# BIM-enabled Learning Environment (BLE)
# Course Manual:
# Pilot Module 3 – Risk Management

**By: Tallinn University of Technology, Estonia**

**May 2023**

Co-funded by the Erasmus+ Programme of the European Union

## PROJECT DELIVERABLE DETAILS

| | |
|---|---|
| **Project Type** | Erasmus+ KA203 Strategic Partnership |
| **Project Acronym** | BENEDICT |
| **Grant Agreement Number** | 2020-1-EE01-KA203-077993 |
| **Project Full Title** | BIM-enabled Learning Environment for Digital Construction |
| **Intellectual Output** | O5 User Guidance Materials |
| **Output Lead Organisation** | TalTech – Tallinn University of Technology |
| **Dissemination level** | Final version to be public |
| **Due date for deliverable** | January 2023 |

## DOCUMENT VERSION HISTORY

| Version | Date | Comments |
|---|---|---|
| 0 | 30th May 2023 | First draft |
| 1 | 4th July 2023 | Final version (for translation and publication) |
| | | |
| | | |

# TABLE OF CONTENTS

1 General Introduction to Course Manuals ..... 5
1.1 Background and purpose ..... 5
1.2 Objectives and scope of the pilot modules ..... 5
1.3 Structure of the Course Manual ..... 6
2 Introduction to the Risk Management Module ..... 7
3 Learning Outcomes ..... 7
4 Module Structure ..... 8
4.1 Scope of the module ..... 8
4.2 Module delivery process ..... 8
5 Teaching Methods ..... 9
6 Assessment Procedures ..... 9
7 Teaching Materials ..... 10
7.1 Introductory Lecture ..... 10
7.2 Workshop 1 ..... 10
7.3 Workshop 2 ..... 11
7.4 Workshop 3 ..... 11
7.5 Assessment ..... 11
Appendix A – Presentation Slides ..... 12
A.1. Introductory Lecture Slides ..... 12
A.2. Workshop 1 Mini-lecture Slides ..... 29
A.3. Workshop 2 Mini-lecture Slides ..... 33
A.4. Workshop 3 Mini-lecture Slides ..... 38
Appendix B – Activity Materials ..... 45
B.1. Workshop 1 Qualitative Risk Management Exercise and Template ..... 45
B.2. Workshop 2 Quantitative Risk Management Exercise Materials ..... 48
B.3. Workshop 3 Risk Management Documentation Exercise Materials ..... 51
Appendix C – Assessment Materials ..... 53
C.1. Risk Management Course - Individual reflection questions ..... 54

# 1 General Introduction to Course Manuals

## 1.1 Background and purpose

Digitalization is transforming the real estate and construction (REC) sector and a key feature of this transformation is Building Information Modelling (BIM). BIM refers to the digital representation of buildings and construction operations and it offers opportunities for improving education and training through data rich virtual environments in which project-based learning experiences can be designed and delivered. This could fundamentally change the education and training of REC sector professionals from managers to site workers.

The BIM-enabled Learning Environment for Digital Construction (Benedict) project is an Erasmus+ Strategic Partnership between Tallinn University of Technology (TalTech), Tampere University (TAU) and the University of Bologna (UNIBO) aimed at leveraging the possibilities of BIM to enhance education and training by developing an innovative, BIM-enabled Learning Environment (BLE). The BLE platform is an integrated Moodle – DiStellar installation that is publicly available at www.bim-enabled-learning.com .

To demonstrate the application of the BLE in learning, the project team has developed a series of three pilot course modules that apply BIM-enabled learning using the BLE. These are:
1) Design Management - lead by TAU;
2) Risk Management - lead by TalTech;
3) Time Management - lead by UNIBO.

As the BLE is a novel and innovative concept, it is important to provide clear and easy-to-use guidance materials for all potential users. The purpose of this course manual (which is part of a set of 3 manuals – 1 manual for each module) is to ensure that interested stakeholders (programme directors, teachers, trainers, students, trainees) have access to the full details of the pilot modules so that they can:

- make use of the modules directly, or,
- adapt them to suit their own purposes, or,
- use them as templates for creating their own modules, or,
- simply gain ideas and inspiration for their own, related projects.

## 1.2 Objectives and scope of the pilot modules

The pilot modules were designed to demonstrate how teachers and students of construction-related disciplines can leverage Building Information Modelling (BIM) in their learning activities for:

• Visualizing the project
• Simulating building scenarios
• Analyzing and designing buildings and building elements
• Identifying conflicts between systems
• Developing estimates, e.g. for materials quantities (bill of quantities BOQ), activity durations (time schedules), costs (budget)
• Design and build decisions
• Project and construction management applications.

All partners were actively involved in the design, development and validation of the learning activities. A comprehensive evaluation tool to assess the modules was developed and applied by the Centre for Engineering Pedagogy at TalTech. (The resulting evaluation and assessment toolbox for BIM-enabled learning has been separately reported). The pilot modules were demonstrated to stakeholders at the Benedict project's 2nd Multiplier Event that was held in Tallinn in June 2022 and were directly used to teach students during the 2022/23 academic year in all 3 partner universities.

## 1.3 Structure of the Course Manual

All course manuals follow the same basic structure: in section 2 a brief introduction to the subject of the particular pilot module and why it was chosen is given. Section 3 describes the intended learning outcomes and section 4 presents the structure and delivery process for the module. Teaching methods and assessment procedures are described in sections 5 and 6 respectively, and, an overview of the teaching materials is provided in section 7. All the actual slides, assessment forms, assignment templates, etc. are attached to the manual as appendices.

# 2 Introduction to the Risk Management Module

Risk Management was chosen as a suitable topic to include in the pilot modules because, while it is not commonly associated with typical, current BIM workflows in industry, it is highly dependent on project contextual understanding and historical project data which can and should be enhanced through the use of BIM. Therefore, the risk management topic offers an opportunity to explore the explanatory power of BIM (primarily through visualization of the project) and for systematically structuring historical project data so that it is readily available for analysis. From the point of view of BIM-enabled learning, risk management, particularly qualitative aspects of risk identification and analysis, benefit from techniques that allow students to efficiently understand (complex) construction projects through visualization. For quantitative risk analysis, on the other hand, the benefits of BIM relate to the accessibility of systematically structured project data and, BIM-enabled learning must allow efficient data extraction (and, ideally, data input) from (and to) BIM models.
As with the other pilot module topics, risk management is closely bound with the project development process and is also best carried out in collaborative, multidisciplinary groups. Thus, the pilot module was arranged around a series of risk management workshops carried out by students in groups.

The course activities are undertaken in the form of group work. This is beneficial because the risk management process is best carried out by diverse groups with complimentary perspectives and experience. It also enables students to discuss their work in groups and learn from each other.

# 3 Learning Outcomes

On completion of the risk management module, it is expected that the student:

- is able to describe the process, tools and techniques of project risk management (in a BIM-based work process).
- understands risk and project risk management concepts.
- understands the BIM work flow with respect to risk management and more generally.
- is able to apply the project risk management process, tools and techniques in a realistic project scenario.
- is able to decompose the scenario into constituent elements and analyse risks associated with each element.
- is able to evaluate the identified risks in terms of their relative significance and recommend appropriate mitigation actions.
- is able to critically analyse and reconsider the risk management process and the industrial work flow in order to recommend improvements.

# 4 Module Structure

## 4.1 Scope of the module

The module focuses on the project risk management process (including both qualitative and quantitative risk analysis) using real project data within a BIM-based work flow.
Topics include:

- Terms and concepts of risk management
- The process of risk management in projects
- Tools and techniques for achieving each stage of the risk management process
- Project risk management standards
- Risk management within the BIM work flow;
- Practical risk management on the basis of real project data;
- How risk and risk management link to wider ideas in construction, science and society.

## 4.2 Module delivery process

The module consists of:

1. An introductory lecture – focus on risk management principles and process
2. Three risk management workshops:
   I. At the project preparation stage – focus on qualitative risk analysis
   II. At the pre-construction stage – focus on quantitative risk analysis
   III. At the construction completion stage – focus on documentation and lesson-learning

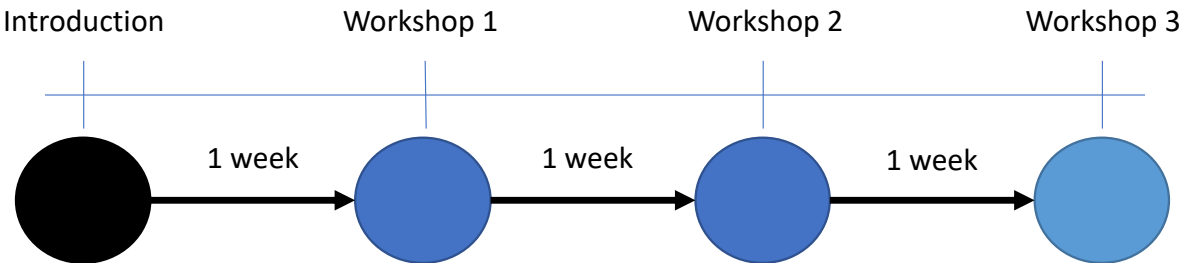



*Figure 4.1 Timeline for the Risk Management module delivery*

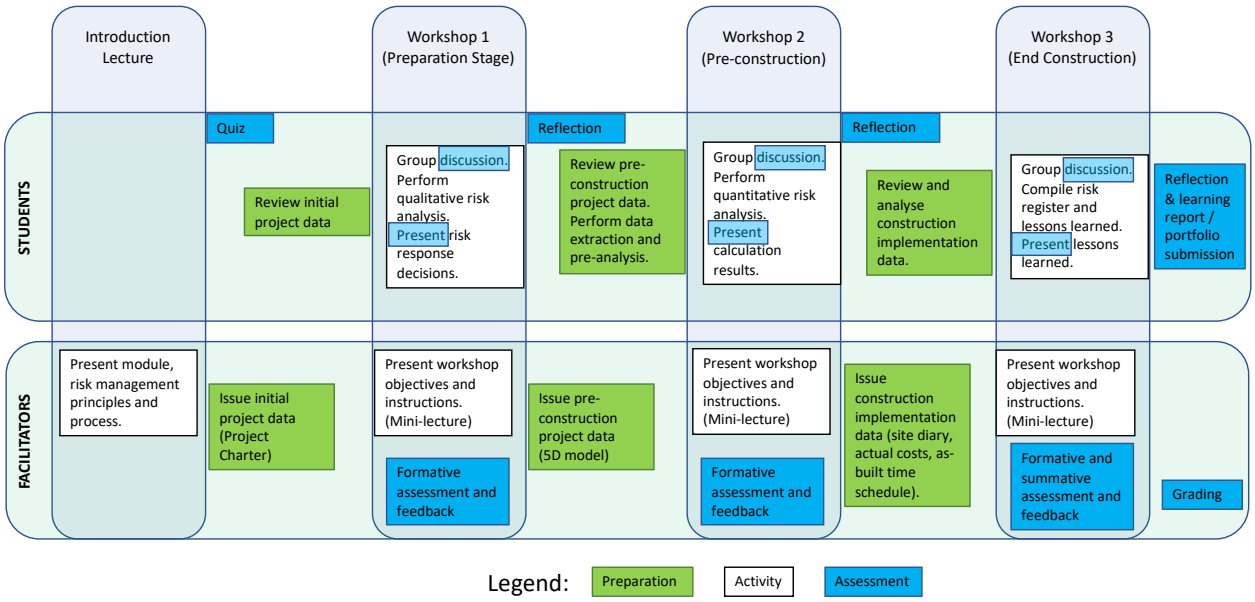



*Figure 4.2 Process map for Risk Management module delivery*

# 5 Teaching Methods

Learning takes place in groups and follows the roles of typical industry stakeholders (e.g. Client, Designers, Contractors, Regulatory authorities, etc.). The mode of teaching is online with a mixture of synchronous activities (e.g. presentations and discussions) and asynchronous activities (preparatory work, individual contributions to groupwork, etc.). A social constructivist model of learning is followed which acknowledges the (often considerable) prior knowledge and experience of the students in order to both build on it and also leverage it to enhance the learning of fellow students. Knowledge is considered to be socially constructed, hence the emphasis on group work and discussion. This does not, however, exclude the use of behaviourist learning approaches and individual activities.
Learning approaches adopted for this course include:

- Problem-based learning (PBL)
- Experiential learning
- The CDIO (Conceive Design Implement Operate) approach which stresses engineering fundamentals set in the context of real-world systems and products.

