

TALLINN UNIVERSITY OF TECHNOLOGY  
ESTONIAN ACADEMY OF ARTS

**Rethinking manuals for machinery products.  
Opportunities created by Regulation 2023/1230/EU.**  
Masinate kasutusjuhendite ümbermõtestamine. Euroopa Liidu  
määrusega 2023/1230 loodud uued võimalused.

Master's Thesis

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Tallinn 2024

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**THESIS TASK**

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**Thesis topic:**

Rethinking manuals for machinery products. Opportunities created by Regulation 2023/1230/EU.

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**Thesis main objectives:**

1. Analyse important changes between the Machinery Directive and Machinery Regulation.
2. Identify shortcomings regarding the requirements for user manuals in the Machinery Regulation.
3. Develop a guide or framework that could be used to create user manuals that would help to increase safety of machinery operators.

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## **Abstract**

The thesis explores the different aspects of writing and improvement of user manuals for machinery products marketed in the European Union. The work emphasizes the need for more accessible and clearer instructions for operators of machinery in order to change the trend of increasing work accidents that are machinery related in the EU. The thesis is written in the framework of the new Machinery Regulation in the EU that is in effect from 2027. This work is based on various technical standards, directives, and regulations as well as the authors notable experience in the field. The analysis conducted showed clear shortcomings from the previous Machinery Directive as well as the new Machinery Regulation that the work tried to address in order to offer better guidance for the compilers of user manuals for machinery products.

The new machinery regulation includes some changes regarding user manuals for machinery products – one of the being the possibility of online-only manuals. These new possibilities are analysed, and design solutions are proposed based on this by using the user centered design approach. Often the current user manuals are too complex and inaccessible for the average machinery operator. To better understand who the operator of the machine is an analysis of the users was conducted. The analysis showed that in addition to the actual day-to-day worker who operates the machine also people who transport, maintain, clean, store and utilize the machine are considered operators according to the Machinery Regulation. Therefore, the user manuals also must, as a legal requirement by the regulation, offer clear and safe instructions for them.

When analysing the written part of the current user manuals for machinery it became evident that the manuals should be written in as simple language as possible to ensure that all the readers of the manual understand the instructions as well as possible. In addition to simple language the user manuals should use step-by-step instructions that include illustrations where possible. Too often the examples that were analysed in this thesis were written in a language that was difficult to understand, lacked illustrations and procedures that could be written as step-by-step guides were written as plain text.

Integrating digital technologies and product as a service approach allows to create a system where communication between the machine operator and the machine producer is improved significantly leading to improved machinery design, better safety for the operators and longer lasting machinery.

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## **Foreword**

The initial idea to study and analyse the instructions for machinery users came from my own professional work at different positions related to mechanical engineering, manufacturing, and producing machinery. The experience that I accumulated over several years of working with production machinery as maintenance person and operator was followed by a decade as mechanical engineer. This has given me an overview of how different companies operate and how machines are put to market and used in production companies. Working as an operator made me realize that quite often the user manuals that are written for machinery are hard to understand and this can lead to workplace hazards. The experience as a mechanical engineer showed me how this topic is seen from the engineering perspective. I also experienced how machinery producers see the user instructions mainly as a document to limit their legal liability if an accident were to occur. In the whole process of writing user manuals and using them I noticed quite many shortcomings. This would maybe not be that noteworthy if the result of these shortcomings weren't making workplaces more dangerous. Based on this I decided to dedicate my master thesis on this topic with the end goal of improving safety of machinery users.

Keywords: Safety, user manual, machinery, design, master thesis.

# 1. Introduction

In any modern society, human life and our well-being in general is of the highest value. States and institutions go to great lengths to ensure that different laws, regulations, and value systems are in place to comply with that. One could say that one of the main purposes of countries and states is to ensure the safety and well-being of its citizens. If we think about the number of resources and funds that go to the social system for example from our taxes, then it's quite clear that this is the case. We have an expectation that our general safety and security is guarded by the state. The states use different laws and regulations to ensure the well-being of its citizens. The people, the state itself and the private sector are expected to follow these laws and regulations, or they can expect penalties and legal action. These rules regulate everything from food products, housing, taxes, intellectual property to medicine and documentation. In the current thesis we are going to look at the aspect of human well-being through the lens of workplace safety and more particularly the safety of machinery.

People tend to have a general expectation that the world around us is getting safer by each year. When it comes to machinery in the European Union then this is not the case. Eurostat states that in 2021 the most common causes for accidents at work were machinery related [1]. The European Trade Union Confederation in 2022 wrote that from 2014 to 2019 the number of machinery related work accidents in the EU rose 6,3% [2]. This is quite significant if we think about the increasing number of different work safety measures and regulations that are in place – especially in the field of machinery related work. For most machinery the operators need extensive training and, in some cases, even a separate licence in order to start working. In 2006 when the current legislation that regulates most of the machinery in the EU called "Directive 2006/42/EC - Machinery Directive" was introduced it actually made it easier for machinery producers to put unsafe machines to market. The European Trade Union Confederation Deputy General Secretary Claes-Mikael Stahl said in 2022 [2]:

*"The rise in the number of people suffering what can be life-changing injuries while operating machines at work shows just how irresponsible it was to cut safety checks at the behest of business lobbyists".*

The "Directive 2006/42/EC - Machinery Directive" is currently in effect in the European Union but a new version has been put to force called "Regulation 2023/1230/EU – Machinery". From 2027 onwards only the regulation is in force [3]. The regulation aims to somewhat undo the oversights of the previous directive in regards of safety of machinery. It also takes a more up-to-date approach regarding machinery user



manuals. For example, in some cases it allows digital-only machinery user manuals that the previous directive did not allow [3].

Whilst we can hope and expect the regulations and laws to ensure safety of machinery no machine is safe to operate without the proper instructions for the operators. A research called "Analysis and prevention of serious and fatal accidents related to moving parts of machinery" written in 2015 at the Department of Mathematics and Industrial Engineering, Polytechnique Montreal studied over 100 accident reports about machinery related accidents in US, Canada, and Sweden. The summary of the work lists unclear instructions for the machinery operators as one of the main reasons for machinery related accidents [4].

Another research named "The Causes of Workplace Accidents and their Relation to Construction Equipment Design" analysed work related accidents at work sites. The research found that inadequate instructions from the manufacturer was one of the main reasons behind a fatal work accident studied in the research and that this example highlights a broader issue with lack of adequate and clear instructions for workers and machinery operators [6].

The aim of this master thesis is to analyse the new possibilities created by the Regulation 2023/1230/EU regarding user manuals and improve the safety of machinery. The thesis seeks to explore the possibilities of reframing the user manual as something that could connect different stakeholders in a totally new manner and offer new benefits to all parties.

## **2. Theoretical framework**

The theoretical framework for this thesis is mainly guided by the different EU regulations, standards and laws that are in place at the moment of writing this thesis in the field of machinery and machinery production. In addition

The main regulations that this thesis is based on are the following:

1. Machinery Directive 2006/42/EC – This is the main framework and law that machinery producers and parties who put machinery to the European market need to comply by.
2. Machinery Regulation 2023/1230/EU – This is the new Machinery Regulation that is going to replace the current Machinery Directive. From the year 2027 onwards only the Machinery Regulation will be in place and therefore all machinery on the EU market needs to comply by this.
3. ISO 12100:2010 – This standard is the main international standard that specifies machinery safety regarding design, risk assessment and risk reduction. Although this standard is not mandatory for machinery producers to follow it is widely accepted in the sector as sufficient framework for machinery safety.
4. Product service systems – The business model of product service systems integrates products and services to create additional benefits for the customer as well as the provider. The emphasis is focused on offering a complete solution for forementioned parties rather than just selling the product. This approach often includes aspects like maintenance, software updates and various support services by the provider to the customer to achieve increased product sustainability, increased lifetime, and greater customer satisfaction.
5. Industrial digitalization – Using digital technologies to develop and transform businesses, processes, products, and services is vital in the current industry. Industrial digitalization deals with the integration of digital technologies into all aspects of industry. It includes but is not limited to internet of things, automation, online platforms, robotics, and data analytics. The aim of industrial digitalization is to improve efficiency, productivity and also flexibility of industries in the most general sense.

## **2.1. Regulation 2023/1230/EU**

This new Machinery Regulation gives all involved parties requirements for safely putting machinery products to the European market. The document is roughly 100 pages long and consists of requirements and recommendations for machinery producers. All EU member states must take this document and its content as a requirement with only some minor adjustments allowed by the member state [6].

According to this regulation a machine is an assembly fitted with a drive system consisting of linked parts where at least one moves in order to perform a specific application [6].

Exact percentage of how big part of all machinery products falls under this regulation is difficult to name but it is widely considered to be vast majority of all the machines built in the EU. Therefore, not all machines that are produced and sold in the EU must comply by the regulation. There are other regulations and directives in place that specify specific requirements for some machines. Examples could be found from the forestry and sawmill industry, construction products, pressure vessels and so on. Many of the named machinery types have their own directive or regulation in place. The Machinery Regulation however deals with all the machinery that is not governed by a specific regulation, standard or directive. This leads to the fact that most of the machinery produced in EU falls under the scope of the Machinery Regulation.

The regulation applies to the following products [6]:

1. All machinery that does not have its own specific regulation, directive or standard
2. Interchangeable equipment
3. Safety components
4. Lifting accessories
5. Chains, ropes, and webbing
6. Removable mechanical transmission devices
7. Partly completed machinery

The regulation does not apply to the following products [6]:

1. Safety components as spare parts
2. Equipment for use in fairgrounds or amusement parks
3. Machinery and related products for the nuclear installations
4. Weapons and firearms
5. Transport machinery (vehicles) and trailers
6. Aeronautical products

7. Vessels
8. Military related machinery
9. Research machinery for laboratories
10. Mine winding gear
11. Machinery for artistic performances
12. Household appliances
13. Audio and video equipment
14. IT equipment
15. Office machinery
16. Electric motors and low-voltage switch and control gear
17. Transformers

Therefore, the Regulations 2023/1230/EU from 2027 is the main framework by which machinery products are built, certified, and put to market in the European Union from the year 2027 onwards. Without fulfilling the requirements of this regulation, the machines that fall under the scope of the regulation are not permitted to be sold in the EU. Furthermore, not fulfilling the requirements of this regulation is a criminal act and is punishable by the EU and member states laws [6].

