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Intellectual Output 1 (IO1)

Needs Analysis

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A) State of the art – Examples with possible use for IO2 and IO3.

This report summarizes the available and most used tools on the market in terms of BIM-based AR/VR in the research and the industrial fields. The report starts by listing the relevant example and uses for each BIM tools (IO2) and the VR/AR Tools (IO3).

CASE 1. 3M Releases Construction Safety Virtual Reality Programs for Hands-on Learning

3M has recently released a series of VR construction safety modules. 3M's virtual reality training platforms are available online.

Field Applications
Several modules on the website for training. This case study is for the preparation and construction phases.

Software:
Revit, 3D Studio, EON Studio, EON Viewer with CAVE

Hardware:
HTC VIVE, Samsung Gear VR, Oculus Go, 2 Joysticks

IO2
BIM was not an essential tool inside this case study although integrating BIM will help for a training module.

IO3
Platform where some VR devices may be attached and get an immersive training experience.

CASE 2. How Cat Safety VR Improves Jobsite Training

CAT started with safety in road construction and simulating real life scenarios. CAT designed the VR tools as a multiplayer environment so a group of workers could train simultaneously. Application is implemented in the preparation phase.

Software:
Revit, Game engines

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Hardware:
Gaming laptop preloaded to run the program, HTC VIVE, 2 Joysticks

Training module presents a wrap-up to reinforce the positive lessons learned and stress that no emergency at the jobsite is worth risking the safety of the worker or anyone else.

IO2
BIM is not applied in this safety experience.

IO3
Communication and mobile modules are possible contributions.

CASE 3. SRI International Augmented Reality Solutions for Construction Inspection (youtube video)

SRI uses AR to simulate job site operations for construction inspectors. Using drones it is used for inspection while comparing with BIM models. SRI international AR tool is designed for site inspection. Application targets construction phase for inspection by safety managers and engineers.

Software:
Revit, Several data collection software

Hardware:
Drones, Vehicles, AR Glasses

IO2
BIM is used to model and inspect possible errors or differences in the construction by comparing it, using AR, with BIM model.

IO3
AR captures images with headset and tags these with notes and sharing with other devices.

Case 4. Safety Compass - Augmented Reality Workplace Safety

Gives access to live information updated based on the location of the worker. Uses AR technology to identify potentially risks at location. It

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uses mapping on a tablet or phone. This application also allows interaction and collaboration of all on site construction fields.

Software:
Location tracking system (LTS), location database (LD), user identification interface (UII), user database (UD), Revit

Hardware:
iPhone, AP sensor, computer, GPS

IO2
BIM is linked to the GPS and the mobile app will give risk alerts and notifications based on the location.

IO3
Workers will be notified of potential risks pinpointed on an interactive mapping system. The AR app is effective and easy to develop.

Case 5. Augmented and Virtual Reality for Safety Training

Blog by a group from e-learning industry placing questions about the use of AR and VR in safety training. These comprise pragmatic considerations like costs, number of learners, business impact of training, business risk, or cost incurred due to the situation, commonness of the situation, etc.. It presents some scenarios that may help the decision about using VR or AR. "So let's proceed on the assumption you have a worthy case before you. How would VR help? Let's take the 'defusing a bomb' thing as an example.

- You don't need to incur the expense of purchasing the physical objects you would otherwise need in your training simulation (e.g. the fake bomb that goes 'pffffff' and releases smoke if you've made a wrong move).
- You don't have the recurring expense of replacing those physical (probably custom-made) objects for each batch of learners (because you can't economize on each person getting the 'pffffff' feedback).
- You can control, customize, and even change up the environment more efficiently (the bomb can go 'pffffff', squirt paint, and release smoke and tick at an increasing volume up to detonation point).
- Your learners can wear the headset anywhere to access the training, not just have to be physically at the training simulation room you've created (on-demand 'pffffff', who would've thunk!). These reflections can be used either on IO2 or IO3.

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Case 6. Virtual Reality in Construction

Presents many applications and one is about Construction Safety. "More effective and safer training of construction workers that is less expensive and much safer to train heavy-equipment workers – e.g., crane operators – in virtual reality. The thing is that many graduates with an engineering degree get their diplomas without sufficient practice at a construction site. Here is where VR training comes into play. With its help, engineers and architects could get much more experience before graduation. Also, the virtual environment allows workers to operate dangerous equipment without any risks whatsoever. It's cheaper than real-life training where you'd need a real tower crane to train the operators. CertifyMe.net, a training and certification company that specializes on forklifts, has a VR program for practicing in a risk-free environment. Using it, they eliminate any type of injuries and equipment damage, allowing for a trial-and-error approach without adverse consequences. It provides the training and assessment in one hour with awarding the certificate immediately and online. The approach can be used in IO2 or in IO3 depending on the activities.