# 6 Assessment Procedures

Formative assessment is provided during and after each risk management workshop in the form of peer and teacher feedback. Summative assessment is based on students' active participation and also their individual reflection on the module and what they have learned. A pass/fail grading system is recommended for this module as it is based on group work and the focus should be on ensuring that all students are engaged and actively work through all the module

activities. It is also possible to incorporate quiz questions relating to risk management principles and risk management process-based assessment in an exam format. For the initial pilot module implementation in TalTech, as it formed part of a larger course, a few risk management-related questions covering the material of the pilot module were also included in the overall course exam.

# 7 Teaching Materials

## 7.1 Introductory Lecture

The introductory lecture sets the scene for the entire module. It gives students an overview of the module and prepares them for the workshops by explaining the concept of risk and the risk management process in the context of construction projects.

Risk is a very widely used concept and its definitions, implications and how it is dealt with are highly dependent on context. Therefore, students require an appreciation of the broader principles and concept of risk and their implications to educate and inspire them as well as a much narrower, practically oriented, risk management process for the construction project context which they can directly apply. This introductory lecture provides them with both.

All the Powerpoint slides for the introductory lecture are provided in Appendix A.1.

## 7.2 Workshop 1

Workshop 1 refers to the project preparation stage and requires students to identify and qualitatively analyze risks associated with the construction of a case study project – a multi-storey parking building.

A mini-lecture serves to present the objectives of Workshop 1 and the instructions for the student groups to carry it out. (All the Powerpoint slides for this mini-lecture are provided in Appendix A.2.)

Further project information is provided to students in the form of a BIM model and a video „fly-through“ of the model (both uploaded to the BLE) which allow very efficient visualizations of the proposed building. Student groups are then tasked with carrying out a process of risk identification, qualitative risk analysis and risk response. A copy of the instructions and a template for recording their findings is provided to ease their reporting and ensure that students can concentrate on a collaborative and discussion-based risk management process (these materials are available in Appendix B.1.)

## 7.3 Workshop 2

Workshop 2 considers the project stage just prior to construction at which point the design is well-developed and budget and time estimates have been made. The focus of workshop 2 is on quantitative risk analysis – the consideration and modelling of the uncertainty that surrounds these cost and time estimates and the generation of probability density functions to represent time and cost estimates in preference to simple, single point estimates.

This workshop follows a similar pattern to Workshop 1 in that it commences with a mini-lecture (slides in Appendix A.3.) to explain the objective, task and reporting requirements for Workshop 2.

For this workshop, the project data needs to be extracted from the BIM model and then processed in a spreadsheet application (Excel, in this case) with a simulation add-in (Argo, in this case). Detailed task steps are provided to students as are Excel templates to standardize and simplify their group work and its reporting. More information on the specifics of these tasks including links to the Excel templates can be found in Appendix B.2.

## 7.4 Workshop 3

Workshop 3 refers to the end of construction project stage and focuses on the documentation requirements of the risk management process including capturing lessons learnt for improving performance on future projects. Similarly to Workshops 1 & 2, it begins with a mini-lecture (slides in Appendix A.4.) to explain the objective, task and reporting requirements for Workshop 3.

Detailed task instructions are available in Appendix B.3.

## 7.5 Assessment

Formative assessment takes place as feedback and discussion of all the submissions from the group work undertaken in the workshops. This is done prior to commencing the next workshop.

Summative assessment takes the form of exam questions of two forms. The first being quiz type questions (e.g. multiple choice) relating to the material covered in the introductory lecture. The second being longer questions requiring students to carry out a risk management process of identifying and qualitatively analysing risks associated with a specific construction project context and then proposing risk mitigation strategies to deal with the most significant risks. (A similar process to that carried out in Workshop 1 but, this time, individually and under exam conditions).

Finally, students are required to reflect on their own learning experiences during the module. An example questionnaire format for the self-reflection exercise is provided in Appendix C.1.

# Appendix A – Presentation Slides

## A.1. Introductory Lecture Slides

(From next page)

# Risk Management

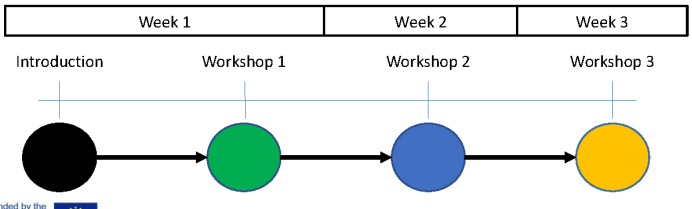
## A BIM-enabled Learning Course

Introduction Lecture

1

## Risk Management Course Outline

- Introductory lecture – **risk management principles and process**
- Three risk management workshops:
  1. At the **project preparation** stage – focus on **qualitative risk analysis**
  2. At the **pre-construction** stage – focus on **quantitative risk analysis**
  3. At the **construction completion** stage – focus on **documentation** and **lesson-learning**
- Schedule:




| 2

2

*The European Commission support for the production of this publication does not constitute an endorsement of the contents, which reflects the views only of the authors, and the Commission cannot be held responsible for any use, which may be made of the information contained therein.*


3


4

# Risk definitions...

Probability theory (De Moivre)

*the product of the sum adventured multiplied by the probability of the loss*

Risk = qB

(Mathematical expectation of gain = pA)

5

# Risk definitions...

Finance – Portfolio Theory (Markowitz)

Risk = variance of return

Insurance – Actuarial Risk Theory (Tetens)

Risk = the expected loss to the insurance company

Insurance – Risk Management (Denenberg & Ferrari)

Risk = the difference between actual and expected outcomes

6

## Risk definitions...

Economics (Knight)

Risk = measurable uncertainty

Project Risk Management (Chapman)

Risk = the possibility of departures from expectations which matter

7

***"I cannot define it but I know it when I see it"***

Justice Potter Stewart on pornography

*"When the Society for Risk Analysis was brand new, one of the first things it did was to establish a committee to define the word "risk" – it labored for 4 years and then gave up"* (Kaplan)

8

## The Concept of Risk

Risk refers to:

- uncertainty;
- time (the future);
- probability;
- expectations;
- outcomes.


9

## Wider ideas - MODERNITY

*"The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods and that men and women are not passive before nature."*

*Bernstein – Against the Gods*

10

## Wider Ideas - EVIDENCE

*Probability = degree of belief based on the available evidence*

"All propositions are true or false, but the knowledge we have of them depends on our circumstances; and while it is often convenient to speak of propositions as certain or probable, this expresses strictly a relationship in which they stand to a corpus of knowledge."

*Keynes – A Treatise on Probability*

11

## Wider Ideas - INFERENCE

*"We **perceive** the world before we react to it, and we react not to what we perceive but always to what we **infer**."*

*Knight – Risk Uncertainty and Profit*

12

# Wider Ideas – ETHICS

*"Can the possibility of an ecological catastrophe be accepted to satisfy economic interests? "*

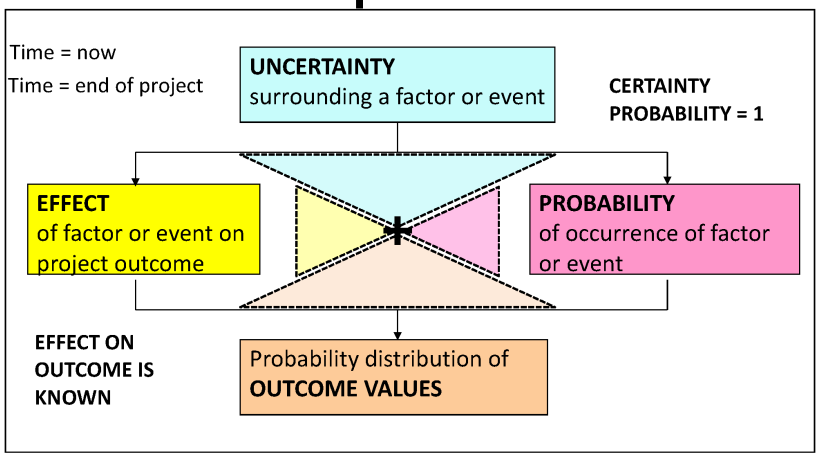
*"There is a systematic 'attraction' between extreme poverty and extreme risk."*

*The hazardousness of risks cannot be objectively determined: "prognoses of safety cannot even be refuted by actual accidents."*

*Beck – Risk Society*

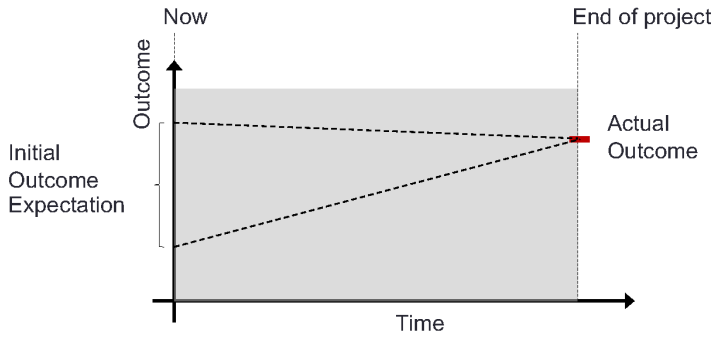
13

# Project Risk Concept




14

## Project Risk Concept




Initial, partial knowledge of factors / events which may affect the project

Complete knowledge of all factors / events that affected the project

Knowledge

15

## Project Risk Management

**Intentions**

- to make the best use of the available knowledge in making plans and estimates
- to actively search for and incorporate all relevant new knowledge as it emerges
- to capture knowledge from this project for future projects

