Research Article

# Artificial Intelligence in the Service of Health and Safety at Work: Perspectives and Challenges From Now to 2035 - A Prospective Study

**Marc Malenfer[1], Michael Sarrey[2,3], Jennifer Clerté[1], Michel Hery[1], Martin Bieri[4], Bertrand Braunschweig[5], Régis Chatellier[4], Nazim Fates[6], Sylvain Halluin[7], François de Jouvenel[5], Vincent Mandinaud[8], Jorge Munoz[9], Anani Olympio[10], Thimotée Silvestre[5], Jean-François Soupizet[5]**

1. Mission Veille et prospective, Institut National de Recherche et de Sécurité (INRS), Paris, France; 2. Institut National de Recherche et de Sécurité, Vandœuvre-lès-Nancy, France; 3. Département Ingénierie des équipements de travail, Institut National de Recherche et de Sécurité (INRS), Paris, France; 4. Laboratoire d'innovation numérique de la Commissions nationale de l'informatique et des libertés (LINC/CNIL), Paris, France; 5. Independent researcher; 6. Inria Nancy - Grand-Est research centre, Villers-lès-Nancy, France; 7. Direction régionale des risques professionnels, Caisse régionale d'assurance maladie d'Ile-de-France, Paris, France; 8. L'Agence Nationale pour l'amélioration des Conditions de Travail, Lyon, France; 9. Labers, Université de Bretagne Occidentale, France; 10. Cnp Assurances, Paris, France

**Artificial intelligence systems are developing very rapidly in all areas. This is particularly true in the case of work, where we are seeing their use in the robotisation of industrial production or the automation of certain functions in services (from chatbots to robotic process automation). In the context of a prospective study devoted to the use of artificial intelligence for occupational risk prevention, a very diverse project group was set up: occupational health practitioners, artificial intelligence specialists, lawyers, futurists, sociologists, and everyday users of artificial intelligence techniques. Using the method of contrasting scenarios, this project group successively documented variables likely to influence the use of artificial intelligence in the service of occupational health and safety, put forward hypotheses on their possible development over the next ten to fifteen years, and constructed scenarios. These relatively general scenarios were then adapted specifically to the subject studied, in particular during seminars devoted to specific uses (possible uses of artificial intelligence tools in epidemiology and accidentology, technologies for securing working environments using artificial intelligence, advanced robotics using artificial intelligence). Based on all the material produced during the study, the study finally resulted in recommendations of the project group on the use of AI in occupational risk prevention proposed for discussion. The subject is indeed of interest to**

**the whole community of practitioners involved in occupational risk prevention whose practices will certainly be affected by these new technological developments.**

**Corresponding author:** Michel Hery, m.hery@wanadoo.fr

## 1. Introduction

Debates on the consequences of the development of artificial intelligence (AI) have been sending tremors through society for several years. The risks of intrusion into private life [1], the subordination of humans to machines or, on the contrary, the enrichment of daily life and tasks [2][3], the destruction of jobs or a general increase in qualification levels [4][5], etc.: there are many areas in which views clash without any really satisfactory answers being found.

More specifically, in the field of work and its organisation, the availability of AI to improve productivity [6] to reduce the vulnerability of supply chains [7] or for geopolitical reasons of relocation of activities in strategic sectors [8], or for the management of occupational risks [9][10] is perceived as an asset.

The INRS (Reference body for occupational risk prevention in France) has already addressed these issues in the field of Occupational Safety and Health (OSH) through foresight exercises devoted to the development of the use of information and communication technologies (ICTs) in the workplace [11], the evolution of production modes and methods in France by 2040 [12], the circular economy [13], and the changes in the organisation of work following the Covid-19 crisis [14].

It was therefore logical for INRS to devote specific work to the issue of AI, especially since the mission of its Watch and Foresight department is explicitly defined along two main lines:

- To provide information that will help the Board of Directors to develop the Institute's various programmes (studies and research, training, information products),
- To encourage collaborations between the different professions and disciplines represented within the Institute.

Through its Watch and Foresight mission, INRS is also explicitly designated within the occupational risk prevention system of the French Social Security system as the body responsible for initiating and


doi.org/10.32388/NRENI6

coordinating reflection on emerging subjects likely to have an influence on workers' health and safety in the more or less long term. As such, the network's stakeholders and recipients are many and varied:

- The system's national and regional governance bodies (joint bodies bringing together representatives of employers and trade unions);
- Agents responsible for providing advice (and carrying out inspections) in the field, organised on a regional basis, who are responsible for checking that occupational risk prevention rules are being applied satisfactorily in companies;
- These field agents also carry out monitoring activities in the field and can pass on information to regional and national coordination bodies (or to INRS itself).

This foresight work is made public and is therefore accessible to any interested person or organisation, in particular companies, trade unions, all players likely to be directly or indirectly involved in occupational risk prevention in France, etc. The forms of this communication are varied: in this case, we will see later that the first form of communication chosen was that of Recommendations, which will enable the network to adopt these themes for the first time.

INRS's foresight work is therefore intended to serve as a basis for initial reflection on new issues in various forms: in this case, AI. Depending on needs, it will then be pursued by other players in the prevention system (researchers, experts, specialised working groups of network staff, etc.) in more or less close association, depending on the case, with the governance bodies.

However, given the extent of AI applications in the professional sphere, it was essential to limit reflection to a relatively limited scope to avoid unfocused reflection. It was therefore decided to focus on the possible uses of AI systems for OSH protection purposes, with a horizon of a dozen years, in other words the use of AI in a rationale of occupational risk prevention. The aim of this study was to explore various consequences of this use of AI, be it favourable or potentially destabilising, rather than to determine specifically in which areas and under which conditions AI could play a beneficial role. Indeed, the introduction of new technologies or new forms of work organisation inevitably has an influence beyond the strict technological field in which it is introduced.

