Terms of Reference for Bridge Analytical Module for the Bridge Management System

(Version 1.1, November 2021)

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1 PURPOSE OF THE DOCUMENT

This document presents the Terms of Reference (ToR) for procurement for the Bridge Analytical Module (BAM) software. Firstly, background on the implementation of the BMS system in North Macedonia is given. Next, the objectives of PESR with respect to the BMS are reviewed, and here the importance of the Bridge Analytical Module in the estimation of the bridge investment plan (BIP) is emphasised. The scope of the BAM is given, focusing on functional and technical requirements. Project management and deliverables of the project, payment schedule and Client responsibilities are defined. The content of this document is intended to aid in the preparation of tender documentation for bids for a consultant that will develop the BAM software.

2 LIST OF ACRONYMS

BAM	…	Bridge Analytical Module
BIP		Bridge investment plan
BCD	…	Bridge Condition Data
BCS	…	Bridge Condition Survey
BDC SW	…	Bridge Data Collection Software
BMS	…	Bridge Management System
CS	…	Condition state
GDP	…	Gross domestic product
GIS	…	Geographic Information System
HW	…	Hardware
IR	…	Inception Report
IT	…	Information Technology
PESR	…	Public Enterprise for State Roads
RAMS	…	Road Asset Management System
RDB	…	Road Data Bank
RRS	…	Road Reference System
RUDP	…	Road Upgrading and Developing Program
SW	…	Software
ToR	…	Terms of Reference
WEB GIS	…	Geographic Information System WEB application
WB	…	World Bank

3 BACKGROUND

3.1 The Purchaser - Public Company for State Roads

Public Company for State Roads (PESR) is manager of state roads in North Macedonia. PESR is mandated to plan, construct, reconstruct and rehabilitate the National and Regional roads and bridges in the country. Bridges are broadly categorized as follows: (1) Bridges on National Roads (these bridges are on roads primarily connecting to neighboring countries but also to the largest regional centers in the country), and (2) Bridges on Regional Roads (these bridges are on roads connecting two or more municipalities and securing critical in-country connectivity). The current road network in Macedonia comprises a length of 14,159 km, of which 1112 km are National Roads (consisting of 236.5 km highways and 876 km of non-motorway National Roads), 3,721 km are Regional Roads and the remaining 9,240 km are Local Roads. National and Regional Roads are under the responsibility of PESR.

3.2 General information on Bridge infrastructure in North Macedonia

Under the responsibility of PESR there are 1268 bridges on national roads and regional roads (Figure 1~~Figure 1~~). According to current data, 75% of bridge stock is built from reinforced concrete, while for 266 bridges (21%), no information about the material could be retrieved. The remaining 4% are composite, steel or masonry bridges. Nearly two-thirds of structures are classified plainly as bridges, while other bridge-like structures such as overpasses, underpasses, and viaducts represent 17, 11 and 6 % of bridge stock, respectively. Only 10% of bridges are more than 50m long, while about 29% and 33% of bridges are between 10-20 and 20-50m long, respectively. It is necessary to be aware that given numbers are indicative, as it is necessary to check inventory data in the field.

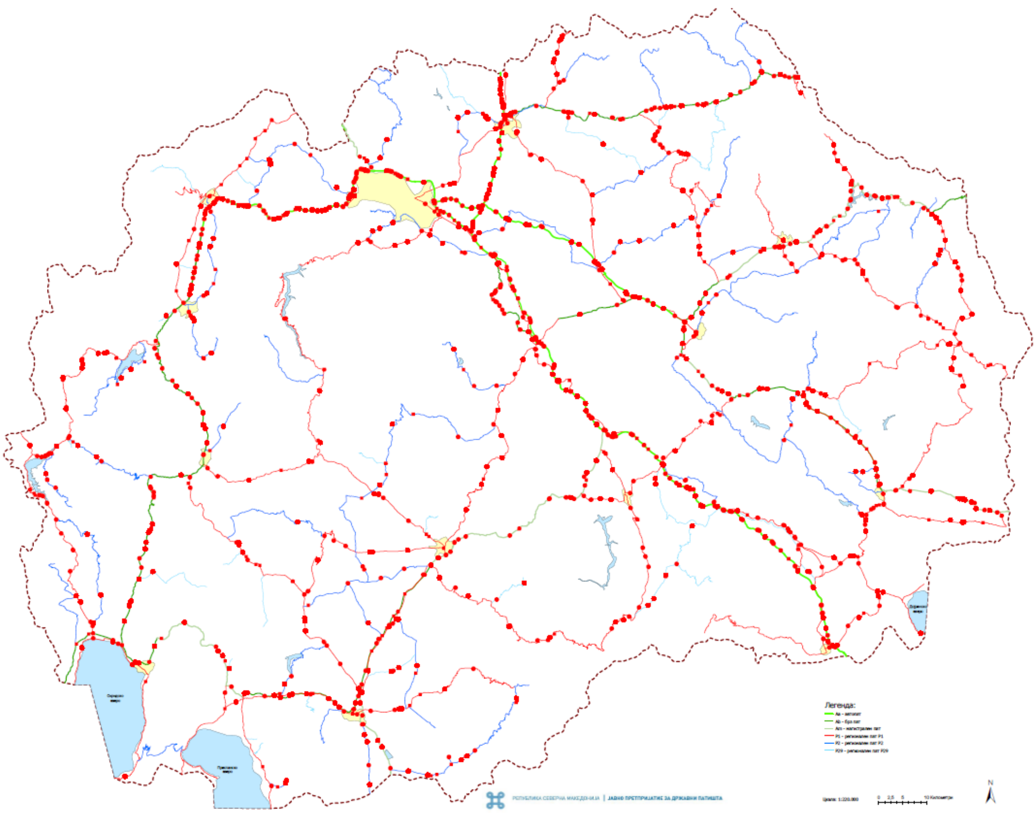

Figure 1: The bridges (red dots on the map) on regional and national roads in North Macedonia under the responsibility of PESR

There is no bridge inventory and condition data available; these data will be collected inside the BCS project that will run in parallel. Also, Bridge data collection SW will be delivered as part of the BCS project and will serve as a tool for bridge data collection (both inventory and condition data). The management of bridge data will be assured through the RAMS SW, where XML data exchange with BCS SW will be implemented. The inventory and condition information on bridges will be stored in the RAMS database and will be at the full disposal of the BAM. The related bridge data model that will be implemented inside of RAMS and BCS SW is given in Appendix 1. Also, WEB GIS for bridge data presentation on the map will be available as part of the RAMS system.

3.3 Project Background information

The World Bank (WB) is supporting the Public Enterprise for State Roads (PESR) in the Republic of North Macedonia in their efforts to establish a Road Asset Management System (RAMS).

