

CONSTRUCTION SITE ORGANISATION, TRAINING FOR MACHINERY

Every profession, every activity and every work situation is specific and includes permanent interaction between people, material, environment and machines. Next to ensuring high quality ergonomic and safety-related standards for the materials and machines used, it is essential to have a good site organisation and good qualifications of the employees involved. This fact sheet lists the important elements of construction site management and employee qualification.

DESIGN PHASE

A safer construction company, also working safer with the handling of machines, starts in the planning phase of a project. As described in the "Mobile sites" Directive, the client has to take into account, during the planning phase and together with the coordinator, the principles of hazard prevention on the basis of the health and safety "Framework" Directive (Article 6). The results must be taken into account in the project-related safety and health protection plan.

What does this mean in terms of a safer use of machines ?

The first step is the improvement and then the implementation of the overall framework conditions.

The following elements, amongst others, are part of this framework:

- Access for vehicles and mobile machinery to the construction worksite. There are height, width, or weight limitations. There are restrictions on the building permit as well as the number of movements. With a higher number of smaller devices, there are also more frequent interactions between workers and machines. A large-scale transport concept, including public transport, should also be established (for example, one-way traffic system on the worksite during the construction phase).
- During which time, which works must be carried out?
How many machines does the company need to carry out the works in the given time frame?
How many different companies must work simultaneously with which machines?

In the planning phase, the various supply and disposal trips of the companies and their suppliers must also be taken into account. Particularly critical are the construction phases in which overlapping of several machine-intensive activities occurs (for example during the first phases of housebuilding within a city). The main construction company erects the construction site facility, the specialist foundation company sets the excavation protection and the earthworks company already begins with the excavation of the secured areas. The delivery vehicles must not stop on public roads, in order not to interfere with the public traffic.

On the basis of the assessment and of the existing framework conditions, the coordinators have to define the protective measures in the Health and Safety (H&S) plan. The STOP (Substitution-Technical-Organisational-Personal) principle must, of course, be applied.



Proper planning? Each builder, in cooperation with the coordinator, must specify in the planning phase which activities are to be carried out at what time.



Technical protective measures: separation between vehicle traffic and pedestrians.



Instructions on the equipment to be used.



Taking into account all surrounding aspects can avoid damage, accidents and catastrophes.



Knowledge check.

Substitution solutions, examples:

- Physical separation between vehicle traffic and pedestrians (road barriers)
- Temporal separation between vehicle traffic and pedestrians (no journeys in the work area during the works)
- Temporary deviation of high voltage lines or their neutralization during the duration of the works
- Take account of local wind conditions

Technical solutions, examples:

- Mirrors, cameras, warning devices
- Adjustment of the tires (winter-> summer-tires)
- Visual marking of the danger areas

Organisational solutions, examples:

- Traffic rules (for ex. priority of pedestrians before machines)
- Speed limits
- Load securing measures
- Road cleaning, adapting to weather conditions
- Timely warning when a machine is approaching
- Identification of traffic areas
- Banksman, flagman

Personnel-related solutions, examples:

- Safety training for operators of machines
- Personal protective equipment: warning clothing
- Observe instructions for correct behaviour in hazardous areas

Often it will be a combination of various possible solutions. The measures applicable to all the companies and laid down in the safety and health protection plan must be clearly described separately. In order for the measures to be implemented, the H&S plan must be available from the tender phase and included as a contract component when awarding the contract.

EXECUTION PHASE

The basis for the execution of the project is the main contract including the H&S plan. There are different ways of awarding a contract: awarding it to a general/main contractor, the client awards the various contracts directly to the concerned companies, etc. However, the safety and health protection plan with the stipulated measures must be binding for every company operating on the same construction site. The size of the company is just as little relevant as the type of contract (sub, direct) or the contract volume.

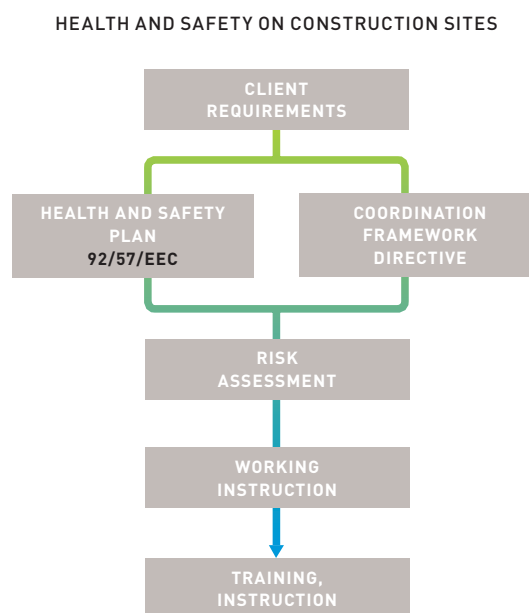
The safety and health protection plan is therefore also the basis for the respective risk assessments in the companies.

In the execution phase, however, there are always new dangers or the originally planned protective measures cannot be implemented or only partially implemented. In order to minimise the risks to all persons, regular meetings with all the concerned companies have to be organised by the site coordinator, amongst others on the basis of a "bottom up" input/feedback provided by the concerned persons on the field or

their representative(s). The frequency and duration of these meetings depend on the potential threat, the number of enterprises and the degree of implementation of the protective measures. By involving all the companies, the protective measures are adapted, the responsibilities for the implementation of these measures are redefined and the results are subsequently reintroduced in the H&S plan.

Of course, the risk assessments of the companies have to be adapted accordingly and the workers have to be informed promptly about the changed protective measures. In order to be able to adapt quickly, it is necessary that the representatives of the concerned companies are present at these meetings. A company representative must be taken into account in the same way as experts, visitors, construction supervisors, surveyors or the main contractors. Each subcontractor is also considered an equivalent company.

