Final Report
IGF-Vorhaben Nr.: 100 EN

02.09.2016

TeSaMa

Technical Safety Maintenance System in Mechanical Engineering

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1 Administrative data

1.1 Title of the project IGF-Vorhaben No. 100 EN

Project acronym:	**TeSaMa**
Full title:	Technical Safety Maintenance System in Mechanical Engineering

1.2 Coordinating Institute

Institute:	**Assoc. Institute for Management Cybernetics e.V. (IfU)**
Name:	Prof. Dr. rer. nat. Sabina Jeschke
Tel.:	+49 241 80 91110

1.3 Duration of the project

Start date:	**10/01/2013**
End date:	12/31/2015

1.4 Manpower

Partner	**mm**
IfU	19
IPT	36
CIOP-PIB	101

1.5 Budget and funding

Participant	**Function**	**Country / Region**	**Project costs / expenditures in € ***	**Requested funding in €**	**Own financial contribution in €**
IfU	Association /	Germany	144.910,15	144.480,00	430,15

	Research Organization				
IPT	Research Organization	Germany	266.616,11	259.500,00	7116,11
DROMA	Association /	POLAND	4.723,68	697,35	4.026,33
CIOP-PIB	Research Organization	Poland	220.230,00	220.230,00	0
TOTAL:			**636.479,94**	**624.907,35**	**11.572,59**

1.6 Applicants

1.6.1 Coordinating association and research partner IfU

1.6.1.1 Organisation

Short name	IfU
Full name	Assoc. Institute for Management Cybernetics e.V. (IfU)
Street	Technologiezentrum am Europaplatz Dennewartstraße 27
Postal code	52068
City	Aachen
Province / region	North Rhine-Westphalia
Country	Germany
Telephone	+49 241 - 80 911-00
Fax	+49 241 - 80 911-22
Web address	https://www.ifu.rwth-aachen.de

1.6.1.2 Contact person data

Last name	Lahl
First name	Kristina
Function	Research Group Leader
Title	Dr. phil.
Direct telephone	+49 241 80 91150
Fax	
E-mail	kristina.lahl@ifu.rwth-aachen.de

1.6.1.3 Organisation type

Organisation type	Registered non-profit association
Number of employees	10
Number of members	50
Thereof SME members	9

1.6.2 Research partner IPT`

1.6.2.1 Organisation

Short name	Fraunhofer IPT
Full name	Fraunhofer Institute for Production Technology IPT
Street	Steinbachstraße 17
Postal code	D-52074

City	Aachen
Province / region	North Rhine-Westphalia
Country	Germany
Telephone	+40 241 8904 100
Fax	+49 241 8904 198
Web address	www.ipt.fraunhofer.de

1.6.2.2 Contact person data

Last name	Von Cube
First name	Philipp
Function	Research Fellow
Title	Dipl.-Ing. MBA
Direct telephone	+49 (0)2418904 491
Fax	+49 (0)2418904 6491
E-mail	philipp.von.cube@ipt.fraunhofer.de

1.6.2.3 Organisation type

Organisation type	Non-profit research institute

1.6.3 Research partner DROMA

1.6.3.1 Organization

Short name	DROMA
Full name	Association of Manufacturers of Woodworking Machinery, Devices and Tools
Street	AL. Niepodległości 34
Postal code	63-200
City	Jarocin
Province / region	Wielkopolska
Country	Poland
Telephone	+48 62 747 31 61
Fax	+48 62 747 34 54
Web address	http://droma.com.pl/

1.6.3.2 Contact person data

Last name	Półrolniczak
First name	Andrzej
Function	Chairman
Title	M. Sc.
Direct telephone	+48 602 151 056
Fax	
E-mail	droma@onet.eu

1.6.3.3 Organisation type

Organisation type	Registered non-profit association

Number of employees	2
Number of members	21
Thereof SME members	20

1.6.4 Research partner CIOP-PIB

1.6.4.1 Organisation

Short name	CIOP-PIB
Full name	Central Institute for Labour Protection – National Research Institute
Street	Czerniakowska 16
Postal code	00-701
City	Warsaw
Province / region	Mazovia
Country	Poland
Telephone	+48 22 623 36 98
Fax	+48 22 623 36 93
Web address	www.ciop.pl

1.6.4.2 Contact person data

Last name	Dźwiarek
First name	Marek
Function	Head of the Department of Safety Engineering

Title	Ph.D.(Eng.), D.Sc. (Eng.)
Direct telephone	+48 22 623 46 35
Fax	+48 22 623 36 93
E-mail	madzw@ciop.pl

1.6.4.3 Organisation type

Organisation type	Non-profit research institute

1.6.5 Members of the User Committee

COMPANY **(incl. legal form and address)**	**CONTACT PERSON** **(delegate who will attend the meetings)**	**SME** **(X)**
CAE Elektronik GmbH **Steinfurt 11** **52222 Stolberg** **Deutschland**	Bernd Kohl	
RJ Lasertechnik **Boschstraße 20** **52531 Übach-Palenberg**	Dennis Frantzen	X
CE Kompetenz **Vennstraße 38** **52224 Stolberg**	Alexander Wille	X
BAD GmbH **Rotter Bruch 6** **52068 Aachen**	Sebastian Schönen	

Ingenieurbüro für Arbeitssicherheit **Weststraße 76** **52134 Herzogenrath**	Jörg Wortmann	X
Heim und Haus Holding GmbH **Hochstraße 7-9** **47169 Duisburg**	Dr. Thorsten Grundmann	
HELLA KGaA Hueck & Co. **Rixbecker Straße 75** **59552 Lippstadt**	Andree Allewelt-Müller	
B+B Anlagenbau GmbH **Gießerallee 33** **47877 Willich**	Dr. Reinhold Grewatsch	X
Cerobear GmbH **Kaiserstraße 100** **52134 Herzogenrath**	Jens Wemhöner	X
Fionec GmbH **Ritterstraße 12a** **52072 Aachen**	Kai Bittner	X
Przedsiębiorstwo Innowacyjno-Wdrożeniowe ”TECHMAR” Sp. z o.o. **ul. GLINKI 27 A** **63-200 JAROCIN**	Andrzej Półrolniczak	X
FAMAD Fabryka Maszyn i Urządzeń Przemysłowych Sp. z o.o. **ul. Wojska Polskiego 28** **48-370 Paczków**	Mieczysław Fluder	X
Zakład Produkcyjno-Usługowo-Handlowy “OSKA” Z. Oskwarek, K. Kasprowicz Sp. J. **Przyłęki, ul. Wydmowa 7** **86-005 Białe Błota**	Zbigniew Oskwarek	X

2 Project Description

2.1 Executive Summary

The project TeSaMa provides a holistic approach for Mechanical Engineering companies, and small and medium-sized enterprises in particular, giving them the ability to conduct and obtain sector-specific risk assessments that include safety measure recommendations for both production phase work places and machine development processes. To fulfil this target, the project partners collaborated to develop a web-based tool that guides the user through the whole process and supplies all necessary background information in a comprehensible manner. Furthermore, concrete and individualised information has been provided, outlining the expected savings for the user, via the assessment itself and the correct application of proposed measures. This enables the companies to fulfil legal requirements, minimise financial, reputational and productivity losses and improve overall productivity and reliability.

2.2 Economic Relevance for SMEs

a. Targeted Market Sector

The project targeted companies within the European mechanical engineering (ME) sector, with focus on small and medium sized companies (SMEs).

With 41% of the global output, the European ME sector is the world's largest producer and exporter of machinery. It is not only one of Europe's largest industrial sectors, accounting for 9% of total manufacturing output of respectively €502.1 billion, but also one of the largest employers with about 140,000 companies providing about 2.90 million people with jobs. The strong domestic European market for the ME industry (in 2010: EU 27, €301.7 billion) represents about 60% of the total EU production and reinforces both the competitiveness of the industry and the overall stability of employment in the regions (Ifo, 2012). For Germany, the sector machinery and plant manufacturing generated an annual turnover of €173.4 billion in 2009 and employed more than 913,000 people in over 6,000 companies, making the industry the largest industry by number of employers in Germany (VDMA, 2012). The industry is dominated by small and medium-sized companies, with 87.9% of the companies employing less than 250 employees (or a total number of approximately 423,000 employees) and generating a turnover of about €74 billion per year (VDMA, 2010). In Poland in 2010 there were 1,485 machinery and equipment manufacturing companies with €8.1 billion of sold production and 124,500 employees (SME: 1,402 companies (94%), €3.8 billion (47%) of sold production, 73,100 workers (59%)) (Statistical Yearbook of Industry, 2011).

The topic of product safety and occupational safety and health (OSH, sometimes referred to as health, safety and environment, or HSE) is of great importance to each of the companies in the ME sector. This research proposal addresses every company in the target market sector, leading to a potential market coverage of 100%. Most companies are checking the conformity of their products to the machine directive. Thus, they all benefit through less amounts of work, fewer mistakes in the CE conformity process and therefore less charges and losses due to non-conformity. Besides, the customers, e.g. the metalworking industry and other processing industries/companies benefit from a higher standard of products and fewer machine- or equipment-related incidents as a result of the project TeSaMa.

In the value chain of ME products, the target group of ME companies lies – as with all producing companies – somewhere in between the raw material suppliers and the machinery users. As ME products usually consist of different subcomponents, the ME companies can be suppliers and consumer of other ME companies, often at the same time. ME consumers can be companies from nearly all industry sectors, private households and governmental organisations. Within the ME company, the research addresses a broad selection of departments such as the board of management, business development, production, maintenance, quality, logistics, in-house training and research and development (R&D). These departments were considered either to generate input for the tool (like R&D, production, quality, maintenance and logistics), to interpret results and give advice or decide (board of management, business development) or to disseminate the results and train the staff (in-house training or individual project leaders).

The project results add significant value to all ME SMEs when dealing with training of new employees, mitigating risks in production and maintenance, especially for new production lines, as well as in the product development process (PDP) when dealing with CE conformity and risk analysis. Concerning the first part, the project results help to reduce the probability of incidences during production and maintenance and therefore lower costs due to absence from work, production stops because of incidents, legal costs and costs due to delayed delivery and quality issues (because of missing qualified personnel). The latter one significantly reduces costs for CE training, external consulting or external training.

Conclusions

The target market sector is the German and Polish ME sector with an estimated annual turnover of approximately €180 billion and more than 1,000,000 employees. This sector is heavily dominated by SMEs in both countries, forming almost 88% in Germany and 94% in Poland of the total number of companies in the sector. With respect to the ubiquitous topic of safety at work in manufacturing and machine safety, the results of the project have high relevance for the whole industry throughout Europe.

b. Economic Impact

The overall economic and social costs of occupational injuries are immense. At the same time, defining the costs for economies and companies is a complex task.

A study by Booz & Company from 2011 estimates the costs of absence from work and ill presence at work in Germany at €130 billion per year, resulting in a total loss of productivity worth €225 billion for the whole German economy: Only one third of these costs, following their argumentation, is a result of absenteeism (Booz & Company, 2011). The Federal Institute for Occupational Safety and Health in Germany (BAuA) estimated the costs due to loss of productivity in 2010 to be €68 billion (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2012a). In Poland, accident related costs can be estimated by analysing recompense paid by the Social Insurance Institution (ZUS). In 2011, overall recompense paid from accidents in work insurance was 5,378 million PLN, or about 0.34% of the Gross National Product per year. Pensions in respect of accidents at work and occupational diseases created the main part of those costs and were received in average amount of 4,180 million PLN (ZUS, 2011).

The costs of accidents are a serious concern for small and medium-sized enterprises because SMEs account for 82% of all occupational injuries and 90% of all fatal accidents within the EU (European Commission, 2007). According to Eurostat annual data, for every 100,000 workers in the European SME sector, there are more than 4,100 accidents which lead to 'over three days' absence'; while the same rate is 3,088 in larger firms (Eurostat, 2007). The risk of fatal accidents is also higher in the European SME sector, where the 2004 incident rate of fatal accidents (defined as the number of fatalities per 100,000 workers) was 4.9 in firms with less than 250 employees and 1.8 in larger companies (Arocena & Nunez, 2010). The BenOSH assessed costs and benefits of 401 OSH projects and quantifies the median costs to the employer as €1,651 per accident for cases with low severity, €4,986 for medium severity and €11,760 for high severity. 69% of the accidents were of low severity, 18% of medium and 13% of high severity, so the overall median costs are €3,565 (European Commission, 2011).

The second part of the developed tool improves the product safety of the SMEs products. The costs for SMEs are difficult to assess, as usually there are no costs if there are no complaints. However, if there are, the costs can be immense. Articles state that medium-sized companies are likely to lose more than €2 million per call-back, which is one of the most severe consequences of insufficient product safety (Focus, 2007). Nevertheless, another important but hardly quantifiable part of the costs is the loss of reputation and – due to that – the loss of key customers, which may lead to a company's bankruptcy within a short time.

Conclusions

The quantification of OSH costs obviously poses a considerable challenge, since a lot of factors, like social costs are hard to quantify. Consequently, the project attempted to find a substantial, clearly defined classification of costs for OSH, leading to the identification of benefits that a company using the developed tool gains could utilise. Although some literature refers to the financial assessment of safety costs, the advantage of a professional OSH approach is rarely quantified. One study even came to the result of a ratio of between 1:5 and 1:16 (Aldana, 2001). The benefits of such a health program can be an increased productivity, decreased absenteeism, and decreased life insurance claims. Some countries in the EU have promoted favorable insurance conditions for companies that focus on improving OSH (European Agency for Safety and Health at Work, 2009).

For the OSH benefit that was integrated into the project, it is estimated that a professional method for risk assessment and OSH management is necessary for SMEs to achieve the incident rates of large companies. This follows the argument that big enterprises have superior incident rates because they invest in OSH management and professional risk assessment of work places, which are both integral parts of the developed tool. The results take into account the SME market size in the regions of Germany and Poland, the median accident costs of companies and the difference in accident rates between SMEs and large enterprises as well as an estimated market coverage of 100%. The financial benefits of the project result in SMEs in the ME sector having a 0.013% reduced incident rate, or €22,987,120 worth of savings in OSH factors. But these are only the benefits due to saved working time, also called direct costs. According to the International Labor Organization overall costs related to work accidents are about 4 times higher than direct costs (Takala, 2011), so a more realistic approach would be to estimate the real amount of financial benefits at about €90 million.

Further substantial benefits lie on a social level: increased working conditions, higher morale among the work force, better-qualified personnel and less fluctuation are some of the crucial benefits to SMEs (Dorman, 2000).

c. The Need

In all enterprises, both public and private, the quality of health and safety management systems and workplace assessment is remarkably higher in large, rather than small, enterprises (Sorensen, 2007). It is most evident in studies of fatalities and major injuries, as a large number of studies report that the risk is highest in small enterprises. The number of lost work days is also consistently found to be higher in small rather than medium and large enterprises (Fabiano, 2004; Stevens, 1999; Oleinick, 1995; Mayhew, 2000; McVittie et al., 1997).

The literature points to a number of generic factors that can potentially explain the poorer safety performance of SMEs. Compared with larger enterprises, SMEs lack financial resources and managerial skills for an appropriate OSH management. Managers often have a weak commitment to OSH activities. OSH regulatory inspections are often insufficient and the general preference for informal and non-formalised approaches to preventive activity is unsustainable (Mayhew, 1997; Rigby & Lawlor, 2001; Champoux & Brun, 2003; Lamm & Walters, 2003). The impact of a serious OSH incident could be catastrophic for a small enterprise, as it is far more difficult for SMEs to recover from any OSH incident. Besides, the relative impact is greater than on comparable larger enterprises and key workers can only hardly be replaced. Furthermore, short-term interruptions of business can lead to loss of clients and important contracts and one single serious incident can lead to closure of a business due to the direct costs of dealing with the incident or the loss of contracts and/or customers (European Agency for Safety and Health at Work, 2009). A study by DEKRA from 2011 assessed legal actions against companies that were made after accidents in five EU countries (France, Germany, Netherlands, Poland and Spain) over the last two years. Poland is the country with the most actions, as legal actions followed 16% of the accidents. 6% of the French and 5% of the Polish companies with an incident over the last two years reported a significant financial impact. However, concrete financial figures are not given (DEKRA, 2011). As most of the reasons for problems between SMEs and OSH are unchangeable, there is a need to mitigate the risk of incidents as much as possible. Another interesting fact is that 78% of the companies in Germany that have experienced fatalities state that they planned on renewing the risk assessment of the work place, which underlines the urgent need for professional and easily accessible risk assessment support (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2012b).

Another important safety issue for SMEs is the safety of their designed and produced goods. Half of all work place fatalities occur in two branches: the construction (30%) and manufacturing branch (20%) (Angermann et al., 2007). Companies of the ME industry, playing a substantial role as a supplier of machinery or machinery components for different manufacturing sectors, are often linked to the incidents at their customers' plants. If such an incident is based on a machine malfunction or even an unintended misuse of a machine, the CE conformity and especially a correct and well documented risk assessment of the machine may prevent the product manufacturer from high legal costs. A recent study of incidents in Germany states that 90 out of 142 fatal incidents that were linked to technical products in 2011 were linked to products that fall under the machine directive (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2012b). The study states that for 2010, 23% of the fatal incidents could probably have been avoided, if the designer of the product had done a risk assessment properly, not only including the intended use of the product, but as well other predictable types of use (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2011). So the need that was addressed in TeSaMa was a more distinct – and especially for SMEs – user-friendly way to support designers in effective risk identification and assessment during the product development phase.

Conclusions

As SMEs have substantial disadvantages in the prevention of incidents and the risk mitigation during development of new machinery, they lose profit and are under constant substantial, even existence-threatening danger of getting sued by severely injured workers or their customers. As insufficient machine safety and major accidents will always be a major threat, the only appropriate solution is to mitigate the risks as far as possible.

2.3 Cooperation Framework

CIOP-PIB is Poland's main research institution, comprehensively dealing with the problems of improving working conditions. The main aim of the Institute's research and development works is the building scientific foundations to create a system for preventing occupational hazards. The Institute's main activities in the field of safety and health include: research and implementation work, standardisation, determination of exposure limits, testing and certification of machinery and manufacturing devices, personal and collective protective equipment; certification of the competence of personnel and educational bodies active in the field of OSH, promotion, implementation and certification of OSH management systems; consultations, education and training in OSH as well as promotion, information and publishing activity in this area, and international cooperation with OSH institutes and international organisations. CIOP-PIB employs 288 people, including: 109 researchers, 118 engineers and technicians involved in research, 61 administration & service personnel.

The IfU primarily contributed research expertise concerning the evaluation of investment factors and the management of complex decision scenarios. In a long row of applied and SME-centred research projects, the IfU has successfully applied its core competencies both on the topic of risk evaluation and on occupational safety and health. During past and on-going projects (e.g. Q-Risk), the IfU has gained extensive experiences in conducting and managing applied research projects as well as in the productive collaboration with the IPT.

The Fraunhofer IPT has its core competencies in research on process technology, production machines, mechatronics, production quality and metrology as well as technology management. The IPTs reputation on those fields is maintained through the co-organisation of the Aachen Machine Tool Colloquium (AWK), a triennial meeting point for over 1,000 international experts. Furthermore, the IPT has a wide experience in the field of technical risk assessments in various fields like procurement, production machinery and product development. A central task of the IPT is to transfer the current research directly into industrial practice. The Fraunhofer IPT currently employs a about 380 people and has affiliated organisations in Paderborn, Germany and Boston, USA.

The goal of the cooperation was to join forces where expertise met. While the IPT has its core competencies in the process technology and process analysis in a production-related environment, these competencies were ideally enhanced by the CIOP-PIBs profound knowledge of safety in the workplace. For machine safety, both institutes have competencies, but have different perspectives, so an exchange of experience provided a more complete view on the topic. The IfU provided the necessary expertise through their competence in the field of cost-benefit-analysis and further risk assessment techniques. Another major advantage lay in the geographical situation of the institutes: Whereas Germany possesses the biggest ME industry in the EU, Poland has a rapidly growing economy that focuses on manufacturing. The scope of project required experience in the European legislation, as well as in national roles for the ME sector in Poland (CIOP-PIB) and Germany (IPT).

3 Technical description of the project (WPs and deliverables)

The project can best be described by the following chart (Figure 1). It was separated into three chronological phases, the definition phase, the development phase and the validation phase. Furthermore, the project consisted of eight Work Packages. The approach and the results of the Work Packages are described in detail in chapter 3. In the definition phase, the first content was generated by overviewing the legal obligations SMEs have to fulfill in the sectors of OSH and machine safety. Therefore, based on the RTOs' substantial background knowledge, the most current developments in law-making have been investigated and pointed out, and sorted to ME subsectors and company sizes. In parallel, a system was designed with the prospect of being the basis of the then developed software tool. In the next chronological phase, the development phase, the tool has been developed and in parallel, the main elements of the tool were researched, developed, edited and integrated. The last phase, the validation phase, mainly consisted of the verification of the integrated functionality and the optimisation of the tool and the content. In parallel, as the usability and the covered functionality was conceivable, a cost-benefit analysis for the users has been conducted and integrated into the tool.

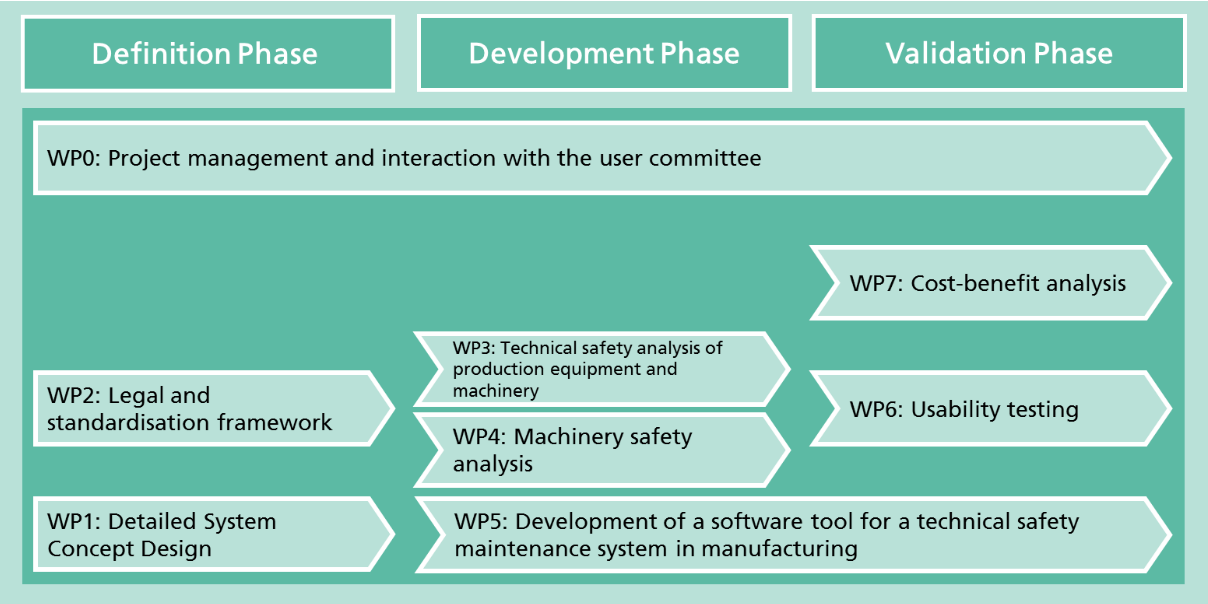

Figure 1: Phases and Work Packages of the project TeSaMa

3.1 Work Package 0: Project management and interaction with the User Committee

3.1.1 Summary

Work Package 0 enabled efficient project management and interaction between the research partners and the user group, in doing so achieving the project goals and deliverables agreed upon in the planning stage (for a tentative Gantt chart see the work plan in Annex 3). Internal communication and interactions were maintained by means of regular meetings, reports and documents. The achieved aims were a well-managed research project with a frequent exchange of information between the research partners, the relevant associations and the users committee. Due to the fact that close collaboration with the user group was key to the success of this project, regular meetings between the research partners and the SMEs have been conducted. Despite the IfU being appointed the work package leader (project coordinator), all partners have contributed to this collaboration in order to achieve the goals of the project.

