Task O2/A1.3

LIST ROBOTISED AND AUTOMATED EQUIPMENT FOR CONSTRUCTIONS SECTOR AND RELATED TO RISK

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1. INTRODUCTION

In this Intellectual Output 2, the key situations will be proposed to be included in the 3D environments. As we have indicated in the aims of the work package the key situations will be based on previous reports, taking into account the main risk situations in robotic construction companies and the application of health and environmental prevention measures currently applied in this sector. These situations will be sent to all partners who will comment any addition or change that should be done.

In this subtask O2/A1.3, the main objective of this report is to compile and define the main robotic and automated equipment for the construction sector, as well as to define the associated risks, in order to define the main risk situations to be implemented in the SafeCRobot learning tool.

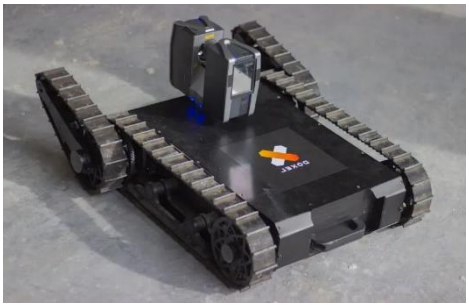
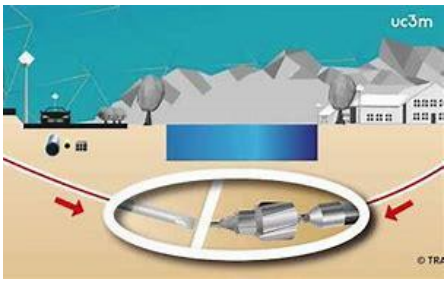
2. LIST

Name of robotised or automated equipment	Image and video	Risks inherent
Demolition robot	 Demolition Robot - YouTube  https://www.arerobot.com/?lang=en	**Safety risks:** -Mechanical hazards due to unintentional movements or the release of tools. -Collision of workers with equipment, crushed or trapped by equipment. -Injury from falling elements of equipment. -Falls to the same level, tripping. -Falls to different levels. -Crushes. -Blows, cuts. -Particle projection. -Electrical hazards -Heavy objects falling from height -Operator falling from height -Incorrect assessment of the demolition object (construction, strength) -Running over the feet: broken bones, amputation of feet or toes -Bruises, contusions, burns during maintenance work

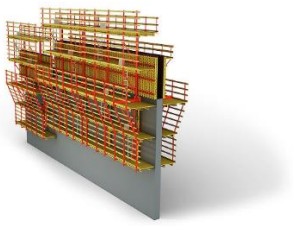
	 Robotic Demolition - YouTube 	**Chemical risks:** -Dust inhalation. -Inhalation of chemicals -Inhalation of fumes or gases from machinery. **Physical risks:** -Noise -Vibrations
Mason robot	 Robotic bricklayer builds houses 3x faster than humans - YouTube  "UK's first" robot-built home made by automated bricklayer - YouTube	**Safety risks:** -Crushes. -Blows, cuts. -Entrapment -Collision -Objects falling from height **Chemical risks:** -Inhalation of fumes or gases from machinery. **Physical risks:** -Noise

Drone. For aerial and terrestrial **laser scanning**	 Major benefits of using drones in construction - YouTube  Major benefits of using drones in construction - YouTube  DJI PHANTOM 4 RTK – A Game Changer for Construction Surveying - YouTube	**Safety risks:** -Operator falling from height -Distraction of workers -Collision -Device failure -Losing control of the device -Falling or hitting a ground obstacle or a person -Hazards resulting from the local terrain conditions and weather conditions -Third parties / animals -Fire hazard -Electric shock -Falls to the same level, tripping. -Blows, cuts. **Chemical risks:** -Dust inhalation. **Physical risks:** -Noise