There are many definitions of AI. Some of them are based on a definition in intension, i.e. they indicate the internal content of the term or concept: this corresponds to its formal definition. The definition in extension corresponds to the set of things to which the definition in intension applies. Thus, one of the main references used in this work is the definition of AI proposed by a group of experts commissioned by the European Commission. This is a definition in intension:

> "Artificial intelligence (AI) refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals.
>
> AI-based systems can be purely software-based, acting in the virtual world (e.g., voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g., advanced robots, autonomous cars, drones or Internet of Things applications)." [15]

However, in the course of the discussion, reference was often made to parameters that are more akin to a definition in extension, such as the capabilities given to machines (hardware and software) to carry out tasks requiring intelligence when performed by humans, examples of applications of these capabilities (autonomous vehicle, conversational agent, image recognition, etc.), and technologies at the service of these functions (knowledge representation, reasoning, learning, planning, etc.).

In brief, this article describes the use of foresight in a study designed to create a body of thought common to all the participants in a national and regional occupational risk prevention network, faced with the irruption of the use of AI in both the organisation of production and occupational health.

## 2. Method

Foresight studies at INRS are governed by two principles:

- They are an opportunity to promote multidisciplinarity within the institute by associating different teams and divisions, each of them contributing their different academic specialties and their different modes of intervention.
- Since INRS focuses only on occupational risk prevention, it is necessary to set up partnerships with various organisations that are involved in the subject and address it from other points of view; INRS's strategic foresight studies are always conceived and carried out with universities, trade unions, professional organisations, enterprises, etc.

Regardless of the subject and the partnership, the end goal is always to improve safety and health at work.

The aim of the study is to explore the range of possible futures via contrasting scenarios. The method used to build scenarios is morphological analysis (for more information about this method, see, for example, [16]). It has the particular advantage of presenting a whole range of possible situations (desirable or not) in an attractive and easily understandable way and of making it possible to highlight weak signals, technological discontinuities, and ruptures. It has sometimes been criticized for being time-consuming, requiring the participation of specialists in the field under investigation and possibly favouring the choice of black and white scenarios or of the most likely scenario (wishful thinking) [17]. These issues will be considered in the "Discussion" section.

This study, devoted to the possible uses of AI devices for OSH protection purposes, was conducted in six steps:

1. A 16-member team (reduced later to 15) was formed to follow the project from start to finish. This project team brought together strategic foresight experts, OSH experts and IA specialists, INRS researchers and representatives of external partners. The main professional qualifications of the members of the expert group are listed in Table I. It is completed by that of the members of the groups devoted to the study of the use cases described in point 5 below: the latter are mainly OSH specialists who in their activity have already been faced with the use of AI (which does not make them specialists in these techniques) to which have been added several AI practitioners who have already been faced with its use in occupational risk prevention. These experts were recruited on the basis of successive aggregations based on the professional relations of the initiators of the study and the recruitment of several national experts on these issues. This was particularly true for the creation of the project team, which involved fairly demanding specifications: participation in all the meetings (7 in total) and drafting of technical texts. The workload was more limited for the groups set-up for the use cases, in which several members of the project group took part: half a day.

| Project team | Group 1: Possible uses of AI tools in epidemiology and accidentology | Group 2: Technologies for securing working environments using AI | Group 3: Advanced robotics using AI |
|---|---|---|---|
| AI user, banking and assurance* | Statistician, OSH | Biomechanics, OSH | Automation engineer, OSH |
| AI designer, former researcher* | Historian, foresight specialist* | Historian, foresight specialist* | AI designer, former researcher* |
| Historian, foresight specialist* | Statistician, OSH | Historian, documentalist, foresight* | Specialist in man-machine systems |
| Former senior official of the European community, AI domain* | Pharmacist, public health | Physiologist, OSH | Safety of automated systems, OSH |
| Sociologist, public health, university* | Epidemiologist, OSH | Ergonomist, psychologist, OSH | Robotics, OSH |
| Lawyer, national regulatory body* | Sociologist, public health, university* | Physicist, research management, OSH | Historian, foresight specialist* |
| Political scientist, foresight* | Chemist, AI user | Historian, OSH, foresight* | Historian, documentalist, foresight* |
| Engineer, philosopher, AI researcher* | Lawyer, national regulatory body* | Lawyer, national regulatory body* | Political scientist, digital economy |
| Architect, AI user, construction* | Historian, OSH, foresight* | Engineer, robotics, automation, AI* | Physiologist, OSH |
| OSH specialist, AI user* | Engineer, IT, AI researcher* | Engineer, chemist, OSH, foresight* | Psychologist, ergonomist, OSH |
| Engineer, IT, AI researcher* | Engineer, chemist, OSH, foresight* | Personal protective equipment specialist, OSH | Physicist, research management, OSH |
| Sociologist, use of new technologies* | OSH specialist, AI user* | Engineer, IT, AI researcher* | Historian, OSH, foresight* |
| Historian, documentalist, foresight* | Former senior official of the European community, AI domain* | Psychologist, ergonomist, OSH | Engineer, robotics, automation, AI* |
| Historian, OSH, foresight* | Historian, documentalist, foresight* | Engineer, IT, AI technology for safety issue | Engineer, chemist, OSH, foresight* |
| Engineer, chemist, OSH, foresight* | | | Robotics designer, AI |


doi.org/10.32388/NRENI6

| Project team | Group 1: Possible uses of AI tools in epidemiology and accidentology | Group 2: Technologies for securing working environments using AI | Group 3: Advanced robotics using AI |
|---|---|---|---|
| Engineer, robotics, automation, AI* | | | Engineer, IT, AI researcher* |

**Table I.** List of participants in the foresight exercise by qualification

** Project team members*

- All of the experts had the equivalent of a postgraduate degree. The ratio was approximately two men to one woman.

2. The first task of the project team was to identify the main key factors for the development of AI in the specific domain considered here. This was achieved by pooling the knowledge of the project team members on the topic in question. The multiple and varied competences of the participants made this step even more fruitful. Each of these key factors will henceforth be referred to as a variable in this article. The list of these variables is given in Table II in the Results section.

