Real-Time Bridge Monitoring
Requirements Specification

Version 1.3

Revision History

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1. Introduction

1.1 Purpose of this document

The purpose of this document is to state all gathered requirements and to explain system in more details. This document will be used to proof that development team and customer have the same view of what the system is supposed to do and how. The document will also be helpful to the developing team in the design and implementation phase in order to implement the desired functional and non-functional requirements. The requirements that are specified in this document are written in a way that makes them testable, so they will be further used in the testing phase to ensure that all the requirements have been met. Finally, the document will also be object of supervision from the supervisor of the project.

1.2 Scope

The document is split into five major parts: Description of the system, Requirements description, Requirements definition, Future development and Appendix.

In the part "Description of the system", at the beginning brief recall of the background of the existing system is given. After that the functions of each actor from use case diagram is explained. The constraints and assumptions are also covered in this part.

The second part of this document is "Requirement description". All requirements, regarding Sensor data presentation, engineer functionality, administrator functionality, external user functionality and calculations are described in details in this section. Also, future development requirements are stated in this section, although they will not be considered in the further development phases of this project, for now.

The purpose of the third section, "Requirement definition", is to give a priority to each requirement described in Requirement description section. This is done by putting all the requirements in a table along with their priorities.

At the end, table of parameters used in document is given, this way it is easier to understand the document and meaning of the requirements.

1.3 Definitions and acronyms

1.3.1 Definitions

Keyword	Definitions
Labview Encode	Number of seconds that have elapsed since 1st January 1904, on the Greenwich meridian
Debris	Obstacle stuck on the pillar 30 of the bridge

1.3.2 Acronyms and abbreviations

Acronym or abbreviation	Definitions
ANE1	Mean wind speed in 10 minutes
ANE2	Maximum wind speed in 10 minutes
ANE3	Mean wind direction in 10 minutes
ANE4	Direction of the maximum wind speed in 10 minutes
IDRO1	Mean water depth/water height in 10 minutes
IDRO2	Variance of the sample in 10 minutes
Data of type ①	Parsed sonar height value, with format Rxx.xx
Data of type ②	Parsed sonar height value, with format Rxx.xxE
Data of type ③	Parsed sonar height value, with format xx.xx
Data of type ④	Parsed sonar height value, with format R99.99E
Data of type ⑤	Parsed sonar height value, E1 or missing data
SONAR1	Mean value of the height of the bottom (only with data of type ① and ②), in 10 minutes
SONAR2	Variance of the sample (only with data of type ① and ②)
SONAR3	Percentage of data of type "① + ②" used compared to the 600 elements of the sample data, in 10 minutes
SONAR4	Percentage of data of type "③" there are in the sample data, in 10 minutes
SONAR5	Percentage of data of type "④" there are in the sample data, in 10 minutes
SONAR6	Percentage of data of type "⑤" there are in the sample data, in 10 minutes
SONAR7	Percentage of data of type "②" there are, considering as sample the "① + ②" set of data (so not all the 600 data), in 10 minutes
S_{Vplank}	The push of the wind on the planking
S_{Vtraf}	The push of wind on the traffic.
$V_{EFFwind}$	Effective value of the wind speed
C_{Dwi}	Drag planking
ρ	Air density
A_{PLANK}	Planking area
$S_V(A1\,traf)$	Traffic combination A1
$S_V(A2\,traf)$	Traffic combination A2
$S_V(A3\,traf)$	Traffic combination A3
h_{water}	IDRO1
Q	Flow rate value
V_{water}	Relative value of water speed
$h_{MAXwater}$	Maximum water height. If $h_{water} > h_{MAXwater}$, the river has overflowed.
$PP_{structure}$	Portion of palking

1.4 References

It is necessary to read through the following documentation in order to fully understand the system that is being developed.

[1] Project plan and description document of the project Real-Time Bridge Monitoring
[2] Real-Time Assessment of Bridge Vulnerability, Gianluca C., Francesco B. et al.
[3] Sistema di monitoraggio di Borgoforte, Francesco B., Alfredo C, Gianluca C. et al.

2. Description of the system

2.1 Background

The bridge we are monitoring, named "Borgoforte", is situated on the Po river. On the bridge some of the piles are enforced but there is one pile which is week and needs to be monitored. On this pile there is a number of sensors measuring physical force that different sources make on bridge. Moreover, two cameras are providing pictures from both sides of the bridge. All data from sensors and pictures from cameras are stored in files and sent to the server in packages each hour.

Our goal is to make a system for storing, calculating and presenting all relevant data of the bridge. We have to extract data from .txt files and store them to a database. After that calculations have to be done according to a large number of parameters which all influence the bridge status. The calculated level of danger of the bridge is also stored in the database. Finally, both current and history data along with pictures can be presented to the user.

2.2 User Characteristics

Four types of actors have been identified: the Administrator, the Human Controller, the Engineer and the External User. The way of interacting with the system depends on the type of the user. The users are presented in the following illustration.

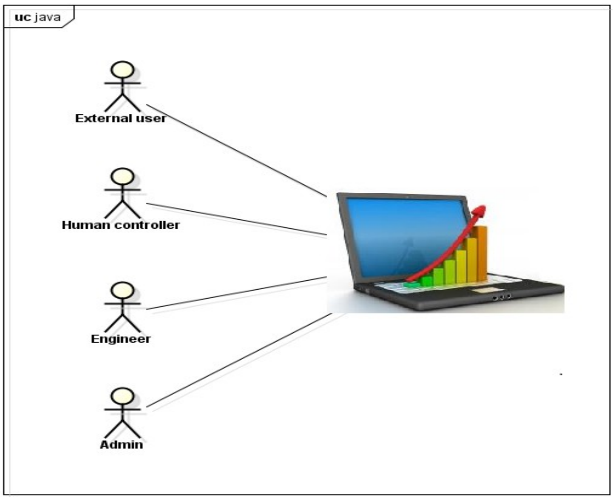

Illustration 1: Users of the system

The Administrator manages the users accounts, the human controller monitors the bridge current state and history, the Engineer is the one who has all knowledge about equations and is allowed to change the parameters, and the external user doesn't need to have any knowledge of the system since he is only allowed to see reduced set of current state of the bridge.