Independently of the coordination meetings, the coordinator has to check whether the agreed protective measures are effectively applied or implemented by the companies. The findings of these controls are also part of the regular meetings.



TRAINING

In addition to the safety measures of the H&S plan, the users of equipment/machines must have sufficient knowledge to operate them safely. For this purpose, it is necessary to have on the one hand the special knowledge of the specific device, as well as sufficient knowledge about the environmental conditions in which the machine is used or operates.

As regards the training for a specific machine/equipment, for example:

- Use of the safety devices on the machine/equipment
- Field of view of the machine/locating blind spots
- Maintenance and repair
- Attachment points
- Optical and acoustic signals
- Regular inspection requirements
- Specifications based on the manufacturer's operating instructions
- Responsibility of the operator
- Safe distance from the slope edge
- The limitations on the use of machines

As regards the ambient conditions, two different types of issues can be distinguished between the general and the project-specific ones.

Examples of general issues:

- Work in the area of high-voltage cables
- Public transport (car, railway)
- Dangers in the subsoil (gas pipelines, water pipelines, high-voltage cables, war residuals, etc.)

Examples of project-related issues:

- Project-related environment
- Contents of the H&S plan
- Emergency management
- Traffic rules
- Personal protective equipment
- Protection measures based on hazard assessment
- Identification, light signals

In all training courses it is crucial to ensure a sufficient level of language understanding (communication). Whether this is done by a native speaking person or by an interpreter is less important.

Depending on the subject, the transfer of knowledge can also take place through e-learning, a theoretical lecture and through practical exercises. After the training an assessment of the acquired knowledge is absolutely necessary. The worker can be authorised to operate the concerned device/machine only after a positive assessment of the knowledge acquired. Obviously the instructions following changes, new knowledge, accidents, near-accidents, etc. have to be repeated.

Finally, in general there is a need to strengthen safety-related aspects already from the initial education, in order to ensure that the basic concepts and competences/skills are acquired as early as possible.

ERGONOMICS FOR CONSTRUCTION MACHINERY

The complexity of construction sites calls for a high level of safety, reliability and comfort in the interaction between workers, work equipment and work environment. This objective can be achieved by incorporating ergonomic principles into the machinery design process. This fact sheet summarizes useful aspects to be taken into account to ensure safe, sustainable and productive operation in construction sites across Europe.

THE REGULATORY FRAMEWORK

Ergonomics is an essential ingredient of construction machinery design: it is a key element to be considered by manufacturers when carrying out the risk assessment and – if necessary – risk reduction. Ergonomic principles are among the inherently safe design measures to be applied by machinery manufacturers, and as such they play a very important role in the risk reduction strategy. The understanding of the interactions between humans and construction machinery, and the application of theory, principles, data and methods to construction machinery design is indispensable to optimise human well-being; at the same time, ergonomics increases the overall human-machine performance and productivity.

Construction machinery placed on the market in the European Union must satisfy the ergonomic principles set out in the Machinery Directive 2006/42/EC which requires manufacturers of all categories of machines to take into account a number of general ergonomic

factors (*operators variability, space of movements, work rate, concentration, human/machine interface*) and additional ergonomic aspects (*like lighting, handling of machinery or parts of machinery, seating, operating positions and control devices, extreme temperatures, noise, vibrations, risk of tripping, slipping and falling, access to operating positions and servicing points, information, signs, signals and warnings*) with the objective to minimise physical and psychological stress, discomfort and fatigue.

Research and experience show that good design reduces the negative effects of these factors on persons whereas inadequate design is likely to give rise to discomfort, fatigue or physical or psychological stress. These effects may, in turn, give rise to for example musculoskeletal disorders. They also tend to make accidents more likely to occur.

Additional public information on the legislative requirements associated to ergonomics is available on the ErgoMach website.

<https://ergomach.wordpress.com/>

THE TECHNICAL (STANDARDISATION) FRAMEWORK

European and International standards can significantly help manufacturers of construction machinery in complying with the ergonomic requirements of the Machinery Directive. On the one hand, the International and European technical committees dealing with general safety of machinery (ISO/TC 199 and CEN/TC 114) have produced basic standards on how to carry out risk assessment and risk reduction; on the other hand, the International and European technical committees dealing with ergonomics (ISO/TC 159 and CEN/TC 122) have produced a wide range of standards providing concrete provisions facilitating the compliance with the ergonomic requirements of the Machinery Directive.

Most of the standards produced by CEN/TC 122 are “harmonised” according to the Machinery Directive and published in the Official Journal of the European Union: therefore, their application confers a presumption of conformity with the legislative



Machines with side boom; side view obstructed by the boom.



Front view obstructed by window pillar; the driver is not in a position to see his companions.

requirements they aim to cover. In a dedicated webpage, the European Commission provides additional guidance to manufacturers by describing which standards (harmonised or not) are available to help them comply with a wide range of ergonomic factors.

CRITICAL TOPICS

Progress has been made over the years to improve the **ACCESS** to operating positions and servicing points of construction machinery. On average, the driver of construction machinery gets on and off the cabin as often as between 15 and 50 times a day (depending on the type of construction activity). Maintenance operations may require up to one hundred movements in a day around a machine: they include lubrication, cleaning, refuelling, replacement of filters. These numbers highlight the importance of design solutions striking the proper balance between different characteristics of the machine (visibility, transportation, travelling), and the need to minimise the risk of slips, trips and falls and unhealthy postures and excessive effort.