3.1.2 Execution & deliverables

Task 0.1: Overall management and external reporting (M1-M24)

The project management was comprised of all administrative, financial and contractual tasks (e.g. involvement with the national funding agencies, consortium agreements, etc.) that needed to be fulfilled in accordance with to the CORNET rules. The creation of external reports involved documents and reports being sent to the national funding authorities. Interim and Final Reports to AiF and NCBiR as well as a Final Report to Cornet (identical to the one sent to AiF) in which all partners contributed were prepared by the coordinator.

The following personnel have been deployed:

CIOP-PIB: 0,75 mm	IPT: 0 mm	IfU: 1 mm	DROMA: 0 mm

Proceedings and Results of Task 0.1

Deliverables 0.2-0.4: Three semi-annual interim reports: These deliverables as stated in the proposal have not been sent individually, but were integrated in the required single Interim Report to AiF and NCBiR, as stated in the AiF, NCBiR and CORNET regulations.

Deliverable 0.5: Final report: This report will be sent no later than four months after the end of the project.

Deliverables 0.6-0.9: Regional reports to NCBiR: An Interim Report has been sent to and was approved of by NCBiR after the first year of the project. The Final Report was sent 60 days after the end of the project. The last, Post-Project-Report that includes all dissemination after the project closure will be sent in five years.

Deliverables 0.10-0.13: Regional reports to AiF: An Interim Report has been sent to and was approved of by the AiF after the first year of the project. The Final Report to the AiF is identical to this Final Report to CORNET.

Task 0.2: Project management and internal communication (M1-M24)

Internal communication involved the coordination of technical activities in order to update one another about the progress and results of the work. Therefore, intensive cooperation between partners and the User Committee proved to be very valuable for the project. Meetings between research partners occurred in the form of on-site meetings or teleconferences as well as continual exchange regarding the project's proceedings and dissemination activities via email.

On a semi-annual basis, the project status and the results were discussed between the research partners. The planning for the respective next six months was discussed, having taken into account the feedback from the User Committee. If needed, changes were proposed towards the subsidiary authorities. At the end of the meetings, a detailed minute report was prepared and communicated internally.

The following personnel have been deployed:

CIOP-PIB: 0,77 mm	IPT: 1 mm	IfU: 1 mm	DROMA: 0 mm

Proceedings and Results of Task 0.2

Deliverable 0.1: Set-up of a tool for internal communication: The joint project website served as a platform for the internal communication and the distribution of research progress and results.

Milestones 0.1-0.5: Consortium meetings: The consortium meetings took place alternately in Poland and Germany as well as via telephone conferences with participation of all project partners. They were accompanied by presentations and documented in detailed reports.

Task 0.3: Organisation and active involvement of the User Committee (M1-M24)

Representatives of end-user companies closely followed the research. An active User Committee, consisting of representative companies in the target sector, guided the developments in the direction that fitted their specific needs/challenges (e.g. detailed user requirements, supplied and validated developments on generic reference cases, incorporated feedback, specified technological advice etc.). Project results were presented at each milestone of the project and feedback was collected so as to guide the developments in the next phase of the project. Here, the User Committee obtained full access to the project proceedings and to the developed tool in order to give feedback.

The following personnel have been deployed:

CIOP-PIB: 0,75 mm	IPT: 0,5 mm	IfU: 0,5 mm	DROMA: 0 mm

Proceedings and Results of Task 0.3

Milestones 0.6-0.9: User Committee Meetings:

User Committee meetings were organised on:

- 03.07.2014, Poznań, Poland
- 25.08.2014, Aachen, Germany

- 29.08.2014, Poznań, Poland
- 30.01.2015, Poznań, Poland
- 19.05.2015, Poznań, Poland
- 23.06.2015, Stolberg, Germany
- 11.09.2015, Poznań, Poland
- 21.12.2015, Aachen, Germany

Task 0.4: Dissemination and valorisation plan (M1-M24)

A dissemination and valorisation plan enabled the coordination of all the dissemination and valorisation activities of the consortium partners and created a defined strategy in which the project goals could be achieved. The project manager, and to a lesser extent the consortium partners, were responsible for maintaining and following-up these plans. On a semi-annual basis, these plans were discussed between the consortium partners and associations at the semi-annual project meetings during which decisions were made regarding the direction the project was to be taken.

The following personnel have been deployed:

CIOP-PIB: 0,75 mm	IPT: 0,5 mm	IfU: 0,5 mm	DROMA: 0 mm

Proceedings and Results of Task 0.4

Dissemination deliverables: The dissemination included many different measures for informing external interested parties from science and industry about the project's findings and results via presentations at scientific and industry-related conferences as well as fairs, publication in journals, support of B.A., M.A. and Ph.D.-theses among others (for the full dissemination plan see point 4. Valorisation of the research results).

Task 0.5 Preparation and publication of dissemination material (M3-M24)

Communication infrastructure and dissemination materials were published so that the target market was made aware of the opportunities and results of the project. Here, the partners' communication channels, the project website and external international conferences were used for project presentations, newsletters, a white paper about project results, guidelines etc. During the project, poster presentations at different conferences were given and a paper was published and presented at the ESREL conference.

The following personnel have been deployed:

CIOP-PIB: 0,75 mm	IPT: 1 mm	IfU: 2 mm	DROMA: 0 mm

Proceedings and Results of Task 0.5

The details concerning dissemination activities are available in point 4. Valorisation of the research Results.

Cooperation in WP 0

CIOP-PIB and IfU were responsible for all external reporting activities from their sides, the communication to the regional UC and the organisation and conduction of the regional UC meetings. All joint activities like publications, guidelines etc. were carried out together and in agreement with the distribution of managerial functions regarding the leading or assisting organisation agreed upon. Furthermore, the IfU as project coordinator has prepared the interim reports and the final report and therefore collected all relevant information from the other partners.

All deliverables and milestones of WP 0 have been fulfilled.

3.2 Work Package 1: Detailed System Concept Design

3.2.1 Summary

The general goal of the proposed system is to support maintenance work carried out by machinery users and manufacturers. In this work package, and in accordance with the general goal, detailed assumptions regarding the structure and functionality of the system have been developed. The development process started with an in-depth analysis of existing (partial) solutions that are currently on the market. The system concept development tasks focused on: information content introduced to the system; the range of supporting tools for system users; methodology of system access content and evaluation of their own tasks using supporting tools; experience interchange among users; software platforms, tools for system implementation and general system management, and finally user access profiles. The outcome is a profound and documented database of competing tools, meeting desired functions and structures, whilst also being technically feasible. They are also fully reconcilable with existing basic software environments that are the technical basis of the developed tool. The solution for the technical implementation and the generic requirements for the tool was developed end of this work package as it was needed for the development phase in WP5.

3.2.2 Execution & deliverables

Task 1.1: Analysis of existing tools and methods (M1-M3)

This task comprised an overlook of existing solutions or partial solutions and an analysis of their strengths and weaknesses. Therefore, the market share of those solutions and the experience users have with the solutions were identified and estimated via a questionnaire. Thus, a database of the currently covered functionalities of competing tools, their acceptance on the market and their performance (or perceived performance) among SMEs within the target group was conducted.

The following personnel have been deployed:

CIOP-PIB: 2 mm	IPT: 0,5 mm	IfU: 0,25 mm	DROMA: 0 mm

<u>Proceedings and Results of Task 1.1</u>

As an initial step, an overview was created outlining and assessing the existing and partial solutions for product and occupational safety and health currently on the market. The analysis included German, Polish and also English software-based and non-software-based methods, e.g. questionnaires, checklists and software solutions. The structure, advantages and disadvantages of the solutions discovered were then examined more closely. Alongside this, general information was collected, e.g. on the implemented standards, databases and prices.

A questionnaire has been set up to collect information from the User Committee and any other companies involved. It contained questions regarding which tools companies use, what advantages or disadvantages the tools entail and what needed to be improved. The results of this questionnaire have been included in the results of this work package.

The results of this analysis are shown in the following table (Table 1 and Table 2), which is a summary of the deliverables 1.1, 1.2 and 1.3.

Deliverable 1.1: Analysis report for existing HSE tools (M3)

Deliverable 1.2: Analysis report for existing machine safety tools (M3)

Deliverable 1.3: Questionnaire report about tool-use within industry (M3)

<u>Tools for machine safety</u>

Title	**Information**	**Advantages**	**Disadvantages**
Safe-expert	• 1060 € (Basic); 2100 € (Compact); 2965 € (Professional) • Database:	• Manager for standards • Interface with Sistema	• High cost • First impression: „complex“

	○ VistaDB (for single-user installation) ○ MS-SQL Server 2008 R2 ○ Oracle (optional) • Integrated standards: ○ EN ISO 12100 ○ Low voltage directive 2006/95/EG ○ ATEX directive 94/9/EG ○ Pressure equipment directive 97/23/EG ○ EC machinery directive 2006/42/EG ○ EMV directive 2004/108/EG	• Plausibility check • Operating Manual assistant	
WEKA	• WEKA MEDIA GmbH & Co. KG • 979 € + 19% VAT (Full version) • Integrated standards: ○ EN ISO 14121-1 ○ EN ISO 12100:2010 ○ EC machinery directive 2006/42/EG	• Supports creating verification documents • Question catalogue to other directives exists • Constructed along the CE process • Regular updates provided • Further explanations for single steps • Inquiry mode	• Only suitable for machinery • Updates at the owner's expense

		(no steps can be forgotten)	
Safety Evaluation Tool	• Free • Data interface is the Standard sheet VDMA 66413 published by Siemens TÜV Süd u. Rheinland, IFA • Deposited standards: • IEC 62061 • ISO 13849-1 - ISO 13849-1	• Free • Data interface • Example projects • Risk assessment • Overview area • Web-based • Usable on all internet capable devices (notebook, tablet, smartphone)	• Only applicable on sensors
Clever	• 89 € (Standard); 139 € (Professional); also possible in-house for an extra fee • Deposited standards: - EC machinery directive 2006/42/EG - DIN EN ISO 12100:2010 - DIN EN ISO 13849-1 - DIN EN ISO 62061	• Customizable • Filter function • CE guide • Web-based	• Only suitable for machinery • No interface, only manual transfer
DOCUFY	• 0 € Starter version (Freelancer, Small enterprises); 3500 € Professional (mid-tier, large scale enterprises); x € (individual arranged software)	• Interface with SISTEMA • Risk assessment • Version man-	• Only risk assessment

	• Deposited standards: • DIN EN ISO 12100, • DIN EN ISO 13849	agement	
CSafe	• 260 € +19 % VAT (includes updates for 1 year, 1 license) • Deposited standards: DIN EN ISO 12100:2010	• Take phases of life into consideration	• Solely risk assessment
SISTEMA	• Deposited standards: DIN EN ISO 13849-1	• Coloured support • Beginners' support • Distributed as an interface for many systems • Free • Assessment of safety related machine control • Input for a variety of tools	• Solely risk assessment
Safety App	• Deposited standards: DIN EN ISO 13849-1	• Free	• Only available for iOs • Only risk assessment
CE-Elektrotechnik	• 698 € + 19% VAT • Deposited standards: • Low Voltage directive 2006/95/EG • EMC directive 2004/108/EG • RTTE directive1999/5/EG • EC machinery directive	• Checklists • Complete CE marking process • Many standards provided	• Checklists • Complete CE marking process • Many standards provided

	2006/42/EG • EU Measuring device directive 2004/22/EG • ATEX directive 94/9/EG • Medical device directive 93/43/EWG • Directive for active implantable medical devices 90/385/EWG • In vitro diagnostics 98/79/EG		
Safety Calculator Pascal	• Inspired by VDMA standard sheet 66413 • Deposited standards • IEC 62061 • ISO 13849-1	• Coloured marking	• Only functional safety • Issued (.pdf)
PRO-M	• Computer program concerning risk assessment during machinery design	• The risk assessment is conducted step by step • Final results of the system is documentation required by directive 2006/42/EC	• only in Polish languages
CETech	• software for maintaining the essential components of the technical file	• Available in the cloud	• Paid • Unable to download demo version

Table 1: Tools for machine safety

Tools on Occupational Safety and Health

Title	• Information	• Advantages	• Disadvantages
SGU Guideline	• Homepage	• Separate guidelines for the different industries	
GPS SST Matrix	• Excel tool	• Free • Includes people who are in touch with occupational safety on a daily basis	• Only for already implemented OSH management • No benchmark or audit tool
Check: guter Mittelstand	• Homepage	• Free • Integrated into business processes of SME	• Not finished yet (release 2018)
Health and Safety of Maintenance Engineering	• Tool	• Free	• Only for aviation industry
NOSACQ-50	• Questionnaire • In various languages available (25)	• Free • Based on various OSH, psychological and empirical theories • Creation of an international database for identifying benchmark purposes	

IAEA Guidance for use in the enhancement of safety culture	• Guideline	• Free	• Applicable to various industries but created specifically for nuclear
Safety Climate tool	• Web based tool • Price depends on employee number	• Personalisation is possible • Web based	• Price related to employee number
Score your safety culture checklist	• Questionnaire	• Free	• Not to prevent accidents just to check up on implementation
Hearts & Minds program	• Tool • Price depends on the software package • Available in various languages (not Polish)	• Proactive and generative approach to HSE • Various languages	• Price dependent on package
OHRIS	• Guideline	• Free • Prevention and control instrument	• Only applicable on SME
Risk Assessment Gefährdungsbeurteilung	• Guideline • Risk Assessment / Procedural guidelines	• Free • Documentation of single measures through user, date, effectiveness • Risk assessment for various sectors and aspects	

BASA II	• Questionnaire	• Free • Screening instrument for the various workstations	• No interface, questionnaire done on paper
SIGMA	• Questionnaire	• No interface, questionnaire done on paper	• No interface, questionnaire done on paper
Basic-net	• Web based tool • A basic and an extra package exist	• No interface, questionnaire done on paper	• No interface, questionnaire done on paper
Line Management Competency Indicator tool	• Web based tool • A basic and an extra package exist	• Free • Flexible course of questionnaire	
Tool zur Selbstbeur teilung	• Available in various languages	• Free • Flexible course of questionnaire	• Only intended for people in leading positions • No help in daily work • Status quo check
PRIMAet	• E-Learning	• E-Learning • Free	• Just in the beta phase right now • No help in daily work • Status quo check
Workplace Strategies for Mental Health	• Homepage	• Various techniques like guidelines, brochures, questionnaires	• Intended for Canadian employer

		• Free	
Safety and Health Leader-ship Quiz	• Online Questionnaire	• Free • Web-based and automatically calculated result	• No help in daily work • Status quo check
Involving your workers in OSH	• Guideline	• Free • Real life exam-ples	• No help in daily work • Status quo check
Ar-beitssicher heit online	• Various price models • Various tool	• various tools, can be tailored to own require-ments • Support within the working en-vironment	• expensive
Check-listen	• Checklists	• Free	• Only Checklists • Must be done manually
GDA-ORGA-check	• Online questionnaire	• Free • Especially for SMEs • Benchmarks provided • Includes help for risk assessment	
MESS CMMS	• Informatics tool	• Free • Tool for organis-ing machinery maintenance • Increasing work efficiency and decreasing ma-	• Destination for larger compa-nies • Includes mod-els for small en-terprises

		chinery exploitation costs	
STER	• Computer tool for risk assessment	• Supporting complex OSHA actions	• More useful for large companies
Asystent BHP (Assistant of OSH)	• The computer programme supporting the work of health and safety services	• The ability to use available templates • Access to databases and legal acts	• Paid • Ability to run only in Windows
Ocena ryzyka zawodowego (Risk assessment at work)	• Computer program supporting risk assessment	• Number of jobs at which it is possible to draw up a risk assessment	• Paid • Ability to run only in Windows
MKRO-BHP Micro HSE)	• The computer programme supporting the work of health and safety services	• Focuses on the needs of smaller enterprises	• Ability to run only in Windows
Forum – Ocena Ryzyka (Forum – Risk assessment	• Website concerning risk assessment practice	• Access to databases and legal acts • The ability to use available templates	• Paid • Ability to run only in Windows
IRYS	• Interactive computer system for risk assessment	• Risk assessment based on measurements results • Free	• Only in Polish

OiRA (Online Interactive Risk Assessment)	• Online software for risk assessment	• Free • Online availability	• Lacks explanations of national standards

Table 2: Tools on Occupational Safety and Health

Task 1.2: Definition of functionality requirements for the system

Based on the content-related findings of task 1.1 an assumption regarding the system's functionality was developed in relation to the needs of WP2, WP3 WP4 and WP5. The following aspects were considered: general philosophy of system performance, user access to required knowledge, solving problems by delivered dedicated tools, access to useful examples of solutions and good practices, safety maintenance activity registration and documentation, possibility of experience interchange, access to the system, system and system data management. There were also the following subjects to discuss: language for system-user communication, free or limited access to the system, copyrights of presented knowledge and formal requirements for documentation and more aspects. The work was conducted with the help of the User Committee members, then all information was put together and ideas for the overall system were generated with the help of creative techniques. Finally, all requirements were derived from the lists and the concept creation procedure and arranged.

The following personnel have been deployed:

CIOP-PIB: 1,4 mm	IPT: 0,3 mm	IfU: 0,25 mm	DROMA: 0 mm

Proceedings and Results of Task 1.2

Based on the results of task 1.1, three classes of tools have been identified:

1. Computer programs supporting in conducting and documenting of the assessment of the machinery state.
2. Web-services allowing for the possibility of completing the assessment online.
3. Web-services with similar guidance, recommendations and interpretations

Conclusion

The following table (Table 3) outlines the main advantages and disadvantages of the tool:

Advantages	**Disadvantages**

• Simplicity in use • Overall assessment of the problem • Examples of the relevant documents and solutions • Step-by-step procedures	• One way communication • Discontinuing the use of mobile technologies • Lack of case studies • Does not cover the particular safety requirements of the machine throughout its whole life time

Table 3: Main advantages and disadvantages of the tool

Deliverable 1.4: Functionality requirement specification:

Following the analyses of Task 1.2, the necessary functionality requirements for the proposed tool were decided upon. The needs of WP2-5 were incorporated in this development stage. Aspects considered in this approach are:

- System performance
- User access to necessary knowledge
- Solving problems using dedicated tools
- Access to examples
- Documentation
- Possibility of exchanging the gained experience
- Access to the system
- Data management systems

The tool is divided into a restricted section, which can only be accessed via login and password, and a commonly available section. The latter includes general information for the interested user, such as case studies, publications, guidance, information papers and a list of rules. The restricted area is divided into "product safety" and "machinery in use" sections. In these parts, the basic functionality of the openly accessible area is extended to create a project in which online assessments can be conducted and the necessary documents created, archived and printed. Furthermore, the administrator has the ability to grant the necessary access rights for the various users. As a result of the transnational research partners and User Committee involved in this project, the tool has been developed in three different languages. English is the mother language of the system, while German and Polish have also been sufficiently developed by the partners for use in the tool.

The basic approach to the "product safety" assessment and the "machinery in use" sections is depicted in the following two diagrams (Figure 2 and Figure 3):

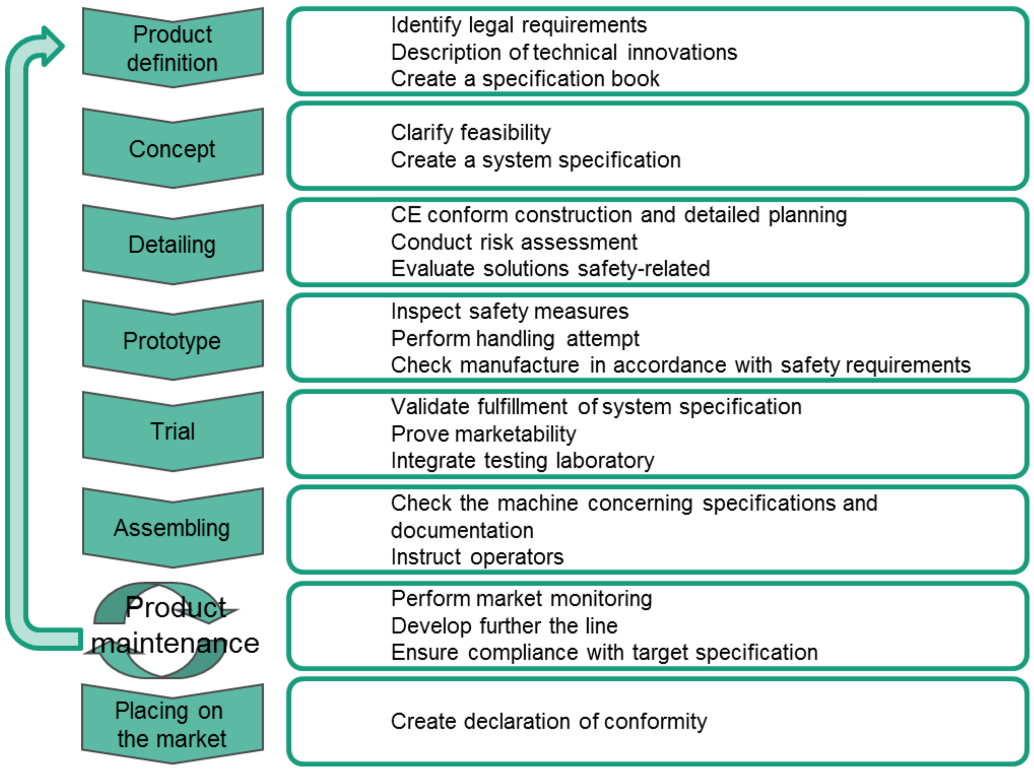

Figure 2: The product safety process

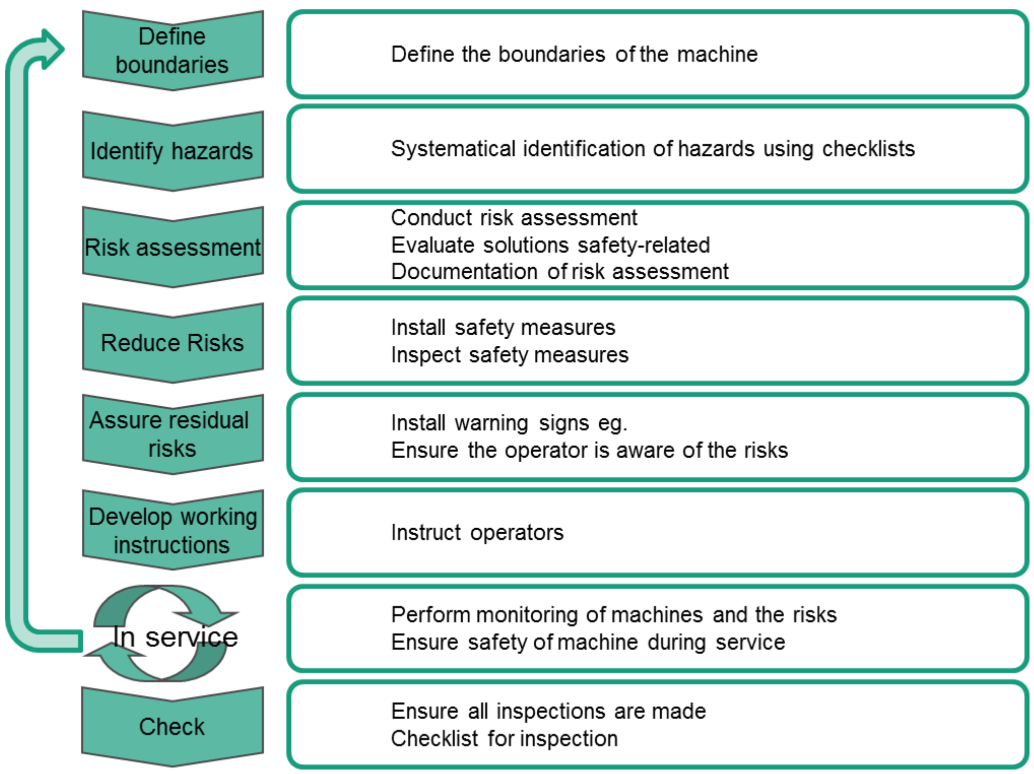

Figure 3: The machinery in use process

Task 1.3: Definition of technical requirements for the system

Based on the achievements made in task 1.2, the technical requirements were investigated and arranged in lists and portfolios. The following aspects were considered: system software platform suitable for the most computer environments, the way of software distribution to potential users, the reduction of user effort for any software installation, user interface to system functionality, the methodology of system updating and upgrading, the methodology of system and user data management and the methodology of the document hard copy. The technical requirements were arranged in the same way as the content-related requirements as they belong closely together.