To better understand the implications of the new EU Machinery Regulation the exact content of this document should be analysed. Some important outtakes from the regulation regarding user manuals and instructions are the following [6]:

- 1. With a view to ensuring the health and safety of the users of products within the scope of this Regulation, economic operators should ensure that all relevant documentation, such as the instructions for use, while containing precise and comprehensible information, is easily understandable and available in a language which can be easily understood by users, as determined by the Member State concerned, takes into account technological developments and changes to user behaviour, and is as up to date as possible.*
- 2. Instructions and other relevant documentation may be provided in a digital printable format. However, the manufacturer should ensure that distributors can provide, at the request of the user at the time of the purchase, the instructions for use in a paper format free of charge.*
- 3. Manufacturers shall ensure that the machinery or related products are accompanied by the instructions for use and the information set out in Annex III. The instructions may be provided in a digital format. Such*

*instructions and information shall clearly describe the product model to which they correspond.*

4. *When the instructions for use are provided in digital format, the manufacturer shall:*
  - (a) *mark on the machinery or related product, or, where that is not possible, on its packaging or in an accompanying document, how to access the digital instructions.*
  - (b) *present them in a format that makes it possible for the user to print and download the instructions for use and save them on an electronic device so that he or she can access them at all times, in particular during a breakdown of the machinery or related product; this requirement also applies where the instructions for use are embedded in the software of the machinery or related product.*
  - (c) *make them accessible online during the expected lifetime of the machinery or related product and for at least 10 years after the placing on the market of the machinery or related product.*
5. *The instructions for use, the safety information and the information set out in Annex III shall be in a language which can be easily understood by users, as determined by the Member State concerned, and shall be clear, understandable and legible.*
6. *When designing and constructing machinery or a related product and when drafting the instructions for use, the manufacturer shall envisage not only the intended use of the machinery or related product but also any reasonably foreseeable misuse thereof. The machinery or related product shall be designed and constructed in such a way as to prevent abnormal use if such use would engender a risk. Where appropriate, the instructions for use shall draw the user's attention to ways – which experience has shown might occur – in which the machinery or related product should not be used.*
7. *The contents of the instructions for use shall cover not only the intended use of the machinery or related product but also take into account any reasonably foreseeable misuse thereof.*

8. *In the case of machinery or related products intended for use by non-professional operators, the wording and layout of the instructions for use shall take into account the level of general education and acumen that can reasonably be expected from such operators.*
9. *Instructions for use shall contain, where applicable, at least the following information:*
  - (a) the business name and full address of the manufacturer and, where applicable, of its authorised representative.*
  - (b) the designation of the machinery or related product as marked on the machinery or related product itself, except for the serial number (see section 1.7.3);*
  - (c) the EU declaration of conformity, or the internet address or machine readable code, where the EU declaration of conformity can be accessed, in accordance with Article 10(8);*
  - (d) a general description of the machinery or related product.*
  - (e) the drawings, diagrams, descriptions and explanations necessary for the use, maintenance and repair of the machinery or related product and for checking its correct functioning.*
  - (f) a description of the workstation(s) likely to be occupied by operators.*
  - (g) a description of the intended use of the machinery or related product.*
  - (h) warnings concerning the ways in which the machinery or related product must not be used that experience has shown might occur.*
  - (i) assembly, installation and connection instructions, including drawings, diagrams and the means of attachment and the designation of the chassis or installation on which the machinery or related product is to be mounted.*
  - (j) instructions relating to installation and assembly for reducing noise or vibration.*

*(k) instructions for the putting into service and use of the machinery or related product and, if necessary, instructions for the training of operators.*

*(l) information about the residual risks that remain despite the inherent safe design measures, safeguarding and complementary protective measures adopted.*

*(m) instructions on the protective measures to be taken by the user, including, where appropriate, the personal protective equipment to be provided.*

*(n) the essential characteristics of tools, which may be fitted to the machinery or related product.*

*(o) the conditions in which the machinery or related product meets the requirement of stability during use, transportation, assembly, dismantling when out of service, testing or foreseeable breakdowns.*

*(p) instructions with a view to ensuring that transport, handling and storage operations can be made safely, giving the mass of the machinery or related product and of its various parts where these are regularly to be transported separately.*

*(q) the operating method to be followed in the event of accident or breakdown; if a blockage is likely to occur, the operating method to be followed so as to enable the equipment to be safely unblocked.*

*(r) the description of the adjustment and maintenance operations that should be carried out by the user and the preventive maintenance measures that should be observed taking account of the design and the use of the machinery or related product.*

*(s) instructions designed to enable adjustment and maintenance to be carried out safely, including the protective measures that should be taken during these operations.*

From these it can be concluded that the requirements for user manuals in the regulation are quite specific at some points but rather vague in others. For example, the regulation mentions many times that the instructions should be easily understandable and clear. Yet the regulation does not go into more detail what these terms actually mean.

Another observation is that whilst the regulation list numerous points that the instructions have to cover it does not specify how these instructions shall be given. Let's take point 9(s) as an example. This point states that machinery instructions for operators shall include information about safe ways to conduct adjustments and maintenance operations. Whilst this is by any means vital in machinery instructions book the regulations does not specify in which form or way these instructions shall be given. It is not specified whether these instructions should be given in a form of text, photos, images or illustrations. This leads to the fact that the party who compiles the user manual (usually the machinery producer) can decide by themselves which way of communicating this information to the end user, the operator, they choose. In many cases this could lead to instructions that are hard to understand that can cause hazardous situations or even work-related accidents.

It seems that whilst the new regulation aims to improve some key areas compared to the old directive it still leaves a lot to be interpreted by the part who compiles the user instructions for a machinery product. Since human well-being and workplace safety are important then the way safe and clear instructions should be given could be studied further. If this kind of additional guideline or framework would be available, then instructions for machinery operations could potentially be better understood which would lead to less hazardous situations at workplaces and less work-related accidents that are caused by machinery.



### **3. Methodology**

User centered design approach – This approach includes stakeholder analysis, persona creation, journey creation and other design thinking tools in order to create solutions that keep the end-user in the forefront [7]. In the context of the current thesis, it will be used to analyse the current situation and to design new solutions. It is vital for critical examination of existing problems and areas for improvement. By using human centered design methodology, the thesis will analyse the problems and solutions from the viewpoint of the different stakeholder in order to propose solutions that would have benefits for all stakeholders. The thesis will not only address the immediate needs or possibilities of the parties but also will use human centered design approach to analyse future possibilities and opportunities.

### **3.1. User centered design approach**

In order to create a framework for creating user manuals for machinery that in addition to legal requirements also takes emphasis on the actual needs of the user a design method or methods can be used. In this case one of the design tools that will be used is the user centered design process. After all the user (the operator) is in the centered of this problem.

User centered design, according to Interaction Design Foundation, is a mixture of investigative methods and tools (like surveys and interviews) and generative ones (like brainstorming) to develop an understanding of user needs [7]. User centered design process could help to see the creation of a machinery user manual in a totally new light. In a field where legal experts, programmers and engineers dominate using a design thinking approach may lead to new useful results.

The user centered design process consists of four main stages [7]:

1. Understanding the user and context
2. Specifying user and business requirements
3. Creating design solutions
4. Evaluating effectiveness

In order to propose any potential solutions, according to user centered design philosophy, we must understand the whole user experience. In the case of machinery instructions, it should be thought through how machinery operations access these instructions, at what environment are the operators reading these instructions, who exactly are these operators and what is their motivation. This all means that the whole process should be analysed from start to finish from the perspective of the user – in our case the machinery operator. Often at first glance important observations might be overlooked and that can lead to unsatisfying end results.

In the context of the current thesis user centered design approach is mainly used in order to create a structure of analysing the problem. In addition, during the idea generation and offering of potential solutions, the user centered methodology is again relied on for guiding the process. The evaluating effectiveness step in the user centered design proves in the current thesis relies on the analysis of the author. In the future it could be continue in more detail in a real-word prototyping context.

The analysis of operators is based not only on various regulations, standards, and articles, but also on the professional experience of the author. Interviews and other similar methods have not been conducted since to produce usable results the number of operators to be interviewed would need to be very high.

## 4. Understanding the user and context

### 4.1. Operators

To create design solutions that focus mainly on the user then we need to first understand who the user is. We need to analyse the users to have a change of designing solutions that would be effective and usable. In addition, we will have to investigate the aspects of who is considered the user of the machine and at what point of machines life they access it. It is equally important to find out what are the expectations, hopes and problems of the user. Then it is possible to address these points and create a design thought out design solution.

According to the Machinery Regulation everyone who at one point of the machine's lifetime uses the machine is an operator [6]. To further illustrate this let's take the machinery safety standard ISO 12100 and list different lifetime phases of machinery. As described in the Machinery Regulation machinery instructions must cover all stages of machinery's life. From this we can conclude that a machinery user manual that satisfies the requirements of the Machinery Regulation must cover all stages of a machine's lifecycle. Therefore, the user manual is not just meant for the person who operates the machine daily but all people who come into contact with the machine.

According to ISO 12100 machinery lifecycle consists of the following phases [8]:

Lifecycle phase	Occupations	Education levels
<b>Transport</b>	Transport worker, logistics operator	Basic to advanced
<b>Installation</b>	Installation technician, electrician	Intermediate to advanced
<b>Configuration</b>	Machine operator, software programmer, mechanics	Basic to advanced
<b>Operation</b>	Machine operator, production worker, cleaning personnel	Basic to advanced
<b>Maintenance</b>	Technician, service personnel, mechanics, cleaning personnel	Basic to advanced
<b>Troubleshooting</b>	Machine operator, technician, mechanic	Intermediate to advanced
<b>Storage</b>	Warehouse worker, technician	Intermediate to advanced
<b>Utilization</b>	Mechanic, recycling worker	Basic to intermediate

Table 1 - Machinery lifecycle phases and operators.

Basic education level – Equal to or less than lower secondary education.

Medium education level – More than secondary education but less than or equal to upper secondary education.

High education level – More than secondary education

Users in our context are the people who participate in one or many of the listed activities from transportation to utilization. Usually this means that the machine has many different users during its lifetime. The users also work at different fields. For example, transport workers who take the machine from the producer to the purchaser have a different job than the people who operate the machinery daily. They have different professional backgrounds, education, and skills. This means that, to make the user manual understandable, it needs to be put together in a way that is understandable for most people even if they have different backgrounds, education levels and professions. Whilst machinery is something that is very technical by its nature, the user manual of machinery cannot rely on the fact that operators have high technical skills. In order to create a truly user centered user manual it must be as easily understood as possible even for people who do not have high level of technical skills. The manual must be easy to read and understand for everyone no matter their background or skill level.

## 4.2. Stakeholder analysis

To better understand the current problem space, the stakeholders should be mapped, and their main concerns and responsibilities analysed. Stakeholder mapping is a common method in design related work. It allows to see the issue from different perspectives and is important to come out with approaches and solutions. Whatever a solution to a problem might be it is vital that it keeps in mind and understands the different stakeholders and their needs.

<b>Stakeholder</b>	<b>Main concern</b>	<b>Responsibility</b>
<b>Operator</b>	The main concern of the operator is their safety. They want to work in a safe environment.	The operator needs to read the user manual and follow its content while they work with the machine. They need to be aware of the dangers and notice any possible dangerous situations.
<b>EU/EU states</b>	They are the legislative power and give out laws and regulations that regulate the sale and usage of machinery. They must do it in a way that ensures safety for everyone but also keeps the business environment active.	They must make sure unsafe machinery cannot be legally sold or used.
<b>Machinery producers</b>	The producers want to sell their products and want to maximize profits. They want to limit their legal liability in cases of accidents.	They must follow the EU and state laws and regulations. It is their responsibility to compile user manuals for their products.
<b>Machinery purchasers</b>	The machinery purchasers are the companies who buy the machines and give them to their personnel to use and manufacture goods. Their main concern is the long life of the machine.	Purchasers of the machinery need to make sure that the machines that they give their personnel to use have the necessary documents (CE marking, user manual). They need to make sure that the work environment for their personnel is safe.

*Table 2 – Stakeholder analysis.*

From this table we can already see that the concerns and responsibilities of the different stakeholders vary and in many cases are contradictory. This of course is often the case when doing stakeholder analysis but, in this case, the safety and life of people is in the center of the analysis.

When taking a closer look at the table we need to keep in mind that although the different stakeholders have different concerns and responsibilities the operators of the machine are the main stakeholder. This is because failure by the other stakeholders to fulfil their responsibilities could result in a great risk of injury. If, for example, the EU or state fails to give out sufficient legislation and unsafe machinery can be sold legally then it is the operator who will pay the price and work with an unsafe machine which may lead to an accident or even death in some cases. Another example would be where the machinery purchaser knowingly buys a machine that does not have the required paperwork. This again may lead to dangerous situations or accidents for the machine operator. Third example could be where a machine producer designs unsafe machinery or fails to provide sufficient instructions for its use. Again, the machine operator is the one who pays the price and would be put to risk.

Therefore, the machine operator should be the main stakeholder in this thesis. Their safety and needs in more general should be but to the forefront of any analysis.

### 4.3. Machinery producers

The machinery producers have a responsibility to ensure the safety of the operators of the machinery during all lifecycle phases of the machine. This means everything from unpacking a new machine to utilizing it after years of use needs to be safe and it is the responsibility of the machinery producer to ensure that. According to the international standard "ISO 12100:2010 - Safety of machinery - General principles for design - Risk assessment and risk reduction" the machinery producer has various ways how they can ensure the safety of the machine operators [8]. The first and most important thing is safe design. This means that the machinery is designed in a way that eliminates dangerous moving parts or sharp edges and hot surfaces for example. Another example would be controlling systems that utilize hold-to-run principles which means that the machine will stop if the operator for whatever reason releases the controls of the machine.

