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COMPUTER PROGRAM FOR EVALUATING "BRIDGE AESTHETICS AND CULTURAL VALUES"

Preface

The *ETSI III Project* consists of several subprojects and *Task Groups*. The present subproject belongs to *Task Group 1 (TG 1)* "*Testing of the Developed Tools*". It was given the name "*LCE*" to distinguish it from "*LCA*" and "*LCC*" that also are subprojects of the *ETSI III Project*.

To support the work a *Project Group* was created. It consists of the following persons:

> *Birit Buhr Jensen*, Cowi A/S, Denmark
> *Aarne Jutila*, Extraplan Oy, Finland
> *Marianne Hvaal Larsen*, Norwegian Road Administration, Norway
> *Yishu Niu*, Aalto University, Finland
> *George Racutanu*, Royal Institute of Technology, Sweden
> *Antti Rytkönen*, Finnish Traffic Agency, Finland
> *Mohammed Safi*, Swedish Road Administration, Sweden
> *Lauri Salokangas* Aalto University, Finland.

The work was carried out under the leadership of *Aarne Jutila*. He also created the theory and methodology on which the program is based. The *Excel*-based program code was written by *Yishu Niu*. The supervisor of the work was *Lauri Salokangas*.

The practical work of the *LCE Project*, *i.e.*, the code writing, was started in *June 2011* and completed in *December 2011*. During that time one *Project Group* meeting was arranged in Otaniemi, Finland. The text for this *Report* was prepared in the early 2012.

The work is continuation to a similar project carried out in the *ETSI Project (Stage 2)* completed in 2009 [1]. Another important source of information is the *Special Assignment* of the second author [2]. Most of the text below is based on these two publications.

BACKGROUND THEORY OF THE COMPUTER PROGRAM

When evaluating a bridge for its whole life cycle, it is not enough to consider only the construction cost but environmental and aesthetic values should be given attention as well. The difficulty is how to measure and express these things so that they would be commensurable. For the construction cost, here C_{LCC}, naturally money is the only thinkable unit. Through some manipulations, environmental values can also be transferred to be expressed as money, here C_{LCA}. For the aesthetical value, however, a similar manipulation is not relevant, but this difficulty can be overcome by using a *reduction coefficient k_{rel}* that relates this value to the construction cost. Consequently, the *total cost*

$$C = k_{rel}C_{LCC} + C_{LCA} \qquad\qquad (1)$$

The current computer program is developed to calculate the value of the *reduction coefficient* k_{rel}.

For the calculation, four main aspects are needed: *classification of the bridge site*, a *scaling factor a*, *weights w* and *points p*.

Classification of the bridge site is based on a system developed by the *Finnish Road Administration* (*Finnra*). It considers the value of the scenery. A publication "*Siltapaikkaluokitusohje*" (*Guide for Grading a Bridge Site*) already exists (in Finnish) [3].

A four-grade system is used for evaluation of a bridge site:

Class I	Very demanding considering the landscape and city view.
Class II	Demanding considering the landscape and city view.
Class III	Remarkable considering the landscape and city view.
Class IV	Ordinary considering the landscape and city view.

Bridge sites belonging to the highest class, **Class I**, are considered as "*very demanding*". This means that the site includes nation-wide valuable views or city views, culturally valuable landscape or the most important joints in the transport network. Also the most remarkable waterway crossings within the country and museum bridges belong to this group.

Bridge sites belonging to **Class II**, "*demanding*", possess similar characteristics as those belonging to the previous class but their importance is local, for instance remarkable city or village objects and big bridges crossing waterways with less modest views.

Class III, "*remarkable*", consists of bridge sites including ordinary waterway crossings and bridge sites at crossings with heavy traffic located outside city or village areas.

Class IV, "*ordinary*", consists of bridge sites including roads with low amount of traffic located in an ordinary landscape outside city or village areas as well as sites with low importance where a road or railway crosses a waterway. These kinds of bridge sites usually do not require any special environmental or aesthetical consideration or design.

The basic equation in the calculation is

$$k_{rel} = 1 - a\,\frac{\sum_{i=1}^{n} w_i p_i}{\sum_{i=1}^{n} w_i p_{i\max}} \qquad\qquad (2)$$

The non-dimensional *scaling factor a* defines generally, how much value is given to aesthetical aspects. It varies between 0 and 1. The higher value, the more aesthetics is appreciated.

Weights w_i consider, how important different evaluation *items i* in relation to each other are. The higher value, the more important *item* is in question.

Finally, *points p_i* indicate, how well the requirements of *item i* are fulfilled by the design or bridge evaluated. The higher score, the better. In the current *Computer Program* only five values are accepted, namely -2, -1, 0, +1 and +2, *i.e.*, "*poor*", "*modest*", "*medium*", "*good*" and "*excellent*", respectively.

The system described above enables comparison between different design proposals, existing bridges and bridge types as well as evaluation of even different construction methods.

PRACTICAL USE OF THE PROGRAM

The computer program developed forms a unique system that enables to incorporate aesthetical, environmental and cultural values to bridge design or construction projects and to make them comparable with construction and lifecycle costs. The program can be utilised beneficially in the following cases:

- Evaluation of aesthetical, environmental and cultural values with respect to the construction costs.
- Comparison of different bridge design proposals within a project or in engineering skills - including bridge design - competitions.
- Comparison of different routes where bridges are involved during the feasibility study stage or construction phase.

The program can as easily be used by an individual as by a jury or group of evaluators. Its practical use is simple, as explained below. At the first stage one has to consider the bridge site and determine, which class the bridge site belongs to. The second stage is to agree about the items that will be evaluated and to determine weight to each item. This should be done before the evaluation process begins. The weights should be considered as "*fixed values*" and may not be changed during the evaluation process. Some initial items and weights are given, but the user is totally free to change them or choose any items or weights according to the user's wish. Good practice might be that items and their weights are determined by the bridge owner in advance.

A similar value as the weights is the *scaling factor a*. It also needs to be determined in advance, because it has a decisive influence on the level of appreciation of aesthetical values compared to costs. Initial values depending on the *Bridge Site Class* are given, but again the user is totally free to change them.

The third and final stage includes the evaluation itself, *i.e.*, the determining of *points p_i*. Before that, however, the scale to be used has to be determined. In the *Program* a fixed scale with $p_{max} = -p_{min} = 2$ is used, but the system as such allows any scale. Changing of this scale would require reprogramming and is not recommended to be done. With steps equal to 1 one has to decide between five different values, *i.e.*, -2, -1, 0, 1 and 2. Only integer values are allowed.

When the evaluator has inserted the *points p_i*, the *Program* uses a simple mathematical operation to calculate the final values of interest, *i.e.*, the *reduction coefficient k_{rel}*.

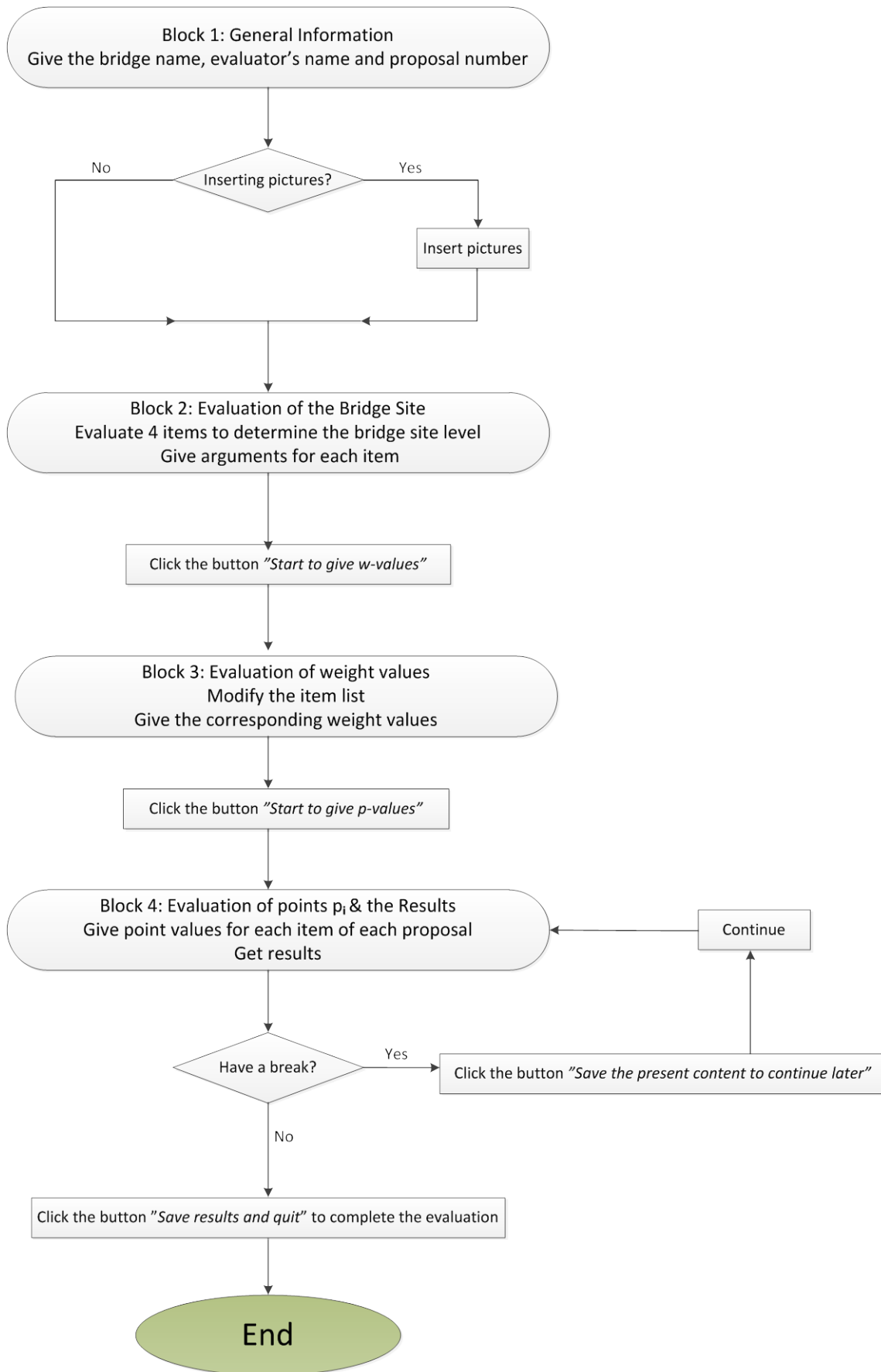The flowchart is given below and a more detailed description of the *Program* is given after that.

```
┌────────────────────────────────────────────────┐
│            Block 1: General Information          │
│ Give the bridge name, evaluator's name and       │
│              proposal number                      │
└────────────────────────────────────────────────┘
```

No ◄──────── ◇ Inserting pictures? ◇ ────────► Yes

Insert pictures

```
┌────────────────────────────────────────────────┐
│         Block 2: Evaluation of the Bridge Site   │
│   Evaluate 4 items to determine the bridge site  │
│                     level                         │
│            Give arguments for each item           │
└────────────────────────────────────────────────┘
```

Click the button *"Start to give w-values"*

```
┌────────────────────────────────────────────────┐
│         Block 3: Evaluation of weight values     │
│               Modify the item list               │
│         Give the corresponding weight values     │
└────────────────────────────────────────────────┘
```

Click the button *"Start to give p-values"*

```
┌────────────────────────────────────────────────┐
│    Block 4: Evaluation of points $p_i$ & the Results │
│  Give point values for each item of each proposal│
│                   Get results                     │
└────────────────────────────────────────────────┘
```

Continue

◇ Have a break? ◇ ────► Yes ──► Click the button *"Save the present content to continue later"*

No

Click the button *"Save results and quit"* to complete the evaluation

End

Fig. 1. Flowchart of the Computer Program.

