THE RISCONA SYSTEM: CONSTRUCTABILITY APPRAISAL THROUGH THE IDENTIFICATION AND ASSESSMENT OF TECHNICAL PROJECT RISKS SOURCES

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IMPLEMENTATION OF CONSTRUCTABILITY AND CPRA

INITATION
- Feasibility study
- Design and construction procurement
- Conceptual planning

EXECUTION
- Procurement of subcontractors (if applicable)
- Continuation of designs
- Start of field operations

DELIVERY
- Finalization of design
- Finalization of field operations
- Project delivery

OPERATION & MAINTENANCE

DE-CONSTRUCTION

- Risk identification
- Risk assessment
- Risk response
- Risk control

- What is constructability and its goal?
- What is construction project risk analysis (CPRA) and its goal?

RESEARCH PROBLEM

- Constructability and CPRA: methodological frameworks utilized in construction management

- **Never been methodologically and computationally integrated in a single construction management framework**

- To tackle this research problem and create a unified framework (constructability assessment through CPRA elements), both unsupervised and supervised machine learning were used

BENEFITS IN TACKLING RESEARCH PROBLEM

- Better cooperation, communication, and dissemination of knowledge
- Better organization and integration of design and construction phases
- More targeted capital investments and implementation of innovative technologies
- Better construction supply chain management
- Better assessment of construction site conditions
- Greater emphasis on health and safety in construction
- More informed deals between owners and contractors
- More informed procurement, management, and administration processes

MODELING OF THE INDEPENDENT VARIABLES (GENERAL RISK SOURCES)

Development and toolification of an original unsupervised machine learning algorithm, which performs semantic processing and clustering of linguistic data organized in lists

applied on an

exhaustive part of the relative literature research (dataset)

See in:

Kifokeris D., and Xenidis Y. Application of linguistic clustering to define sources of risks in technical projects. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering. 2018; **4**(1): 04017031-1 – 04017031-13.

MODELING OF THE INDEPENDENT VARIABLES (GENERAL RISK SOURCES)

Overhead clusters:

- K1 – Technical design and drawings (13 risk sources)
- K2 – Productivity in construction (26)
- K3 – Economy, cost and finances (17)
- K4 – Time and schedule (7)
- K5 – Construction process (12)
- K6 – Environment (5)
- K7 – Site safety and accidents (12)
- K8 – Project management (general) (21)
- K9 – Contracts and procurement (9)
- K10 – Sociopolitical factors (7)