Case 7. New construction safety school will use virtual reality to educate workers

School to improve worksite safety through a new training centre targeting the construction industry. A key feature of the Construction Safety School is experiential learning by using AR and VR. Possible scenarios are created in this school with demonstration of equipment connected to the contracting industry. It may certify workers in terms of construction safety. Application may involve workers, engineers, safety professionals, project managers, students, safety managers and safety coordinators.

IO2
BIM is not used in these training scenarios.

IO3
AR and VR are used in a wide range of scenarios and with several risks.

Case 8. YellowJacket

The software, available also on mobile app, can monitor and report on quality, health, safety and processes on construction sites. May save

time, save money, improve performance and ultimately save lives. Adopting YellowJacket health and safety software and fully integrating it within the organisation´s culture and throughout the supply chain then it is possible to achieve real improvements to health, safety and quality management on construction sites and beyond. The capabilities of the software will help users not only achieve the above but also assist with the demands of project monitoring and reporting. It is designed to be as user friendly as possible –giving 'at a glance' overview of health, safety and quality across the projects. It has an easy data inputting through the YellowJacket health and safety mobile app. The YellowJacket mobile app allows employees and contractors on the site to easily input information relating to health, safety and quality – meaning data is captured 'as it happens', rather than staff waiting to get back to a computer. It can be used in IO2 and in IO3.

Case 9. VR Safety Training for Construction companies (LandMarkVR)

Participants experience risky scenarios where each one has to choose adequate precaution in order to pass a certifying test. It uses full immersion by visual, sound, and physical effects. It has a multi-scenario selection, supports trainer and trainee real-time guidance, tracks individual behavior, and tailor made for conducting practical training. The scenarios are created in CAVE environment.

Software:
Revit, 3D Unity

Hardware:
CAVE, HTC VIVE, High performance computer

IO2
The application did not demonstrate any BIM integration.

IO3
Training solutions and scenarios were used with low cost equipment.

Case 10. A critical review of virtual and augmented reality (VR/AR) applications in construction safety

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90 VR/AR-CS related articles from 2000 to 2017 are reviewed. The review taxonomy was consolidated by technology characteristics, application domains, safety enhancement mechanisms, and safety assessment and evaluation. The top three application domains include hazards identification, safety education and training, and safety inspection and instruction. The paper is useful for IO2 and IO3 and organizes fundamental knowledge and concepts related with use of AR and VR in Construction Safety

Case 11. Fulmax

Called the Fulmax Cube it provides possibilities to communicate, share and collaborate as a team in an immersive BIM environment. It may introduce stakeholders to the virtual asset before it is built. It can help to refine design and engineering solutions through 1:1 scale viewing in a BIM environment. The system may educate and train personnel and communicate onsite, simulate operational based activities virtually before setting foot on site. Hardware and software can be used to enhance the effectiveness of design reviews, build activities, tool box talks and maintenance tasks. The tool may provide a dedicated BIM space for virtual exploration of the built asset coupled with the associated valuable BIM data.

The Cube is fast to assemble, may be installed in just 3 hours, users are up and running within 15 minutes, BIM models and data are processed in minutes for the Fulmax environment. It is secure while managing BIM content related with each project, it does not require an external model and it is provided training to operate the tool. It is easy to navigate and to explore the digital asset and to access BIM data, it is a compact solution and it is ideal for reviews, stakeholder engagement and collaboration. Can be used in IO2 or in IO3.

Case 12. Role of Visualization Technologies in Safety Planning and Management at Construction Jobsites

Teste a 4D BIM model used in three projects. Used advanced visualization technologies applications for safety in building projects. Only tools commercially available were used and designers, engineers and contractors tested them. The tools were used to train workers. The application targeted preparation and construction stages.

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Software:
Revit, Sketchup, 3Ds Max, Unity 3D, AutoCAD, Synchro, MS Project, Camtasia, MS Movie Maker

Hardware:
Oculus Rift

IO2
BIM was used in 4D simulations.

IO3
VR used common and affordable tools.

Case 13. A framework for construction safety management and visualization system (SMVS)

The proposal (of 2013) includes a visualization engine for the integration of all information. Visualization engine is the hub of the SMVS that imports and exports external information such as BIM-based site model, safety information data, and sensor signal location data that is created in other software engines for its use in each system module. Microsoft XNA Game Studio 4.0 program environment has been employed considering the interoperability of data necessary to the system operation. All information from/to interfaces of the modules is displayed on visualization engine browser (VEB). It is a framework for a safety management and visualization system (SMVS) that integrates BIM, location tracking, AR, and game technologies. A prototype system has been developed and tested based on an illustrative accident scenario.

Software:
Microsoft XNA Game Studio 4.0, Visualization engine browser (VEB), risk identification interface (RII), location tracking system (LTS), location database (LD), user identification interface (UII), user database (UD), Revit

Hardware:
iPhone, AP sensor, Computer, GPS , Mouse, Keyboard, Joystick

IO2
Integrates BIM with other tools.