<b>STEP 1</b>	<p><b>Inherently safe design measures</b></p> <p>Inherently safe design measures eliminate hazards or reduce the associated risks by a suitable choice of design features of the machine itself and/or interaction between the exposed persons and the machine.</p>
<b>STEP 2</b>	<p><b>Safeguarding and/or complementary protective measures</b></p> <p>Considering the intended use and the reasonably foreseeable misuse, appropriately selected safeguarding and complementary protective measures can be used to reduce risk when it is not practicable to eliminate a hazard, or reduce its associated risk sufficiently, using inherently safe design measures.</p>
<b>STEP 3</b>	<p><b>Information for use</b></p> <p>Where risks remain despite inherently safe design measures, safeguarding and the adoption of complementary protective measures, the residual risks shall be identified in the information for use.</p>

*Table 3 - Risk reduction levels in machinery design according to ISO 12100:2010.*

Unfortunately, not all risks can be mitigated with safe design measures. Machinery and especially industrial machinery are often still dangerous even if the upmost care has been taken when designing the machine. When the safe design and protective

measures have been exhausted the next way of ensuring the safety of operators is information for use. The information for use may come in the form of verbal training or written instructions. It is important to note that machinery operators are everyone who at some point of the lifetime of the machinery come into contact with the machine [6]. This means a person who cleans the machine after use or unpacks the machine when it is first received is also considered to be an operator. Operators are not only the people who use the machine to fulfil its main purpose.

Training of operators is vital for safety. The training can have different forms from lectures in classrooms by the machinery producer before a new machine is put to use to comprehensive written guides called user manuals. The in-person training of operators by the machinery producer is not required by the EU Machinery Directive or the regulation but providing the written user manual in a paper or digital form is a legal requirement for the machinery producer [6].

The new Machinery Regulation specifies in detail the purpose and nature of the user manuals of machinery [6]:

*“With a view to ensuring the health and safety of the users of products within the scope of this Regulation, economic operators should ensure that all relevant documentation, such as the instructions for use, while containing precise and comprehensible information, is easily understandable and available in a language which can be easily understood by users, as determined by the Member State concerned, takes into account technological developments and changes to user behaviour, and is as up to date as possible”. The directive also specifies: “instructions for use means the information, provided by the manufacturer when the machinery or related product is placed on the market or put into service, to inform the user of the machinery or related product, of the intended and proper use of that machinery or related product, as well as information on any precautions to be taken when using or installing the machinery or related product, including information on the safety aspects, and on how to keep that machinery or related product safe, and to ensure that it remains fit for purpose during its entire lifetime;”*

Therefore, written machinery user manuals are the main way of communicating the safety information from the machine manufacturer to the machine user. The written manuals are the last level to ensure the safety of machinery when design and protective measures are exhausted by the machine producer.



## 4.4. Compiling user manuals

In order to offer possible solutions, it is necessary to understand how the user manuals are compiled today. Of course, there are different levels of quality and different approaches when it comes to machinery user manuals. Most of the companies in the machinery sector are small or medium sized enterprises. There are machinery manufacturers who take writing the user manuals very seriously and put a lot of effort into it. In larger companies there are often specific work positions or even departments who are responsible for creating user manuals. In addition to the machine programmers, and engineers there are also legal experts who work in these departments to compile the user manuals. The role of the legal staff is to ensure that the manuals comply with the regulations that are in place and that the liability of the machinery producer is limited as much as possible.

In small or medium sized companies this is often not the case and compiling user manuals is often the task of the engineers who are responsible for the design and engineering of the machine itself. This comes from the fact that the engineers are the authors of the machine and its design and therefore know the most about the machine from a technical standpoint. In addition, the engineers use computer aided design software that allows creating images, drawings, schemas of the machine that are required for the user manual.

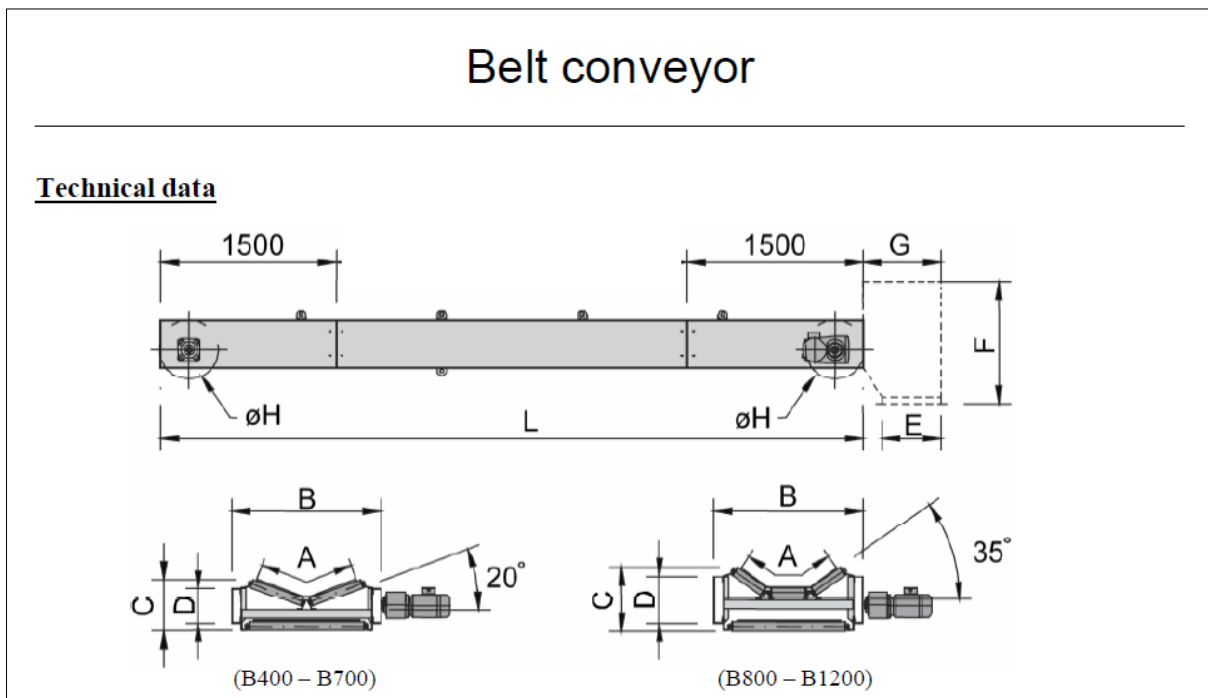


Figure 1 - Example of an engineering schema from a belt conveyor user manual [9].

From this, two important aspects arise that are related to the shortcomings of user manuals today. One of them being the fact that the manual is mostly put together by

engineers, programmers, and legal experts who might not even have used the machine once in their life. Secondly, the operators of the machine are often not part of the creation of the instructions.

Whilst requirements for the manuals that the engineers and legal experts must fulfil are quite clearly stated in the new Machinery Regulation the need of having the manual focus on the actual needs of the end user is not. For example, the legal requirements like distributing rights, liability and documentation for the manual are very clearly stated in the directive. The same is true for the engineering aspects like mass, dimensions, center of gravity and so on. These are clearly listed as requirements and can be fulfilled with a legal form, schema, table, or a technical drawing.

When it comes to the understandability and readability the requirements in the directive are quite vague and lacking. For example, the regulation states that the manual must be "*easily understandable*" but does not specify what it means or how it should be achieved [6]. This leaves a lot of room for interpretation and gives the possibility to manufacturers to not really focus on this aspect.

### Mechanical Maintenance Safety

Lubricate conveyors when they are not in motion, wherever practical. Only trained personnel who are aware of the hazard of the conveyor in motion should be permitted to lubricate a conveyor that is operating.

After you lubricate the conveyor, check to make sure that none of the lubricants or other process liquids have spilled or dropped onto the floor. These liquids create a hazardous condition. If you notice a drip, install a drip pan or other means of eliminating the hazard.

### Electrical Maintenance Safety

When an equipment problem occurs, the first priority is to ensure that power is disconnected from the affected area, as well as from the control panel where troubleshooting and repairs are performed.

Once you verify that power is locked out, make sure you inform other personnel in the area of the situation so they do not unexpectedly restore power.

After you inform your co-workers, recheck the power supply to ensure that power is disconnected in the affected control panel. Using insulated fuse pullers only, remove fuses and check terminal strips for current-carrying wires. Before you perform any repairs with an exposed conductor or terminal, use an approved voltmeter to check for continuity to ground and continuity between other current-carrying conductors.

When you perform any kind of maintenance or repair involving electrical components, follow the guidelines listed below:

#### Safety Guidelines

- **NEVER** reset a circuit breaker or replace an open fuse before determining and correcting the cause of the circuit interruption.
- **NEVER** bypass or use a jumper to replace any limit switch, fuse, circuit breaker, or other circuit protection or safety device.

- **NEVER** replace an open fuse with another that is not rated at the proper current and voltage. Always double-check correct fuse specifications rather than replace the open fuse with one of the same current and voltage rating.
- **NEVER** rest tools on motors, transformers, terminal strips, or other control panel or electrical components. All tools used should be kept in a tool box or pouch.
- **NEVER** restore power or restart equipment before verifying that all tools, spare parts, etc., are removed from the work area and are safely stored.
- **NEVER** restore power or restart equipment before verifying that ALL personnel are aware of the condition and are safely clear of the equipment.
- **ALWAYS** replace any safety devices and guards, removed during maintenance or repair, before you restore power or restart equipment.
- **ALWAYS** use extreme caution and follow recommended safety procedures while you perform any electrical inspection or maintenance operations.

### Application Safety

The equipment used in your system is designed to convey specified commodities or materials within a certain rate and speed. It might not be possible to safely use the equipment outside of the intended capacities or speeds. Check with your supervisor if you have questions regarding the safe operation of the equipment.

#### Backstop Devices

Provide anti-runaway, brake, or backstop devices on all incline, decline, or vertical conveyors with which the effect of gravity might allow uncontrolled lowering of load if that lowering would cause injury to you or co-workers.

Figure 2 - Example of a user manual that consists of text without schemas or explaining images [10].

The fact that the manual is in many cases compiled by people who are not familiar with the actual work usage of that machine or in some cases any machine at all creates serious issues. This leads to the manuals being often hard to read and understand. If the machine operators fail to understand the content sufficiently or the content is difficult to read, then it can lead to serious consequences like work accidents as stated before.