16

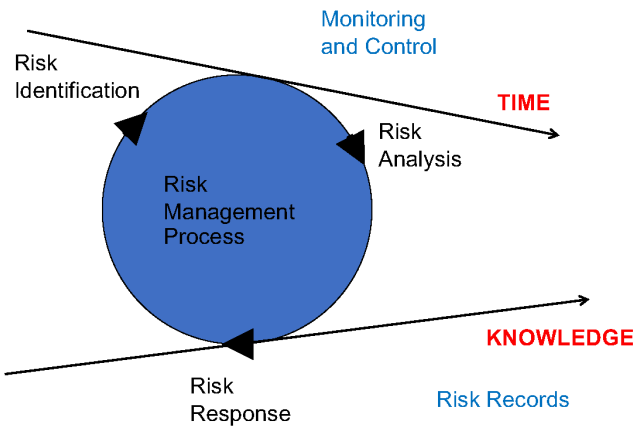
# Project Risk Management

**Purpose**

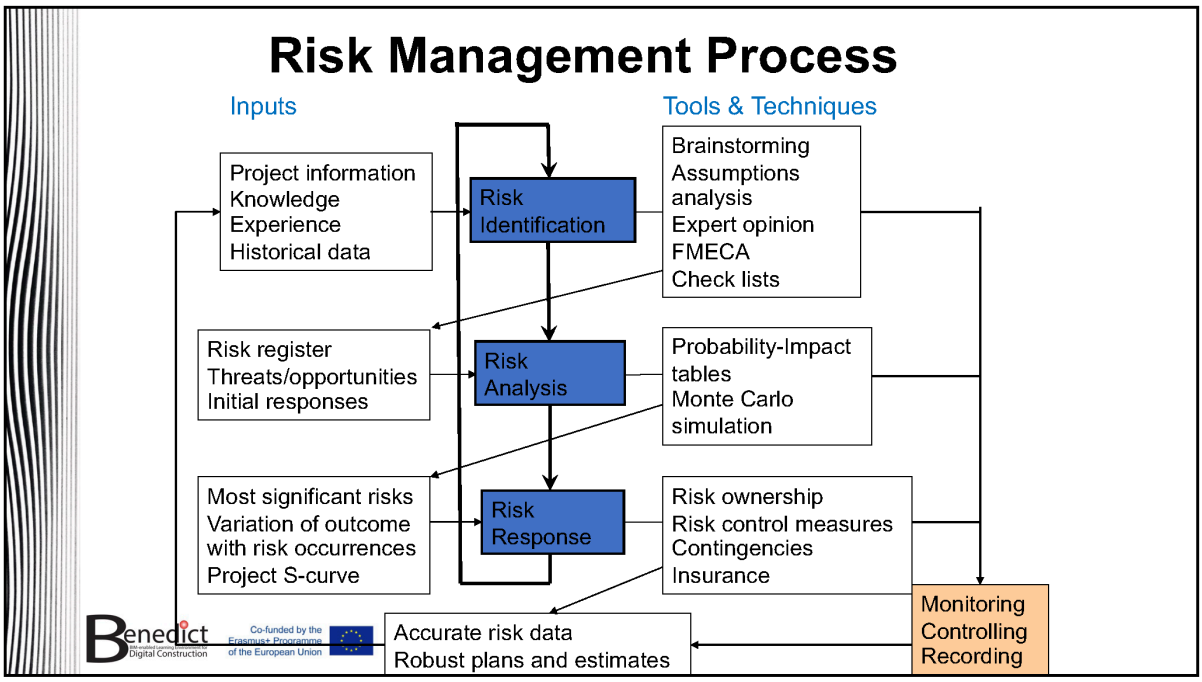
- to develop better plans and estimates in order to improve performance and meet expectations

17

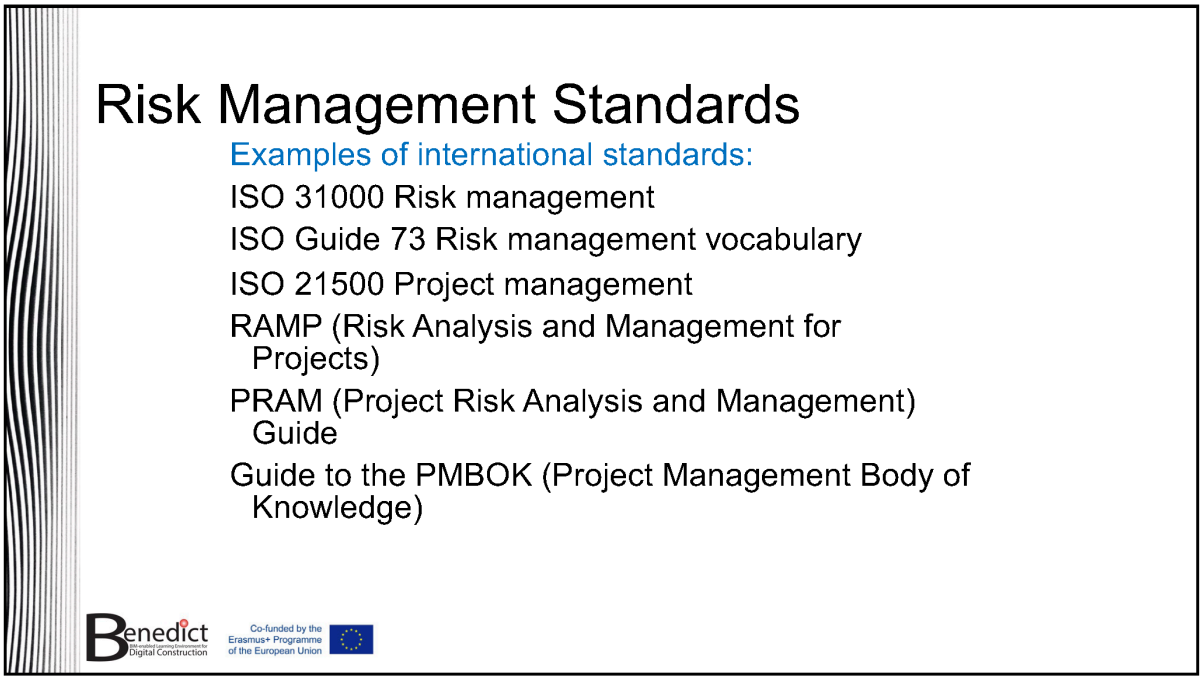
# Project Risk Management Process




18




19



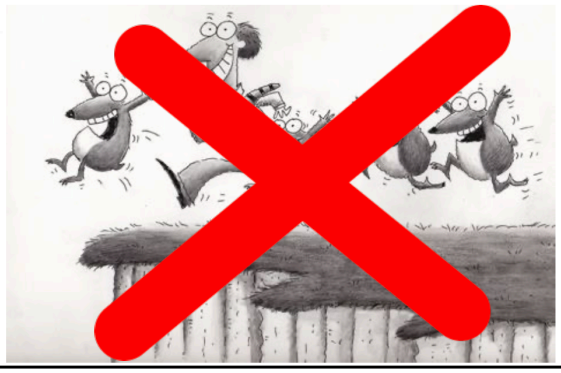

20

## More on Risk Management

- Team NOT individual work
- Often as a series of facilitated workshops


Beware of:

- 'group think'
- optimism bias



21

## More on Risk Identification

- Risk classification systems can be useful
  - check lists
  - helps set consistent level of detail

By type:

- Technical
- Logistical
- Construction
- Political
- Financial

By ability to control:

- Elemental – within the project / project packages – controllable
- Global – external to project / project packages – uncontrollable

22

# More on Risk Analysis

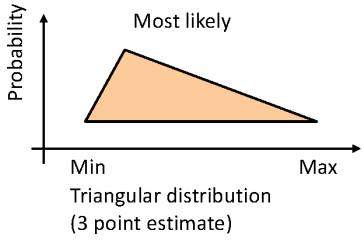
## Probability – Impact matrix

| Impact | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Probability | | | | | |
| Very Low | 1 | 2 | 3 | 4 | 5 |
| Low | 2 | 4 | 6 | 8 | 10 |
| Medium | 3 | 6 | 9 | 12 | 15 |
| High | 4 | 8 | 12 | 16 | 20 |
| Very High | 5 | 10 | 15 | 20 | 25 |

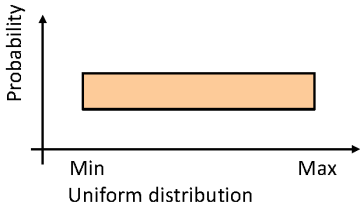
23

# More on Risk Analysis

## Commonly applied probability distributions for risk factors in quantitative risk analysis




Triangular distribution
(3 point estimate)

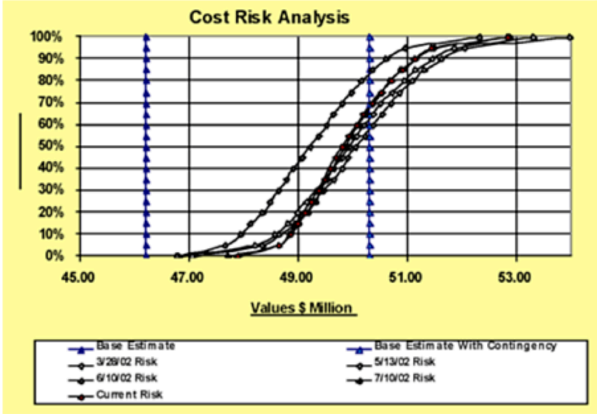



Uniform distribution

24

# More on Risk Analysis

## Project S- curve




Source: www.wbdg.org

25

# More on Risk Analysis

## Wisdom of the crowd

- Crowd-sourced forecasting
- 'Superforecasters' – The Good Judgement Project

26

## More on Risk Response

**Principles:**

- *significant risks should be managed :*
  - *controllable risks –> by control measures*
  - *not (or only slightly) controllable –> by diversification*
- *risks should be owned by the party best able to manage them*

27

## More on Risk Response

**Response options:**

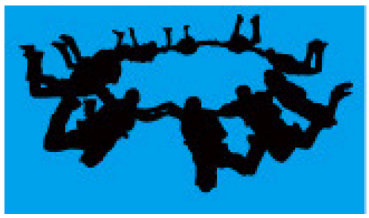

- Avoidance
  - alternative design and/or construction methods
- Reduction
  - contingency plans, financial provisions, control measures


- Transfer
  - contractual arrangements, insurance


- Retention
  - diversification, do nothing


28

## More on Risk Response



**Transfer by contract:**

- Obligations divided according to contract
- Choice of payment mechanisms
- More integrated forms of contract (e.g. IPD) seek to *pool* risk **not** *transfer* risk
- A project risk contingency fund can then be shared amongst project partners if it is not spent.