The following personnel have been deployed:

CIOP-PIB: 1,5 mm	IPT: 0,3 mm	IfU: 0,25 mm	DROMA: 0 mm

Proceedings and Results of Task 1.3

Deliverable 1.5: Technical requirement specification:

According to the end-user's needs, the very same software will run in the three modes presented below:

1. Single desktop PC (with or without Internet connection)
2. Different devices (desktop PC, laptop, tablet, smartphone) connected to the server (e.g. Desktop PC) through Local Area Network LAN (with or without Internet connection)
3. Different devices (desktop PC, laptop, tablet, smartphone) connected to dedicated web server through Internet

To accomplish the abovementioned requirements we have decided to prepare the software using client-server architecture with the assumption that both client and server could be run on the same device (PC, see usage mode no. 1). The program running on the client side has the form of thin client – namely a web browser is used. The data between server and client is sent using secure protocol if required. The thin client depends heavily on its server to fulfil its computational roles; however, some computations which do not require access to the whole database are performed on the client side.

In the basic mode (mode no. 2 and no. 3), there is no need for end-users to install any additional software beyond a web browser. Since most computations will be performed on the server side, there is no need to store control instructions (i.e. programs) locally (on the client side). Therefore, the software upgrade will not require any additional actions performed by the user. In the case of web browsers, most of the latest versions (e.g. Firefox 29) can automatically be updated without the need for user involvement in this process (internet connection is required only). For other modes of the system associated with the operation within LAN (Local Area Network), there is need to download and install the software on a chosen computer, which will be work as a server for other computers. Other devices on the same network (LAN) will have automatic access to the latest content and features without the need for any actions from the user.

Supported operating systems:
Any with ability to run web browser, e.g. Windows, Android, Linux, MacOS, iOS.
Additional software required:
Web browser with full HTML5 support, e.g. Mozilla Firefox 29, Google Chrome 35.
Additional requirements:
In some cases an internet connection is required.

Table 4: Summary of Technical Requirements for Supported Software (on the client side)

Task 1.4: Analysis of appropriate software solutions

Task 1.4 was the coactive follow-up of task 1.3, finding and comparing software environments that meet the previously generated requirements best. The main problems to be solved were: possibility of system functionality implementation, simplicity of programming, software popularity and availability for the user and user cost of software purchase. Further stress was laid on long-term strategic considerations, e.g. if the environment will be supported when updating the tool years later. The output of this task is be a well-reasoned decision for a programming environment, based on a well-documented decision making process.

The following personnel have been deployed:

CIOP-PIB: 1,6 mm	IPT: 0,4 mm	IfU: 0,25 mm	DROMA: 0 mm

Proceedings and Results of Task 1.4

Deliverable 1.6: Software environment analysis:

According to the assumptions, the software should be:

- Relatively easy to maintain,
- Flexible end easy to extend functionality,
- Based on very popular software packages and software development tools,
- Inexpensive, especially in terms of license costs,
- Enable global and local data storage, i.e. both on the server and client side.

The implementation of all needed software features (described in details in Deliverables 1.1 – 1.5) requires the use of technology dedicated dynamic web designing and database management systems.
When considering the software development environments dedicated client-server architecture facilitating the preparation of a Web site, it is important to consider first of all the fact that only part of the instruction is executed on the client side. The vast majority of instruction (computations) is run on the server side. A special case of such instructions (without which the creation of modern websites allowing for extensive interaction with the user is nowadays impossible) are instructions enabling cooperation with the database management system.
The following software environments supporting preparations programs executed on the server were analysed:

- CGI
- Perl
- PHP
- ASP

To achieve the above-mentioned goals, we have decided to rely mainly on free, open source solutions with very large communities supporting its development:

- PHP – for server side computations and data preparation for client using database, etc.
- MySQL – as Database Management System (DBMS)
- Apache – as web server responsible for communication between server and clients,
- Web browser – as a thin client. Any web browser with full HTML5 support will be suitable.

Software	**Recommended**	**Minimum**	**More information**
PHP	5.4 +	5.2.4 +	http://www.php.net
Supported Databases:			
MySQL	5.0.4 +	5.0.4 +	http://www.mysql.com
Recommended Web Server:			
Apache (with mod_mysql, mod_xml, and mod_zlib)	2.x +	2.x +	http://www.apache.org
Recommended FTP Server (Windows):			
FileZilla	0.9.42	0.9.40	https://filezilla-project.org/

Table 5: Summary of Technical Requirements for Supported Software (on the server side)

Cooperation in WP 1

CIOP-PIB was the dedicated WP leader, and provided the development resources for the software tool that was mainly developed in WP5. Therefore, it also was the main researcher for the technical requirements of the tool and especially the software environment analysis. Besides, CIOP-PIB, IfU and IPT worked on the task of tool analysis and the content-related requirements in close cooperation.

All deliverables and milestones of WP 1 have been fulfilled.

3.3 Work Package 2: Legal and Standardisation Framework

3.3.1 Summary

Understanding the legal and normative requirements that reflect the needs of the target sector SMEs was a key requirement in the development of the system. The information transferred to the system from the documents, together with the systematic knowledge gained from WP3, WP4 and WP7, created the system's knowledge base and thus its ability to create comprehensible tools for system users. All suitable documents related to machine safety were considered best practice examples.

3.3.2 Execution & deliverables

The three tasks in WP2 are very closely linked and build on one another which is why the proceedings and the results of the different tasks are collectively covered in this report. The objectives of the three tasks were:

Task 2.1: Analysis of current legal framework for OSH in the selected regions and industry sectors (M1-M6)

One major task of the tool is to inform the SME workers of their duties, their rights and the consequences of malpractice in the field of safety at work, case-oriented on their work place. Therefore, the legal situation had to be elaborated for the relevant industries, workplaces and regions. In addition, much weight had to be put on depicting the information in an easy-to-understand and unambiguous way, and to give examples, if appropriate. It was also crucial to depict differences within the SME sector that are depending on the exact size of the SME (by number of employees). In view of the large quantity of information generated in this task, the key deliverable of this task was to arrange the information with respect to the integration into the tool.

The following personnel have been deployed:

CIOP-PIB: 2,5 mm	IPT: 1,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Task 2.2: Analysis of current legal framework for machine safety in the selected regions in the ME sector (M1-M6)

This task was similar to task 2.1, as there are a number of legal acts and directives, European as well as national, which oblige ME companies to certain documentations, procedures and even investments. For SMEs, especially when developing machinery for new markets or customers, knowing and obeying these rules, especially the machinery directive 2009/104/EU, is critical and therefore this knowledge is essential. The collection and depiction of all necessary legal information was therefore the core task, completed through the arrangement of the information towards the tool integration.

The following personnel have been deployed:

CIOP-PIB: 2,4 mm	IPT: 1,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Task 2.3: Analysis of standards and other safety related publications having influence on machine safety (M3-9)

In addition to the legal acts concerning machine safety, and through machine directives, there are some harmonised standards each newly developed machine has to oblige to in order to become a legal product on the European market. These standards include complex standards like the EN ISO 12100 – covering general principles for safe design that have to be considered. The system arranges and delivers information from the relevant standards for the selected industry and from other documents which deliver safety related solutions and good practices to the user, so this task generated a large quantity of information.

The following personnel have been deployed:

CIOP-PIB: 3,3 mm	IPT: 0,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 2.1-2.3

Proceedings

As an initial step and in order to get a comprehensive understanding of all necessary legal and normative requirements regarding the machinery manufacturing sector, a general analysis was conducted on the basic structure of the legal framework. A number of standards exist, such as Type A, Type B and Type C standards, but European and national laws must also be taken into consideration. The general structure of the laws and standards is depicted below (Figure 4):

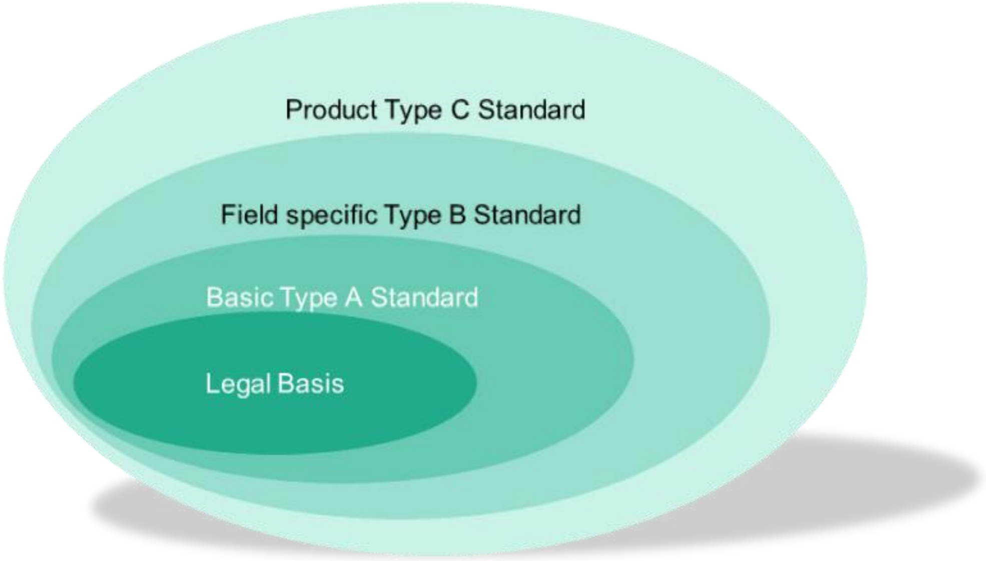

Figure 4: Degree of Specification of European laws and standards

Following this initial overview, a more detailed approach was conducted regarding the existing European and German legal acts. The analysis focused on two main parts with three subsections. The first part included the analysis of all legal acts and standards that apply to the development of a machine. This analysis has then been divided into three subsections. First of those includes all necessary documents for machinery in general, while the other two focus on machinery with optical radiation and external blinds.

The second part contains all legal documents that were identified as being related to machinery in service, and in turn the necessary inspections they require. Here too, the analysis was divided into a general overview with the focus being on machinery with optical radiation and external blinds.

Deliverable 2.1: List of documents (legal acts, standards and other suitable publications) to be implemented in the system (M9)
Milestone 2.1: Decision on selected documents to be presented as the knowledge, simple tools and examples in the system (M9)

<u>Machinery development</u>

On a European level, the manufacturer has to consider the following directives when placing his product on the market. It has to be noted that not all directives are applicable to all machinery and it is up to the manufacturer to identify those applicable:

- The machinery directive 2006/42/EC,
- The directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility,
- The low voltage directive 2006/95/EC.

Furthermore, on the German market, manufacturers need to fulfil additional requirements. These are outlined within the following regulations and laws:

- German Produktsicherheitsgesetz (ProdSG),
- Maschinenverordnung (9. ProdSV),
- Law on electromagnetic compatibility of resources (EMVG).

During the development of the product, the manufacturer has to consider all requirements set in the aforementioned legal acts. The safest way to fulfil all the requirements is by applying a Type-C standard. This is not legally mandatory but allows for the presumption of conformity. In the case that type C-standard does not exist, it is recommended that standard type B and A, or other international and national standards are used. During the analysis, the following standards were identified:

1. DIN EN 349 Sicherheit von Maschinen - Mindestabstände zur Vermeidung des Quetschens von Körperteilen
   Safety of machinery – Minimum gaps to avoid crushing of parts of the human body
2. DIN EN ISO 13850 Sicherheit von Maschinen – Not-Halt – Gestaltungsleitsätze
   Safety of machinery – Emergency stop function – Principles for design
3. EN ISO 7731 Ergonomie – Gefahrensignale für öffentliche Bereiche und Arbeitsstätten - Akustische Gefahrensignale
   Ergonomics - Danger signals for public and work areas - Auditory danger signals
4. DIN EN 547-1 Sicherheit von Maschinen – Körpermaße des Menschen - Teil 1
   Safety of machinery – Human body measurements – Part 1
5. DIN EN 547-2 Sicherheit von Maschinen - Körpermaße des Menschen – Teil 2
   Safety of machinery – Human body measurements – Part 2
6. DIN EN 547-3 Sicherheit von Maschinen – Körpermaße des Menschen – Teil 3
   Safety of machinery – Human body measurements – Part 3
7. DIN EN ISO 13732-1 Ergonomie der thermischen Umgebung – Bewertungsverfahren für menschliche Reaktionen bei Kontakt mit Oberflächen – Teil 1: Heiße Oberflächen
   Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces
8. DIN EN 574 Sicherheit von Maschinen – Zweihandschaltungen – Funktionelle Aspekte – Gestaltungsleitsätze
   Safety of machinery – Two-hand control devices – Functional aspects; principles for design
9. DIN EN 614-1 Sicherheit von Maschinen – Ergonomische Gestaltungsgrundsätze Teil 1
   Safety of machinery – Ergonomic design principles – Part 1
10. DIN EN 626-1 Sicherheit von Maschinen – Reduzierung des Gesundheitsrisikos durch Gefahrstoffe, die von Maschinen ausgehen – Teil 1
    Safety of machinery – Reduction of risks to health from hazardous substances emitted by machinery – Part 1
11. DIN EN 626-2 Sicherheit von Maschinen – Reduzierung des Gesundheitsrisikos durch Gefahrstoffe, die von Maschinen ausgehen – Teil 2

Safety of machinery – Reduction of risks to health from hazardous substances emitted by machinery – Part 2

12. DIN EN 809 Pumpen und Pumpenaggregate für Flüssigkeiten – Allgemeine sicherheitstechnische Anforderungen
    Pumps and pump units for liquids – Common safety requirements
13. EN ISO 13857 Sicherheit von Maschinen – Sicherheitsabstände gegen das Erreichen von Gefahrenstellen mit den oberen und unteren Gliedmaßen
    Safety of machinery – Safety distances to prevent danger zones being reached by the lower and upper limbs
14. DIN EN 842 Sicherheit von Maschinen – Optische Gefahrensignale – Allgemeine Anforderungen, Gestaltung und Prüfung
    Safety of machinery – Visual danger signals – General requirements, design and testing
15. DIN EN 981 Sicherheit von Maschinen – System optischer und akustischer Gefahrensignale und Informationssignale
    Safety of machinery – System of auditory and visual danger and information signals
16. DIN EN 13855 Sicherheit von Maschinen – Anordnung von Schutzeinrichtungen im Hinblick auf Annäherungsgeschwindigkeiten von Körperteilen
    Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body
17. DIN EN 1012-2 Kompressoren und Vakuumpumpen – Sicherheitsanforderungen – Teil 2
    Compressors and vacuum pumps - Safety requirements – Part 2
18. DIN EN 1037 Sicherheit von Maschinen – Vermeiden von unerwartetem Anlauf
    Safety of machinery – Prevention of unexpected start-up
19. EN ISO 12100 Sicherheit von Maschinen – Allgemeine Gestaltungsleitsätze - Risikobeurteilung und Risikominderung
    Safety of machinery – General principles for design – Risk assessment and risk reduction
20. EN ISO 61800-5-2 Elektrische Leistungsantriebssysteme mit einstellbarer Drehzahl – Teil 5-2
    Adjustable speed electrical power drive systems – Part 5-2
21. EN ISO 60104-1 Sicherheit von Maschinen – Elektrische Ausrüstung von Maschinen – Teil 1: Allgemeine Anforderungen
    Safety of machinery – Electrical equipment of machines – Part 1: General requirements
22. EN ISO 4413 Fluidtechnik – Allgemeine Regeln und sicherheitstechnische Anforderungen an
23. Hydraulikanlagen und deren Bauteile
    Hydraulic fluid power – General rules and safety requirements for systems and their components
24. EN ISO 4414 Fluidtechnik – Allgemeine Regeln und sicherheitstechnische Anforderungen an Pneumatikanlagen und deren Bauteile
    Pneumatic fluid power – General rules and safety requirements for systems and their components
25. EN ISO 13849-1 Sicherheit von Maschinen – Sicherheitsbezogene Teile von Steuerungen

Safety of machinery – Safety-related parts of control systems

26. EN ISO 62061 Sicherheit von Maschinen – Funktionale Sicherheit sicherheitsbezogener elektrischer, elektronischer und programmierbarer elektronischer Steuerungssysteme
Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems
27. IEC 61508-1 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 1: Allgemeine Anforderungen
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements
28. IEC 61508-2 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 2: Anforderungen an sicherheitsbezogene elektrische/ elektronische/ programmierbare elektronische Systeme
Functional safety of electrical/ electronic/ programmable electronic safety-related systems – Part 2: Requirements for electrical/ electronic/ programmable electronic safety-related systems
29. IEC 61508-4 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 4: Begriffe und Abkürzungen
Functional safety of electrical/ electronic/ programmable electronic safety-related systems – Part 4: Definitions and abbreviations
30. IEC 61508-5 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 5: Beispiele zur Ermittlung der Stufe der Sicherheitsintegrität
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 5: Examples of methods for the determination of safety integrity levels
31. IEC 61508-6 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 6: Anwendungsrichtlinie für IEC 61508-2 und IEC 61508-3
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3
32. IEC 61508-7 Funktionale Sicherheit sicherheitsbezogener elektrischer/ elektronischer/ programmierbarer elektronischer Systeme – Teil 7: Überblick über Verfahren und Maßnahmen
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 7: Overview of techniques and measures
33. DIN EN 61496-1 Sicherheit von Maschinen – Berührungslos wirkende Schutzeinrichtungen – Teil 1: Allgemeine Anforderungen und Prüfungen
Safety of machinery – Electro-sensitive protective equipment – Part 1: General requirements and tests
34. DIN EN 13478 Sicherheit von Maschinen – Brandschutz
Safety of machinery – Fire prevention and protection

While the above standards specify the general requirements set for nearly all machinery, there are also various standards for specific machines. The analysis focused on the standards applicable for machinery with optical radiation and for external blinds. The results are listed as follows:

Machinery with Optical Radiation

1. DIN EN 207 Persönlicher Augenschutz; Filter und Augenschutz gegen Laserstrahlung (Laserschutzbrillen)
   Personal eye-protection equipment – Filters and eye-protectors against laser radiation
2. DIN EN 208 Persönlicher Augenschutz; Brillen für Justierarbeiten an Lasern und Laseraufbauten (Laser-Justierbrillen)
   Personal eye-protection – Eye-protectors for adjustment work on lasers and laser systems
3. DIN EN 12254 Abschirmungen an Laserarbeitsplätzen; Sicherheitstechnische Anforderungen und Prüfung
   Screens for laser working places – Safety requirements and testing
4. DIN EN 56912 Sicherheitstechnische Anforderungen für Showlaser und Showlaseranlagen und Prüfung
   Safety requirements for Lightshow lasers and laser lightshow systems
5. DIN EN 60601-2-22 Medizinische elektrische Geräte – Teil 2: Besondere Festlegungen für die Sicherheit von diagnostischen und therapeutischen Lasergeräten,
   Medical electrical equipment – Part 2-22: Particular requirements for basic safety and essential performance of surgical, cosmetic, therapeutic and diagnostic laser equipment
6. DIN EN 60825-2 Sicherheit von Laser-Einrichtungen – Teil 2: Sicherheit von Lichtwellenleiter-Kommunikationssystemen
   Safety of laser products – Part 2: Safety of optical fibre communication systems
7. DIN EN 60825-4 Sicherheit von Laser-Einrichtungen – Teil 4: Abschirmungen an Laserarbeitsplätzen
   Safety of laser products – Part 4: Laser guards
8. DIN EN 61040 Empfänger, Messgeräte und Anlagen zur Messung von Leistung und Energie von Laserstrahlen
   Power and energy measuring detectors, instruments and equipment for laser radiation
9. DIN EN ISO 11145 Optik und optische Instrumente; Laser und Laseranlagen; Begriffe mit Formelzeichen
   Optics and photonics – Lasers and laser-related equipment - Vocabulary and symbols
10. DIN EN ISO 11553-2 Sicherheit von Maschinen; Laserbearbeitungsmaschinen – Teil 2: Sicherheitsanforderungen an handgeführte und handbediente Maschine
    Safety of machinery – Laser processing machines – Part 2: Safety requirements for hand-held laser processing devices

External Blinds

- DIN EN 14351-1 Fenster und Türen – Produktnorm, Leistungseigenschaften
  Windows and doors – Product standard, performance characteristics
- DIN EN 13561 Markisen – Leistungs- und Sicherheitsanforderungen
  External blinds and awnings – Performance requirements including safety

1. CEN EN 572-9:2004 Glas im Bauwesen
   Glass in building – Basic soda lime silicate glass products – Part 9: Evaluation of conformity/Product standard

4. New Construction Products Regulation – Information for manufacturers of construction materials

Machinery in Service

In addition to the product safety part of the tool, all necessary legal acts and standards for machinery in service had to be identified as well. Therefore, a detailed analysis was conducted regarding the relevant European and German legal acts. There are two significant European directives to be considered in regards to this topic:

- Directive 89/391/EEC
- Directive 2009/104/EC

The directives are implemented differently within the national laws of various European countries. In Germany, two legal acts and a number of legal regulations exist and the companies involved have to take all of these into account when installing the machinery in their production processes:

Legal acts

- Law on Safety at the Workplace
- Betriebssicherheitsverordnung (BetrSichV)

Legal regulations

- Unfallverhütungsvorschrift „Sicherheits- und Gesundheitsschutzkennzeichnung am Arbeitsplatz“ (BGV A8)
  Prevention regulation „Safety and health signs at work”
- „Explosionsschutz-Regeln – (EX-RL)“ (BGR 104)
  „Explosion protection rules – (EX-RL)“
- VDI Richtlinie 4064 – Technik und Organisation der betrieblichen Sicherheit – Arbeitsschutzorganisation in KMU – Handlungsanleitung zur praxisorientierten Vorgehensweise
  Technique and organization of operational safety – Organization of occupational health and safety in small- and medium-sized enterprises (SMEs) – Practical guidance
- Produktsicherheitsgesetz 1. ProdSV
  Product Safety Act
- DGUV Vorschrift 3 – Elektrische Anlagen und Betriebsmittel
  Electrical installations and equipment
- DGUV Vorschrift 4 – Elektrische Anlagen und Betriebsmittel
  Electrical installations and equipment
- DGUV Vorschrift 5 – Electrical installations and equipment
- DGUV Regel 100-501 – Betreiben von Arbeitsmitteln – Auflistung
  Operation work materials

- DGUV Regel 103-011 – Arbeiten unter Spannung an elektrischen Anlagen und Betriebsmitteln
  Working on live electrical installations and equipment
- DGUV Regel 103-013 – Elektromagnetische Felder
  Electromagnetic fields
- DGUV Regel 103-014 – Elektromagnetische Felder
  Electromagnetic fields
- DGUV Regel 109-002 – Arbeitsplatzlüftung – Lufttechnische Maßnahmen
  Ventilated workplaces – Ventilation guidelines
- DGUV Regel 112-989 – Benutzung von Schutzkleidung
  Usage of protective clothing
- DGUV Regel 112-992 – Benutzung von Augen- und Gesichtsschutz
  Usage of eye and face protection
- DGUV Regel 112-995 – Benutzung von Schutzhandschuhen
  Usage of protective gloves
- DGUV Regel 113-011 – Sicheres Arbeiten in der Kunststoffindustrie
  Safe working in plastics industry

Polish legal acts:

- Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 29 listopada 2002 r. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy (Dz. U. 2005 nr 212 poz. 1769, ze zm.).
  Regulation of the Minister of Labour and Social Policy of 29 November 2002 on highest admissible concentrations and intensities of harmful factors for health in work environment (Journal of Laws 2005 No. 212, item 1769, with later edited).
- Rozporządzenie Ministra Pracy i Polityki Socjalnej z dnia 26 września 1997 r. w sprawie ogólnych przepisów bezpieczeństwa i higieny pracy (T.j. Dz. U 2003, nr 169, poz. 1650, ze zm.)
  Regulation of the Minister of Labour and Social Policy of 26 September 1997 on general safety and health rules (Uniform text Laws of 2003 No 21, item 1650, with later edited).
- Rozporządzenie Ministra Gospodarki, Pracy i Polityki Społecznej z dnia 15 października 2001 r. w sprawie bezpieczeństwa i higieny pracy przy produkcji wyrobów gumowych (Dz. U. nr 131 poz. 1462, ze zm.)
  Regulation of the Minister of Economy, Labour and Social Policy of 15 October 2001 on safety and health at rubber articles production (Journal of Laws No. 131, item 1462, with later edited.
- Rozporządzenie Ministra Gospodarki z dnia 7 czerwca 2002 r. w sprawie bezpieczeństwa i higieny pracy przy przetwórstwie tworzyw sztucznych. (Dz. U. nr 81 poz. 735)
  Regulation of the Minister of Economy of 7 June 2002 on safety and health at plastics processing (Journal of Laws No. 81, item 735)

- Rozporządzenie Ministra Gospodarki z dnia 10 maja 2002 r. w sprawie bezpieczeństwa i higieny pracy przy użytkowaniu wózków jezdniowych z napędem silnikowym (Dz. U. nr 70 poz. 650, ze zm.)
  Regulation of the Minister of Economy of 10 may 2002 on safety and health at using of fork-lifts with motor drive (Journal of Laws No. 70, item 650, with later edited)
- Rozporządzenie Ministra Gospodarki z dnia 19 lutego 2002 r. w sprawie bezpieczeństwa i higieny pracy przy procesach galwanotechnicznych (Dz. U. nr 19 poz. 192)
  Regulation of the Minister of Economy of 19 February 2002 on safety and health at plating processes (Journal of Laws No. 19, item 192)
- Rozporządzenie Ministrów Pracy i Opieki Społecznej oraz Zdrowia z dnia 19 marca 1954 r. w sprawie bezpieczeństwa i higieny pracy przy obsłudze przenośników. (Dz. U. nr 13 poz. 51).
  Regulation of the Ministers of Labour and Social Care as well as Health at using of conveyors (Journal of Laws No. 13, item 51)

Polish standards:

- PN-M-68051:1999 Bezpieczeństwo maszyn – Zautomatyzowane systemy maszynowe do kształtowania wyrobów na zimno (*Safety of machines – Automated machine systems to cold forming of articles)*

Other publications

- IEC/TS 62046:2008 Safety of machinery – Application of protective equipment to detect the presence of persons.