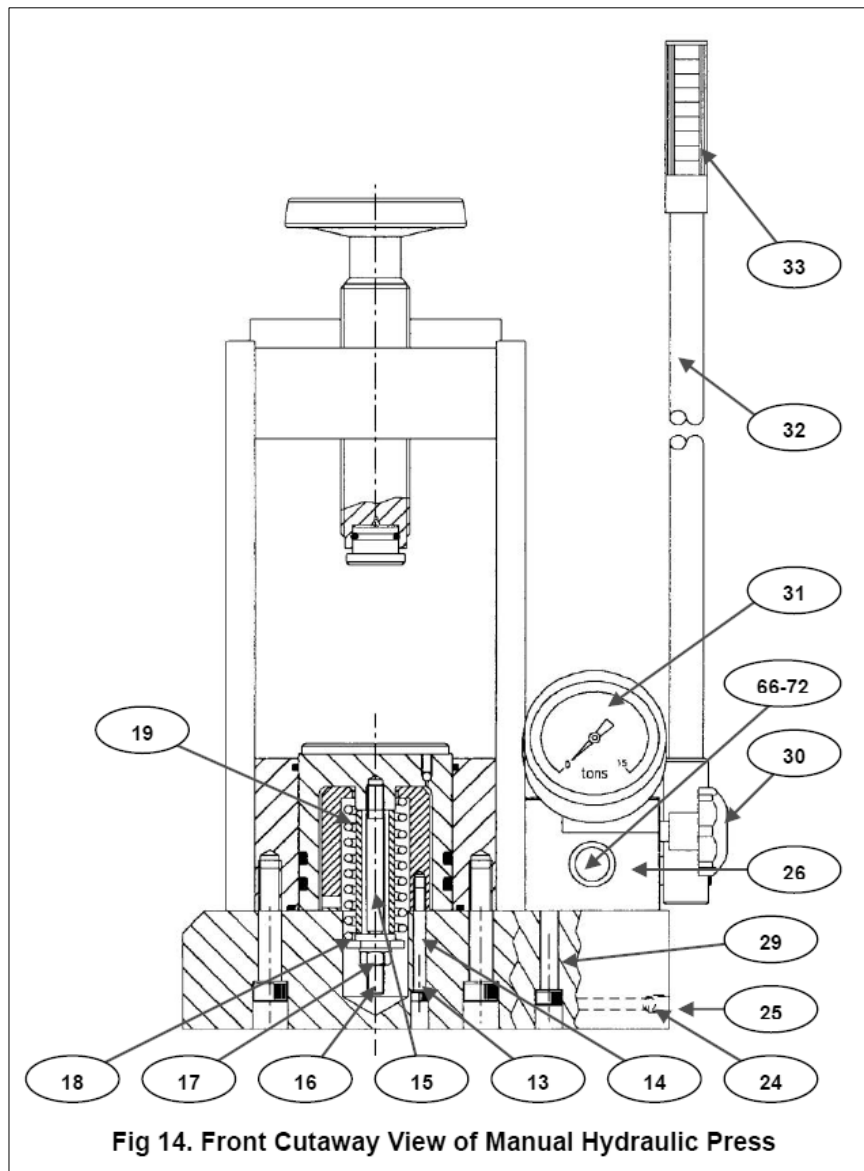


Figure 3 - Example of a schema from a hydraulic press user manual [11].

These findings are also confirmed by a comprehensive research called "Controlled readability of Seveso II company safety documents, the design of a new KPI" by P. Lindhout, J.C. Kingston-Howlett and B.J.M. Ale. Their research found that safety document writers often produce documents that are difficult for the readers to understand [12]. In the case of high-risk Seveso companies who handle and manufacture dangerous substances like oils, explosives and chemicals in the Netherlands 50% of the documents are too difficult to read for the users. This can lead to human errors and compromise safety. The authors go on and state that this issue is quite easy to solve when the authors of documentation are provided with the right guidance. In addition, their research found that safety documents are often written by engineers and managers who don't have sufficient skills for writing clear and easily understandable instructions.

## 5. Specifying user and business requirements

### 5.1. User requirements

Machinery users are everyone who at one point of the machine's lifetime come into contact with the machine. This means that the users have very different backgrounds, skill levels and education levels. According to the Machinery Regulation the user manual must be easily understandable for all operators [6]. To specify the user requirements, we need to understand what makes a manual easily understandable.

An analysis of what makes a user manual easily readable and understandable must be conducted. In this regard the earlier cited work by P. Lindhout, J.C. Kingston-Howlett and B.J.M. Ale was analysed. Their research focused on the readability of safety documentation in the chemical industry, and they found that safety related documentation and manuals should be written on level A2 of language skill. In that case 95% of the readers would be able to read the documents without difficulties. This means that 5% of the readers would still have difficulties understanding the written text. The research states that for this 5% graphical layout could be used to improve the understanding of the documents.

In other words, the wording of the user manuals should be as easy as possible – sometimes even childlike to ensure safety. In addition, the length of sentences should be as short as possible.

<b>A1, A2</b>	Starting user
<b>B1, B2</b>	Independent user
<b>C1, C2</b>	Skilled user

*Table 4 - Language levels according to Common European Framework [14].*

The research showed the readability and understandability of documents can be increased by graphical additions. These additions can be technical drawings, schemes or images that further explain and empathize a given situation or part of a machine. In the case of machinery user manuals visual additions are vital and should be a part of any well-made user manual.

When it comes to text or graphical content, we as humans tend to sometimes understand the same content in a different way. This can be the cause of different language skill levels but also cultural and economic background. When compiling a machinery user manual, one must take into account the fact that not all readers may understand the same text or images in a similar manner. This is something that

research by Fukuoka, Waka; Kojima, Yukiko; Spyridakis, Jan H. touches upon. The authors studied attitudes of American and Japanese readers concerning user manual formats that differ from one another by the use of illustrations. The study named "Illustrations in User Manuals: Preference and Effectiveness with Japanese and American Readers" showed that there were no significant differences between the American and Japanese subjects when it comes to understanding illustrations in user manuals [14]. All subjects in the study preferred a user manual format that included text and illustrations, and they believed that such format would be better than a text-only format. In addition, the people in the study stated that step-by-step instructions were preferred to just text and illustrations. This research is important in showing that even with very different cultural backgrounds people understand illustrations better than written text. It is also interesting that the subjects in that study preferred step-by-step instructions that consisted of text and illustrations.

In addition to understanding what makes an user manual easily understandable we must also think about what happens if some parts of the manual are not clear for the reader. Let's take for example a case where a newly trained machinery operator at a factory has read the manual but has several questions about the content. Where can the operator turn to find answers to their questions? After all working with a machine when you do not fully understand the instructions is inherently dangerous. At the moment most manuals include a sentence that reads something like "In case of any questions please contact the machinery producer". If we think about the setting where the operator is reading the manual, then this might be a bit problematic.

For technical questions that are not addressed in this Operating manual, please contact the manufacturer, NOVEXX Solutions.

*Figure 4 - Information about contacting the manufacturer in a conveyor manual [15].*

Usually, the manuals include contact information of the machinery producer like a phone number and an email address. If the operator were to seek answers to their questions, they would need to either write an email or make a phone call.

**Manufacturer**  
Novexx Solutions GmbH  
Ohmstrasse 3  
D-85386 Eching, Germany  
Tel.: +49-8165-925-0  
Fax: +49-8165-925-231  
[www.novexx.com](http://www.novexx.com)

*Figure 5 - Contact information of a manufacturer in a conveyor manual [15].*

Email is inherently quite passive way of communicating and a reply would probably take days if not weeks in a real-world scenario. We also need to keep in mind that the contact email that the machinery producers are listing in the manual is in most cases a generic information email address that does not really belong to a certain individual or department. These email addresses also are used for all sorts of other communication and a question about a user manual might easily be overlooked or the answer delayed. Another possibility would be to call the machinery producer. Of course, this in theory is a quicker way of exchanging information compared to the email. Also, in the case of the phone call an actual person (in most cases) would answer and the communication would be much more direct that compared to the email. With the phone call the problem is the possibility that the call might not be answered. Even if it would be answered then in most cases the contact phone number does not take you to the person who would be able to answer questions about a specific machine. In both cases – either with the email or phone call the way of communicating leaves a lot to be desired and this should be considered when proposing new design solutions.

Therefore, it can be concluded that to ensure that a user manual is easily readable and understandable even by operators with different backgrounds and language skill levels the manual must:

- Be written in a very simple language.
- Use as short sentences as possible.
- Use instructions where text is combined with visual illustrations.
- User step-by-step instructions where possible.

## 5.2. Business requirements

The stakeholder analysis and the name “user manual” itself suggest that the user should be the main focus of any machinery manual. The user is the person who the manual should be made for. However, the user and his/her needs are often left to the side and the legal aspects are put to the forefront by the compiler of the manuals.

The buyer is responsible for ensuring that users are properly trained, that they are aware of all the information and instructions in this document and that they are aware of the potential risks of operating the Lathe.

***The manufacturer will not be held responsible for any damage to people and/or property caused by non-compliance with any instructions in this manual.***

***Operators will be held fully responsible for any changes they have made to the machine; the manufacturer will not be held responsible for any damage to persons and/or property resulting from maintenance performed by unqualified personnel and in a manner that differs from the operating procedures shown below.***

Figure 6 - Section of a lathe machine regarding legal liability [16].

When talking about the needs or requirements of the user we need to keep in mind that the main focus is safety. This is true also for the new Machinery Regulation. The European Agency for Safety and Health at Work writes that [3]:

*“The objective of the Machinery Regulation is to allow that machinery, related products as well as partly completed machinery are made available on the market while ensuring a high level of protection of the health and safety of persons, in particular consumers and professional users”.*

Unfortunately, in many cases the machinery producers only fulfil the minimum requirements of the legislation and see the user manual as a tool to limit their legal liability in the case of an accident or malfunction of a machine. If the user manual is difficult to read and understand and is written in a type of language that is hard to understand it is easy to miss something important and create a dangerous situation with the machine. When an accident happens the producer of the machinery can show that the user failed to fulfil one or many aspects of the manual and therefore not be responsible for the outcome.

On the other hand, it is also important to see the situation from the aspect of the manufacturer. If a machine operator is not reading the user manual or ignores its content while working, then the machine producer should not be responsible for possible accidents. The machinery producer needs to have a possibility to defend itself against legal claims that arise from accidents that are not their fault. It is also important to note that overregulating the field of machinery production is also not a



good solution. If the EU and/or member states would impose tough new regulations of machinery production then this might lead to economic problems, bankruptcy of businesses, and loss of jobs. This leads to the question of how to make user manuals that keep the user needs and safety at the forefront whilst fulfilling the requirements of the new Machinery Regulation and the different stakeholders.

To ensure that the framework that will be developed in this thesis would be something that would have real-world applications we need to take a deeper look into the machinery producers – after all they are responsible for the design of the machines and also the compiling of user manuals. It is vital that their interests are understood and considered. First of all, we need to take into account that the sizes of these companies vary by a lot. We must differentiate between a small to medium sized companies that produce up to a thousand machines per year and a large corporation that sells and produces tens of thousands of machines per year. Some of the differences between these companies were discussed in the previous chapters. One being that the larger corporations have their own dedicated team for compiling user manuals, but the smaller ones do not. The same can be said about the team sizes in general. The teams in the smaller companies often must take more diverse roles and take part in more than one aspect of the companies work. One such example would be the product development engineers who in addition to designing the machine also compile or at least help to compile the user manual for that machine.

When it comes to product development process the process usually consists of 6 phases (Product Design and Development by by Karl T. Ulrich, Steven D. Eppinger) [17]:

1. Planning
2. Concept development
3. System-level design
4. Detail design
5. Testing and refinement
6. Production ramp-up

This book and this process is often used by the larger and the smaller companies during product development and is widely respected in the product development companies. When looking at the development step-by-step process compiling of user manual or related documentation is not mentioned. When taking a deeper look at the book user manuals are only mentioned a few times and it is stated that operating instructions are usually part of the detailed design phase [17]. From this one can derive that compiling of user manuals usually takes place in the later stages of product

development. This means that the machinery producers and the engineers consider the user and user manual only after the main decisions regarding design of the machine are already taken. The detailed design phase where the operating instructions are mentioned is the phase where final, detailed technical drawings of the machinery are put together. At this phase any major changes to the design of the machine are avoided. Limiting larger, costly changes to the design in later stages of the development is one of the main purposes of this step-by-step process. In other words, the user manual and machine usage in large part are considered late in the design and development process where bigger changes to the machine are not welcomed. From this it can be concluded that in most cases user manual is something that the machinery producer sees as a legal document and not an actual how-to-guide for machine operators.

From the legal standpoint the importance of the user manual for the machinery producer is vital. This is made clear in the Machinery Regulation as well. The producers must compile the user manual and provide it to the machine purchaser since it's a requirement in the Machinery Regulation. It is in the interest of the machinery producer to make sure that their liability is minimized in a case of a workplace accident that happens with their product. Therefore, the legal aspect is likely much more important for the machinery producer than the needs of the user. If an accident happens with a machine the machinery producer needs to show that the operator violated the content of the user manual and therefore the machinery producer cannot be held accountable for the financial damages that might arise. This makes the machinery producers try to cover every possible accident in the user manual. This might seem like a good thing but writing too many warnings about every theoretical dangerous situation in the user manual does not make the user understand how to use the machine in a safe manner. On the contrary, this makes the user manual more difficult to read and understand.

