# IMPLEMENTATION OF RSMS KUBA – EXPERIENCE REPORT

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**ABSTRACT**

KUBA is a comprehensive road structure management system (RSMS), developed for the Swiss Federal Roads Office (FEDRO). KUBA relies heavily on the inspection data to obtain deterioration functions and on data on performed maintenance interventions to obtain unit cost data. The collection of inspection data is well established and proceeds quite smoothly. The collection of maintenance data poses a severe problem due to organizational and technical problems.

In this experience report the data collection for KUBA is described with the focus on the measures to ensure data quality and work efficiency.

In the first part, the lack of data in “bad” condition states is discussed, which proves to be a serious obstacle to obtain meaningful deterioration functions. The paper describes the consequences if the raw data is used to obtain deterioration functions.

In the second part, the agency organization is described and the organizational issues are addressed that hinder the meaningful exploitation of data on maintenance interventions. The split in responsibilities between the asset management and construction management seems to pose an obstacle to obtain data that can be used for planning purposes. The possible organizational measures are described – some of them are implemented – that can improve the work flow and consequently facilitate the accessibility of necessary information.

In the third part, a method for the monitoring of workload related to inspections and the analysis of the monitoring results are presented. The influence of different properties was analyzed in order to determine the ones that govern the inspection workload.

*Keywords*: Road structure management system (RSMS), Calibration, Collection of inspection and maintenance data, Workload of inspections, Deterioration functions, Correlation analysis

## INTRODUCTION

The Swiss Federal Road Office (FEDRO) is responsible for high volume road infrastructure, of approximately 12,500 road structures, which include 4,300 Bridges and 220 tunnels. Each of its five regional offices is in charge with the operational asset management and the construction management.

For road structures, FEDRO performs visual inspections every five years. Within FEDRO's inspections, a condition assessment is performed for the whole structure, its elements (like pillars, bearings, joints, etc.), damage areas of the elements. The data on damages can be also stored (Figure 1). In some cases, elements can be further divided into segments to account for different deterioration process and/or exposition. The inspection results are stored in the RSMS named KUBA. For this purpose, the inventory data on road structures and its elements have to be collected before the first inspection. For the main inspections, FEDRO spends approximately 3 million US$ per year.

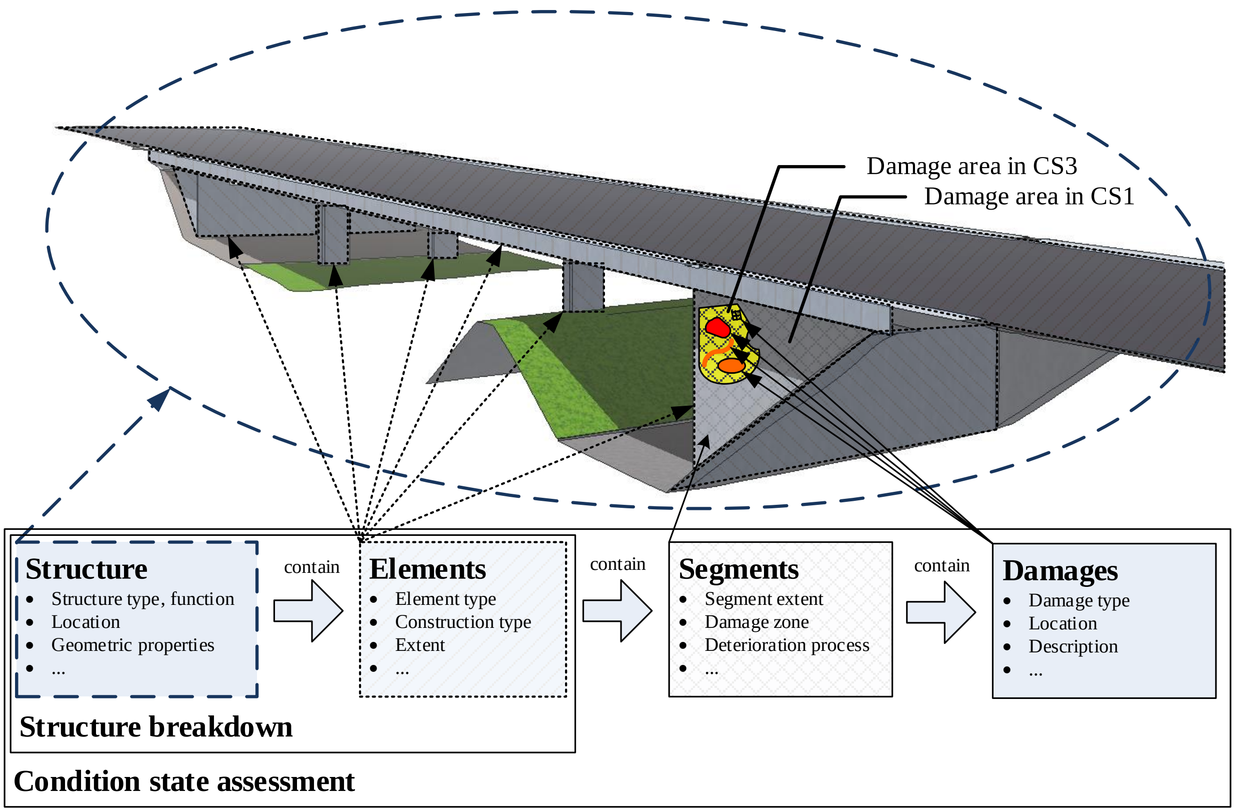


**Figure 1: Structure breakdown and condition state assessment within RSMS KUBA**

Based on the stored data, the RSMS KUBA furnishes the condition forecast and financial needs for the period of 40 years and proposes maintenance interventions.