29

## Benefits of Risk Management

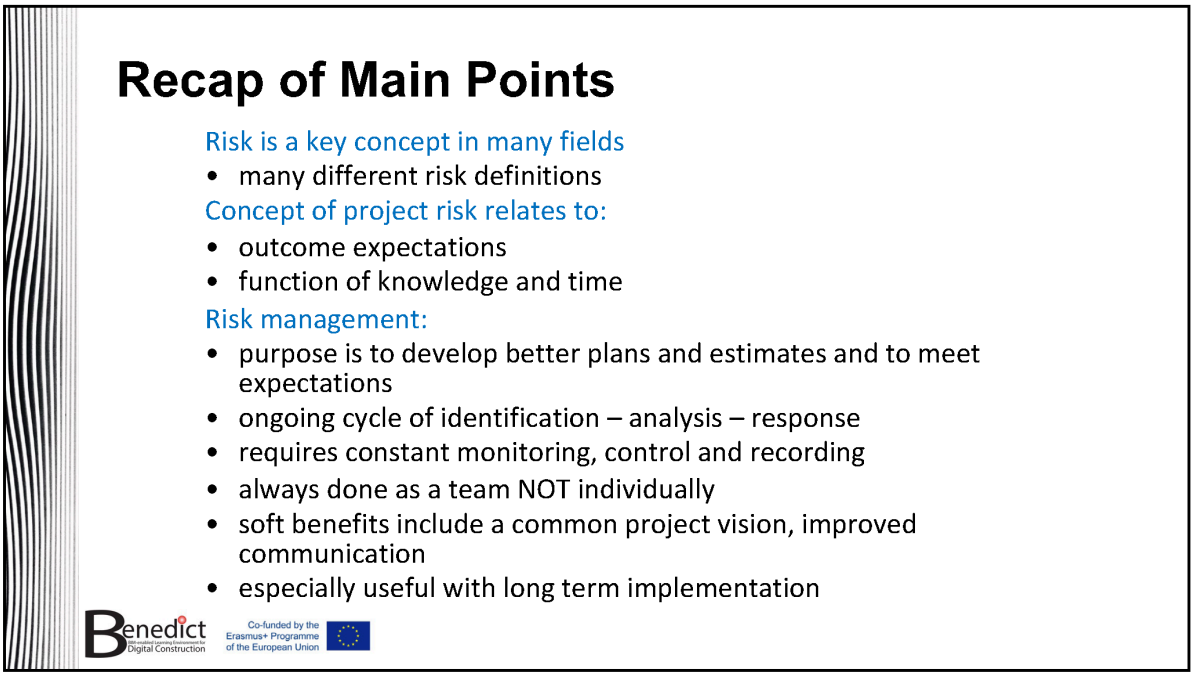
***Hard* benefits:**

- Better plans, schedules, budgets
- Use of most appropriate form of contract
- Better assessment and management of contingencies
- Knowledge collected, organised and used in future projects (corporate learning)
- Expectations met

***Soft benefits:***

- Common project vision developed
- Better communication and understanding – improved team spirit
- Demonstrates a responsible approach to clients

30

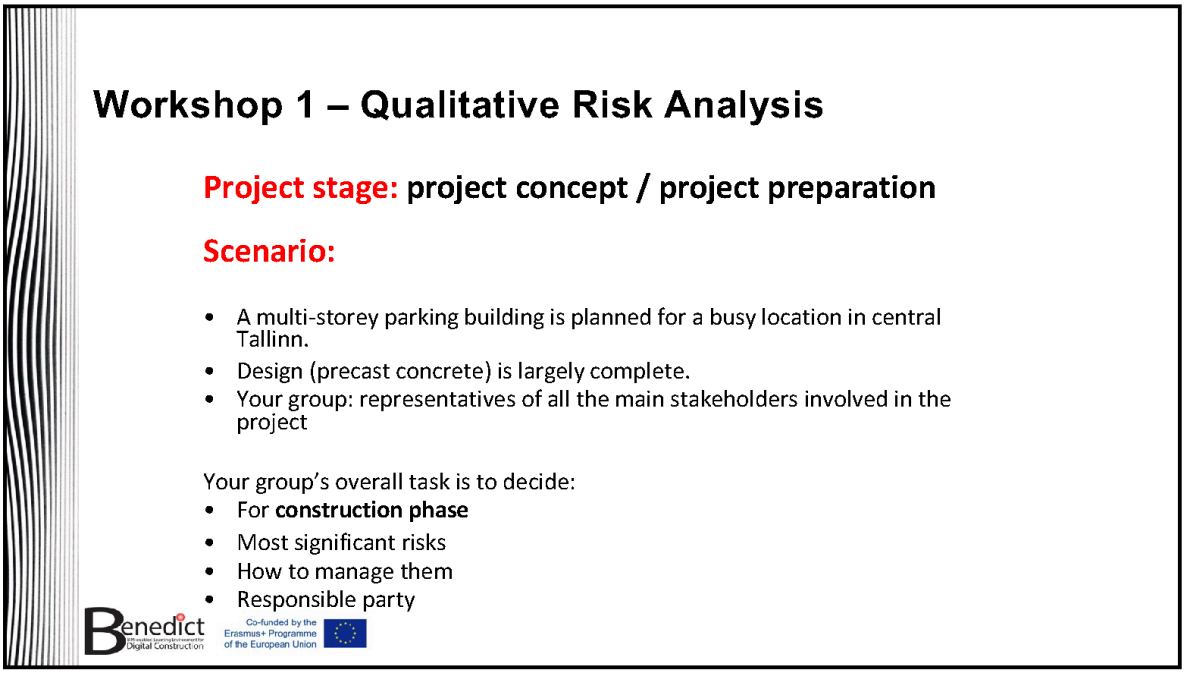



31

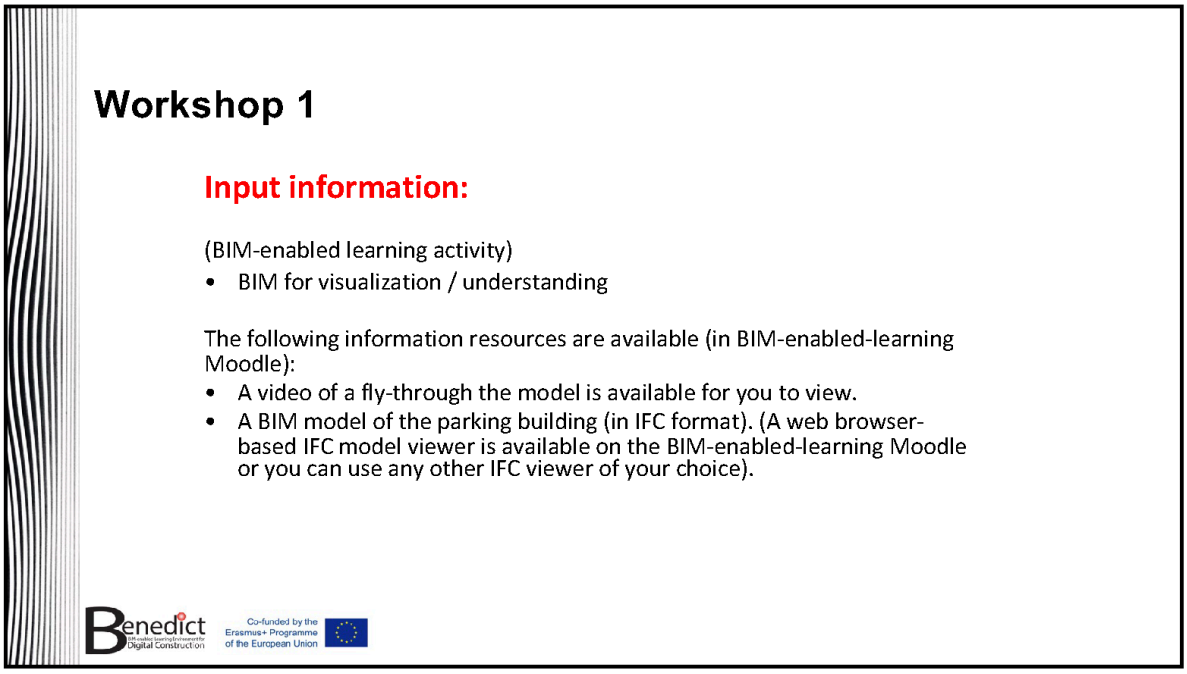
## A.2. Workshop 1 Mini-lecture Slides

(From next page)

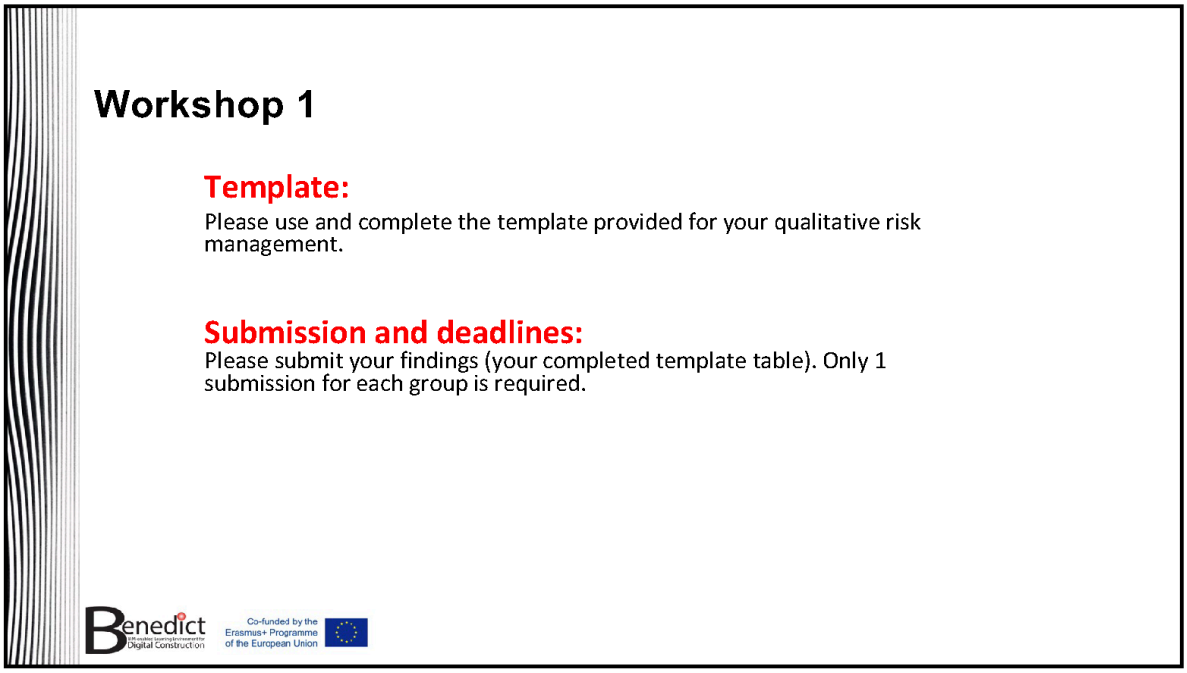

1




2




3




4

# Activity – Qualitative Risk Management for Construction Projects

## Tasks:

### Task 1 – Risk Identification

- In your group, conduct a brainstorm session to identify about 20 risks (use the check list to help give you ideas) that are relevant to the construction of this parking building and agree on their descriptions. (Descriptions are adequately precise if all group members understand them in the same way.)