In 2017 PESR established RAMS, and it is currently operational and managed by the Sector for road management and safety (also called RAMS team/unit), which falls under the Maintenance Department of PESR. In its current stage of development, the RAMS is used for pavement management based on an IT system consisting of independent components RAMS Portal, Road DataBank (RDB) and WEB GIS. They are integrated into standard IT solution where HDM-4 software is used for road data analysis and programming purposes. A road reference system (RRS) in both alphanumerical and graphical (GIS) form was established, and all existing road data were transformed and inserted into RDB. Data collection and entry have so far been performed using Ground Penetration Radar measurements, Falling Weight Deflectometer measurements, and Bridge Weigh-In-Motion measurements.

The following is a description of the current RAMS components:

- Road Data Bank (RDB); It includes a database and application for road data management. The RDB database is designed as an integrated relational and GIS database that stores all road data in a standardized relational database MS SQL server according to the road reference system (road section and chainage) and geometry (coordinates) simultaneously. The RDB application is implemented as a Web solution to enable use of the RDB by as many users as possible but also as a client/server solution with more advanced functionality for advanced users (RAMS team). An important functionality of the RDB is the customized data handling module that is used for road data analyses and defining homogenous sections and importing prepared data to HDM-4 software. The data handling module was customized according to the HDM-4 needs. The RDB database was filed with road reference data as well as GPR- and WIM-measured data. All available data were transformed to new RRS, adapted to RDB structure and imported to RDB. Also, GPR data (for almost 4,400 km of state roads) and WIM data (for 20 locations) were inserted to RDB.
- Goal of the GPR measurement was to determine pavement structures (material type and thickness of pavement structure layers). The roads survey was made by Road Doctor Survey Van, that includes ground penetrating radar (GPR), video, laser scanner, accelerometer and positioning system (GPS with MU). Data taken are continuous but were homogenized by 10m sections before delivery for bound, second and unbound layer. Important results of this measurements are also road pictures now integrated in WEB GIS - a total of 69000 images were produced with an image interval of 50m. Also source measurement data were delivered including video of road - data can be viewed with Road Doctor software.
- The WIM measurements were made through bridge WIM systems installed over the full width of roads.
- Metadata were prepared for all transformed data, but also for other data -road reference system data, GIS background maps data, etc.
- Road Reference System (RRS): In the GIS application, road data collected in RDB are effectively presented through visualization with appropriate background maps. The GIS application covers also the presentation of results of data analyses made by the RDB data handling module, as well as HDM-4-prepared programs of road works. As there was no existing road reference system (except road definition), a new RRS was established defining road sections and nodes and the methodology for road section definition and digitalization

were defined as a first step. Digitalization of road centerlines for state roads took place subsequently, where "Open street" maps was taken as background and road ramps on motorways were also digitized. For RRS data maintenance, an IT environment inside ESRI ArcGIS Desktop was established and user training for RRS data maintenance was done.

To further improve its management of road assets, PESR is planning to complement the existing RAMS through the additional Bridge Management System (BMS) module and strengthen the RAMS unit with additional BMS experts. To achieve the above goals, PESR employed a consultancy firm to support the RAMS team in establishing and strengthening the BMS function, detailing a roadmap for BMS and supporting PESR in preparing and implementing subsequent specialised assignments/procurement activities. In addition to consultancy services, the establishment of BMS will be done through the next outsourcing activities:

- national Bridges Condition Survey (BCS) project,
- delivery of BMS software that consist of:
    - upgrade of RAMS,
    - Bridge Condition Survey SW (as part of BCS project),
    - Bridge Analytical Module,
- additional hardware and system software for BMS project.

PESR will commission these assignments with the loan of the WB under the Road Upgrading and Development Project (RUDP).

3.4 Business Objectives of the Purchaser

PESR is mandated to plan, construct, reconstruct and rehabilitate the National and Regional roads and bridges in the country. While rationalised management of roads was already addressed and successfully implemented within the project Road Asset Management System (RAMS), the design of strategy and implementation of the BMS in North Macedonia is now underway.

The main strategic objective of PESR's BMS is defined as:

> *With the successful implementation of the bridge management system at PESR, rationalise the maintenance processes to provide safe and serviceable bridges for road users and reduce the impact on the economy by minimising travel time when closing bridges needing rehabilitation.*

This objective is to be fulfilled by improving and maintaining the condition state of the bridges under the jurisdiction of PESR (1268 bridges on national roads and regional roads). Here, the decision making on the optimal maintenance program needs to be based on a bridge inventory, reliable and regularly gathered bridge condition data in inspections.

PESR started the implementation of BMS in September 2020 with the project "Assistance to the Public Enterprise for State Roads in Carrying Out Preparatory Activities for Introduction of Bridge Management System". The Project includes engagement of external Consultant to:

- Establish and strengthen the BMS function
- A detailed roadmap for the introduction of BMS as part of RAMS
- Prepare the Bridge Investment Plan
- Define and support the execution of ToR for BMS HW and SW and
- Define and support the execution of ToR for project-funded consultancy to prepare the national bridges condition survey (scope of this ToR)

It is planned that all three outsourcing projects (national BCS project, delivery of BMS software and delivery of additional hardware and system software for BMS project) will run in parallel, including consultancy services, and will last for the next 12 months when integrated results from all projects will present implemented BMS.

A BAM consultant should deliver a tailored BAM SW.

The overall objective of the purchaser inside of this project is the establishment of a fully functioning Bridge Analytical Module (BAM) as part of BMS SW. The Consultant to be selected for delivery and installation of the Bridge Analytical Module (BAM Consultant) shall deliver the fully functional BAM SW, integrated with existing RAMS and implemented in available RAMS IT infrastructure. The collection of bridge data is not part of the assignment of the BAM Consultant; it will be organized separately by BCS project and stored in RAMS database.

The functionality of the BAM will be tested using sample data (at least 100 bridges) that be collected by the BCS project. No additional data collection is required as part of this tender, all data requested for BAM will be provided by PESR and stored in RAMS database.

The primary business objective of PESR in establishing the BAM are as follows:

- *having a system that will enable knowing current bridge condition based on predefined methodology and bridge data collected;*
- *having a tool that will be able to help define the classic questions of a BMS: Where (to invest); When (to invest); and What (treatment to utilize);*
- *encouraging local population confidence in PESR's ability to maintain the bridged on state road network for the road users;*
- *being able to set investment priorities on the bridges on the state road network based on both engineering and economic criteria;*
- *having a ready database of knowledge on the bridges on state road network.*

Detailed requirement for the BAM are specified below, including the services to be provided regarding specification, development, testing, installation, user training and to support programming of road works.