The machinery producers of course do not use the user manual as a legal document without a reason. When a machine operator is negligent and does not follow instructions or does not read them at all then the machinery producer cannot be held accountable when an accident happens. Safety requires both parties to be constructive and professional.

In most cases of course the machinery producer is concerned with the operator's well-being. They try to do their best to give instructions for the operator to make sure that the machine is operated in a safe manner. We should not see the machinery producer as a malicious party trying to only think about their own responsibilities and discard safety of operators. The current reality of the user instructions sphere just somewhat

favours this kind of approach. If we think about an operator who has questions about the user manual but does not ask them and then goes on to operate a machine without fully understanding the instructions, then this situation is not good for the machinery producer. If an accident happens then an investigation is started to make sure what caused the accident and who's at fault – either the machinery producer or the operator. For sure this is something that is very unpleasant for the machinery producer. They would much rather avoid this outcome. As concluded in a previous chapter of this work the communication between the machinery producer and the operator should be improved and this is in the interest of both parties.

When coming up with a framework for creating user manuals the interests of the machinery producer must be considered. The machinery producers see the user manual as a legal document that can help them limit their liability in case of an accident. It is important to try to give the machinery producer reasons but also possibilities to put more emphasis on the user manual from the machine operator perspective.

### 5.3. Accessing user manuals

Even the best user manual that fulfils the requirements of the stakeholders is useless when it is not easily accessible when it is needed. User manuals today are mainly available in a physical paper form but there are also new innovative solutions out there. Quite often the user manuals are printed out and stored on the machine or near it in a plastic holder. This means that the user manual in paper form is always on the machine and accessible by the operator.



*Figure 7 - User manual fixed to a machine [18].*

Although this might seem a good way to make the user manuals available at first it actually comes with quite many issues:

1. If the user manual for whatever reason is not put back to the holder that is located on the machine, then it might get lost and then there would be no manual available. One of the highest risk levels according to ISO 12100 standard is the situation where the user does not have a manual available to familiarize themselves with the machine and its hazards.

2. If we think about the average lifetime of a machine, then this could easily be over 10 years or even more. Let's try to imagine a situation where the same exact manual, in printed form, has been read and used for 10 years. This would probably mean that the manual would be broken, dirty and plain unusable at some point.
3. In many scenarios the environment where a machine is working does not have good lighting and this would make it difficult to read the user manual if it is on a paper form.
4. After the user manual has been given out by the machinery producer then no changes to it can be made. Let's imagine a situation where the machinery producer, after selling a particular machine for 3 years, finds out that some important information was missing from their user manuals. For the new machines that they sell they could include a new and improved version of the manual. On the other hand the old manuals would stay as they were and possibly important information about hazards could be missing.

There are some new innovative ways to make the user manuals accessible for the machinery operators. In the recent years some machinery producers are including a QR code on the machine that when scanned with a tablet or smartphone will take the operator to a webpage where a digital format user manual is located.



*Figure 8 - QR code that leads to an online user manual [20].*

Attaching a QR code to the machine to access the user manual removes many of the issues with the paper form manual. The manual could be updated after the dispatching of the machine by the machinery producer. An example of a machinery producer noticing this concern is shown on Figure 9 where the producer clearly notifies the

reader of the manual that not all changes to the machine might make it to the printed manual.

*We guarantee the Machine complies with the specifications and technical instructions described in the Manual on the date of issuance and listed herein; On the other hand, the machine may also be subject to important technical changes in the future, without the manual being updated.*

*Therefore, contact FERVI for information about modifications that may have been implemented.*

*Figure 9 - Machinery producer warning about possible future changes to the manual [16].*

Reading the manual from a smart device like a phone or tablet allows it to be read in an environment that is not well lit. In addition, the manual would not get worn by using it over many years. Some potential issues emerge with the QR code type manuals. One of them is the fact that the user would need to have internet access to access the manual. This probably is not that major of a problem since almost everyone who has a smartphone also has internet access. Only potential problem would be in an environment where there is no internet access like a basement.

Another potential issue is connected to storing the manual online. The Machinery Regulation states that the online manual must be available for 10 years after the sale of the machine [6]. At first this might not seem like an issue but when we look at the details of how this could be achieved, we see some concerns. What if the server where the manual is store no longer operates or the company who rents this server space no longer exists? This would mean that the manual would not be available. As state before this is a very serious hazard. User manuals must be accessible for the operator during the lifetime of the machine.

When analysing how user manuals are made available today, we see that there are different opportunities that all come with some potential issues. Some are rather old fashioned but seem to be more foolproof whilst others are modern and innovative but raise some technological concerns before they could be deemed improvements over the older approaches.

## 6. Creating design solutions

From the previous analysis in this work, we have found some important insights and points that should be considered while offering new design solutions. Let's summarize them:

1. The main aim and goal of the old Machinery Directive and the new Machinery Regulation is to ensure safety of operators.
2. The main stakeholder is the machinery operator. Which by the Machinery Regulation definition is anyone who at some point of the machine's lifetime encounters the machine during their work.
3. Machinery operators have very different skill and education levels and technical competence.
4. User manuals are the main way of communicating safety information from the machinery producer to the operator.
5. User manuals should be written in as simple language as possible and use step-by-step instructions with images where possible.
6. The new Machinery Regulation offers some new possibilities regarding user manuals that was not permitted before. The most important of these is the fact that machinery producers are allowed to compile manuals in an online-only format. This gives numerous new possibilities that were not possible before with the old Machinery Directive.
7. User manuals are often compiled by people who have very little experience with working with machinery as an operator. This may lead to problems with understanding the person who reads the manual.
8. There are only a few limited possibilities for a machinery operator to contact the machinery producer.
9. Machinery producers often see the user manual mainly as a legal document to limit their responsibility in case of an accident rather than genuine instructions for the machine user.
10. Even the best user manual is worthless if it is not easily accessible whenever the operator needs it.

In addition, a visual map was produced to get a better understanding of the situation in a visual manner. In the map operator safety is in the middle of the analysis and different related topics are connected to this. What stands out from the map is how many different connections the user manuals have. This emphasizes the fact that user manuals are very important in the context of machinery operators' safety. Also, the map helps to understand how different aspects are connected to each other.

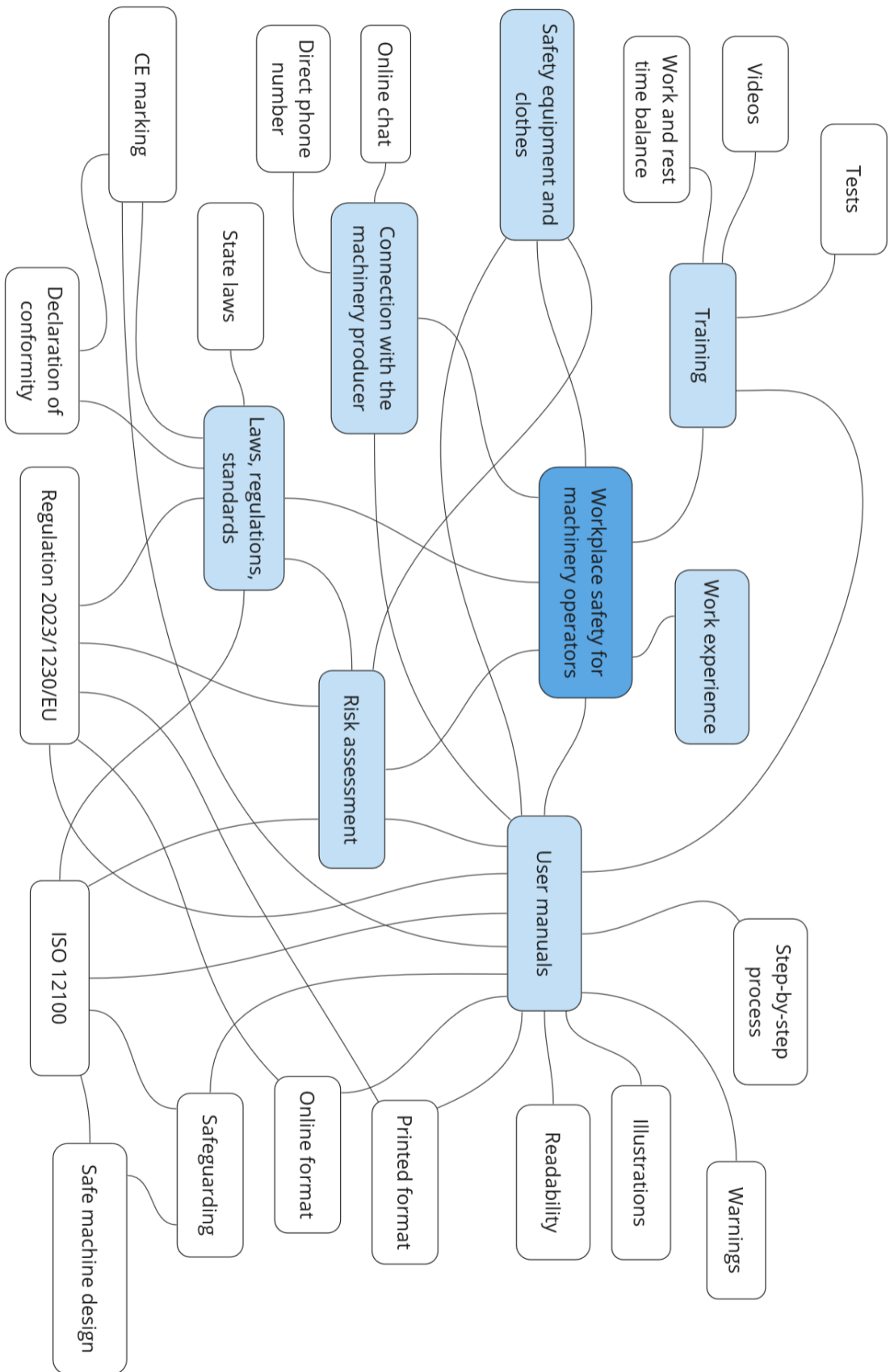


Figure 10 - Machinery operators workplace safety map.



## 6.1. Online-only user manuals

We are going to take a more detailed look at online user manuals and propose how they could be made available by the machinery producer and accessed by the machinery operator. As stated, before online user manuals were made available by the new Machinery Regulation. To be exact they were permitted also with the old directive, but the new directive allows for online-only manuals that the directive did not. In this work we are going to analyse a situation where the machinery producer is giving out a user manual that is only available online. Although not making printable version available might seem like an unnecessary limitation at first the hypothesis is that this limitation is a requirement to truly be innovative.

At first let's think about the new possibilities that an online document has over a printed-out document in our context:

1. The online document can be updated after it has been uploaded. Making changes to a printed document that has been shipped with a machine for example is not possible.
2. The online document could include videos, animation, links, and voice.
3. In the online document you could use the search function. Quite commonly this is achieved by pressing CTRL + F on the keyboard. This could help the reader to quickly search for a term or a number from the manual.
4. Hyperlinked table of content so the reader can just click on the paragraph that they are interested in and be directed to right away to the right spot in the manual.
5. An online only manual is more sustainable. No paper is needed to print out the manual.
6. The online manual could include a direct chat with the machinery producer. This would create a quick direct link between the machinery producer and the machinery operator.
7. A test for the operator could be included in the online manual that the operator would need to pass in order to start working with the machine.
8. The manual would allow the operator to give feedback to the machinery producers which could lead to better machinery design and better user manuals.
9. The online document could be the basis of a custom AI GPT (Generative Pre-trained Transformer) that the operator could use. This would give the operator a totally new possibility of asking questions about the machine or a particular situation instead of just reading the manual.

10. The online only manual could be made accessible via QR code that could be scanned via smartphone or tablet.

Based on these points it becomes clear that online manuals could have clear benefits compared to printed out manuals. Furthermore, these benefits could be something that all the major stakeholders can benefit from. This could ease the implementation of online manuals in the machinery sector as a whole.