   The time frame for the study was also decided at this first meeting. The date chosen had to meet a number of criteria:

   - It had to be sufficiently distant in time to make it easier for the experts to propose significant developments or even breakthroughs relating to the subject under study,; this distance in time should make it possible to overcome the reluctance that the experts may feel about presenting potentially very innovative ideas to their community,

   - On the other hand, it was important to choose a date that did not seem too far away to those who were to benefit from the foresight exercise, so that the thinking behind it did not seem disconnected from the actions they might undertake as a result,

   This date also had to take into account the development dynamics of the subject under study: in the specific case of AI, thinking several decades ahead would a priori make little sense, nor would it be useful in terms of the use of foresight described in this article: that of creating a community of reflection within a network. That is why the year 2035 was chosen, between ten and fifteen years after the date of the study.

3. Each selected variable was documented by a member of the project team: a precise definition of the subject, a description of its developments over the last ten years, and a reflection on those likely to occur over the next ten or twelve years. The draft text was discussed in plenary, with particular attention paid to future developments, including potential deviations from current trend (breakthroughs or significant developments): for each variable three to five contrasting hypotheses were proposed.
4. Global scenarios were constructed by combining hypotheses extracted from the different variables. The objective of these combinations was to create contrasting scenarios describing possible futures. These scenarios focused in particular on the consequences of developments in terms of working conditions and OSH. These scenarios were then embodied in the form of a narrative aimed at making the consequences for occupational risk prevention more concrete for the reader. A summary of these four scenarios is given in the Results section.

   The method for combining the hypotheses is described in Figure 1. It consists in combining the hypotheses derived from the different variables to create scenarios. A scenario is a priori made up of thirteen hypotheses, each derived from one variable. Given the number of variables and the number of hypotheses per variable, this combinatorial logic can result in hundreds or even thousands of different scenarios. This therefore entails carrying out a whole process of successive iterations: for example, a certain number of combinations make no sense because they include contradictory elements. The aim is to construct a limited number of coherent stories (four in this case) that present sufficiently contrasting scenarios to give readers an idea of the range of possible developments in the situation in the years ahead. In concrete terms, each participant in the working group proposed several scenarios that they felt were coherent and corresponded to this logic of contrasting narratives. This was followed by a general discussion during which duplications were merged, different scenarios were brought together and other avenues were explored. Finally, the group agreed on the four scenarios presented below. This is a consensual approach, representative of the different points of view expressed in the group. Another group would obviously have arrived at a different result: the exact content of the scenarios is ultimately less important than the possibility of providing an intelligible and relatively simple overall vision of possible developments.

| | | | | |
|---|---|---|---|---|
| Variable #1 | **Hypothesis #1** | ***<u>Hypothesis #2</u>*** | Hypothesis #3 | Hypothesis #4 |
| Variable #2 | ***<u>Hypothesis #1</u>*** | **Hypothesis #2** | Hypothesis #3 | |
| Variable #3 | Hypothesis #1 | ***<u>Hypothesis #2</u>*** | **Hypothesis #3** | |
| Variable #4 | ***<u>Hypothesis #1</u>*** | Hypothesis #2 | Hypothesis #3 | **Hypothesis #4** |

**Scenario #1** results from the combination of **hypothesis #1 of variable #1** with **hypothesis #2 of variable #2**, etc.

***<u>Scenario #1</u>*** results from the combination of ***<u>hypothesis #2 of variable #1</u>*** with ***<u>hypothesis #1 of variable #2</u>***, etc.

**Figure 1.** Example of the creation of scenarios based on the hypotheses of the different variables identified

5. Another phase of the exercise consisted of seminars devoted to three types of possible applications of AI in OSH (use cases), and to confront them with the possible futures described in the scenarios. These seminars brought together members of the working group and occupational health and safety experts (from within and outside INRS) who had not participated in the initial phase. The categorisation of uses was inspired by similar studies conducted by teams in the United States [18] and in the Quebec province of Canada [19].

   These use cases are:

   - Possible uses of AI tools in epidemiology and accidentology,
   - Technologies for securing working environments using AI,
   - Advanced robotics using AI.

   The conclusions of these workshops are presented in the Results section.

6. As mentioned above, the main objective of the INRS strategic foresight exercises is to help its Board of Directors (social partners) to adjust their policy for the institute. Beyond this internal use, foresight work, as explained in the introduction, is also an opportunity to build a body of thought for the entire national and regional Social Security occupational risk prevention network, of which INRS is a part. As such, it is necessary to produce a reference document that can be used at a later date as a common working basis. For this reason, the project team concluded its work by drafting 22 "key messages" that can be discussed, amended or used as a basis for reflection initiated by others, in

particular within the occupational risk prevention system of the French Social Security system. On the basis of the various documents produced during the study (description of variables, scenarios, minutes of the meetings of the groups that had worked on the use cases), the members of this project team were asked to identify the points on which the use of AI technologies (in production or in occupational risk prevention techniques) were likely to modify occupational risks or their management. The last meeting of the project group was entirely devoted to this task. This meeting resulted in the identification of four main 'issues' likely to modify the current approach to risk prevention (the rapid and strong growth of the market, the technical possibilities of transformation linked to the use of AI and their consequences on the organisation of prevention, the identification of limits linked to the use of AI, actions to be taken that have already been identified). Numerous remote exchanges then fed into and developed the content of these various points.

These key messages are grouped in Tables III to VI in the Discussion section.

To carry out these six steps, the project team met for seven full days, four face-to-face and three by videoconference. Each of the seminars devoted to the use cases lasted half a day face-to-face. Numerous telephone and videoconference exchanges brought together two or more members of the project group to discuss variables, scenarios, key messages, etc. The whole operation took about 14 months.