Before starting to use the *Program*, the user is recommended to move or copy the *Program* into a new file folder, whose name could be the user's name. The purpose is to collect all files related to the evaluation into the same file folder and to make it possible to distinguish the results of different evaluators.

The *Program* contains 3 sheets, whose names are "*Sheet1*", "*Alldrawings*" and "*pvalue*", respectively. The evaluation procedure is carried out in the first sheet, which is activated automatically when opening the *Program*. The function of each sheet will be explained later.

BLOCK 1: GENERAL INFORMATION

In *Block 1 "General information"* the name of the bridge to be evaluated, the name of the evaluator and the evaluation date are given. The date is automatically printed as the current date, but it can be changed by the evaluator. Furthermore, the number of proposals to be evaluated shall also be given. The maximum number is 10.

Here, as throughout the *Program*, pink colour is used in those cells, whose content or value can be changed or chosen by the user.

The last part of this block consists of information concerning the use of pictures during the evaluation process. There are two options: Either no pictures are utilised in the *Program*, or one or more pictures are utilised. In the latter case the user has to activate the "*Alldrawings*" sheet.

BLOCK 2: EVALUATION OF THE BRIDGE SITE

As mentioned before, four *Bridge Site Classes* are used. To make it easier to decide, which *Class* number should be chosen, four sub-blocks and items are presented, namely

- location of the bridge site,
- value of the landscape,
- cultural value of the bridge site, and
- aesthetical demands set to a bridge at this particular bridge site.

In each sub-block the user should determine, which of the four *Classes* is most appropriate considering the *item* related to that particular sub-block. For motivation and remembering, a cell is reserved for writing down some text describing, what was in the user's mind when making the decision.

When that is done, the *Program* calculates the mathematical average value of the sub-block values rounding downwards, if the average is just halfway between two classes. This *Bridge Site Class* again can be changed by the user, if wished.

Finally, the recommended *scaling factor a* is presented in its particular cell. The recommended values used by the *Program* are as follows:

Class I $a = 0,4$
Class II $a = 0,3$
Class III $a = 0,2$
Class IV $a = 0,1$

Again, the user can change the recommended value according to his or her own wish, if needed. With these *a-values* the extreme values of the *reduction coefficient k_{rel}* vary between 0,6 (*Class I*) and 0,9 (*Class IV*) or 1,1 (*Class IV*) and 1,4 (*Class I*).

To complete *Block 2* and continue, the cell with text "*Click to start to give w-values*" should be clicked.

BLOCK 3: EVALUATION OF WEIGHT VALUES w_i

In *Block 3* values for *weights w_i* are given. These values are dependent on the *Bridge Class* and *item*.

The *weights w_i* indicate the importance of each item or aspect of the bridge or design. The user is supposed to change the *weight values* to adjust them to each particular case. In the present program, the proposed *items* and the corresponding *weight values* are as shown in *Table 1*.

Table 1. Proposed *item list* and the corresponding *weight values w_i*.

Item list	Class I	Class II	Class III	Class IV
Integration between the bridge and the site	9	8	7	6
Overall harmony	9	8	7	6
Horizontal and vertical geometry	4	3	2	1
Structural simplicity and order	8	7	6	5
Transparency	6	5	4	3
Slenderness	7	6	5	4
Appearance of substructures and pylons	8	7	6	5
Surfaces, colours and finishing	5	4	3	2
Railing and vehicle barriers	4	3	2	1
Lighting	5	4	3	2
Appearance of access bridges, embankments and cones	6	5	4	3

The proposed 11 item contents can be changed or deleted, but DELETE or INSERT LINES - operations are NOT ALLOWED. Below the proposed items, additional 9 empty rows are left for free use of the evaluator. Thus, the total number of rows is 20, and that cannot be changed. **The weight values,** however, can all be changed freely.

To complete *Block 3* and continue, the cell with text "*Click to start to give p-values*" should be clicked. Consequently, the current file will be saved as a new file named according to the bridge.

BLOCK 4: EVALUATION OF POINTS p_i AND THE RESULTS

In *Block 4* of the *Program* numerical values called *point p_i* shall be given to each *item*. Only the five categories and values presented in *Table 2* are accepted. The higher value, the better the bridge or design corresponds to the *item* in question.

Note: It is NOT ALLOWED to change the content of any items in this block!

Table 2. Acceptable numerical values of *points p_i* and the corresponding explanation.

Category	Explanation
2	Excellent
1	Good
0	Medium
-1	Modest
-2	Poor

If there are several proposals to be evaluated one by one, *points p_i* can be given for each proposal in the sequence of evaluation, but finally all values will be seen in *Block 4*. By this means the different proposals can be easily compared.

When *Block 4* is completed, the *Program* calculates the final result, which is the *relative coefficient k_{rel}*. Its value is printed on the *Result Line* for each proposal. Finally, the user has two options, either to have a break or to finish. In the former case, the user should press the button with caption "*Save the present content to continue later*". In the latter case, the user should press the button with caption "*Save results and Quit*", consequently the current file will be saved as a new file, whose name indicates the bridge name, user name and proposal number.

EXAMPLE: EVALUATION OF THREE PROPOSALS

As a practical calculation, three bridge proposals presented for a bridge design completion in Tampere, Finland, carried out in 2007, are evaluated [4]. Each proposal includes several drawings and other pictures. The evaluation is based on this material.

The bridge called *Laukonsilta* is located in the middle of the town and crosses a 150 m wide river (Fig. 2). The three proposals used in this example are all based on a cable-stayed bridge solution main span varying between 65 and 112 meters. Here the proposals and the corresponding bridges are numbered as 1, 2 and 3. The drawings and pictures used in the evaluation are shown in Figs. 3…17, respectively.
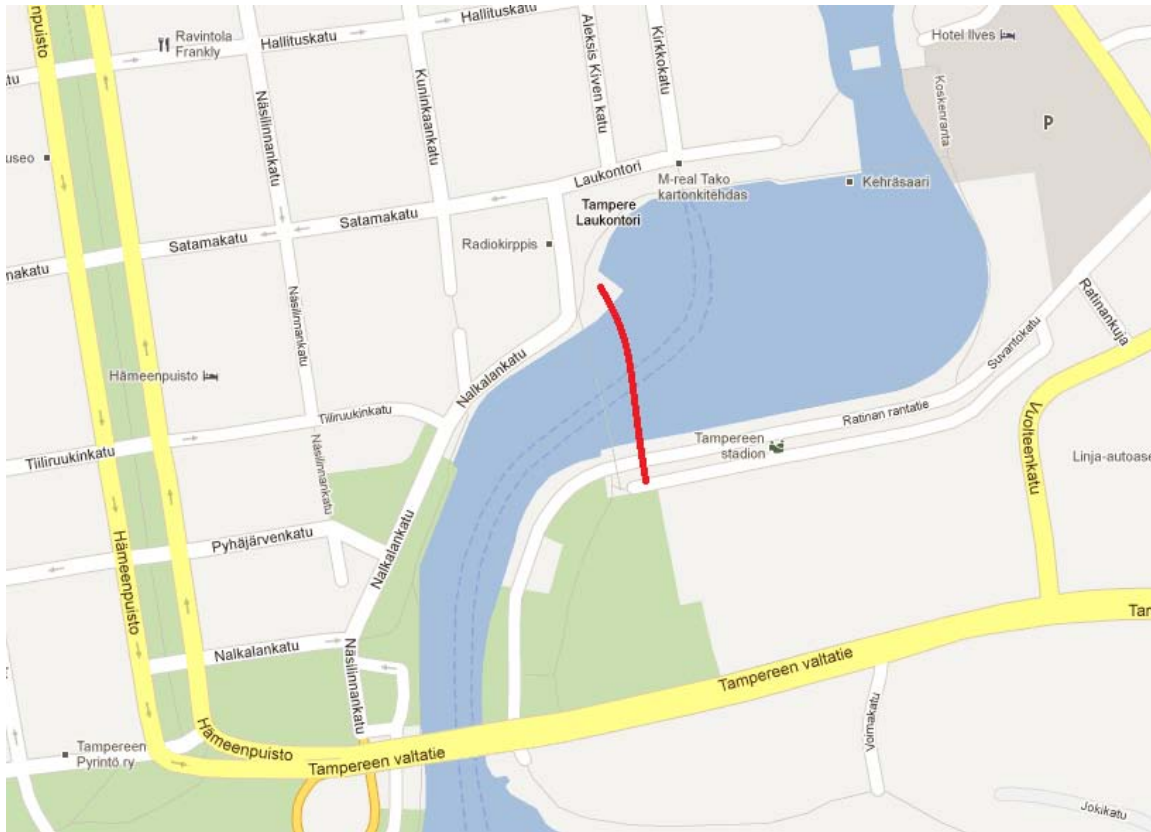
Fig. 2. Location of the Laukonsilta Bridge.