Manufacturers should give particular attention to the design of proper access systems, including enclosure openings,

platforms, guardrails, handrails and handholds, stairways, steps and ladders. The challenge is to provide proper access for the wide range of construction machinery in all the various operating conditions, taking into account the variety of job sites where construction machines operate.

Elderly operators or those below 160 cm in height may still find access to operating positions and servicing points uncomfortable. One specific challenge is the difficulty of providing access at heights inferior to 400 mm, because the ground conditions in construction sites are likely to cause damage to access systems and accumulation of slippery material on means of access.

A second critical ergonomic feature is **VISIBILITY**. Since decades, designing construction machinery providing adequate visibility for the operator has been a constant challenge, especially because due to the functionality of the machine various machine parts inevitably cause restricted sight lines and blind spots from the operator's position. But it is a fact that optimal design may significantly improve visibility and minimise risks not only to people moving and standing in the vicinity of the machine, but also to the drivers themselves: to take an example, drivers can be exposed to musculoskeletal disorders (MSDs) and

back and low back pathologies if they take unhealthy postures trying to adapt and compensate deficient visibility in order to obtain sufficient line of sight and safely manoeuvre in the workplace. Productivity can also benefit from proper visual conditions because operators are able to use the full range of functions and capabilities of the machine they operate.

Another area where ergonomics is being given better attention is the design of **QUICK COUPLERS** that are often involved in serious accidents when the bucket falls off. Investigations carried out by safety authorities have been instrumental to the evolution from manual to semi-automatic to fully automatic couplers, also considering the ergonomic benefit of operating from the cab. Efforts are being made in standardisation with new requirements giving attention to all failure modes in foreseeable situations or misuses.



An ergonomic location of the controls is crucial for safety.



Unpractical access for small operators.



Operator descending instinctively using the tires instead of the unergonomic access system.

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TRENDS AND PERSPECTIVES

The voice of the users (employers) and end users (workers)

There is consensus among stakeholders about the extensive but unseen knowledge base that users possess on the processes and equipment they work with. Knowledge that can be leveraged both in and outside the workplace to improve technical standards, market surveillance strategies, training schemes, organisational procedures at company level: the mine of information gathered from users can be used not just in devising technical solutions, but also in putting them at work. The scientific community's potential input into working out a common approach that is recognised at European level, as well as research needs and resources, are aspects that in the next few years should be evaluated carefully.

The publication of the European standardisation deliverable *CEN/TR 16710-1:2015 Ergonomics methods – Part 1: Feedback method – A method to understand how end users perform their work with machines* can be considered a significant step towards the possibility to carry out cooperative projects for the benefit of the engineering industry, societal stakeholders, OHS Bodies, public authorities.

Ergonomic guidelines for designers

The objective to integrate ergonomics in the design phase of construction machinery can be achieved by considering ergonomics tuition modules and best practices in machine ergonomics. The German Commission for Occupational Health and Safety and Standardisation (KAN, www.kan.de) for example, has developed lecture modules containing information on ergonomics aimed at developing "ergonomic thinking" already during education. The modules deal with machinery and plant construction but are applicable to other sectors. They are articulated in theoretical content, illustrative video clips, cost/benefit analyses and case studies. KAN also offers examples of best practices in machine ergonomics with cases where selected machines properly satisfy ergonomic criteria and principles. Designers and purchasers can benefit from this information, supported by search tools, pictures, examples and descriptions.

USEFUL RESOURCES

European Commission: Guidance on the application of the essential health and safety requirements on ergonomics set out in section 1.1.6 of Annex I to the Machinery Directive 2006/42/EC.

<http://ec.europa.eu/DocsRoom/documents/9484/attachments/1/translations>

End users "Feedback" to improve ergonomic design of machinery: <http://content.iospress.com/articles/work/wor0305>

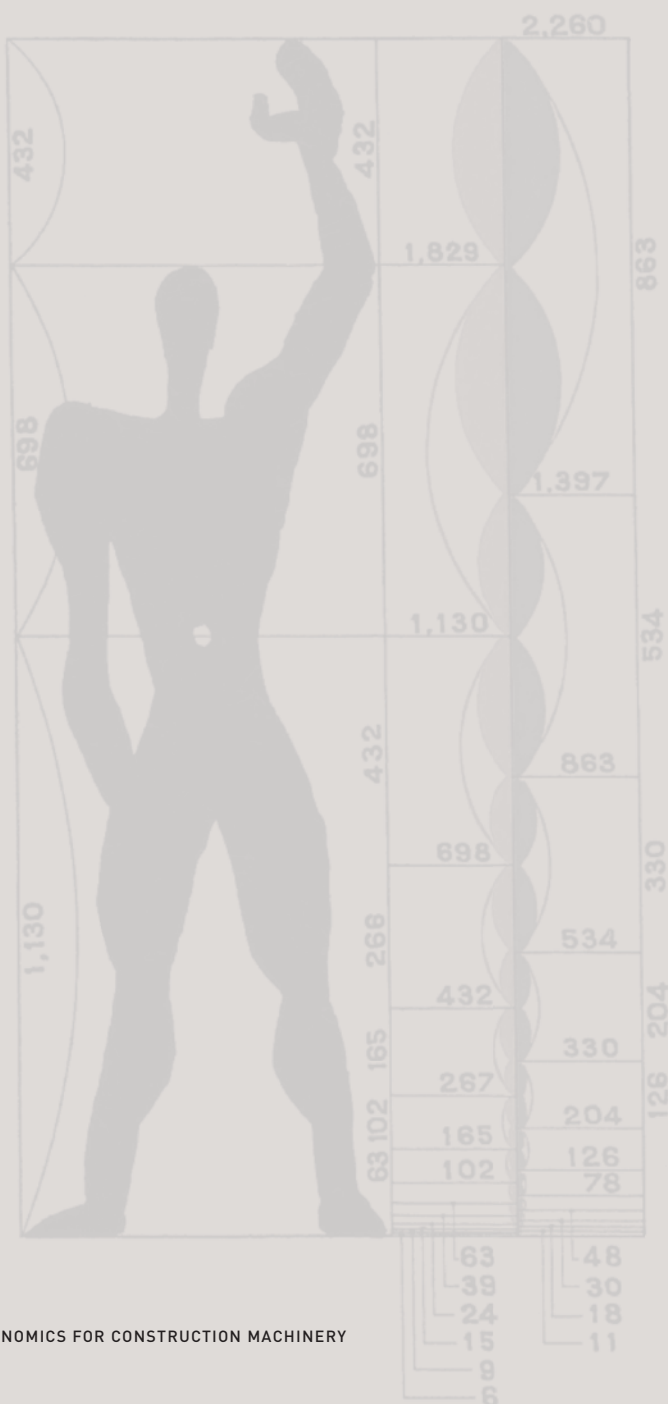
Ergomach website: <https://ergomach.wordpress.com>