The expected benefits of the BAM implementation are as follows:

- *Allowing a better allocation of funds to maintain the bridge system.*
- *Giving information on the bridge system to the broader public and the road users.*
- *Creating a systematic approach to maintaining the bridges, which will also give information and future predictions as to the bridge's state and also help estimate future maintenance and rehabilitation needs.*
- *Automating some procedures which are now performed manually.*
- *Increasing benefits to the national economy both on a micro-economic and macro-economic level.*

4 BUSINESS FUNCTION AND PERFORMANCE REQUIREMENTS

4.1 Objectives

With respect to the main strategic objective of PESR's BMS (Section 04), there is a need to perform regular inspections of bridges to discover and timely treat the damages that can have a critical impact on the functionality of the North Macedonian road network. Also, there is a need to identify the potentially endangered bridges, which require retrofitting in the face of oncoming extreme events (e.g. flooding, earthquake). To facilitate making optimal decisions regarding necessary maintenance, repair and rehabilitation of bridges, a Bridge Management System (BMS) is being established as part of RAMS. Therefore, the BMS can be understood as an inspection–based decision-support tool, which incorporates GIS and database features with engineering and economic factors to support decisions on maintenance. The core of the BMS is a Bridge Analytical Module (BAM), which serves as a tool to aid in estimating optimal investment funding levels and identification of timely and adequate combinations of maintenance measures for bridges over their lifetime (a bridge investment plan (BIP). The procedure of estimating the optimal bridge investment plan is shortly explained.

The crude financial needs for the bridge investment plan can be estimated from experience or in a "top-down approach," e.g. accounting only for the condition state of bridge deck area in the analysed network. However, this is only an initial estimate, which should be further refined in a "bottom-up approach". The idea is to start from elements of bridges and their condition state obtained in inspections. The deterioration of bridge elements over time can be predicted using (stochastic) deterioration mathematical models. The next is to define the corrective measures for various condition states and related damages on bridge elements. The costs of a specific measure depend on element type/material and related extent (e.g., area/length) treated. Each of the maintenance measures needs to have their effectiveness defined, i.e. the effect of their application on the condition state of a bridge element. This predefined set of measures for elements of bridges in the analysed network, which have defined schedule and related costs, is referred to as a maintenance project. To estimate an optimal maintenance strategy, optimisation of discounted long-term costs is performed for the adopted project (e.g. see Figure 2~~Figure 2~~ and Figure 3~~Figure 3~~). Here, the related owner costs include the costs of applied maintenance measures in a specified time, while user costs result from bridge closures due to maintenance, which can be evaluated via additional travel time that users spend driving on the detours. In the absence of other sources, the unit user costs (EUR/h) can be estimated based on the gross domestic product (GDP).

Net present value analysis is used to compare costs occurring at different times in the bridge lifetime. Cash flows that occur in the future are discounted to the present value and compared as single numbers. Discounting considers that the same amount of cash received today is more valuable than the one received in the future. There is no standard value for the discount rate in Northern Macedonia. A reasonable rate consistent with agency policy (e.g., between 1-2%) should be selected, reflecting more or less the productivity increase in the civil engineering industry. In any case, it should be consistently used across all asset types managed by the agency. By setting the (annual) budgetary constraints in the optimisation process, the working program and related financial needs, i.e., a refined bridge investment plan is obtained.

The decision to be made by a bridge maintenance planner has two dimensions: scope and timing. The planner must decide how long the first waiting period should be and what kind of intervention to undertake. Naturally, if the waiting period is extended, deterioration will continue and the scope and cost of the first intervention will likely increase. So, scope and timing are interrelated. If the program horizon is long enough, the decision becomes a multi-stage process. After the first intervention and its rest period, the need may arise for another intervention. The scope and timing of the second intervention depend on the decisions made about the first intervention.

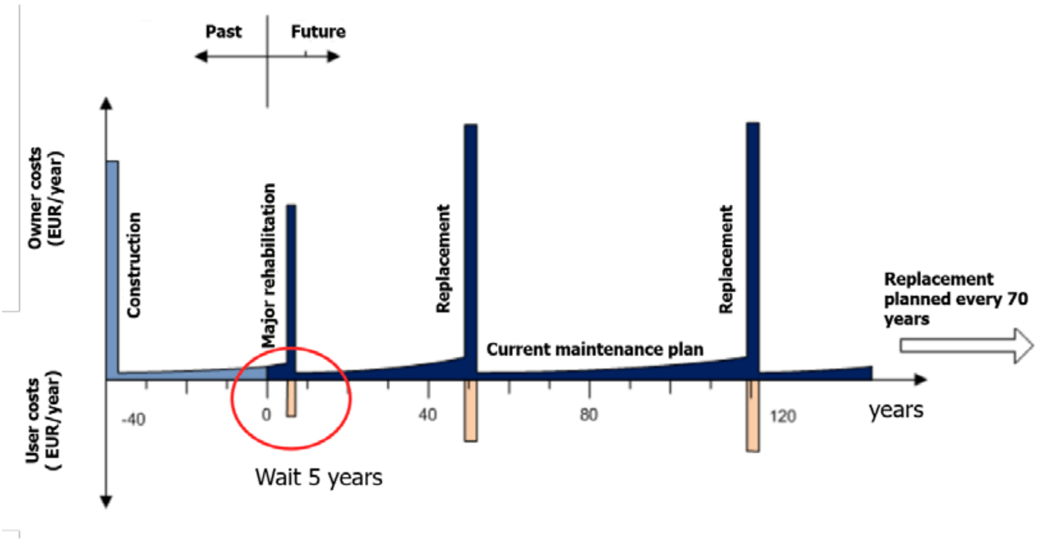

Figure 2: Long-term cash flow for a selected maintenance project

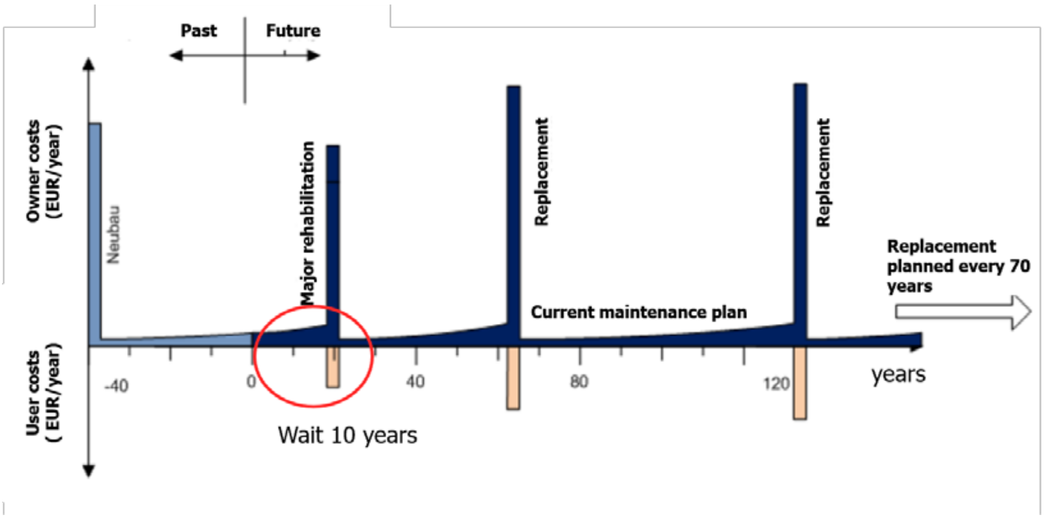

Figure 3: Long-term cash flow for a selected maintenance project with the adjusted schedule of application

To perform the above-mentioned analysis, there is a need to develop a BAM as a combination of software with analytical capabilities and data storage, which is in the case of the North Macedonia road network envisioned to be part of the existing RAMS system.