IO3

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May need updating of tools.

Case 14. OSHA PIXO safety compliance Virtual Reality

Application for safety compliance created a space that tries to be realistic. Training explores these spaces featuring construction sites and sounds that blurs virtual and actual realistic environments. For example, one mode is safety sweep that tries to potential OSHA violations, faulty equipment, inadequate storage of hazardous materials or co-workers not wearing safety gears or working unsafely. It comprises digital tests and assessments based on OSHA standards. This application focus on preparation and construction stages.

Software:
Unreal Engine

Hardware:
Oculus Rift, Leap Motion, High performance computers

IO3
Training is based on OSHA standards, assessment is digital, randomized scenarios, several training methods and detailed in terms of graphics, sound and scenarios making it fully immersive.

Case 15. Web-based Collaborative Virtual Environments (LIRKIS G-CVE)

Collaborative virtual environments mediate interaction in virtual space among more participants that may be spread over large distances. Globally, multi-user groups can participate together in one completely immersive virtual environment to achieve goals. Distributed virtual environments can be purposely used as training tools for real-time 3D simulations or scenarios.

Benefits of G-CVE (developed at Technical University of Kosice

- Multi User
- No Expensive SW/HW Needed
- Web Based (Only Web Browser Needed)
- Without Installation of Any Software

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- Work on Any Operation System – Any Device (Also With Oculus, Htc, Ms Hololens Products)
- Switch to VR Mode (With VR Headset)
- Open Source

Demo App Link - http://csetir.glitch.me/

Software:
Web-based system, built on top of the Networked-Aframe framework.

Hardware:
Any online device/any operation system, Any Headset - Oculus, HTC, Microsoft Hololens, etc.

IO3
Own prepared team training solutions and scenarios executable on any device.

B) Identifying strategies and solutions

IO2 will be decisive in this topic based on the report on which tools to use and explore. Several strategies can be considered when addressing the use of virtual environments to improve education and training for safety in construction sites. Indeed, the targets of training initiatives are a diverse group, including site workers, safety specialists, among others. The technical skills and education levels for these groups differ considerably, as do their work environments, and functions. This diversity must be considered when defining strategies and solutions, even when the suitable available hardware and software options overlap largely for the different user groups.

Indeed, as described in this document, the same VR and AR hardware and the software components have been adopted in a range of applications. This is considered as an opportunity, as solutions that target one user group might be adapted for different uses. The main current VR and AR development technologies are cross-platform, which largely reduces the importance of the choice of specific equipment within similar types of hardware such as Head Mounted Displays (HMD) or motion controllers. Naturally, different training environments demand different types of hardware, due to cost, time and other practical considerations. For instance, despite recent developments in CAVE (Computer Assisted Virtual Environment) technology, which allow for lower-cost and quicker

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deployment, HMDs remain a more practical solution for virtual immersion, while computers and mobile devices are ubiquitous, and provide acceptable VR experiences in many instances.

The use of BIM models as a source of information (including geometry) for the virtual models is regarded as an obvious choice. BIM models are increasingly common in practice, they support different types of information, thus providing great flexibility when deciding on technical solutions, and are compatible with other components such as game engines.
Alternative solutions, such as the use of generic 3D modelling tools would require the development of models from scratch, with no relationship with the actual construction process. This means that changes in design or in construction plans would not be quickly or easily reflected in the virtual training environments. These factors greatly reduce the feasibility of a non-BIM solution.
Since BIM authoring tools are interoperable, and standard open formats exist for exchanging BIM data, the choice of BIM tools is not considered to be a critical issue when designing a strategy for the development of training solutions.

C) Survey of technologies and of equipment

IO2 - BIM implementation

There are several BIM programs used but major and most used was Autodesk Revit with the combination of BIM 360 for tracking, collaboration and document management. Autodesk Revit is a building information modelling software for architects, landscape architects, structural engineers, mechanical, electrical and plumbing engineers, designers and contractors. BIM 360 is a unified platform connecting the project teams and data in real-time, from design through construction, supporting informed decision-making and leading to more predictable and profitable outcomes. Other 3D and visualization software were used like 3Dmax, Blender, AutoCAD, ArchiCAD, Bentley and SketchUp.

First programs addressed three dimensional visualization. Later other dimensions were added like planning, motion, cost and sustainability. These visualization methods were also structured as a gamified structure for training and risk predictions of accidents. Other methods based on BIM models rely on tracking devices to obtain an onsite visualization of the models, safety information data and sensor signal location data.