# 3. Results

## *3.1. Variables*

In strategic foresight, possible futures are conceived as the results of dynamic interactions between various components. The project group has therefore identified the main variables that make it possible to describe the issue in which the use of AI in occupational risk prevention belongs. These variables are listed in Table II.

| Variables | Definition of the scope |
|---|---|
| Component 1 : AI offer | |
| **1. Technical advances in AI** | Exploration of possible evolutions of AI techniques and tools (connectionist, symbolic, hybridisation...), less energy consuming devices, transmission networks, algorithms... |
| **2. Resources available for the production and operation of AI devices** | Technical skills, hardware (processors, storage servers, sensors, etc.), energy, mineral resources, etc.; possible shortages that could hinder the development of AI. |
| **3. Reliability and safety of AI devices** | Robustness, validation, qualification of results, cybersecurity, prevention of bias and errors... |
| **4. Actors and dynamics of AI diffusion, standardisation process** | Supply side actors (States, internet giants, service companies, users, general public...) and dynamics of AI diffusion through technical and economic models |
| Component 2: Acceptability of uses | |
| **5. General societal acceptability of AI** | Acceptance of AI according to its applications, the fields concerned, the impact on daily life, and the different categories of population; technophobia vs. technophilia |
| **6. AI and data regulation (World, EU, France)** | Protection of personal data, legal frameworks for AI innovations (framework of uses vs. framework of technologies) put in place by the different States |
| **7. Acceptability in the world of work (employers, employees)** | Exploration of reactions to issues such as: understanding of the algorithm, monitoring of workplaces or situations, enslavement, dependence, etc. |
| **8. Acceptability in terms of prevention of the use of AI in the world of work** | Questioning the ethical limits to the possible uses of AI in terms of health and safety at work; possible obstacles |
| Component 3: Work and occupational prevention | |
| **9. Economic growth and geography of production (industry and services)** | What will be produced in France and where? Which sectors and occupations will undergo significant changes in terms of volume or content? |

| Variables | Definition of the scope |
|---|---|
| **10. Labour demography (ageing, qualifications, training...)** | This sheet aims to describe possible changes in the characteristics of the working population: age, gender, origin, levels of education, etc. |
| **11. Modes of work organisation and status of workers** | Possible changes in work organisation methods and workers' status; consequences for work groups |
| **12. Automation (all sectors), cobotisation and worker equipment** | Autonomous mechanisation, automation of administrative, service or decision-making tasks, man-machine collaboration, monitoring of work situations, digital work equipment |
| **13. Responsibilities and management of prevention** | Responsibilities of the actors (employers, workers, principals) in terms of health and safety at work; methods of managing occupational risks (particularly in prevention) |

**Table II.** The thirteen variables describing the system under study

### *3.2. Scenarios*

The drafting of scenarios is not an end in itself: they should be seen as an embodiment of the different development hypotheses put forward by the project group. They make it easier for readers outside the group to understand the work. They are also convenient tools which facilitate the subsequent stages of the work.

#### *3.2.1. Scenario 1: The digital giants impose their solutions and vision*

Technological exuberance continues in a framework of competition for the mastery of artificial intelligence. The main players are the digital giants, essentially the MAAMAs (Meta, Alphabet, Amazon, Microsoft and Apple) in the West and the BATXs (Baidu, Alibaba, Tencent, Xiaomi) in China. Their power extends far beyond the digital field to the point where they control the bulk of innovation and dominate entire sectors of the global economy. In a context of systemic international rivalry, States must deal with these players and rely on them to maintain their power as well as to ensure the key functions of their sovereignty. Regulation is fragmented among States and largely influenced by these giants. Users accept these standards out of convenience and because they have become indispensable. Automation is


doi.org/10.32388/NRENI6

progressing and the monitoring of processes and operators is becoming the preferred tool for safety at work in a context of close collaboration between men and machines.

### *3.2.2. Scenario 2: States guarantee a framework for the integration of AI*

The unbridled development of AI has prompted European states to work on a common regulation to provide a framework for the ecosystem and ethical principles. During this period, the increasing number of accidents causing harm to citizens, companies and workers has led to a narrowing of this framework in a context of growing environmental concerns. States have decided to allocate resources solely to the development of sober AI systems that meet exacting requirements (particularly in the public interest), in non-critical sectors and under human supervision. This requires better control of manufacturers, the development of European and national centres of expertise, as well as an obligation to demonstrate the harmlessness of AI. Control and audit measures are also planned. AI in the workplace is therefore developing in a fairly regulated environment, allowing for implementation once the interest and non-hazardousness of the devices have been approved.

### *3.2.3. Scenario 3: Democratic development*

The 2020s will see the establishment of processes of democratic control by workers and citizens. This framework is necessary for the ethical development of AI in everyday life, whether private, public or professional. The global context is favourable: economic growth, job creation in industry and services, strong investments in training. The conditions are right for AI systems to be widely deployed in the world of work and contribute to the gradual acquisition of the collective control of these technological projects. The use of AI devices is facilitated by the rise of open source tools and the development of quite accessible solutions (low code, nocode). Moreover, the AI research launched since the 2010s will eventually lead in the 2030s to the design of hybrid AI systems, combining the power of machine learning with the transparency of logical reasoning systems. By restoring the ethical principle of explicability as a key to appropriation, these results contribute to collective trust in AI. These techniques are placed in the service of performance, health and safety in work organisations.

### *3.2.4. Scenario 4: AI winter*

At the beginning of the period, the uses of AI systems are developing in all professional fields. Thanks to technological progress, the widespread digitalisation of society and new work organisations, AI is well accepted in the majority of the working world. Since 2022, it has been seen as an asset for employers (automation, productivity, quality, etc.) and for workers (less drudgery, overall safety, etc.). However, a rejection of AI systems in the world of work is gradually emerging. This is a consequence of disappointment in the face of applications in the field that ultimately perform poorly, while flaws of these systems cause incidents, accidents or crises, in a context where the issue of the very high energy consumption associated with the use of AI has not been addressed. From the 2030s onwards, this rejection leads to a decline in this technology and its professional uses.

### *3.3. Use cases*

#### *3.3.1. Possible uses of AI tools in epidemiology and accidentology*

Thanks to its capacity for intelligent processing of massive data, AI opens up promising possibilities in OSH. Some of the areas of use come to mind here:

- AI can offer new possibilities for sophisticated and rapid processing in epidemiology from data collected for populations identified for their vulnerability, exposure (especially multiple exposures), etc. It should also allow better cross-use of different distinct databases (health indicators, occupational trajectories, individual or environmental measurement data, etc.).
- In accidentology, automatic language processing systems also open up possibilities for better exploitation of poorly structured data, in particular textual data. Examples include death certificates, occupational accident declarations, occupational health service data on medical skills, data on occupational accidents and diseases recorded by the Social Security, machine malfunction registers, etc.