## 6.2. Readability and clarity

Although the contact with the machinery manufacturer is important for the factory and machine operators the main aim of the user manual is to ensure that the operators can operate the machine in a safe manner after reading the manual. In this chapter we are going to take a look at how a clear and well written user manual would be compiled and what would the content look like.

First, let's think about the previous analysis in this work. It clearly showed that an easily understandable user manual would have to have the following characteristics:

1. Written in as simple language as possible. This is approximately A2 level.
2. Has text that is enhanced with images.
3. Uses step-by-step process where possible.

Let's take a few examples from existing user manuals of machinery and analyse what could be improved. The first example that we are going to analyse is an instruction for chain installation by the company called Modular Conveyor Express (*Figure 11*). These kinds of instructions are a requirement by the Machinery Regulation, and they fall under the maintenance category. The guide starts off with listing things that you need to do before installing the chain.

Point 1 tells the operator to check the conveyor for flatness and obstructions. Unfortunately, the instruction does not explain what do the terms "flatness" and "obstructions" mean or how to check them. Also, there are no indication where to check them or with what tools if any are needed for this task. What is even more surprising is that the instructions do not mention that the machine probably needs to be stopped, unplugged from the power grid and probably also needs to be cleaned before any such operation as chain replacement could start.

Point 2 gives instructions to the operator to check sprocket alignment. Which sprockets are meant here or how to check their alignment is not indicated. There is also the question what to do if they are not aligned or what is proper alignment.

Point 3 gives instructions how to place the new chain to the conveyor. It uses term that should be clarified as "obstructions", "tight clearance" and "tab". These should be explained to make sure that the operator has the right instructions to perform these tasks without hazards.

Point 4 also uses terms that should be explained further and fails to say what is proper clearance or how to measure it.

Point 5 just says install the chain. Probably here the operator needs to fasten to bolts and nuts to finish the chain installation. There is no mention of procedures how to check that all the operations have been done correctly and when is it safe to restart the conveyor.

In conclusion, whilst the guide uses step-by-step process, it uses no images or illustrations, and the terms are not easy to understand by an average operator. These kinds of instructions should be considered hazardous to the operator and should be improved to ensure safety of personnel and good operation of any machine.

Mechanical Assemblies and Equipment

***Installation***

Before installing chain:

1. Check conveyor for flatness and obstructions.
2. Check sprocket alignment.
3. Pull a short (about three feet) section of chain through the entire conveyor to detect any obstructions or areas of tight clearance. Make sure tab chains have plenty of clearance, especially on the inside of curves.
4. If necessary, remove obstructions and provide proper chain clearance.
5. Install the chain.

**CAUTION**

***Install chain in 10 foot sections, making all connections on the conveyor frame. Make sure that all connection pins are flush. Thread chain onto conveyor carefully to avoid twisting and possible damage to the chain. Make sure all chains are facing in the correct direction for travel as indicated on the bottom or side of the chain!***

Figure 11 - Chain installation information from MCE user manual [10].

The second example (Figure 12) we are going to analyse are instructions for operations that need to be done before using a drill bench. This, as the previous example is also a required section in the instructions according to Machinery Regulation.

What can be seen from the instructions right away is that each point refers to certain number. These numbers are references to an illustration (Figure 13). This is a clear improvement when compared to the previous example of conveyor chain replacement.

What could be improved here is that the list should also indicate the page where the illustration can be found in the manual. In addition to that the lines on the illustration that indicate different parts of the machine could have a clearer end point. In some cases, here it is difficult to distinguish which part of the machine the line is showing.

Similarly to the conveyor instructions this list of instructions also uses words and phrases that could be explained further like "tool shank", "taper shank", "chuck key", "jaws of the chuck", "vice", "hood" and so on. If an operator has trouble understanding these terms then this could lead to hazards for the operator as well as issues with the machine working.

Operation

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### Preparations

1. Fold the protective hood **14** up.
2. Use the enclosed chuck key **24** to loosen the jaws of the chuck **13**.
3. From below, insert the drill bit/tool vertically in the chuck opening and use the chuck key to tighten the chuck jaws. **Then be absolutely sure to pull out the chuck key.**  
The drill bit/tool must be clamped in place in a central position.

**i**

- Only use drill bits and tools with a shank diameter of 1.5 to max. 13 millimetres with a cylindrical tool shank or taper shank.

4. Clamp the workpiece in the vice **19** included in the product contents.
5. Place the vice on the drilling table **12**.
6. Use the fixing screws, washers, spring washers and nuts **20** to secure the vice (see chapter "Clamping the workpiece in the vice").
7. Position the drilling table at the required height (see chapter "Adjusting the drilling table").
8. Fold the protective hood down again.
9. If applicable, adjust the length of the protective hood (see **Fig. G**) so that it offers optimal protection (see chapter "Setting the height of the protective hood").
10. Set the speed so that it corresponds to the workpiece and the fitted drill bit/tool (see chapter "Setting the speed").
11. Unlock the emergency stop switch **17** by pushing it upwards.

The drill is now ready for operation.

*Figure 12 - Drill bench preparations before operation [20].*

This instruction also uses the step-by-step process that makes it easier for the operator to understand and conduct his or her work. Another positive aspect about these instructions is the fact that at point 3 it has a separate warning that specifies which tools to use. Very likely this is something that the machinery producer knows might be done in a wrong manner and therefore they have added this warning to remind the operator this. Overall, these kinds of warning at specific operations where

operator often do something wrong is a good way of improving safety for the operators.

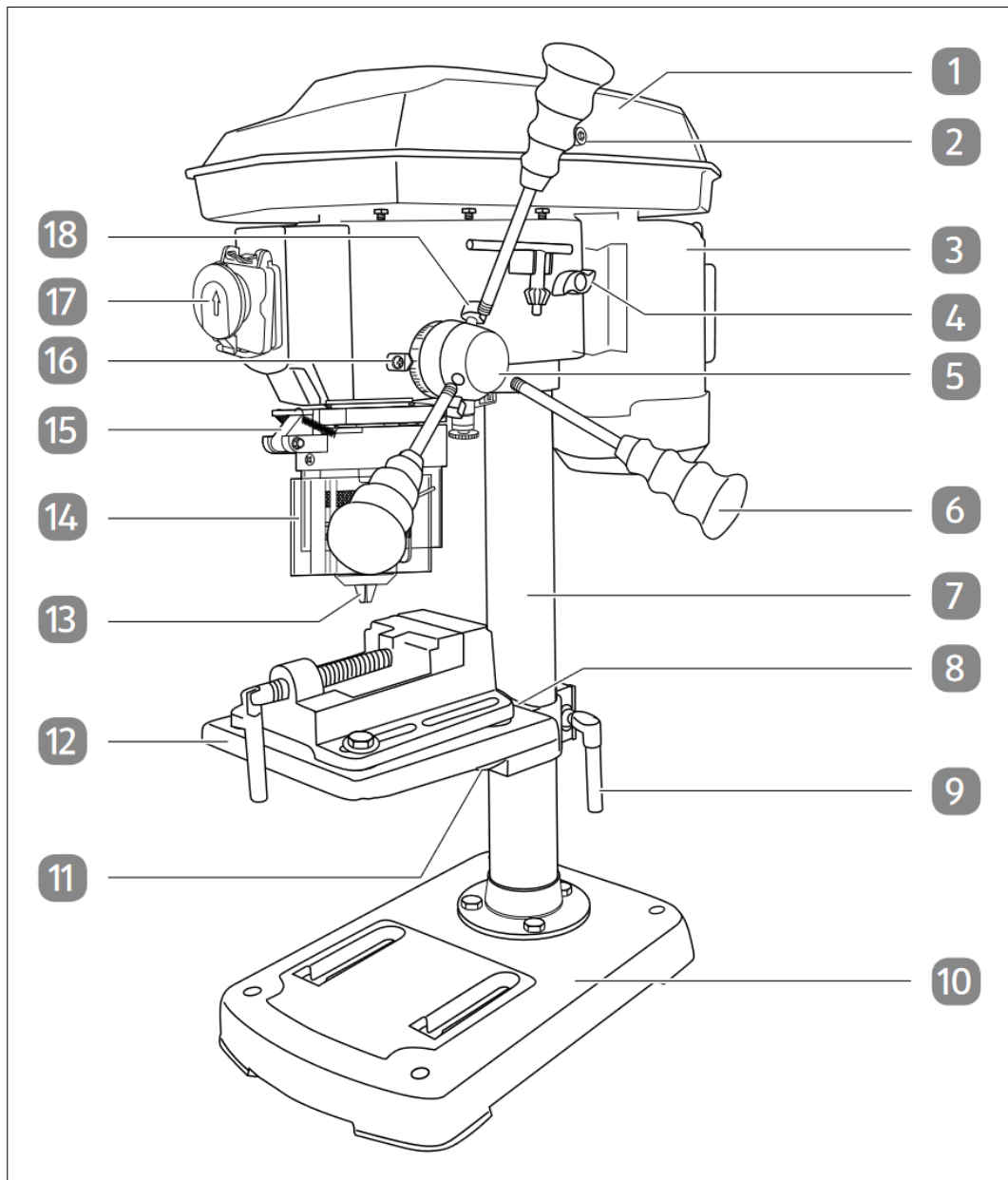


Figure 13 - Drill bench parts illustration [20].

### 6.3. Hazard warnings and drawing attention

As stated before in this work the main reason for the existence of an user manual for the operator is to ensure safety of people who at some point of the machines lifetime come into contact with it. Therefore, the notifying the reader of the manual about possible dangers and hazards is a vital part of any instructions. The Machinery Regulation also states that the compiler of the manual should not only consider the intended use of the machine but also consider the foreseeable misuse of the machine. This means that the manual should be compiled so that it also takes into account how operators might misuse the machine and what dangers and hazard could arise from this behaviour.

In general, the whole user manual is considered to be guidance document that draws the attention of the reader to important aspects and behaviours that should or should not be done in order to achieve safety and limit hazards. However, some particular situations or actions require additional attention from the reader. There usually are situations and actions that have higher potential consequences regarding hazards than others. These require the manual compiler to draw the attention of the reader in order to make sure that the reader does not miss this particular point.

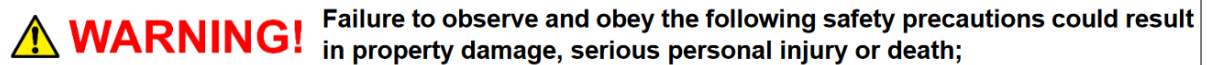


Figure 14 - Warning from a Hi-Force manual [21].

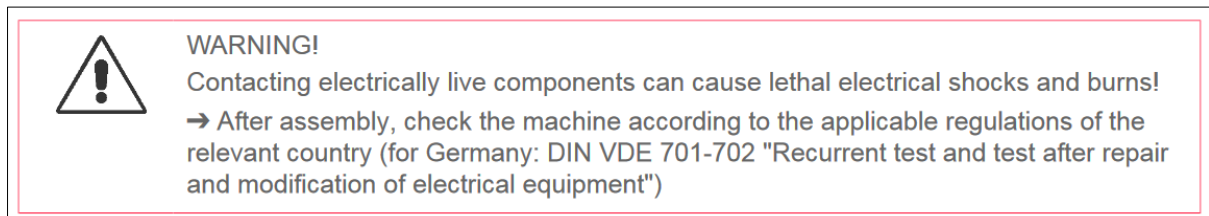


Figure 15 - Warning from a Novexx manual [15].