Proposal No. 1 pictures:
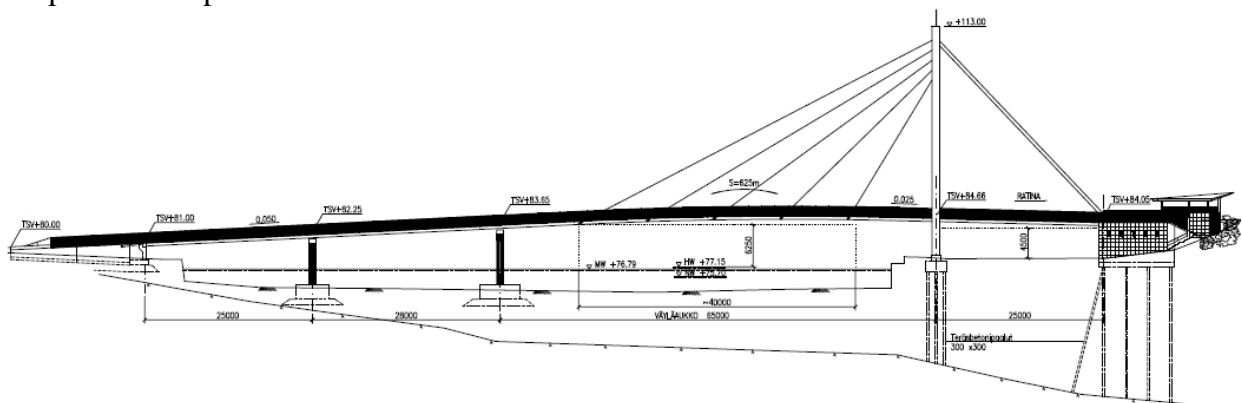
Fig. 3. Side view drawing of Bridge No. 1.
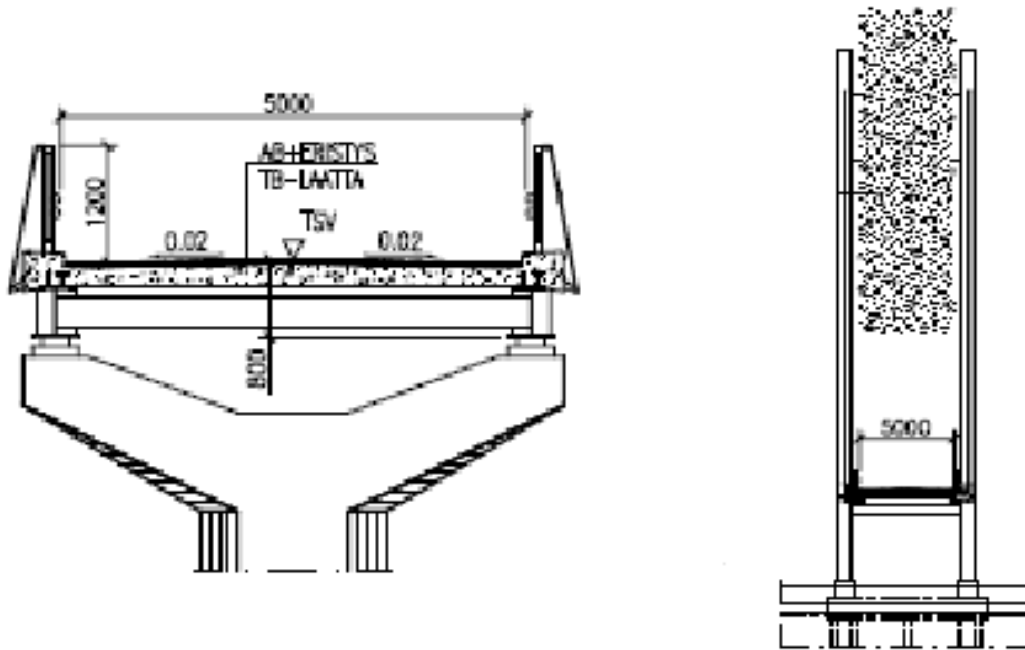
Fig. 4. Cross-sections of Bridge No. 1.

Fig. 5. Photomontage A of Bridge No. 1.

Fig. 6. Photomontage B of Bridge No. 1.

Fig. 7. Photomontage C of Bridge No. 1.

Proposal No. 2 pictures:
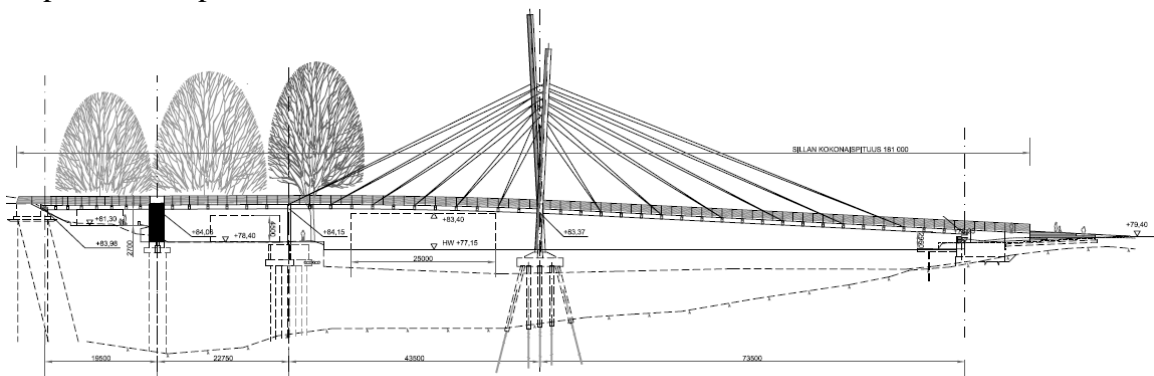
Fig. 8. Side view drawing of Bridge No. 2.
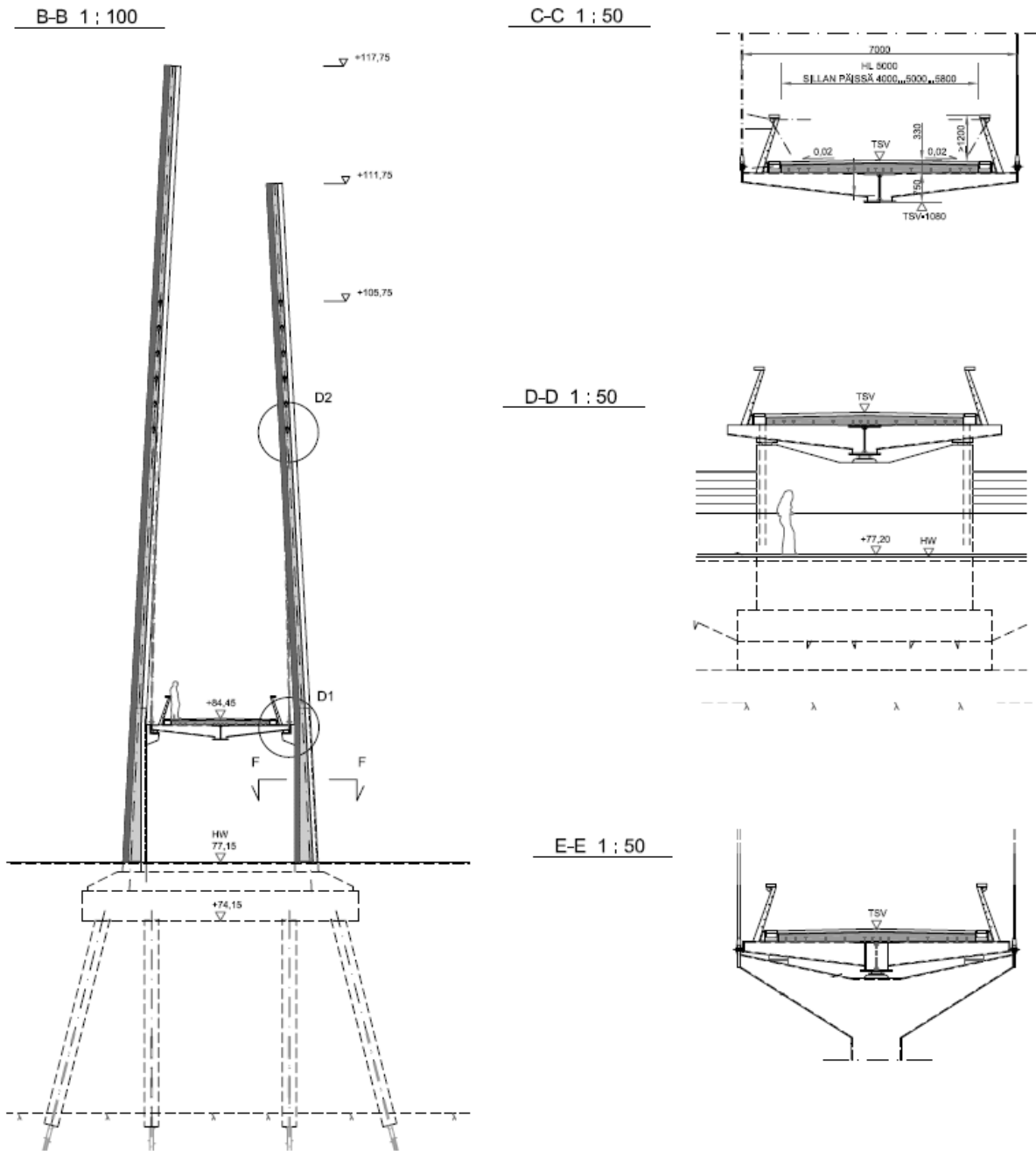
Fig. 9. Cross-sections of Bridge No. 2.

Fig. 10. Photomontage A of Bridge No. 2.

Fig. 11. Photomontage B of Bridge No. 2.

Fig. 12. Photomontage C of Bridge No. 2.