While the aforementioned regulations cover machinery in general, others focus on specific machinery. For manufacturers who utilise machines with optical radiation or external blinds, the following directives, legal acts and regulations are also applicable:

Woodworking machinery

Polish legal acts:

- Rozporządzenie Ministra Gospodarki z dnia 14 kwietnia 2000 r. w sprawie bezpieczeństwa i higieny pracy przy obsłudze obrabiarek do drewna. (Dz.U. 2000 nr 36 poz. 409)

  Regulation of the Minister of Economy of 14 April 2000 on the safety and hygiene when handling woodworking (Journal of Laws No. 36, item. 409)

Polish standards

- PN-ISO 7960:2000. Hałas obrabiarek – Warunki pomiarów dotyczące obrabiarek do drewna.
  Airborne noise emitted by machine tools – Operating conditions for woodworking machines
- PN-ISO 7984:1998. Maszyny do obróbki drewna – Klasyfikacja techniczna obrabiarek i maszyn pomocniczych do obróbki drewna.
  Woodworking machines – Technical classification of woodworking machines and auxiliary machines for woodworking
- PN-D-01008:1993. Uzębienia pił do drewna – Kształt zarysu – Terminologia i oznaczenie
  Saw teeth for woodworking saws – Profile shape – Terminology and designation
- PN-D-54001:1969. Obrabiarki do drewna – Określenia i wytyczne tworzenia nazw
  Woodworking machines – Definitions and guidelines on creating of designations
- PN-D-56180:1993 Obrabiarki do drewna – Tokarki – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Turning lathes – Nomenclature and acceptance conditions
- PN-D-56201:1993. Obrabiarki do drewna – Strugarki wyrówniarki – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Surface planning machines with cutterblock for one-side dressing – Nomenclature and acceptance conditions
- PN-D-56202:1993. Obrabiarki do drewna – Strugarki grubiarki – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Thickness planning machines with rotary cutterblock for one-side dressing – Nomenclature and acceptance conditions
- PN-D-56207:1993. Obrabiarki do drewna – Dłutarki łańcuszkowe – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Single chain mortising machines – Nomenclature and acceptance conditions
- PN-D-56208:1993. Obrabiarki do drewna – Pilarki tarczowe poprzeczno-wzdłużne – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Single blade circular saw benches with or without travelling table – Nomenclature and acceptance conditions
- PN-D-56209:1993. Obrabiarki do drewna – Wiertarko-frezarki – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Slot mortising machines – Nomenclature and acceptance conditions
- PN-D-56210:1993. Obrabiarki do drewna – Wiertarki jednowrzecionowe – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Single spindle boring machines – Nomenclature and acceptance conditions
- PN-D-56211:1993. Obrabiarki do drewna – Frezarki górnowrzecionowe – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Routing machines – Nomenclature and acceptance conditions

- PN-D-56213:1993. Obrabiarki do drewna – Czopiarki dwustronne – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Double-end tenoning machines – Nomenclature and acceptance conditions
- PN-D-56215:1993. Obrabiarki do drewna – Pilarki tarczowe jednopiłowe ze stołem przesuwnym – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Single blade circular sawing machines with travelling table – Nomenclature and acceptance conditions
- PN-D-56216:1993. Obrabiarki do drewna – Pilarki tarczowe do płyt jednopiłowe z przesuwnym wrzecionem – Nazewnictwo i sprawdzanie dokładności.
  Woodworking machines – Single blade stroke circular sawing machines for lengthwise cutting of solid woods and panels – Nomenclature and acceptance conditions
- PN-D-56220:1993. Obrabiarki do drewna – Pilarki tarczowe ramieniowe – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Radial circular saws – Nomenclature and acceptance conditions
- PN-D-56221:1993. Obrabiarki do drewna – Pilarki tarczowe górnowrzecionowe wielopiłowe – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Double edging precision circular sawing machines – Nomenclature and acceptance conditions
- PN-D-56247:1993 Obrabiarki do drewna – Frezarki dwu-, trzy- i czterostronne – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Two-, three- and four-side moulding machines – Nomenclature and acceptance conditions
- PN-D-56249:1993 Obrabiarki do drewna – Pilarki taśmowe stolarskie – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Table band sawing machines – Nomenclature and acceptance conditions
- PN-D-56250:1993 Obrabiarki do drewna – Przekrawarki pakietów forniru – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Veneer pack edge shears – Nomenclature and acceptance conditions
- PN-D-56264:1993 Obrabiarki do drewna – Wyrówniarko-grubiarki – Nazewnictwo i sprawdzanie dokładności
  Woodworking machines – Surface planning and thickening machines – Nomenclature and acceptance conditions

Machinery with optical radiation

EU directives

- Directive 2006/25/EC of the European Parliament and of the Council of 5th April 2006 on the minimum health and safety requirements regarding the exposure of the workers to risks arising from physical agents (artificial optical radiation, 19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).

German legal acts

- Verordnung zum Schutz der Beschäftigten vor Gefährdungen durch künstliche optische Strahlung (Arbeitsschutzverordnung zur künstlicher optischer Strahlung – OstrV)
  Regulation on providing safety and health at work regarding artificial optical radiation
- Verordnung über den Schutz des Publikums von Veranstaltungen vor gesundheitsgefährdenden Schalleinwirkungen und Laserstrahlen (Schall- und Laserverordnung SLV)
  Acoustic noise and laser regulation
- Unfallverhütungsvorschrift Laserstrahlung (BGV B2)
  Regulation on prevention of accidents

German regulations

1. BG-Regel „Benutzung von Augen- und Gesichtsschutz" (BGR 192)
   BG rule „governing the use of equipment for eye and face protection"
2. BG-Information „Expositionsgrenzwerte für künstliche optische Strahlung" (BGI 5006)
   BG information „Exposure limit values for artificial optical radiation"
3. BG-Information „Laser-Einrichtungen für Show- und Projektionszwecke" (BGI 5007)
   BG information „Laser installations for show and projection purposes"
4. BG-Information „Umgang mit Lichtwellenleiter-Kommunikationssystemen" (BGI 5031)
   BG information „Handling of optical fibre communication systems"
5. BG-Information „Auswahl und Benutzung von Laser-Schutzbrillen und Laser-Justierbrillen" (BGI 5092)
   BG information „Selection and use of laser protective googles and laser adjustment eye-protectors)
6. DGUV Vorschrift 11 – Laserstrahlung
   Laser radiation
7. DGUV Vorschrift 12 – Laserstrahlung
   Laser radiation

Polish regulations

- Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 27 maja 2010 r. w sprawie bezpieczeństwa i higieny pracy przy pracach związanych z ekspozycją na promieniowanie optyczne (Dz. U. nr 100 poz. 643)

  Regulation of the Minister of Labour and Social Policy of 27 May 2010 on provisions for safety and health at work regarding the exposure on optical radiation (Journal of Laws of 2010 No 100, item 643 with amendments);

- Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 29 listopada 2002 r. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy (Dz. U. nr 217 poz. 1833)

  Regulation of the Minister of Labour and Social Policy of 29 November 2002 on maximum permissible concentration and intensity of agents harmful to health in the working environment (Journal of Laws of 2002, No 217, item 1833 with amendments)

European and Polish standards

- EN ISO 15616-1:2003 – Acceptance tests for CO2- laser beam machines for high quality welding and cutting. Part 1 General principles, acceptance conditions
- EN ISO 15616-2:2003 – Acceptance tests for CO2- laser beam machines for high quality welding and cutting. Part 2: Measurement of static and dynamic accuracy
- EN ISO 15616-3:2003 – Acceptance tests for CO2- laser beam machines for high quality welding and cutting. Part 3: Calibration of instruments for measurement of gas flow and pressure
- IEC/TR 60825-10:2002 – Safety of laser products – Part 10. Application guidelines and explanatory notes to IEC 60825-1
- IEC/TR 60825-14:2004. Safety of laser products. A user's guide

External blinds

EU directives

- Directive 89/106/EEC – construction products of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products

German legal acts

- Bauproduktverordnung
  BauPVO (Construction Products Regulation)

German regulations

1. DIN EN 14351-1 Fenster und Türen – Produktnorm, Leistungseigenschaften
   Windows and doors - Product standard, performance characteristics
2. DIN EN 13561 Markisen – Leistungs- und Sicherheitsanforderungen
   External blinds and awnings – Performance requirements including safety
3. CEN EN 572-9:2004 Glas im Bauwesen
   Glass in building – Basic soda lime silicate glass products – Part 9: Evaluation of conformity/Product standard

Deliverable 2.2: List of selected information derived from listed documents to be implemented in the system as data, tools or examples (M9) / Milestone 2.2: Decision on selected information to be implemented in the system (M9)

Following this initial analysis of all legal frameworks, a subsequent analysis was conducted. During this analysis, information relevant to the project was filtered out of these laws, regulations and standards, a step necessary in order to provide companies with only the most important information and so that a lean organisational structure could be implemented within the software tool. During this analysis, the IPT focused on the German legal acts and regulations for machinery with optical radiation and external blinds mentioned above, whereas the CIOP-PIB focused on general European and Polish regulations that concern woodworking machinery and the optical radiation of machinery. A short summary is outlined below, given that a complete overview of all the information discovered would go beyond the scope of this work:

Machinery development

General:

Information delivered from European and Polish legal acts

- Short description of legal act scope
- Indication the provisions which could be important for manufacturers
- Case studies for manufacturers
- Interpretation of particular articles with examples e.g. link to http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide-appl-2006-42-ec-2nd-201006_pl.pdf (Guide to Directive 2006/42/EC.pdf)
- List of Polish notified bodies (link to Polish Accreditation Centre)
- Check lists with essential requirements
- Check list of technical documentation

Information delivered from European standards

- Guiding principles for non - guarding and complementary protective measures of machines
- Guiding principles for guarding safety measures of machines
- General rules and safety requirements for pneumatic and hydraulic systems and their components in machines
- Requirements, design and testing of warning equipment
- Requirements and checking of marking and information requirements of machines
- Requirements for integrated manufacturing systems of machinery
- Requirements for machinery safety-related parts of control systems

Woodworking machinery

- Short scope description of the document

- Indication the requirements which could be important for manufacturers of woodworking machines (articles strictly concerning woodworking machines)
- Manufacturers' obligations due to electromagnetic compatibility of woodworking machines
- List of essential requirements concerning woodworking machines for use outdoors
- Examples of functional testing of woodworking machinery control systems (for users)
- Rules and good practices on marking of woodworking machines
- Assurance of stability of stationary woodworking machines
- Assurance of stability of movable woodworking machines
- Assurance of material stability while woodworking (for users)
- Practical methods of verification and/or adjustment of adjustable guards and interlocking guards with or without guard locking in woodworking machines (for users)

Machinery with optical radiation

- Short description of the standard scope
- Main definitions
- List of the main requirements for lasers documentation
- List of safety requirements
- Description of lasers classes and related risk
- Short description of physics relating to the dangers posed by laser products, so that the user may correctly interpret its requirements. The application of this technical report is limited to laser products with finite accessible emissions of laser radiation
- Description of rules of labelling and information requirements
- Examples of eyewear labelling and choosing
- Specimen labels for lasers equipment
- Checklist

External blinds

- Short description of the standard scope
- Indicate the provisions that could be important for manufacturers of external blinds
- List of the main requirements related to external blinds
- Checklist for manufacturer
- List of main requirements

<u>Machinery in service</u>

General

- Short description of the scope of act
- Indication the provisions which could be important for employers and employees

- Case studies for employees
- Interpretation of particular articles with examples
- Check lists with minimum OSH requirements for different machines
- Methodology for conducting of inspections of the work equipment
- Indication the provisions which could be important for employers and employees
- Interpretation of particular articles with examples
- List of requirements for OSH machinery users training
- Guidance for general methodology for application of protective equipment to detect the presence of persons
- Check list for decommissioning of the protective equipment
- Check lists for the periodical inspection of the equipment

Woodworking machinery

- Basic requirements concerning controls and safety signals in machinery
- Inspections concerning of woodworking machines and safety devices
- Elaboration of a checklist with comments
- Examples of good practices when handling woodworking
- Interpretation of particular articles with examples

Optical radiation

- Short scope description
- Indicate the provisions that could be important for laser' manufacturers (lasers' safety classes and obligatory determination of exposure to laser radiation by employer)
- Interpretation of particular articles with examples
- Information of hazardous effects of laser radiation to skin and eye
- Table with exposure limits
- Description of different protective googles

External blinds

- Short scope description
- List of documents related
- Interpretation of particular articles with examples
- List of limiting values
- Table of requirements

Based on these findings, the collected information has been included into the system in the form of short descriptions and a content list of the standards.

Cooperation in WP 2

Both CIOP-PIB and IPT, partly assisted by the IfU, were working on the research and selection of documents on the legal framework for OSH and for machine safety respectively and on the collection and formatting of all information to be built into the system. IPT was the WP leader as an intensive exchange of knowledge to the IfU was advisable for preparation of WP7. IPT maintained the organisation of actions within the tasks and the setting of due dates and regular telephone conferences.

All deliverables and milestones of WP 2 have been fulfilled.

3.4 Work package 3: Technical safety analysis of production equipment and machinery

3.4.1 Summary

The core process in the ME sector is the production process. For the ME industry, as for many others, this is also the process where the most and more severe incidents happen. To prevent incidents, or at least minimise the risk, all companies within the EU are obliged to follow the satisfy requirements outlined in directive 2009/104/EU. This means that inspections (initial, periodic and special) must be performed periodically to monitor the status of the machinery's safety features. Some cases identified require risk assessment procedures for work places and for machinery hazards. The goal of this work package was to identify and develop inspection procedures and the applicable risk assessment methods, which was to be enhanced by self-explanatory tools supporting the procedures and suitable reference examples. These support measures, all of which are case-oriented to ME industry subsectors, were integrated into the developed system.

3.4.2 Execution & deliverables

A general methodology for regular inspections and risk assessments has been developed within the third work package. Based on the information collected in work package two, a questionnaire was developed. This questionnaire contains all necessary information and guides companies through the mandatory inspections and risk assessments. It is divided into five main parts, which were again separated in subsections. Due to the extensive nature of the questionnaire, only the main parts and their subsections are displayed below:

A) General information

☐	Single Machine	☐	Group of working equipment / machinery
	Description of working equipment / machinery:		
	Manufacturer:		
	Year of construction / Commissioning:		
	Serial number, batch code:		
	Location / Installation point:		
	Corporate labelling (z. B. inventory no.):		
	Operation / Scope of the assessment:		

B) Hazards created by the working equipment:
1. **Mechanical hazards**
2. Electrical hazards
3. Chemical hazards
4. Fire and explosion
5. Thermal hazards
6. Physical hazards
7. Other hazards

C) Environmental conditions that influence the means of production
1. **Possible hazardous interactions between means of production because of …**
2. Influences that cause damages

D) Analysing safeguarding measures:
1. **Technical requirements – Minimum standards**

2. Use and provision
3. Organisation and documents
4. Instruction
5. Applicable documents
6. Necessary inspections corresponding to § 3 or 10

E) Risk assessment		
Estimation		Explanation / Necessary measures
☐	No endangerment to be expected	
☐	Endangerments probable	
☐	Endangerments exist	
☐	Work equipment unsafe / not usable	

After having checked all the applicable boxes and having filled out the additional explanations, it is possible for the manufacturer to quickly identify potential hazards and initiate the appropriate measures. This can include the wearing of protective gear or the relocation of the machine to another section of the factory.

Task 3.1: Development of a recommended approach for machinery and work equipment inspection (M4-M9)

This task focused on the elaboration of a systematic inspection approach for machinery in production. A self-explanatory methodology supporting required activities has been developed together with suitable examples typical for target industries. The development was based on good industrial practices and suggestions collected on the base of questionnaire answers and interviews with managers, experienced organisations and safety engineering offices. This methodology will help to document the process of inspection and obtained results.

The following personnel have been deployed:

CIOP-PIB: 3,63 mm	IPT: 1 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 3.1

Deliverable 3.1: A systematic approach for machinery and work equipment inspection (M9) / Milestone 3.1: The inspection methodology is ready to be implemented into the tool (M9)

Based on the analysis of European and Polish regulation recommendations and standards concerning the inspections of machines, the methodology of the inspections has been developed and they are now categorised as:

- initial inspection
- periodic inspection
- special inspection

The methodology was characterised into five categories, which discuss the benefits of carrying out periodic inspections and their relevance:

- general principles, on all machines
- protective devices and screens used in machinery
- woodworking machines
- lasers used in machines
- lighting equipment

The proposed methodology for inspection of the machinery in service is shown in the following figure (Figure 5).

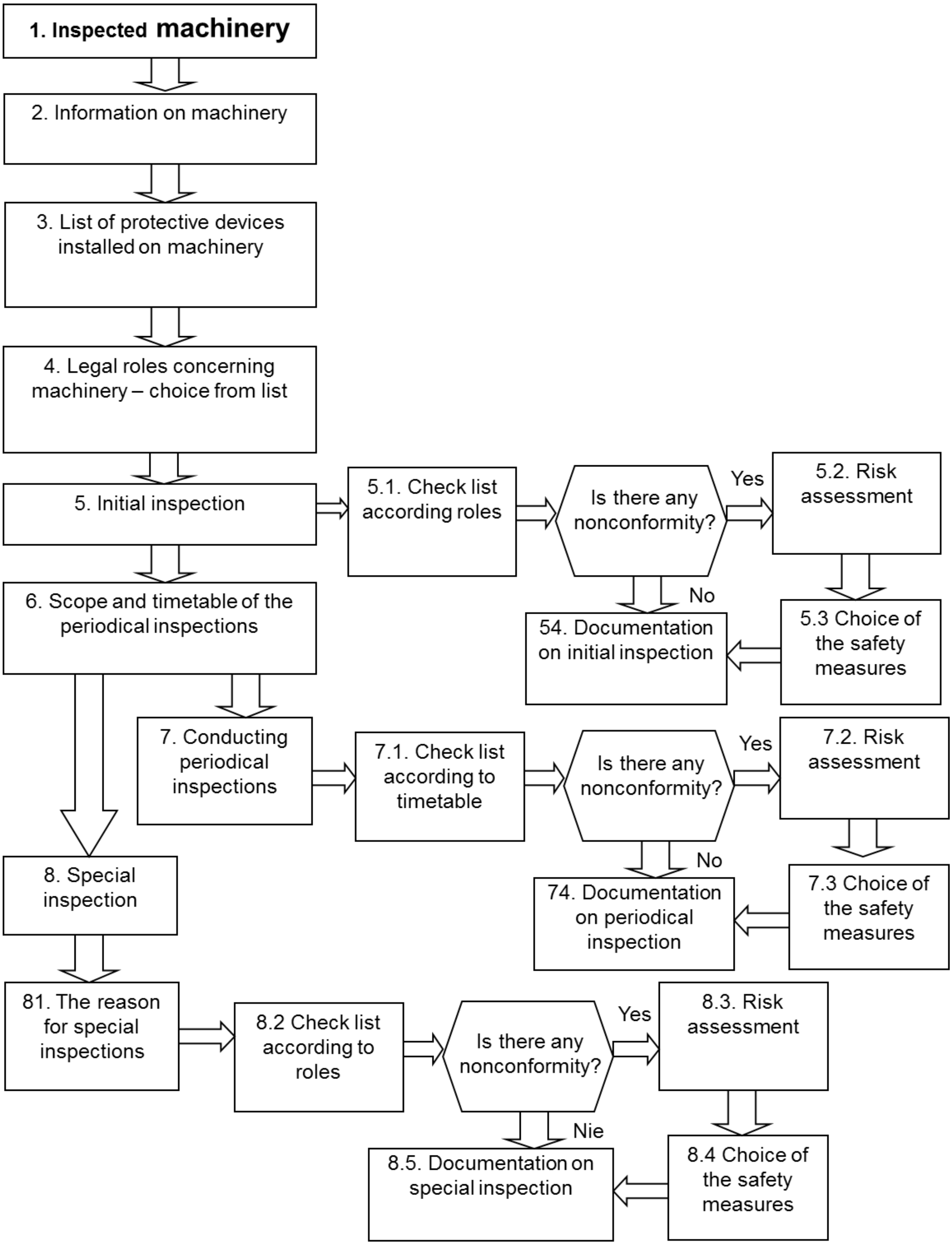

Figure 5: A systematic approach for machinery and work equipment inspection.

The documents have been translated into English and Polish and have been placed in the system TeSaMa. Furthermore, the following checklists have been developed, which take into account the requirements and standards identified in Work Package 2 (WP2) and outline the different types of inspections and the types of machine relevant to these standards. The lists have been included as part of the TeSaMa tool.

1. Check list according to requirements of the 2009/104/WE directive
2. Check list according to polish roles concerning overall safety requirements in work
3. Check list concerning safety requirements for conveyors
4. Check list concerning safety requirements for forklifts
5. Check list concerning safety requirements for rubber articles production
6. Check list concerning safety requirements for rubber plastic processing
7. Check list concerning safety requirements for woodworking processing
8. Check list for inspections of the internal light on machinery
9. Check list for inspections of the machinery equipped with laser

Task 3.2: Development of typical hazards identification procedures and selection of suitable risk assessment methods (M5-M16)

The results of machinery and working equipment inspections should indicate the safety problems existing in typical SME's working environment. To properly solve the indicated safety problems, a holistic risk assessment and risk reduction methodology was applied. This task was dedicated to the identification and classification of typical hazards found in the selected industries environment and choosing the appropriate risk assessment methods. This has been done by defining the reference production processes. The first step involved interviews and questionnaires and was conducted with representatives of selected industries (companies and manufacturer's organisations), experienced safety offices and liability insurance associations. After that, and based on literature reviews and practical evaluation experience, a proposal for risk assessment methods that identify hazards was issued. The selection of risk assessment methods has led to a complete risk methodology, which is self-explanatory, effective and well-adjusted to SME's conditions. The results of these developments are presented in the form of risk assessment algorithms to be implemented in the system as extra functions. In parallel, the necessary descriptions of methods and suitable examples were prepared for tool integration. Together with developed algorithms, the necessary report patterns were delivered.

