive parameter for objective decision making in the context of asset management. It can be calculated in two different ways, first, from a more economic and accounting point of view and second, as a technically oriented solution. The asset value should be used

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as a key performance indicator (KPI) for controlling but also for benchmarking in the context of life-cycle assessment. The integration of an unified assessment framework should be conducted respectively for both approaches.

The main objective of the international research project TAniA is the development and practical approach of a calculation procedure for a technical, condition-based asset value of road infrastructure assets (Weninger-Vycudil, et al. (2021)). It is designed as an integrated approach of a sustainable life-cycle solution within the strategic and technical decision making process (keyword maintenance targets and objectives). TAniA, funded by the federal road administrations of Germany, Austria and Switzerland (D-A-CH), provides an essential principle for decision making and controlling of maintenance requirements, considering target values of decisive performance indicators and their influencing factors. A basic requirement for the comparison of different road networks is the unified calculation procedure, which leads TAniA to a practical oriented solution and defines a base for benchmarking between Germany, Austria and Switzerland.

2. Methodology

As a starting point, a comprehensive literature research in D-A-CH region was conducted to analyse the current state of the art, the valid standards and guidelines as well as the results of research and current projects. In this process, national projects and literature of the three countries were analysed as well as international literature, in the latter especially PIARC's Asset Management Manual as well as ISO standards and a FIB Model Code (PIARC (2017), ISO 15686-3 (2002), ISO 15686-2 (2012), ISO 15686-5 (2017), ISO 55001 (2014) FIB Model Code (2010)). The knowledge gained forms the basis for defining a holistic framework for the assessment as well as the essential definitions. In workshops the important definitions were standardised with a clear demarcation to other areas, such as accounting, in order to create the same understanding in all three D-A-CH countries.

Knowledge about the existing structures and their conditions plays an important role in the assessment of infrastructure facilities. Hence, the next step was the analysis of the currently existing data basis and data management systems of the individual road operators. For the purpose of a systematic assessment, the data were first divided into the categories network data, inventory data, condition data, stress data and other data. These were examined in terms of data availability and completeness (>90% network coverage) as well as data quality and actuality. It should be clearly noted that the assessment was only considered in the sense of a facility assessment. An assessment for other purposes may also lead to different results.

Using this framework and existing data, the definition of a condition-based technical asset value is mathematically stated as a monetary and as a non-monetary indicator (scale from 0 to 100). The relevant method for the calculation of the asset value at a given point in time, considering the current and predicted condition in combination with necessary maintenance treatments (life cycle and maintenance treatment strategies), can be applied for road pavements, bridges and tunnels (structural and electro-mechanical components). Therefore, different life cycle scenarios have been investigated and a proposal for standard life cycles is given. In case of missing results from life cycle approaches, these standardized life cycles can be applied. In addition, cost factors for different maintenance measures within the life cycles were developed through data analyses and literature research. These cost factors are required for the monetary evaluation.

3. Basic concept

The basic idea of calculating the technical asset value (TAW) is shown in Figure 1. When determining and forecasting the technical asset value of a structure, the asset values of the individual asset parts X are first determined, which are then aggregated for the structure. The technical asset value of an asset part results from the combination of a given condition (Z) and a defined correlation of condition and the renewal value (EW). In precise terms, this means that a past or predicted development of condition over time Z(t) and the already mentioned defined correlation of condition score and technical asset value of an asset part EWX are converted into a technical asset value as a time-dependent variable TAWX,t.

For this purpose, an allocation of the asset parts in construction and equipment is made for the three assets road pavements, bridges and tunnels (structural and electro-mechanical components). Based on this, it is possible to determine two indicators, the construction indicator (KI) and the equipment indicator (AI). The KI is used to describe the TAW for the constructive-structural asset parts of a road infrastructure asset that are not completely replaced within the technical life cycle of the entire structure. In comparison, the equipment indicator (AI) is used to describe the TAW for the constructive-functional parts of a road infrastructure asset, which are replaced or renewed one or more times within the life cycle of the overall structure.