Proposal No. 3 pictures:
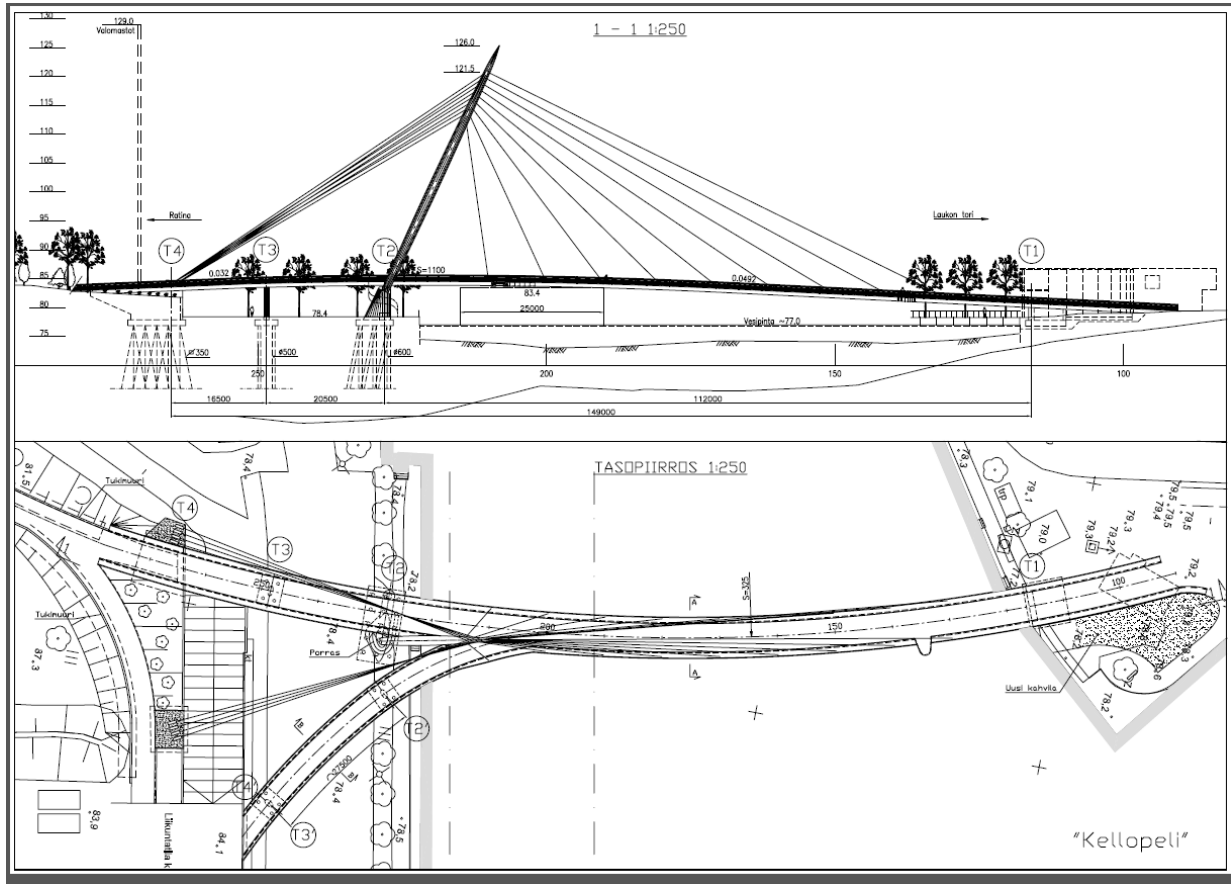
Fig. 13. General drawing of Bridge No. 3.
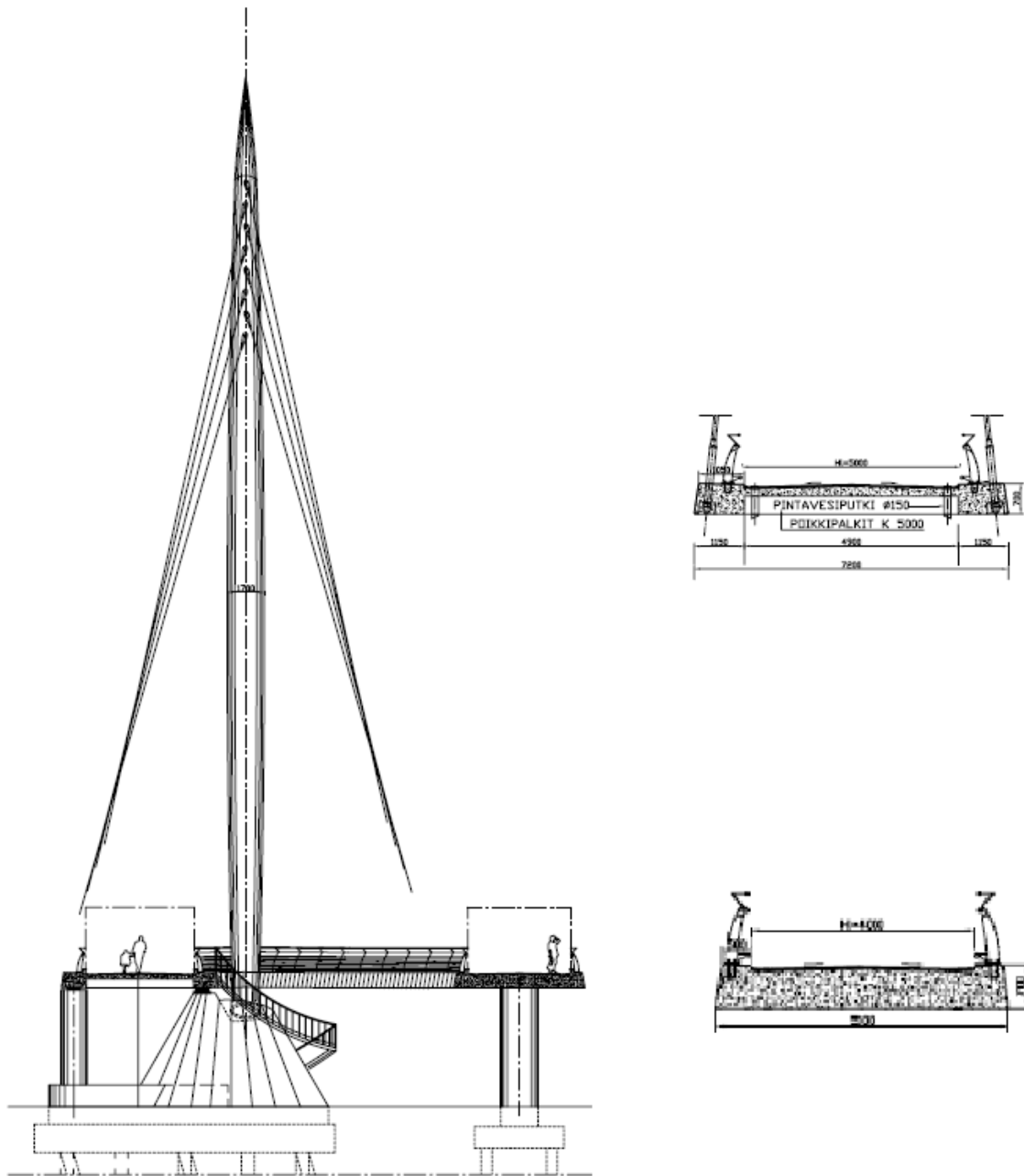
Fig. 14. Longitudinal view and cross-sections of Bridge No. 3.

Fig. 15. Photomontage A of Bridge No. 3.

Fig. 16. Photomontage B of Bridge No. 3.

Fig. 17. Photomontage C of Bridge No. 3.

Actions related to Block 1:

As the first step, open the basic program and click button "*Enable content*" above the Formula Bar. Then give general information for the evaluation in Block 1.
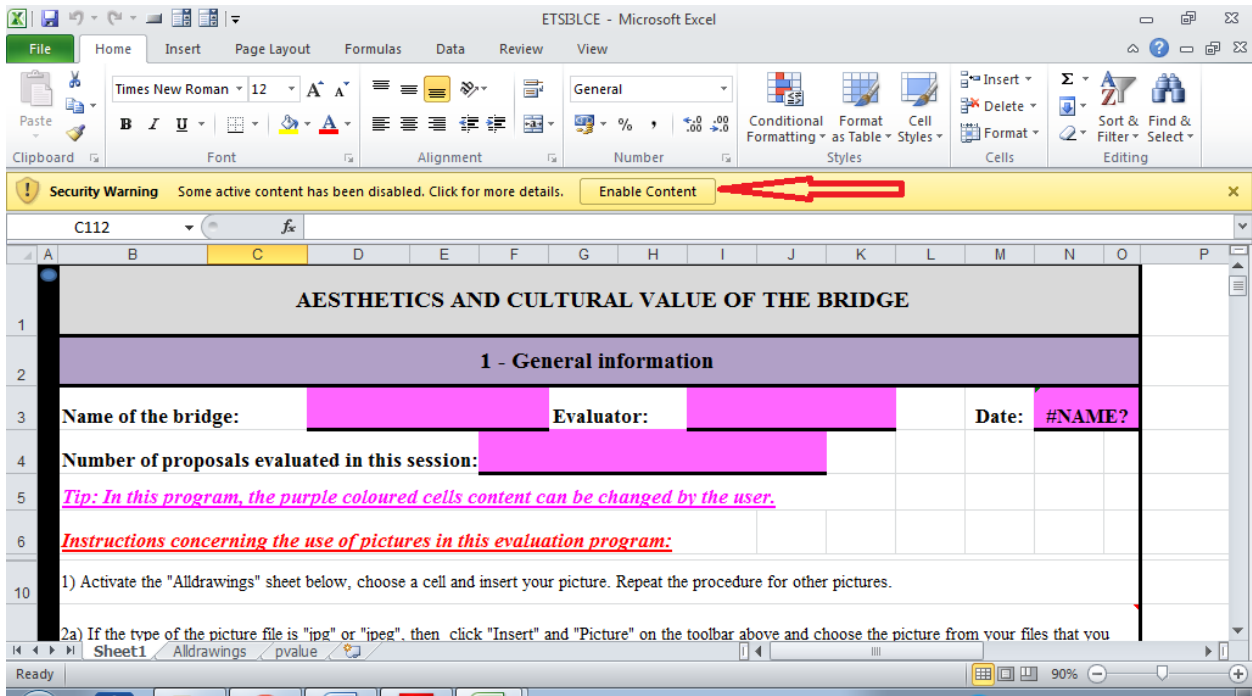
Fig. 18. Clicking "*Enable Content*".
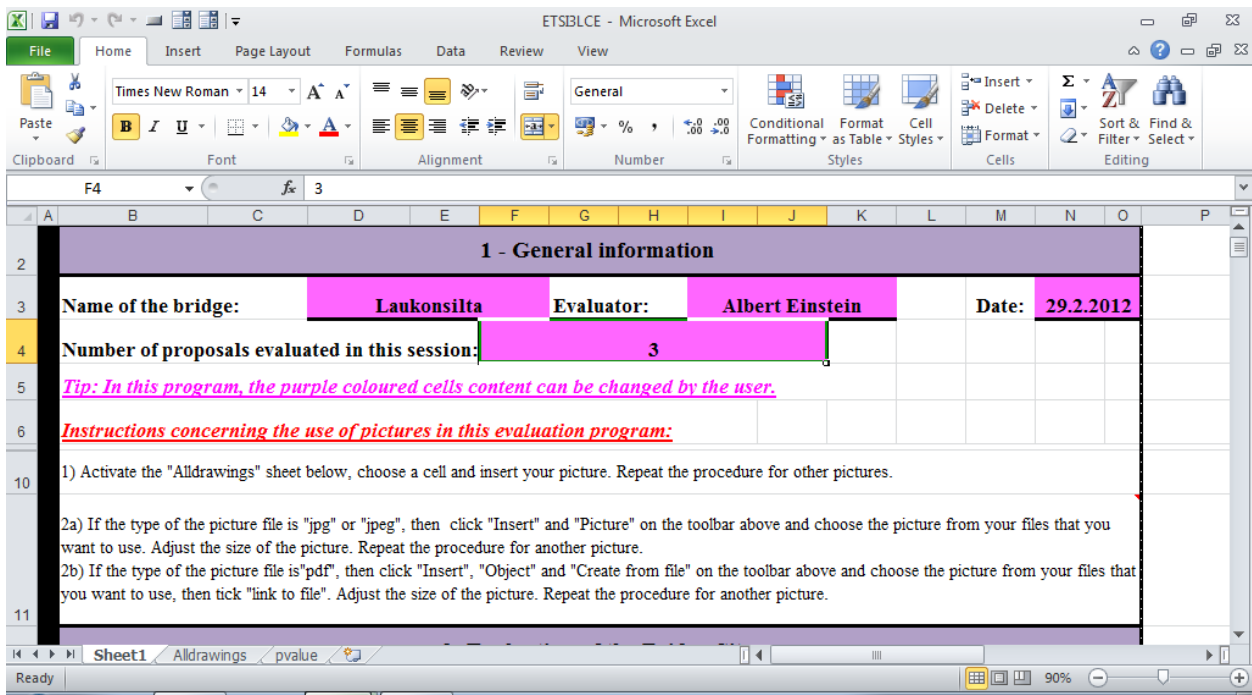
Fig. 19. Giving information: the bridge name, user name, etc.