KUBA uses Markov chains for modeling the condition development. Each combination of deterioration process and exposition is modeled by its characteristic Markov chain. At first the transition matrices of the Markov chains were estimated by a pool of experts. As time goes by, the matrices are updated using suitable statistical analysis of the condition data collected during inspections.

Possible interventions are classified in a relatively small number of intervention types. Each of it is characterized by unit costs and effectiveness. KUBA's cost forecasts depend on these values. The unit costs refer to a specific unit in which the extent of an element is measured. The unit for maintenance work on reinforced concrete, for example, is the square meter [$m^2$] of the surface area.

A maintenance intervention results in a condition state improvement expressed by transition probabilities, which represent the effectiveness of the intervention. This approach incorporates the empirical knowledge that a maintenance intervention often does not restore an element into the best condition state. The transition probabilities representing intervention effectiveness are calculated and updated by a statistical analysis of the condition data collected during inspections before and after the interventions (1, 2).

In this experience report the data collection for KUBA is described with the focus on the measures to secure data quality and work efficiency.

The lack of data in bad condition states is a serious obstacle for the determining of condition development in KUBA. The estimation of the Markov chains relies on observations in each condition state and since FEDRO seldom allows structures and elements to deteriorate into the worst two condition states, reliable calibration can hardly be performed. Even if the calibration algorithms are able to bridge data voids (2), they cannot overcome the problem of lack of almost all data in bad condition states. In the next section the results of just using the raw data for the calibration are presented.

Within FEDRO, the two areas of responsibility of the asset and the construction management are clearly separated. Since the asset management does not have direct managerial authority over the construction management and the design and construction phases are under the responsibility of the construction management, the construction management is almost free to decide which interventions are to performed and how they are to be documented respectively which data is to be collected. The asset management defines the standards and control mechanisms, but due to cost and time pressure as well as due to the lack of manpower, the control mechanisms are not effective and the data on performed interventions is not collected in sufficient quality. The lack of this data hinders the tracking of the road structure’s history and the quality improvement of the unit costs.

In the third section of this paper, these issues are described in detail. Furthermore, possible organizational measures are described – some of them are implemented – that can improve the work flow and consequently facilitate accessibility of information.

Finally, although the standards defined for KUBA as well as the software itself are well documented and known in Switzerland, the inspections which are contracted out to private consultants has to be supervised in order to ensure data quality. The stiff competition among private consultants and related cost pressure may tempt consultants to assign inspectors with little experience in structure diagnostics and expertise in working with KUBA. To overcome the lack of expertise and experience, the employees of the private consultants had to attend training course. Private consultants are required to register the amount of work for each structure in monthly time sheets. By this, the workload can be evaluated in combination with the data stored in KUBA. Results of the evaluation – e.g. determining factors influencing the workload for inspections – will be presented in the last section of this paper. The workload on almost 500 road structures was analyzed.

# DATA COLLECTION OF DETERIORATION

## Collected data and missing data in bad condition states

KUBA provides decision support in the planning of maintenance interventions. In order to compare maintenance strategies, the system forecasts the deterioration using discrete Markov chains. Estimating the transition probabilities of a discrete Markov chain is rather straightforward when observational data are available at each discrete time instance. KUBAs algorithms used to obtain transition probabilities are described in detail in (2).

For corrosion of reinforced concrete with average exposition, the number of transitions between any two condition states observed in two consecutive inspections is presented in the matrix below. The row CS3 in the matrix – for example – is to be read as follows: the total of 49 transitions from CS3 to CS4 was observed; whereas – 1,201 damage areas stayed in CS3. The initially mentioned exposition is used to consider that portions of an element may behave differently. In order to consider these differences, each segment is attributed a so-called "exposition indicator." Three exposition indicators are used: favorable, average and unfavorable, which are correlated to the segment having slow, moderate or fast deterioration.

Observed number of transition

| | CS1 | CS2 | CS3 | CS4 | CS5 |
|---|---|---|---|---|---|
| CS1 | 41,491 | 14,798 | 4,520 | 370 | 10 |
| CS2 | 0 | 2,572 | 329 | 23 | 0 |
| CS3 | 0 | 0 | 1,201 | 49 | 0 |
| CS4 | 0 | 0 | 0 | 75 | 3 |
| CS5 | 0 | 0 | 0 | 0 | 3 |

In the following figure on the left-hand side, the polygonal lines represent the deterioration pattern of each observed damage area. The transitions between identical condition states are ignored, so that the lines connect the points of the first observations in each condition state. In the figure on the right-hand side, the total number of transitions from starting condition state is shown. It can be understood as sample size in each starting condition state.

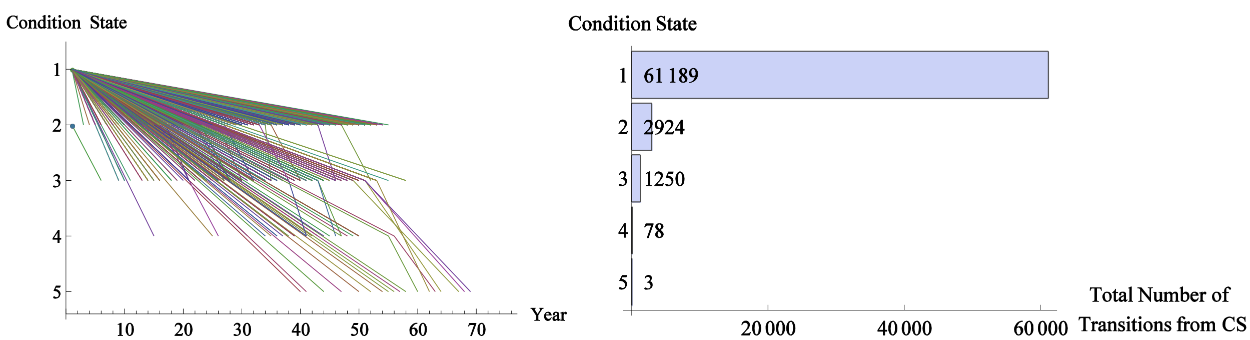


**Figure 2: Transitions of CS by age and number of transitions by CS for corrosion of reinforced concrete with average influence**