2.3 Product functions

2.3.1 Administrator functions

The Administrator can only manage the users and does not have authorization to change any system parameters. He can view all users, register a new user, edit users, delete a current user and log out. The administrator does not need to have knowledge about the calculations or how the system works at all.

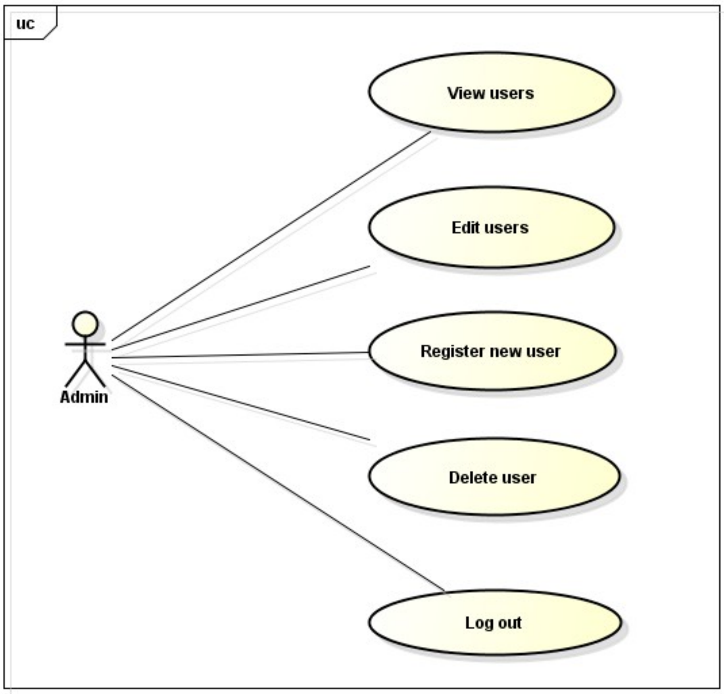

Illustration 2: Administrator functionalities

2.3.2 Human Controller functions

The purpose of the Human Controller is only to monitor the condition of the bridge view the historical data of the bridge. The human control can see the current status of the bridge and the historical status of the bridge. In the current state, the M-N domain is presented, with a graphical representation of each pylon and its position in this domain. This information includes also the safety factor and alarm state. The safety factor is a product of the calculations. The alarm state represents the level of current danger of bridge to collapse. It can be on or off. If the alarm is on, the human controller can decide if he wants to send an email to a person responsible for the danger state of the bridge. The Human Controller can log out and then interacts with the system as an external user.