For inserting pictures, activate sheet *Alldrawings*" next to "*sheet1*", activate one cell, then click button "*Insert*" and choose "*Picture*" (Fig. 20).
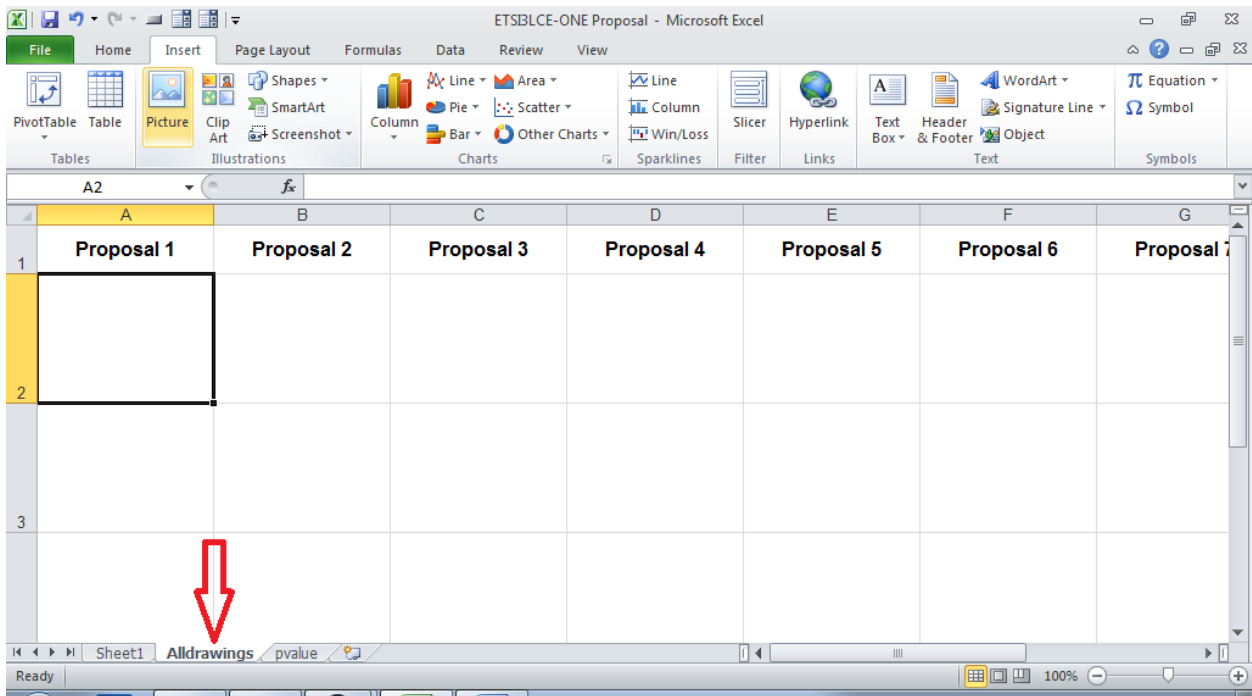
Fig. 20. Activating one cell and clicking button "*Insert*" and then "*Picture*", respectively.

A new window will pop up, from here choose the picture you want to insert then click "*Insert*" in the right upper corner (Figs. 21 and 22).
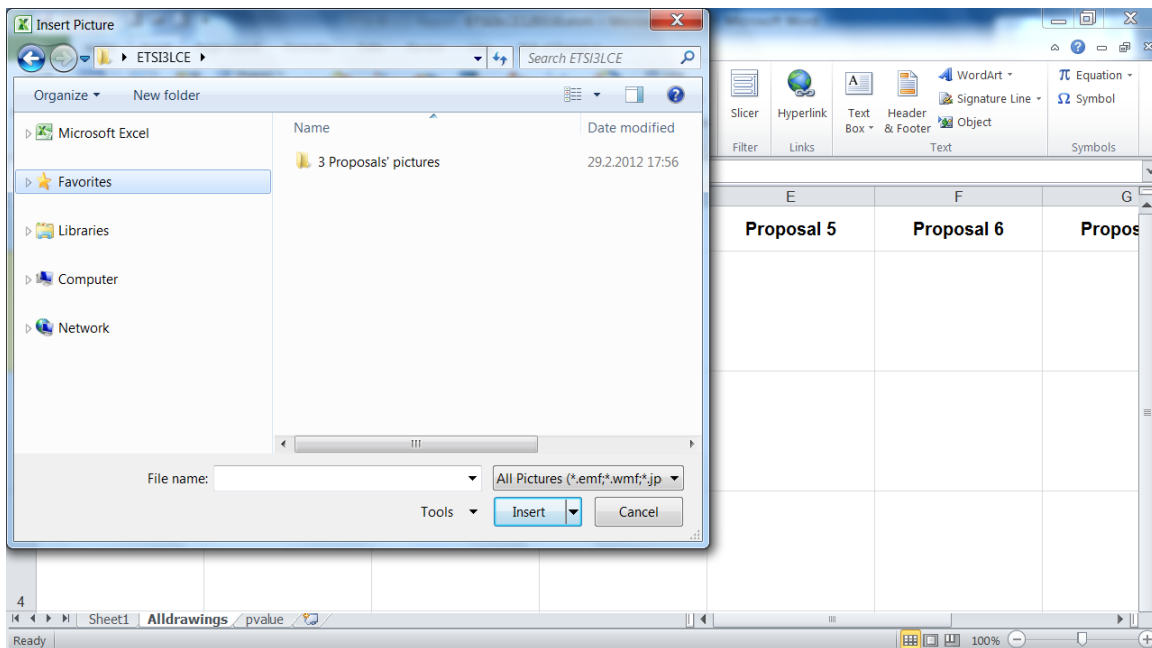
Fig. 21. Choosing file that is being inserted.
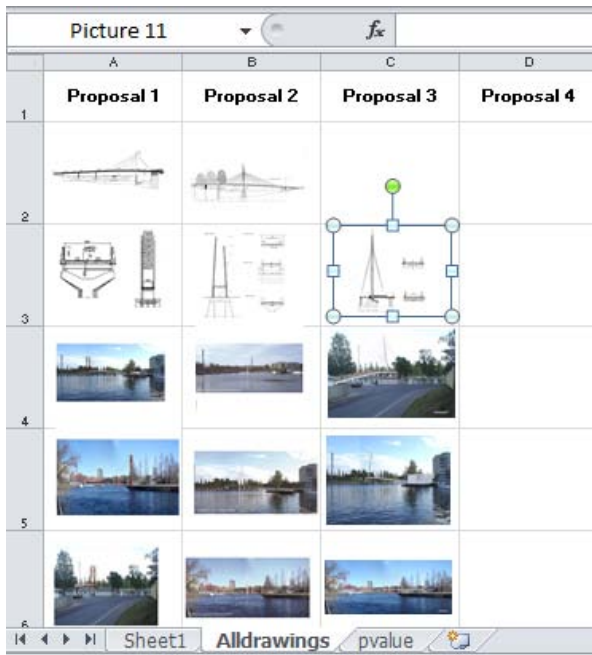
Fig. 22. Adjusting the size of the picture or drawing.

If the pictures are of "*pdf*" type, then activate one cell by clicking "*Insert*" and choosing "*Object*". Now, a new window will pop up, then activate "*Create from file*" and "*browse*" the "*pdf*" file. Finally, tick "*Link to file*" and click "*OK*" in the end (Figs. 23, 24 and 25).
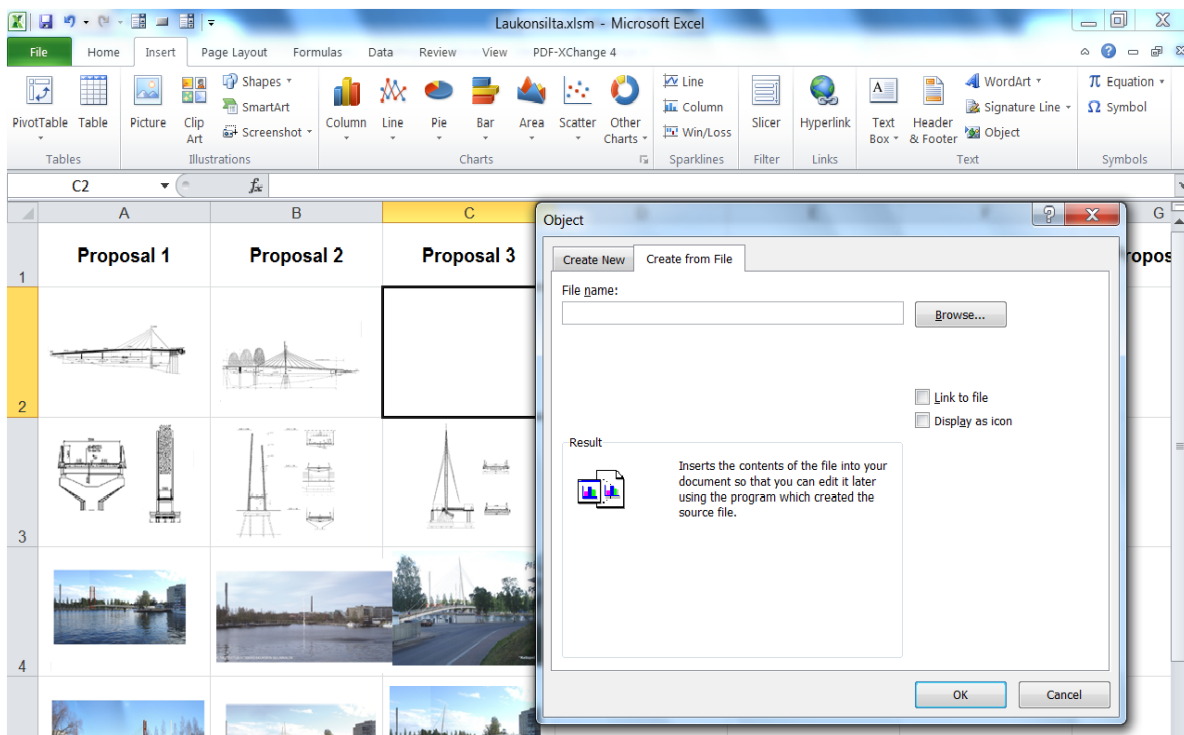
Fig. 23. Clicking "*Insert*" button and then "*Object*".
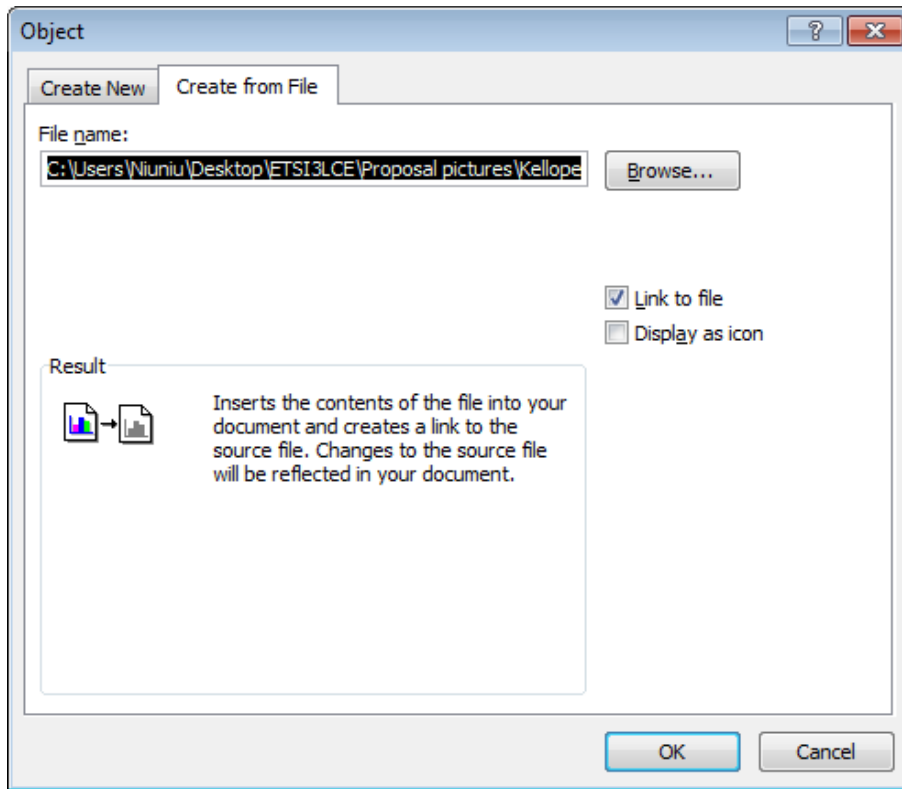
Fig. 24. Activating "*Create from file*" and choosing the file to be inserted.
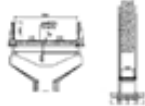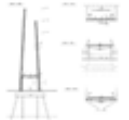
Fig. 25. The "*pdf*" file example (cell B2).