A good initiative has been developed by KAN in Germany: www.kan.de

Lecture modules on ergonomics: <https://ergonomie.kan-praxis.de/en>

Tool on machinery ergonomics: <https://maschinenergonomie.kan-praxis.de/en>

A guide on anthropometric data: <https://koerpermass.kan-praxis.de>



STANDARDS FOR MACHINERY

Creating European standards on the safety of machinery is complex and challenging. Much progress has been made but the involvement of users needs to be encouraged in order to take account of the whole lifetime of machinery.

THE NEED FOR STANDARDS

Even when travelling only in countries within the European Union, European citizens may have trouble plugging in their different electrical devices, and frequent travellers quickly buy an adapter. For some of the countries the plugs are similar, designed with the same standard providing compatibility. In the past there were also several types of power supply, meaning that the traveller could not use some of the devices in some countries. This is still the case for the railway systems and consequently many locomotives which need to cross borders have to incorporate several electrical systems, increasing the cost considerably. Standards improve compatibility and save time and money.

For all types of products customers need to make a comparison in order to make a good choice. To compare every aspect of a technical product is extremely difficult for a customer who does not have a high degree of specialised technical knowledge and consequently experts have established

standards in order to help customers identify products fulfilling a defined quality level.

Standards were originally published by separate nations and then later collaboratively at international level, before there was any legal requirement to do so, in order to improve compatibility and quality.

HIGHER LEVEL OF PROTECTION FOR WORKERS THROUGH EUROPE

The European Union provides a single market for the manufacturers of machines which simultaneously means the same level of safety for the machines in the Union. The Machinery Directive includes a coherent set of requirements, called essential health and safety requirements, for all types of machines. An important package of safety standards has been published for various types of machines including 94 standards for construction machinery. Therefore all workers throughout the

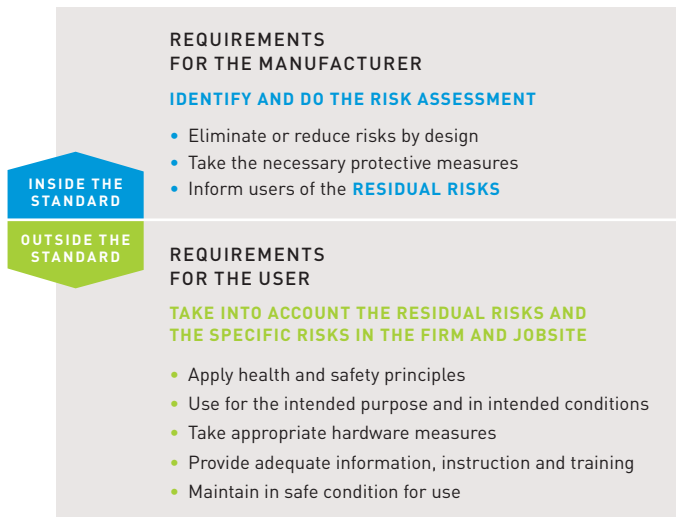
Union have the benefit of a high level of safety and their employers also gain a measure of protection due to the safety standards.

Even though overall the number of machines on construction jobsites has significantly increased in the two last decades the absolute number of accidents has decreased.

A LINK BETWEEN MANUFACTURERS AND USERS

Standards for machinery include design requirements for manufacturers and the way to confirm that these requirements have been met. They also define the minimum contents of the instructions for use, helping to define the borderline between the manufacturer and the user: where the manufacturer's responsibility ends and that of the user begins. These instructions for use include production, maintenance, installation, transport and dismantling. (See figure, page 2)

DUTIES OF MANUFACTURERS AND USERS



At national level the National Standards Bodies (NSBs) help stakeholders to draft and translate proposals. Final users are needed in the process in order to explain their specific applications and environment. Workers and workers' organisations are also welcome to explain their constraints in order to help manufacturers to better understand user needs in the design of machines. The delegates of health and safety, national social insurances as well as public authorities will ensure a technical, scientific and legal support for all. Meetings provide real opportunities for exchanges and final users are able to influence the design of machines.

The involvement of the different stakeholders is fundamental to the process of developing standards and EU laws have been developed to guarantee access to workers' and consumers' organisations. EU regulation 1025/2012 requires the member states to encourage and facilitate the involvement of SMEs and worker representative groups, such as the European Trade Union Institute (ETUI), in the standardisation process.

Each national committee can send experts to working groups at European level. Thousands of experts are working for improving the safety of the machines in the construction industry.