4.2 Scope

[Tech. Req. 1] The Bridge Analytical Module (BAM) is envisioned as a web-based software. It needs to be compatible with the existing RAMS solution, enabling full implementation of an envisioned methodology for managing bridges. This relates to an overview of bridge inventory data, bridge inspection data, condition rating of bridges, and further, to predict bridges' deterioration over time and estimate financial needs for future maintenance measures. The BAM software should enable PESR users to visualise the data on bridges via tables, graphs, reports and GIS, and perform data reporting in predefined templates. The BAM software needs to consist of the following segments:

- **Inventory**

  Overview of static information on bridges in the network (e.g. geometry, materials, documentation). This data is stored in the RAMS database and serve as the basic input.

- **Inspections**

  Overview of static information on condition states of bridges & bridge elements gathered in regular inspections (incl. description and figures of damages/damage processes). This data is stored in the RAMS database and serve as the basic input.

- **Maintenance history**

  Overview of static information on the history of performed maintenance measures on bridges in the inventory (e.g., type, costs, the scope of work). This data is stored in the RAMS database and serve as the basic input.

- **Planning of maintenance measures and budgetary requirements**

  Comprises specification of technically feasible maintenance measures and elaboration of working programs. The outputs are based on a condition forecast for bridges in the inventory, predefined maintenance measures, annual budget and heuristics. This data is related to a working session of BAM, but certain values of parameters that are used in calculations will be stored in the RAMS database. Also, some basic data for prepared BIP should be stored back in the RAMS database.

These segments in the following text will be referred to as BAM segments.

4.3 Functional Requirements

The functional requirements give more detail on what data types are to be used in BAM and how is it envisioned for a user to work with this data within BAM (e.g., read, write, select, query, calculate, generate outputs).

4.3.1 General functionalities of BAM segments

4.3.1.1 Selection of BAM segments

[Tech. Req. 2] The selection of a bridge in BAM segments: Inventory, Inspection and Maintenance history, to overview related data should be done by using a tree-navigation menu structure. Here, the nodes of this structure should be bridge IDs. Also, it is necessary to enable bridge(s) selection on a GIS map. For a performed selection of bridges, the menus/tables/graphs visualising the data in an active BAM working session need to be appended accordingly.

4.3.1.2 Displaying basic bridge attributes on the map

[Tech. Req. 3] Hovering with a mouse pointer over bridges on the GIS map should display a hover box comprising relevant information concerning the currently active BAM session. The scope/type of information in hover boxes will be specified together with PESR and should be as much as possible compatible with an existing similar feature in RAMS.

4.3.1.3 Data filtering

[Tech. Req. 4] Advanced data filtering for overview/reporting purposes needs to work for an arbitrary number of bridge attributes and related values. The output of advanced filtering is a table, and the related bridges are highlighted on a GIS map. It must also work with saved groups of bridges, which contain objects obtained via selection and/or advanced filtering, to facilitate work with certain bridge types, bridges on different roads, etc. This option should be as much as possible compatible with the existing similar features in RAMS.

4.3.1.4 Data visualization

[Tech. Req. 5] Within BAM, there should be predefined visualisations of statistics on the entire bridge stock or a group of bridges, in the form of pie charts/histograms, representing % of bridge types with a certain attribute, condition states of bridges, etc. The scope and contents of the visualisations are to be specified together with PESR.

4.3.1.5 Reporting

[Tech. Req. 6] Reporting in BAM should be pertinent to the working session and a group of bridges selected. Here, a user should choose predefined templates in .xlsx/.docx format to make intended outputs of tables, text, graphs, and the .pdf template format, which can also include images (e.g. from an inspection report), snapshots of a GIS map showing selected assets, etc. The scope and contents of the templates are to be specified together with PESR.

4.3.2 Data types

[Tech. Req. 7] The data used in the BAM segments can be distinguished as Catalogues & Code lists, Input data, Configuration data and Derived data. The input data and catalogues are envisioned to be stored within the RAMS database. Also, the default values of configuration data and part of the Derived data (see optimisation procedure in the planning segment within Section 4.3.3) are to be stored in the RAMS database. The data uploaded in BAM from the RAMS database needs to meet the quality requirements (i.e. accuracy, completeness, consistency, timeliness, validity, and uniqueness). The user-modified configuration data and resulting derived data are pertinent to a BAM working session (visualisation and reporting).

4.3.2.1 Catalogue data & Code lists

[Tech. Req. 8] The catalogue data and Code lists predefine entries for RAMS database object attributes. This information is considered to be static data. The examples are listed below:

Code lists

- Measurement units (e.g. m, km, m^2, pcs, ^{o}C)
- Currency (e.g. MKD, EUR)
- …

Catalogues:

- Materials (e.g. concrete, steel, wood, composite)
- Type of the bridge structural system (e.g. simple span, frame, suspension)
- Bridge element types
    - Foundations (e.g. caisson, spread)
    - Bearings (e.g. roller, Teflon, rocker)
    - …
- Maintenance measure types (local maintenance, repair, repair with strengthening and replacement/change)
- and other

The given list is not exhaustive. The contents of catalogue data need to be in line with the adopted methodology for bridge management (inventory, inspection, maintenance planning) and approved by PESR. This information will be stored in the RAMS database.

4.3.2.2 Input data

[Tech. Req. 9] These data are retrieved from bridge documentation, bridge inspection(s) and performed maintenance activities. A BAM user can only read the input data depending on his/her access rights. The input data mainly consists of numbers and letters but can also be images in .jpg, .bmp, .tiff and similar formats, and/or standard document file formats, like .docx, .xlsx, .pdf, .txt. This data relates to the following BAM segments:

- Inventory
- Inspection
- Maintenance history

The condition score for a whole bridge, which is derived based on the inspection records for bridge elements and an adopted condition rating methodology (e.g. a weighted sum of condition scores of bridge elements), should also be regarded as input data, i.e. stored in the RAMS database.

Detailed structure of availible input data is presented in Attachment 1 - Bridge Management System Data Model.

4.3.2.3 Configuration data

[Tech. Req. 10] This data is used as an input in calculations performed within the BAM segment: Planning of maintenance measures and budgetary requirements. The default values for configuration data are stored in the RAMS database and are uploaded in BAM for each working session. The configuration data comprises information on maintenance measures, deterioration models for bridge elements and calculation parameters.