Actions related to Block 2:

Choose *Class Level* relevant to the bridge site by utilising the four aspects (Figs. 26, 27 and 28). The recommended *Class Level* and the corresponding *a-value* are automatically calculated, but they can be changed by the evaluator.
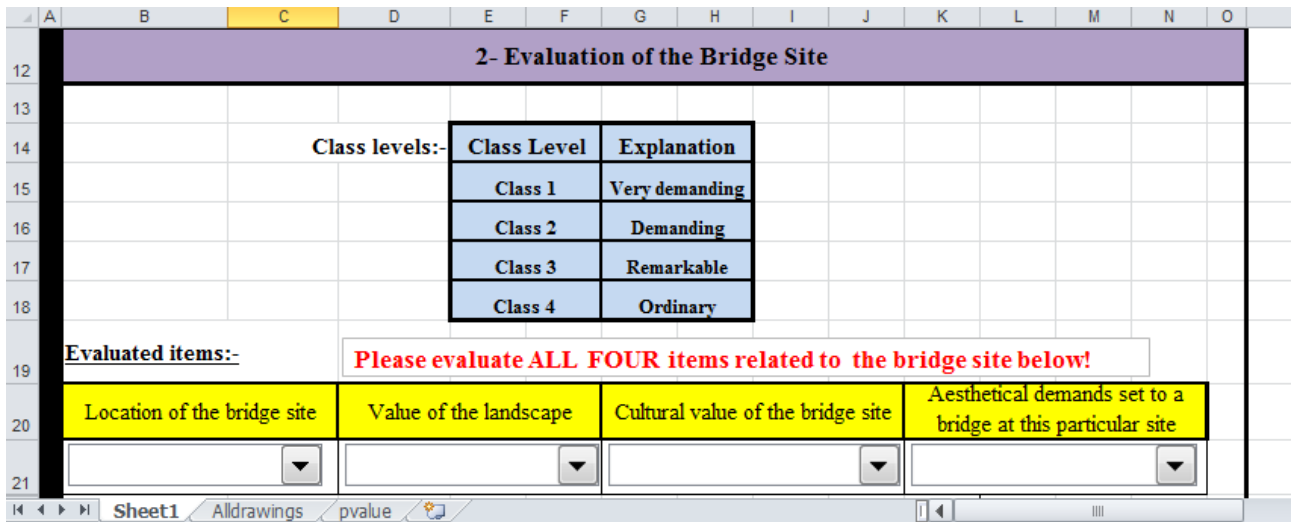
Fig. 26. Choosing *Class Levels*.

In this example calculation, the following *Class Levels* are chosen:

Location of bridge site: 2
Value of the landscape: 1
Cultural value of the bridge site: 2
Aesthetical demands set to a bridge at this particular site: 1
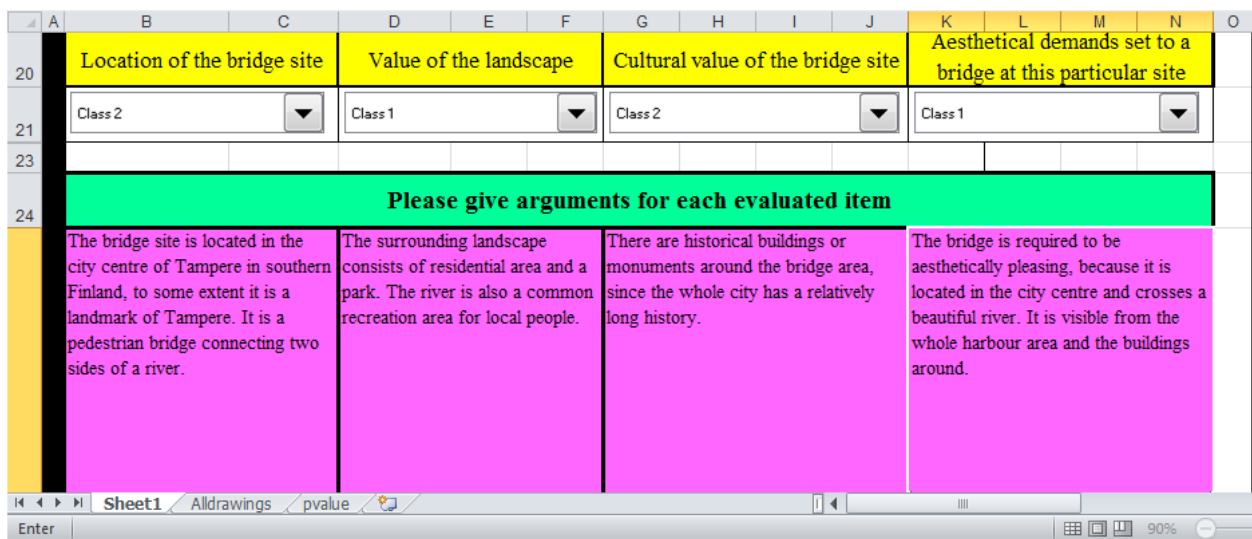
Fig. 27. Giving description of each item.

Thus the recommended *Bridge Site Class* will be "1" as shown in Fig. 28. Correspondingly, the recommended "*a-value*" is "0,4".

Fig. 28. Display of *Bridge Site Class Level* and "*a-value*".

Actions related to Block 3:

Click button "*Click to start to give w-values*". In this example, one item, "*Others*", is added to the basic item list (Fig. 29).
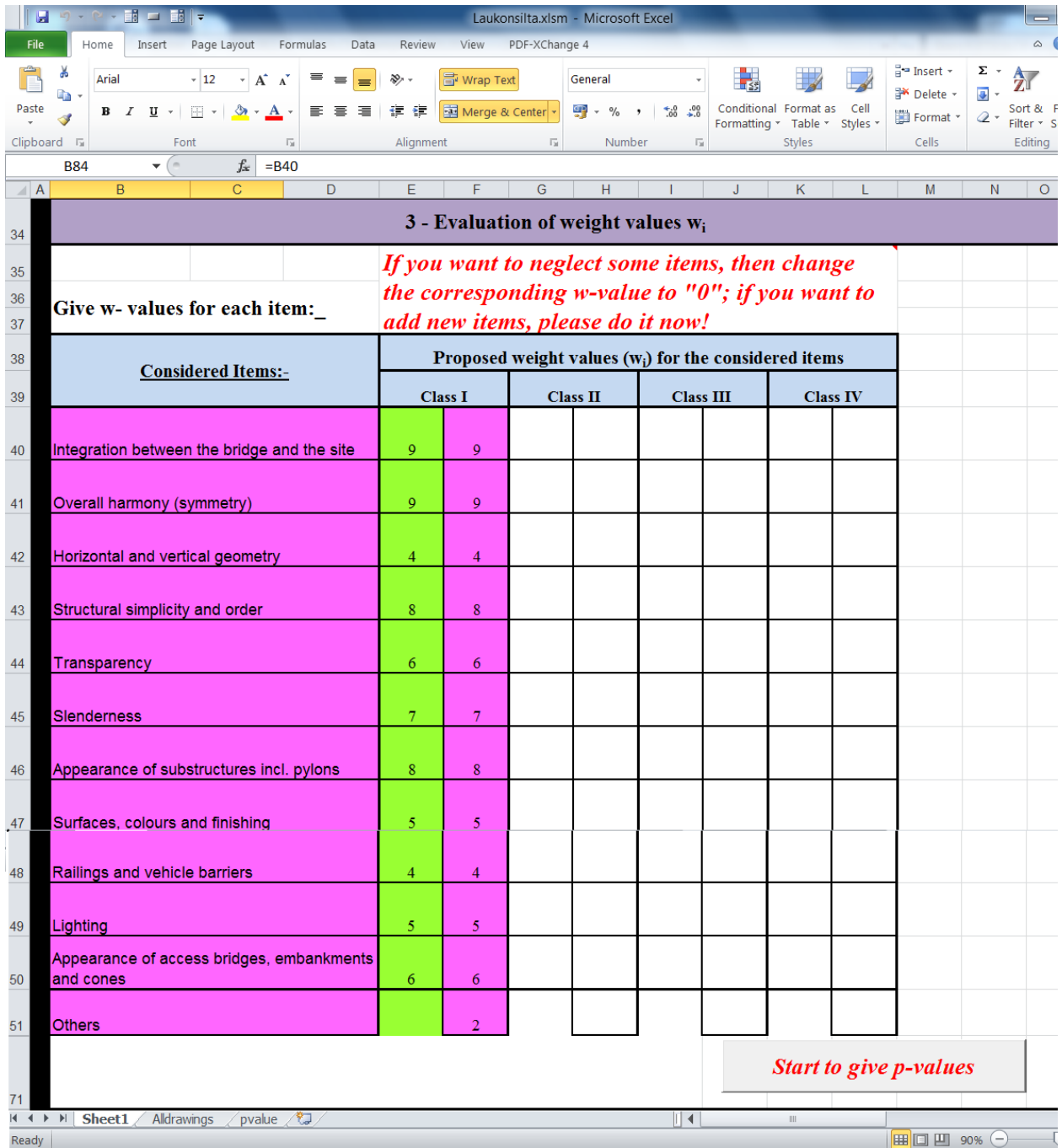
Fig. 29 Giving *w-values* in pink cells.