The following personnel have been deployed:

CIOP-PIB: 5,68 mm	IPT: 2,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 3.2

Deliverable 3.2: The identification procedure for typical hazards at selected industrial environments (M16) / Milestone 3.2: The hazard identification methodology is ready to be implemented into the tool

Besides performing a general check on the safety of the machinery, additional aspects must also be considered – like lighting for example. In order to fulfil all the requirements mentioned in the *Arbeitschutzverordnung* in Germany, a company has to perform a risk assessment of the work place and machinery's lighting systems. The regulation provides a long list of every aspect needing to be checked and if some of these requirements are not fulfilled, the necessary measures are taken to ensure that the workers can fulfil their duties in a safe and adequately lit working environment.

When installing machinery with optical radiation, additional assessments have to be carried out to ensure the safety of the workers. The regulations "Arbeitsschutzverordnung zu künstlicher optischer Strahlung" and the "DGUV Vorschrift 12" are of particular importance and are legally mandatory in Germany. Firstly, the company has to determine the important parameters, such as exposure limits, and possible hazards, like fire or explosion hazards. After having answered all 32 questions and taking notes where necessary, potential countermeasures are suggested in accordance to the regulations; however, the regulation implemented is dependent on their economic situation and the effect it would have on workers' safety.

Deliverable 3.3: A complete risk assessment methodology description for typical hazards

The principles developed that deal with machine inspections have been analysed in detail to identify hazards and consequently create risk assessment methods to combat the hazards identified during the inspection. Recommendations for hazard identification for machines in use and methods of risk assessment for these machines have been developed. These recommendations formed the basis of forms and checklists created to assess the relevant machinery, which, when used correctly, lead to the necessary standard being achieved.

The overall methodology for safety assessment of machinery, including risk assessment, implemented into TeSaMa tool is shown on the following figure (Figure 6).

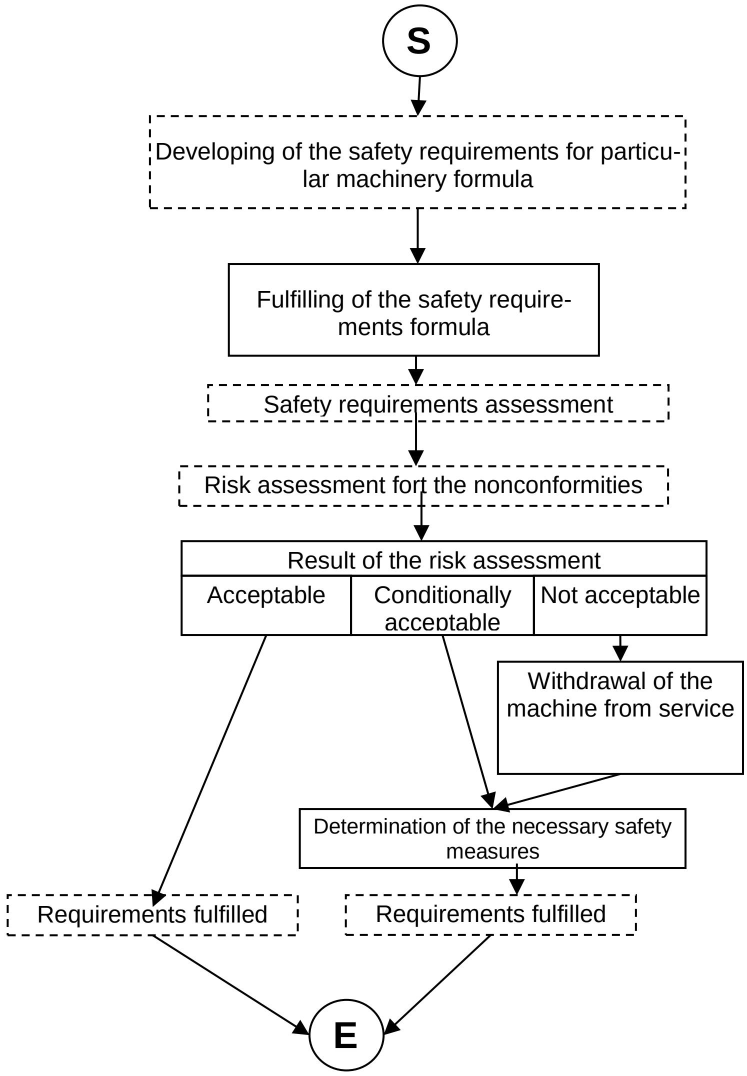

Figure 6: Overall methodology for safety assessment of machinery

This overall methodology has been completed using formulas to conduct risk assessments for inspections of the:

- guards
- protective equipment
- safety measure of woodworking machinery
- internal lighting of the machinery
- machinery equipped with laser

Task 3.3: Development of safety measures selection procedures (M9-M24)

Having achieved the results of hazard identification and risk assessment, the next necessary step was the selection of safety measures to reduce the risks to the required level. According to identified hazards and hazard situations and with the relation to present manufacturing and working environment, the appropriate safety measure selection process has been performed. The safety measure selection process has been presented in a step by step procedure (selection algorithms) oriented to identify hazards, typical machinery and target industries. The safety measure selection process has also covered additional technical solutions (guards, protective equipment, safety related control elements and systems), environment monitoring, personal protective equipment application, safety good practices, staff training, workplace safety instructions, maintenance safety requirements and instructions and others. These also have been presented in parts for knowledge, simple tool, example modules and necessary report patterns to be implemented in the system. The task was performed with participation of experienced safety engineering offices, machinery and working equipment manufacturers, labor inspection and insurance company.

The following personnel have been deployed:

CIOP-PIB: 10,12 mm	IPT: 3,5 mm	IfU: 0,33 mm	DROMA: 0 mm

<u>**Proceedings and Results of Task 3.3**</u>

Deliverable 3.4: The complete safety measures selection procedures for reducing risks relevant to typical hazards (M24)

If the assessment of compliance with the minimum requirements and general occupational safety and health requirements (OSH requirements) fails to confirm the fulfilment of the requirements and an answer obtained is negative, the use of appropriate safety measures is required. The application of these measures should lead to achieving the compliance with the OSH requirements. This may require the machine user to repair machine components and/or safety equipment, upgrade or modify the machine and/or safety equipment (provide additional safety measures, change technology and manufacturing conditions, etc.), change the machine's operational environmental conditions (improvement of ambient lighting) and, in extreme cases, when there are no acceptable solutions for solving the problem, it would require a decision to decommission the machine (e.g. when the risk assessment results indicates its unacceptable level). After the application of safety measures meeting the specified requirement, this risk should be reduced to a level corresponding to at least the legal requirements with regard to the current state of the art.

For risk reduction, the following order of precedence of activities shall apply:

- Inherently safe design solutions

  Inherently safe design solutions eliminate hazards or reduce the risk by appropriate selection of the design characteristics of the machine itself and/or interaction of people exposed and the machine.

- Engineering control measures and/or supplementary protective measures

  Considering the use of the machine in accordance with the intended purpose and foreseeable inappropriate use, engineering control measures or complementary protective measures are used to reduce the risk, if it is not possible to eliminate the hazard or sufficiently reduce the associated risk using inherently safe design solutions.

- Information concerning the use

  Information concerning the use, in terms of the identified residual risks should include in particular:
  - machine operating procedures appropriate for the personnel who will operate the machine or other persons potentially exposed to the hazards posed by the machine
  - recommended safe methods to use the machine and related requirements for required training
  - relevant information, including a warning about residual risks occurring at different stages of machine life
  - description of the recommended personal protection equipment, stating the necessity for its use and provision of training in its use.

An adoption of abovementioned measures should lead to achieving a sufficient risk reduction, which is the condition in which:

- all types of work and methods of interaction are taken into account,
- all hazards were eliminated or risks caused by them were reduced to the lowest level possible in practice,
- all new hazards that have emerged along with the protective measures were properly demonstrated and appropriate protective measures were used,
- users were fully informed and warned of the residual risks,
- mutual compatibility of protective measures used was achieved,
- protective measures taken do not adversely affect the working conditions of the operator or the usefulness of the machine

Protective measures must permit easy use of machines in accordance to their intended purpose, so that users do not attempt to defeat or circumvent the actions of those measures. Such actions may occur when a safety measure:

- slows down the production process
- conflicts with another activity
- interferes with the user’s preferences
- is difficult to use
- engages persons other than the operator
- is not recognised by the user
- is not accepted as appropriate to the implementation of the intended function

For risk identification, a general methodology of risk reduction through the application of security measures was developed, taking into account all necessary activities. The general methodology is complemented by the implementation of specific rules concerning the selection of protective devices by the user on the basis of the residual risks identified by the manufacturer and risk assessments. This methodology has been developed taking into account the following aspects:

- actuators
- visibility of danger zones from the operator station
- control systems
- starting up the machine
- normal stop
- emergency stop
- emission or ejection of substances, materials
- falling or ejected objects
- emission of gases, vapours, liquid or dust
- detachment or disintegration of machine parts
- stability
- moving parts
- lighting of places where work is performed
- extreme temperatures
- warning signals

Additional recommendations have been prepared for organisation of the machinery operation and for training of qualifications of the operators, taking into account:

- maintenance works
- isolation of energy sources
- signs and other safety labelling
- access to places where machines and equipment are used
- fire, explosion and electric shock

Those recommendations have been presented in the form of the tables, including safety requirements and appropriate safety measures for particular requirements.

The overall methodology has been completed by additional recommendations concerning application of safety measures for reducing particular risk:

- typical for woodworking machinery
- related to electrical lighting of machines
- typical for laser devices

For supporting of the proper selection of the safety measures a set of forms and check lists have been developed. Clarifications of the legal documents and standards identified in Task 2.1 have been written to aid the user of the TeSaMa tool. The developed methodology has been prepared in the form of information articles for implementing into the TeSaMa tool as a support for the user.

Cooperation in WP 3

CIOP-PIB and IPT worked together in researching and methodology creation during all tasks. The reference processes were established in both countries by IPT for Germany and CIOP-PIB for Poland respectively, while communication secured that best practices and experiences were constantly exchanged. The safety measures selection procedures have also been elaborated by both institutes in cooperation, while each of them was responsible for translation into national languages. IfU assisted and kept track to assure the close connection of generated methodologies and knowledge to the findings of WP7. CIOP-PIB was the WP leader and maintained the organisation of actions within the tasks and the setting of due dates and regular telephone conferences.

All deliverables and milestones of WP 3 have been fulfilled.

3.5 Work package 4: Machinery safety analysis

3.5.1 Summary

Newly manufactured machinery must comply with the essential safety requirements outlined in machinery directive 2006/42/EC. The aim of this work package was to provide the machinery manufacturers with the following: the necessary knowledge about recommended procedures, comprehensible tools for certain risk assessment procedures and risk assessment reporting with suitable examples, thus satisfying the essential safety requirements for machinery according to directive 2006/42/CE and selected harmonised standards. These supporting items, all aligned for target industries, will be integrated into the established system.

3.5.2 Execution & deliverables

The applicable legal acts, relating standards and necessary information a manufacturer needs for the development and production of machinery were analysed within this work package. The relevant information has been revised and reprocessed into a clear and understandable form so that users who lack the necessary background knowledge gain an easy and quick understanding of the necessary steps to be taken. The safety requirements of the directives and standards have been discussed with the User Committee members for identifying the critical problems needing to be solved. The experts in specific fields have created very particular questionnaires covering all aspects of machinery safety. The general ideas have been explained in information papers prepared for clarification of the approach for the TeSaMa tool users.

Task 4.1: Elaboration of a recommended methodology for machinery safety requirements definition during design and industrialisation (M4-M9)

The important task for machinery manufacturers is to complete all necessary activities, which demonstrate that essential safety requirements depicted in the directive 2006/42/EC were complied fully and properly and the machinery usage risk level is adequately low. The task was focused on elaboration of typical methodology for conducting the machinery manufacturer through all safety requirements aspects as it is done by the machinery directive with giving the indications to harmonised standards, which can help to solve the specific safety problems by adding suitable technical information and to publish recommendation for use. This methodology was applied to develop the simple tool, which helps the manufacturer to monitor the progress of machinery development process in case of safety requirements and then to document it. The task has covered the development of necessary knowledge modules, the modules of the tool as described above and suitable example modules mainly oriented on safety aspects of machinery development at selected industries.

The following personnel have been deployed:

CIOP-PIB: 2,66 mm	IPT: 2 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 4.1

Deliverable 4.1: A methodology for completion of machinery safety requirements during design and fabrication (M9) / Milestone 4.1: The requirements methodology is ready to be implemented into the tool (M9)

In the first step, a methodology for the completion of machine safety requirements during design and fabrication is developed. This methodology ensures that essential requirements are complied with and consists of the following steps:

1. Opening of a new project
    - Project title
    - Manufacturer’s identification data
    - Identification data (including login and password) of a project manager authorised to fill in and modify forms.
    - Project identification number assigned by the project manager
    - Employer’s identification data
    - Project start and end dates
    - Other

2. Indication of the legal act relating to machinery. If the machinery is listed in Annex IV of the Machinery Directive – choice of the conformity assessment procedure
3. Checking for the availability of a type C harmonised standard concerning designed machinery
4. Determination of restrictions concerning the machinery (risk assessment stage)
5. Preliminary hazard identification (risk assessment stage)
6. Preliminary determination of safety requirements (checklist)
7. Specification of harmonised standards for safety requirements (checklist)
8. Selection and application of safety measures
9. Verification of steps 2 to 5
10. Final listing of safety requirements (checklist)

Steps 2 to 4 constitute stages of the risk assessment procedure. It will include, however, tools supporting the execution of steps 1, 5, 6 and 9, taking into account the results of step 7. This methodology has been implemented into the general part of the TeSaMa tool. Particular attention has been focused on the requirements identified that concern guards and protective devices as well as internal lighting of machinery.

The general methodology has been complemented by detailed methodological approaches used for woodworking machinery and machinery equipped by laser.

Requirements concerning wood processing machines

For wood processing machines, common requirements for all machinery are set out in Part 1 “Essential health and safety requirements” of Annex I of the Machinery Directive, as well as in Part 2.3 “Machinery for working wood and materials with similar physical characteristics”. In the case of hand-held wood processing devices, there are also requirements set out in Part 2.2 “Portable hand-held and/or hand-guided machinery”.

Additionally, the tab concerning wood processing machinery includes tools facilitating evaluations of the following:

1. Whether a given machine is listed in Annex IV of the Directive.
2. Which group of machinery (stationary, portable, mobile or hand-held) a given machine can be classed as.
3. Whether the type C standard for a given machine is available (when taking into account an evaluation conducted in accordance with Part 2. If the appropriate type C standard is not available and a given machine is listed in Annex IV of the Directive, the evaluation of compliance procedure, combined with internal check during machine construction phase, shall be unavailable. In this case, the necessity to refer to a notified body which can carry out EC type examination or full quality assurance procedure shall be indicated.

An additional document contains project identification data recorded in the general part of the tool and allows for the data concerning the evaluated machinery, such as the following, to be entered:

1. Type and name of the machine

2. Type (variant) of the machine
3. Serial number
4. Year of construction
5. Name and address of the manufacturer
6. Identification data of technical documentation
7. Description of the machine's intended use
8. Basic technical parameters:
    - Weight
    - Dimensions
    - Tool working speed
    - Feeding speed
    - Cutting tool parameters
    - Supply voltage
    - Number of motors
    - Rated power (or current)
    - Other important parameters
9. Photography of the machine

The standards tab includes the option to automatically or manually create a list containing the most important (of those included in these lists) safety standards pertaining to a given machine.

Requirements concerning machinery where laser equipment is used

Requirements concerning laser radiation emitted in machines are set out in Annex I of the Machinery Directive, Part 1.5.12 "Laser radiation". The requirements are included within the checklist for essential safety requirements and are subject to general rules set out in Chapter 1.

The tab concerning machinery that uses laser equipment also includes tools facilitating an evaluation of compliance with requirements 1.5.12, and the use of harmonised standards in particular.

An additional document created in this tab contains project identification data that was collected in the general section. Moreover, it provides space for entering an identification number, which is automatically entered into the right field on the checklist. The document also provides space for the identification of laser equipment:

1. Function performed by laser equipment in a given machine
2. Applied standard (selected from the list) → a field for a project document identification number
3. Technical data of the applied laser equipment
4. Designated laser safety class

"Determination of safety requirements" is the name of the next tab, and contains fields corresponding to the designated laser class.

The “Laser shield” tab includes the following fields:

- Type of shield (passive/active)
- EN ISO 60825 standard – check-box
- Identification of project document

When designing laser-processing machines, one needs to account for the safety requirements set out in the two parts of EN ISO 11553: 2010 “Safety of machinery. Laser processing machines”:

- Part 1: General safety requirements – concerns laser equipment manufactured exclusively and specifically for applications in photolithography, stereolithography, holography, medicine and data storage.
- Part 2: Safety requirements for hand-held laser processing devices – concerns hand-held or hand-operated equipment not listed in Part 1.

When designing types of protection, the following need to be determined:

- Direction of propagation of laser beam (fixed, variable) with respect to a workpiece
- Type of operation performed (cutting, welding, etc.)
- Material and shape of a workpiece
- Fixing of the workpiece
- Visibility of a processing area

Requirements concerning external blinds

The analysis focuses on the requirements for external blinds. The general requirements are stated in the Construction Products Regulation 305/2011 and the Detail in Standard DIN EN 13561 regulation. In accordance with these regulations there are seven steps that have to be taken into account:

1. Mechanical stiffness and stability
2. Fire protection
3. Hygiene, health and environmental protection
4. Safety and accessibility while usage
5. Noise protection
6. Energy savings and insulation
7. Sustainable use of resources

There are five different hazards specifically named in this regulation. These have to be evaluated by the manufacturer before a product can be placed on the market. The five hazards are:

- Wind load
- Water gatherings
- Operational force

- Safety of usage
- Incorrect operation

In addition to the findings above, an external blind equipped with a motor has to fulfil all the common requirements described in Part 1 of the “Essential health and safety requirements of Annex 1 of the machinery directive”. To ensure that all of these requirements are being fulfilled, a questionnaire has been set up for the tool, in which the manufacturer can check if all the necessary requirements are fulfilled, or if changes have to be made to the design.

Taking the Construction Products Regulation 305/2011 into account was not within the scope of the project, nor a concern of the User and Steering Committees during its meeting on 16.09.2015 in Warsaw. Consequently, they decided that external blinds will be excluded from the TeSaMa tool.

Task 4.2: Development of a case-oriented risk assessment methodology for machinery development (M5-M16)

To comply with essential safety requirements according to directive 2006/42/EC, in several cases it is necessary to perform specific risk assessment procedures. There is not one, common risk assessment method for all machinery hazards, so the hazards must be identified from within possible procedures. Also some experience in risk assessment was desired, especially for the risk estimation section, so that proper results are gathered and risks are effectively reduced. The task focused on the elaboration of hazard recognition methodology, the application of a proper risk estimation method and finally the risk evaluation determining the necessity of additional safety measures. The results of the task were presented as a guide through the full risk assessment procedure for machinery according to the requirements of directive 2006/42/EC (knowledge part) – thus linking specific risk estimation procedures (simple tools part) to examples of these procedures in application (example part). It was also developed as a simple tool for useful progress monitoring support and as a complete risk assessment procedure for machinery.

The following personnel have been deployed:

CIOP-PIB: 8,89 mm	IPT: 3 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 4.2

Deliverable 4.2: A complete risk assessment methodology for the machinery development (M16) / Milestone 4.2: The risk assessment methodology is ready to be implemented into the tool (M16)

The objective of this task was to develop a methodology for risk assessment, which should be undertaken by the machine designer in accordance with Directive 2006/42/EC. This methodology has been included in the system as a simple tool that is useful to the manufacturer of the machine at the point where a risk posed by the machine is too big and the use of safety measures to its reduction is necessary. As per provisions set out in WP1, multiple tools are currently available to facilitate the risk assessment procedure, and therefore the TeSaMa system will not include any special tools for risk assessment. However, recommendations on how to conduct the risk assessment have been developed.

In accordance with the methodology for determining the safety requirements during the design and manufacturing of new machines, the conformity assessment process should be applied according to the requirements of Directive 2006/42/EC based on the provisions of the harmonised standards. A general algorithm of conduct includes the following points:

1. Whether a specific requirement of the directive 2006/42/EC will be implemented with the use of the harmonised standard type C (standard contains the requirements for the selected machine or group of machines)? If so, in terms of the requirements it is not necessary to conduct a detailed risk assessment, and it should indicate the specific solution associated with specific security measures derived from the C-type standards. The fulfilment of the requirements must be documented by corresponding entries, thus it is recommended to draw up specific requirements checklist bulk here according to type C covering the specified range to the requirements of Directive 2006/42/EC.
2. Whether a specific requirement of the directive 2006/42/EC will be implemented with the use of the harmonised standard PN-EN ISO 12100: “safety of machinery-2012 – General principles of design-risk assessment and reduction of risks” (General standard type and containing the basic safety requirements relating to all machines)? If so, the requirements of a risk assessment should be carried out and the recommended safety measures have to be chosen. This procedure is recommended in the case of machinery in respect of which no standards have been developed. The fulfilment of the requirements must be documented.
3. Whether a specific requirement of the directive 2006/42/EC will be carried out directly on the basis of an entry in the directive? If so, in terms of requirements, it is necessary to carry out a risk assessment, which in practice is carried out only by checking the application of proven solutions. The use of innovative methods of risk assessment and selection of safety measures requires careful documentation of their effectiveness and relevance to the issues.

Evaluation of the fulfilment of the essential requirements of the directive 2006/42/EC shall be carried out on the basis of a properly prepared checklist, which contains the reference to risk assessments associated with various threats and situations and to the results of the selection of security measures. The principle of developing a checklist assumes that it will result in answers to questions (issues) included in the list. The answer Yes (positive, type "Yes") confirms the fulfilment of the requirements. Alternately, when for some reason a question does not apply to machinery or is not compliant with the requirements is answered in the negative (negative, such as "no"). At this stage in the evaluation the fulfilment of these requirements could not be confirmed.

Conducting an evaluation of the fulfilment of the essential requirements for machinery based on the aforementioned checklists and using computer tools, requires the development of an electronic form (e-form), which allows an evaluation result of each partial requirement to develop in a uniform way, thus resulting in a comprehensive assessment.

Evaluation of the fulfilment of the specific safety requirements is connected to carrying out specific project activities, whose essence boils down to the implementation of the procedures for risk assessments. It should be noted that the full procedure consists of an assessment strategy and risk reduction (see p. 4 and 5 of the standard PN-EN ISO 12100:2012):

- determination of the limits of the machinery (see p. 5.3 PN EN ISO 12100:2012)
- the identification of hazards and hazardous situations – in this respect point 5.4 of the standard PN-EN ISO 12100:2012 will help
- estimation and evaluation of risk (see p. 5.5 standard PN EN ISO 12100:2012)
- the decision on the application of the safety measures (see p. 5.6 PN EN ISO 12100:2012)
- inherently safe design to eliminate hazards or specific emergency situations (see p. 6.2 standard PN EN ISO 12100:2012)
- the use of technical safety measures that reduce the risk (see p. 6.3 PN EN ISO 12100:2012)
- the framework of the implementation of technical safety measures shall be subject to the selection and use of guards and protective devices, design requirements for guards and protection devices, the use of technical protection measures mitigation
- the use of complementary safety measures that reduce the risk (see p. 6.3.5 PN EN ISO 12100:2012)
- the development of information for safe operation (see p. 6.4 PN EN ISO 12100:2012) – including, in particular, the location and the type of information relating to the use, signals and warning devices, marking, symbols and inscriptions, warning accompanying documentation including the user manual

The identification of hazards and hazardous situations and the use of the supplementary and technical safety measures are crucial from the point of view of the fulfilment of the essential requirements. Especially important is the residual risk remaining after the application of the safety measures and information about safety measures which should be applied by the user of the machine.