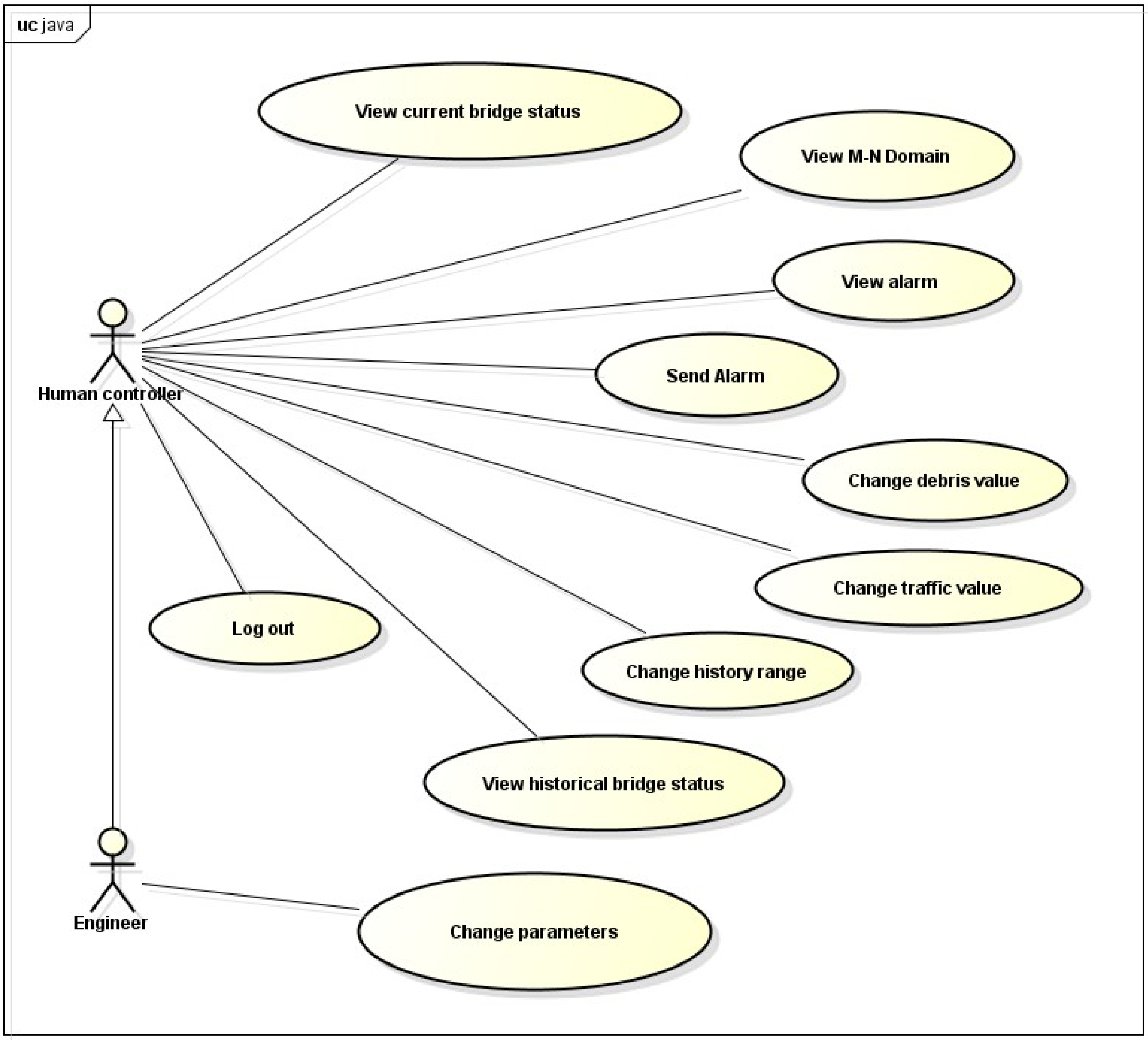

Illustration 3: Human Controller and Engineer functionalities

2.3.3 Engineer functions

The Engineer has the same functions as the Human Controller and an additional one. The Engineer can change all variable parameters that are taken into account while performing the calculations. Moreover, engineer can also log out and then interacts with the system as an external user.

2.3.4 External User functions

The External User doesn't need to have any knowledge of the calculations and historical data, since he is just a guest. The External User can see just basic information of the Bridge. This information is current status of the bridge. He can log in and then interacts with the system as a registered user.

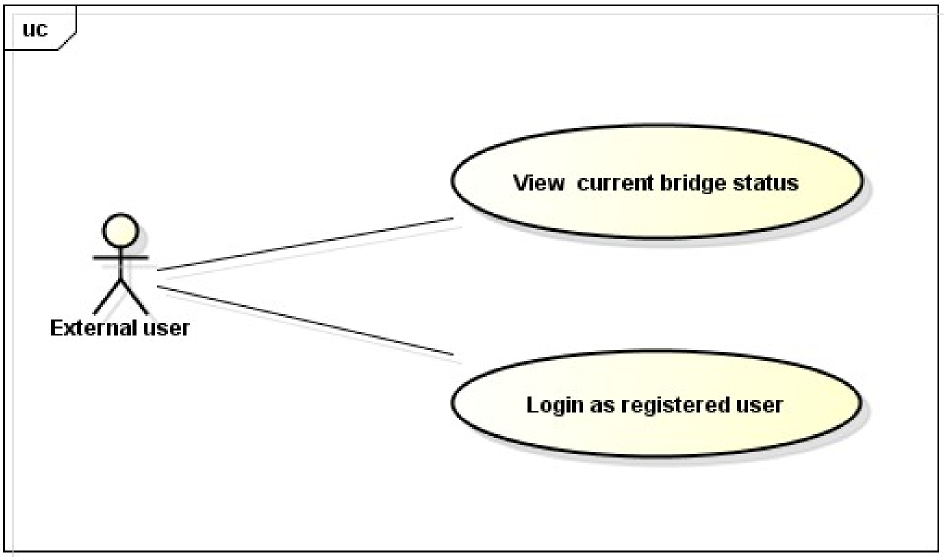

Illustration 4: External User functionalities

2.4 Use Cases

2.4.1 Register New User

Goal: To add a new registered user.
Participating Actors: Administrator
Related Use Cases: none
Precondition: The user must be logged in as an administrator
Main flow of events:

1. The user enters all the information of the new user
2. The user defines the permission level of the new user.
3. The user clicks on "Save" button.
4. The system checks all the entered information.
5. The system shows the message "Added new registered user".

Alternatives

5. a. The system shows the message "Incorrect entered information".
   b. Resume at 1.

2.4.2 Delete User

Goal: To delete a current registered user.
Participating Actors: Administrator

Related Use Cases: Register User
Precondition: The user must be logged in as an administrator
Main flow of events:

1. The admin. selects a user.
2. The admin. clicks on “Delete” button.
3. The system shows a confirmation window.
4. The admin. clicks on “yes”
5. The system shows the message “ xxx user is deleted” where “xxx” is the username of the user.

Alternatives

4. a. The admin. clicks on “no”.
   b. The system closes the confirmation window.
   c. Resume at 1.

2.4.3 Log out

Goal: To log out a registered user.
Participating Actors: Administrator, Human Controller, Engineer
Related Use Cases: Log In
Precondition: The user must be logged in as a registered user
Main flow of events:

1. The user clicks on “Log Out” button.
2. The system logs out the user.
3. The system redirects the user to the home page.

2.4.4 View Current Status

Goal: To let the user see the current status of the bridge.
Participating Actors: External User, Human Controller, Engineer
Related Use Cases: none
Precondition: None
Main flow of events:

1. The user clicks on “Current Status” button.
2. The system shows the information about the current status of the bridge.
3. The user views the information of the current status.

2.4.5 View Historical Status

Goal: To let the user see the historical status of the bridge.
Participating Actors: Human Controller, Engineer
Related Use Cases: Change history range
Precondition: The user must be logged in as a Human Controller or as an Engineer. The user must choose the period of time he wants to view the history for.
Main flow of events:

1. The user clicks on “Historical Status” button.
2. The system shows the page with information about the historical status of the bridge.
3. The system shows the historical status of the bridge according to the chosen historical period.
4. The user views the information of the historical status.

2.4.6 View Alarm

Goal: To let the user see the current status of alarm.
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as a Human Controller or as an Engineer
Main flow of events:

1. The system shows the alarm. It can be on or off.
2. The user views the alarm.

2.4.7 Change Debris Value

Goal: To let the user change the debris.
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as a Human Controller, Engineer
Main flow of events:

1. The user change the Debris Parameter by checking a check box.
2. The system updates the M-N domain or the historical graph representation, according to the Debris parameter.