In order to calculate the deterioration matrix, the year – in which the transition is observed – has to be taken in account. It is therefore not possible to simply divide the total number of transitions from the condition state (respectively the sample size) by the number of observed damage areas that stay in the same or change to the next worse condition state.

For deterioration of expansion joints with average influence, the number of transitions between any two condition states observed in two consecutive inspections is presented in the matrix below.

Observed number of transition

$$\begin{array}{cc} & \begin{array}{ccccc} \text{CS1} & \text{CS2} & \text{CS3} & \text{CS4} & \text{CS5} \end{array} \\ \begin{array}{c} \text{CS1} \\ \text{CS2} \\ \text{CS3} \\ \text{CS4} \\ \text{CS5} \end{array} & \begin{pmatrix} 1{,}071 & 843 & 493 & 70 & 1 \\ 0 & 104 & 52 & 2 & 0 \\ 0 & 0 & 89 & 6 & 0 \\ 0 & 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}$$

As already described, in the following figure on the left-hand side, the polygonal lines represent the deterioration pattern of each observed damage area. In the figure on the right-hand side, the total number of transitions from starting condition state is shown.

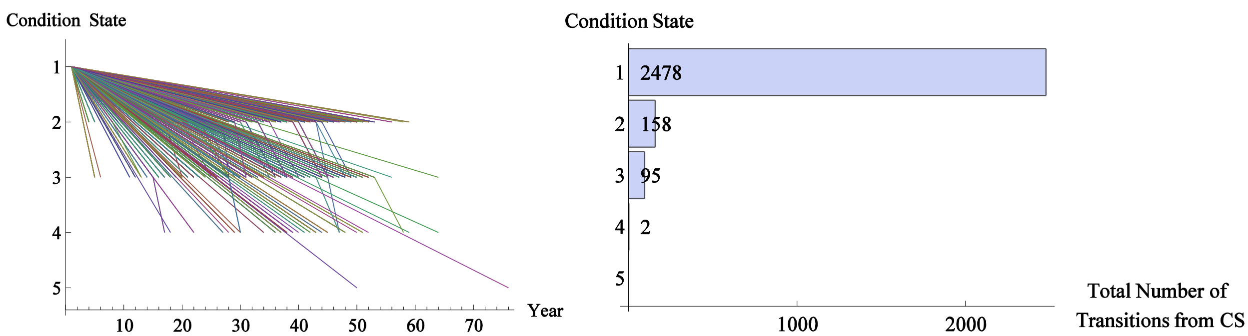


**Figure 3: Transitions of the CS by age and number of transitions by CS for corrosion for expansion joints with average influence**

The figures and matrices show that few transitions are observed from CS2, very few from CS3 and almost none from CS4 (Figure 2 and 3). It is supposed that the reason is to be found in the common practice in Switzerland, according to which interventions are mostly performed in CS3. Unfortunately, these observations are missing since no inspections are stored immediately before performing the intervention.

The described analysis was made for all relevant deterioration processes in KUBA. The results are very similar to the ones above and present the same problem.

## Issues of using raw data for calibration

In order to obtain the deterioration functions, the number of transition from a CS is set into relationship with the number of observations staying in a CS or switching to the next worse CS. The deterioration is therefore governed by the number of observed transitions into the next condition state. If raw data would be directly used for calibration, the condition development as presented in the following figures would result.

The figures are to be read as displayed in Figure 4 on the left-hand side: after 40 years, for instance 42% will be in CS1, 30% will be in CS2, 24% will be in CS3 and 30% will be in CS4; this also means that after 80 years, 27% are in CS3 or worse. Furthermore, according to Figure 4 and Figure 5 almost no or no deterioration is observed to CS5.

Transition probability at t+5years

| | CS1 | CS2 | CS3 | CS4 | CS5 |
|---|---|---|---|---|---|
| CS1 | 0.947 | 0.053 | - | - | - |
| CS2 | - | 0.926 | 0.074 | - | - |
| CS3 | - | - | 0.968 | 0.032 | - |
| CS4 | - | - | - | 0.986 | 0.014 |
| CS5 | - | - | - | - | 1.000 |

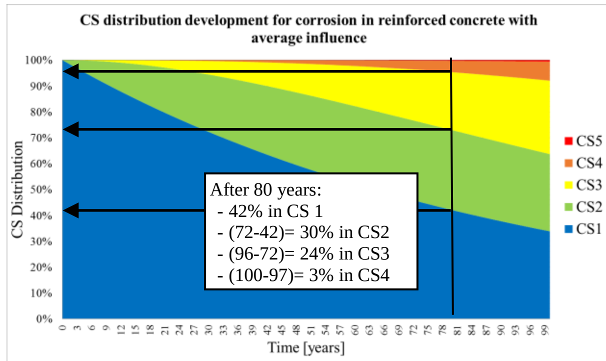


**Figure 4: Matrix and graph of the development of the condition state distribution for corrosion in reinforced concrete with average influence using raw data**