The form for the assessment of the fulfilment of the essential requirements for the machines should be the basic document providing for the right to carry out risk assessment and selection of the appropriate safety measures. For this reason, its content is adapted to the kind of threats and hazardous situations and safety measures. In addition, the form should include information about residual risk and the need for additional safety measures (for example, the use of personal protective equipment, organisational measures, or the appropriate lighting of the place of use of the machine).

Given the above, the evaluation of the fulfilment of the essential requirements should include the following:

- the symbol of the form – a unique code that identifies the type and the next version of electronic form
- machine ID – a unique designation code assigned to a digital machine
- electronic form date – this date should match the date of the risk assessment
- the name of the machine, its type, possibly information about the series
- description of the machine – brief information about how to use it in accordance with the intended purpose
- information about the limitations of the machine
- information about the prohibited ways to use
- identification of the essential requirements of the directive 2006/42/EC (according to points of annex I, the content of the point)
- information on whether the requirement applies to machines – select "yes" or "no"
- information on whether the requirement has been met – select "yes" or "no"
- a description of the hazards should refer to the requirements of Directive 2006/42/EC
- kind of expected risk assessment – is it anticipated that the risk assessment can be carried out
  a) according to the type of C,
  b) according to the standard EN ISO 12100:2012 and standards type B
  c) according to Directive 2006/42/EC with proven safety measures
- the basis of the risk assessment – an indication of the risk assessment methods or document (standards) on the basis of the risk assessment
- the result of the risk assessment – description of the risk assessment and an indication of the document that contains the specific information or an indication of conformity declaration on the basis of whether it fulfils of requirements
- applied safety measures – description of the safety measures to reduce the risk to the level required by Directive 2006/42/EC
- information about residual risk

For supporting risk assessment procedure the following have been developed:

- a set of definitions concerning risk assessment.
- suggestions concerning the definition of the machine
- a set of important aspects of the machinery use
- characteristics of the harmonised standards
- examples of tasks and accompanied hazard
- a list of hazards: sources and possible consequences
- dangerous events
- qualitative risk assessment
- quantitative risk assessment

- risk evaluation – acceptance criteria
- risk evaluation – comparison with other similar machines
- risk assessment tables – examples
- form of risk assessment in the conformity assessment process

Additionally for an overall methodology for risk assessment, the particular forms have been developed for assessing of risk related to:

- failures of the control systems
- woodworking machinery
- machinery equipped with lasers
- internal lighting of the machinery.

Task 4.3: Development of safety measures selection methodology for the machinery development (M9-M24)

The selection of safety measures for machinery is an important part of risk assessment and risk reduction recurrent process, which should lower the existing risk level to the level not higher than required by directive 2006/42/EC. The proper safety measure selection process is not obvious, because of different hazards, different technical possibilities, different environment influences and different machinery limits. It is also necessary to comply to safety measures with human limits and possibility of misuse. All this makes the safety measures selection process significantly complicated and demands a clear methodology enabling proper results. The task has focused on this methodology, which is presented in modules dedicated for guiding through safety measure selection (knowledge), necessary calculations (simple tool) and practical examples.

The following personnel have been deployed:

CIOP-PIB: 12,75 mm	IPT: 5,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 4.3

Deliverable 4.3: A complete methodology for the safety measures selection for machinery development (M24) / Milestone 4.3: The methodology for safety measures selection is ready to be implemented into the tool (M24)

The methodology for the safety measure selection for machinery development has been created by taking into account that the objective of risk reduction can be achieved by eliminating hazards or reducing, either individually or simultaneously, each of the two elements of risk:

- the severity of damage caused by the hazard under consideration

- the probability of damage occurrence

Actions aimed to achieve this objective should be taken in a specific order:

- *Application of inherently safe design solutions* – eliminating hazards or reducing the associated risks by an appropriate selection of the design characteristics of the machine itself and/or the interaction of exposed people and the machine. As a result of these actions, the hazard can be eliminated, which makes it unnecessary to use additional protective measures
- *Application of engineering control measures and/or complementary protective measures* – when it is not feasible to eliminate the hazard or reduce the associated risks to a sufficient degree with the use of inherently safe design solutions
- *Information on the use* – if the risk remains despite the use of inherently safe design solutions, engineering control measures and/or complementary protective measures. Information concerning the use should include information on residual risks identified. This information should not be considered as a measure replacing the correct application of the above inherently safe design solutions and engineering control measures or complementary protective measures.

An adoption of these measures should lead to achieving a sufficient risk reduction, i.e. the condition in which:

- all types of work and methods of interaction are taken into account
- all hazards are eliminated or risks caused by them are reduced to the lowest level possible in practice
- all new hazards that have emerged along with the protective measures are properly demonstrated and appropriate protective measures are used
- users are fully informed and warned of residual risks
- mutual compatibility of protective measures used is achieved
- the consequences are sufficiently taken into account, if the machine designed for professional/industrial use is used for non-professional/non-industrial purposes
- protective measures taken do not adversely affect the working conditions of the operator or the usefulness of the machine

Protective measures must permit easy use of machines in accordance with their intended purpose, so that users do not attempt to defeat or circumvent the actions of those measures. Such actions may occur when a safety measure:

- slows down the production process
- conflicts with another activity
- interferes with the user's preferences
- is difficult to use
- engages persons other than the operator
- is not recognised by the user
- is not accepted by the user as appropriate to the intended function

In Figure 8, the algorithm of the selection of safety measures for sufficient reduction of risk is presented.

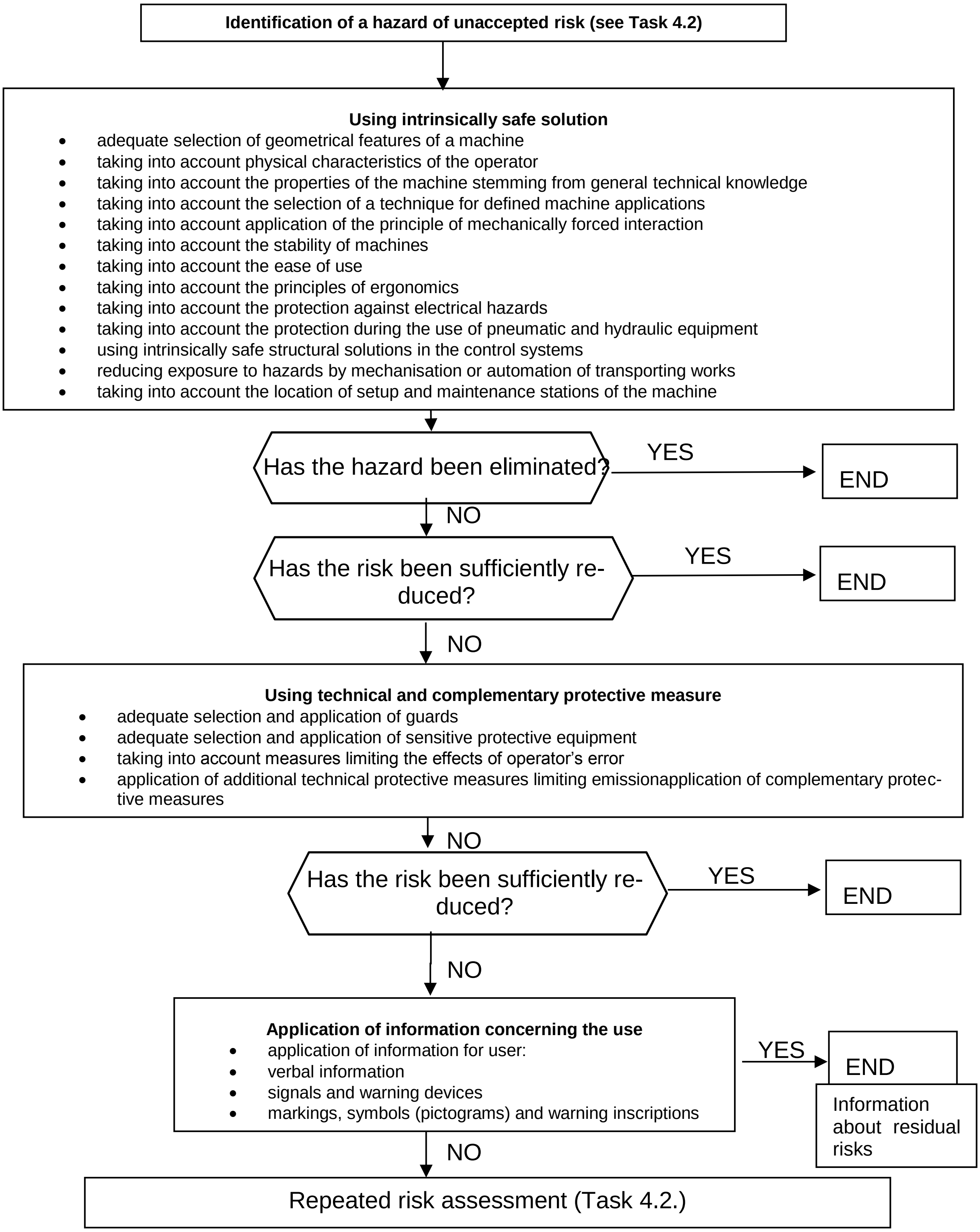

Figure 8: Algorithm of conduct for the selection of safety measures for machines

The guidance, including practical examples, has been developed for every step of this algorithm. Detailed guidance has been developed for selection of the safety measure for:

- woodworking machinery
- machinery equipped with laser
- internal lighting of machinery

For supporting the selection of the safety measure, the forms for assessment of correctness of safety measures used in wood processing machines and the assessment of the safety distances have been created and included into the TeSaMa tool.

Cooperation in WP 4

CIOP-PIB and IPT worked on the development of the required methodologies and procedures and their adaptation to directive requirements and typical practice. The reference processes were established in both countries by IPT for Germany and CIOP-PIB for Poland respectively, while communication secured that best practices and experiences were constantly exchanged. The safety measures selection procedures have also been elaborated by both institutes in cooperation, while each of them was responsible for translation into national languages. IfU assisted and kept track to assure the close connection of generated methodologies and knowledge to the findings of WP7. IPT was the WP leader and maintained the organisation of actions within the tasks and the setting of due dates and regular telephone conferences.

All deliverables and milestones of WP 4 have been fulfilled.

3.6 Work Package 5 : Development of a software tool for a technical safety maintenance system in manufacturing

3.6.1 Summary

In this WP, a software tool for a technical safety maintenance system for machinery has been developed. The software provides access via a web browser to knowledge on OSH problems and outlines some potential manufacturing technical safety solutions and tools for fulfilling the relevant requirements.

3.6.2 Execution & deliverables

Task 5.1: Basic tool development (M1-M9)

The software in the form of web based application was developed. End users have access to all data and tools via a web browser. During this task, a proper CMS (Content Management System) has been chosen and modified in order to implement basic user interface functionality and basic content management algorithms.

During this task, a preliminary version of the software was created. Appropriate technology was chosen in accordance with the results of the analyses described in **Deliverable 1.5: Technical requirement specification**, and in **Deliverable 1.6: Software environments analysis.**

The following personnel have been deployed:

CIOP-PIB: 4,36 mm	IPT: 0 mm	IfU: 0 mm	DROMA: 0 mm

<u>Proceedings and Results of Task 5.1</u>

Deliverable 5.1: Preliminary version of computer tool (M9) / Milestone 5.1: The preliminary version of the tool is finished (M9)

The basic functions developed as part of this project include:

- Simplified graphical user interface
- Simplified version of CMS (Content Management System)
- Simplified login module
- Simplified user management module of the system (9)
- Simplified module content sharing features to be selected after logging in
- Simplified forum module for the exchange of knowledge, allowing for the establishment of new topics and the publication and editing of the message
- Simplified management module concerning the machines assigned to the user logged on the system (ability to add, delete, or modify the selected parameters)
- Simplified calendar module that informs the user about events related to the machines assigned to the user
- The opportunity to change the language of the each web page (three different languages are available)

Figure 9: User management module.

Task 5.2 – Integration phase and tool adjustment (M9-M24)

As part of this task, algorithms were implemented that governed the interactive elements of the tool and made it more user-friendly. The content of WPs 2, 3, 4 and 7 were integrated into the tool and sorted accordingly. The structure of the tool for users from different ME Subsectors was also refined during this task.

The following personnel have been deployed:

CIOP-PIB: 18,94 mm	IPT: 3,5 mm	IfU: 1 mm	DROMA: 0 mm

Proceedings and Results of Task 5.2

Deliverable 5.2: The complete implementation of the content of WP2, WP3, WP4 and WP7 into the software tool (M24)

As an initial step, specific modules of the tool were developed systematically, using the results of WP3 and WP4. For example, the initial graphical user interface was improved based on comments made by the User Committee Members.

The functions of the tool were extended so that projects relating to new machines could be monitored and the user interface automatically adjusted to suit the type of the project. The adaptations include:

- Storing the information in the database for future projects
- Adding, deleting or modifying the project
- List of projects

- Selection of the active project
- Modification of the user interface depending on the type of project (a new kind of machine)
- A unique graphical user interface for new woodworking machines
- A unique graphical user interface for the new machine that is equipped with a laser source

A tool function was also created that, in the case of new machinery, has the ability to

- identify information about the project, and then edit and store it in database form
- identify design solutions for the selection and application of security measures in accordance with Directive 2006/42/EC
- identify the forms needed to meet lighting requirements
- identify the safety requirements necessary and the scope of the laser device in a new type of machine, all in accordance with Directive 2006/42/EC of the machines for woodworking.

The scope of the safety requirements depends on the laser, which affects the safety shields in place and the safety requirements implemented. Additionally, a preliminary version of the new interface was prepared in the alternative languages offered (English and German). Moreover, example content was also drawn-up in order to enable software testing and consequently, the tests were carried out.

Actions were then carried out that ensured that the materials developed in WP 2,3,4 and 7 could be adapted to fit the requirements of an online web-based tool. The materials were grouped and sorted to facilitate the machine's evaluation process and to ensure that the correct sequence of implementing of the assessment is carried out. This encompassed the creation of electronic and interactive forms as well as checklists in particular. In the case of the in-service machinery, the entire operational lifecycle of the machine whilst it is in the factory was taken into account – e.g. when it was put into use, when periodic and special inspections were carried out, etc. A special module was also added that contains a schedule indicating the dates of the next periodic inspection.

In terms of new machines, the main change was the addition of fully functional modules:

- Risk assessment method of qualitative and quantitative data in accordance with the requirements of the selected standards (Figure 10)
- Evaluation of the relevant safety functions
- Selection and application of security measures, taking into account safety solutions in themselves, technical and supplementary protective measures and information concerning their use
- Profitability analysis evaluating the costs and benefits of the various methods of risk reduction – including technical risk reduction. This module contains interactive graphs to help carry out the analysis in a visual manner.

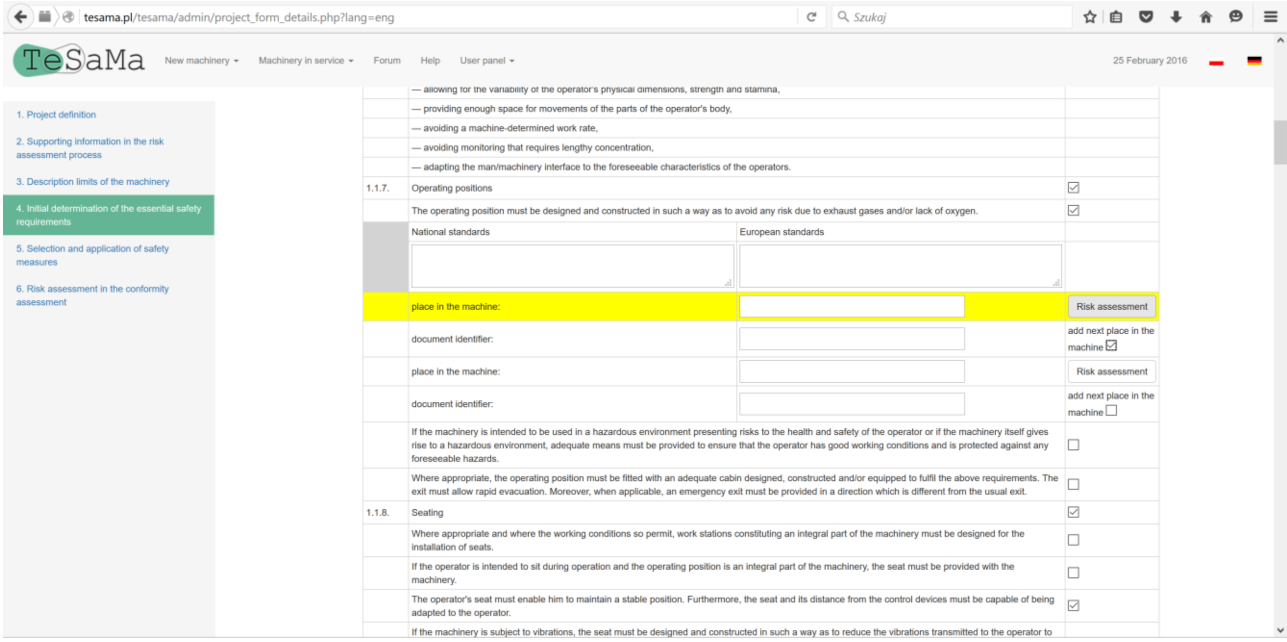

Figure 10: Risk assessment button for operating positions as part of the initial determination of essential safety requirements.

An important element of the work was the addition of an interactive, context-sensitive help system that aids the user in filling out forms and managing the data input (Figure 11).

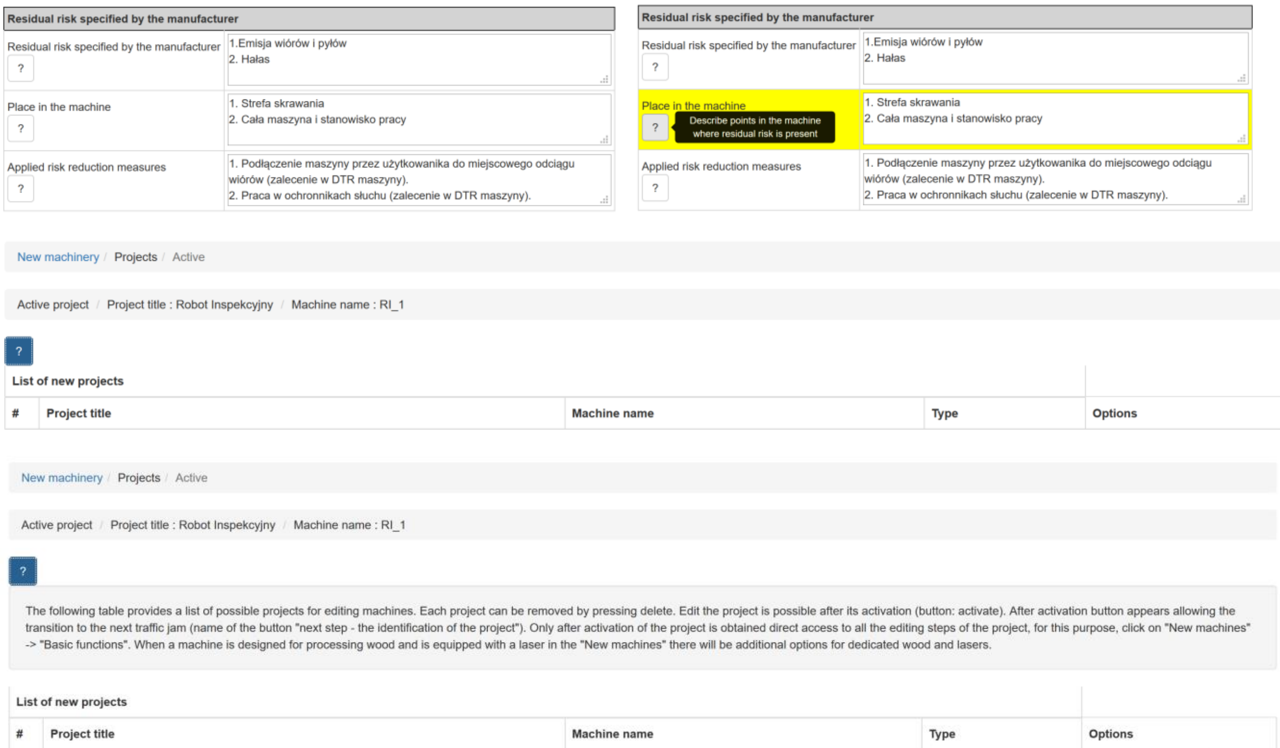

Figure 11: Examples of the interactive, context-sensitive help system.

mPDF, a program which allows you to generate and download selected documents in PDF format (Figure 12), was integrated into the module.

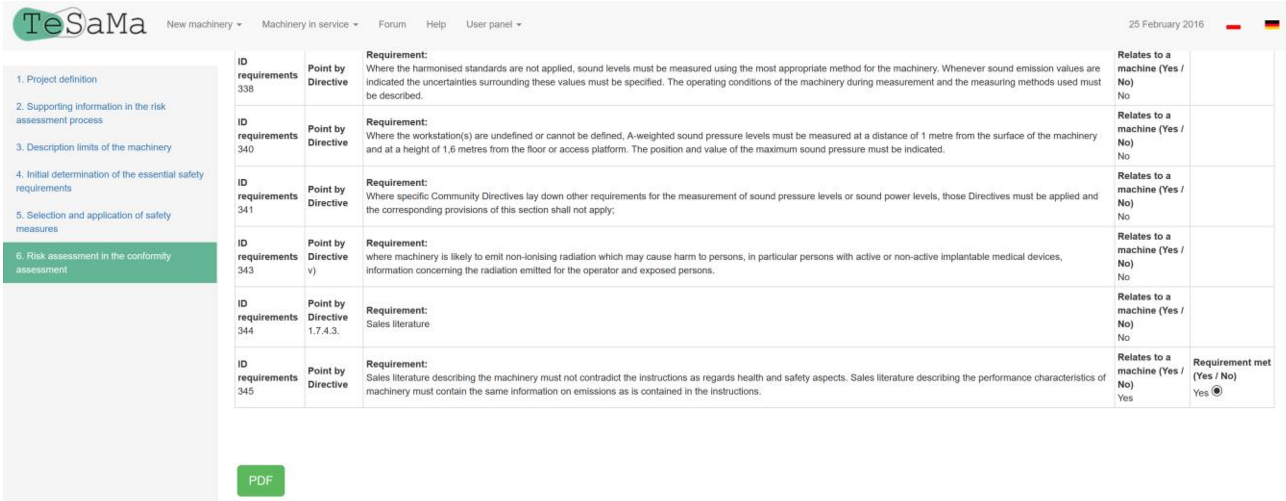

Figure 12: Button for generating the pdf version of the risk assessment as part of the conformity assessment.

<u>Task 5.3: Tool testing and extra functionalities</u>

Taking into account the results of usability tests, the tool was enhanced, optimised and uploaded onto a server. Any functionality that was not integrated during the previous task was analysed and solutions for the integration were elaborated, tested and integrated. Eventually, the final version of the tool was made available online.

The tool was systematically tested after each development step. Work has also begun on testing the tool and removing errors in the system – like the storage of information in the database, project definition, modification of the interface, as well as the definition, editing and storage of information.

The following personnel have been deployed:

CIOP-PIB: 9,56 mm	IPT: 0 mm	IfU: 0 mm	DROMA: 0mm

<u>Proceedings and Results of Task 5.3</u>

Deliverable 5.3: Final version of the web-based tool (M24) / Milestone 5.2: The final version of the tool is available on-line (M24)

In order to facilitate these tests, which were conducted by experts and potential users, a complete tool was placed on a server that could be accessed via the Internet portal www.tesama.pl. Participants taking part in the tests received passwords to access the full system. A form was also drawn-up to facilitate the reporting of problems and errors, as well as to enable the systemisation and verification of the functions of the system. The information gathered from the participants was then used to improve the performance and extend the functions of the system. All of the reports were taken into account and as such, the system was improved. After these changes were implemented, a set of functional tests were carried out, with experts sending reports on system malfunctions. The revised version has now been made available to the public at www.tesama.pl.

Cooperation in WP 5

CIOP-PIB was the WP leader and provided resources for the overall programming of the tool. In the integration phase, CIOP-PIB, IfU and IPT jointly provided the data, methodologies and operations that had to be integrated. CIOP-PIB then provided the technical implementation of those contents via transformation of data, creation of assisting tools (e.g. for upload of data) and creating algorithms. CIOP-PIB also provided the tool tests and the enhancement of the tool.