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Risk investigation, inspection has been using BIM for modelling and inspecting errors or differences by comparing models with the actual construction. AR tools can also be used to view the BIM model and identify errors found on-site. For instance, a video camera attached to the headset may give feedback to BIM model. That may generate composite images of model and physical space. BIM based model can be linked to GPS and a mobile app can provide risk alerts and location-based notifications. Use of heavy machinery can also register movements and identify risks due to site conditions. Linking BIM with a safety standard database, such as OSHA, may allow code checking. These checks may be in an AR environment showing risks on the mapped system.

IO3 – Equipment and applications in VR and AR

Unity Real - Time Development Platform is a cross-platform game engine developed by Unity Technologies. This engine can be used to create 3D models with VR/AR scenarios and simulations.

Unreal Engine - features a high degree of portability and is a tool with available source.

VR Hardware (examples)

VR Headsets - Oculus Rift, HTC Vive,

Multi-sensory - VR CAVEs

Tracking sensors - Kinect (motion sensing input devices), Leap Motion (plug-and-play haptic) and Smartphones iOS or Android.

AR Hardware (examples)

HoloLens mixed reality (apps and solutions that help people learn, communicate, and collaborate), Google Glass Enterprise Edition (hands free), Magic Leap One (AR headset) and DAQRI (AR helmet and glasses).

Reflections:
- Computation capabilities requiring high performance computers;
- Construction site may be more complex than the model;
- Access to internet and satellite signal may be of low quality;
- Difficulty in addressing simultaneous multiple risks;
- Using GPS signal with AR devices may cause compatibility problems.

See Annex for costs and technical specifications

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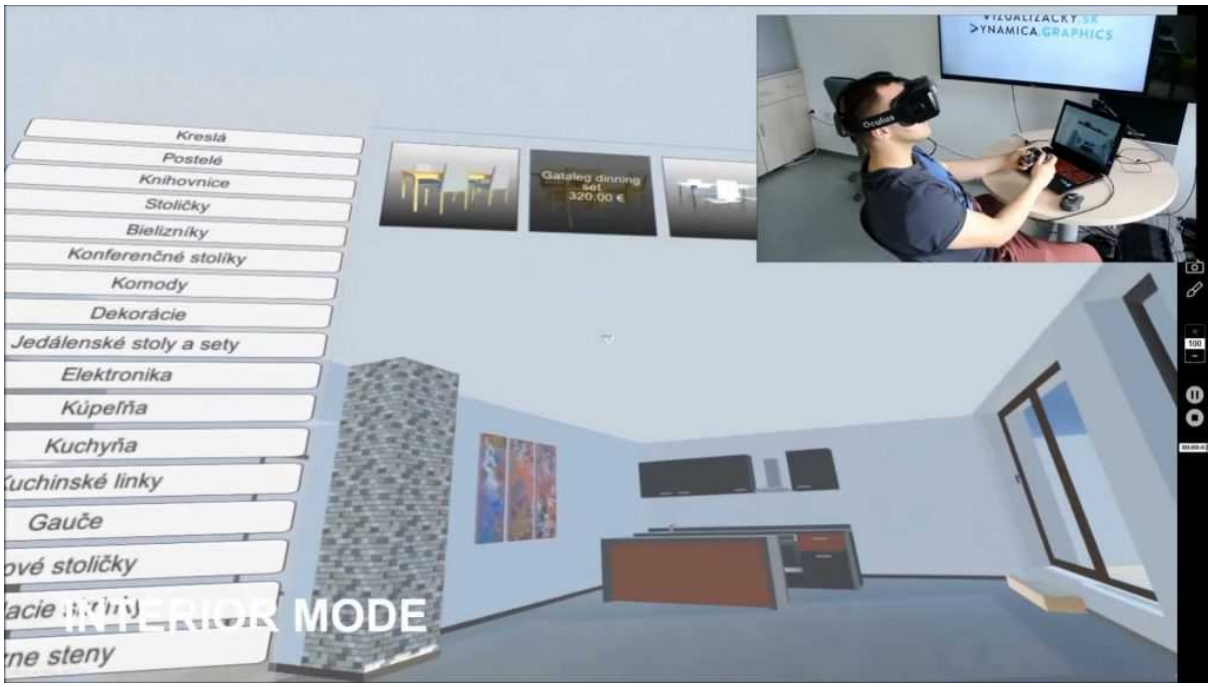
Testing of available hardware and software solutions – examples

1: Photoshooting the place of a future construction site with a drone for integration into a virtual environment