Transition probability at t+5years

| | CS1 | CS2 | CS3 | CS4 | CS5 |
|---|---|---|---|---|---|
| CS1 | 0.927 | 0.073 | - | - | - |
| CS2 | - | 0.848 | 0.152 | - | - |
| CS3 | - | - | 0.946 | 0.054 | - |
| CS4 | - | - | - | 0.993 | 0.007 |
| CS5 | - | - | - | - | 1.000 |

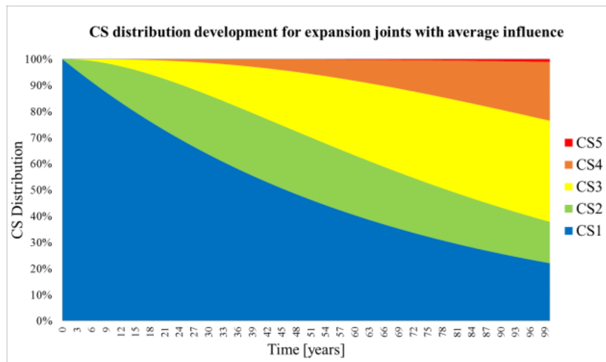


**Figure 5: Matrix and graph of the development of the condition state distribution for deterioration of expansion joints with average influence using raw data**

The raw data can be used directly for the calibration of KUBA's management system. It can be argued that the data corresponds to the practice and thus the results for the commonly applied maintenance strategies are correct.

The calibration results present the cause for concern that the deterioration speed – even from CS1 – appears to be very slow. It can be possible that individuals perceive the lifetime expectation shorter than the actual one since they mostly have to deal with damaged elements. Nevertheless, the discrepancy between the commonly expected and the calibrated lifetime expectation is huge. The common lifetime expectation of expansion joints is for example 10-40 years (3). According to the calibration after 40 years only 20% of the expansion joints are in a CS that is worse or equal to 3; and even after 100 years this percentage raises only to 40%.

A reason for the slow deterioration is that the condition state (normally CS3) immediately before performing interventions is not stored. Since the calibration algorithm is based on stored data it will yield slow deterioration from CS2. According to Figure 2 and 3, the same explanation could be given for the transitions from CS1. Nevertheless, it's not likely that interventions are already performed in CS2. Plausible explanations could be that either the calibration algorithms don't deliver correct results or condition state assessments weren't stored. Since the calibration algorithms were tested and gave robust results, it is assumed that almost no assessments were performed before interventions. This could have been the case since in 2008 the ownership of the road infrastructure was transferred from the Swiss Cantons to the Swiss Confederation. In order to verify this, a sample of elements with apparently long lifetimes ought to be analyzed.

As described, for the application in the management system, the transition matrices of the Markov chains were initially estimated by the pool of experts. As time goes by, the matrices are updated based on inspection results. The analysis shows that the estimation by the pool of experts is still necessary in order to model a realistic deterioration.

## COLLECTION OF DATA ON PERFORMED MAINTENANCE INTERVENTIONS

### Issues for data collection due to the organization

The spilt in responsibilities between the asset management and construction management seems to be a main obstacle to obtain the needed data on performed maintenance interventions.

The idea behind the split is to separate the client – which is played by the asset management – and the contractor – which is played by the construction management. The main issue related to this split is that the asset management and the construction management stand below the same managerial authority. By consequence, the asset management has no direct managerial authority towards the construction management.

Furthermore, the budgets i.e. the resources of the asset management are by far lower than those of the construction management. Due to this circumstance, the organizational weight of the construction management is larger than the one of the asset management. The conserns of the asset management tend to be treated with lower importance.

The construction management sets the priority in the tasks of design, building supervision and partially to as-built documentation. Since the construction management doesn’t perceive an advantage in the data collection, its priority is low.

Additionally, FEDRO’s policy is to contract out most of the task. The asset management contracts out on-site monitoring like inspections to regional units (Cantons) or to private consultants. Generally, the supervision of inspections is also contracted out to third parties. The construction management contracts out the design, the on-site building supervision as well as the supervision of these tasks to private consultants. In order to achieve good results, this kind of policy requires a precise specifications and strict controlling of the task execution.

Finally, FEDRO’s organization is relatively young. The ownership of the road infrastructure was transferred from the Swiss Cantons to the Swiss Confederation on the January 1, 2008. Since then, FEDRO is responsible for the strategic and operational task related to high volume road infrastructure. The organization is well set but – considering the service life of road structure – has relatively modest experience. Furthermore, the standards and the awareness for the importance of data collection aren’t completely established yet.

The described issues and their combination lead to a lack of data on performed maintenance interventions.

*Possible solutions in order to overcome the organizational issues*

In order to overcome the organizational issues, the following solutions are possible:

- Give the asset management direct managerial authority over the construction management: By doing this, the asset management could enforce that its requirements related to the data on performed maintenance interventions are fulfilled. This would be a major organizational change with manifold consequences and would have to be examined in detail.
- Give the asset management the competence for acceptance of work and release funds for the as-built documentation of performed maintenance interventions: This would give the asset management managerial authority to enforce the collection of the needed data. Additionally, it would be needed that the persons involved in the documentation know from the very beginning about the requirements and collect the needed data at the right moment. Otherwise it wouldn't be assured that when the as-built documentation is approved it fulfills the requirements. If the needed data is stored months after the maintenance intervention was performed, its quality is likely to be too low.
- Raising awareness of the construction management of the need for data on maintenance interventions and related advantages: The statistical analysis of performed maintenance interventions yields the unit costs of different interventions on element types that can be very useful for the construction management to improve bid evaluations. Furthermore, making the construction management aware that the data on performed maintenance interventions has influence on the financial need calculated by the management system and the future funds, which will be available, could raise overall awareness. Nevertheless, this solution relies heavily on the insight that this data need to be collected.