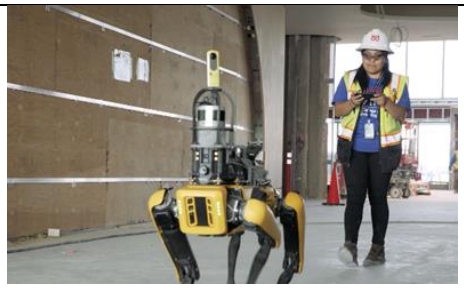
Automated excavator	 Built Robotics — Autonomous Track Loader (ATL) - YouTube  Built Robotics' Autonomous Construction Vehicles - YouTube	**Safety risks:** -Falls to the same level, tripping. -Collisions, crashes, blows or crushing by mobile machinery. -Blows, cuts. -Entrapment, **Chemical risks:** -Dust inhalation. -Inhalation of fumes or gases from machinery. **Physical risks:** -Noise
3D printer at industrial level	 The biggest 3d printed building - YouTube 	**Safety risks:** -Failure of the control system. -Incorrect application of the material builds -Falls to the same level. -Falls to different levels. -Blows -Pinching -Crushing -Falling of gripped components **Chemical risks:** -Dust inhalation. -Inhalation of chemicals **Physical risks:** -Noise

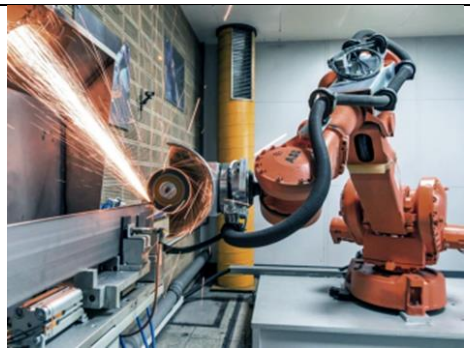
	REbuild Construction 3DCP - Promo Video - YouTube  	
Real time construction site error detector robot	 Doxel Uses AI and Robots to Track Construction Projects - YouTube	**Safety risks:** -Falls to the same level, tripping. -Crashes and blows. **Chemical risks:** **Physical risks:**
Intelligent subway robot for urban environments	 Diseñan un robot subterráneo inteligente para entornos urbanos - YouTube	**Safety risks:** -Falls to different levels. -Fires, explosions. **Chemical risks:** -Dust inhalation. -Inhalation of fumes or gases from machinery. **Physical risks:** -Noise -Vibrations

Autonomous Mobile Robot	 Bouygues Construction uses autonomous and collaborative robot : EffiBOT - YouTube	**Safety risks:** -Falls to the same level, tripping. -Falls to different levels. -Blows or crushing due to falls of transported cargo. - Collisions, crashes, blows or crushing by mobile machinery. -Entrapments, blows and cuts. **Chemical risks:** -Inhalation of fumes or gases from machinery. **Physical risks:** -Noise
Robotic platform for cargo transport (Dumper)	 Electric Autonomous Hauler HX1 – Battery-Electric Hybrid Technology Innovation – Volvo Concept Labs - YouTube  Komatsu Autonomous Haulage System (AHS) - YouTube	**Safety risks:** -Falls to the same level, tripping. -Blows or crushing due to falls of transported cargo. -Collisions, crashes, blows or crushing by mobile machinery. -Entrapments, blows and cuts. **Chemical risks:** -Dust inhalation. **Physical risks:** **-Noise**

Robot reproduction of the operator's movements	 Sarcos Guardian® GT Robot - YouTube	**Safety risks:** -Blows or crushing due to falls of transported cargo. -Collisions, crashes, blows or crushing by mobile machinery. -Entrapments, blows and cuts. -Particle projection. -Fire/explosions **Chemical risks:** **Physical risks:** -Noise.
Track construction trains	 ekorys357 - YouTube Plaser - budowa linii kolejowej 273 - YouTube	**Safety risks:** -Struck by machine in motion -Struck by traction vehicles in motion -electric shock from the overhead railway traction line **Chemical risks:** **Physical risks:** -Noise.
Self-climbing formwork	 Formwork solutions (peri.com)	The risk in the process of operation and use, such as its installation and dismantling, adjustment of position, which is prone to lead to: -template collapse -fall from height -strike by objects