2: Testing of virtual environment processed in Unity 3D with Oculus Rift

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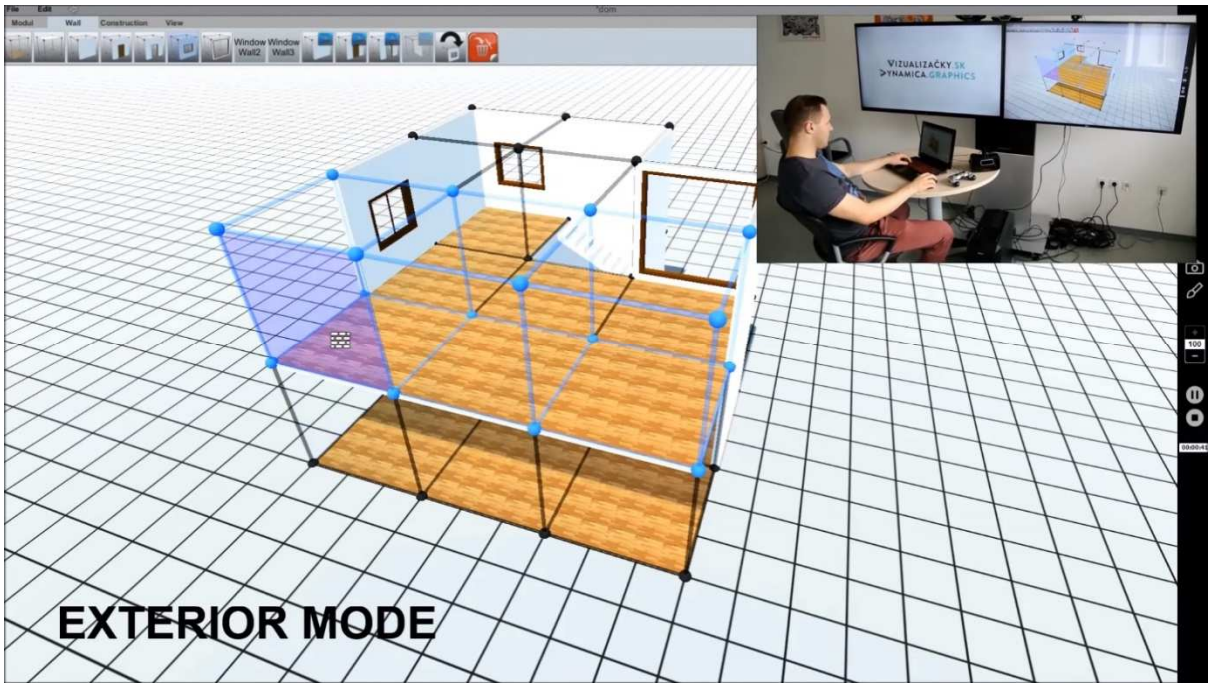
3: Testing the virtual environment of the construction site with Microsoft Hololens



4: Testing of virtual environment processed in Unity 3D with Oculus Rift

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5: Testing of virtual environment processed in Unreal engine with Oculus Rift

6: Testing of virtual environment processed in HTML5 with Samsung Gear VR

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7: Hardware testing for work in virtual reality Oculus Rift, Samsung Gear VR, Google Cardboard, Microsoft Hololens

D) Finding training methods at all levels of qualifications.

Training may be provided for levels 1 to 7 of the European Qualification Framework (EQF). In terms of training methodologies the partnership is mostly composed by higher education institutions that are experienced in training levels 5 to 7. Concerning levels 1 to 4, generally designated as Vocational Education and Training (VET) the partnership will employ the approaches suggested by CEDEFOP and used by VET providers like EVBB or EVTA.

The training will be based on the outcome based method proposed by Tuning Academy. All modules and training activities will be designed and prepared taking into account the knowledge, skills and attitudes required. The competences required will be defined to face the several risks and

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preventive measures adequate for the respective level of qualifications. This outcome based training will allow to prepare everyone from basic level (1) to master level (7). One of the associate partners, ISHCCO, of the project has a qualification framework for levels 5 to 7 that may be used to define the training needed.

Using online training will also be considered as options to train the target groups. Current options are free platforms like Coursera, Moodle, Google Classroom and Microsoft Teams. Certification from the courses may lead to awarding a construction safety passport. This passport may be required to enter the construction sites while ensuring that holders have adequate competences in construction health and safety. Examples are the CCNSG Safety Passport in the United Kingdom and the Occupational Safety Card in Finland. While in Finland the card is recommended in the United Kingdom anyone must have a valid CCNSG Safety Passport to enter many engineering and construction sites.

E) Studying validation and assessment methods of competences.

The validation of competences is relevant to ensure that the competences in terms of construction safety were acquired. The training provided by the project outputs maybe used to qualify some of the participants to be able to enter the construction site or to perform some risky tasks. Therefore the assessment has to be suited to type of competences that are supposed to acquired.

Proper assessment of the different competences (knowledge, skills and attitudes) is based on the use to webtool TALOE. This webtool can suggest assessment methods for the different types of competences at various levels from 1 to 7. The assessment methods will be chosen in accordance with the suggestions, the construction site resources, type of training and purpose of the qualification.