## Technical issues of data collection

Within KUBA, the calibration of maintenance intervention costs is done in two steps. In the first step the unit costs of typical intervention were determined by collecting experts' opinions. In the second step, KUBA automatically calibrates the unit costs based on the stored intervention costs. Consequently, the more performed interventions are stored in KUBA the more reliable unit costs in KUBA can be expected. The issue with this very promising approach is that the breakdown of cost in practice is different from the cost breakdown in KUBA. In KUBA element unit costs are needed and these costs have to be stored, but in practice – during project realization – the costs are relate to the type of work.

To overcome this issue, a research project was carried out and will soon be published. A main result of the research project is that there is no way to bypass collection of element costs during project realization. In order to obtain these costs, the contractor has to track them and the awarding authority has to pay for it (4).

# ORGANIZATION OF THE DATA COLLECTION

FEDRO contracts out the inspections and spends yearly about 3 million US$ for it. Following internal guidelines, FEDRO has to commission the work based on the workload. Besides other quality requirements, FEDRO has to control the workload that is declared by the private consultants. The difficulty of controlling the workload is that each road structure is requiring different workload and no detailed quantitative data exists by which the workload can be forecasted: a bridge with 3,000 m of length in bad condition will require considerably more workload compared to a “common” bridge with a length of 20 meters, which is almost new. Since the road structures vary considerably from network section to network section, it is not or just very roughly possible to assess the workload. In Figure 6 the average workload is presented for different network sections.

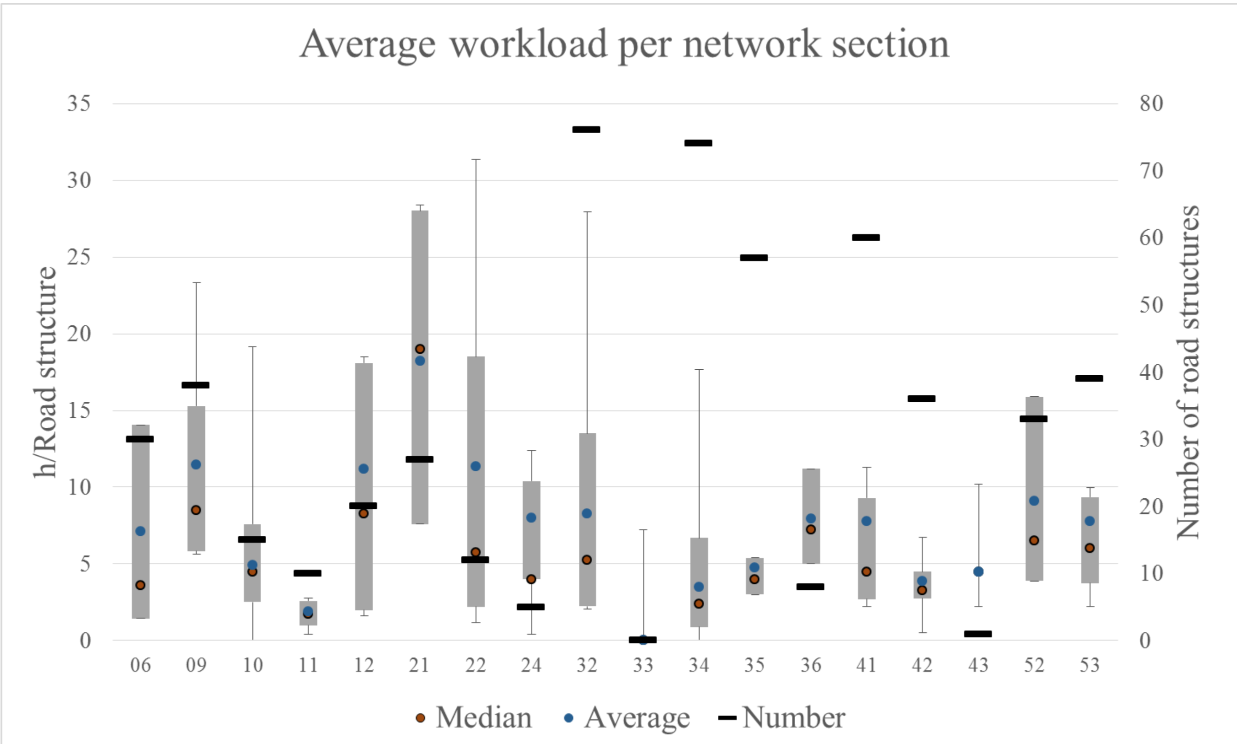


**Figure 6: Average workload for inspections per network section**

In order to improve the planning and controlling of the workload, the private consultants were required to file – in addition to the usual time sheet data like the name of the person, date, work time, work item, etc. – the ID of road structure related to the work item. The IDs of the road structures are unique and these are stored in KUBA. This allows one to link all data stored in KUBA (e.g. the length of the road structure, the number of elements, the condition state of the structure, the number of observed damages) to the workload and to perform a correlation analysis. For instance, one can determine which parameters govern the workload. By analyzing different parameters, one can determine the ones with low scatter as ones that are likely to govern workload. In the first step the workload is plotted as a function of the parameter, which is analyzed and, based on this, meaningful cohorts are built. In the second step the scatter is analyzed by analyzing box-plot diagrams in order to determine which cohorts or parameters have to be analyzed in more detail. A low scatter characterizes itself by low difference between the upper and lower “quantile”, in which the lower “quantile” corresponds to 20% of the values and the upper “quantile” corresponds to 80% of the values. The lower whisker is set to 5% quantile and the upper to 95% quantile. A quasi normal distribution is characterized by little difference between the values for average and median so as a symmetrical boxplot.