### Task 2 – Risk Analysis

- Assess and agree the probability (of the risk occurring) and the impact (on the outcome of the project) of each risk that you have identified.
- Determine their relative severity by multiplying their assessed Probability x Impact.
- Identify the 5 most significant risks

### Task 3 – Risk Response

- Assign ownership to each risk - decide who (client, design team, contractor, etc.) is best placed to manage each of the 5 most significant risks
- Identify risk response actions for managing each of the 5 most significant risks.

### Task 4 – Report / submit

5

### Checklist

- Workforce
- Construction process
- Economic / Political
- Logistics / Supply chain

### Probability – Impact Table

| Impact | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Probability | | | | | |
| Very Low | 1 | 2 | 3 | 4 | 5 |
| Low | 2 | 4 | 6 | 8 | 10 |
| Medium | 3 | 6 | 9 | 12 | 15 |
| High | 4 | 8 | 12 | 16 | 20 |
| Very High | 5 | 10 | 15 | 20 | 25 |

### Risk Table

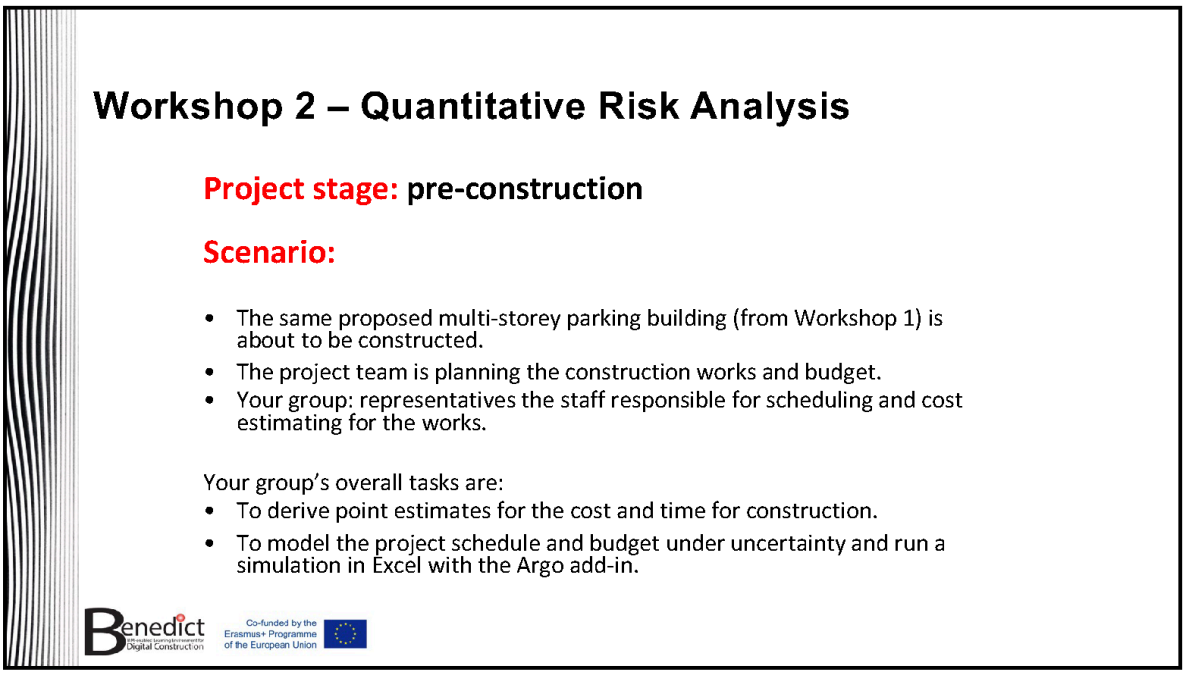
| Risk Description | Prob | Imp | Severity | Owner | Risk Response Actions |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

6

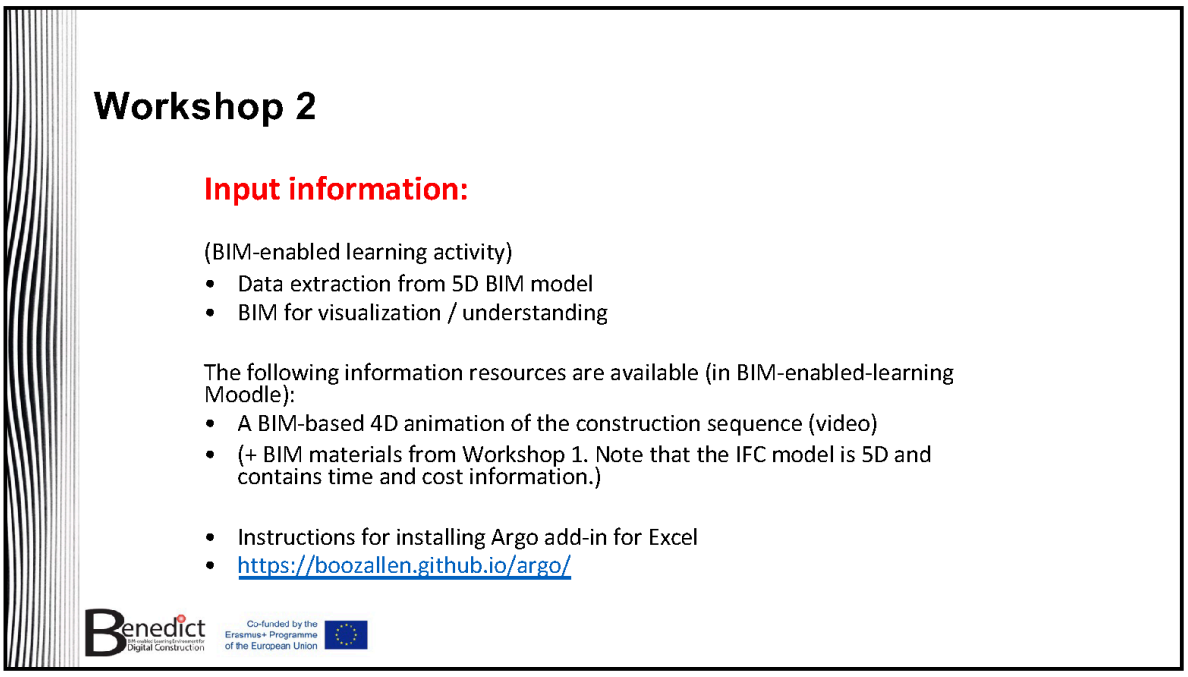
## A.3. Workshop 2 Mini-lecture Slides

(From next page)