The assessment of the workers, technicians and engineers competences to verify if they are qualified to enter a construction site may be applied to other groups like students. This evaluation will imply proper training that is expected to be provided by using effectively the tools involving digital environments.

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F) Contacting stakeholders to diagnose needs and concerns

One associate partner is ISHCCO (International Safety and Health Construction Coordinators Organization). It is an European association with national representatives from 17 countries. The respective qualification framework defines competences from levels 5 to 7 of EQF. ISHCCO members have already agreed to indicate types of training being used, suggest relevant training modules and validate/comment the outputs of the project.

The other relevant stakeholder to cooperate with the partnership is DGGrow from the European Commission. The unit is addressing the construction safety in terms of SMEs. The first study conducted to conclusions that may be useful to define what type of training the project should deliver. The document proposes a tool with a cost analysis of prevention versus accident in construction SMEs.

Another associate partner is AECEF – Association of European Civil Engineering Faculties. The cooperation with AECEF may bring the input from Civil Engineering Faculties in terms of needs of training, current practices and result validation. It is expected that the participation will mostly useful in IO4 and IO5.

The national government agencies may be invited to analyzed the tools proposed and validate the qualification of successful participants in the courses. It is adequate to the success of the implementation of the tools and courses that the formal acceptance by the official agencies is assured by previous testing. Construction associations will also be involved in the proper tuning of the tools and courses and in the validation of the training.

More than 80 major construction entrepreneurs in Slovakia are members of Convention of building businesses of Slovakia (ZSPS). ZSPS presents a local space for the verification of the proposed procedures and training in the field of OHS in the real conditions of Slovak construction. The cooperation with ZSPS will be will be intensive especially in the solution of IO3 and IO4.

G) Setting up digital platform

Project has created already two platforms. The principal platform is the project website with the goal as being the reference in terms of the

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promotion of the activities and outputs. The website will be the major dissemination of the project while being the public image of the project. It will include all relevant news about the project, links to other initiatives and resources, project outputs and testing tools.

Another digital platform proposed in the project is a Wiki intending to concentrate the results of the cooperation among partners and with external stakeholders. It is planned to be a working platform among partners and external stakeholders. The Wiki will be accessible mostly to partners allowing exchanges of documents and of materials concerning the several intellectual outputs.

H) Establish communication channels among partners

A Google Drive account has already been created by UKosice to manage documents and materials essential for the project administrative and financial matters. The communication plan is based on the long-term mutual experience of the project partners guarantees a successful project management and communication. The main communication tool for project management and solution will be biannually face-face project meetings. Other communication channels will be used such as email, virtual conferences, use of online (cloud-based) repository of documents and materials and social media.

The virtual meeting (via zoom.us) will be held once a month. It will be attended by representatives of all project partners. The aim of the virtual meeting will be a discussion on the solution of individual project outputs and project results.

I) Start initial planning of dissemination

Articles written presenting the project are planned for

- SHO2020
- PTBIM
- CIBW99

A chapter about the project has been published in a Springer publication of Occupational Health and Safety. The dissemination will be implemented and it has started by the creation of project's website and publications in relevant journals and conferences. The social media visibility will involve

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the partners´ communities and will include the engagement of each partner and associated partner networks. It is planned to establish communication channels with partners own organizations websites, newsletters and social media pages.

All planned intellectual outputs of CSETIR will be open access and will foster dissemination. The physical outputs, like reports, reviews, manuals, qualification certificates, applications for smart phones, BIM models, VR/AR interactive solutions and training sessions will be available in the project platforms. The targeted groups are teachers, trainers, students, engineers and technicians involved in the construction sector. The goals of these outputs are to prepare the targeted groups preparation to practice and experiment the digital tools to analyze risks and prevent accidents.

J) Setting up administrative and financial arrangements

The project partners were sub-contracted (based on recommendations of the National Agency) and funds were sent to their bank accounts (according to budget relating to the activities). All project partners will provide to UKosice the scans of travel tickets and accommodation after each administration of transnational meeting (administration and financing of transnational project meetings). All project partners will provide to UKosice the scans of time sheets, evidence of the relationship between the employee and project partner and results of IOs solutions (administration and financing intellectual outputs).

K) Setting up possible application for certification of training

Considering the certification some existing examples will be considered:

- FEANI report on validation of competences will be considered since it includes formal, informal and non-formal learning;
- Common Microcredential Framework of OpenEdUp;
- Open Badge Credit System of EDEN.
- Construction Safety Passport or Card.

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ANNEX – Complementary to Chapter C.