For these types of use to develop, large masses of quality data and commensurate storage and processing capacities will be required. The AI tools designed for these purposes will have to make further technical progress. Lastly, the rules for using files (guaranteeing in particular the security and confidentiality of data) that already exist will have to be updated according to the state of the art and the possibilities of technology. There is scope for a public debate on what society finds advantageous and ethical to allow (see the Discussion section).

It is expected that this work will lead to progress in risk assessment and analysis and thus to progress in prevention.


doi.org/10.32388/NRENI6

### *3.3.2. Technologies for securing working environments using AI*

These solutions aim to secure working environments by using devices that analyse information from connected objects in real time. These devices work using sensors capable of measuring different parameters, and actuators (which perform a task, modify the behaviour or the state of a system, etc.). Two types of use of these monitoring systems are distinguished here:

- Systems aimed at monitoring the working environment and capable of activating an alert before the occurrence of a dangerous phenomenon (emission of a toxic product, proximity of moving equipment, etc.), or even of isolating an area or switching off equipment. These systems are defined here as detection solutions.
- Systems used to monitor the worker himself. They could be connected personal protective equipment (PPE) that takes regular measurements of biometric data, or work equipment equipped with biometric measurement sensors.

Future advances are linked to the evolution of computing power which will lead to increased performance and results accuracy. The power consumption of embedded semiconductors is getting lower and lower, which facilitates their deployment. AI developments in the quantum domain could further increase computational capabilities and thus relevance and compactness. They could also reduce power consumption (which is an important parameter for embedded devices on mobile objects). All of this could ultimately reduce the price of these solutions, which currently severely limits their deployment.

In terms of data transfer, 5G will also provide an improved level of security, by reducing latency.

### *3.3.3. Advanced robotics using AI*

Some advanced robotics technologies (embedding AI) offer potentially beneficial solutions to OSH. Two use cases are considered here: tele-operation, which allows removing the operator from harmful or dangerous situations, and human-robot collaboration, which allows physically demanding or dangerous tasks to be carried out by a collaborative robot.

- Tele-operation: in the construction industry, remote-controlled compactors or rock breakers allow the operator to act remotely from these dangerous machines. For more complex tasks or those that must be carried out in a dangerous area, remote control is not always possible. In these cases, the machine must take on board some of the expertise and capabilities of the human operator (or even more than the human operator). These include stereoscopic vision, movement in an environment that may or may not be accessible to humans, and the ability to grasp objects. The remote operator will then only control "macro orders" such as "Go to such and such a place", "Carry out the XDK74 mission". This is known as tele-operation. It requires advanced robotics functions using AI.

- Collaborative robotics allows an operator to work in the immediate vicinity of a robot without physical risk. There are three types of collaboration: direct collaboration where the operator and the robot work simultaneously on the same part, indirect collaboration where the operator and the robot work alternately on the same part and workspace sharing where the operator and the robot work independently in a common space. To be safe, these collaborations require the robot to be equipped with highly sophisticated faculties of perception of the actions of its human collaborator. These skills can be based on AI.

The large-scale deployment of this advanced robotics depends on several factors: the democratisation of the technology (purchase, integration, operation and maintenance costs), the extension of the operational areas (thanks in particular to progress in robotics), and greater acceptability to workers. The integration of these technologies in work organisations will have to be improved. To achieve this, a great deal of preparation and consultation will be needed with the teams, particularly to gain their trust. The objectives must be transparent: increased productivity and/or reduced drudgery, consequences on the pace of work, etc. The change will have to be accompanied, in particular by specific training measures.

## 4. Discussion

### *4.1. Is the method of contrasting scenarios appropriate?*

The advantages and disadvantages of the contrasting scenarios method were briefly discussed in the Method section, and the way in which it is used was then described in more detail. Carrying out this foresight exercise allows us to draw up a critical assessment of the use of this method. As a general rule, foresight is a tool designed to facilitate strategic decision-making. In the particular case of our study, this objective was not absent, but it was also a question of providing the members of the occupational risk prevention network of the French Social Security with elements that could equip them in the face of rapid development in the use of AI techniques in many areas of production. While identifying the variables, documenting them (through their evolution over the last fifteen years, the main factors that have influenced and will influence their evolution in the years to come, possible disruptions, etc.), and choosing the possible development hypotheses up to 2035, are proving to be demanding and time-consuming tasks, they also make it possible to build a minimum base of common knowledge within the project team. As such, they contribute significantly to the multidisciplinary and hybrid nature of the work. They also help to place the issues raised in their global context. It is also thanks to this work that it has been possible to make an informed choice of the various 'use cases' studied.

All in all, therefore, we have a substantial body of documentation (thoughts on the variables and their possible changes, scenarios, applications of these results to a number of practical cases) which has helped to inform our thinking on the key messages. This is due in particular to the presence of context variables, which make it possible to contextualise the issue under study within a fairly broad framework. It was thanks to this wealth of information that it was possible to initiate detailed reflection on these key messages: all the preliminary work was therefore fruitful. However, this final reflection was highly empirical regarding the method employed: as mentioned in the Method section, after a day of in-depth joint work had enabled identifying the main constituents of these key messages, intensive dialogue was still necessary between the different members of the project team in order to obtain the final version presented in this article. The intellectual path of the foresight exercise can itself be traced fairly precisely through the stages it involves (from the choice of variables to the drafting of scenarios), which often constitutes a guarantee of the credibility of the method for its final recipients. On the other hand, the choice of key messages is less clear-cut and more open to discussion. However, no other method commonly used in foresight has been identified as likely to eliminate this subjectivity bias (even if this subjectivity results from the joint and long-term reflection of fifteen people).

In order to allow other stakeholders (e.g., employers, trade unions, other researchers, etc.) to conduct their own reflection on the subject with a smaller volume of work than that of the study described in this article, all the documents produced during the foresight exercise are made available to those interested in reworking the data, but only in the language in which they were produced: French [20]. It would be interesting to compare the results of these studies in order to compare the influences of "the places from which we think" which appear underlie the differences in subjectivities.