2.4.8 Change Parameters

Goal: To let the user change parameters that are used for calculations.
Participating Actors: Engineer
Related Use Cases: none
Precondition: The user must be logged in as an Engineer
Main flow of events:

1. The user changes the variable parameters.
2. The user clicks on “Save” button.
3. The system shows a confirmation window.
4. The user clicks on “yes”.
5. The system shows the message “variable parameters are updated”.

Alternatives

4. a. The user clicks on “no”.
   b. The system closes the confirmation window.

2.4.9 Log in

Goal: To log in an external user.
Participating Actors: External User
Related Use Cases: Log Out
Precondition: The user must be logged out
Main flow of events:

1. The user enters the username and password.
2. The user clicks on “Log In” button.
3. The system logs in the user with his predefined permission level from the administrator.

2.4.10 Change Traffic Value

Goal: To let the user change the traffic.
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as a Human Controller, Engineer
Main flow of events:

1. The user change the Traffic Parameter by checking a check box.
2. The system updates the M-N domain or the historical graph representation, according to the Traffic parameter.

2.4.11 View Users

Goal: To view all the users that are registered in the system
Participating Actors: Administrator
Related Use Cases: none
Precondition: The user must be logged in as an Administrator
Main flow of events:

1. The system displays all users on the page.
2. The administrator views the users

2.4.12 Edit a User

Goal: To edit a user that is registered in the system
Participating Actors: Administrator
Related Use Cases: none
Precondition: The user must be logged in as an Administrator
Main flow of events:

1. The admin. selects a user.
2. The admin. clicks on “Edit” button.
3. The system allows the administrator to edit the information of the user.
4. The admin. clicks on “save”
5. The system shows the message “Are you sure you want to save the changes to the user xxx” where “xxx” is the username of the user.

Alternatives

4. a. The admin. clicks on “no”.
   b. The system closes the confirmation window.
   c. Resume at 1.

2.4.13 View M-N domain

Goal: To view the M-N domain and the position of the pylons in that domain.
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as the Human Controller or Engineer
Main flow of events:

1. The user chooses the value of the Debris and Traffic parameters
2. The system displays the M-N domain according to the chosen Debris and Traffic parameters.
3. The administrator views the M-N domain.

2.4.14 Send alarm

Goal: To send an alarm if the bridge is in danger.
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as the Human Controller or Engineer
Main flow of events:

1. The user clicks on the alarm button, to send an alarm to a responsible person.
2. The system displays a view so that the user can enter the mail of the person the email is intended to.
3. The user enters an email and clicks on 'send'.
4. The system adds information about the pylon that is in danger and sends the mail.

2.4.15 Change history range

Goal: To change the time range for historical data that will be displayed
Participating Actors: Human Controller, Engineer
Related Use Cases: none
Precondition: The user must be logged in as the Human Controller or Engineer
Main flow of events:

1. The user chooses the range of dates, or the specific day, or the specific month for the historical diagram.
2. The system displays the historical diagrams according to the input of the user.

2.5 Constraints

The main constraint of this project is that there is a lot of complex calculations which are hard to understand, since they are related to a specific domain. There is documentation which explains the requirements and calculations, which is only in Italian language so it translated.

2.6 Assumptions

The assumption for this system is that the sensors are working as expected and producing needed .txt files with analog values every one hour. These files are further parsed by the system. There are three kind of input files: analog****.txt, sonar*****.txt, picture****.jpg. Also, two images are received each hour: view of the bridge from Mantova side, view of the bridge from Modena side.

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3. Requirements Description

In this section, all the functional, non-functional and future requirements will be defined. They will be presented in tables which contain the ID of requirement, the requirement definition, the priority and the status of the requirement.

Each requirement will have a unique identification value that will also contain the information of what type of functional requirement it belongs to.

The definition of each requirement is defined in a way that makes the requirement suitable for testing. The definitions will be used as input for the testing phase.

The requirements in the tables are sorted by priority so that it can be made sure that the requirements with higher priority are more visible and fulfilled earlier in the development phase. The highest priority is 1, and lowest is 5. //**TODO prioritize the reqs in the tables**

The status of each requirement will be tracked. The status can be one of the following:

I = initial (this requirement has been identified at the beginning of the project),
D = dropped (this requirement has been deleted from the requirement definitions),
H = on hold (decision to be implemented or dropped will be made later),
A = additional (this requirement was introduced during the project course).
F = future requirement

3.1 Functional requirements

The functional requirements are divided into eight sections: External User Functionalities (EU), Human Controller Functionalities (HC), Engineer Functionalities (E), Administrator Functionalities (A), Parsing (P), Calculations (C), External Interfaces (EI) and Warning Messages (WM).

3.1.1 External User functionalities

The table below shows the requirements for the external user of the system.

Identity EU	Requirement Definition	Priority	Status
EU1	The external user should be able to see the stack image with each pylons, with also the flow direction.	3	I
EU2	The external user should be able to see the latest pictures of the both sides of the bridge.	1	I
EU3	The external user should be able to see the diagram showing the change of value of wind speed for the current day.	1	I
EU4	The external user should be able to see the diagram showing the change of value of wind direction for the current day.	1	I

EU5	The external user should be able to see the diagram showing the change of water level for the current day.	1	I
EU6	The external user should be able to see the diagram showing the change of depth of river bed for the current day.	1	I
EU7	The external user should be able to see the diagram showing the change of maximum wind speed for the current day.	1	I
EU8	The external user should be able to see the diagram showing the change of maximum direction value for the current day.	1	I
EU9	The external user should be able to see the current value of the flow rate.	1	I
EU10	The external user should be able to see the current value of the wind speed.	1	I
EU11	The external user should be able to see the current value of the water speed.	1	I
EU12	The external user should be able to see the current value of the Wind Direction.		I
EU13	The external user should be able to see the current value of the Water level.	1	I
EU14	The external user should be able to see the current value of the River Bed level.	1	I
EU15	The external user should be able to see a Google maps picture of the bridge with a wind rose picture.	3	I

3.1.2 Human controller functionalities

The table below shows the requirements for the human controller user of the system.