- **129 risk sources in total**

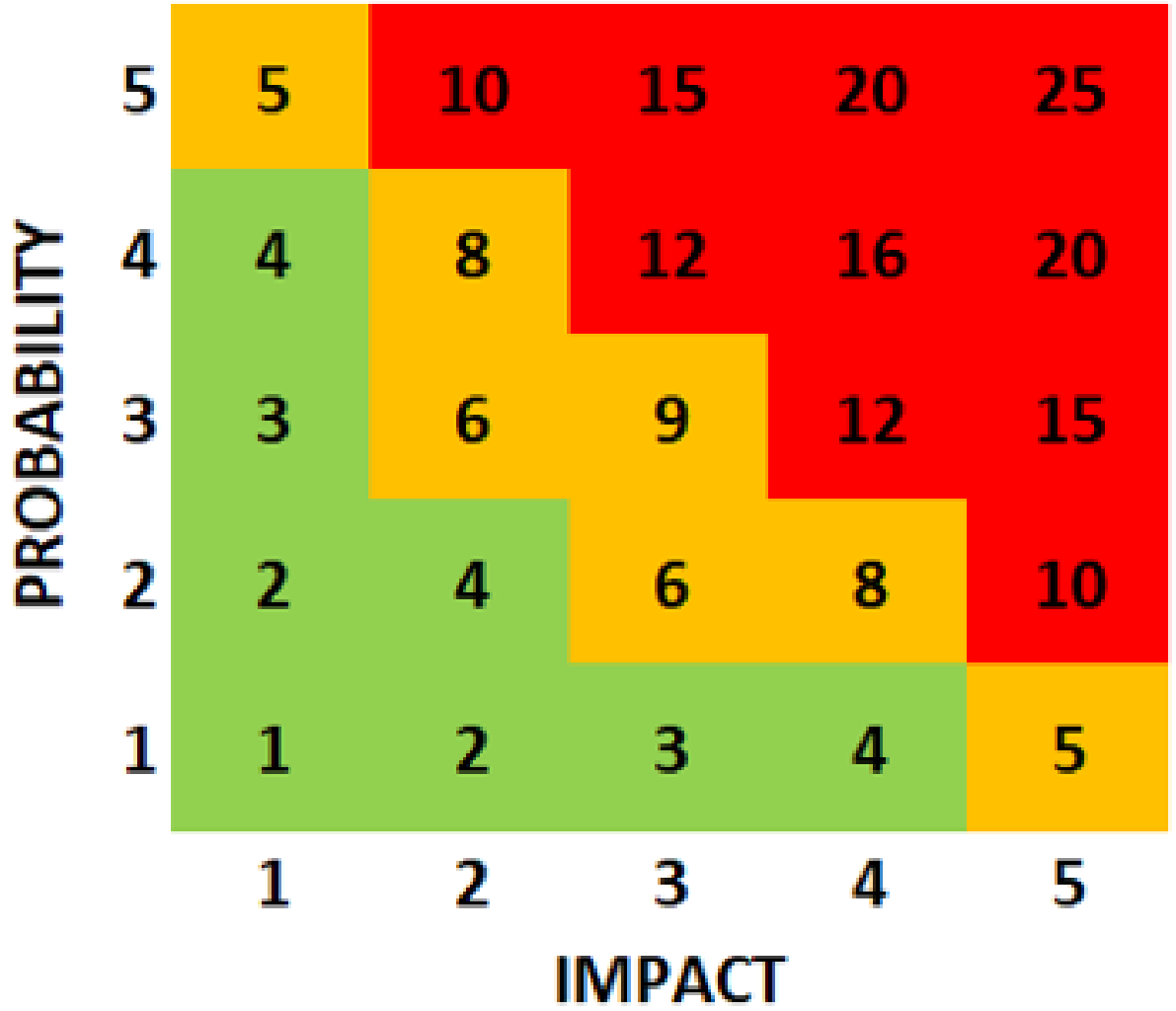
MODELING OF THE INDEPENDENT VARIABLES (GENERAL RISK SOURCES)

General risk sources example (in K2):

- K2.1: Delayed or failed labor, supplier, subcontractor and/or contractor payments
- K2.2: Equipment and/or tools unavailability
- K2.3: Equipment and/or tools delivery/supply delay
- K2.4: Equipment and/or tools failure
- K2.5: Excessive labor overtime
- …
- K2.24: Poor logistics
- K2.25: Spatial clashes among different processes on site
- K2.26: Utility resources shortage on site (e.g. water, fuel, and electricity)

MODELING OF THE INDEPENDENT VARIABLES (GENERAL RISK SOURCES)

- Probability x impact
- 5-point ascending qualitative scales for probability and impact
- Product significance: adaptation of the qualitative CPRA matrix
  - Red: extremely critical
  - Yellow: critical
  - Green: non-critical



CONSTRUCTABILITY CLASSES

- Choice of dependent variables belonging to the field of constructability

- Dependent variables: holistic qualitative constructability labels ("constructable" and "non-constructable»)

  - Constructable: Throughout construction project initiation, execution and delivery, there has been a satisfactory implementation of a constructability program

- Qualitative values (classes):

  - Constructable:1, non-constructable: -1

MODELLING OF INTEGRATION

Development and toolification of an original algorithm using supervised machine learning for the derivation of a classification equation, which will appraise the constructability class of a new construction project when given the values of the identified general risk sources affecting it

which will be trained and validated with the use of

real CPRA- and constructability class-related data from civil engineering projects

MODELLING OF INTEGRATION

1. Modeling as a statistical classification problem
2. Data from *I* real construction projects satisfying certain minimum dataset size constraints
3. Ordering of the data in a *I* x 129 matrix
4. Deploying of regularized stochastic gradient descent non-negative matrix factorization (RSGD-NMF) with missing values
5. Training of soft-margin support vector machines (SVM), with the optimized version of the sequential minimal optimization (OSMO) process, and simultaneous validation with *n*-fold cross-validation
6. Acquiring the classification equation with the best observed accuracy in its predictions, and adapting it for the appraisal of new cases

DATA

- Data collection method: unstructured interviews with experts

- CPRA- and constructability class-related data from *I*=30 civil engineering projects