### *4.2. Using cases of use to illustrate the contributions of AI to OSH*

The use of AI techniques undeniably makes it possible to envisage significant changes in the prevention of occupational risks, the first of which is the securing of working environments. This is of course the case for teleoperation on dangerous sites, but it is also the case in more traditional activities. Statistics show that certain categories of workers are over-accident-prone (and in some cases over-exposed to pollutants, particularly chemical pollutants): new recruits (particularly those at the beginning of their careers), temporary workers or workers on fixed-term contracts, and workers from outside companies present on the site for a fixed period. The same applies to certain specific professions, such as industrial maintenance or cleaning. The identification of risky situations and behaviours made possible using AI is a useful tool. In particular it is through an in-depth analysis of near misses that work processes can be amended to improve safety. It is also through this identification that targeted actions can be envisaged for the populations considered more at risk mentioned above.

The same applies to the development of automation, in particular that of collaborative robots. Their use can relieve workers of the most thankless, repetitive and stressful tasks (particularly for the joints) such as carrying loads, and allow them to devote themselves to more conceptual and interesting tasks. It is also important in terms of inclusiveness when all tasks can be performed by all operators regardless of their gender and age. The same applies to the return to work of workers with work-related disabilities. Overall, this should also result in an increase in workers' qualifications and skills.

On the other hand, attention must be paid to ensure that this development of the use of AI does not result in a reduction in human competence both in the overall organisation of work and in the practical tasks on the ground. On the contrary, it should be an opportunity to redirect the freed-up labour force towards tasks that further reduce the consequences of work on human health (including a reduction in working time). In other words, the use of AI must not result in a decrease in the vigilance exercised in the field of occupational risk prevention for both employers and workers.

Nor should it result in an intensification of work rhythms, particularly in the case of collaboration between workers and robots. Similarly, permanent observation approaches that result in a feeling of coercion for workers are counterproductive because of their possible translation into psychosocial risks and therefore musculoskeletal disorders, and even into occupational accidents. When the robot or AI performs part of the activity, it displaces human activity with the risk that it is no longer seen, making it invisible for prevention. As always in occupational risk prevention, collective approaches should be favoured over those focusing on the individual and his or her behaviour. Phenomena of rejection of AI are always possible.

Finally, the risks of computer hacking inherent in the growing use of ICTs should not be overlooked either.

The development of AI may also allow substantial progress in the processing of data used for statistical developments in the fields of epidemiology or accidentology. This is of particular importance for estimating the effects of co-exposures. Similarly, the problems posed in epidemiology by the individualisation of tasks (and therefore of occupational exposures) and the sharp reduction in the number of workers in the process industries can be at least partly eliminated by the use of stronger techniques supported by AI. The development of these tools could make it possible to detect new risk factors (or combinations of risk factors), whether for accidents or illnesses, or to make progress in the monitoring of workers' health throughout their careers. This is particularly the case of populations such as seasonal workers or temporary workers whose monitoring poses difficulties for institutional players.

The protection of the data collected is therefore of great importance: this is particularly the case for the data sets used to train AI systems. Moreover, as in the use cases devoted to securing workplaces and "augmented robotics", all possible precautions must also be taken to avoid misuse.

Lastly, particular care must be taken to ensure that these systems do not eventually lead to the excessive individualisation of occupational health approaches, integrating individual risk factors (genetics, lifestyle, etc.). This could occur to the detriment of protecting the health of all workers.

It may seem presumptuous to imagine the future uses of AI in the world of work on the basis of three one-day seminars bringing together a limited number of experts. However, a fairly broad consensus has emerged to define the production sectors in which the uses of AI will occur the earliest and most significantly over the ten-year period covered by this foresight exercise. They were mentioned in the Results section: these are surveillance systems, whether they focus on detecting a dangerous phenomenon before it occurs or on the worker. Biometric techniques, which focus on monitoring the workers themselves, will probably take longer to become established, particularly in Europe where the regulatory requirements for protecting personal data may be more stringent.

Relatively rapid progress can also be made in the field of robotics. Remote operation springs to mind. This could be particularly valuable in contexts that are dangerous for humans (high temperatures, radioactive atmospheres), but major technical difficulties need to be resolved both in terms of the robotics itself and the capabilities of AI. Similarly, for collaborative robotics, which are already used in many assembly operations, the potential for development today seems to be concentrated around two challenges:

- Increasing the flexibility of this equipment (the variability of products manufactured and tasks performed),
- Increasing the capacity of this equipment to carry out more complex tasks.

AI is likely to play an important role in this context, both in terms of the tasks that robots will be able to perform and in terms of the safety guaranteed to the operators with whom these robots will be working. As we saw earlier, these advances may be limited by technical constraints such as the compactness of the equipment and its power consumption.

### *4.3. Recommendations of the project group on the use of AI in occupational risk prevention proposed for discussion*

The use of AI for occupational risk prevention is still in its infancy. It was out of the scope of the work carried out to cover the whole range of problems generated by this recent development. This is why the group decided to focus on just three cases of use. It is desirable that others contribute to the construction of this reflection and that an international debate is launched.