Identity HC	Requirement Definition	Priority	Status
HC1	The human controller should be able to log into the system with username and password.	4	I
HC2	The human controller should be able to see the stack image with each pylons, with also the flow direction.	2	I
HC3	The human controller should be able to see the latest pictures of the both sides of the bridge.	2	I
HC4	The human controller should be able to see the diagram showing the change of value of wind speed for the current day.	2	I
HC5	The human controller should be able to see the diagram showing the change of value of wind direction for the current day.	2	I
HC6	The human controller should be able to see the diagram showing the change of water level for the current day.	2	I
HC7	The human controller should be able to see the diagram showing the change of depth of river bed for the current day.	2	I
HC8	The human controller should be able to see the diagram showing the change of maximum wind speed for the current day.	2	I
HC9	The human controller should be able to see the diagram showing the change of maximum direction value for the current day.	2	I

Identity HC	Requirement Definition	Priority	Status
HC10	The human controller should be able to see the current value of the flow rate.	2	I
HC11	The human controller should be able to see the current value of the wind speed.	2	I
HC12	The human controller should be able to see the current value of the water speed.	2	I
HC13	The human controller should be able to see the current value of the Wind Direction.	2	I
HC14	The human controller should be able to see the current value of the Water level.	2	I
HC15	The human controller should be able to see the current value of the River Bed level.	2	I
HC16	The human controller should be able to see a Google maps picture of the bridge with a wind rose picture.	4	I
HC17	The human controller should be able to change the debris value. The debris value is a boolean.	2	I
HC18	The human controller should be able to change the traffic value. The traffic value is a boolean.	2	I
HC19	The human controller should be able to see the alarm button.	1	I
HC20	The human controller should be able to send an alarm by clicking on the 'Send Alarm' button.	3	I
HC21	The human controller should be able to see the M-N Domain graph with the location of each pylon in the domain.	1	I
HC22	The human controller should see the table for CS values for each pylon, their combination label, and values N, M, Tx, Ty, Mx and My.	1	I
HC23	The human controller should be able to see the history diagram showing wind speed during chosen period of time.	1	I
HC24	The human controller should be able to see the history diagram showing wind direction during chosen period of time.	1	I
HC25	The human controller should be able to see the history diagram showing maximum wind speed during chosen period of time.	1	I
HC26	The human controller should be able to see the history diagram showing maximum wind direction during chosen period of time.	1	I
HC27	The human controller should be able to view the history graph showing the water level during chosen period of time.	1	I
HC28	The human controller should be able to view the history graph showing the river bed height during chosen period of time.	1	I
HC29	The human controller should be able to view the history graph showing the safety trend during chosen period of time.	1	I
HC30	The human controller can choose a start date and end date for the historical graphs.	3	I
HC31	The human controller can choose a specific day for the historical graphs.	2	I
HC32	The human controller can choose a specific month for the historical graphs.	2	
HC33	The human controller should be able to log out of the system.	4	I

3.1.3 Engineer functionalities

The table below shows the requirements for the engineer user of the system.

Identity E	Requirement Definition	Priority	Status
E1	The engineer should be able to log into the system with username and password.	4	I
E2	The engineer should be able to see the stack image with each pylons, with also the flow direction.	3	I
E3	The engineer should be able to see the latest pictures of the both sides of the bridge.	3	I
E4	The engineer should be able to see the diagram showing the change of value of wind speed for the current day.	3	I
E5	The engineer should be able to see the diagram showing the change of value of wind direction for the current day.	3	I
E6	The engineer should be able to see the diagram showing the change of water level for the current day.	3	I
E7	The engineer should be able to see the diagram showing the change of depth of river bed for the current day.	3	I
E8	The engineer should be able to see the diagram showing the change of maximum wind speed for the current day.	3	I
E9	The engineer should be able to see the diagram showing the change of maximum direction value for the current day.	3	I
E10	The engineer should be able to see the current value of the flow rate.	3	I
E11	The engineer should be able to see the current value of the wind speed.	3	I
E12	The engineer should be able to see the current value of the water speed.	3	I
E13	The engineer should be able to see the current value of the Wind Direction.	3	I
E14	The engineer should be able to see the current value of the Water level.	3	I
E15	The engineer should be able to see the current value of the River Bed level.	3	I
E16	The engineer should be able to see a Google maps picture of the bridge with a wind rose picture.	3	I
E17	The engineer should be able to change the debris value. The debris value is a boolean.	3	I
E18	The engineer should be able to change the traffic value. The traffic value is a boolean.	3	I
E19	The engineer should be able to see the alarm button.	3	I
E20	The engineer should be able to send an alarm by clicking on the 'Send Alarm' button.	3	I
E21	The engineer should be able to see the M-N Domain graph with the location of each pylon in the domain.	3	I
E22	The engineer should see the table for CS values for each pylon, their combination label, and values N, M, Tx, Ty, Mx and My.	3	I

Identity E	Requirement Definition	Priority	Status
E23	The engineer should be able to see the history diagram showing wind speed during chosen period of time.	3	I
E24	The engineer should be able to see the history diagram showing wind direction during chosen period of time.	3	I
E25	The engineer should be able to see the history diagram showing maximum wind speed during chosen period of time.	3	I
E26	The engineer should be able to see the history diagram showing maximum wind direction during chosen period of time.	3	I
E27	The engineer should be able to view the history graph showing the water level during chosen period of time.	3	I
E28	The engineer should be able to view the history graph showing the river bed height during chosen period of time.	3	I
E29	The engineer should be able to view the history graph showing the safety trend during chosen period of time.	3	I
E30	The engineer can choose a start date and end date for the historical graphs.	3	I
E31	The engineer can choose a specific day for the historical graphs.	3	I
E32	The engineer can choose a specific month for the historical graphs.	3	I
E33	The engineer can view all the parameters that are stored in the database and used for calculations.	2	I
E34	The engineer can change any parameter that is stored in the database and used for calculations.	2	I
E35	The engineer controller should be able to log out of the system.	4	I

3.1.4 Administrator functionalities

The table below shows the requirements for the administrator user of the system.