Give a *w-value* for each item. If the user adds an item, but forgets to give the *w-value* for it, a window will pop up after clicking button "*Start to give w-values*" (Fig. 30).
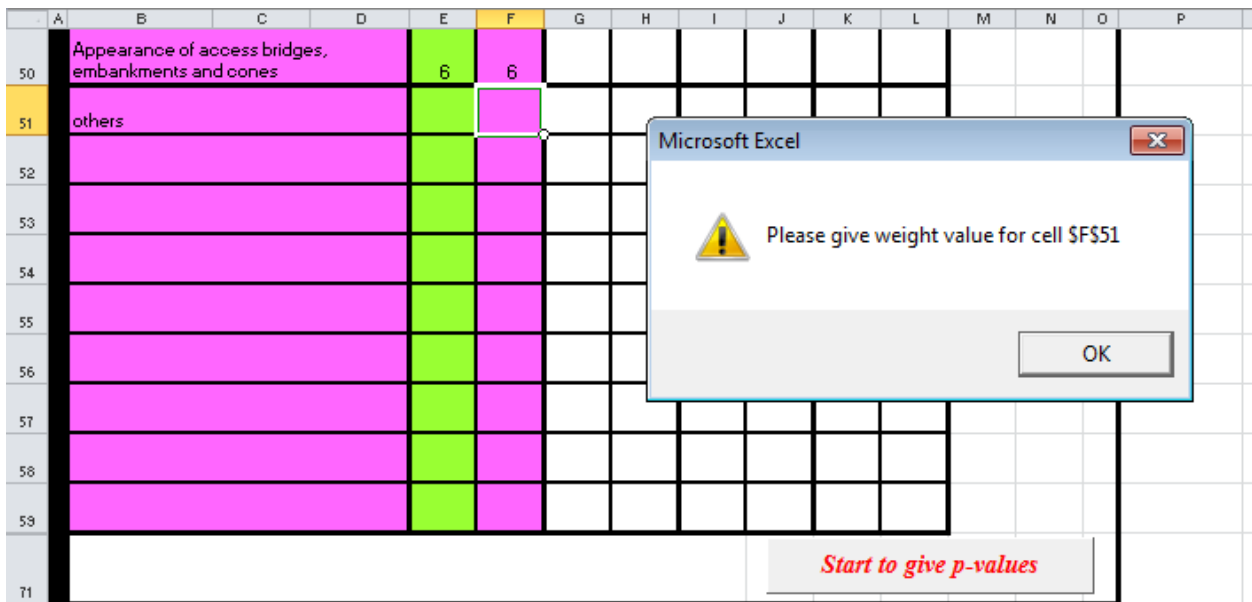
Fig. 30. If there is a missing *w-value*, an alert window will pop up.

After giving the *weight values* for each item, please click the button "S*tart to give p-values*" (Fig. 31).
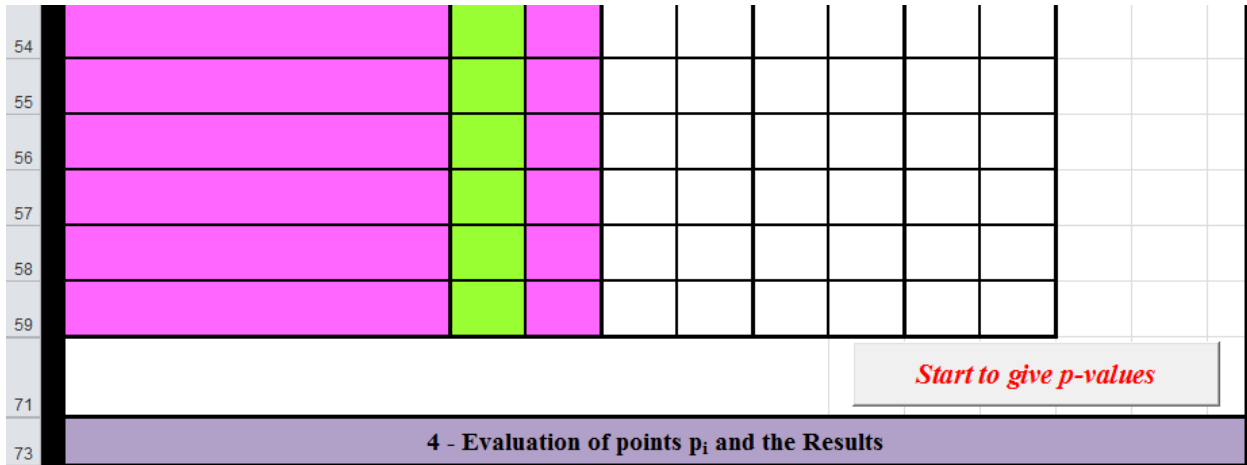
Fig. 31. Clicking the button "*Start to give p-values*"

Actions related to Block 4:

Now the *p-values* related to the different items and proposals, respectively, will be given (Fig. 32). Then the current file's name is changed into "*Laukonsilta*".

Fig. 32. Giving *p-values* for each item in pink cells.

In this step, if the user has inserted pictures into the program, the program provides more convenience for the user. When clicking the picture which the user wants to see, the chosen picture will be enlarged; when clicking another picture, the previous one will be reduced to a suitable size, and the new chosen picture will be enlarged and so on. Also, if the user wants to see all suitable size of pictures, he/she just needs to click any empty *cell* (not an inserted picture) to let them be back. The effect will be like shown in Figs. 33 and 34, respectively.
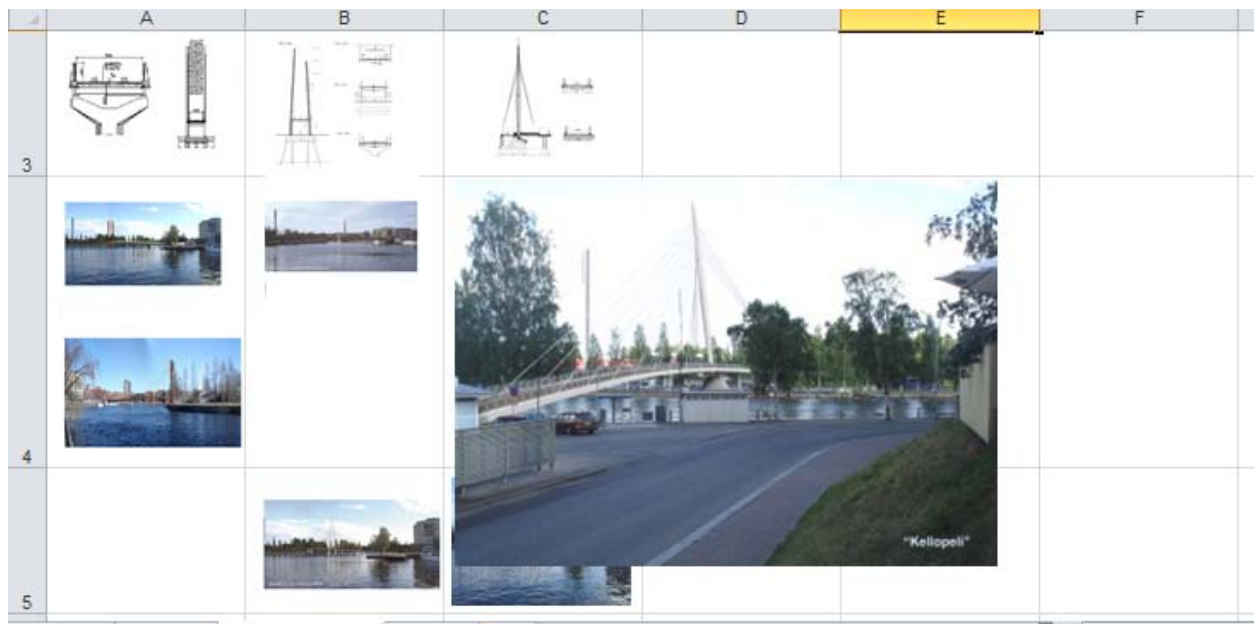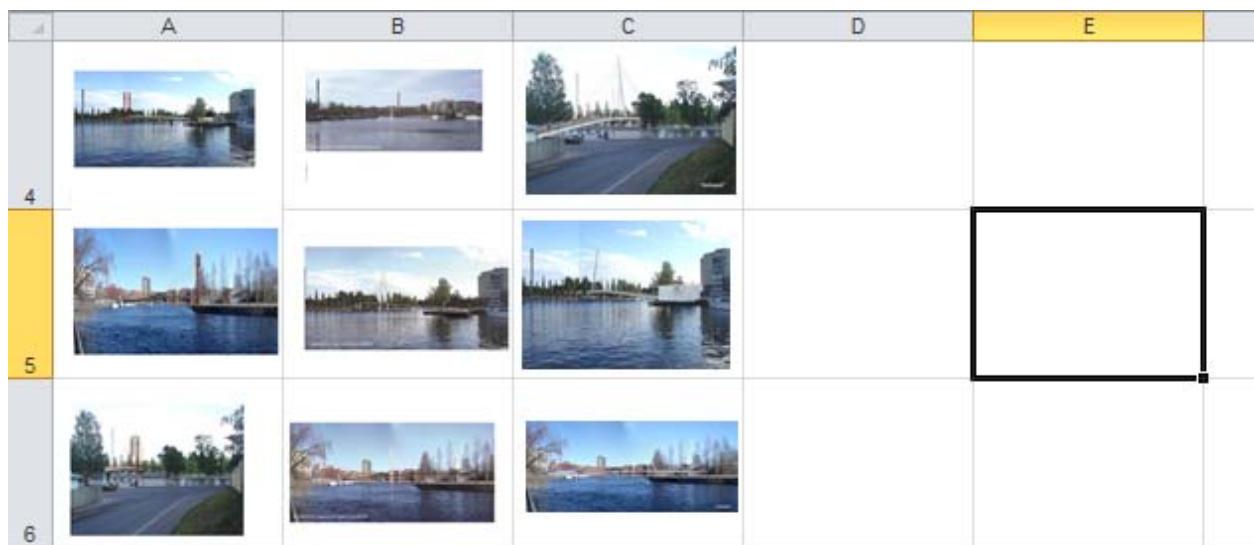
Fig. 33. Clicking the picture to enlarge.

Fig. 34. Activating one empty cell to let the picture be reduced to a suitable size.

After giving all *p-values*, the results will be shown under each *p-value* column (Fig. 35).

Fig. 35. *Relative coefficient k_{rel} of each proposal will be calculated after giving all p-values.*

Please note that if the user inserts a *p-value* outside the range of the five preset values, for example "*3*", then an error message box will pop up (Fig. 36).

Fig. 36. Alert window will pop up, if the *p-value* is given outside the 5 categories.