The maintenance measures are defined for each bridge component, i.e., group of elements (supporting structure, superstructure, equipment, roadway) or a whole bridge:

- type of standardised measures: local maintenance, repair, repair with strengthening and replacement/change, for a component level, and replacement measure for a structure level
- condition state of bridge elements at which measures are applied,
- the unit cost of replacement/change measure (e.g. EUR/m2)
- scaling factors for unit costs of standardised measures with respect to the replacement measure
- effectiveness of a measure on the condition of a bridge element

An example of a set of information for maintenance measures is given in Figure 4~~Figure 4~~.

		CS after a measure					
Measure	**initial CS**	1	2	3	4	5	**Costs /m^2**
Rehabilitation	3	0,6	0,4	0	0	0	1300
Rehabilitation	4	0,6	0,4	0	0	0	1300
Rehabilitation	5	0,6	0,4	0	0	0	1300
Replacement	3	1	0	0	0	0	5000
Replacement	4	1	0	0	0	0	5000
Replacement	5	1	0	0	0	0	5000
Repair	3	0,2	0,8	0	0	0	400

Figure 4: The adopted parameters for effectiveness and costs of maintenance measures

In the example, three maintenance measures are given: rehabilitation, replacement and repair. Numbers in Figure 4~~Figure 4~~, which are delineated with the red, dashed line rectangle, represent probabilities that a bridge element will be in CS 1 or 2, following a specific measure. For example, suppose a rehabilitation measure is performed for the bridge element, which has initial CS=4 (see the related row 2 of the table in Figure 4). In that case, there is a 60% chance that the measure will be most effective and improve CS to 1, and a 40% chance that it will be less effective, i.e. improve CS to 2. The values in Figure 4~~Figure 4~~ are subject to a change in BAM, by the user(s) with a specific role(s), and the related changes are pertinent to the evaluations and output within an active BAM session.

The stochastic deterioration model for elements of a bridge is adopted. Several models should be defined in the form of a matrix (Markov transition matrix), which defines transitional probabilities, i.e. probabilities of a change in condition state of an element. In general, the deterioration models are pertinent to the type of element and material thereof. But some deterioration models can be defined just for a specific element (e.g. bearings) or a material (e.g. concrete, steel). An example of a Markov transition matrix is given in Figure 5~~Figure 5~~. The ordinal scale of condition states (CS) is adopted from 1 to 5 (1-no damage; 5-emergency intervention required).

CS transition matrix for concrete		**Condition state**				
		1	**2**	**3**	**4**	**5**
Condition state	**1**	0,50135	0,49865			
	2		0,82708	0,17292		
	3			0,75005	0,24995	
	4				0,78057	0,21943

Figure 5: The adopted Markov chain transition matrix for deterioration of RC bridge elements

The matrix in Figure 5 represents probabilities that a bridge element with a particular CS remains in the same CS or worsens after a 5-year inspection interval (blue and red arrows, respectively). In this particular case, there is approx. 25% chance that CS will worsen, i.e. change from 3 to 4, but 75% chance that it will remain in the same CS. It should be noted that when applying Markov chains in the prediction of deterioration, the bridges cannot "jump" two or more CS in the adopted interval (here 5 years). Furthermore, only users with specific roles should be allowed to adapt the default values in the Markov transition matrices. The adaptation of transition probabilities should occur from time to time by statistical analysis of condition data.

The user with a specific role can append default calculation parameters directly in BAM. These parameters impact the results of calculations and their visualisation/output (e.g. a simulation interval affects scaling of graphs). These parameters are:

- simulation interval (in years),
- annual budget,
- target condition state of bridges (to be reached at the end of adopted simulation interval),
- discount rate, and
- various heuristics (e.g. % of bridges in the worst condition allowed at any time instance).

4.3.2.4 The Derived data

[Tech. Req. 11] This data is transient and pertinent only to an active BAM session, within segment Planning of maintenance measures and budgetary requirements. The derived data comprises:

- the outputs of an optimisation procedure, which is based on user-defined configuration data and relevant input data,

- the results of simulation of predefined maintenance strategies on the bridge stock or a selected group of bridges.

The derived data can be visualised within a working session via tables/graphs and can be exported in a predefined template file format (e.g., .xlsx).

It should be noted that the outputs of an optimisation procedure for the default values of maintenance measures, calculation parameters and deterioration models is regarded as default configuration data, i.e., stored in a RAMS database.

4.3.3 Working with BAM segments

4.3.3.1 Inventory

[Tech. Req. 12] In this BAM segment, it necessary to enable the overview of bridge inventory data, which is stored in a RAMS database. This data comprises basic information on bridge geometry, type, location, material and related documentation, and it is regarded as static data. For a selected bridge, its inventory data should be visualised in the BAM interface via tab and/or collapsible menus, delineated into specific groups:

- Identification data (numeric/char type)

  bridge ID, type of structure, name, crossing type, crossing name, urban area name, road number, etc.

- Technical data (numeric/char type)

  structural system, materials, total length, skewness, perpendicular length, number of spans, length of spans, pavement width, width of sidewalks, number of lanes, number of piers, height of abutments/piers, clearance, bearings, expansion joints, etc.

- Location data (numeric/char type)

  road section number, start-end mileage, primary location, coordinates, etc.

- Other data (numeric/char type)

  year of construction, year of maintenance/ reconstruction, average daily traffic, length of a detour, etc.

- Project documentation (images, files)

The data given in the list is not exhaustive, and it is pertinent to the available information in the RAMS database. All related data types/attributes are to be adopted as in the RAMS database.

4.3.3.2 Inspection

[Tech. Req. 13] In this BAM segment, for a selected bridge, it is necessary to present the information from past inspections. The regular inspections are to be done every 5 years, and the related history (i.e. records) for each bridge is stored in the RAMS database. Inspection data within BAM should be organised in tab-menu and/or collapsible menus/lists, delineating the following:

- Basic bridge inspection data (numeric/char type):

  bridge ID, inspection date, weather, temperature, inspector name

- Bridge Condition data on the element level (numeric/char type):

  bridge component, bridge element, element material, element location, damage index of element, important damages, photos, suggested measures

- Bridge Condition data on a structure level (numeric/char type):

damage index of the whole bridge, description of current condition state, Description of changes from the last inspection, suggested measures

The data given in the list is not exhaustive and it is pertinent to the available information in the RAMS database. All related data types/attributes are to be adopted as in the RAMS database. There should be a possibility to review, via a simple graph, how the condition score (y-axis) for an element or a structure change over time (x- axis of the graph), for data in inspection records.

4.3.3.3 Maintenance history

[Tech. Req. 14] In this BAM segment, the records on performed maintenance measures per bridge can be viewed and analysed. For each record, which is stored in a RAMS database, the following (numeric/char) data is presented within BAM:

- measure type,
- measure description,
- duration of measure application (i.e., date applied from-to),
- name of maintenance contractor,
- measure cost,
- treated bridge elements (or a whole bridge, depending on the type of an applied measure).