Identity A	Requirement Definition	Priority	Status
A1	The administrator should be able to log into the system with username and password.	4	I
A2	The administrator should be able to register a new user by entering information about the user: first name, last name, username, email and permission level (Engineer or Human Controller).	4	I
A3	The administrator should be able to edit any information about any user (except password).	4	I
A4	The administrator should be able to delete a registered user from the system.	4	I
A5	The administrator should be able to log out of the system.	4	I

3.1.5 Parsing

Identity P	Requirement Definition	Priority	Status
P1	Each received package should be parsed into the database in the following way. Every hour the system receives a packet in which there are an analog file, a sonar file both with 3600 lines of values and two images, one for each camera. All these values are to be converted from the parser into the db.	1	I
P2	For the analog and sonar sensors, the name of the files should be parsed in the following way. In the file names, analog*********.txt and sonar**********.txt, the ID (**...) represents the number of seconds that have elapsed since 1st January 1904 (using Labview encode), on the Greenwich meridian.	1	I
P3	For the picture files, the ID of the name Modean[Mantova]********.jpg should represent the exact time and date when the picture was taken.	1	I
P4	The first column of the analog*********.txt file should be parsed in the following way. Each row in the column represents the wind speed (measured in mA). It should be converted to [m / s] by using the following formula: V [m / s] = (((V [mA] ⋆ 1000) − 4) ⋆ 3,75).	1	I
P5	The second column of the analog*********.txt file should be parsed in the following way. Each row in the column represents the distance between the hydrometer and the level of water (measured in mA). The actual distance [m] should be parsed by using the following formula: h [m] = 20 + (((h [mA] ⋆ 1000) − 4) ⋆ (−1,25)). The water height should be parsed by using the following formula: h_{water}[m] = 29,86 − h [m].	1	I
P6	The third column of the analog*********.txt file should be parsed in the following way. Each row in the column represents the wind direction (measured in mA). It should be converted to [°] by using the following formula: dir [°] = (((dir [mA] ⋆ 1000) − 4) ⋆ 22,5).	1	I
P7	The fourth column of the analog*********.txt file should be parsed in the following way. Each row in the timestamp of the detection of the sample (Labview encode). The decimals for the timestamp are allowed to be dropped.	1	I
P8	The first column from the sonar**********.txt file should be parsed in the following way. The first column is the distance between sonar and the bottom of the river (measured in meters). The height of the bottom [m] should be parsed by using the following formula: hBottom[m] = 12,3 − xx.xx [m].	1	I
P9	The second column from the sonar**********.txt file is the timestamp of the detection of the sample and should be parsed by using the Labview encode: the number represents the number of seconds that have elapsed since 1st January 1904, on the Greenwich meridian.	1	I

3.1.6 Calculations

The table below shows the requirements for the calculations.

<table>
<tr><th>Identity C</th><th>Requirement Definition</th><th>Priority</th><th>Status</th></tr>
<tr><td>C1</td><td>All calculations should be preformed after each parse of the data.</td><td>1</td><td>I</td></tr>
<tr><td>C2</td><td>The push of the wind on the planking should be calculated by the formula:
$$S_{Vplank}=\frac{1}{2}*C_{Dwi}*\rho_{air}*A_{traf}*V^2_{EFFwind}$$</td><td>1</td><td>I</td></tr>
<tr><td>C3</td><td>The push of the wind on the traffic for traffic combination A1 should be calculated by the formula:
$$S_{V(A1\,traf)}=\frac{1}{2}*C_{Dwi}*\rho_{air}*(\beta_1*A_{traf})*V^2_{EFFwind}$$</td><td>1</td><td>I</td></tr>
<tr><td>C4</td><td>The push of the wind on the traffic for traffic combination A2 should be calculated by the formula:
$$S_{V(A2\,traf)}=\frac{1}{2}*C_{Dwi}*\rho_{air}*(\beta_1*A_{traf})*V^2_{EFFwind}$$</td><td>1</td><td>I</td></tr>
<tr><td>C5</td><td>The push of the wind on the traffic for traffic combination A3 should be calculated by the formula:
$$S_{V(A3\,traf)}=\frac{1}{2}*C_{Dwi}*\rho_{air}*(\beta_2*A_{traf})*V^2_{EFFwind}$$</td><td>1</td><td>I</td></tr>
<tr><td>C6</td><td>The parameters a_i , b_i , c_i should be calculated using the table below.
<table>
<tr><th colspan="4">Scale of estimate flow rates with fixed section</th></tr>
<tr><td>Parameters</td><td>h_{water} < 17m</td><td>17m < h_{water} < 22m</td><td>22m < h_{water} < $h_{MAXwater}$</td></tr>
<tr><td>a_i</td><td>46</td><td>60</td><td>96</td></tr>
<tr><td>b_i</td><td>-902</td><td>-1350</td><td>-2800</td></tr>
<tr><td>c_i</td><td>4658</td><td>8000</td><td>22500</td></tr>
</table></td><td>1</td><td>I</td></tr>
<tr><td>C7</td><td>The flow rate should be calculated using the formula:
$$Q = a_i * h^2_{water} + b_i * h_{water} + c_i$$.</td><td>1</td><td>I</td></tr>
<tr><td>C8</td><td>The speed of water should be calculated using the formulas:
<table>
<tr><th colspan="3">2D analysis – fixed bottom</th></tr>
<tr><td>h_{water} [m]</td><td>Q [m^3/s]</td><td>V_{water} [m/s]</td></tr>
<tr><td>3</td><td>510</td><td>0,24</td></tr>
</table></td><td>1</td><td>I</td></tr>
</table>

$$V_{water} = a * h^3_{water} + b * h^2_{water} + c * h_{water}$$

<table>
<tr><th>Identity
C</th><th>Requirement Definition</th><th>Priority</th><th>Status</th></tr>
<tr><td></td><td>