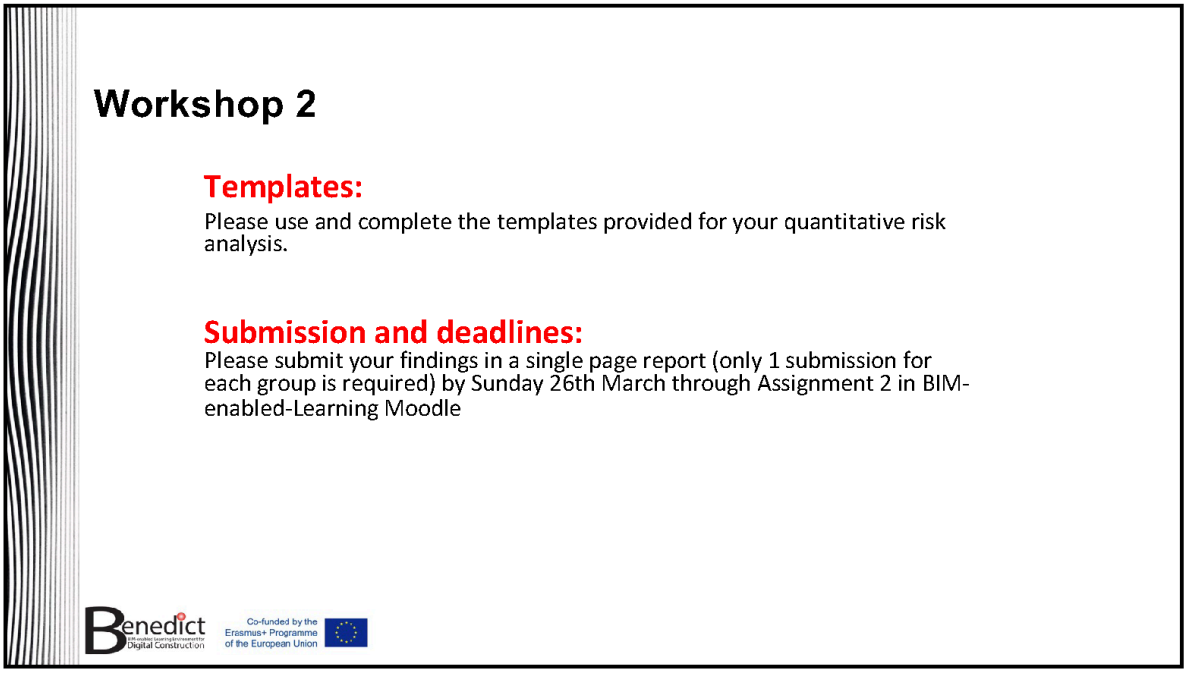

1



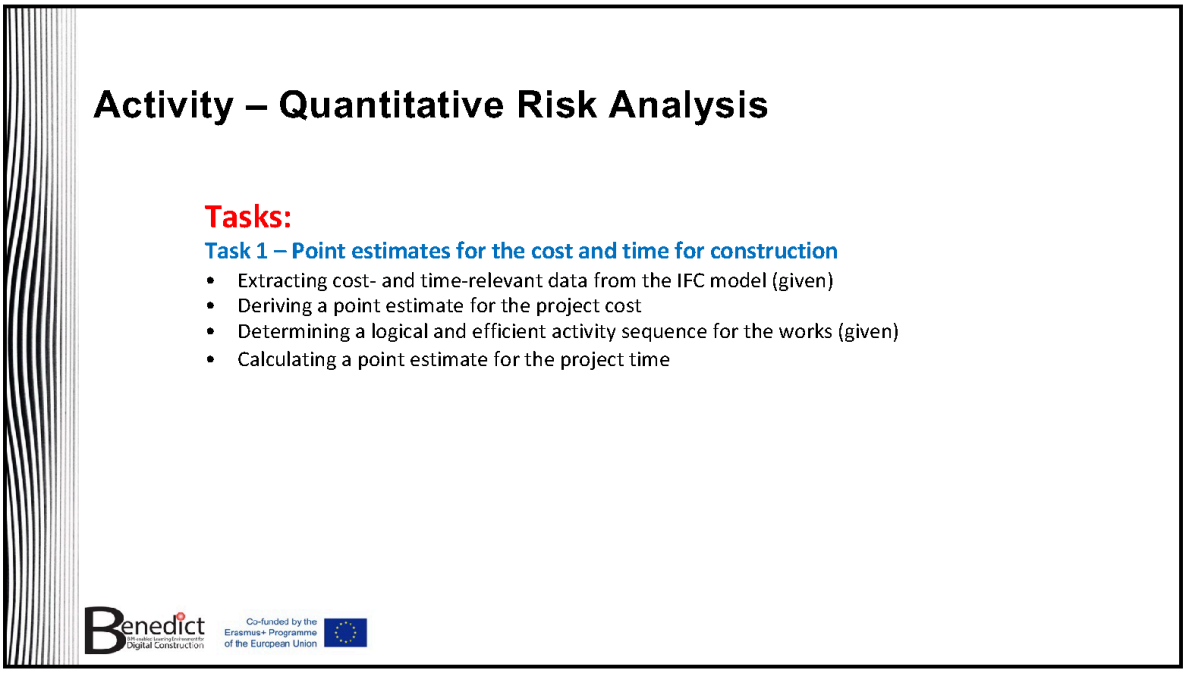

2



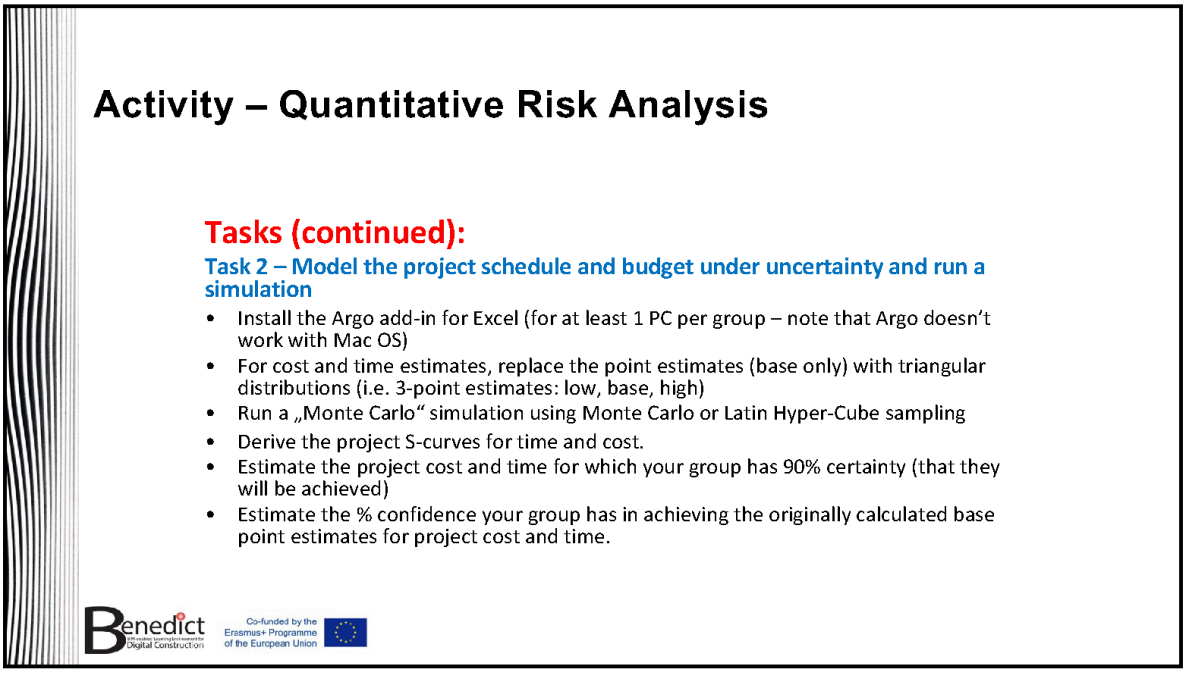

3




4




5




6

## Activity – Quantitative Risk Analysis

### Tasks (continued):

**Task 3 – Report / submit**

- Your project S-curve graphs for cost and time
- Your estimates of the project cost and time for which your group has 95% confidence (certainty)
- Your estimates of the % confidence your group has in achieving the originally calculated base point estimate for project cost and achieving the base point estimate for project time.

7

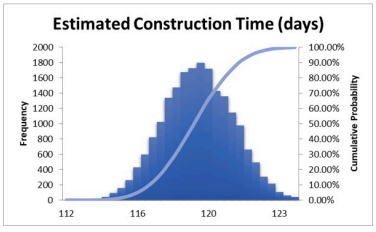
## Example of information to submit:

**Time**

Point estimate = ___ days

**Simulation results:**

- Confidence level = __% for ___ days
- 90% confidence < ___ days

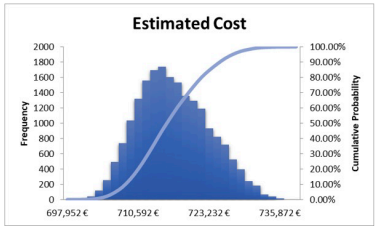



**Cost**

Point estimate = _____€

**Simulation results:**

- Confidence level = __% for _____€
- 90% confidence < _____€

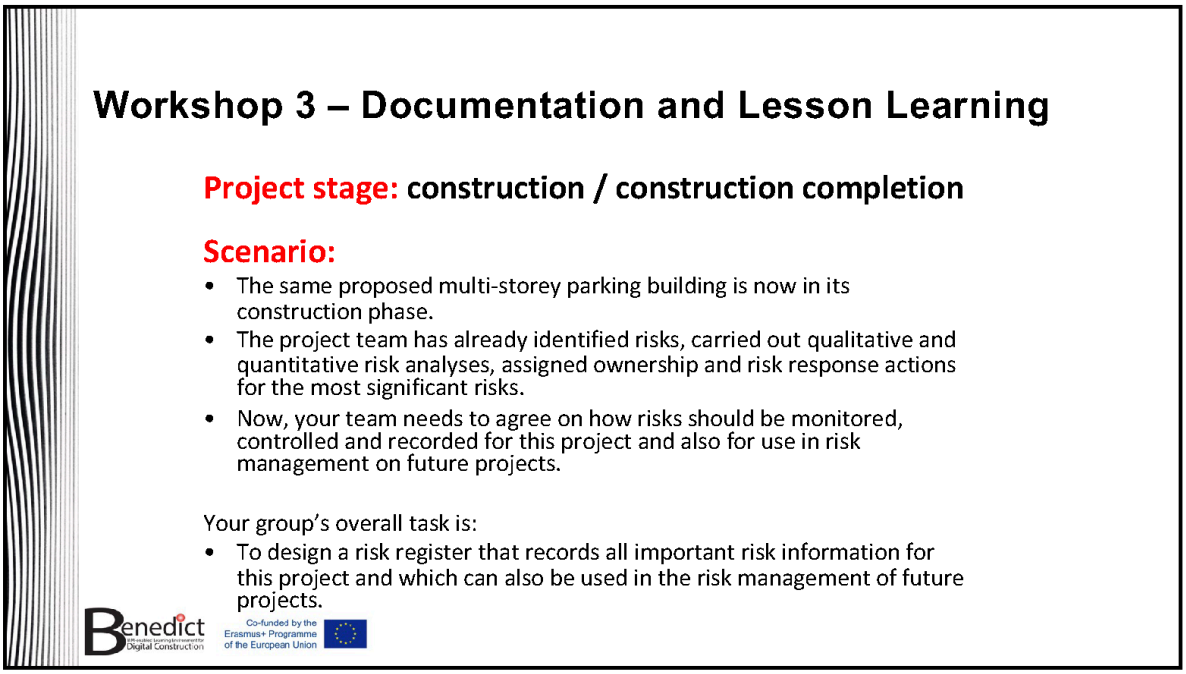



8

## A.4. Workshop 3 Mini-lecture Slides

(From next page)


1




2

## Workshop 3

**Input information:**

(BIM-enabled learning activity)

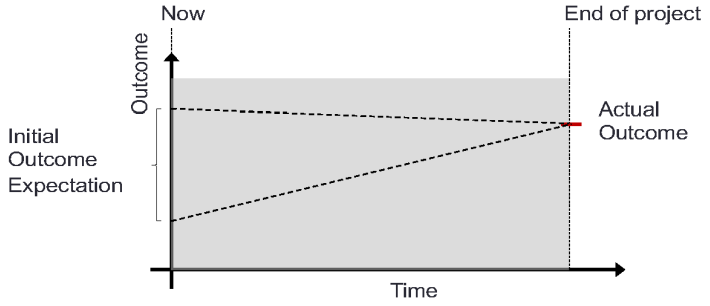
- Your results for Workshops 1 and 2

Also:

- Review key ideas about the project risk management process that were presented in the Introduction Lecture (summarised in next slides).
- Example of risk register (separate file).