Robotic Power Trowel	 Robotic power trowel - YouTube	**Safety Risks:** -Blows -Cuts -Entrapment -Collision **Physical Risk:** -Noise -Lifting/Manual handling
Autonomous Painting Robot	 Autonomous Painting Robot - YouTube	**Safety Risks:** -Collision -Crash -Hit by moving objects -Entrapment **Chemical Risk:** - fumes Inhalation
Glazing Robot	 GGR Glazing Robot EMU 500 Installing glass (Ergonomic Manipulating Unit 500) - YouTube	**Safety Risks:** -Collision -Crash -Entrapment -Objects falling from height
Building cleaner. Robots for dusting and damp mopping		**Safety risks:** -Unplanned movement, overturning leads to bruises, contusions, broken bones. - General danger from battery-powered devices (fire hazard, explosion, electrical shock) - Non-observance of the working environment (stairs, landings, balustrades

		made of glass): falling, tipping, Collision with humans: leads to bruising, entrapment, contusions, fractures. **Chemical risks:** **Physical risks:** -Noise.
Robot Dog	 Spot the robot dog being used on construction sites - YouTube	**Safety Risks:** -Collision -Crash -Fall from heigth -Musculoskeltal injuries from manual handling
Semi-autonomous drilling robot		**Safety Risks:** -Unplanned movement, overturning: leads to bruises, contusions, broken bones; -General danger from battery-powered devices (fire hazard, explosion, electrical shock) -Non-observance of the ground (unevenness, load-bearing capacity): overturning, collision with a human being -Running over the feet: broken bones, amputation of feet or toes -Injuries due to uncontrollably ejected material from the borehole (not robot typical) **Chemical risks:** -Inhalation of drilling dust

		Physical risks: -Noise.
Metalworking trade: Cutting to length, grinding, smoothing, profiling metal workpieces	 	**Safety risks:** -Limbs get into the working area of the cutting robot: Injuries and amputation by cuting off the limbs -Limbs get into the working area of trimming, profiling or bending robots: Injury and amputation of fingers, abrasions -Unexpected movement of the robot arm when inserting and clamping the parts: Squeezing, crushing; bruises, fractures **Chemical risks:** -Inhalation of grinding dust and welding fumes **Physical risks:** -Noise.

Stonemasonry: Cutting robot Grinding robot Profiling robot (e.g. for ornaments, filament, capital)	  	**Safety risks:** -Limbs get into the working area of the cutting robot: Injuries and amputation due to ultra-high pressure water jet -Limbs get into the working area of sawing (e.g. wire saw), grinding and profiling robots: Injury and amputation of fingers, abrasions -Unexpected movements in supplier equipment, e.g. assembly line: stumbling, falling -Impact injuries from splintering and flung stone fragments (planning errors, input of wrong dimensions, etc. -Impact injuries from splintering and flung stone fragments (not robot typical) **Chemical risks:** -Inhalation of grinding dust **Physical risks:** -Noise.

Timber construction, carpenter, joiner: Trimming, cutting, milling, profiling of wood	 	**Safety risks:** -Limbs get into the working area of the cutting robot: Injuries and amputation by sawing off the limbs -Limbs get into the working area of trimming and profiling robots: Injury and amputation of fingers, abrasions -Impact injuries from splintering and flung wood material or foreign substances, e.g. nails **Chemical risks:** -Inhalation of sawing dust **Physical risks:** -Noise.

3. CONCLUSIONS ABOUT THE MOST COMMONLY USED EQUIPMENT

SPAIN:

Considering that the construction sector in Spain in 2019 was the third economic activity that recorded the most work accidents with sick leave and the one that caused the most fatal accidents, it is evident the need for the incorporation and automatons that improve safety conditions at work.

The equipment mentioned in the list created, in general terms, improves the conditions of workers in the construction sector. Obviously, the risks do not disappear completely, but there is a noticeable reduction in risks.

Some of the risks that decrease with the use of robotized or automated equipment are ergonomic risks, since they help in the transport and loading of materials and dust inhalation because some cases human presence is not necessary, but in those cases where it is, workers are less exposed to dust inhalation since they can stay away from the area where it is being generated thanks to the remote control.

POLAND:

The most often used robotised and automated equipment in Poland are **demolition robots.** Many different equipments are used, including one Polish production equipment: ARE1.0 (remote controller demolition robot with hybrid drive system). The risks associated with the use of this equipment include: mechanical hazards, risk of falling disassembled elements, electrical hazard, and noise hazard.

Increasingly, **drones** appear on the construction site. Drones are used for monitoring the progress of works, 3D inventory, area scanning and construction inspections. Depending on the purpose, drones of different design and weight are used. The drone is most often equipped with a high-resolution camera, thermal imaging camera or laser scanner (LiDAR). It is estimated that there are currently about 200,000 drone users in Poland, some of them are used in construction.