If the user wants to have a break during evaluation, then button "*Save the present content to continue later*" should be pressed. Then the file will be saved as a new file. The name of the new file is "*Continue---Not finished yet!*" (Fig. 37).
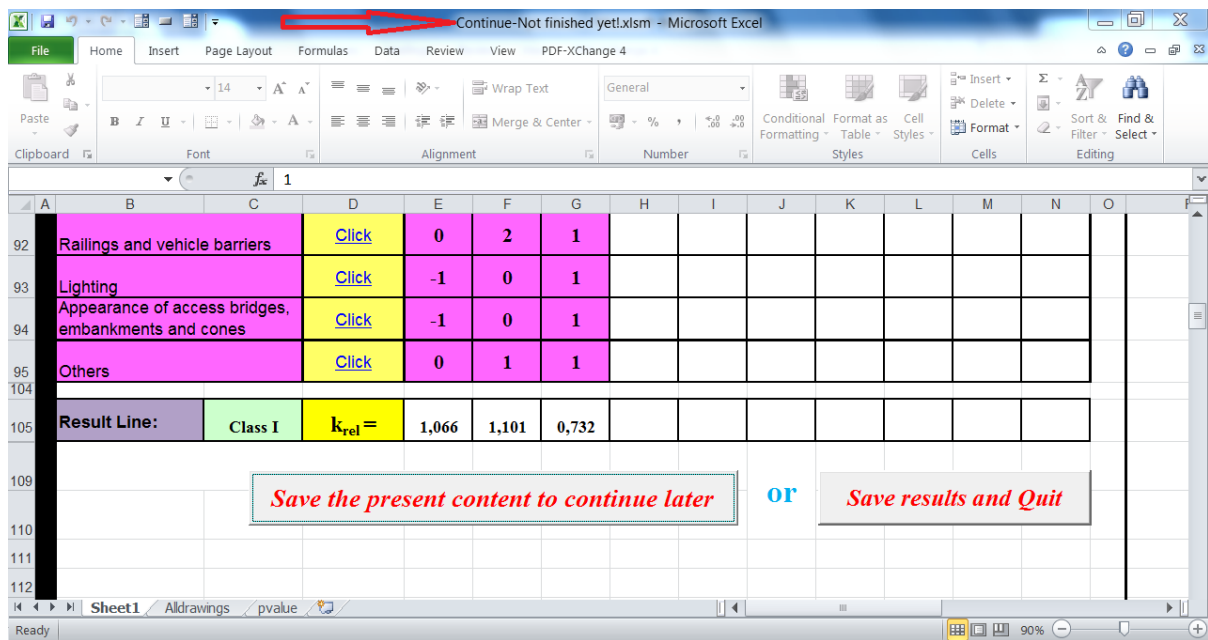
Fig. 37. Clicking the button "*Save the present content to continue later*" for having a break.

To complete the evaluation, click the lower right corner button "*Save results and quit*" to close the program. Consequently, *Block 4* will be copied in the third sheet "*pvalue*" and the sheet's name will be changed as the *user's name* & "*pvalue*". This is done to make comparison with other evaluators' results simple. After that a new Excel file under the current file folder will be created. In the current example the name is "*LaukonsiltaUser1*". Now open this workbook, click button "*Enable content*", and the interface will be like shown in Figs. 38 and 39. Finally, the third sheet's name is "*Userpvalue*".
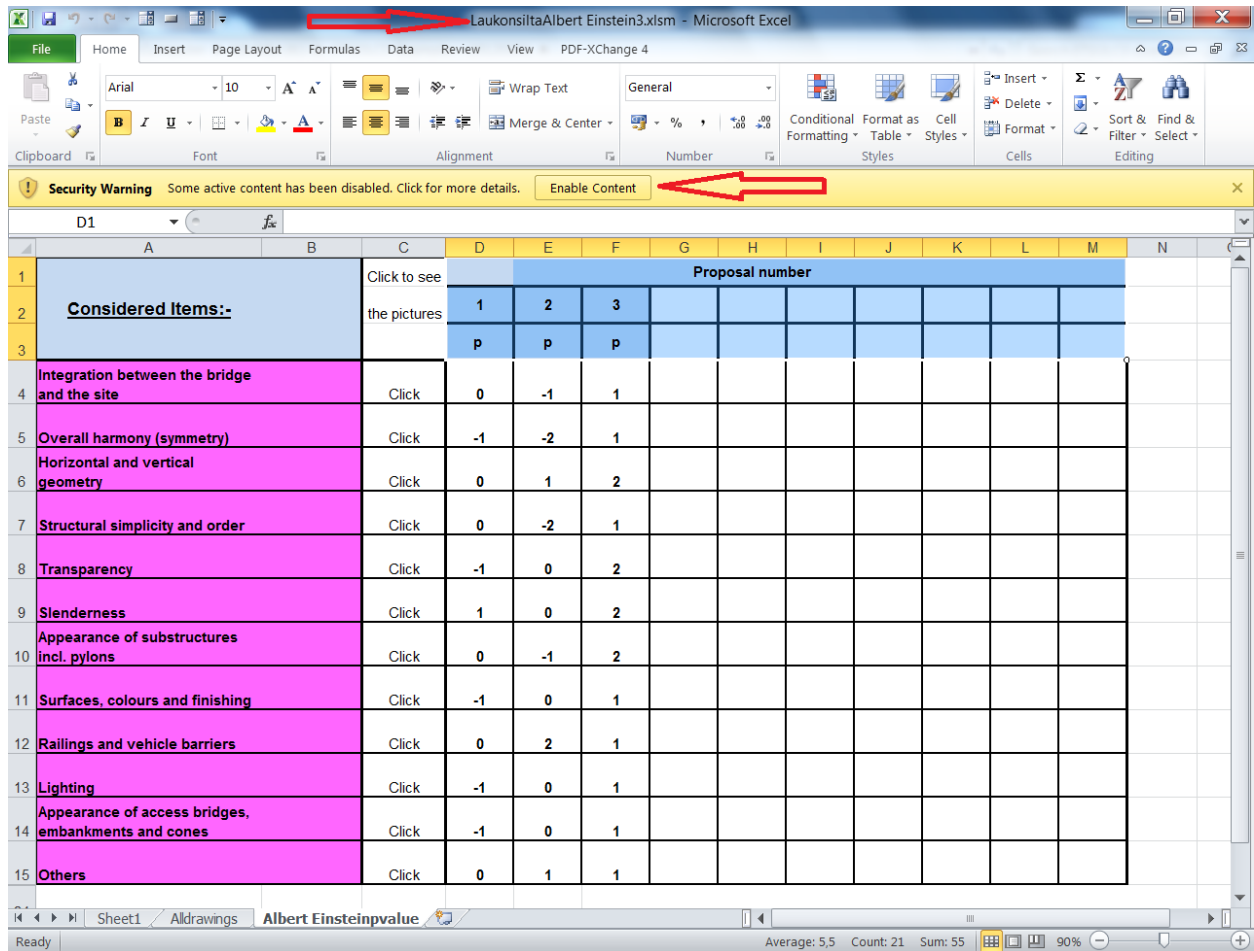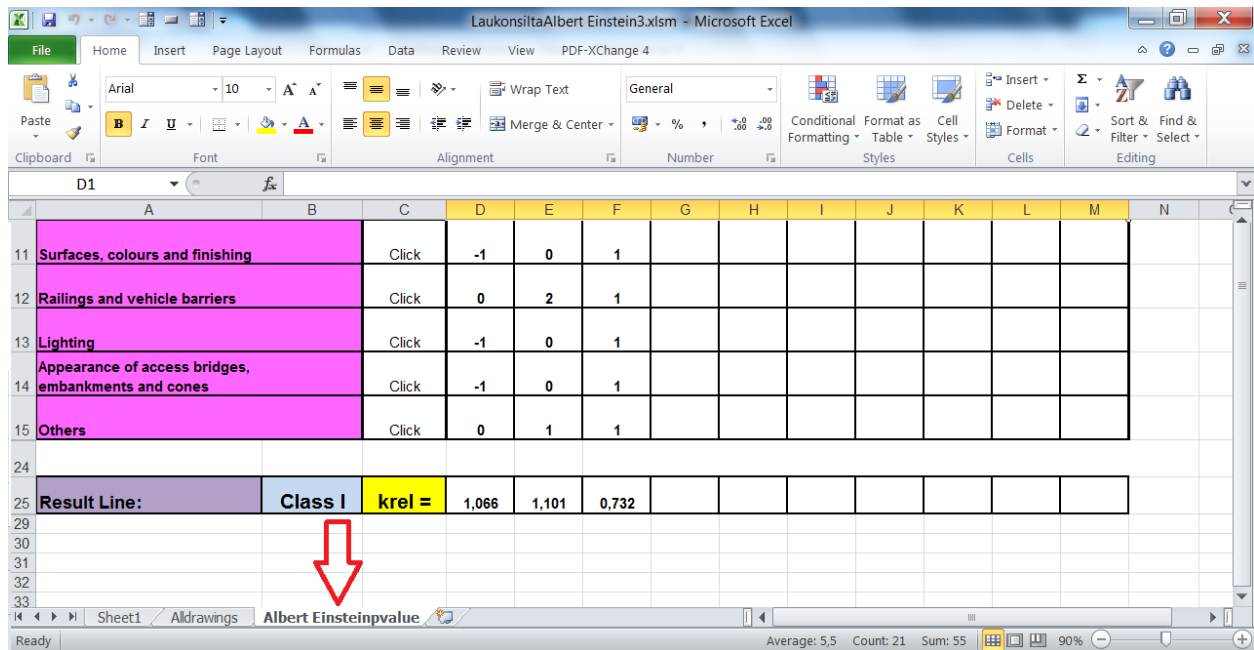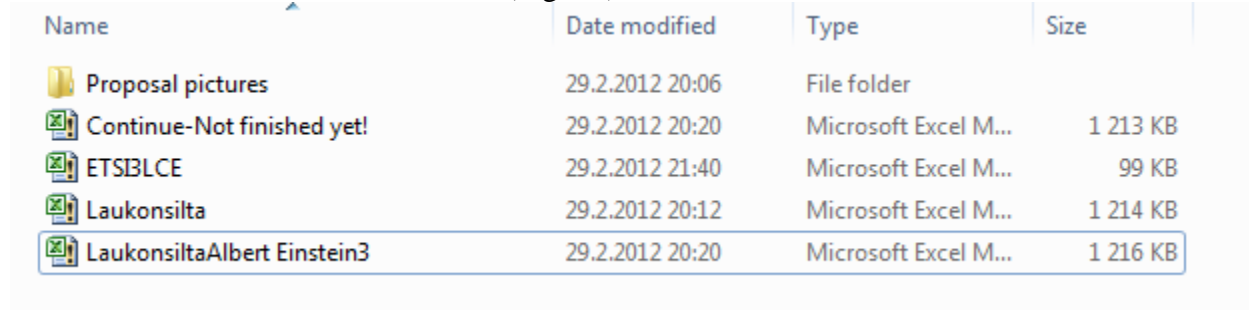
Fig. 38. Clicking "*Enable Content*".

Fig. 39. All *p-values* and k_{rel}-*values* are shown in the third sheet.

Finally, close the workbook and check the file folder. After completing the evaluation, there will be 4 Excel files in the same file folder (Fig. 40).

Name	Date modified	Type	Size
Proposal pictures	29.2.2012 20:06	File folder	
Continue-Not finished yet!	29.2.2012 20:20	Microsoft Excel M...	1 213 KB
ETSI3LCE	29.2.2012 21:40	Microsoft Excel M...	99 KB
Laukonsilta	29.2.2012 20:12	Microsoft Excel M...	1 214 KB
LaukonsiltaAlbert Einstein3	29.2.2012 20:20	Microsoft Excel M...	1 216 KB

Fig. 40. All files in the file folder.

If the user did not press "S*ave the present content to continue later*", then the file folder will have only 3 Excel files without the file "*Continue---Not finished yet!*".

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