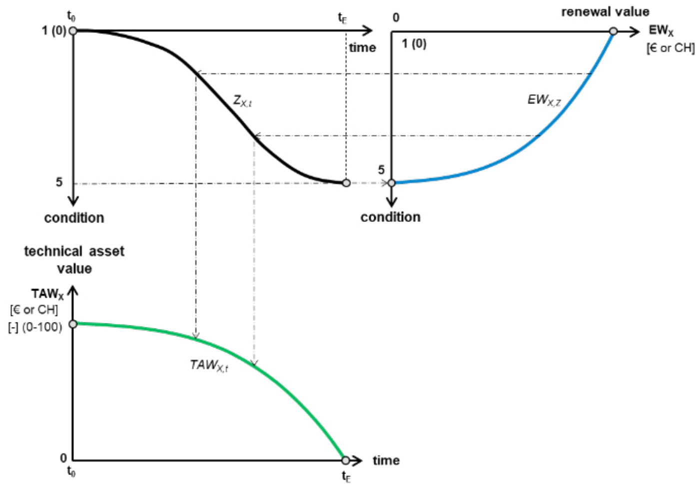

Fig. 1. Basic idea of the calculation of the asset-specific TAW.

4. Life cycle modeling

The asset value within the life cycle of the road infrastructure (road, bridge, tunnel, etc.) is strongly linked to structural condition of infrastructure assets. A technical life cycle generally extends from the construction of the facility to its demolition or decommissioning including interventions such as refurbishment. With reference to the current literature review as well based on experiences of practical applications of degradation curves (Weninger-Vycudil, et al. (2021)) the models for life cycle assessment can principal be grouped into (Weninger-Vycudil, et al. (2016)):

- Mechanistic (analytical) models are based on the theoretical determination of the primary effects (strains and stresses) under external actions (loads, temperature, etc.) and the application of material-specific laws of behavior.
- Empirical models are based on the observation of actual behavior and attempt to find a causal relationship between various influencing variables and the change in state over time (example given in (Weninger-Vycudil, et al. (2016))).

An objective condition prognosis is a prerequisite for its determination. Condition assessment is usually based on visual periodic inspections in cycles of 3 to 12 years, respective to different guidelines and structure types (Weninger-Vycudil, et al. (2021)). The historical condition data is usually grade based in grades from 1 (very good) to 5 (closing of traffic). Data-based tools as an specification of empirical models can use this historical information for modelling individual live cycle curves, which were tested and applied within the project TAniA for modeling the condition stages of given assets. In case of missing data standardized life cycles were proposed for road pavements, bridges, and tunnels (structural and electro-mechanical components).

4.1. Databased methods for life cycle modeling

Data-based models are applicable for deriving individual objective building degradation curves based on historical condition data as well as for identifying the main influencing parameter within the life cycle. Depending on the data quality, completeness and consistency of the databases, forecasts can be made. The applied approach is using a random forest analysis as seen in Figure 2 (a). The complementary data were traffic volume, climate data, year of construction and applied codes and degradation time needed until the condition stage changes by one grade (transition period tpi). The result of this analysis is a clustering on the most important parameters that influence the transition period. To evaluate the stochastic distribution, statistics methods such as distribution fits and Monte Carlo simulations were used to determine the most likely degradation curves for individual assets. For these set of curves, the probability of occurrence at a certain point in time was determined for each grade step (Figure 3 (a)) for different asset parts and analyzed for "do-nothing strategies" without any interventions. For better readability the results are shown with the expected mean value and standard deviation. The whole procedure is seen in Figure 2 right and was applied on different bridge databases of all three D-A-CH countries as seen for an example in Figure 3(a) for a specific bridge superstructure.