10,5	5400	2,73
14	10000	3,54

</td><td></td><td></td></tr>
<tr><td>C9</td><td>

The area of stack should be calculated using the formula: $A_s = B_s * h_s$.

with

a. if [SONAR1] < bottom_ref → **h_s = [IDRO2] – bottom_ref**
b. if [SONAR1] > bottom_ref → **h_s = [IDRO2] – [SONAR1]**

and

a. if D = 0 → $B_s = B_{s0} = c$
b. if D = 1 → $B_s = B_{s1} = 2*D_{pylon}$

</td><td>1</td><td>I</td></tr>
<tr><td>C10</td><td>

The Area Stack and Swater should be calculated using the formulas:

(D = 0)
$A_s = B_{s0} * h_s$ $S_{water} = \frac{1}{2} * C_{D0} * \rho_{water} * A_s * V^2_{water}$
(D = 1)
$A_s = B_{s1} * h_s$
$S_{water} = \frac{1}{2} * C_{D1} * \rho_{water} * (A_s * \beta_A) * V^2_{water}$

</td><td>1</td><td>I</td></tr>
<tr><td>C11</td><td>The portion of palking should be calculated with the formula:</td><td>1</td><td>I</td></tr>
<tr><td colspan="4">

$$PP_{structure} = P_s + [(2 * P_{pu} + 6*P_{tp} + 2*P_b) + 6*(P_p*(h_{beam} - [SONAR1]))]$$

</td></tr>
</table>

To represent the risk of bridge to collapse, the "Safety factor" value is calculated. This value is a product of many forces that affect bridge. Some of the forces are: Wind speed, wind direction, water height and others. The calculation of safety is not trivial. Here are stated the requirements for the final calculations to be done. More about the meaning of formulas can be found in document jsodihfsdihh

The Axial stress (N), is calculated for each pylon using following table of formulas:

	Pylon 1	Pylon 2	Pylon 3
P.P.	$N_4 = \frac{(q_{pu} + q_b) * d}{3} + q_{pylon} * L$	$N_4 = \frac{(q_{pu} + q_b) * d}{3} + q_{pylon} * L$	$N_4 = \frac{(q_{pu} + q_b) * d}{3} + q_{pylon} * L$
N	$N_4 = -\frac{N}{3}$	$N_4 = -\frac{N}{3}$	$N_4 = -\frac{N}{3}$
Ty	$N_4 = -\left[\frac{T_y}{d}\left(h_1 + \frac{L_2}{2}\right)\right]$		$N_4 = \left[\frac{T_y}{d}\left(h_1 + \frac{L_2}{2}\right)\right]$
Mc	$N_4 = -\frac{M_x}{3}$		$N_4 = \frac{M_x}{3}$
qy	$N_4 = -\left[\frac{H_1}{d}\left(h_1 + \frac{L_2}{2}\right)\right]$		$N_4 = \left[\frac{H_1}{d}\left(h_1 + \frac{L_2}{2}\right)\right]$
Tx			

Cutting force (Tx) on Pylons is calculated by following formulas:

	Pylon 1	Pylon 2	Pylon 3
P.P.			
N			
Ty			
Mc			
qy			
Tx	$T_{x4} = \frac{Tx}{3}$	$T_{x4} = \frac{Tx}{3}$	$T_{x4} = \frac{Tx}{3}$

Cutting force (Ty) on Pylons is calculated by following formulas:

	Pylon 1	Pylon 2	Pylon 3
P.P.			
N			
Ty	$T_{y4} = \frac{Ty}{3}$	$T_{y4} = \frac{Ty}{3}$	$T_{y4} = \frac{Ty}{3}$
Mc			
qy	$T_{y4} = \frac{q_y * h_i}{3}$	$T_{y4} = \frac{q_y * h_i}{3}$	$T_{y4} = \frac{q_y * h_i}{3}$
Tx			

Blending stress of the bridge (Mx) is calculated for each pylon by formulas:

	Pylon 1	Pylon 2	Pylon 3
P.P.			
N			
Ty	$M_{x4} = \frac{T_y * L_2}{6}$	$M_{x4} = \frac{T_y * L_2}{6}$	$M_{x4} = \frac{T_y * L_2}{6}$
Mc			
qy	$M_{x4} = \frac{H_1 * L_2}{6}$	$M_{x4} = \frac{H_1 * L_2}{6}$	$M_{x4} = \frac{H_1 * L_2}{6}$
Tx			

Blending stress of the bridge (My) is calculated for each pylon by formulas:

	Pylon 1	Pylon 2	Pylon 3
P.P.			
N			
Ty			
Mc			
qy			
Tx	$M_{y4} = \frac{T_x * L}{3}$	$M_{y4} = \frac{T_x * L}{3}$	$M_{y4} = \frac{T_x * L}{3}$

3.1.7 External interfaces

The table below shows the requirements for the external interfaces of the system.