4.3.3.4 Planning of maintenance measures and budgetary requirements

[Tech. Req. 15] This BAM segment is envisioned to work with configuration data and further perform the simulations of maintenance measures on the bridge stock or a selected group of bridges.

The predefined transitional Markov matrices can be viewed here, and only a user with a specific role can make changes to the default values. Further, for a chosen bridge component, a user can view but also append/add the data on maintenance measures (see Configuration data). Here, several maintenance measures can be defined. One default measure is the "minimum," i.e. the one which implies a replacement measure when the related condition score for a bridge or an element reaches the worst value. It should be possible to add other measures as default, which is to be specified in the agreement with PESR.

An "optimum" maintenance measure is estimated using a simplex algorithm for configuration data in a working session. This result is used further in simulations of maintenance strategies on a bridge stock or a group of selected bridges. Here, the initial condition state of bridges and their elements is taken from the latest inspection. It should be possible to perform simulations for two cases:

- Work program based on budget limitations
- Financial needs to achieve target condition state (can be probabilistic)

In these simulations, the heuristics calculation parameters are either not visible or cannot be changed unless a user has specific permission to do this.

For the first case, estimation of the working program is based on budget limitations and other calculation parameters: simulation interval (years), annual budget and discount rate. The output of the simulation in the first case is a set of graphs which display temporal changes of the condition state of bridges in the network, for both "minimum" and "optimum" maintenance measure. Also, related annual budgetary requirements are represented accordingly with graphs (e.g. showing cumulative expenditures).

In the second simulation case, a simulation is performed to estimate required annual financial needs to reach the goal predefined with calculation parameters: target condition state of bridges in the network, specified interval and the discount rate. The simulation output is a graph of temporal financial needs for both "minimum" and "optimum" maintenance strategy.

Relevant results of the optimisation and simulations, with related input data on bridges and configuration data, are to be exported in a predefined .xlsx template file as tables and graphs.

4.4 Related Information Technology Issues and Initiatives

4.4.1 User Management

[Tech. Req. 16] To work with certain BAM segments, a PESR user need to have an authorisation. The user roles (e.g., administrator, program manager, inspector, maintenance planner) and the scope of related permissions are going to be specified together with PESR. It should be possible that several users can work with the same BAM segment at the same time.

All access to the BAM features will be subject to authentication and authorization for the users logging-in. The user management module will need to cover all components of the BAM system. The user management system must be connected with PESR Active Directory system of users to provide a single sign-on.

The following features are expected for user management:

- *User registration*
- *Defining of user groups*
- *Assigning rights to user groups which will control the access to certain features of the application and attributes of the data items managed by BAM*
- *Data Level Security: The BAM should permit security setup so that user may have different levels of access for different types of data.*
- *Function Level Security: The RAMS should permit security setup so that different users may have access to different application functions.*

Logging of user activities must be done in BAM (user registration and logout, user activities). For any data entry, the user and time entering data must be recorded.

4.4.2 Data Repository

[Tech. Req. 17] The BAM is required to be a web-based software (IIS hosted), stand-alone module, which is to be compatible with the existing RAMS solution. Bridge data and other parameters will be stored in the RAMS database (MS SQL Server with Spatial option). All result of calculation should be stored in MS SQL Server database, also. The compatibility with RAMS is crucial in the database segment as the RAMS database serves as data storage for all BAM segments.

4.4.3 Use of predefined bridge data model

[Tech. Req. 18] BAM must used bridge data available in RAMS database. Draft bridge data model used to store bridge data in the RAMS database (and also used by BCS SW) is given in Appendix 1. The data model should be reviewed in the initial phase of BAM design and aligned with the Client's needs. At the start of the Project, the selected Consultant will get a data model in Enterprise Architect form with all detailed information.

4.4.4 Use of existing WEB GIS

[Tech. Req. 19] BAM must enable visualization of bridge data on the maps. For that integration with WEB GIS that is part of RAMS is planned. PERS will run in parallel the RAMS upgrade project for bridge data management and presentation where final specifications of upgrades will be prepared after the specifications for BAM will be confirmed, so that RAMS upgrades should enable requested functionalities for BAM data visualization. The usage of the current WEB GIS in the BAM is not compulsory, but if the currently existing WEB GIS is not used the BAM Consultant shall provide another equivalent GIS system.

4.4.5 IT infrastructure for BAM installation

[Tech. Req. 20] BAM must be installed and integrated into the new upgraded RAMS IT infrastructure – virtual server environment, WIN servers, MS SQL Server for database. Test and production environment must be set.

BAM should not have any limitation on the number of users. Any licenses needed for BAM operation in production and test environment must be included in project costs.

4.4.6 General Technical Requirements

[Tech. Req. 21]

- Language Support: The BAM application must provide support for the English and Macedonian language. UTF-8-character set must be used for data storing. This language support, at a minimum, shall include: All Screen Labels, Menu Items, and Reports shall be configurable to the Client conventions in English and Macedonian.
- DATES: All information technologies MUST properly display, calculate, and transmit date data, including, but not restricted to 21st-Century date data.

4.5 Service Specifications (Development and Implementation requirements)

[Tech. Req. 22] The BAM SW development and implementation process should be the next:

- Detailed BAM SW development and implementation plan (project plan) must be prepared as part of the Inception report at the start of the Project.
- System analysis and design: in the starting phase, all requirements should be verified with the Client, and detailed functional specification must be prepared for all required functionalities, including any changes to the data model. Also, a draft design (mockup) of the user interface (for all application screens) for all use cases must be furnished. Confirmation from the Client will be done before the SW development phase.
- SW development: Should be divided into at least 2 phases; presentation of draft BAM version should be done 4 months from the start of the project for Client confirmation; the final version for testing should be delivered after 6 months. After testing, a short period is envisaged to eliminate any mistakes and/or implement requested changes.
- Testing: It needs to include internal developer testing and user acceptance testing. Before the user testing, testing protocols should be prepared and delivered. Testing must include all BAM functionalities and integration with RAMS.
- User manual and technical documentation must be prepared and delivered in English. The user manual must also be delivered in Macedonian.
- Client user training must be done before the user testing. The training must be done in Macedonian.
- Client system administrators training must be done for BAM management.
- The source code of BAM SW must be delivered to the Client at the end of the project.