A PROCESS FOR VOLUNTEERS, STANDARDS NEED YOUR INVOLVEMENT

European standards are built at two levels: national committees level and at the European level through the Working Groups. All stakeholders are welcome at both levels.

PARTICIPANTS IN STANDARDS MAKING AT NATIONAL AND EUROPEAN LEVEL



COLLECTING INFORMATION FOR RISK ASSESSMENT IN THE WHOLE OF EUROPE

Each type of machine should have the benefit of a global risk assessment. In order to incorporate the different opinions and understand different ways of operating machinery, a minimum of 5 NSBs, representing 5 countries are needed to create or revise a new standard. Accident data and experience from the different cultures are studied and cross-checked. In addition the presence of health and safety experts and market surveillance authorities provides impartial and balanced information in the working group.

A SEARCH FOR CONSENSUS

Standards are drafted with safety criteria in order to avoid establishing barriers to new technology and innovation, therefore all stakeholders are at the same level. Every comment is recorded and answered and the working group generally takes all aspects into account. Comments should provide for a rationale together with a

structured proposal for the suggested changes. The working group generally drafts the standards by consensus, and where complete consensus is not possible progress can only be made where there is a strong majority.

At European level, the project will only be adopted when there is a 2/3 majority of the NSBs and 2/3 of the weighted votes.

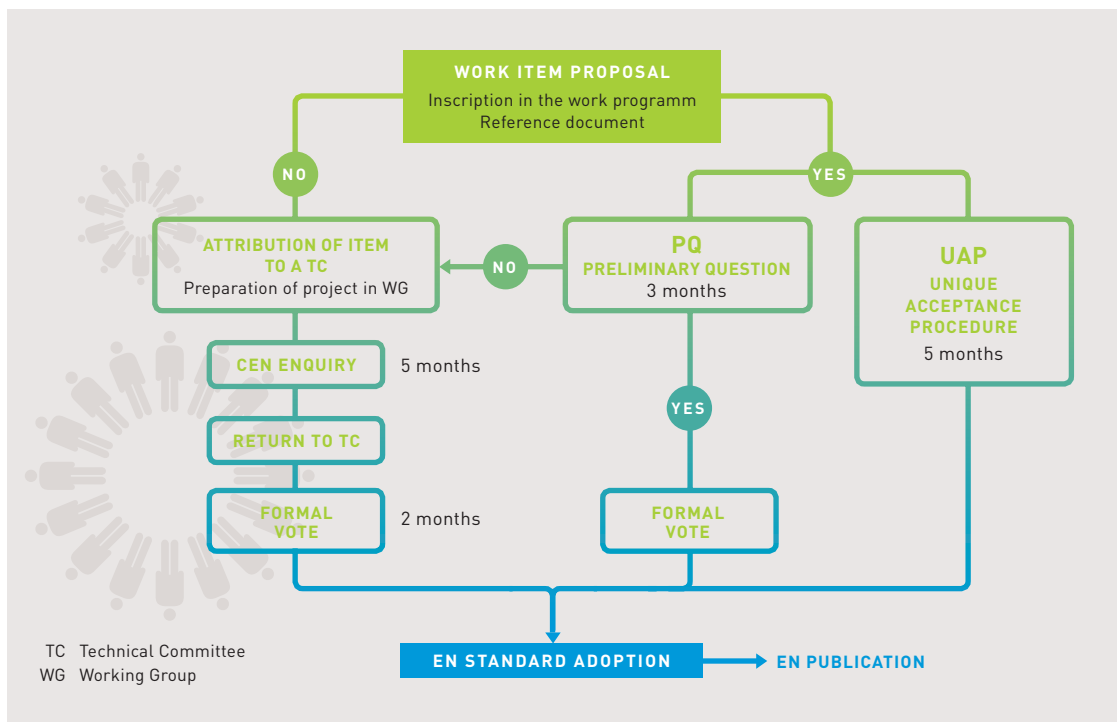
PUBLIC ENQUIRY: A DEMOCRATIC PROCESS THROUGH THE EUROPEAN UNION

Apart from debate within the working groups the public have the possibility to submit comments and proposals during the public inquiry, even those who did not take part at the first draft of the project. At this stage it is also possible to join the national mirror committee in order to contribute new comments. Comments at the public enquiry stage may be to clarify the scope, improve the safety requirements, add some technologies, provide new examples or drawings, etc.

PRESUMPTION OF CONFORMITY

The Machinery Directive has been developed by the Health and Safety specialists and the legal experts of the Member States for all types of machines, although there are some requirements which are relevant to one type of machines and not to others. Moreover some of the technologies are developing quickly, such as electronics, and some more slowly, for example mechanics, therefore it was decided to give a link between the standards and the Law. Harmonised standards published in the Official Journal of the European Union (OJEU) give presumption of conformity. As the standards are developed with the participation of the health and safety organisations, collecting the data of accidents throughout Europe, the risk assessment is made at a wider stage. The standards are helping the manufacturers to do their risks assessment.

KEY PERIODS FOR EUROPEAN STANDARDS PROJECTS



FAIR COMPETITION FOR THE INDUSTRY

Standards are based on minimum requirements to be fulfilled by all manufacturers and therefore provide a basis for fair competition between all manufacturers. This is particularly important for the import of machines into the European Union because machinery safety levels are lower in some other parts of the world.

A TOOL FOR USERS AND FOR MARKET SURVEILLANCE

It is not always easy to quickly check the compliance of the machines to the safety laws and the standards are considered a helpful tool for the users to check the conformity of the machines. The comparison between different machines is much easier if the user knows that all of them conform to the same minimum standard.

Moreover, standards are used by the specialised bodies designated by the authorities to check the conformity of the machines. Because almost all the manufacturers comply with the standards the control is simplified.