In order to contribute to this debate, the project group selected 22 key messages that it considered important for reflection, grouped under four main headings:

1. A growing market
2. Promises in OSH
3. Limitations and points of vigilance on the use of AI in OSH
4. Courses of action

They are gathered respectively in Tables III, IV, V and VI


doi.org/10.32388/NRENI6

| A growing market |
|---|
| 1. The various advances underway in the field of AI, made possible by massive investments by private and public players, foreshadow the development of a significant market in the coming years. The security of working environments is one of the areas of professional use of these innovations. |
| 2. The more intelligent the automation, the more the machine (or algorithm) will perform the tasks previously done by workers. This automation may remove some workers from risk. It will also lead to a change in the tasks of other workers to training, coaching and control functions. |
| 3. There is a challenge for stakeholders to promote the development of AI systems that are compatible with the core values of the European and French approach to OHS (collective approach, data protection, social dialogue). The current hegemonic position of the American and Chinese digital giants therefore raises questions. |
| 4. Faced with the ethical issues raised by these new technologies, many organisations have formulated principles to be respected so that the development of AI can be done for the benefit of all stakeholders in society. It is necessary to identify and promote to companies the relevant recommendations for the ethical use of AI technologies in OHS. |
| 5. The scenario of a new "AI winter", (due to technological blockages ("walls"), energy crises, societal rejections, or cybercrime, etc.) is not excluded. It is therefore important not to rely on these technological solutions for all OHS advances. The search for effective prevention solutions that do not rely on these systems should therefore not be abandoned. |
| 6. The use of AI systems in OHS may come up against the "wall of explicability" (especially for devices using deep learning) and therefore of the understanding of messages and decisions generated by AI. The development of AI uses for occupational risk prevention purposes will require both fostering a good understanding of these tools (virtues and limits) by employees and employers, and promoting the emergence of transparent solutions (e.g. hybrid AI systems: power of AI and transparency of logical reasoning systems) facilitating debates between stakeholders. |

**Table III.** Six key messages about the development of AI to support occupational risk prevention

| Promises in OHS |
| --- |
| 7. Advances in AI have the potential for a variety of uses in OHS. Advances are to be expected in the processing of large amounts of data for accidentology and epidemiology, in silico toxicology, in making work environments safer, and in the development of advanced robotics technologies. |
| 8. The progress of AI using learning techniques opens up interesting prospects, for example in epidemiology and accidentology, provided that reliable data are available and that certain dimensions of OHS for which usable data are not necessarily available (in particular the organisational dimension) are not overlooked. |
| 9. AI also opens up possibilities for the supervision of a working environment, such as a building site or an industrial site. Beyond detection and warning, these devices should be expected to provide useful information for the development of sustainable (organisational) prevention measures; this implies exploitation by people able to analyse them. |
| 10. Some advanced robotics technologies (including AI) offer potentially beneficial solutions for OHS. This is the case for tele-operations and collaborative robotics, which can mitigate or even eliminate exposure to risk factors. However, the implementation of these devices must be systematically assessed to ensure that they do not generate new risks (work intensification, loss of meaning, etc.). |

**Table IV.** Four key messages about the promises in OHS connected with the use of AI


doi.org/10.32388/NRENI6

| Limitations and points of vigilance on the use of AI in OHS |
|---|
| 11. The logic of making investments in these sometimes costly technologies profitable can lead to these systems being positioned at the centre of the organisation of work, at the risk of relegating human work to the background. |
| 12. Generally speaking, inappropriate or misguided use or the absence of prior reflection on the organisation of the integration of these new technologies could lead to deleterious effects in terms of health and safety at work. The apparent ease of use and implementation of these "intelligent" solutions may lead to a complacency effect on the part of the players, encouraging them to take into consideration only the risks identified by the AI system, without regularly assessing the more organisational risks that are not subject to technological monitoring. |
| 13. The use of AI in OHS can lead to the development of tools for monitoring workers and alerting them when the conditions for safe work are not met (instructions not respected, worker's state of health outside the norm, etc.). This permanent surveillance may generate RPS and also lead to an individualisation of OHS and to the sole responsibility of the worker, to the detriment of the employer's implementation of collective prevention measures. |
| 14. Attention should be paid to the possible risks associated with the use in OHS devices of AI algorithms that have not been developed specifically for this purpose (open source libraries, off-the-shelf products). |
| 15. Deep learning technologies are based on training a model on a data set. The use of AI in companies will therefore involve the collection and storage of a lot of data. As soon as a preventive use is envisaged, the question arises of the constitution, qualification and labelling of the data set used during the learning phases in supervised systems. Particular attention must be paid to the data sets so that they correspond to the areas of applicability, which may vary according to the activities and work situations, and so that they are not biased (see also key message 19). |
| 16. Occupational accidents frequently occur in situations that are atypical of the classic course of a production process: degraded situations, breakdowns, maintenance operations, etc. These situations are often unforeseen and therefore not anticipated in the procedures, which makes them particularly dangerous. They thus constitute a possible limit to the training of AI systems, as the necessary data sets are not able to exhaustively integrate the range of hazards that can occur in many work contexts (construction sites, large industrial sites, work on the public highway, etc.). |

**Table V**. Six key messages about the limitations and points of vigilance on the use of AI in OHS

| Courses of action |
| --- |
| 17. Because of the opportunities offered by these new technologies, as well as the potential risks they entail, the training of prevention stakeholders (employers, staff representatives, preventionists) is a key issue in the future integration of AI into work equipment and prevention solutions. These training courses should provide a good understanding of the way these tools work, the ethical issues, the regulatory framework governing them, the possibilities of piloting them, the risks they may represent, but also the acquisition of methods allowing the definition of needs, the drafting of specifications and the integration of devices in the company. It is essential to educate the players in social dialogue, both at the level of the professional branches and at the level of companies (particularly in VSEs and SMEs), so that they are in a position to understand and discuss upstream the changes in working methods and procedures that these new systems entail. |
| 18. The development and marketing of devices using AI techniques presented as prevention tools must be carried out by people with solid OHS skills. In addition to the training to be provided within the company, modules should also be implemented in the curricula of management and engineering schools, in order to make future sponsors and developers of AI systems aware of the opportunities and risks that these new technologies bring with them in terms of OHS. |
| 19. Companies should be encouraged to adopt approaches based on experimentation and evaluation, which make it possible to measure in real conditions the consequences of new systems on the organisation of the company and on the work of operators, and to retain the possibility of going backwards. |
| 20. The standards and regulations governing AI are developing (AI act of the European Union). It is therefore essential that the principles of OHS are taken into account in the development bodies. This is particularly true at the level of European regulations, but also in standardisation committees. |
| 21. A collective reflection (such as a consensus conference) will have to be conducted on the issue of data used in AI devices relating to OHS. In particular, it will be necessary to define rules for the constitution of data sets and the framework for their use according to the fields of application. In addition to the users, the social partners and qualified personalities (experts, philosophers, ethics specialists, lawyers, etc.) will be involved. |
| 22. In general, advances in AI offer prospects for progress in the prevention of occupational risks. Like any change, they also entail certain risks. The development and dissemination of methodological tools to guide the players in the face of these innovations are a major challenge for prevention organisations. |

**Table VI.** Six key messages about courses of action of the use of AI to support occupational risk prevention

This reflection, although somehow “local”, represents a starting point to understand the subject in a more global context. It was produced by a group of French contributors and is part of the French context of occupational risk prevention. However, France's membership of the European Union and the broad convergence of EU countries in terms of OSH policy extends the scope of these discussions to the whole of the European continent.