In a third and final step the scatters of the different cohorts are compared between each other and discussed.

In the following paragraphs the results of the analysis are presented.

## Analysis of scatter and distribution of the workload in function of different properties

*Analysis of the influence of structure types*

In a first step the scatter and the distribution of the average workload per road structure type was analyzed.

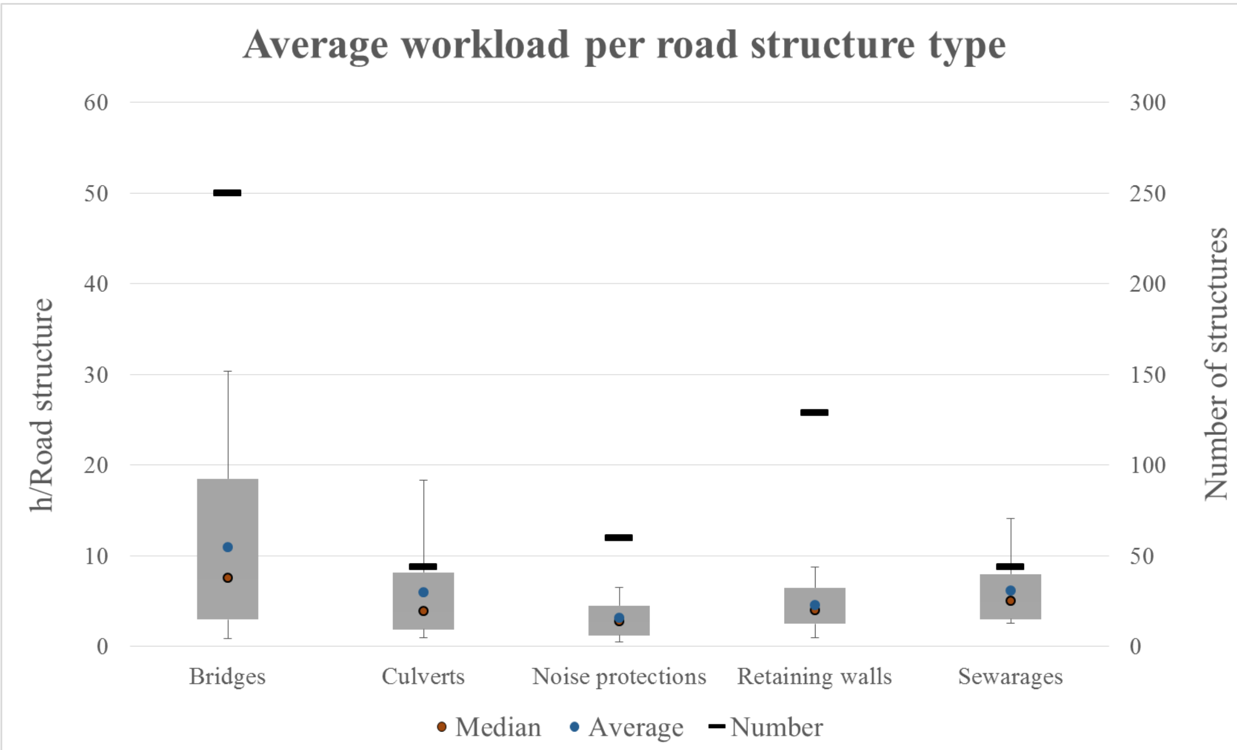


**Figure 7: Average workload per road structure type**

As can be seen in the upper figure, the scatter for noise protections, retaining walls and sewerages is low and the workload is quasi normally distributed. For culverts this is less the case but the values are still acceptable. For bridges, in contrast, the scatter is big and the workload isn't normal-distributed. Consequently, the bridges are analyzed in more detail in order to reduce the scatter and achieve a distribution which approaches the normal distribution.

*Analysis of the influence of length, deck area, number of elements, number of "newly" collected damages and condition states*

In the second step, cohorts were defined for bridges as a function of the length, deck area, number of elements, number of "newly" collected damages and condition states. This was done in order to determine which properties govern the workload.

Based on the average workload per bridge length, obvious cohorts couldn't be the defined. For the purpose of representation, cohorts were defined for bridges with 0-80 m, bridges with 80-340 m and bridges with 340-3,155 m. The same analysis was also done for the deck area of bridges.

Following the same procedure, i.e. by analyzing the average workload over the number of elements, cohorts were defined for bridges with 20 or less elements, bridges with more than 20 and equal or less than 50 elements and more than 50 elements.

The comparison of the box-plox from Figure 8 shows that the scatter for bridges with 20 or less elements is low and the workload is quasi normally distributed. For bridges with more than 20 and equal or less than 50 elements this is less the case but the values are still acceptable. For bridges with more than 50 elements the scatter is significant.