CEN AND ISO

The NSBs develop standards in CEN (European committee for standardization) working in the three official languages (English, French and German). The three versions are always available throughout Europe for the public enquiry, but of course some of the NSBs also translate the project documents and finished standards into national languages.

Where the European and the International Technical Committee agree, the standard may be developed at international level according to the Vienna Agreement route. In this case there will be two parallel votes, one at ISO level with the rule one vote per country, and one at European level with the same rules as a European standard. Only when there is a positive vote at European level will the standard be considered suitable for Europe, regardless of the international vote.

REGULAR IMPROVEMENT

Standards are regularly improved in order to follow the improvement of technology. A periodical review is conducted every 5 years. In addition, clarifications and technical updates are possible through amendments when required.

VIGILANCE OF MEMBER STATES, PARLIAMENT AND COMMISSION

Where standards do not represent the state of the art, either because they include requirements in contradiction to the machinery Directive, or because they miss key requirements, the National Authorities, the European Parliament and the European Commission all have the possibility to raise a formal objection against a standard. The publication of the standard may be withdrawn from the OJEU or the European Commission may publish a warning highlighting the deficiencies. Furthermore all stakeholders will be invited to debate the objection and improve the standard.

COLLISION AVOIDANCE FOR MACHINERY

Collisions between machines and pedestrians are amongst the most dangerous situations on construction sites. The design of machinery, coherent jobsite organisation and the training of bystanders all need to be improved simultaneously and urgently.

CONTEXT

Collisions between mobile machines and pedestrians are the second main concern raised by workers on construction sites after falling from height. Fortunately over the years the number of accidents has continuously decreased even though the number of mobile machines has gone up. However, the consequences of a collision are generally severe and fatalities still occur, in particular due to reversing of machines.

THE FRAMEWORK DIRECTIVE

The most important legal act for the safety of the workers is the European Framework Directive (89/391/EEC). This Directive establishes general principles for managing safety and health, such as responsibility of the employer, rights/duties of workers, using risk assessments to continuously improve company processes and workplace health and safety representation.

The following table is showing some main examples of the application of the general principles.

PRINCIPLES	EXAMPLES
Prevention Hierarchy	<ul style="list-style-type: none"> Avoid all risks and evaluate remaining risks STOP principle: <ul style="list-style-type: none"> Substitution – use safer materials or machinery Technical – good ergonomics, visibility, aids Organisation – see separate fact sheet Personal – personal protective equipment
Adapting to technical progress	<ul style="list-style-type: none"> Use machines with positioning /detection system
Evaluating the risks	<ul style="list-style-type: none"> Identify the machines where persons need to work in close proximity Evaluate the risks, taking into account masking, blind spots Segregate the areas where machines are operating Decide your action plan Monitor and review
Combating the risks at source	<ul style="list-style-type: none"> Minimise the number of machines Choose the right machines Minimise the movements of the machines Separation of machines and pedestrians
Adapting the work to the individual	<ul style="list-style-type: none"> Provide machines with seat adjustment and, preferably, direct visibility
Replacing the dangerous by less dangerous or safe	<ul style="list-style-type: none"> Replace standard machines in tight or cluttered areas by smaller machines or machines with slow movements Use or retrofit machines with rear view cameras or other visibility aids
Developing a coherent overall prevention policy	<ul style="list-style-type: none"> Install stops, parking areas Organise at design stage separate entrances and exits for pedestrians and vehicles of the construction sites Set up stops, storage and park areas
Prioritising collective protective measures	<ul style="list-style-type: none"> Separate traffic lanes by design or by effective obstacles (e.g. concrete blocks)
Giving appropriate instructions to the workers	<ul style="list-style-type: none"> Train workers about blind spots of machines Give appropriate instructions to clean and maintain visibility aids of the machines Control the effective use of high visibility jacket

TEMPORARY AND MOBILE CONSTRUCTION SITE

Considering the examples shown in the above table it is clear that job site organization together with the sound design of machinery is one of the key techniques to minimise the number of collisions as they are the only ones that lead to the avoidance of risks and the only ones that are not dependent on the behaviour of the drivers or the bystanders. Notably, accidents occur not only with large machines but predominantly with smaller ones, such as mini excavators and dumpers, where visibility is generally good. This is because the smallest machines commonly operate close to workers, who often underestimate the related risks.

The temporary and mobile construction site Directive 92/57/EEC aims to achieve safer working conditions on work sites, requiring that safety and health considerations be taken into account during the design stage of projects. This includes risk assessment, in particular for large constructions sites, avoiding or minimizing the interaction of pedestrians and mobile machines.

The risk assessment needs to take account of the machines to be used including their capabilities and limitations. In order to do this effectively the contractor will need information from the machine supplier about hazards which could not be eliminated by design which have to be considered (see below).

VIBRATORY SOIL COMPACTORS ISO: 5006 FEEDBACK

Soil compactors height, width and length are driven by shipping constraints and customer requirements. Changing these dimensions to meet 1x1 is not an option.

MACHINERY DIRECTIVE

The Machinery Directive (2006/42/EC) places duties on machine suppliers and covers all aspects of machinery safety, including visibility and ergonomics. Its main aims are to ensure that machinery placed on the market or put into service in Member States meets a common minimum level of safety and to ensure freedom of movement of those machines within the European Union. The Directive includes Essential Health and Safety Requirements (EHSRs) aiming at safety integration.

In relation to collision avoidance no means are available to completely eliminate the risks. The key point of the Directive is:

“Visibility from the driving position must be such that the driver can, in complete safety for himself and the exposed persons, operate the machinery and its tools in their foreseeable conditions of use. Where necessary, appropriate devices must be provided to remedy hazards due to inadequate direct vision.” (EHSR 3.2.1).