    - PR1: Biogas electric power plant station

DATA

- PR2: T9-T11 ravine bridge →
- PR3: Prestressed roadway bridge
- PR4-PR10: Electrical lighting projects
- PR11: Design, construction, and delivery of four added classrooms for a municipal primary school
- PR12: Reconstruction of a municipal road axis
- PR13: Sustainable public installations →

DATA

- PR14: Reconstruction and delivery of a road section
- PR15: Design and delivery of a road bypass section
- PR16: Design and construction of a highway section
- PR17: Reconstruction and delivery of a road bypass section
- PR18: Bioclimatic hotel unit
- PR19: Part of a photovoltaic park
- PR20: Hydroelectric power plant station

MTB megaproject:

- PR21: Baggage handling system (BHS)
- PR22: Reinforced concrete structural members
- PR23: Structural steel structural members
- PR24: Electric systems
- PR25: Building envelopes and facades
- PR26: Interior and exterior fit-out
- PR27: Fire, life, and safety (FLS) systems
- PR28: Light equipment transport (LET) systems
- PR29: Assorted mechanical systems
- PR30: Security systems

DATA

ID	Project identity	RSC (%)
PR1	Biogas powerplant	19,380
PR2	Prestressed ravine bridge	2,326
PR3	Prestressed roadway bridge	24,031
PR4	Lighting & structural assets replacement (LSAR) 1	41,860
PR5	LSAR 2	41,860
PR6	Reconstruction of municipal lighting assets	41,860
PR7	LSAR 3	45,736
PR8	LSAR 4	44,186
PR9	Municipal lighting assets repair	43,411
PR10	Municipal road lighting and structural assets replacement	42,636
PR11	Primary school expansion	46,512
PR12	Roadaxis reconstruction	46,512
PR13	Sustainable installations in municipal square	46,512
PR14	Bioclimatic hotel unit	86,047
PR15	Photovoltaic park	86,822
PR16	Hydroelectric powerplant	88,372
PR17	Bypass motorway section	87,597
PR18	Bypass roadway section	85,271
PR19	Roadway section	85,271
PR20	Bypass highway section	85,271
PR21	ATB – Baggage handling systems	53,488
PR22	ATB – Reinforced concrete members	34,884
PR23	ATB – Structural steel members	59,690
PR24	ATB –Electrical systems installations	40,310
PR25	ATB – Building envelopes and facades	64,341
PR26	ATB – Interior and exterior fit-out	67,442
PR27	ATB – Fire, life, and safety systems installations	45,736
PR28	ATB – Light equipment transfer systems installations	38,760
PR29	ATB – Assorted mechanical systems installations	42,636
PR30	ATB – Security systems installations	38,760
General		52,584

- Contextual and linguistic correlation with 129 general risk sources → on a 0-3 qualitative scale
- All real risk sources correlated one-to-one with respective general risk sources, with a degree of 2 or 3 → **in practice, risk sources were identified and assessed, instead of risks themselves!**
- Generally, non-constructable projects → severe CPRAs
- 13 constructable and 17 non-constructable projects

More in upcoming journal paper:

Kifokeris, D., and Xenidis, Y. An analysis of the impartial implementation in practice of risk identification in technical projects. ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems. 2019; **In press.**