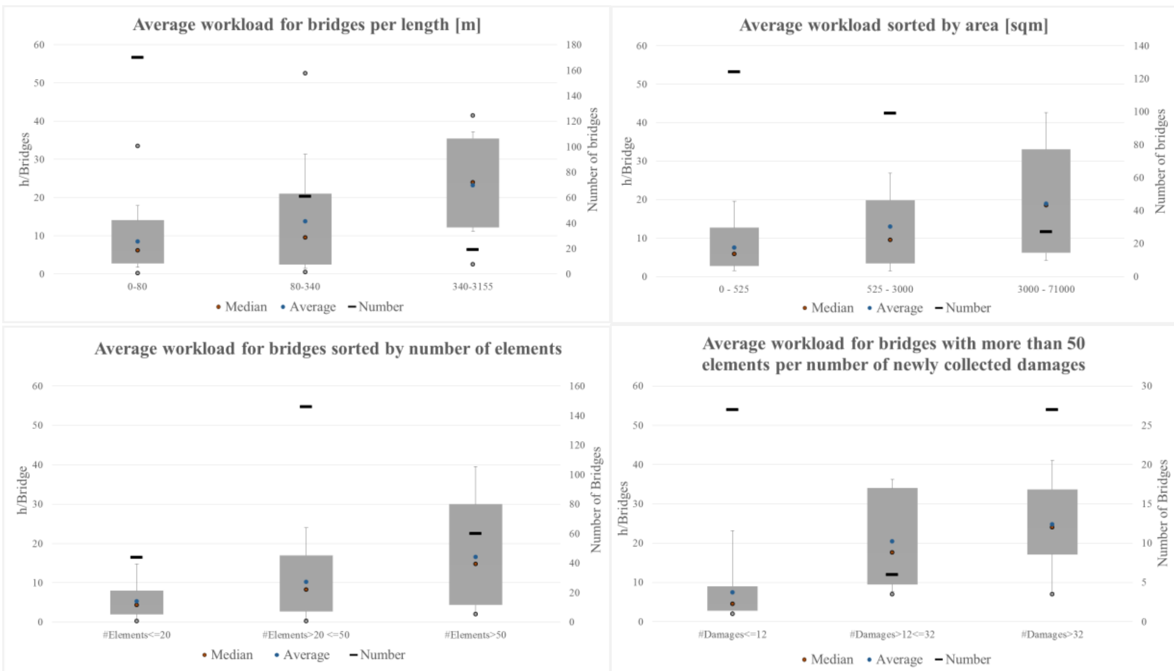


**Figure 8: Average workload for bridges**

In order to reduce scatter for bridges with more than 50 elements the number of “newly” collected damages, respectively damages which were stored for the first time during the inspection were analyzed. Based on this, cohorts were defined for bridges with 12 or less damages, bridges with more than 12 and equal to or less than 32 damages and more than 32 damages.

As can be seen in Figure 8 the scatter of bridges with more than 50 elements can be reduced significantly by differentiating by number of damages. The scatter for bridges with more than 12 and equal or less than 32 damages is still quite big, but it has to be considered that the number of considered bridges is low.

The consideration of newly collected damages was analyzed in the last step since it can just be for controlling of the performed workload but not for the workload forecast. Since it seems that the number of newly collected damages significantly influence the workload, the workload per number of damages and per condition state is analyzed. Based on this analysis, cohorts for bridges with 12 or less damages, bridges with more than 12 and equal to or less than 32 damages and more than 32 damages are built. Since the number of damages is related to the condition state, the box plot diagrams were also plotted for the condition state.

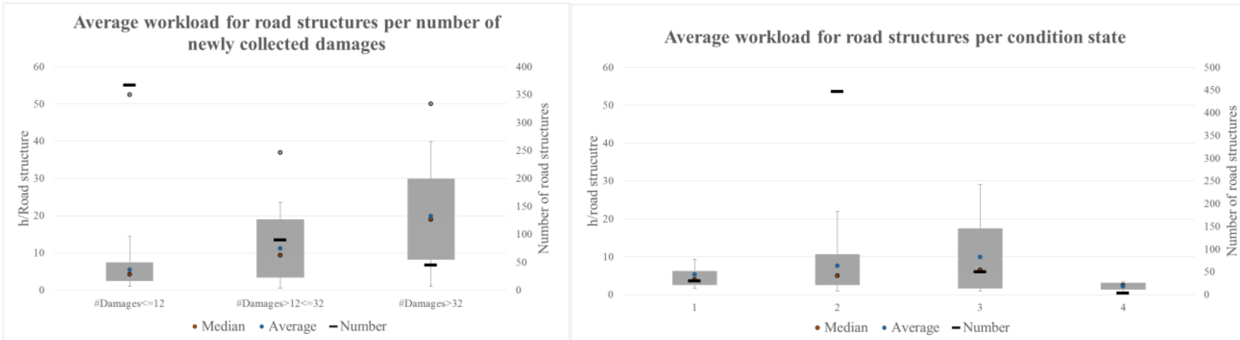


**Figure 9: Average workload for road structures per number of newly collected damages and average workload for road structures per condition state**

As can be seen in Figure 9, the scatter of workload for bridges can be reduced significantly by differentiating by number of damages and especially by differentiating over CS. Especially the CS is a good parameter for benchmarking in order to control the declared amount of work.

Based on the analysis the average workload for the inspection and its scatter is summarized in the following table.