3

## Project Risk Concept

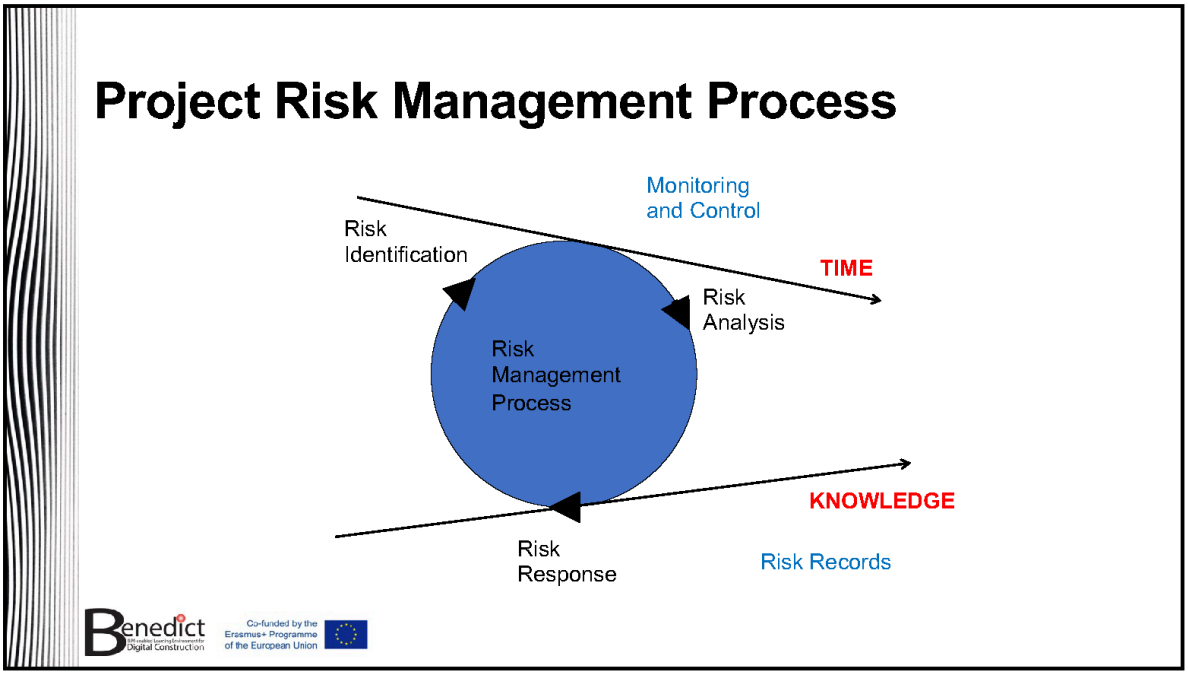



Initial, partial knowledge of factors / events which may affect the project

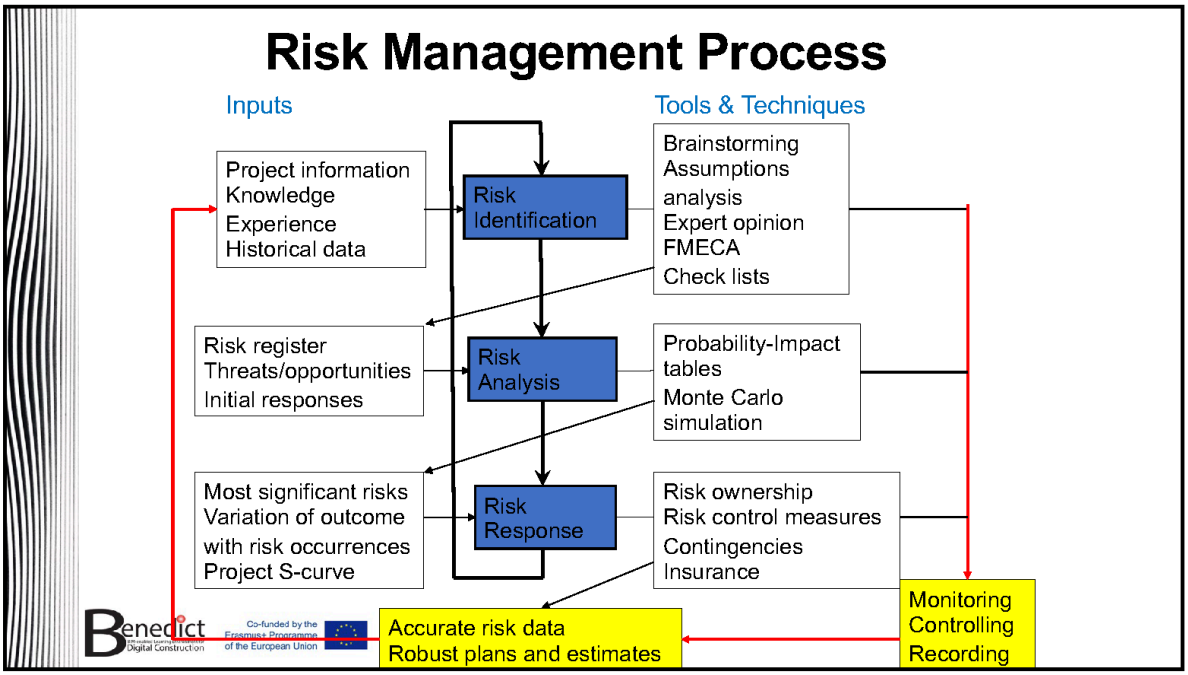
Complete knowledge of all factors / events that affected the project

Knowledge

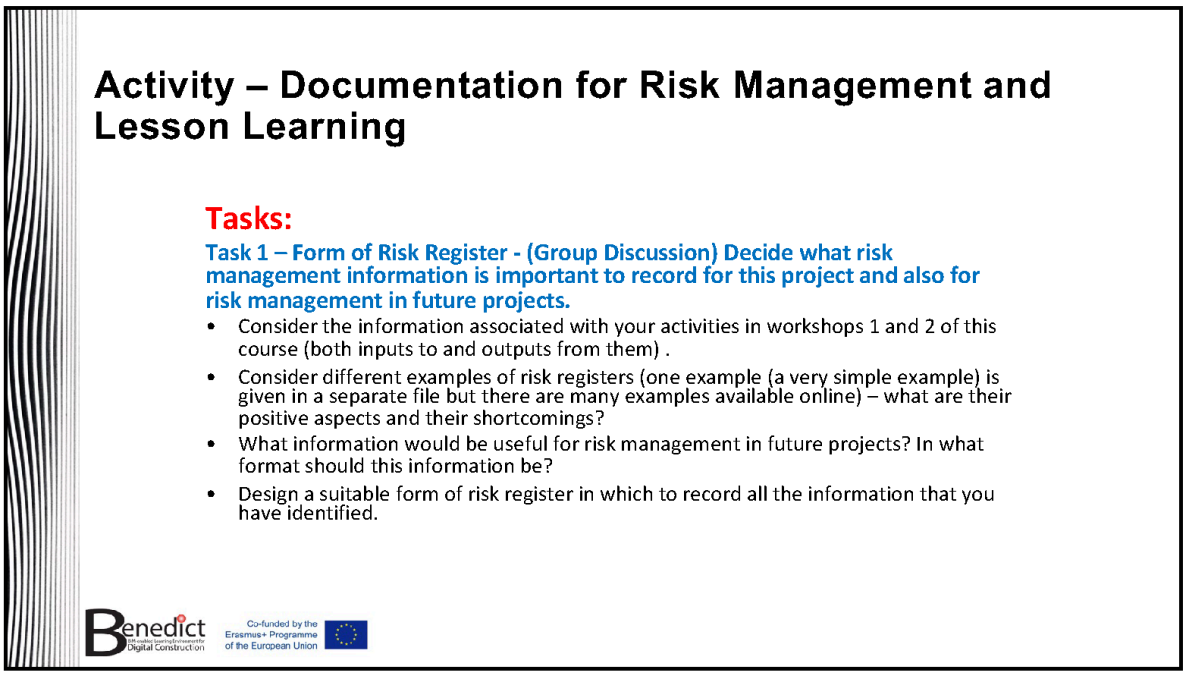
4



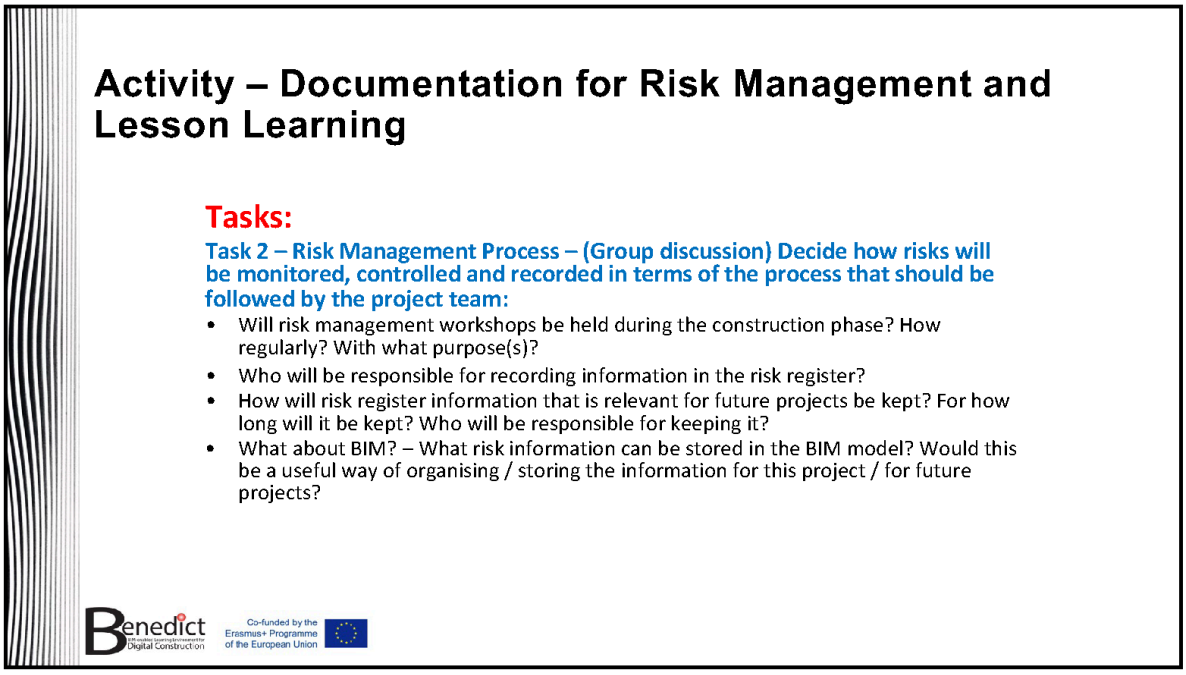

5




6




7




8

# Activity – Documentation for Risk Management and Lesson Learning

## Submission and deadlines:

**Please submit your findings in a 2 page report (only 1 submission for each group is required) by Sunday 2nd April through Assignment 3 in BIM-enabled-learning Moodle:**

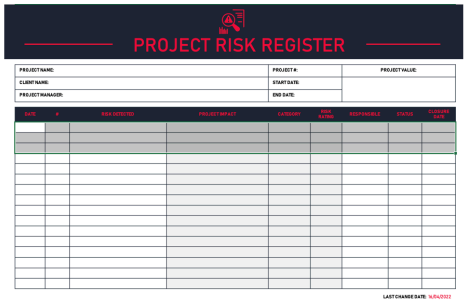
- **On page 1: Your group's Risk Register form (just the form, it doesn't need to be filled in)**
- **On page 2: Your group's responses to the following questions (approx. 1 paragraph for each response, you can include a process flowchart / diagram if you wish):**
  1. What process for managing risk during the construction phase does your group recommend?
  2. What risk information will be useful for future projects and how will this be recorded and stored and by whom?
  3. How can risk-related information be integrated with BIM? Are there limits to what information can be conveniently integrated?