Considering the state of the art it may not be possible to achieve this objective completely. In this case the manufacturer needs to provide information in the operation manual on the remaining hazards, such as ‘blind spots’.

The provision of visibility and aids needs to be achieved taking into account the principles for ergonomics (EHSR 1.1.6):

“Under the intended conditions of use, the discomfort, fatigue and physical and psychological stress faced by the

operator must be reduced to the minimum possible, taking into account ergonomic principles such as:

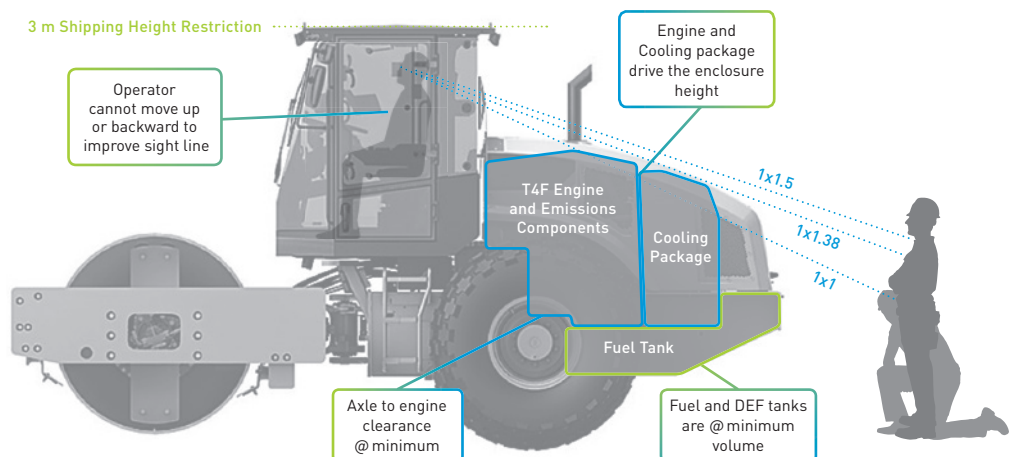
- *allowing for the variability of the operator’s physical dimensions, strength and stamina,*
- *providing enough space for movements of the parts of the operator’s body,*
- *adapting the man/machinery interface to the foreseeable characteristics of the operators.”*

This means that the supplier needs to make sure that, for example, the operator is not overloaded with screens or mirrors which all need to be checked, and that all visibility aids can be checked as necessary without uncomfortable movements.

VISIBILITY AND VISIBILITY AIDS

Direct visibility should always be a priority when designing a mobile machine. Although accidents do occur even with machines with full visibility, because of the behaviour of drivers and bystanders, research has shown that better direct visibility can reduce the number of accidents by a third. Defrosting and demisting systems are essential in machine cabins in order to optimise direct visibility. In addition, regularly cleaning the windows is essential to enhance safe operation of machines on construction sites.

Some ergonomic features (such as the structure of the cab) or safety equipment (e.g. roll-over protective structure,



ROPS) can impair direct visibility. Where visual information is necessary for the work or for the movements of the machine it is obvious that the driver will try to obtain this information, even by adopting uncomfortable postures. However, the lack of visual information increases the risks:

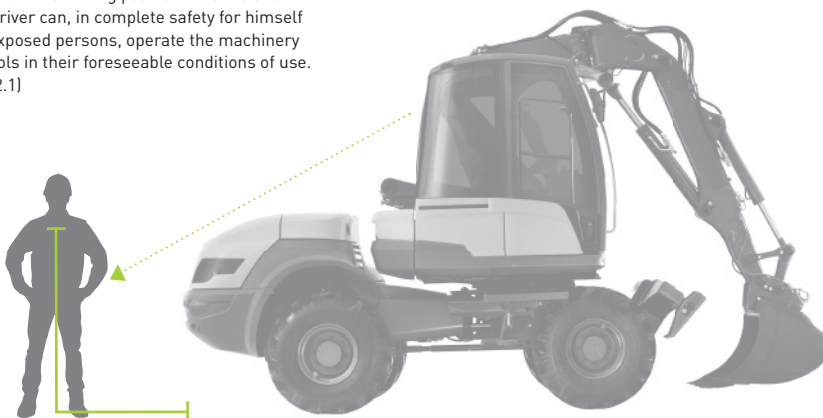
- for the driver himself (e.g. because he cannot see a slope, or a counter slope and this might affect the stability of the machine)
- for the persons in the vicinity (risk of collision)

Visibility aids (CCTV systems, mirrors) may reduce the risks but should not be considered as equivalent to direct visibility because of the necessary mental adaptation to analyse and recognize the information delivered by the visibility aids. Visibility aids need to be regularly cleaned and adjusted to ensure proper functioning.

It needs to be remembered that the operator's attention will primarily be directed at the work objective. It is not always possible to simultaneously take account of multiple visibility aids. It has been recorded that there are four times more judgement errors made by the operator when multiple screens are located in several places compared with combining that information in a single screen.

It might be beneficial to install obstacles or person detection devices in addition to CCTV systems in order to alert the driver to a risk of potential collision.