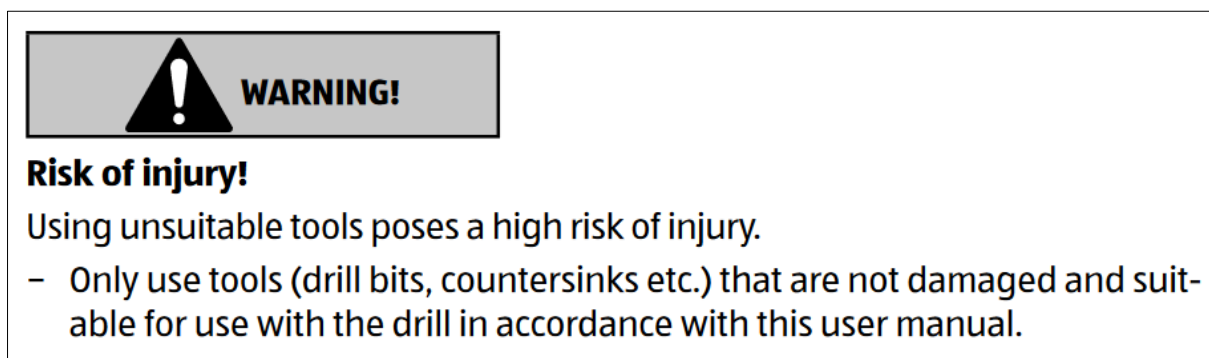


Figure 16 - Warning from a ALDI manual [20].

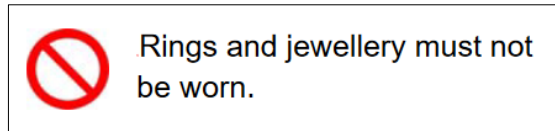


Figure 17 - Warning from a hydraulic lift manual [22].



Figure 18 - Warning from a MCE manual [10].

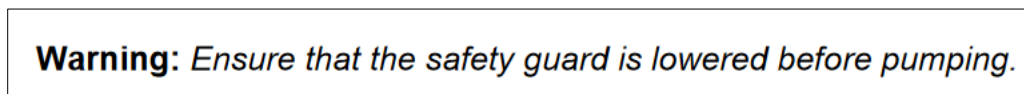


Figure 19 - Warning from a Specac manual [11].

From these examples we can see that different user manuals use very different ways of drawing attention to more important pieces of information and warnings. This is in line with what was stated in the beginning of this thesis – whilst the old Machinery Directive and the new regulation state that the purpose of user instructions is to ensure safety of operators, it offers no specific guidance. This leads to the fact that the party that compiles the user manual has to decide by themselves how to design the warnings.

The warnings are a vital part of any user manual for machinery products and they should definitely be included in manuals in a way that draws attentions to specific hazards or situations. It is important to keep in mind that whilst the current thesis focuses on online-only manuals the user manuals should also be printable. This means that the hazard warnings should be clearly noticeable in both forms – digital and printed. It should be kept in mind that documents can be printed in colour as well as black and white. When a document that includes warnings that use colours to draw attention of the reader are printed in black and white the colour loses its effectiveness. This is also the case with colourblind people who could have difficulties differentiate between colours. Therefore, the warnings should be designed in a way that clearly makes them noticeable but should be black and white.



## **6.4. Images, schemas, and illustrations**

Graphical content like technical drawings and schemas are part of any well compiled user manual. These kinds of illustrations can help user understand complex technical information in a simplified and more understandable way. As discussed previously in this thesis understanding the content of the manuals is vital in order to ensure safety. Therefore, illustrations and graphical content has an important role in user manuals.

Illustrations could be used to show:

1. The main dimensions (length, width, height)
2. Center of gravity
3. Indicating different parts
4. Explaining operations like maintenance, repair, tool changing etc
5. Position of lifting points
6. Correct way of storing
7. Working positions
8. Hazard zones
9. Installation points and methods

As can be seen from the list the illustrations are important part of most parts of the machinery user manual and can be used to explain and instruct the operator in every single part of the machine's lifecycle. There are several different types of illustrations that can be used in order to give information to the reader of the manual. The illustrations may be actual photos of the machine or its parts, technical drawings, screenshots of 3D models, 3D renderings and so on. Since in most cases the user manual is put together during the design and manufacturing process of the machine then this limits the types of illustrations that can be used. This means that actual photos of the machine are difficult to produce when the machine itself has not yet been finished. This leads to many compilers of the manuals to use methods that either use the already made technical drawings of the machine or the machines 3D model to generate the illustrations and images.

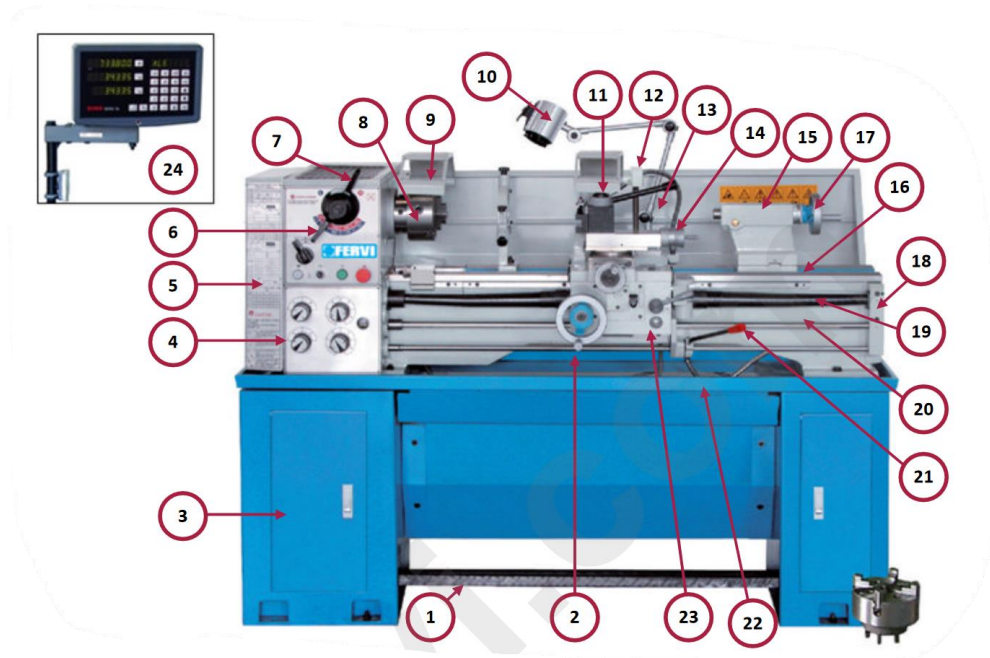
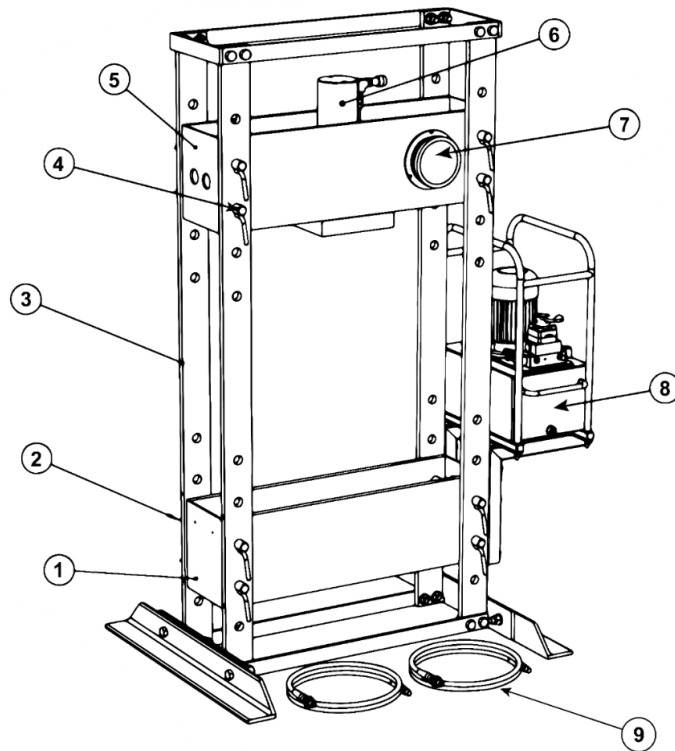


Figure 20 - FERVI bench lathe machine photo [16].

Whilst an actual photo of a machine or its part is probably the easiest for the operator to understand we need to take into account the fact that the new Machinery Regulation allows online-only user manuals. When a machinery producer needs to change the user manual after the machine has been shipped then the online manual gives them this opportunity. If a new photo of a machine is needed to be added to the manual to indicate something that was not originally included when the manual of compiled in the first place then this is difficult to do. That particular machine has already been shipped and making photos of it is not possible by the manufacturer. Therefore, we can conclude that whilst actual photos of the machine are a good way to illustrate aspects of the machine it is not as flexible as it should be. When designing a framework for innovative new approach to machinery manuals we need to take into account that adding images, schemas and illustrations can happen also after the machine has been shipped by the manufacturer. This means that photos are not the best way to illustrate aspects of the machine.

Let's look at the alternative ways of generating images and illustrations for user manuals. These consist of technical drawings, screenshots of 3D models and renderings that use 3D models. Technical drawings are usually made in black-and-white and this is important when we think about the fact that if a online manual is printed it might be printed in black-and-white instead of colour. This means that using colours in the manual is not advisable since the party who compiles the manual can not ensure that the manual is printed in colour. If a manual that uses colours to increase clearness and understandability is printed in black-and-white it loses much of

its intended purpose. From this we can conclude that black-and-white technical drawings are quite reasonable solution to illustrations in machinery manuals.