Identity EI	Requirement Definition	Priority	Status
EI1	The alarm button should turn red if any pylon is outside the M-N domain.	1	I
EI2	A Google Earth picture of the bridge and an icon of a wind rose should be visible on each page.	5	I
EI3	A link to external webpages which show the measurements of river Po should be present on each page.	5	I
EI4	A film of the day, the week and month based on the pictures should be visible to the human controller.	5	I

3.1.8 Warning messages

The table below shows the requirements for the warning messages.

Identity WM	Requirement Definition	Priority	Status
WM1	A warning message "Are you sure you want to delete this user?" should appear if the administrator chooses to delete a registered user.	5	I
WM2	A warning message "Are you sure you want to change the range of risk factors" should appear if the engineer chooses to change ranges of risk	5	I

Identity WM	Requirement Definition	Priority	Status
	factors.		

3.2 Non-Functional requirements

There are five types of non-functional requirements: Performance (PE), Usability (U), Extensibility (Ex) and Security (S). They are presented in the following table.

Identity	Requirement Definition	Priority	Status
PE1	The system should parse the data from the sensors and perform calculations every one hour.	3	I
PE1	The loading time for each page should be less than 20 seconds.	4	I
U1	Each new user of the system should be able to learn how to operate with the system within one day of tutorial.	4	I
Ex1	It should be able to add new sensors to the system in the future.	4	I
S1	A log in is required to sign into the system and view internal data.	4	I

3.3 Requirements for the future

The requirements for the future will not be prioritized since no plan is made for their implementation yet. They represent possible extensions to the system that is being developed.

Identity F	Requirement Definition	Priority	Status
F1	Create an Android application of the system.	N/A	F
F2	Have a local and remote Database. Local with 'current' data (last X years). Remote with 'historical data (older than X years ago).	N/A	F

4. APPENDIX

GEOMETRY OF THE STACK N.30			
D_{pylon}	1.5	m	Diameter of the pylon
c_{span}	9.5	m	Distance between two line of pylon
h_{beam}	17.5	m	Height of the lower beam
bottom_ref	10	m	Height of the reference of the bottom of the river
h1			
h2	7.5	m	Distance between the inferior beam and the bottom_ref
(h1)/2	3.65	m	Mean value of h1
k	0	m	Sinking of the joints over the ground
d	8.5	m	Width of the chassis
R_{Ipylon}	0	m	Internal radius
numb_id_bar	12	--	Number of identical bars
D_{bar}	0,024	m	Bars diameter
Ccb	0,042	m	Barycentric concrete cover
Steel_class	FeV44K	--	Steel class
Concrete_class	C25/30	--	Concrete class
WIND THRUST	**WIND THRUST**	**WIND THRUST**	**WIND THRUST**
α	6	°	Planimetric anticlockwise inclination of the bridge form the north
C_{Dwi}	2	-	“Drag planking” coefficient
ρ_{air}	1.2	Kg/m^3	Air density
A_{stack}	168	m^2	Planking area exposed to the wind pressure
A_{traf}	177	m^2	Surface of traffic exposed to the wind pressure
β_1	1	-	Coefficient of reduction for A1 and A2 traffic scenarios
r	2.25	m	Thrust center due to longitudinal asymmetry, only of S_{Vplank}
e_{plank}	1.91	m	“arm” for bending moment of S_{Vplank}
e_{traf}	3.41	m	“arm” for bending moment of S_{Vtraf}
HYDRODYNAMIC THRUST	**HYDRODYN**	**HYDRODYN**	**HYDRODYNAMIC THRUST**

	AMIC THRUST	**AMIC THRUST**	
C_{D0wa}	2.4	-	“Drag planking” coefficient (D=0)
C_{D1wa}	2	-	“Drag planking” coefficient (D=1)
ρ_{water}	1000	Kg/m^3	Water density
β_A	0.5	-	Area reduction for D=1
a	-0.0014	-	Coefficient for the relation $V_{water(}$[IDRO1])
b	0.0341	-	Coefficient for the relation $V_{water(}$[IDRO1])
c	0.052	-	Coefficient for the relation $V_{water(}$[IDRO1])
h_{water1}			
a1	46	-	Coefficient for Q(h) when [IDRO1] < h_{water1}
b1	-902	-	Coefficient for Q(h) when [IDRO1] < h_{water1}
c1	4658	-	Coefficient for Q(h) when [IDRO1] < h_{water1}
h_{water2}	22	m	Height limit of the river for parameters a2,b2,c2
a2	60	-	Coefficient for Q(h) when [IDRO1] < h_{water2}
b2	-1350	-	Coefficient for Q(h) when [IDRO1] < h_{water2}
c2	8000	-	Coefficient for Q(h) when [IDRO1] < h_{water2}
h_{max}	25.3	m	Max height level of river and limit for use parameter a3,b3,c3
a3			
b3	-2800		Coefficient for Q(h) when h_{water2} < [IDRO1] < hmax
c3	22500		Coefficient for Q(h) when h_{water2} < [IDRO1] < hmax
WEIGHT OF THE STACK	**WEIGHT OF THE STACK**	**WEIGHT OF THE STACK**	**WEIGHT OF THE STACK**
Pp	10710	kN	Plank weight on the stack
Ppu	1680	kN	Weight of single pulvino
Ptp	1601	kN	Weight of the trunk of pylon
Pb	1007	kN	Weight of the single beam
Ppy	44	kN/m	Weight per meter of pylon
Mt	9720	kNm	Moment generated by asymmetry

SHIFTING WEIGHTS	**SHIFTING WEIGHTS**	**SHIFTING WEIGHTS**	**SHIFTING WEIGHTS**
N(A1)	4024	kN	Axial load for load combination A1
Mxx(A1)	4368	kNm	Bending moment for load combination A1
Myy(A1)	3908	kNm	Bending moment for load combination A1