Market prices and Specification

Softwares	Prices	Specifications
Autodesk Revit	Monthly 305$, Yearly 245$, "203$ monthly" 3 years 6,550$, "182$ monthly"	System requirements for Revit 2021 products
BIM 360	Docs pricing starts at $480/yr., per user.	BIM 360 is a unified platform connecting your project teams and data in real-time, from design through construction, supporting informed decision-making and leading to more predictable and profitable outcomes. Predict safety hazards, proactively manage quality, automate tasks, and reduce rework so that you can control costs and stay on schedule. Centralize your project data and access the information you need in real-time, anywhere, so you can track your project and make decisions in the field.
Bentley	Term Licenses on Project selection	Bentley Systems is a leading global provider of software solutions to engineers, architects, geospatial professionals, constructors, and owner-operators for the design, construction, and operations of infrastructure. Bentley's MicroStation-based engineering and BIM applications, and its digital twin cloud services, advance the project delivery (ProjectWise) and the asset performance (AssetWise) of transportation and other public works, utilities, industrial and resources plants, and commercial and institutional facilities
ArchiCAD	$4,995 for licens free educational version for students, teachers, and schools.	ARCHICAD is an architectural BIM CAD software, it is a complete design suite with 2D and 3D drafting, visualization and other building information modeling functions for architects, designers and planners. A wide range of software applications are integrated in ARCHICAD to cover most of the design needs of an architectural office: 2D CAD software — drawing tools for creating accurate and detailed technical drawings 3D Modeling software — a 3D CAD interface specially developed for architects capable of creating various kind of building forms Architectural rendering and Visualization software — a high performance rendering tool to produce photo-realistic pictures or videos Desktop publishing software — with similar features to mainstream DTP software to compose printed materials using technical drawings pixel-based images and texts Document management tool — a central data storage server with remote access, versioning tool with backup and restore features Building Information Modeling software — not just a collection of the above-mentioned applications with an integrated user interface but a novel approach to building design called BIM
Blender	Free and Open source	free and open-source 3D computer graphics software toolset used for creating animated films, visual effects, art, 3D printed models, motion graphics, interactive 3D applications, and computer games.

AutoCAD	210$/Month 4,565/ 3yeas $1,690 /year Free students and teachers licenses free 30 days trial	computer-aided design and drafting software application, is used in industry, by architects, project managers, engineers, graphic designers, city planners and other professionals. ESRI ArcMap 10 permits export as AutoCAD drawing files. Civil 3D permits export as AutoCAD objects and as LandXML. Third-party file converters exist for specific formats such as Bentley MX GENIO Extension, PISTE Extension (France), ISYBAU (Germany), OKSTRA and Microdrainage (UK); also, conversion of .pdf files is feasible, however, the accuracy of the results may be unpredictable or distorted
SketchUp	55$/year	3D modeling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil and mechanical engineering, film and video game design
Tridify	Light 20$ / Months Standard 90$ / Months Large 400$ / Months	Uses Open Standard IFC so you can upload any BIM from any software; Provides multiple models in one view by combining different IFCs together & publishing to web; Is developed for mobile first viewing, so everyone can access models anywhere they are, on devices they already have; Has all the clever programming hidden, so no apps, software or training is required for teams and clients to view the link; Is incredibly cost effective with multi user access starting from only $20 a month
Unity Real	Free	Development Platform is a cross-platform game engine developed by Unity Technologies. This engine can be used to create 3D models with VR/AR scenarios and simulations in Real time and physics. With Multiplatform converters and builds. Unity real-time development platform. Create 3D, 2D VR & AR visualizations for Games, Auto, Transportation, Film, Animation,
Unreal Engine	19$/ month	Development Platform is a cross-platform game engine developed by Unity Technologies. This engine can be used to create 3D models with VR/AR scenarios and simulations in Real time and physics. Although initially developed for first-person shooters, it has been successfully used in a variety of other genres, including platformers, fighting games, MMORPGs, and other RPGs
Oculus Rift,	$399,00	Recommended Specs: Graphics Card NVIDIA GTX 1060 / AMD Radeon RX 480 or greater Alternative Graphics Card NVIDIA GTX 970 / AMD Radeon R9 290 or greater CPU Intel i5-4590 / AMD Ryzen 5 1500X or greater Memory 8GB+ RAM Video Output DisplayPortTM 1.2 / Mini DisplayPort (with adapter included in the box) USB Ports 1x USB 3.0 port OS Windows 10
HTC Vive,	Cosmos Elite Headset 619€ Cosmos Elite 999,00 € Cosmos 829,00 € Pro Eye Series 1.439,00 €	Pro Eye Series Evolving Perception. Precision Eye Tracking combined with professional-grade sound and graphics - designed for enterprises, home offices, and VR users who require a premium PC-VR experience. Pro Eye Designed for studios, home offices and VR users that require immersive experience.