4.6 Project management and deliverables

[Tech. Req. 23] The BAM Consultant must establish an appropriate project organisation to manage the development of the Project. In the first month of the Project (M1), the BAM Consultant must prepare a detailed project work plan, which must be included in the inception report (IR). This report has to be presented, coordinated and approved with and by the Client. In IR, the work plan for all activities within the project needs to be considered. BAM Consultant needs to present project organisation, project management approaches, staff, etc. In IR, a detailed schedule for all activities related to BAM development and implementation phases need to be prepared. Chapters in the Project Plan shall address the following subject:

(a) Project Organization and Management Plan;
(b) Development Plan
(c) Delivery and Installation Plan
(d) Training Plan
(e) Pre-commissioning and Operational Acceptance Testing Plan
(f) Warranty Service Plan (during warranty period)

Attention must also be put towards risk assessment of the project and mitigation measures that will be applied to reduce their impact. Special attention needs to be put into works related to pandemic issues.

The BAM Consultant must also set up a project portal (e.g. SharePoint), which will be used to exchange information with the Client and will provide access to the entire project documentation.

Coordination meetings between the Client and the BAM Consultant to review and coordinate the Project will be held every month. Before the meeting, the BAM Consultant must also submit an overview report on BAM SW development progress. A short report based on the work plan from the inception report should present work done, alignment with a time plan, any deviation in development and a short plan of activities for the next month. Monthly reports delivered to the Client should be discussed at regular monthly project meetings. After BDC SW development and implementation, a final report on BAM SW development and implementation must be delivered. The following deliverables are planned:

- Inception phase, finishing with inception report, including detailed project plan (D1)

  The Consultant shall submit an inception report within the first month of his assignment detailing his initial actions, identifying priorities within his scope of work and proposing a work plan for the remainder of his engagement listing the deliverables expected and timing thereof.

  The draft Inception report shall be submitted to the Purchaser for approval one (1) month after start of the assignment. The final Inception report shall be submitted 5 days after receipt of the Purchaser comments.

- System analysis and design specifications (D2)
- BAM SW Development (D3):
  - phase 1: Development of initial draf version, finished with demonstration of the draft BAM version (D3.1)
  - phase 2: Development of final version, finished with presentation of final BAM version (D3.2)
  - phase 3: BAM Updates based on testing findings (D3.3)
- BAM SW testing (D4)
  - Testing plan (D4.1)
  - Testing protocols (D4.2)

- User testing report (D4.3)
- Acceptance testing report (D4.4)

– BAM SW implementation (D5)
  - BAM SW installed in test environment (D5.1)
  - BAM SW installed in production environment (D5.2)
  - BAM system technical documentation (D5.3)
  - User manual (D5.4)
  - User and system administrators' training report (D5.5)

    The Consultant shall prepare a detailed training completion report, including details of the training programs and list of participants. The activity shall be completed within 8 (eight) months of the assignment.

  - BAM SW Source code delivery (D5.6)

– Project management (D6)
  - Monthly progress reports (D6.1-X) (short, up to 3 pages), summarizing:
    - (i) results accomplished during the prior period;
    - (ii) cumulative deviations to date from schedule of progress milestones as specified in the Agreed Project Plan;
    - (iii) corrective actions to be taken to return to planned schedule of progress; proposed revisions to planned schedule;
    - (iv) other issues and outstanding problems; proposed actions to be taken;
    - (v) resources that the Consultant expects to be provided by the Purchaser and/or actions to be taken by the Purchaser in the next reporting period;
    - (vi) other issues or potential problems the Consultant foresees that could impact on project progress and/or effectiveness.
  - Final project report (D6.2)

    The Consultant will submit a final report to the PESR upon completion of the assignment. The Final Report will be submitted in draft form 5 days before completion of the assignment and in final form within 20 days after receipt of the Purchaser's comments on the draft report. The Final Report is a subject of Purchaser’s approval.

4.7 Technical Support

[Tech. Req. 24]

- Warranty Service: coverage period is 12 months; response time and problem-resolution performance standards in seven days; modes of service is on-site or internet based – VPN access to the BAM will be enabled.
- User support / hot line: N/A
- Technical Assistance: N/A
- Post-warranty maintenance services: N/A

4.8 Documentation Requirements

4.8.1 END-User documents:

[Tech. Req. 25] The following deliverables are planned:

- Inception report

- System analysis and design specifications
- Testing plan and testing protocols
- User manual and technical documentation
- Training report
- Testing reports (user testing, acceptance testing)
- Monthly progress reports
- Final project report

All documentation should be prepared in English; User manual for BAM should be prepared in Macedonian, also. All documents must be delivered electronically in standard form (original in Word, Excell, etc.; signed versions in PDF format) and signed documents in paper form in 2 copies. All delivered documents should be revied by PESR and response to BAM Consultant should be done in 7 days otherwise documents are considered as accepted and confirmed.

4.8.2 Technical Documents:

[Tech. Req. 26] The Consultant shall deliver source code with detailed full explanations on all the code implementing the BAM system, including database scripts, deployment scripts and other documentation developed during the implementation of the system.

4.9 Testing and Quality Assurance Requirements

4.9.1 Pre-commissioning Tests

[Tech. Req. 27]

- In addition to the Supplier's standard check-out and set-up tests, the Consultant (with the assistance of the Purchaser) must perform the following tests on the System and its Subsystems before Installation will be deemed to have occurred and the Purchaser will issue the Installation Certificate(s) (pursuant to GCC Clause 26 and related SCC clauses).
- *Before the development of BAM will start, the PESR and Consultant will agree upon implementing an agile development methodology, if needed, and defining roles and responsibilities of the team members involved in the project, so that an adaptive and incremental approach will be followed. Development methodology should be included in project time plan and Inception report.*
- *The Entire System: Pre-commissioning Tests for the entire System are: Demonstrate that each element of the BAM function properly based on tests to be performed by the PESR. Certificate of Approval will be given by PESR.*

4.9.2 Operational Acceptance Tests

[Tech. Req. 28]

- Pursuant to GCC Clause 27 and related SCC clauses, the Purchaser (with the assistance of the Supplier) will perform the following tests on the System and its Subsystems following Installation to determine whether the System and the Subsystems meet all the requirements mandated for Operational Acceptance.

- The Entire System:

For each deliverable, there shall be three stages of the software testing and acceptance:

- Supplier's internal testing (FAT) according to approved test plan.
- End User Acceptance Test (UAT).

The Consultant shall deliver a test plan compliant to IEEE 829-2008 guidelines and the principles of agile method. The test plan shall contain:

- Test strategy
- Time schedule for testing and acceptance
- A list of test scenarios
- Test cases
- Datasets to be used for the tests

During the development stage of an iteration, the Consultant shall prepare detailed test case specifications for all delivered functionality and test scenarios in the test plan. The test cases shall be approved by PESR. PESR shall have the right to request modifications to the test case documentation.

All modifications to the test cases and the outcome of the actual tests performed according to the cases will be logged while tracking the contributions from each user during the whole process from creation to the closing of a test case.

4.10 Assistance to be provided by the Client

The PESR will ensure that the Consultant has access to all relevant information and data in the PESR that is deemed necessary to the performance of the services. This includes all bridge inventory and condition data, BMS data model and access to PESR IT server infrastructure, including RAMS database.