All deliverables and milestones of WP 5 have been fulfilled.

3.7 Work Package 6 : Usability testing

3.7.1 Summary

Usability tests were performed using an expert inspection (UI) method and a user testing (UT) method. Necessary improvements and corrections were added to the tool.

3.7.2 Execution & deliverables

During and after the development of the software tool IfU, IPT and CIOP conducted analyses on a regular basis. The analyses were performed by applying an example case to the tool.

Task 6.1: Task 6.1: Usability testing by expert inspection (M17-M22)

Experts from CIOP-PIB and IPT used the system for conducting examples with existing machines and work places and use cases by experts of CIOP-PIB and IPT. During these test cases, the functionality of the system was reviewed and assessed. As a result, recommendations for the improvement of the system as well as information about any additional content were collected and implemented.

The following personnel have been deployed:

CIOP-PIB: 5,28 mm	IPT: 1,5 mm	IfU: 0,33 mm

Proceedings and Results of Task 6.1

Deliverable 6.1: A complete list of experts recommendation (M24) / Milestone 6.1: Finalised expert inspections (M22)

Testing of the EI method was conducted by 6 experts from CIOP-PIB and IPT. Experts conducted independent action attempts to the system and tools developed, by applying them to practical cases:

- Bending machines for reinforcing bars
- Woodworking machinery
- Laboratory model for inspecting robots
- Machine tools for metals with internal lighting
- Safety component – emergency stop controller

Each of the machines was used by a different expert and in order to standardise how successful the error reporting system was, "an incorrect declaration from the TeSaMa system" was used. During the tests, the same machines were used, but were treated as new machines and equipment, which allowed for a mutual relationship to develop between the two modules. As a result, the entire range of developed tools was tested 6 times, which allowed for the identification of virtually all programming errors.

IPT was able to check various factors at once by creating a project for a drawbridge. Testing could be carried out regarding the extent of conformity the tool has to the necessary requirements for this project. The focus areas of these analyses are the following two aspects:

- Improving the graphical user interface
- Testing the process structure

Improving the graphical user interface

The interface was tested throughout the validation process. This process not only involved changing the arrangement of buttons and text fields on the screen, but also checking the existing information texts. These texts were analysed in regard to their ability to guide uninformed users through the conformity process. The aim was to create a tool that users with little knowledge about the product safety process can use and easily access the necessary information about required procedures. In order to make this information available, additional information (help texts) were created and added to the various steps of the tool. The grammar of the text fields already implemented was checked, as was their ability to inform the user about the necessary steps to be taken. These checks of the text were conducted on both the English and German sections of the tool and the IPT provided the CIOP with all necessary German translations.

Focus was also placed on the arrangement and functionality of buttons during the graphical user interface test. The aim of this step was to identify whether the tool had a clear recognisable structure, i.e. the arrangement of the buttons in a user-friendly way that meant the required button could be found without the need to search for it. Furthermore, the different steps of the tool have been designed in a similar fashion to allow the user the ability to quickly find the necessary information.

Testing the process structure

By applying a use case to the software tool, factors in need of improvement and the functionality of the graphical user interface can be extensively tested. The user case was necessary in order to check the logical connections between each step of the assessment. The choice of a specific option then has ripple effects on the steps that follow. The manufacturer, for example, must choose to evaluate either the mechanical or electrical hazards of the machine and consider counter-measures, should something happen during the use of the machine. These choices are logical connections and must be periodically evaluated in case errors are present, thus affecting the solutions offered.

The tests also reveal whether there are important safety features missing from the text, in which case the missing features are added to the list to ensure all safety hazards and requirements were covered by the test.

Task 6.2: Usability testing by users (M17-M22)

In addition to task 6.1, the system was checked by selected members of the User Committee. They used the system for conducting examples with existing work places in their production machines and their own machine development. Afterwards, they assessed the practicability and usability of the system and gave constructive feedback. Their recommendations were introduced into the system in work package 6.3.

The following personnel have been deployed:

CIOP-PIB: 0 mm	IPT: 1,5 mm	IfU: 0,33 mm	DROMA: 0 mm

Proceedings and Results of Task 6.2

Deliverable 6.2: Results of user assessment (M24) / Milestone 6.2: Finalised user testing (M22)

After implementing the necessary modifications identified in the EI task, the system was tested by potential users, who were selected from among the User Committee members. They attempted to use the TeSaMa system to evaluate the produced machines and also machines used. Comments on the usefulness and usability of the system were collected from specially designed survey forms. The survey supplied was based on adaptations of the THERE (extended Technology Acceptance Model, on the basis of Venkatesh and Davis, 2000) and SUS (the System Usability Scale) questionnaires. Each of the questions (with the exception of one descriptive question) were answered by a 7-degree Likert scale from 1 (strongly disagree) to 7 (strongly agree).

System errors identified during tests carried out by experts during Task 6.1 were corrected in Task 5.3. Completed questionnaires assessing risk assessment evaluations and checklists used in the TeSaMa system were used as case studies.

As a result, surveys from 3 members of the Polish User Committee and 2 from the German User Committee members were obtained. The vast majority (18 of 21) of questions were positive ("I would like to use the system", "the system is useful", "it improves my performance and efficiency", etc.). The average responses ranged between "somewhat agree" and "agree". In the case of negative answers ("the system is difficult to use", "the system requires a large effort" etc.), "I don't agree" was the dominant answer (8 of 11). It can, therefore, be considered that a positive assessment of the usefulness of the system has been gained.

Task 6.3: Review of the pilot cases (M22-M24)

The generated data of the tasks 6.1 and 6.2 has been reviewed carefully in order to separate individual information seen in the test cases from universally valid results that can be implemented into the tool. Besides, as the generated data may be available in different forms such as excel sheets or presentations or prose, the reviewed data had to be formatted to be a useful input into the tool. Data of test cases conducted with members of the User Committee have been made anonymous due to non-disclosure agreements.

The following personnel have been deployed:

CIOP-PIB: 0,22 mm	IPT: 1,32 mm	IfU: 0,33 mm	DROMA: 0 mm

<u>Proceedings and Results of Task 6.3</u>

As a results of task the tasks 6.1 and 6.2, the full documentations of the 6 machines has been created. It includes information concerning machinery development process, as well as the information concerning inspection of that machinery during exploitation. The documentation has been created for the following machinery:

- Bending machines for reinforcing bars
- Woodworking machinery (2 types)
- Laboratory model for inspecting robots
- Machine tools for metals with internal lighting
- Safety component - emergency stop controller

Those documentations have been analysed in detail. The most typical solutions have been chosen as examples and case studies for incorporation into the TeSaMa tool.

Cooperation in WP 6

CIOP-PIB was the WP leader and responsible for the constant feedback from the test cases to the tool developers, who were at the same time working on the integration task, which is task 5.2. CIOP-PIB and IPT established and conducted use cases together with selected User Committee members, both for Germany and Poland respectively. In addition, self-generated use cases were used and the results were assessed by experts from CIOP-PIB, IfU and IPT likewise. Close cooperation was necessary to assure the relevance of the generated use cases and to learn from the use cases conducted by the other institute. Also, the formatting of data had to be organised, and in the end the integrated material had to be translated into the national languages by both partners.

All deliverables and milestones of WP 6 have been fulfilled.

3.8 Work Package 7 : Cost-benefit analysis

3.8.1 Summary

The core task of this project is to standardise the assessment of work and product-related risks by making them accessible to SMEs in the mechanical engineering sector via an easy to use software tool. Yet past experience has shown that these types of knowledge bases are only used if businesses are able to quickly assess the potential monetary benefits and costs. Thus, the task of this work package was to provide SMEs with the appropriate tools to be able to approximate the monetary benefits and risks of their current OSH-status, their product safety compliance status and evaluate potential improvements. WP7 culminated in a monetary assessment manual, which outlines the evaluation software.

3.8.2 Execution & deliverables

3.8.2.1 Task 7.1 Analysis of existing concepts

In order to enable an evaluation of costs and benefits that is suitable for an SME, existing concepts were analysed and compared in regards to performance, applicability, degree of independence from business intelligence, costs and other factors identified as key requirements.

The following personnel have been deployed:

CIOP-PIB: 0 mm	IPT: 0,5 mm	IfU: 3 mm

Proceedings and Results of Task 7.1

Deliverable 7.1: Systematisation of cost- and benefit-evaluation concepts (M9) / Milestone 7.1: Finalised evaluation concept analysis (M6)

Before implementing new safety measures, an economic assessment is required to determine whether the proposed safety measure can improve work and machine safety, whilst being profitable. The oldest and easiest approach to measure profitability is to calculate the quotient of the benefits and costs:

$$profitability = \frac{benefits}{costs}$$

This approach is essential to most profitability analyses. An overview of different models can be seen in Figure 13. There are different approaches to these profitability evaluations: Traditional Profitability Analysis (TPA); an Advanced Profitability Analysis (APA) and static and dynamic methods. Static methods monitor changes in cash flows over time, whereas dynamic methods are suitable for longitudinal evaluations. Several static and dynamic TPA approaches are introduced in the following paragraphs (Hoffmeister 2008, Vining & Meredith 2000).

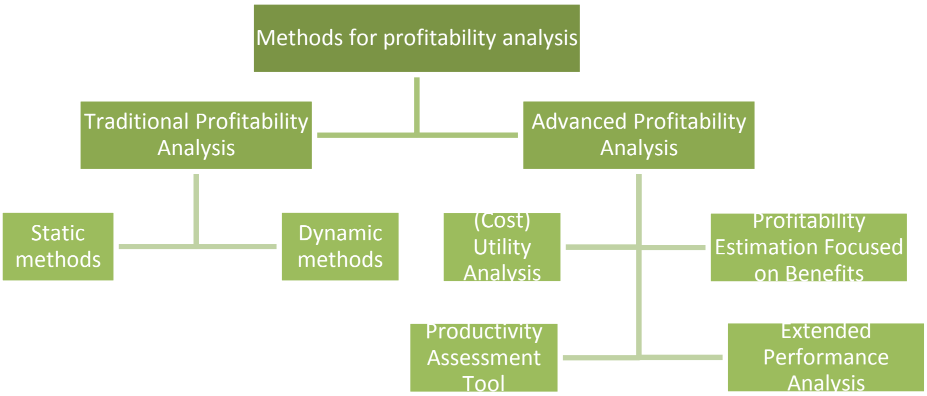

Figure 13: Overview of Methods for profitability Analysis

Static methods of Traditional Profitability Analysis

All static methods work on the same principle: a statement about the advantageousness of different alternatives is made by comparing averages of the chosen selection criterion in one representative period.

Two very easy static TPA methods are the Cost Comparison Method, which compares average costs per period, and the Profit Comparison Method, which compares average benefits per period. Based on these comparisons, the option with the lowest costs or the highest benefits is chosen. In this manner, all direct cost and benefit types can be taken into account.

Another commonly used method is the calculation of Return on Investment (ROI), which is the quotient of average profits and the capital expenditure of one of these alternatives. The results of the Cost and Profit Comparison methods are used to calculate both the numerator and the denominator of the ROI formula.

$$ROI = \frac{benefits}{costs} \cdot 100\% \tag{2}$$

The Static Payback Rule uses the results of Cost- and Profit Comparison Methods to calculate the “break-even-point” (where the average profits exceed the average capital expenditure). Mathematically the payback time is inverse of the ROI. The payments after the break-even-point are not included in the calculation.

All static methods have similar advantages and disadvantages.

Advantages	**Disadvantages**
• Easy to use • Easy information procurement via input from accounting department	• No complex decisions • Only monetary values → easy information procurement • Only one “representative” period • Only comparisons • No uncertainties or risks • Some methods have no theoretical foundation • Implicit assumptions

Table 5: Advantages and disadvantages of static methods of TPA

Dynamic methods of Traditional Profitability Analysis

The main advantage of static methods is their simplicity; however, they are unsuitable for long-term investment decisions. Dynamic methods allow the user to view and evaluate cash flows over time, making dynamic models much more practical as they can handle more complex situations (Hoffmeister 2008).

The most frequently used dynamic method, the Net Present Value (NPV), uses the sum of all cash flows C_t in every period of time t, including the initial negative cash flow C_0- i.e. the initial investment. The sum of all cash flows is discounted with the interest rate r. The sum of all Discounted Cash Flows is called the Present Value and by adding $C_{0,}$ the Net Present Value is calculated.

$$NPV = C_0 + PV = C_0 + \sum_{i=1}^{T} \frac{C_t}{(1+r)^t} \tag{3}$$

If the NPV is positive, the decision can be considered advantageous and if it is negative then disadvantageous, making a general statement concerning advantageousness possible (Brealey et al. 2011).

The Dynamic Payback Period Rule determines the point in time at which the NPV is 0 – the break-even-point – by taking the time of each payment into consideration (Hoffmeister 2008).

A similar approach is the Internal Rate of Return, with the only difference being that it does not calculate a point in time at which the NPV is 0; instead it calculates the average interest rate *r*. The decision is advantageous if the interest rate calculated is higher than the Internal Rate of Return and it is assumed that the payback period is known or it can be estimated (Hoffmeister 2008). However, some criticise this method as it uses inconsistent assumptions (Bieg, Kußmaul 2000).

The Annuity Method is another approach used that is based on the NPV. It calculates the constant cash flow (Annuity) that could be taken from the profits of the project, allowing the NPV to be just above 0. The decision can be considered advantageous if the annuity is positive (Hoffmeister 2008).

Advantages and disadvantages of dynamic approaches are similar as all are based on the NPV.

Advantages	**Disadvantages**
• Well suited for complex decisions • Changes monitored longitudinally • Explicit assumptions (more or less). → better theoretical foundation • Use of financial-mathematical methods • Partly expandable • General statement concerning advantageousness • Relatively easy to use	• Simplifications used to make models work • Uncertain interest rates • Considerable efforts to collect all necessary data • Some inconsistent assumptions • Complicated comparison of alternatives

Table 6: Advantages and Disadvantages of dynamic methods of TPA

Most business decisions today, including investments in machine- and workplace safety, are rather complex and affect many different aspects of work life. These aspects can have different probabilities of occurrence, durations and approximation accuracies. However, the Traditional Profitability Analysis approaches are not meant to incorporate these uncertainties and instead need to be filled in with monetary values. Non-monetary aspects are either not considered or have to be monetised before they are incorporated into the formula. TPA methods usually do not give concrete advice on how to deal with situations in which uncertainties occur or non-monetary aspects have to be considered. Advanced Profitability Analysis Methods were developed to take into account monetary and non-monetary aspects, which are generally not that easy to ascertain, and give concrete guidance on how to conduct the analysis in various situations. All APA methods are based on the general principles of TPA methods.

Advanced Profitability Analysis Methods

Advanced Profitability Analysis methods can be divided into either “single-layered”/“multi-layered” methods or “one-dimensional”/“multi-dimensional” methods. Whilst in single-layered methods all effects are transferred into one monetary or non-monetary unit, in multi-layered methods monetary and non-monetary effects are evaluated separately. The separation into one- and multi-dimensional methods derives from the dimensionality of the target system, i.e. whether there are numerous dimensions to the objective (Zangemeister 2000).

As part of the Cost Benefit analysis, APA methods should combine the advantages of TPA and pure qualitative approaches. Monetary and non-monetary aspects are calculated, in order to divide aspects into direct, indirect and uncertain impact classes (Pittermann 1998), which also need to be weighted and prioritised. Information searches and evaluations should not purely be executed by financial experts – as is the case with TPA – but also by a holistic group of experts. Finally, it should be easy to perform in order to save time, effort and money (Printz et al. 2015).

While TPA methods have been extensively researched in the past, APA methods are, despite their potential, still underrepresented (Graham & Harvey 2001).

The Utility Analysis is a single-layered, non-monetary and multi-dimensional method that allows the user to evaluate qualitative effects on the target system. The use value U is calculated from the sum of all weighed (w_j) target values $u(k_j)$. The target value is calculated for all m criteria from the target income k_j of the evaluated comparison alternatives.

$$U = \sum_{j=1}^{m} \left[w_j \cdot u(k_j) \right] \; mit \; j = 1, \dots, m \; und \sum_{j=1}^{m} w_j = 1 \tag{4}$$

There is no standardised way of weighing the target values, so the w_j are always subjective and interdependence and probabilities of occurrence are not factored in, which can distort the results. (Warnecke et al. 1996)

The Cost Utility Analysis can be transferred into a monetary analysis method by monetising all the values of $u(k_j)$ instead of using only qualitative measures. Based on the Cost Utility Analysis, the Cost Effectiveness Analysis uses the calculated utility as the numerator and compares it to the costs in the denominator (Zangemeister & Nolting 1999).

Advantages	**Disadvantages**
• Use of common units of measure • Weighing of target values • Incorporation of qualitative and quantitative variables • High transparency	• Weighing is always subjective • Interdependencies between variables cannot be factored in • No probabilities of occurrence for different variables • Monetisation can be difficult

Table 7: Advantages and Disadvantages of Cost Utility and Cost Effectiveness Analysis

The Extended Performance Analysis was developed as a holistic evaluation tool for RFID investments. It is based on the combination of Balanced Scorecards and Strategy Maps. It was developed for evaluating costs, benefits and risks of RFID applications, which can be characterised as monetary and non-monetary (both directly and not directly quantifiable respectively). The latter can be evaluated using proxy attributes. After collecting all the data about different effects, they can be transferred into the Evaluation Map and sorted into four different perspectives – market, processes, resources and information systems. The Evaluation Map shows cause and effect relationships between the perspectives (Seiter et al. 2007).

Advantages	**Disadvantages**
• Holistic measurement • Objectification of results • Sensitivity analysis is possible (use of distribution functions)	• Very elaborate/complex method • Not easy to use • No application in other fields outside of RFID investments yet • No objective evaluation of the technique available yet

Table 8: Advantages and Disadvantages of the Extended Performance Analysis

Another APA method is the Productivity Assessment Tool – a “computer-based cost benefit analysis model for the economic assessment of occupational health and safety interventions in the workplace” (Oxenburgh, Marlow 2005). It takes into account direct costs of injury, as well as additional “hidden” costs. It calculates the productivity and losses as a result of injuries, by comparing the decrease in the rate of production to the rate of production at the ideal state (the employee at full productivity) (Oxenburgh, Marlow 2005).

The method is based in the computer software productAbility. TeSaMa can compare the situation before and after an OHS intervention, even if it is only for relatively short time frames, and also compare suggestions for improving cost effectiveness. Additionally the software allows sensitivity analyses and rehabilitation cost effectiveness calculations. The analysis consists of four parts:

- employee data
- workplace data
- the intervention itself
- reports concerning the intervention and its effects

The data can usually be obtained from accounting and payroll systems (Oxenburgh, Marlow 2005).

Advantages	Disadvantages
• Computer software available • Direct and “hidden” costs • Relatively easy to obtain data from accounting and payroll systems • Sensitivity analysis possible	• Large amounts of data required • Mainly for ergonomics and job design → not 100% suitable for machine safety • No objective assessment of method available

Table 9: Advantages and Disadvantages of the Productivity Assessment Tool

The Profitability Estimation Focused on Benefits (PEFB) is a management cybernetic approach for the evaluation of costs and benefits of an investment. It is based on the Cost-Utility Analysis of IBM from the 1980’s and was originally developed by Dirk Weydandt at the Institute for Management Cybernetics e.V. (IfU), the Institute of Information Management in Mechanical Engineering (IMA) and the Centre for Learning and Knowledge Management (ZLW) of RWTH Aachen University. It is suitable for use in the evaluation of decisions for technical investments, training measures and many other areas (Weydandt 2000).

The PEFB method combines the classical economic analysis in monetary terms and the relevant non-monetary variables. This approach expands the limited quantifiable objectives (costs and revenues – hard factors) of traditional economic efficiency approaches. The PEFB approach also considers the non-monetary objectives like quality, flexibility and employee motivation (soft factors), facilitating a holistic overview of the investment being assessed (Strina et al. 2003).

Advantages	Disadvantages
• Holistic approach • Incorporation of hard and soft factors • Comparability (monetisation) • Incorporation of different levels of assertiveness of costs, benefits and probabilities of occurrence • Complex technical and financial (micro- and macroeconomic) problems • Ex-ante and ex-post evaluation • Easy interpretation of results • Participation-based • Relatively low effort necessary	• Mostly static • Dependent on subjective, already established factors/numbers • Dependent on quality of data • Monetisation necessary (single-layered) • Possibility of interdependencies in the target system

Table 10: Advantages and Disadvantages of the Profitability Estimation Focused on Benefits

Table 11 summarises the advantages and disadvantages in regards to the four key factors identified by the research team. These key factors are divided into several sub-factors, which are assigned a qualitative value consisting of positive (+), neutral (0) and negative (-) evaluations. The last rows show the total assessment values and all methods are ranked accordingly.

Table 11 shows that the Profitability Estimation Focused on Benefits achieves the highest value in the rankings. The method's performance is high, its applicability broad, information procurement easy and its costs are usually in an appropriate frame. Based on this assessment, PEFB is chosen as the preferred method for profitability assessment within the machine and work place safety tool. The next chapter gives an overview of the principles and application of the method.

Table 11: Comparison of methods for profitability analysis

Key Factor/Method	Static Traditional Profitability Analysis	Dynamic Traditional Profitability Analysis	(Cost)Utility Analysis/Cost Effectiveness Analysis	Extended Performace Analysis	Productivity Assessment Tool	Profitability Estimation Focused on Benefits
Performance	---	+	0	++++	++++	+++
Complexity of Decision	low	middle	middle	high	high	high
Objectivity	high	high	subjective weightings	partly subjective, sensititvity analysis possible	high, sensibility analysis possible	subjective factors, incorporation of probabilities
Different aspects/impact classes	only monetary	only monetary	usually non-monetary OR monetary	monetary, non-monetary direct, non-monetary indirect	direct injury costs and "hidden" costs	monetary, non-monetary, direct, indirect and difficult to ascertain factors, all monetized
Time dependency (short-/longterm)	no	yes	possible	possible	yes, usually short-term	mostly static
General statement (advantageousness)	only comparison	partly	(C)UA: comparison, CEA: general statement	yes	yes	yes
Applicability	+	0	+	--	+	+++
General Applicability	easy investment decisions	more complex investment decicions	different kinds of decisions	so far only RFID Investments	so far mainly for ergonomics and job design	technical, financial, economical problems
Suitability für OHS/MS	limited	limited	limited	no information	probable	probable
Easy to use	very easy	easy	easy	elaborate	rather easy, software available	rather easy, participation based
Information Procurement	+	--	0	0	-	++
Different Experts (holistic)	only financial data	only financial data	possible to include different points of view	possible to include different points of view	usually data from accounting and payroll systems	participation based approach, holistic, experts from different fields
Effort to collect data	low	middle	middle	high	middle	middle
Estimation quality	usually no estimation necessary	with specific uncertainty	subjective estimations with uncertainty	dependent on quality of data, specific uncertainty	dependent on quality of data, specific uncertainty	dependent on quality of data, specific uncertainty
Costs	++	+	+	-	0	0
Total	+	0	++	+	++++	++++++++
Ranking	5	6	3	4	2	1

Profitability Analysis Focused on Benefits

As can be seen from Table 11, the Profitability Analysis Focused on Benefits was chosen as the most promising method to use in the developed tool. An overview of the method and its advantages and disadvantages was provided in the previous chapter. This chapter describes how to perform a profitability analysis using the seven-step PEFB method (Figure 14). The phases are outlined below:

Step 1 sees the creation of an interdisciplinary team that represents the complete sociotechnical system of the enterprise. Step 2 is an analysis of the current situation, taking into account all the important factors, without copying the system already in use. Step 3 involves predefining the target situation by identifying and classifying all requirements according to their necessity. Actions to be taken are defined and compiled in Step 4. The interdisciplinary team should be involved in all of these decisions (Strina et al. 2003).