Benedict
BIM-enabled Learning Environment for Digital Construction
Co-funded by the Erasmus+ Programme of the European Union

9

## Example of information to submit:

### Page 1 – Risk Register form




### Page 2 - responses

1. Process

   (your response)

2. Information for future projects

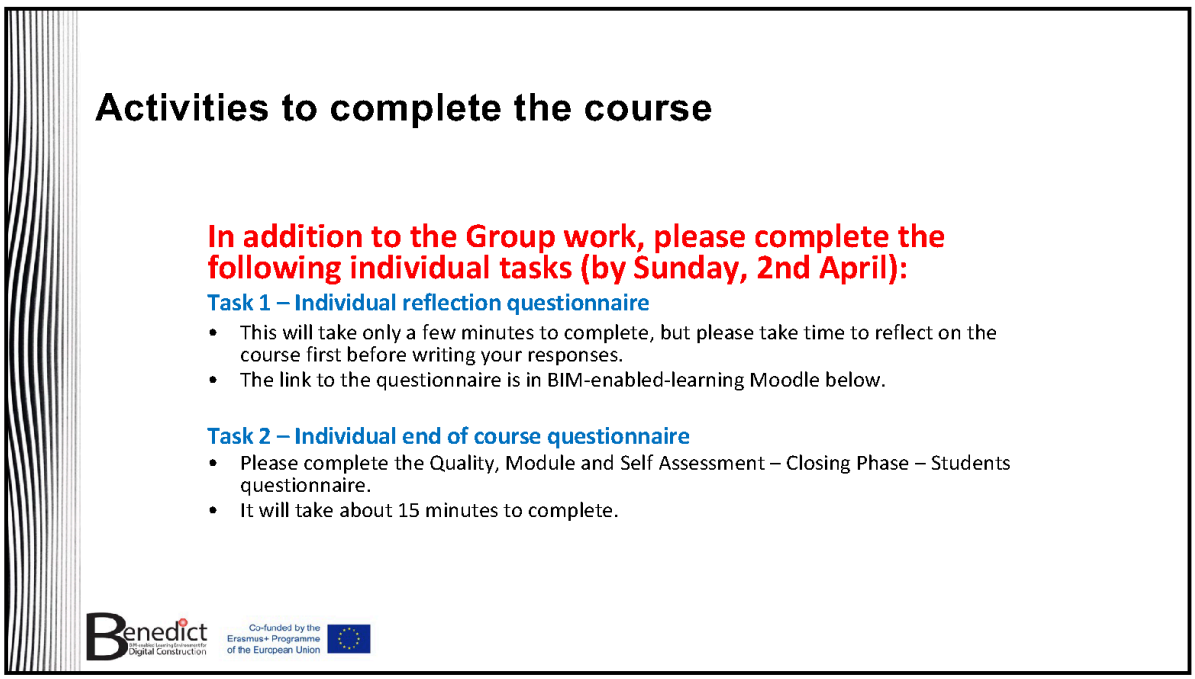
   (your response)

3. Integration with BIM

   (your response)

Benedict
BIM-enabled Learning Environment for Digital Construction
Co-funded by the Erasmus+ Programme of the European Union

10




11

# Appendix B – Activity Materials

## B.1. Workshop 1 Qualitative Risk Management Exercise and Template

(From next page)

**Risk Management Workshop – Risk Management in Construction Projects**

**Scenario:**

A multi-storey parking building is planned for a busy location in central Tallinn. The design (which is a fairly standard, precast concrete design) is largely complete. Your group is made up of representatives of all the main stakeholders involved in the project (the client – a real estate development company, the designers, the main contractor for the construction works, etc.)

Your group's overall task is to decide (in a qualitative sense) what the most significant risks of the construction phase of this project are, what should be done to manage them and who should be responsible for managing them.

**Tasks:**

**Task 1 – Risk Identification**

- In your group, conduct a brainstorm session to identify about 20 risks (use the check list to help give you ideas) that are relevant to the construction of this parking building and agree on their descriptions. (Descriptions are adequately precise if all group members understand them in the same way.)

**Task 2 – Risk Analysis**

- Assess and agree the probability (of the risk occurring) and the impact (on the outcome of the project) of each risk that you have identified.
- Determine their relative severity by multiplying their assessed Probability x Impact.
- Identify the 5 most significant risks

**Task 3 – Risk Response**

- Assign ownership to each risk - decide who (client, design team, contractor, etc.) is best placed to manage each of the 5 most significant risks
- Identify risk response actions for managing each of the 5 most significant risks.

**Task 4 – Reporting**

- Submit your findings (complete and submit the risk table on next page).

**Probability – Impact Table**

| Impact / Probability | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Very Low | 1 | 2 | 3 | 4 | 5 |
| Low | 2 | 4 | 6 | 8 | 10 |
| Medium | 3 | 6 | 9 | 12 | 15 |
| High | 4 | 8 | 12 | 16 | 20 |
| Very High | 5 | 10 | 15 | 20 | 25 |

**Checklist**

- Workforce
- Construction process
- Economic / Political
- Legal / Regulatory
- Logistics / Supply chain

**Risk Table (please format and extend this table to suit)**

| Risk Description | Probability (P) | Impact(I) | Severity (P*I) | Risk Owner | Response Actions |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## B.2. Workshop 2 Quantitative Risk Management Exercise Materials

(From next page)

**INSTRUCTIONS FOR THE QUANTITATIVE RISK MANAGEMENT (COST) EXERCISE**

**(Note that these instructions refer to data extracted from a BIM model and a template provided in an Excel file (available at: Quantitative Risk Analysis - Cost estimate data and template.xlsx ) and also to the use of the open source simulation software: Argo (available from https://boozallen.github.io/argo/ )**

1. The sheet [Extracted element data] contains the cost-relevant rows of data extracted from the 5D BIM IFC model. Note that this data has been cleaned up considerably from the original .csv file extracted from the BIM (IFC) model.
2. The sheet [Cost estimate] has grouped similar elements together in order to create a summary of the costs. Note that, for each Element type, there is a Unit Cost Estimate x No. of Units = Base Amount and the sum of all Base Amounts = the single point cost estimate = 693 086 € for this project.
3. For each Base Amount (= Mode), agree in your group the minimum and maximum values for a triangular distribution. Enter these minimum and maximum values in the appropriate cells in columns J and L of the [Cost estimate] sheet.
4. From the Argo (Distribution) menu, choose a Triangular distribution (with any input values for min, mode, max) and enter it into cell N5 of the [Cost estimate] sheet Now replace the input values with cell addresses (J5,K5,L5) and then copy the Triangular distribution formula all the way to the bottom of the table (N163)
5. Enter the summation formula " =SUM(N5:N163) " into cell N167 to calculate the sum (= Cost estimate). Select the cell N167 and add it as the result using the Argo (Result) menu.
6. Run a simulation. First set the Argo simulation (Options) using 2000 trials, 100 bins and Latin Hyper-Cube Sampling. (You can also try running one or more simulations with up to 20000 trials using Monte Carlo sampling) - which is better?
7. Generate the analysis output report from the Argo (Embed Charts) menu (Single, histogram + S-curve) for the result cell N167 (This will appear in its own sheet). Note that this operation may generate an error - if it does, you can overcome this by changing the Regional Format on your PC to English (United States) or use the Argo (Analysis Wizard) to generate the S-curve and histogram.
8. Answer the questions:
    a. What is the project cost for which your group has 90% confidence (that the project out-turn cost will be less than or equal to this amount)?
    b. What level of confidence (%) does your group have that the project out-turn cost will be less than or equal to the originally calculated point cost estimate of 693 086€?
9. Submit your answers together with the output chart generated by Argo through the Workshop 2 assignment in the bim-enabled-learning moodle.

**INSTRUCTIONS FOR THE QUANTITATIVE RISK MANAGEMENT (TIME) EXERCISE**

**(Note that these instructions refer to data extracted from a BIM model and a template provided in an Excel file (available at: Quantitative Risk Analysis - Time schedule and template.xlsx ) and also to the use of the open source simulation software: Argo (available from https://boozallen.github.io/argo/ )**

1. The sheet [Extracted element data] contains the time-relevant rows of data extracted from the 5D BIM IFC model. Note that this data has been cleaned up considerably from the original .csv file extracted from the BIM (IFC) model.
2. The sheet [Time schedule (for 4D video)] has scheduled the construction activities as they can be seen in the 4D construction sequence video. Note that the schedule has been updated to current time (i.e. a June 2023 start date for the construction works)
3. The sheet [Precedence Ntwk - Pt Estimate] shows the activity sequence logic (as per the 4D construction sequence video). The activity durations are given but you must calculate the Early Start (ES) and Early Finish (EF) values for each of the activities.
4. Calculate the point estimate for the total duration of the construction. Enter your answer in cell G24.
5. In the sheet [Precedence Ntwk - Simulation], complete the precedence network by inputting triangular distributions for each of the activity durations. Do this manually using the activity durations from the point estimate as the Mode values and agreeing in your group appropriate Min and Max values for each activity.
6. In cell G24, enter a function to calculate the total construction duration. Select the cell G24 and add it as the result using the Argo (Result) menu.
7. Run a simulation. First set the Argo simulation (Options) using 2000 trials, 100 bins and Latin Hyper-Cube Sampling. (You can also try running one or more simulations with up to 20000 trials using Monte Carlo sampling) - which is better? Note that this operation may generate an error - if it does, you can overcome this by changing the Regional Format on your PC to English (United States) or, in the Argo (Simulation / Options) select. the Native Excel analysis option.
8. Generate the analysis output report from the Argo (Embed Charts) menu (Single, histogram + S-curve) for the result cell G24. (This will appear in its own sheet.) Note that this operation may generate an error - if it does, you can overcome this by changing the Regional Format on your PC to English (United States) or use the Argo (Analysis Wizard) to generate the S-curve and histogram.
9. Answer the questions:
    a. What is the project time for which your group has 90% confidence (that the project out-turn cost will be less than or equal to this amount)?
    b. What level of confidence (%) does your group have that the project out-turn cost will be less than or equal to the originally calculated duration point estimate?
10. Submit your answers together with the output chart generated by Argo through the Workshop 2 assignment in the bim-enabled-learning moodle.

## B.3. Workshop 3 Risk Management Documentation Exercise Materials

(From next page)

# INSTRUCTIONS FOR THE RISK MANAGEMENT DOCUMENTATION AND LESSON LEARNING EXERCISE

**Task 1 – Form of Risk Register - (Group Discussion) Decide what risk management information is important to record for this project and also for risk management in future projects.**

- Consider the information associated with your activities in Workshops 1 and 2 of this course (both inputs to and outputs from them).
- Consider different examples of risk registers (one example, a very simple example, is given in a separate file but there are many examples available online) – what are their positive aspects and their shortcomings?
- What information would be useful for risk management in future projects? In what format should this information be?
- Design a suitable form of risk register in which to record all the information that you have identified.

**Task 2 – Risk Management Process – (Group discussion) Decide how risks will be monitored, controlled and recorded in terms of the process that should be followed by the project team:**

- Will risk management workshops be held during the construction phase? How regularly? With what purpose(s)?
- Who will be responsible for recording information in the risk register?
- How will risk register information that is relevant for future projects be kept? For how long will it be kept? Who will be responsible for keeping it?
- What about BIM? – What risk information can be stored in the BIM model? Would this be a useful way of organising / storing the information for this project / for future projects?

**Submission and deadlines:**

Please submit your findings in a 2 page report (only 1 submission for each group is required) by Sunday 2nd April through Assignment 3 in BIM-enabled-learning Moodle:
On page 1: Your group's Risk Register form (just the form, it doesn't need to be filled in)
On page 2: Your group's responses to the following questions (approx. 1 paragraph for each response, you can include a process flowchart / diagram if you wish):

1. What process for managing risk during the construction phase does your group recommend?
2. What risk information will be useful for future projects and how will this be recorded and stored and by whom?
3. How can risk-related information be integrated with BIM? Are there limits to what information can be conveniently integrated?

# Appendix C – Assessment Materials

(From next page)

## C.1. Risk Management Course - Individual reflection questions

Please consider the following questions and enter your responses as short paragraphs.

1. Describe 1 new thing that you learned in this course.

2. Describe 1 thing that you found interesting in this course.

3. Describe 1 thing (from this course) that could be useful in your work or in (an)other course(s).

4. Do you have any other comments and/or observations about the risk management course which you would like to share?