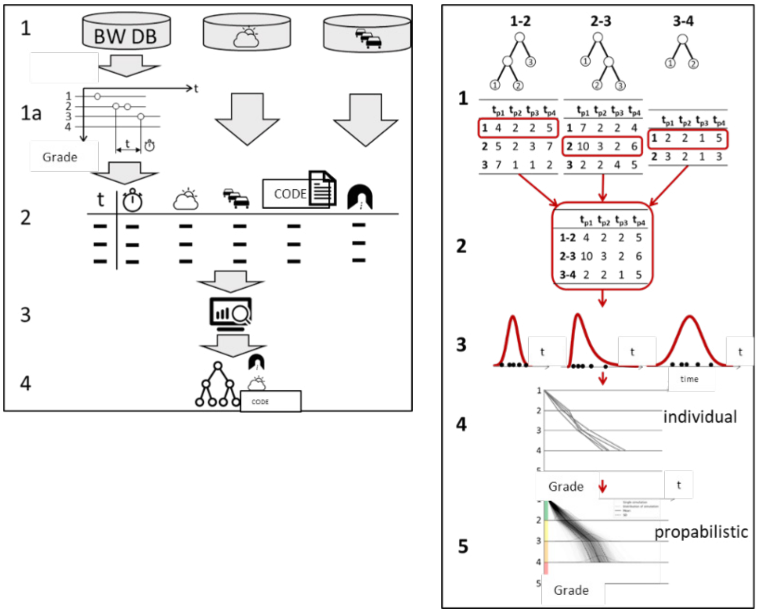

Fig. 2. (a) Data based approach for clustering the data using a random forest analysis (left); (b) framework for development for probabilistic degradation curves (right).

4.2. Standardized life cycles

Parameter for standardized life cycles have been adapted to the individual objects, whereby the selection of the defined parameters is in the responsibility of the respective user (country, administration, etc.). In this context, it was necessary to define parameters for different asset groups and distinguish between construction components and easy renewable components defined as equipment. The principal framework is seen in Figure 3 (b).

When calibrating a standard life cycle, it is necessary to resort to corresponding degradation curves that change the construction interval and/or the equipment interval depending on the object-related properties. The proposed standard life cycles define a basic framework. They are based on the discussions within the scope of the project (Weninger-Vycudil, et al. (2021)), which should be individually, calibrated, supplemented, extended, and modified. The allocation of these specifications to certain object-specific properties also represents a proposal that can also be further specified and extended. For these reasons, no claim to completeness is made.

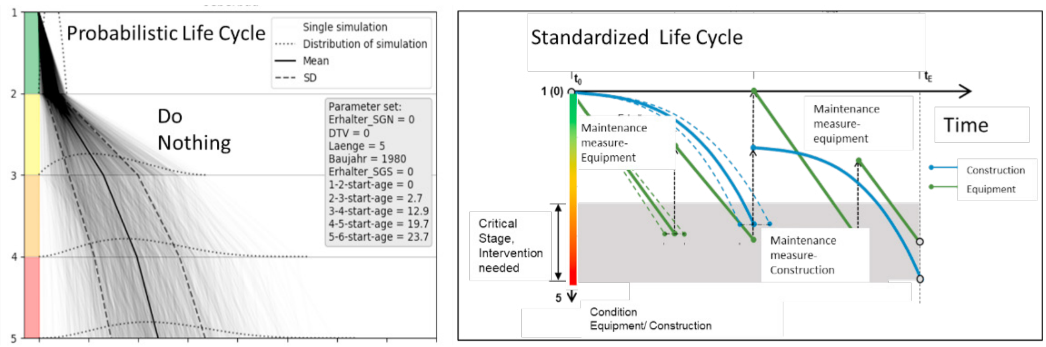

Fig. 3. (a) Definition of probabilistic life cycles (left); (b) standardized life cycles (right).

5. Modeling of technical asset value and renewal value

The initial point to calculate the TAW is the renewal value. The renewal value represents the TAW as new construction condition, which corresponds to the best condition (condition grade 1.0) according to the assessment system in the D-A-CH area for structures and roads. To improve the condition along the life cycle it is required to conduct structural maintenance measures. The linked costs of these measures which comprise material, equipment, personnel, etc., yield to the amount by which the TAW has been reduced by this point in time and therefore display the difference between the renewal value and the current TAW. Thus, the current TAW of an asset is determined by subtracting the average cost for the measures which are necessary to raise the current condition to the best condition from the renewal value of the asset.

The progress of the current TAW of an asset part is determined by the condition progress and the progress of the correlation between the TAW and the condition score of the considered asset part. Section three of this paper describes the condition progress. The correlation progress between the TAW and the condition score of an asset part is determined. Therefore, the renewal value for each asset part of the different asset types must be determined by, e.g. the help of characteristic values from road authorities or estimates based on engineers' evaluation. Furthermore, the feasible maintenance measures of the asset parts of all asset types considered must be known regarding their cost and their applicability to each condition state, respectively. Economic data can be acquired from previous conducted measures, considering discounting, if applicable. In addition, it must be known how the maintenance measures affect the change of an asset part´s condition, as well as the dependency of different maintenance measures among each other.