Visibility from the driving position must be such that the driver can, in complete safety for himself and the exposed persons, operate the machinery and its tools in their foreseeable conditions of use. [EHSR 3.2.1]



AUDIBLE WARNING SYSTEMS

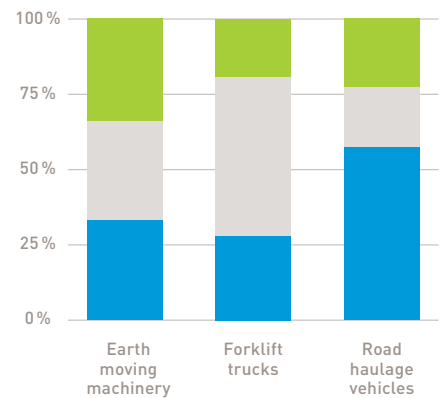
Audible warnings can be helpful in suitable circumstances. They can be activated automatically on selection of reverse gear or by object sensors to reduce the number of activations. They can be conventional sounders or 'white noise' generators which may reduce the environmental impact.

DETECTION SYSTEMS

Technology has developed quickly over recent decades and detection systems, in particular radar and ultrasonic devices, are being adopted for collision avoidance in various applications. However, work conditions on constructions sites are different because of dust, humidity, vibrations and also weather conditions such as heavy rain or snow and these can have a big impact on reliable operation of such detection systems. The table (page 4) provides a brief summary of existing technologies.

It is recognized that the current state of the art of these detection systems does not provide a single solution, able to cover on its own all the risks generated by the movement of a mobile machine. Error in a system may lead to non-detection or false detection. Consequently they are to be used as aids and should not interfere with e.g. the brakes of the machine. These systems can only warn the operator and/or the exposed person. It is the operator that still needs to take the adequate decision (e.g. braking).

ESTIMATED PERCENTAGE OF ACCIDENTS, IN WHICH BETTER VISIBILITY WOULD HAVE (OR WOULD NOT HAVE) AN INFLUENCE ON THEIR OCCURRENCE



- Better visibility would probably have prevented the accident. In these situations, the driver did not know the victim was present and in the blind spot, when the vehicle was started (to move forwards or backwards).
- In principle, better visibility would not have prevented the accident. These are situations, in which the driver and victim saw each other.
- Cases in which no opinion can be given: either because the account is too brief or because it reveals that visual attention is shared between task and machine driving.

OVERVIEW TABLE OF DETECTION SYSTEMS

TECHNOLOGY	DESCRIPTION	ADVANTAGES	DISADVANTAGES
Ultrasonic	Presence and distance of object measured by time of travel of reflected ultrasonic impulses	<ul style="list-style-type: none"> • Appropriate indication of target distance; either by visual and/or audio signals to the operator • available technology • reasonable costs 	<ul style="list-style-type: none"> • Time delay restricts usage to slow vehicles • Limited to operating at reverse speeds up to 10 km/h • Can be affected by adverse weather conditions • Multiple sensors required to cover entire rear area of machine • Does not discriminate between people and other objects • To be installed at a significant height above ground level
Radio Frequency modulated	Presence and distance of object measured by time of travel of reflected radio waves	<ul style="list-style-type: none"> • Can identify the ranges of multiple targets • Can be designed to detect speed and direction of object 	<ul style="list-style-type: none"> • Can sense objects outside path of vehicle. • Does not distinguish between persons and objects
Radar/lidar	Lidar systems typically use one rotating laser unit	<ul style="list-style-type: none"> • Inform the operator of objects around the machine • can work in more challenging conditions 	<ul style="list-style-type: none"> • Does not distinguish between persons and objects • More expensive than optical vision camera systems
Signal transponder (Tag)	The system uses an electronic device (tag) that is worn by a worker and a detection system that is installed on machinery	<ul style="list-style-type: none"> • Mutual warnings to both parties; monitors every direction 	<ul style="list-style-type: none"> • Control of workers wearing RFID tags is not within control of the machine operator • Very strong worksite supervision is required to ensure that everybody on site is wearing a tag • No ability to sense if the system is operating correctly
Satellite local positioning	System that maps location of machinery on site, based on their GPS location	<ul style="list-style-type: none"> • Can warn mobile machine operators when other machinery or vehicles are in their proximity 	<ul style="list-style-type: none"> • Typically requires a site map to be pre-programmed and all machines on site need to share the same system • Do not specifically detect the presence of persons
infrared	Senses changes in infrared emissions from objects	<ul style="list-style-type: none"> • Detects the difference between a person and an object 	<ul style="list-style-type: none"> • Cannot measure distance • Cannot distinguish a close person from a hot surface • May be affected by vibration, dirt
Vision systems and shape recognition	Vision systems using cameras and video analysis algorithms to detect obstacles and their classification according to their shape	<ul style="list-style-type: none"> • Obstacle detection • Capability to differentiate between objects and persons (to avoid false alarms) • Video analysis and object detection system functionalities integrated by design • Easy installation • Detection zone can be precisely configured 	<ul style="list-style-type: none"> • Cameras must have direct visibility on the surveillance area • Might not detect a person whose posture, clothing or position to the camera is not recognizable for the system such as a person in unusual posture • Dirt on lenses can lead to degraded detection/recognition capabilities
Moving object OVD	System that detects objects by analysing visual image of moving objects from the CCTV then warns the operator (and the person on the ground)	<ul style="list-style-type: none"> • Allows the distinguishing of multiple objects simultaneously • It is theoretically possible to detect velocity and direction of the person 	<ul style="list-style-type: none"> • Difficult to detect stationary objects • Can fail to detect an object when the machine itself is moving • Where persons do not move it can be difficult to distinguish the persons from static objects • Possible interference with direct sunlight • Objects in shadows may be difficult to detect • Performance can be affected by adverse weather conditions
270/360 degree camera systems	Multiple camera images joined together by software to display a "bird's eye" view	<ul style="list-style-type: none"> • Shows the close area all around the machine on one monitor • No blind spots close to the machine 	<ul style="list-style-type: none"> • Correct adjustment of cameras is critical • Image distortion • Can leave gaps in image at the joints between camera ranges • Limitation on range

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