DEPLOYMENT OF WEKA AND RESULTS

Explanation of results after solving for k_{opt}=5

Classification equation results	Real class		Predicted class		Confidence level
0,930961347152737	Constructable	1	Constructable	1	93,096%
1,12021447941773	Constructable	1	Constructable	1	100%
-0,999943984787055	Non-constructable	-1	Non-constructable	-1	99,994%
-1,09099024874888	Non-constructable	-1	Non-constructable	-1	100%
-1,09073114459136	Non-constructable	-1	Non-constructable	-1	100%
-0,990432423175803	Non-constructable	-1	Non-constructable	-1	99,043%
-0,981601855202267	Non-constructable	-1	Non-constructable	-1	98,160%
-0,961369942011749	Non-constructable	-1	Non-constructable	-1	96,137%
-0,995350546959907	Constructable	1	Non-constructable	-1	99,535%
-0,9827830852474	Constructable	1	Non-constructable	-1	98,278%
-1,03739557045505	Non-constructable	-1	Non-constructable	-1	100%
-0,998893830767 39	Non-constructable	-1	Non-constructable	-1	99,889%
-1,31702188932952	Non-constructable	-1	Non-constructable	-1	100%
-0,122190686354803	Non-constructable	-1	Non-constructable	-1	12,219%
0,664884362967404	Constructable	1	Constructable	1	66,488%
-0,999096864220797	Non-constructable	-1	Non-constructable	-1	99,91%
0,4767783					
1,000234					
1,273508					
1,127442					
-0,280219812983305	Constructable	1	Non-constructable	-1	28,022%
-1,00063939517003	Non-constructable	-1	Non-constructable	-1	100%
-0,914677432638896	Non-constructable	-1	Non-constructable	-1	91,468%
0,279204690233528	Constructable	1	Constructable	1	27,921%
-1,15030331760894	Non-constructable	-1	Non-constructable	-1	100%
-0,768677579526154	Non-constructable	-1	Non-constructable	-1	76,868%
-0,347062161638947	Non-constructable	-1	Non-constructable	-1	34,706%
-0,502540855550232	Constructable	1	Non-constructable	-1	50,254%
0,0107501682079711	Constructable	1	Constructable	1	1,075%
-0,500007675244237	Non-constructable	-1	Non-constructable	-1	50%

Legend: Correct classification / False classification

1,12021447941773	Constructable	1	Constructable	1	100%
-0,999943984787055	Non-constructable	-1	Non-constructable	-1	99,994%

DEPLOYMENT OF WEKA AND RESULTS

Final classification equation that predicts the constructability class of a new construction project, when given the identified and assessed general risk sources affecting it:

$$CON = -(2,028\frac{\mathbf{LF}_{1,1} - (3,5e-16)}{1,055} + 0,727\frac{\mathbf{LF}_{1,2} - (2,2e-05)}{0,891} + 0,746\frac{\mathbf{LF}_{1,3} - (2,2e-05)}{0,782} + 0,263\frac{\mathbf{LF}_{1,4} - (7,3e-14)}{0,833} + 1,536\frac{\mathbf{LF}_{1,5} - (3,5e-16)}{0,776}) + 1,622$$

where the user's new LF are derived from the user's RM^{new} through:

$$\mathbf{LF}_{1,k}^{new} = \mathbf{LF}_{1,k}^{new} \cdot \frac{\sum_{j\in[1]} \mathbf{RSF}_{k,j}\mathbf{RM}_{1,j}^{new}}{\sum_{j\in[1]}\left(\mathbf{RSF}_{k,j}\sum_{k=1}^{5}\mathbf{LF}_{1,k}^{new}\mathbf{RSF}_{k,j} + \lambda_{LF}\mathbf{LF}_{1,k}^{new}\right)}$$