### *4.4. The French study in an international context*

The European Union has launched an ambitious debate on the development of artificial intelligence, which it sees as a major area of progress for the development of economic activity in the coming years [21]. This support has been accompanied by the introduction of a regulatory framework designed to ensure that its use does not, in certain cases, lead to a deterioration in living conditions. Issues of health and safety at work are (among others) targeted, whether indirectly with recommendations aimed at banning the discrimination and bias that the uncontrolled development of AI could lead to, or more directly via specific provisions.

However, the recommendations remain fairly vague, focusing on the fair sharing of the value generated by productivity gains, the need for workers to remain at the centre of the production system and not be subordinated to machines or to production logics such as the gig economy.

The European Agency for Safety and Health at Work (EU-OSHA), a specialist agency of the European Union, has also tackled this issue, focusing mainly on human-robot cooperation and stressing that this transformation of work can result in the pace of work being aligned with that of the robot, increasing the mental and physical strain of workers [22]. The collection and use of data is another source of concern, in that it may contribute to an imbalance in social relations. The statement remains vague, as does the conclusion, which calls for the use of AI to be a factor for progress in occupational health and safety, without spelling out any specific courses of action.

The model proposed by the European legislator to regulate AI has been analysed and judged insufficient by Jarota in two articles published in 2021 and 2023 [23][24]. In particular, he questions the absence of any obligation for employers to carry out studies to objectivise the possible consequences of the use of AI on working conditions and occupational risks. In his view, this is due to the point of view adopted, which sees AI as a subject of law and not as a set of techniques used to improve the performance of work tools and equipment: what the world of work needs is active regulation. This regulation must provide for the setting of objectives to be achieved, accompanied by mechanisms for sanctions, incentives and rewards. It is simply a matter of aligning the treatment of the AI issue with what has already been done by the European Union to ensure the harmlessness of different production techniques for workers.

In Germany, Niehaus et al carried out a questionnaire study involving workers, some of whom were affected by the use of information and communication technologies (ICTs) and others by the use of artificial intelligence in the robotisation of their activity [25]. The theory distinguishes between two scenarios:

- If the impact of these technologies is strong, it may limit the control that workers can have over their work;
- But highly autonomous and reliable systems can also create opportunities for more flexible and diversified work, resulting in increased autonomy for workers which is beneficial for working conditions.

One of the key findings of the study is that the consequences of the use of these new technologies are mainly felt at the organisational level, rather than at the level of human initiative (more prescribed work), and that this translates in particular into a change in working patterns, in which workers lose autonomy. All in all, the overall trend is downwards in terms of physical strain, repetitive tasks and information overload.

In the aforementioned REDECA study [18], Pishgar et al explored the use of AI techniques for occupational risk prevention purposes in five major industrial sectors with a high accident rate. These uses have increased significantly in recent years. Referring to the work of the European Union cited above [21], the authors of the article call for cooperation between the various stakeholders to be undertaken as quickly as possible, given the significant challenges they see in the face of development that is sometimes insufficiently controlled.

This is the rationale behind the approach described in this article. The purpose of the key messages produced is to initiate a collective debate at the French level and to provide certain structural elements: a certain number of essential rules of occupational risk prevention could be called into question (the centrality of the human being, the machine at the service of Man) more or less insidiously, and it is important to preserve them. This is all the more important given that, in parallel with the emergence of new technologies (including AI), and partly because of them, the world of work is becoming increasingly fractured, to use David Weil's phrase [26]. The aim is to avoid prolonging or exacerbating the phenomenon he describes as follows: *The changes in business organization that underlie the fissured workplace have been transformative. But workplace policies have not adequately factored these profound changes into the rights and protections for workers and the responsibilities placed upon business and other organizational entities.*

## 5. Conclusion

The stakeholders of occupational risk prevention will have to develop their skills to be able to conduct studies on systems implementing AI techniques, and to train, advise and assist the stakeholders concerned, in particular administrations, actors in prevention and the social partners (i.e. employers and labour unions). This approach should not be limited to tools, but also take into account the organisational logic in which they will be used.

Given the complexity of these issues and their emerging nature, it will be necessary to consider grouping and pooling the data collected from companies in the same sector of activity (or neighbouring sectors) to form a database under the aegis of occupational risk prevention research organisations. This will facilitate the joint appropriation of knowledge.

It will also make it possible to organise information and training aimed at prevention workers in the field and at companies. In particular, this will entail raising awareness about the points of vigilance to be borne in mind, as well as the good practices to be implemented in the face of the development of AI in support of prevention.

Actors in prevention will also be responsible for alerting and reminding companies that these AI tools are not similar to safety systems and that they do not exempt them from carrying out risk assessments and primary prevention in their company.

## Statements and Declarations

- **Ethics approval and consent to participate:** not applicable (no use of any animal or human data or tissue)
- **Consent for publication:** not applicable (no data from any individual person)
- **Competing interests:** The authors declare that they have no competing interests
- **Funding:** No specific funding was used for this study, which was financed from the regular budget of the institute that led the work

- **Authors' contribution**: All the authors contributed to the work described in this article as members of the project group
- **Data availability statement:** All the data (description of variables, hypotheses, combination of hypotheses to create scenarios, consequences for health and safety at work) used in this article have been brought together in a document (in French) accessible on this page: https://www.inrs.fr/media.html?refINRS=PV%2019

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## Declarations

**Funding:** No specific funding was received for this work.

**Potential competing interests:** No potential competing interests to declare.