Earthmoving machines used in Poland make limited use of automation and robotics. Remote control devices are used in the conducted earthworks. Unfortunately, the various sensors and limiters of remote control do not replace the human factor.

3D printers for the construction of buildings are a rarity in Polish construction. So far, only one project related to a printed building with a small area (7 m^2) has been completed. This technology is just entering to the construction industry in Poland.

Self-erecting formwork is used in cubature construction, which significantly accelerates the implementation of construction works. Self-climbing formwork has markedly improved safety performance related to the traditional formwork. However, self-climbing formwork with a complex structure is still the focus of construction safety control. There is still a great safety risk in the process of operation and use, such as its installation and dismantling, adjustment of position, which is prone to lead to template collapse, fall from height, and strike by objects.

In civil engineering (in railway construction) **track construction trains** are used to facilitate the modernization of existing and construction of new railway lines. Currently, the National Railway Program is being implemented in Poland, which includes over 230 railway investment projects during which work trains will be used.

UNITED KINGDOM:

The construction industry is one of the most hazardous industries in the UK. Fatal injury rates are over four times the national average (HSE, 2018). Apart from the pain and suffering caused, these accidents and fatalities pose a considerable amount of economic burden to society. Estimates indicate that in the UK alone, the annual cost of the injuries exceeds 1.2 billion which accounts for 8% of the total cost across all industries as well as a loss of 2 million working days (HSE, 2019). Studies suggest that construction robots can not only improve productivity by automating repeated tasks but also could improve the safety of the personals involved in the construction activity while “implemented responsibly”.

The list of smarter machines identified in the above table is those which are most commonly used or are expected to witness an exponential application within the UK construction industry. For example, it has been forecast by PricewaterhouseCoopers (PWC) that there will be 76,233 drones in operation in the UK across all sectors by 2030, with 4,816 of these being employed by the construction and manufacturing sectors. Currently, drones are operated by construction companies such as Skanska, for purposes such as mapping, and are likewise used to observe the degradation of infrastructures such as motorways and railways. Similar is the application of demolition robots in the UK construction sector which can assist human workers to complete strenunous, challenging and high risk demolition works.

While it is quite evident that the application of smarter machines or “Cobots” (collaborative robots) in construction could improve productivity and safety, 46% of the construction workers in the UK are concerned about the perceived safety risks with the application of robotic technology itself, highlighting the importance of adequate training, proper protocols and cybersecurity measures.However, it ought to noted that

Cobots which share samework space with the human poses more safety concerns when compared those used in manufacturing factilties which are guarded to avoid unwanted human-robot interactions.Infact studies conducted in Sweden and Japan suggest that robotics pose safety treats to human during programming, maintenance or adjustments and not during normal operation conditions.

GERMANY:

The robots most frequently used in the German construction industry are stationary robots in the prefabrication of construction elements (reinforced concrete parts, wooden structures, natural stone elements). These are highlighted in yellow in the table above.

Almost all accidents are caused by improper use and by the non-observance or even manipulation of safety devices.

Semi-autonomous robots, which are controlled by remote control from a human, are not yet widely used in Germany. Therefore, there are still no statistics on accidents with these machines. The hazards are shown in the rows of the table highlighted in orange.

Autonomous robots (see highlighted green row) are mainly used in building cleaning (facility sector). Accidents here are primarily caused by untrained personnel (incorrect operation; in the cleaning industry, personnel turnover is very high; there is often no time for qualification).

Masonry robots are an intermediate between semi-autonomous and autonomous robots. They are controlled by special software (based on CAD or BIM). Human control is rather not foreseen. In Germany, according to the Berufsgenosschenschaft Bau (BG Bau), at most 500-1000 people (out of approx. 885,000) work with these robots, mostly in prototype projects. Therefore, a statement on accidents or statistics is not yet available.

Conclusion: Human behaviour or misconduct (overestimation of one's own capabilities, recklessness, negligence, convenience) leads to accidents with robots. The learning content should focus on correct human behaviour.

Sources: Accident prevention regulations of the German Social Accident Insurance Institutions (BG); recommendations for action of the German Society for Accident Protection (DGUV); many personal discussions with the DGUV and BG responsible persons and officials.