$$\forall k = \{1,2,...,5\}$$

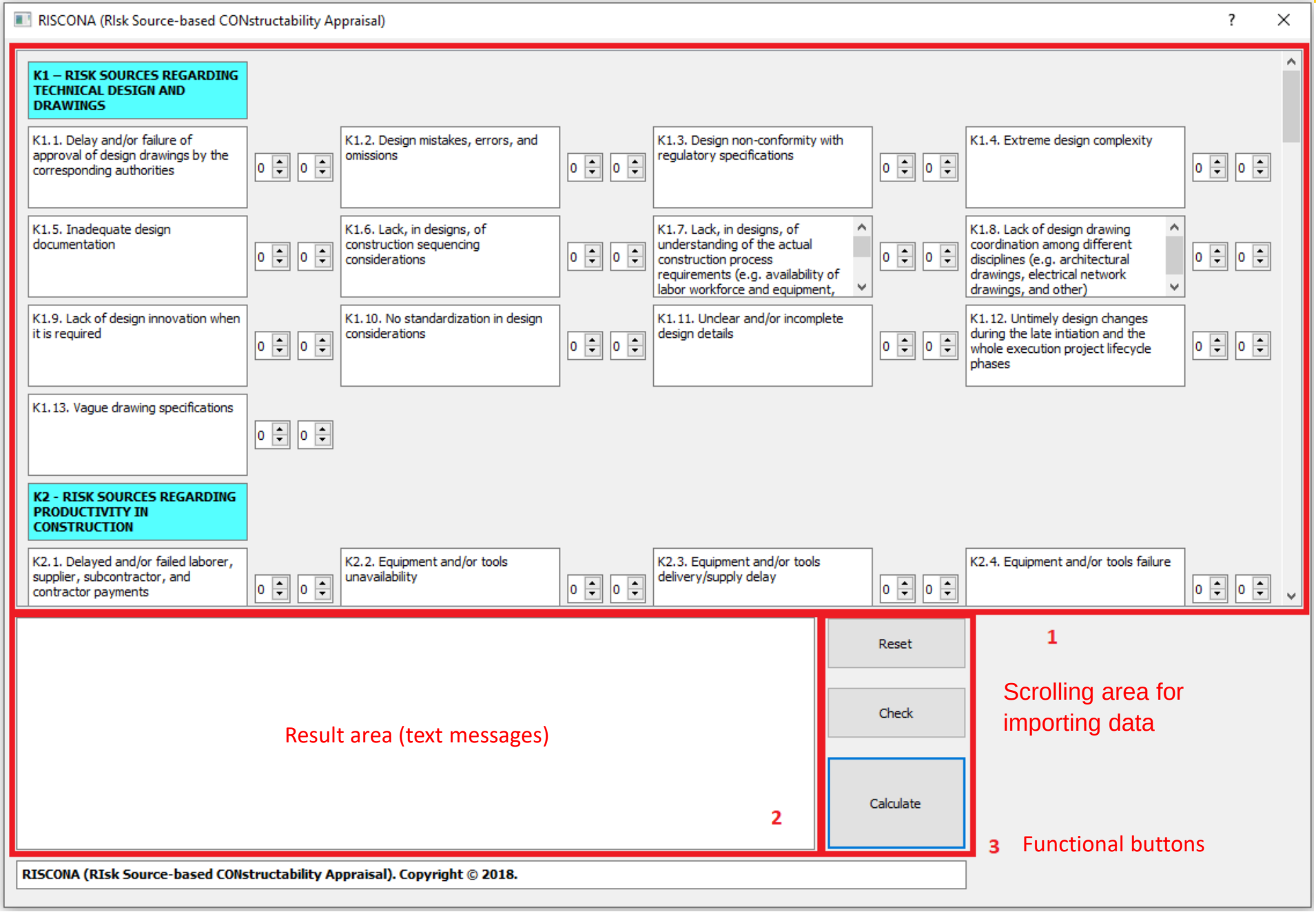
$$j = \{1,2,...,129\}$$

DEPLOYMENT OF WEKA AND RESULTS

- If $CON \geq 1 \rightarrow$ constructable with 100% confidence level
- If $CON \in (0,1) \rightarrow$ constructable with confidence level $|CON|(\%)$
- If $CON \leq -1 \rightarrow$ non-constructable with 100% confidence level
- If $CON \in (-1,0) \rightarrow$ non-constructable with confidence level $|CON|(\%)$
- If $CON = 0 \rightarrow$ the constructability class cannot be predicted with any confidence level

THE RISCONA PROTOTYPE APPLICATION

- RISCONA (*RIsk Source-based CONstructability Appraisal*)
  - **Dedicated graphical user interface (GUI)** operating in Python (Anaconda)
  - **Implementation of the first two steps of the expanded CPRA** → the user inserts the values of the *probability* and *impact* (ascending 5-point scales) of the 129 general risk sources for construction projects
  - All the calculations of the model are then performed in the background
  - The user gets the **constructability class of the new construction project**