**TABLE 1** Average, Median, lower & upper quantile and number of considered structures

| | Average | Δ | Median | Lower quantile (20% of values) | Δ | Upper quantile (80% of values) | Number of considered structures |
|---|---|---|---|---|---|---|---|
| **Type of road structure** | | | | | | | |
| Noise protections | 3.1 | 0.3 | 2.8 | 1.3 | 3.2 | 4.5 | 60 |
| Retaining walls | 4.5 | 0.5 | 4 | 2.5 | 4 | 6.5 | 129 |
| Sewerages | 6.1 | 1.1 | 5 | 3 | 5 | 8 | 44 |
| Culverts | 5.9 | 2 | 3.9 | 1.9 | 6.3 | 8.2 | 44 |
| Bridges | 10.9 | 3.4 | 7.5 | 2.95 | 15.55 | 18.5 | 250 |
| **Number of bridge elements** | | | | | | | |
| <= 20 | 5.3 | 0.9 | 4.4 | 2 | 6 | 8 | 44 |
| >20 and <=50 | 10.3 | 2 | 8.3 | 2.8 | 14.2 | 17 | 146 |
| >50 | 16.6 | 1.8 | 14.8 | 4.4 | 25.6 | 30 | 60 |
| **Number of newly collected damages for bridges** | | | | | | | |
| <= 12 | 7.3 | 1.5 | 5.8 | 2.8 | 7 | 9.8 | 133 |
| >12 and <=32 | 12.1 | 0.2 | 11.9 | 3 | 16.5 | 19.5 | 72 |
| >32 | 19.9 | 1.1 | 18.8 | 7.9 | 22.1 | 30 | 44 |
| **Number of newly collected damages for bridges with > 50 elements** | | | | | | | |
| <= 12 | 7.4 | 2.9 | 4.5 | 2.75 | 6.25 | 9 | 27 |
| >12 and <=32 | 20.5 | 2.9 | 17.6 | 9.5 | 24.5 | 34 | 6 |
| >32 | 24.8 | 0.8 | 24 | 17.1 | 16.6 | 33.7 | 27 |

| | Average | Δ | Median | Lower quantile (20% of values) | Δ | Upper quantile (80% of values) | Number of considered structures |
|---|---|---|---|---|---|---|---|
| **Condition states for bridges** | | | | | | | |
| CS1 | 6.9 | 2.9 | 4 | 2.5 | 3.8 | 6.3 | 11 |
| CS2 | 10.9 | 3.4 | 7.5 | 3 | 15 | 18 | 212 |
| CS3 | 13.2 | 0.6 | 13.8 | 1 | 20 | 21 | 26 |
| **Condition states for bridges with > 50 elements** | | | | | | | |
| CS1 | 7.9 | 1.9 | 6 | 3.2 | 3 | 6.2 | 7 |
| CS2 | 34 | 17 | 17 | 4.4 | 26.7 | 31.1 | 50 |
| CS3 | 33.7 | 12.7 | 21 | 15.8 | 14.6 | 30.4 | 7 |
| **Number of newly collected damages for road structures** | | | | | | | |
| <= 12 | 5.5 | 1.2 | 4.3 | 2.5 | 5 | 7.5 | 367 |
| >12 and <=32 | 11.2 | 1.8 | 9.4 | 3.4 | 15.6 | 19 | 90 |
| >32 | 19.9 | 0.9 | 19 | 8.2 | 21.8 | 30 | 45 |
| **Condition states for road structures** | | | | | | | |
| CS1 | 5.3 | 1.3 | 4 | 2.5 | 3.8 | 6.3 | 30 |
| CS2 | 7.6 | 2.6 | 5 | 2.5 | 8.2 | 10.7 | 447 |
| CS3 | 9.9 | 3.4 | 6.5 | 1.6 | 15.9 | 17.5 | 50 |
| CS4 | 2.2 | 0.3 | 2.5 | 1.3 | 1.8 | 3.1 | 3 |

## CONCLUSIONS AND DISCUSSION

Given that the paper addresses three distinct topics related to the deployment of RSMS KUBA within FEDRO, the conclusions are also threefold.

The first topic addresses the estimation of the deterioration functions with calibration algorithms. It can be concluded that even with the calibration algorithms that are able to bridge data voids (2), the problem of lack of almost all data in bad condition states cannot be overcome. Since FEDRO seldom allows structures and elements to deteriorate into the worst two condition states, the deterioration function from these worst two condition states rely on the estimates of a pool of experts. The failure to collect condition data immediately before performing intervention is an additional drawback to reliably estimate deterioration functions. The awareness that these data has to be collected need to be reinforced.

The second topic addresses the organization focusing on the split in responsibilities between the asset and the construction management. This split seems to be an obstacle to obtain valuable data that can be used for planning purposes. The proposed solution of giving to the asset management the competence for acceptance of a performed intervention and for funds release for the as-built documentation of performed maintenance interventions, would directly address the issue and thus be an effective measure. Furthermore, additional research projects should be conducted in order to overcome the issues related to the difference between the breakdown of cost in construction practice from the one in asset management.

The third topic addresses the collection of inspection data that is well established and proceeds quite smoothly. As the workload for inspections varies considerably, the performed inspections are analyzed to determine the parameter that influence the workload. Based on this analysis, the type of road structure, the number of newly collected damages and especially the condition state seem to govern the workload. For bridges, the newly collected damages clearly govern the workload. Since the information about the condition state and the newly collected damages isn’t available à priori, it just can be used for controlling the registered workload and not for planning purposes. For planning purposes, the number of elements can be used, but they don’t provide accurate values for large bridges. It is clear that the workload heavily depends on the data which is collected during inspections. It is therefore important to be aware of the workload related to the data which is required to be collected. On the other hand, the improvements in the processes and tools are more effective if done for data on damages. Another possibility for analyzing the data would be to perform regression analysis and plot the regression graphs. Regression graphs have the advantage to give a better overview of the scatter. On the other hand, regression graph doesn’t show so clearly cohorts and their distribution. Since a goal of the analysis also was to provide benchmarks, the representation with box-plots was chosen.

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