The difference between renewal value and the maintenance measures cost shows an at least selectively correlation, but it has to be evaluated by engineers' evaluation. The result can be expressed as regression line or as linear function of the two determined points which is then normalised to the share of the renewal value. The following Figure 4 shows the procedure described above schematically.

The TAW of the entire structure equals to the sum of the TAW of the individual asset parts of the structure. Basically, the asset parts and the indicators are evaluated individually and normalised on a scale from 0 to 100, but it is necessary to aggregate the monetary equivalents for an overall evaluation. The monetary values of the construction and the equipment tend to be very different, but in most cases the construction provides the largest share of the TAW. A comprehensive recommendation can be taken from final report (Weninger-Vycudil, et al. (2021)), which has been published on the FFG project website (https://projekte.ffg.at/projekt/3112898) and includes the relation between condition and asset value / renewal value for the individual asset parts.

To evaluate an asset it is highly relevant, to state the economic efficiency of a maintenance measure strategy of a selected life cycle, besides the calculation of the TAW over time. An economic evaluation is advisable and reasonable to compare different variations of maintenance measure strategies, however it is required that more than one measure strategy is viable for a specific asset. From the condition progression as well as the effects of the maintenance strategies on the construction and equipment indicator, the main metrics to be evaluated can be determined. Besides the impact of the maintenance measures, expressed by the impact index WI (as a proportion of the TAW with respect to the year of the maintenance measure conducted), the index area IF of the maintenance measure strategy S below the graph of the TAW is of essential interest.

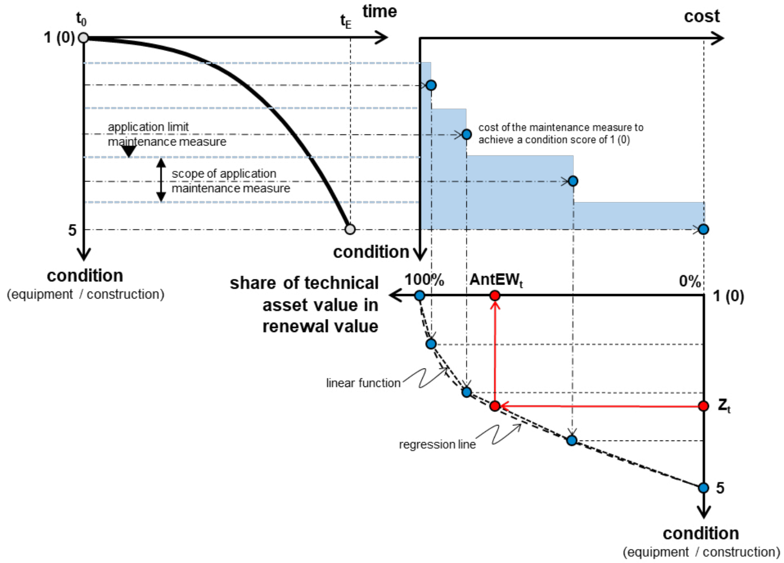

Fig. 4. Linear interpolated (left) and stepped (right) qualitative relation TAW.

The effectiveness diagram "TAniA" is able to state the economic efficiency of different maintenance measure strategies and graphically describes the relation between the index area and the cumulative WI over the considered period, i.e. the cumulated effects of the maintenance measures on the TAW. Figure 5 schematically shows the TAniA effectiveness diagram and the evaluations that can be derived.

Each point in the TAniA effectiveness diagram shows a maintenance measure strategy. The closer a maintenance measure strategy is to the effectiveness graph (surrounding of the "cloud of points of maintenance measure strategies"), the more efficient - from the TAW's perspective - the respective strategy is (see strategy S). However, this also indicates that uneconomic solutions can be sorted out, like strategy Z in Figure 5. Comparable maintenance measure strategies which achieve a higher impact with the same effort represent a more efficient solution from the TAW's perspective.