Kinect (motion sensing input devices),	149.99 GBP	The technology includes a set of hardware originally developed by PrimeSense, incorporating RGB cameras, infrared projectors and detectors that mapped depth through either structured light or time of flight calculations, and a microphone array, along with software and artificial intelligence from Microsoft to allow the device to perform real-time gesture recognition, speech recognition and body skeletal detection for up to four people, among other capabilities. This enable Kinect to be used as a hands-free natural user interface device to interact with a computer system. Kinect is a peripheral that sits atop the user's display similar to a webcam.
Leap Motion	Free licensing $89.95	he Leap Motion Controller is an optical hand tracking module that captures the movements of your hands with unparalleled accuracy. Low processing power, a wide field of view, and near-zero latency. Whether you're an indie developer or a multinational company, the Leap Motion Controller makes human interaction in digital worlds natural and effortless The VR Developer Mount is an accessory for the Leap Motion Controller that enables virtual reality experiences on Windows PC VR headsets such as the Oculus Rift and HTC Vive. It may also be mounted onto AR headsets (as long as the controller cameras are not occluded).
HoloLens mixed reality	HoloLens 2 with Dynamics 365 Remote Assist Same-day deployment Low-cost financing for the device Enterprise-grade security No custom development required Starts at USD $125 per user, per month. HoloLens 2 (device only) HoloLens 2 offers the most comfortable and immersive mixed reality experience available—enhanced by the reliability, security, and scalability of cloud and AI services from Microsoft. USD $3,500 per device. Developer wearing HoloLens 2 headset HoloLens 2 Development Edition Start building for mixed reality with this offer that combines HoloLens 2 with free trials of Unity software and Azure credits for cloud services. HoloLens 2 Unity Pro & PiXYZ Plugin trial $500 Azure credit Starts at $99 per month.	HoloLens tech specs Display Optics See-through holographic lenses (waveguides) Resolution 2k 3:2 light engines Holographic density >2.5k radiants (light points per radian) Eye-based rendering Display optimization for 3D eye position Sensors Head tracking 4 visible light cameras Eye tracking 2 IR cameras Depth 1-MP time-of-flight (ToF) depth sensor IMU Accelerometer, gyroscope, magnetometer Camera 8-MP stills, 1080p30 video Audio and speech Microphone array 5 channels Speakers Built-in spatial sound Human understanding Hand tracking Two-handed fully articulated model, direct manipulation Eye tracking Real-time tracking Voice Command and control on-device; natural language with internet connectivity Windows Hello Enterprise-grade security with iris recognition Environment understanding 6DoF tracking World-scale positional tracking Spatial Mapping Real-time environment mesh Mixed Reality Capture Mixed hologram and physical environment photos and videos Compute and connectivity SoC Qualcomm Snapdragon 850 Compute Platform HPU Second-generation custom-built holographic processing unit Memory 4-GB LPDDR4x system DRAM Storage 64-GB UFS 2.1 Wi-Fi Wi-Fi: Wi-Fi 5 (802.11ac 2x2) Bluetooth 5 USB USB Type-C Fit Single size Fits over glasses Weight 566g Software Windows Holographic Operating System Microsoft Edge Dynamics 365 Remote Assist Dynamics 365 Guides 3D Viewer Power Battery life 2–3 hours of active use

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Magic Leap One	Enterprise edition $2,995	3D computer-generated imagery over real world objects, by "projecting a digital light field into the user's eye",involving technologies potentially suited to applications in augmented reality and computer vision. It is attempting to construct a light-field chip using silicon photonics
Google Glass Enterprise Edition	$1.195,00	Glass intuitively fits into your workflow and helps you remain engaged and focused on high value work by removing distractions. Using voice commands, you can activate the right application for you at any time. location searching Improve accuracy Access training videos, images annotated with instructions, or quality assurance checklists that help you get the job done, safely, quickly and to a higher standard. video call Collaborate in real-time Glass can connect you with coworkers in an instant, bringing expertise to right where you are. Invite others to “see what you see” through a live video stream so you can collaborate and troubleshoot in real-time.
DAQRI	Currently unavailable	Weight Smart Glasses: 335g Compute Pack: 496g Processor 6th Generation Intel® Core™ m7 Processor (Up to 3.10 GHz) Dedicated vision processing unit for 6-DOF tracking Optics Dual LCoS Optical Displays 44° Diagonal FOV Resolution: 1360 X 768 Frame Rate: 90 fps Connectivity WiFi 802.11 A/B/G/N/AC 2.4/5 GHz Bluetooth Battery Built in rechargeable lithium ion battery 5800 mAh Storage 64 GB Solid State Drive I/O Ports 2 USB 3.1 Type C Ports 3.5mm Headphone Jack Audio 2 Microphones with Active Noise Cancellation Depth Sensor Camera Range: 0.4m to 4m Resolution: 640 x 480 Frame Rates: 30, 60, 90 fps Color Camera RGB 1080p HD Camera, 30 fps AR Tracking Camera 166° Diagonal Wide-Angle Fisheye Lens Resolution: 640 x 480 Frame Rate: 30 fps