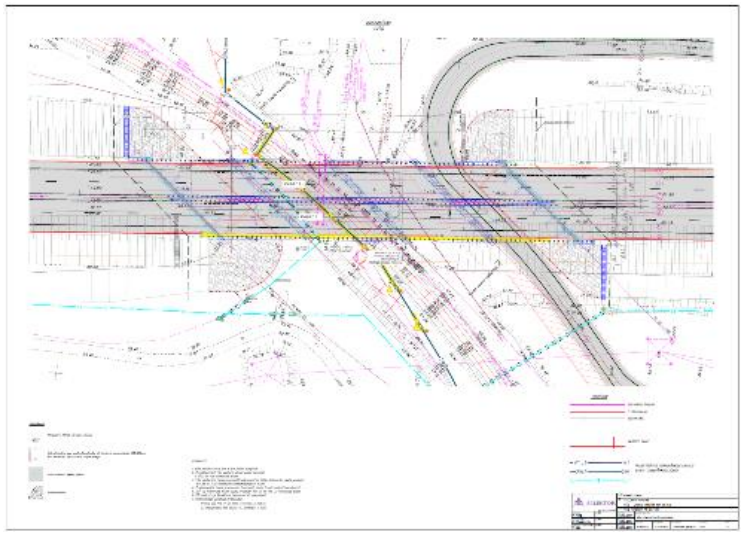


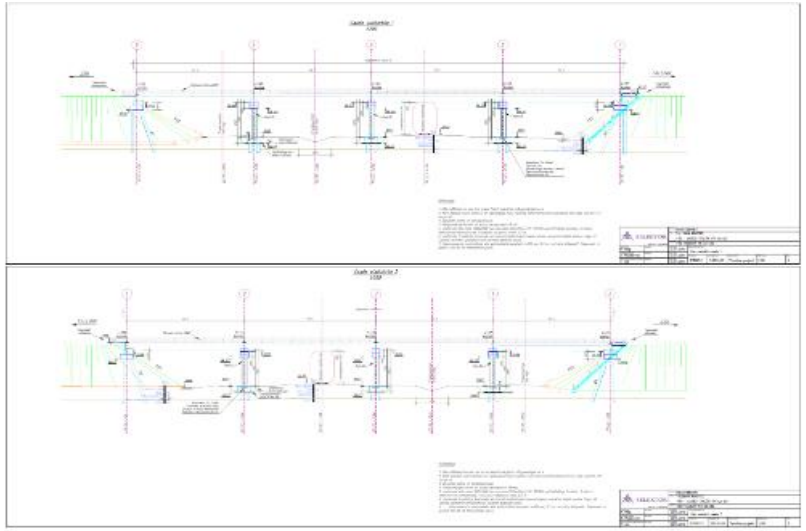
The RISCONA prototype application

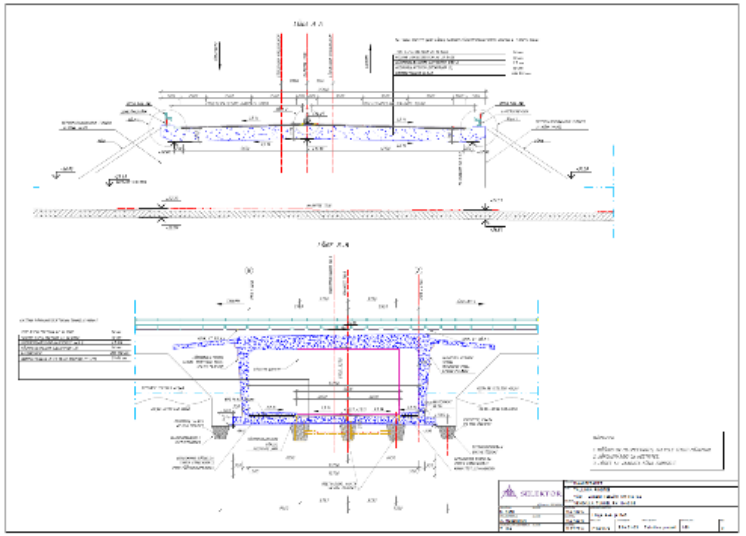
Command prompt results

THE RISCONA PROTOTYPE APPLICATION

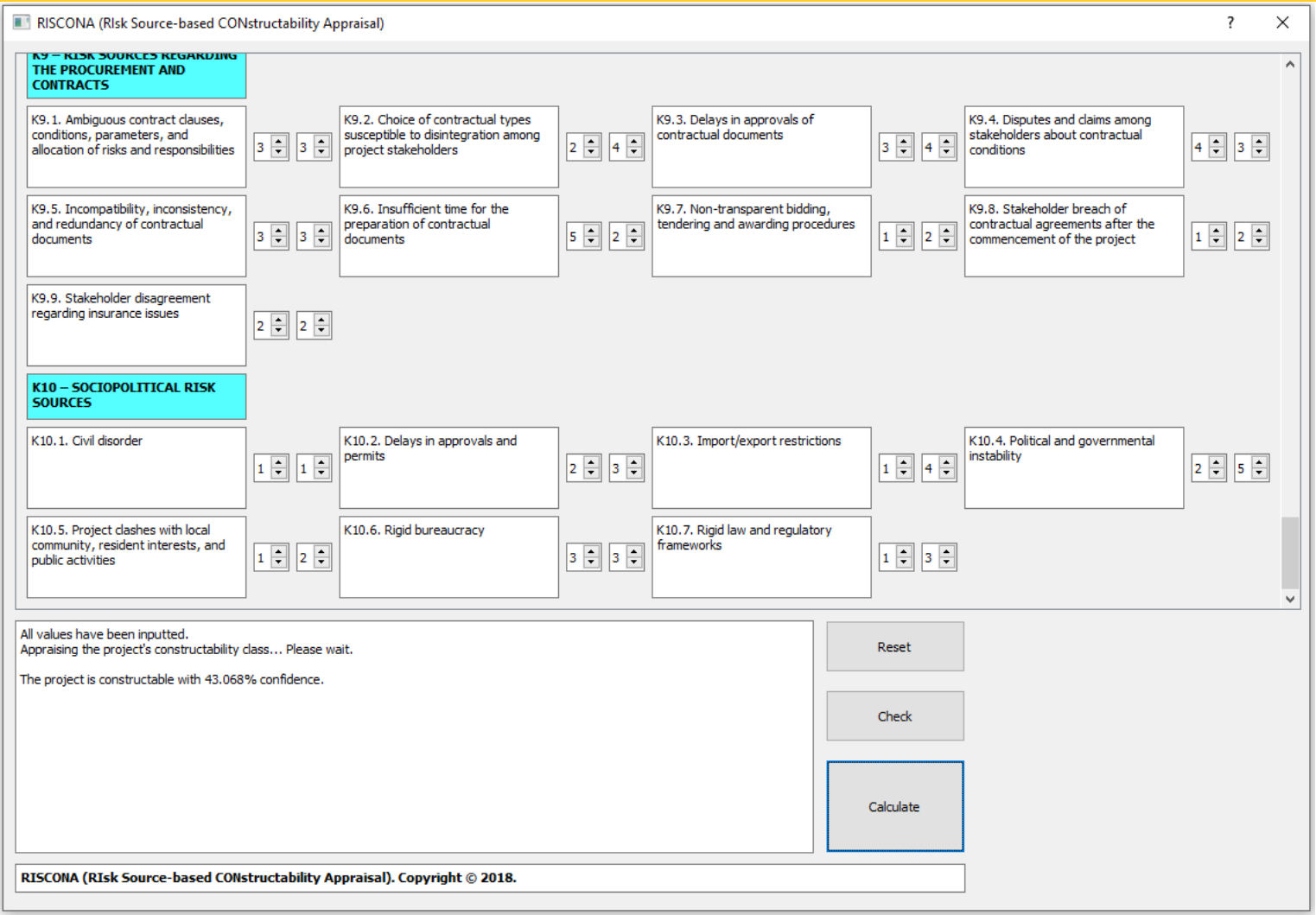
- Use and verification of RISCONA (and the integration model) in a case study
  - Case stydy: Design and construction of an overpass road bridge in Estonia (*Estonian Road Administration, Estonia*)







THE RISCONA PROTOTYPE APPLICATION



General risk sources	CS			
	Probability	Consequence	Product	Normalized product
K1.1	2	2	4	0,16
K1.2	3	2	6	0,24
K1.3	3	1	3	0,12
K1.4	3	3	9	0,36
K1.5	3	3	9	0,36
…	…	…	…	…
K10.1	1	1	1	0,04
K10.2	2	3	6	0,24
K10.3	1	4	4	0,16
K10.4	2	5	10	0,4
K10.5	1	2	2	0,08
K10.6	3	3	9	0,36
K10.7	1	3	3	0,12

- Constructable with 43.068% confidence

THE RISCONA PROTOTYPE APPLICATION

- Evaluation:
  - RISCONA is a **simple and easy-to-use tool** that can aid in construction management decision-making
  - The "translation" of the risk source values into constructability classes was well-received
  - **Satisfactory description of reality**
  - List of 129 general risk sources: quite inclusive and suitable as a stepping stone for the expansion of CPRAs

CONCLUSION (IN A SENTENCE)

The contribution of this work is that it provides – **for the first time** – a civil engineer (and/or construction manager) with the capability of executing an **understandable and fully defined analysis of risk sources**, so that through it a **very good constructability assessment** of the currently developed project can be obtained.

DIMOSTHENIS KIFOKERIS, YIANNIS XENIDIS – THE RISCONA SYSTEM

THANK YOU FOR YOUR ATTENTION!