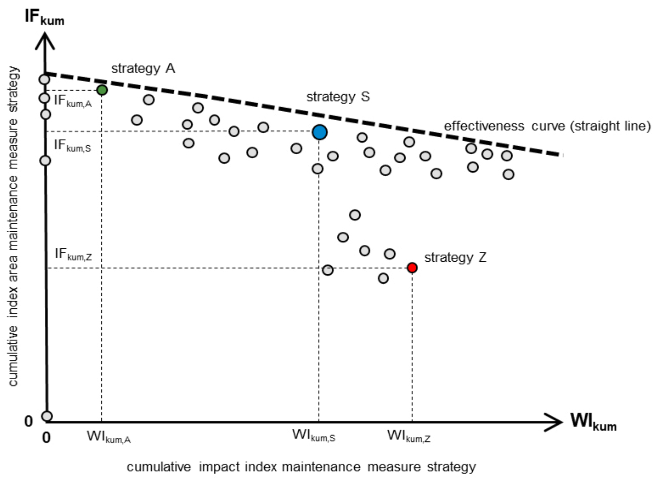

Fig. 5. Evaluation of the cost-effectiveness of maintenance measure strategies using the TAW (effectiveness diagram).

6. Practical application and implementation

As an essential project step the applicability of the developed algorithm was tested comprehensively on three test sections in Germany, Austria and Switzerland and on a sub-network in Austria (Vienna region). The required information, provided by the federal road administrations, has been imported into a cloud-based Asset Management System (dTIMS – Deighton Total Infrastructure Management System), which was extended with the developed algorithm and procedures for the calculation of the technical asset value and the other TAniA indicators. The following Table 1 gives an overview of the three test sections and the sub-network.

Table 1. Assets of the test sections and the sub-network.

Section	Route	Pavement	Bridges	Tunnels
Testsection D	A44 AK Meerbusch – AS Tattingen-Ost	41,590 km carriageway	65 objects	6 (0) objects
Testsection A	A9 ASt. Übelbach – Ast. Gratkorn Süd	31,982 km carriageway	49 objects	6 objects
Testsection CH	N1 Yverdon-les-Bains – Payerne	49,968 km carriageway	23 objects	12 objects
Sub-network A	A4, A6, A21, A23 ASFINAG network Vienna area	283,863 km carriageway	312 objects	12 (10) objects

The value in brackets shows the number of analyzed objects

In order to calculate the technical asset value over time, the results of existing life cycle assessments from all assets were implemented into the dTIMS TAniA prototype in the form of annual condition information including the effects of the planned maintenance treatments (construction program) and analyzed according to the specifications of the calculation algorithm. After the analysis has been carried out, the calculation results are available for each individual object as well as for the entire test section and the sub-network, where the results of the test sections or the sub-network are a summary of the object related results. Basically, the results are as follows:

- Technical asset value (monetary and scaled from 0 to 100) in each year of the analysis period (e. g. 15 years) under review for each individual object analyzed
- Values of the indicators in each year of the analysis period for each analyzed facility
- Courses of the status with the effects of the maintenance measures
- Parameters of the effectivity analysis
- Development of the technical asset value as a monetary variable over the entire analysis period for the entire test section or sub-network
- Development of the technical asset value on a scale from 0 to 100 over the entire analysis period for the entire test track or sub-network (see following Figure 6 and Figure 7)

As shown within the practical application the results enable an assessment of the technical asset value for all investigated assets and offer a high potential for a comprehensive practical implementation in all D-A-CH countries. Particularly, the normalized technical asset value can be applied for benchmarking purposes.

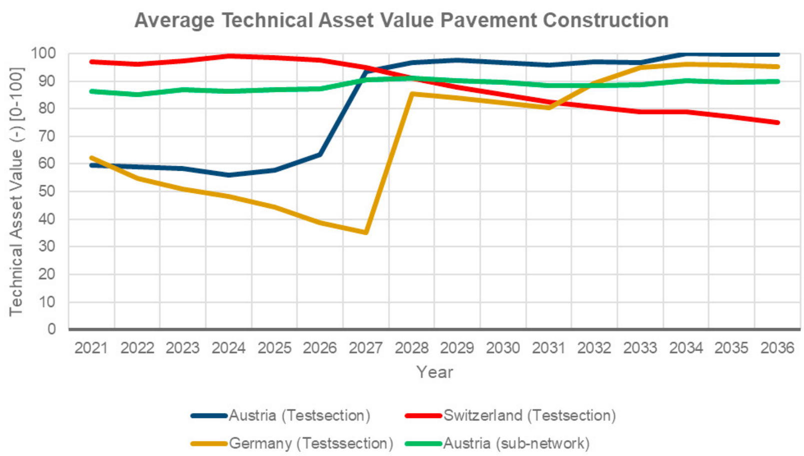

Fig. 6. Results practical application – Average Technical Asset Value (normalized on scale 0-100) - pavements.