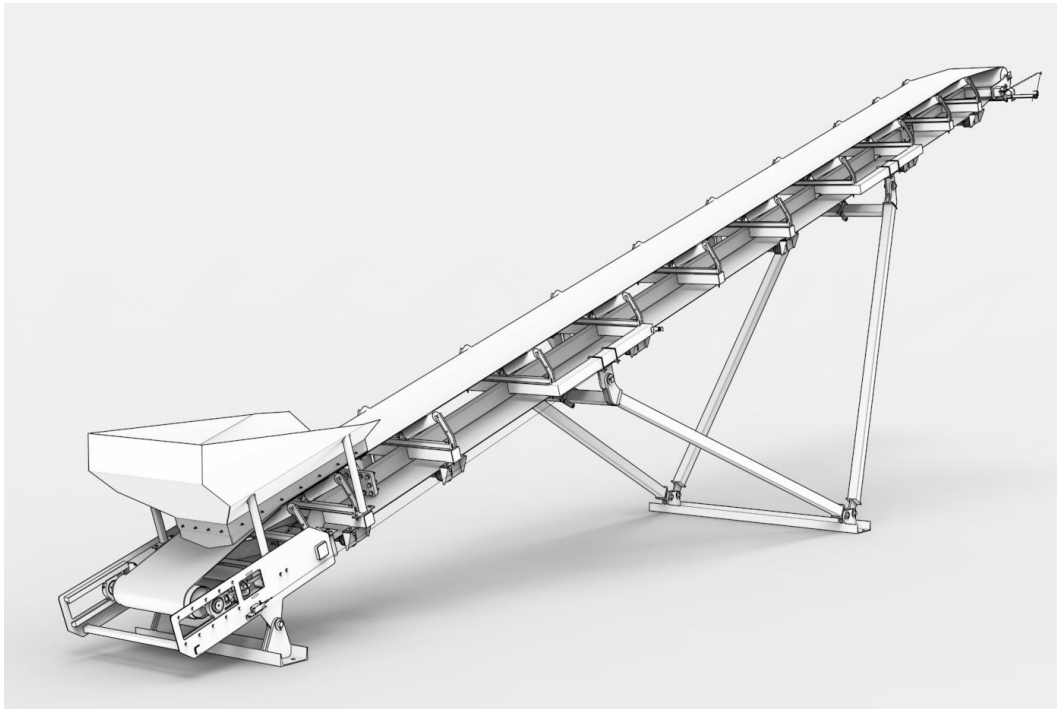


*Figure 21 - Hi-Force hydraulic press technical drawing [21].*

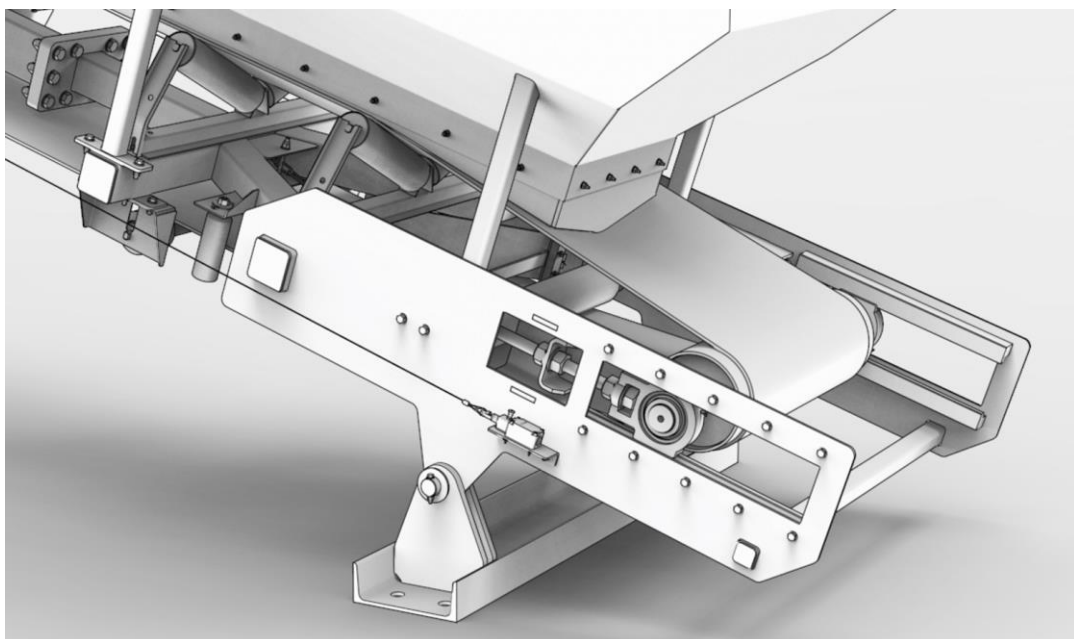
Of course, the technical drawings come with some shortcomings. Often, when the technical drawings are complex it can start to hinder the clarity and make it quite difficult for the reader to get a good understating of that illustration. When we take a look at the alternative way of generating images then we see that screenshots of 3D models are also a possibility. These 3D models use shading, outlines, and colours of illustrate the machines 3D model and its shape. One of the main differences when comparing technical drawings to images created from 3D models is the shading aspect. Shading adds clarity to the model and makes it easier for the human eye to process information since shading is something that is present in real world as well. Another important aspect that is important is the perspective of the image. Technical drawings in most cases do not user perspective in their view. This simply means that objects that are far away from the viewer are smaller than the objects that are closer. When generating the images from the 3D model real-world-like perspective can be enabled allowing for more realistic view of the machine or its parts.

As stated before using colours is not advisable. The benefit of using 3D models as basis for illustrations is of course that the 3D model is in most cases available for the compiler of the manual. If a change or additional image is needed for the online

manual, then it can be quickly and easily be made and added. Another benefit of using the 3D model is the fact that from the 3D software one can access parts of the machine that would be very difficult to do with a photo camera. Examples would be the inside parts of the machine that would require taking the machine apart in order to access it with a photo camera. Another example would be parts that are dangerous to access. With the 3D model these concerns are addressed, and the illustrations can be generated quickly and in a safe manner.



*Figure 22 – Conveyor 3D illustration [23].*



*Figure 23 – Conveyor 3D illustration [23].*

Another benefit of the 3D model-based illustrations is that images can be created that would not be possible with a photo camera. These would include images that highlight one or many parts of the machine in order to indicate their position, views that have one or many parts of the machine hidden in order to show something that is located behind these hidden elements or exploded views that show how different parts of the machine are put together and in what order. The last example especially is useful when creating instructions for servicing and maintenance.

Something that the compiler of the manual needs to consider is that in order for the illustrations to be helpful and usable the 3D model of the machine needs to reflect the actual shape and function of the machine as closely as possible. Although in most cases this is true since the manufacturers technical drawings for the machines production are also based on this 3D model, it is still worth pointing out that if the 3D model is not accurate and does not represent the actual machine accurately then this can cause hazards and not make the manual easy to understand.

## 7. Proposed framework

Taking into account what has been researched and analysed in this thesis a framework that parties who compile user manuals for machinery products according to the new Machinery Regulation could use. The aim of the framework is to simplify compiling these manuals with the aim of increasing workplace safety.

1. Read the new Machinery Regulation and other relevant documents to ensure compliance with legal requirements.
2. Add a QR code to the machine that when scanned leads to the online version of the user manual of that machine. The QR code should be made in a way that ensures that it will not fade or be damaged during the machine's lifetime.
3. Make sure to use as simple language in the manual as possible. The language should be at the A2 level. This means that the sentences and wording are very easy to understand and not very long. Avoid long paragraphs that include only text.
4. Use step-by-step instructions where possible. Number and list the different steps in the correct order to ensure that the operators don't have trouble with understanding the instructions.
5. Serious hazards and dangerous situations should be emphasized by adding a separate warning that is clearly visible and clearly stands out from text. In addition to the hazard also indicate the possible consequences.
6. Include illustrations in the manual where possible and try to find a good balance between text and illustrations to ensure clarity. The illustrations should be based on 3D models and use shading and perspective to increase understandability.
7. Create a direct link like an online chat or direct email between the operator and the machinery producers' technical team. This ensures that in case of questions or issues the operator has direct access to relevant technical support.
8. Update the user manuals with relevant new information even after the machine has been shipped out of the factory.
9. Create an online test that the operators need to pass in order to work with the machinery. The test should be based on the user manual and should be taken frequently to ensure that the operators understand the content of the user manual.
10. Compile the manual in a manner that could be printed if necessary. Make sure that the manual is designed black-and-white to ensure good readability even when printed without colours.

## **8. Scenario for using the online manuals**

Let's summarize by having a look at a scenario where the proposed framework is used. This scenario helps to create a better understanding of the whole process from purchasing of the machine to the end of its lifetime. In addition the scenario is useful for understanding how different stakeholders benefit from the framework and in what way.

A factory purchased a new machine to their production from a company who is specialized in the design and manufacturing of these types of machines. The machine is a punch press that works with sheet metal and weighs about 2 tonnes. The factory had existing operators that will start working with the new machine. The machine is installed to the factory by the machinery producer, and they conduct a 1-day training for the operators at the factory. During this training user manuals are made available for the operators and the machinery producer goes over them and explains the most important aspects of safety and working principles. The training takes place in meeting room where computers are located to see and read the online manual. The training consists of reading the manual and also the videos and animations that are in the manual. After the training is conducted all the operators need to pass a test that the machinery producer put together in order to start working with the machine. There is a requirement to redo the test every 6 months to ensure that the operators remember the content of the manual and its safety instructions.

Since the machine has 12 possible operators in the factory who all work in shifts there is no need to print out 12 different manuals for everyone to see whilst being together meeting room of the factory. Nevertheless the manual is created in a format that allows printing when needed and it is easily understandable even when printed in black and white. The manufacturer has also made the manual available in three different languages so that operators who are not very confident in English for example can also read the manual in their mother tongue. This is very important from safety standpoint since not fully understanding the content of the manual can lead to serious hazards.

After passing the test the operators can start working with the machine. There is a QR code located on the machine that the operators can scan with their tablet whenever they need. If there are internet connection issues, then they could always also use the computers located in the factory's office. Since reading the manual from a tablet is much more comfortable most operators prefer the tablet option. By having the QR code on the machine the operators, the factory and the machinery producer are confident that relevant information for the operator is always accessible. After 6 months passes by the operators have a requirement to retake the test to make sure

that no important knowledge or skills has been forgotten by the operator. If needed the operator can read through the manual in order to make sure they pass the test. If the test is failed, then they have another opportunity to take the test. Wrong answers are shown, and the correct answers displayed. This means that taking the test is also a learning experience for the operators.

After working with the machine for 4 months there is an issue with the machine. The operators notice unusual vibrations and noise coming from the machine. The operator uses the search function in the online manual to look for information about these symptoms but does not find any. After reading the manual fully it is discovered that these symptoms are not explained in the manual. Since these symptoms are something that are not present in the user manual, the operator scans the QR code and chooses the option of chatting with the machinery producer. Since the online chat is directly connected with the technical department of the machinery producer, the operator gets relevant feedback in a timely manner.

After analysing the problem with the machine, the machinery producer conducts warranty repair work on the machine. In addition, the machinery producer will edit the existing online user manual to add the symptoms that the operator described to the troubleshooting list. The feedback that the machinery operator gave helped to improve the user manuals for all user of this machine since. Since this punch press is serially produced and sold over the world this new important update reaches everyone who uses the online manual. In addition, the machinery producer takes this information about the repaired issue and implements machinery design changes for future machinery making them more reliable and safer for everyone.

The factory where the machinery is located, and the operators are working is also satisfied since the direct communication was done in a timely manner and for future similar cases changes to user manual for other future operators were made. The online manuals help to keep a closer connection between the machinery producer and the factory that purchased it.

After using the machine for 8 years the QR code on the machine is still visible and clear since the material that it was printed on was though plastic that is very durable. The new operators that start working with the machine have the most up-to-date information about the machine. This is because the machinery producers can take the feedback from various factories that use the machine and continuously update and improve the manual. Since the machinery producer has a legal obligation to make the online manual accessible for a minimum of 10 years the factory doesn't have to worry about storing and keeping the manual for themselves.



## Kokkuvõte

Töös uuritakse Euroopa Liidus turustatavate masinate kasutusjuhendite koostamise ja täiustamise erinevaid aspekte. Töös rõhutatakse, et masinate kasutajatele mõeldud kasutusjuhendid peaksid olema kättesaadavamad ja selgemad, et muuta ELis masinatega seotud tööõnnetuste arvu suurenemise trendi. Töö on kirjutatud ELi uue, alates 2027. aastast kehtiva määruse 2023/1230 (Masinamääruse) raames. Töö põhineb erinevatel tehnilistel standarditel, direktiividel ja määrustel ning autori kogemustel selles valdkonnas. Läbiviidud analüüs viitab puudustele nii praeguses Masinadirektiivis kui ka uuest Masinamääruses, mida töös püütakse lahendada, et pakkuda paremaid juhiseid masinate juhendite koostamiseks.

Määrus 2023/1230 pakub uut võimalust seoses masinate juhenditega - ainult veebipõhised kasutusjuhendid. Seda uut võimalust töös analüüsitakse ja pakutakse sellest lähtuvalt välja lahendused kasutades kasutajakeskse disaini meetodikat. Sageli on praegused kasutusjuhendid liiga keerulised ja keskmisele masinaoperaatorile raskesti arusaadavad. Selleks, et paremini mõista, kes on masina operaatorid, viidi läbi vastav analüüs. Analüüs näitas, et lisaks igapäevaselt masinat kasutavale töötajale loetakse operaatoriteks ka inimesi, kes masinat transpordivad, hooldavad, puhastavad, hoiustavad ja kasutavad ja nendel kasutajatel võib olla väga erinev oskuste- ja hariduse tase. Määrusest tuleneb juriidiline kohustus pakkuda juhendis kõikidele masina operaatoritele selgeid ja arusaadavad juhiseid masina kasutamise osas.

Masinate kasutusjuhendeid analüüsid selgus, et juhendid tuleks kirjutada võimalikult lihtsas keeles, et kõik juhendi lugejad saaksid juhenditest võimalikult selgelt aru. Lisaks lihtsale keelele tuleks kasutusjuhendites kasutada samm-sammult juhiseid, mis võimaluse korral sisaldavad illustratsioone. Käesolevas töös analüüsitud näited olid tihti kirjutatud raskesti mõistetavas keeles, puudusid illustratsioonid ja tegevused, mida võiks kirjutada samm-sammult juhenditena, olid kirjutatud tekstina.

Lisaks eelpool nimetatule võimaldab digitaaltehnoloogiate ja toode kui teenus põhimõtte integreerimine luua süsteemi, kus side masinaoperaatori ja masinatootja vahel paraneb märkimisväärselt, mis toob kaasa parema masina disaini, parema ohutuse operaatorite jaoks ja masinate pikema eluea.

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