The BAM Consultant shall work directly with the PESR IT group, PESR RAMS Unit and BMS Consultant. Through the IT group and RAMS Unit, PESR shall make available to the Consultant existing information relating to the assignment, in particular:

- existing IT infrastructure and virtual environment,
- results of the BCS as they become available, for testing & demonstration purposes,
- RAMS SW.

For integration with RAMS SW, PESR will ensure coordination with the Contractor for RAMS SW upgrades provider and coordination with the Contractor for BMS HW and system SW provider to establish a BAM virtual server environment. For bridge data resulting from the BCS project, PESR will ensure coordination with the Contractor for the BCS project.

The Client will provide:

- a meeting room at the PESR premises;
- the venues for the demonstration and training.

5 IMPLEMENTATION SCHEDULE

This section indicates key timelines that the Supplier/Consultant should be aware of in preparing the proposal and designing the project.

The duration of the BAM project is eight (8) months from the start of the project - contract signature. At the moment, this assignment is estimated to commence in April 2022 and end in December 2022.

No.	Tasks	Due Date (weeks from the start of project)
	Project start	**0**
1	Inception Report (D1)	4
2	Verification of ToR requests - technical and functional requirements (included in D2)	4
3	System analysis and design (D2)	8
4	BAM Development – phase 1: Demonstration of the draft BAM version (D3.1)	16
5	Interim reports (D6.1-X)	8,12,16
	MILESTONE 1	**16**
6	Delivery of testing plan (D4.1) and testing protocols (D4.2)	20
7	BAM Development – phase 2: Delivery of final BAM version (D3.2)	24
8	BAM SW installation in test environment (D5.1)	25
9	User documentation (draft D5.4) and user trainings (PESR BMS Unit) (D5.5)	26
9	User testing (D4.3)	28
10	BAM Development – phase 3: BAM Updated based on testing findings (D3.3)	30
11	BAM SW installation in production environment (D5.2)	31
12	Delivery of technical documentation for BAM and PESR system administrators training (D5.3)	31
13	Final user documentation (D5.4)	32
14	User acceptance testing (D4.4)	32
	BAM SW Source code (D5.6)	32
15	Interim reports (D6.1-X)	20, 24, 28
16	Final Report (D6.2) **MILESTONE 2 – End of the project**	32 **32**

Payments in the project will be dane according to the finished Milestones from the above Implementation Schedule.

6 EXPERIENCE AND QUALIFICATIONS

Consultant experiences and qualifications

The Consultant shall be a firm or group of firms with following qualifications:

- evidence of registration for performance of activities that are relevant for this assignment in the past five (5) years.
- proven experience in implementation of similar assignment in the Western Balkans regions and/or countries in the EU shall be considered an advantage.
- evidence of successfully completed at least 2 (two) software projects related to assisting road authorities on a state level in improving their Transportation Infrastructure Management practice, which relate to engineering structures such are bridges, tunnels, earthworks and retaining walls, each at least of the value of the bid, in the period of last 5 (five) years. In addition, it is required for each of these projects to involve:
    - web architecture with spatial and relational databases and standard GIS services (WMS, WFS) and
    - development/maintenance of a management system or its module(s) (database, analytical module(s) for maintenance planning)

The credibility of mentioned experience shall be presented in a list of at least two (2) similar project references within last five (5) years with description of services provided (including information on contract value, contracting entity/client, project location/country, duration, assignment budget, percentage carried out by consultant in case of association of firms or subcontracting and main activities) and accompanied by certificates of orderly fulfilment of the contracts verified by other party from such contracts.

Financial Capacity

The Consultant shall have the organizational (staff) and financial capacity (a minimum annual revenue i.e. turnover of at least 500 000 Euro for each of the last three (3) years i.e. 2019, 2019 and 2020) to perform this assignment as well as available appropriate skills among staff.

Personnel capability

The Consultant shall provide a team of qualified experts with proven technical and managerial competence and experience. The Consultant is free to propose the composition of its team, but it is expected that the key staff as identified below would be the key team members. When proposing the team members, the Consultant should make sure that the proposed staff is available and aware of the intensity of the work on the software development and training of Client users.

The working languages of the Project are English and Macedonian. Day-to-day communication with the Client's employees will be held either in English or Macedonian, but the training must be in the Macedonian language.

For the purposes of establishing a Cunsultant’s qualifications for the Personnel capability any key expert employed at the Consultant, JV or Subcontractor will contribute to the Consultant’s qualifications.

The Consultant shall provide adequate staff in terms of expertise and time allocation, as well as the equipment (as relevant) needed to complete the activities required under the scope of work and to finally achieve the objectives of the project in terms of time, costs and quality.

It is expected that the core team shall comprise of following four (4) experts:

a) Project manager/Team leader

Field of expertise: Expert in project management in software development

Required education: University degree (MSc) in any of the technical fields: computer science, electrical engineering, geoinformatics or software engineering

Conditions:

- At least 10 (ten) years of professional experience as a project manager in development of software for management of civil infrastructure and at least one IT project for bridge management.
- Experience in leading teams of similar (or greater) size, working on similar assignment complexity and with a wide range of stakeholders, including the government sector. Experience in preparation and delivery of plans, reports, presentations and other project documentation.
- Software developer with minimum 10 (ten) years of overall professional experience
- Experience in the region is an advantage but not compulsory.
- Fluency in English.

b) IT Development Lead

Field of expertise: Expert in software development

Required education: University degree (MSc) in any of the technical fields: computer science, electrical engineering, geoinformatics or software engineering

Conditions:

- Software developer with minimum 10 (ten) years of professional experience
- Experience in design/development of a geospatial information system, including relational databases with spatial data; must have at least 2 (two) related software implementations of BMS, including a GIS system where road/bridge data are presented.
- Experience in the region is an advantage but not compulsory.
- Fluency in English.

c) Senior Bridge Specialist

Field of expertise: Expert in bridge inspections/design and bridge management

Required education: MSc or PhD in Civil engineering

Conditions:

- Civil Engineer with a minimum 10 (ten) years of the professional experience.
- Experience in bridge design/assessment projects.
- Experience in bridge management projects that relate to updating of the existing methodologies for bridge condition rating and/or application of the state-of-the art methodologies for bridge assessment based on inspection data and related planning of maintenance measures.
- Experience in the region is an advantage but not compulsory.
- Fluency in English.

d) Bridge management training specialist

Field of expertise: Expert in inspections and assessment of bridges

Required education: MSc or PhD in Civil engineering

Conditions:

- Civil Engineer with a minimum 5 (five) years of professional experience.
- Experience in bridge inspection and assessment. Experience in preparation and delivery of plans, reports, presentations and other project documentation.
- Experience in the region is an advantage but not compulsory.
- Fluency in English.
- Fluency in Macedonian.

7 ATTACHMENTS

- Attachment 1 _Bridge Management System Data Model