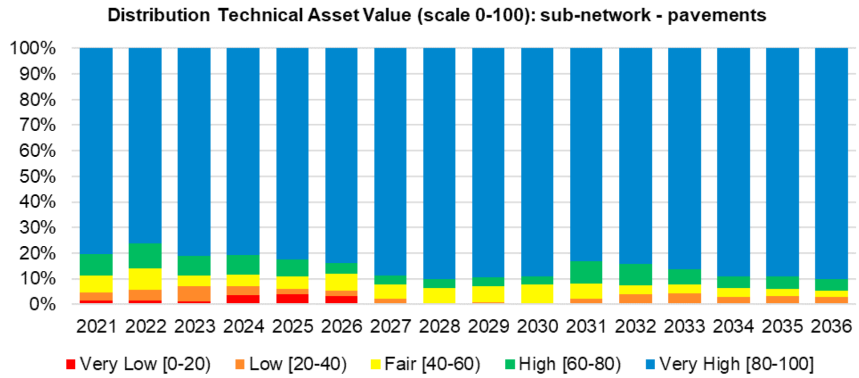

Fig. 7. Results practical application – Technical Asset Value (normalized) for pavements on the sub-network including the effects of the planned maintenance program.

7. Conclusion and future works

TAniA enables to close existing gaps in the actual assessment and decision processes. It extends the existing life cycle approaches, considering the requirements of a holistic and sustainable solution. The application of the TAniA approach on test routes in Germany, Austria and Switzerland shows that it is possible to evaluate different maintenance strategies and construction programs from the asset value point of view. The method is able to compare current and planned investments to evaluate the necessity of investments for the road infrastructure. In addition, asset valuation in combination with life-cycle approaches could be identified as a repeatable and comprehensible base for the dialogue with the decision makers on all, the technical the management and the policy level.

The research project has also highlighted the possibilities and potentials of the currently available road operator data for the evaluation of different asset types. By using standard life cycles, the TAniA approach provides a basis for comparison of data management systems at different stages of development and at the same time gives an outlook on the necessary development of these for a more detailed assessment. All three countries focus on implementing the findings from this research project and are prepared for a more comprehensive and comparable dialogue in the challenging field of road infrastructure asset management.

References

Weninger-Vycudil A., Brozek B., Kessel T., Pasderski J., Sietas J., Chylik B., Schranz C., Prammer D., Vorwagner A., Curchellas P., and Bühlmann R., 2021. TAniA - Technical asset value assessment within asset management. D-A-CH road research 2018 (D-A-CH Verkehrsinfrastrukturforschung 2018, https://projekte.ffg.at/projekt/3112898), final report, in German.

PIARC, 2017. Asset Management Manuals – Guideline for Practitioners. World Road Association, Paris, 2017.

ISO 15686-3:2002. Buildings and constructed assets – Service life planning – Part 3: Performance audits and reviews. ISO – International Organization for Standardization, Switzerland, 2002.

ISO 15686-2:2012. Buildings and constructed assets – Service life planning – Part 2: Service life prediction procedures. ISO – International Organization for Standardization, Switzerland, 2012.

ISO 15686-5:2017. Buildings and constructed assets – Service life planning – Part 5: Life-cycle costing. ISO – International Organization for Standardization, Switzerland, 2017.

ISO 55001:2014. Asset management – Management systems – Requirements. ISO – International Organization for Standardization, Switzerland, 2014.

FIB Model Code 2010. International Federation for Structural Concrete, Switzerland, 2010.

Weninger-Vycudil A., Simanek P., Brozek B. und Litzka J.: Handbuch Pavement Management in Österreich (Ausgabe 2016). PMS-Consult GmbH im Auftrag der ASFINAG, Wien, 2016.