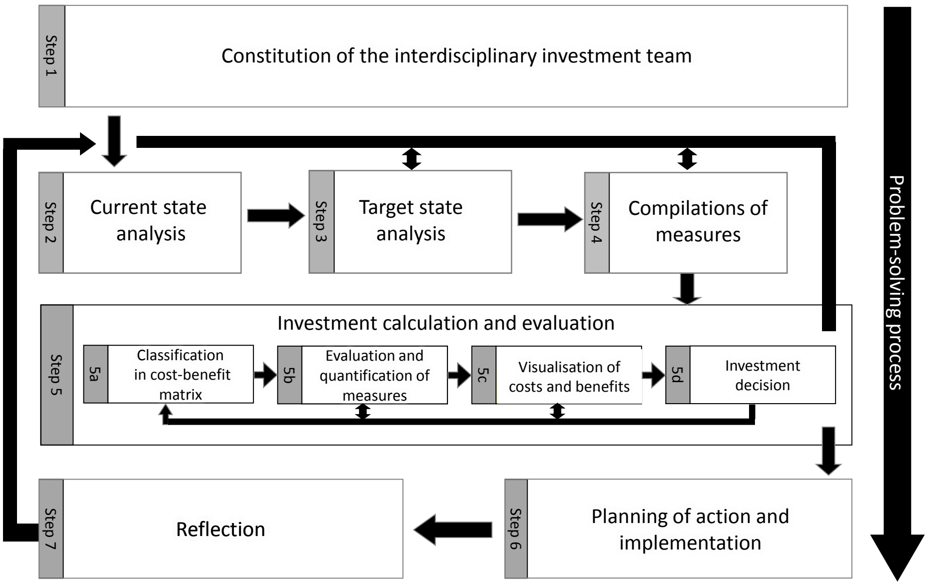

Figure 14: The PEFB Method (Printz et al. 2015)

In Step 5, the investment evaluation is divided into four sub-steps 5a to 5d. Step 5a classifies the defined measures into 3x3 cost-benefit-matrixes. In the matrix the different factors are characterised as “direct, indirect and difficult to ascertain” (Strina et al. 2003).

Direct benefits occur as a result of savings on certain costs or increases of incoming cash flow and are therefore easy to ascertain (e.g. decrease of capital and maintenance costs). Factors classed as indirect benefits include future savings or increased positive cash flows. These are more difficult to directly assess, e.g. increased productivity. The advantages of Strategic Benefits, like the positive effects of image improvement for example, are difficult to assess (Weydandt 2000).

Direct costs, like acquisition, education and training costs, are widely known and easy to assess. Indirect costs are future costs that can be estimated, like external consulting costs, and are usually more difficult to assess than direct costs. Consequential costs are difficult to ascertain because they are hard to assess, like, for example, costs that occur through noise-induced stress (Weydandt 2000).

In step 5b, using the classifications from 5a, the factors are valued and probabilities of occurrence classified as “high, medium or low”. To visualise the results of steps 5a and 5b the risk levels must be first prioritised and then ordered (see Figure 15) in matrixes. The prioritisation and accumulation of the benefits is carried out using data from the groups with direct benefits and a high probability of occurrence, down to groups with difficult to ascertain benefits and low probability of occurrence. The prioritisation and accumulation of the costs is done in the inverse direction (Strina et al. 2003).

		Probability of occurence		
		high	medium	low
Cost/Benefit component	direct	1	3	6
	indirect	2	5	8
	difficult to ascertain	4	7	9

Figure 15: Cost-Benefit portfolio (Printz et al. 2015)

Step 5c involves of the visualisation of the cumulated costs and benefits within the risk-levels, which importantly reverses the direction of the cumulated cost curve, thus contrasting the “safe” benefits with “unsafe” costs curve and vice versa. If the benefit curve exceeds the cost curve, a gain in benefits is expected and contra to this a loss of benefit is expected. The area to the left-hand side of risk level 5 can be interpreted as the “pessimistic” section and the area to the right as “optimistic” (Strina et al. 2003).

If the intersection point of the two curves is located in the pessimistic section, the investment is advantageous and profitable. Figure 16 depicts the cost-benefit curve. The investment decision is made in Step 5d.

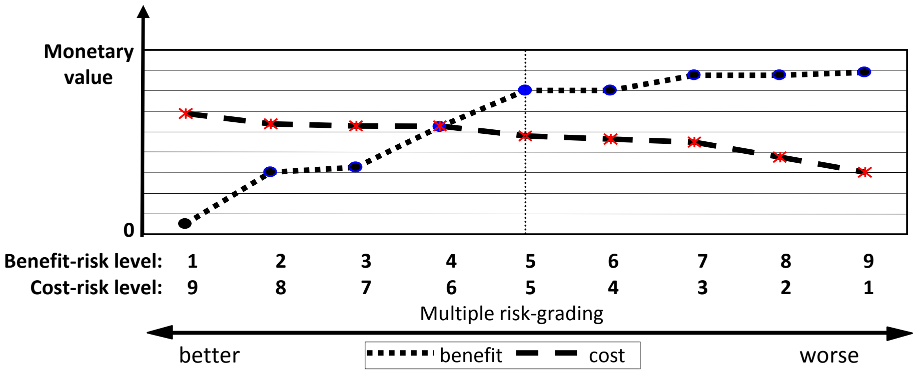

Figure 16: Risk levels visualisation based on costs-benefits evaluation (Printz et al. 2015)

In step 6 the relevant measures are implemented if the investment decision made is positive. It is important that participants from the interdisciplinary investment team are directly involved in the process in order to directly incorporate strategy evaluations into the transfer process (Strina et al. 2003).

Step 7 involves a reflection by the interdisciplinary team on the decision-making process, the decision itself and experiences of the process (planning, evaluation, implementation and supervision). Recommendations are then made on possible courses of action and improvements for subsequent training sessions and further education processes (Strina et al. 2003).

Due to its broad field of application and the holistic approach, incorporating both hard and soft factors and the ability to include difficult to ascertain costs and benefits, the PEFB method can be used for profitability analysis of many different situations.

3.8.2.2 Task 7.2 Monetary quantification of key risk-factors and potential countermeasures

Building upon the results of WP3 and WP4, the risks and benefits identified for OSH and product-safety are analysed within a scenario, thus identifying the relevant cost drivers that determine the costs of removing a work or machine related safety issue. In a second step, an evaluation of these cost drivers is carried out in order to determine their relevance to generic work or machine related safety issues. A qualitative system dynamics model is also built at this stage to uncover potentially complex dependencies between cost drivers, which in turn could change the relevance of individual factors and easily identify the relevant cost factors to the TeSaMa users. Task 7.2 results in a final list of cost factors deemed likely to determine the costs of implementing machine and work safety solutions.

The following personnel have been deployed:

CIOP-PIB: 0 mm	IPT: 0,5 mm	IfU: 3 mm

<u>**Proceedings and Results of Task 7.2**</u>

Deliverable 7.2: Systematisation of risk-factors and countermeasures by monetary impact (M12) / Milestone 7.2: Finalised monetary quantification factors system (M10)

System Dynamics Model of cost factors

Figure 9 shows the intermediary result of Task 7.2, the qualitative System Dynamics Model of the identified cost factors, which determines the average costs of implementing a safety measure. The factors displayed were identified in a workshop held by the German TeSaMa User Committee. In this workshop, a real case study – regarding the operation of a drawbridge to a flight simulator – from the User Committee member CAE Elektronik GmbH was used and analysed.

The drawbridge scenario was chosen as it is an example of a work (CAE as operator) and machine (CAE as manufacturer) safety-critical component. A potential safety risk arises due to the drawbridge's slow lowering speed (30+ seconds for the full process), which causes annoyance with the flight simulator users who might approach and enter the drawbridge too early, i.e. while the bridge is not fully lowered, risking severe injuries. A safety barrier was installed to prevent such a scenario, though this mechanism can be bypassed. Considering this safety risk, the User Committee offered two technical designs for improving the safety of the barrier. Firstly, increasing the speed of the bridge, thus reducing the incentive to bypass the barrier and secondly, installing a second safety mechanism, keeping the barrier closed until the bridge is fully lowered. It was decided that that the first solution should be discarded as it would require substantial modifications of the whole technical system. Therefore, the second solution was selected to be the subject of the PEFB-workshop (see Chapter 3.8.2.1). In the workshop, the cost factors of implementing the solution were collected, aggregated, systematised, and valuated according to the PEFB-method.

In order to generate a complete list of the most relevant generic cost factors associated with work or machine safety solutions, the cost factors from the CAE case have been expanded. In the following sections the research institutes discuss additional cases until iteration resulted in no additional factors. The result is a list of generalised cost factors, which were used in the TeSaMa tool to evaluate the monetary consequences of a work or machine safety risk solution.

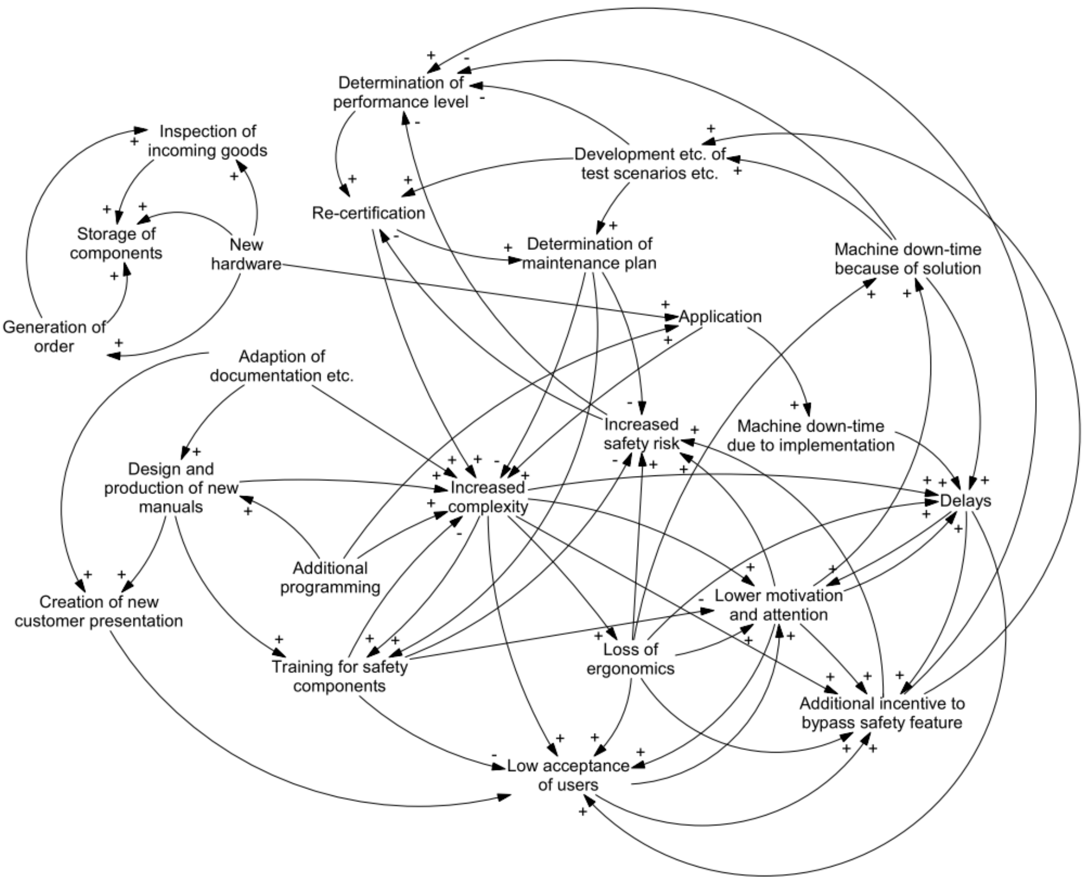

Figure 17: System Dynamics Model of cost factors

List of cost factors

Table 12 provides the cost factors identified in Task 7.2. On the left-hand side of the table, the cost factors mentioned at the UC-meeting are listed alongside their PEFB-categorisation (see Figure 6), including the type of cost (direct, indirect and difficult to ascertain) and the likelihood of occurrence (high, middle and low). The right-hand side of the table lists the generalised cost factors potentially applicable to other development and safety projects. Again, the list is accompanied by the PEFB-categorisation. The columns “Influenced by” and “Influencing” are based on the links between the cost factors in the System Dynamics Model shown in Figure 17.

Table 12: Cost factors from workshop and general-

Workshop					Generalised					
Name	Category	Type	Likelihood	Value	Name	Category	Type	Likelihood	Influenced by	Influencing
Adaption of documentation, design, planning, production	1	direct	high	3000	Cost for the adaption of documentation, design-changes and production planning (personnel costs, stationary etc.)	1	direct	high		Manuals (+) Customer presentation (+) Increased complexity (+)
Production planning	1	direct	high	-						
CAD-sketch	1	direct	high	-						
Expenses for product planning	1	direct	high	-						
Performance level	1	direct	high	500	Expenses for determination of the performance level (safety engineers, software, stationary etc.)	1	direct	high	Test scenarios (-) Machine down-time because of solution (-) Bypassing safety feature (-) Increased safety risk (-)	Re-certification (+)
Develop, check and document test scenarios, technical approval	1	direct	high	1000	Costs for the development, checking and documentation of test scenarios, possible faults and emergency functions (safety engineers, software, stationary etc.)	1	direct	high	Bypassing safety feature (+) Machine down-time because of solution (+)	Performance level (-) Re-certification (+) Maintenance-plan (+)
Looking at possible failures and emergency functions	1	direct	high	-						
Hardware	1	direct	high	18000	Expenses for new hardware (material costs)	1	direct	high		Application (+) Generate order (+) Inspection of incoming goods (+) Storage (+)
New handling procedure (manual)	1	direct	high	2500	Expenses for the design and production of new manuals (maintenance and operation) (personnel costs, material costs, production and distribution costs)	1	direct	high	Documentation (+) Programming (+) Maintenance plan (+)	Training (+) Customer presentation (+) Increased complexity (+)
Deliver documentation	1	direct	high	200						

Table 12 (cont.): Cost factors from workshop and generalised

Workshop					Generalised					
Name	Category	Type	Likelihood	Value	Name	Category	Type	Likelihood	Influenced by	Influencing
Re-certification	1	direct	high	500	Costs for re-certification (material costs for documentation, personnel costs for safety engineers or outside contractors etc.)	1	direct	high	Test scenarios (+) Performance level (+) Increased safety risk (-)	Maintenance plan (+) Increased complexity (+)
-	-	-	-	-	Expenses for additional programming (programmers, software costs etc.)	1 3	direct	high or middle		Application (+) Manuals (+) Increased complexity (+)
Determine maintenance plan	3	direct	middle	-	Costs for determination of maintenance plan (personnel costs, stationary etc.)	1 3	direct	high or middle	Test scenarios (+) Re-Certification (+) Increased complexity (+)	Training (+) Increased complexity (-) Increased safety risk (-)
-	-	-	-	-	Storage costs for components	1 3	direct	high or middle	Generate order (+) Hardware (+) Inspection of incoming goods (+)	
Expenses for application	1	direct	high	6000	Expenses for the application (cost for technicians, functional testing, machine down time due to installation and testing etc.)	1 2	direct or indirect	high	Hardware (+) Programming (+)	Machine down-time due to implementation of solution (+) Increased complexity (+)
Generate order	1	direct	high	6000	Cost for formal generation of order (procurement department, delivery cost etc.)	1 2	direct or indirect	high	Hardware (+)	Inspection of incoming goods (+) Storage (+)

Table 12 (cont.): Cost factors from workshop and generalised

Workshop					Generalised					
Name	Category	Type	Likelihood	Value	Name	Category	Type	Likelihood	Influenced by	Influencing
Inspection of incoming components	1	direct	high	600	Inspection of incoming goods (personnel costs)	1 2	direct or indirect	high	Generate order (+) Hardware (+)	Storage (+)
Training for safety components	3	direct	middle	2000	Expenses for training for safety components	1, 2 3, 5	direct or indirect	high or middle	Manuals (+) Maintenance plan (+) Increased complexity (+)	Increased complexity (-) Lower motivation and attention (-) Increased safety risk (-) Low acceptance of users (-)
Create "Customer presentation"	5	indirect	middle	5000	Expenses for the creation of new "Customer presentation" (personnel costs, stationary, software etc.)	3 5	direct or indirect	middle	Documentation (+) Manuals (+)	Low acceptance of users (-)
-	-	-	-	-	Delays (loss of productivity - loss of income)	2 5	indirect	high or middle	Machine down-time due to implementation of solution (+) Machine down-time because of solution (+) Increased complexity (+) Loss of ergonomics (+)	Bypassing safety feature (+) Lower motivation and attention (+) Low acceptance of users (+)
Schedule installation (system down time)	6	direct	low	60000	Machine down-time due to implementation of solution (loss of income)	2 5 8	indirect	high, middle or low	Application (+)	Delays (+)
System failure due to solution	6	direct	low	-	Machine down-time because of solution (loss of income)	8	indirect	low	Loss of ergonomics (+) Lower motivation and attention (+)	Performance level (-) Test scenarios (+) Delays (+)

Table 12 (cont.): Cost factors from workshop and general-

Workshop					Generalised					
Name	Category	Type	Likelihood	Value	Name	Category	Type	Likelihood	Influenced by	Influencing
Not-calculated costs (10 %)	4	difficult to ascertain	high	12500	Not-calculated costs (10 %) (costs that cannot be foreseen but usually occur in safety projects, dependent on experience of safety engineers and technicians)	4 7	difficult to ascertain	high or middle	all	
-	-	-	-	-	Costs for increased complexity	4 7	difficult to ascertain	high or middle	Documentation (+) Application (+) Manuals (+) Programming (+) Training (-)	Training (+) Delays (+) Bypassing safety feature (+) Loss of ergonomics (+) Lower motivation and attention (+) Low acceptance of users (+)
-	-	-	-	-	Loss of ergonomics (loss of productivity - loss of income)	7	difficult to ascertain	middle	Increased complexity (+)	Delays (+) Machine down-time because of solution (+) Bypassing safety feature (+) Lower motivation and attention (+) Low acceptance of users (+) Increased safety risk (+)
-	-	-	-	-	Lower motivation and attention (loss of productivity - loss of income)	7	difficult to ascertain	middle	Training (-) Increased complexity (+) Loss of ergonomics (+) Low acceptance of users (+)	Delays (+) Machine down-time because of solution (+) Bypassing safety feature (+) Increased safety risk (+) Low acceptance of users (+)

Table 12 (cont.): Cost factors from workshop and generalised

Workshop					Generalised					
Name	Category	Type	Likelihood	Value	Name	Category	Type	Likelihood	Influenced by	Influencing
Additional incentive to bypass safety (maintenance)	7	difficult to ascertain	middle	20000	Additional incentive to bypass safety feature (costs for additional safety risks)	7 9	difficult to ascertain	middle or low	Delays (+) Increased complexity (+) Loss of ergonomics (+) Lower motivation and attention (+) Low acceptance of users (+)	Performance level (+) Test scenarios (+) Increased safety risk (+)
Problems of acceptance (user)	9	difficult to ascertain	low	-	Low acceptance of users (loss of productivity - loss of income)	7 9	difficult to ascertain	middle or low	Delays (+) Training (-) Customer presentation (-) Increased complexity (+) Loss of ergonomics (+) Lower motivation and attention	Bypassing safety feature (+) Lower motivation and attention (+)
-	-	-	-	-	Increased safety risk (additional costs that might occur through new safety risks)	9	difficult to ascertain	low	Maintenance-plan (-) Training (-) Bypassing safety feature (+) Lower motivation and attention (+) Loss of ergonomics (+)	Performance level (-) Re-certification (-)

In the following section the different cost factors from Table 12 and Figure 17 are listed. The factors to be considered in safety projects are clustered in accordance with the PEFB method into direct, indirect and difficult to ascertain cost groups.

Direct cost factors

- Cost for the adaption of documentation, design-changes and production planning
- Expenses for the determination of the performance level
- Costs for the development, checking and documentation of test scenarios, possible faults and emergency functions
- Expenses for new hardware
- Expenses for the design and production of new manuals (maintenance and operation)
- Costs for re-certification
- Expenses for additional programming
- Costs for determination of maintenance plan
- Storage costs for components
- Expenses for the application
- Cost for formal generation of order
- Inspection of incoming goods
- Expenses for training for safety components
- Expenses for the creation of new "Customer presentation"

Indirect cost factors

- Delays (loss of productivity)
- Machine downtime due to implementation of solution
- Machine downtime because of solution

Cost factors that are difficult to ascertain

- Not-calculated costs (10%)
- Costs for increased complexity (for worker and developer)
- Loss of ergonomics
- Lower motivation and attention
- Additional incentive to bypass safety feature
- Low acceptance of users
- Increased safety risk

3.8.2.3 Task 7.3 Development of assessment manual and integration into the software tool

The results of Task 7.1 and Task 7.2 were combined to identify and develop the methods for best approximating the costs and benefits of OSH and product-safety related risks. The conclusion is summarised in a manual containing the necessary knowledge for understanding and undertaking an evaluation of the costs, benefits and countermeasures of a new safety feature.

The following personnel have been deployed:

CIOP-PIB: 0 mm	IPT: 0,5 mm	IfU: 2 mm

Deliverable 7.3: Cost-benefit assessment manual ready for implementation (M24) / Milestone 7.3: Delivery of ready to implement assessment manual (M24)

The following manual uses screenshots to guide the user through the application of the PEFB-method via a software tool.

The profitability analysis is integrated into the tool after the user completes the "Selection and application of safety measures" section. Profitability analyses of different safety solutions are conducted separately and are later compared to one another to find the best solution.

An overview is provided (see Figure 18), outlining all applicable design solutions, which the user can view in more detail. Direct (hardware-) costs can also be determined up-front.

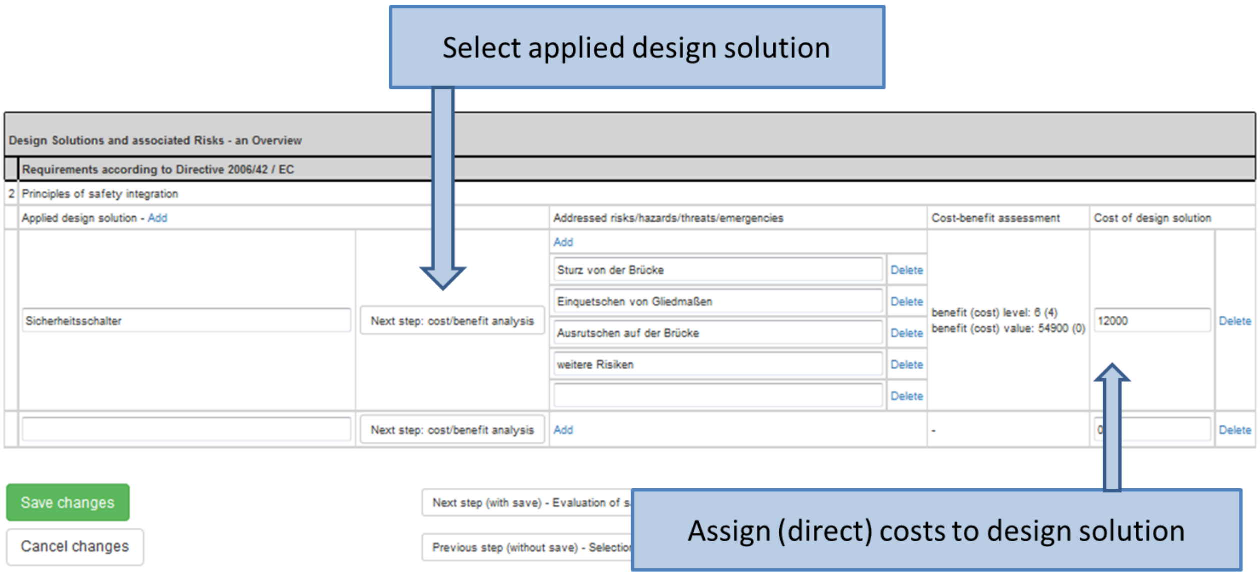

Figure 18: New overview: design solutions and associated risks

The next step for the user is to incorporate additional costs relating to the implementation of the safety measure into the tool. At this stage the cost categories (direct, indirect or difficult to ascertain), the likelihood of occurrence (high, middle, low), and monetary values, are assigned in the same step. If the user does not assign cost factors a monetary value, they will not be included into the analysis.

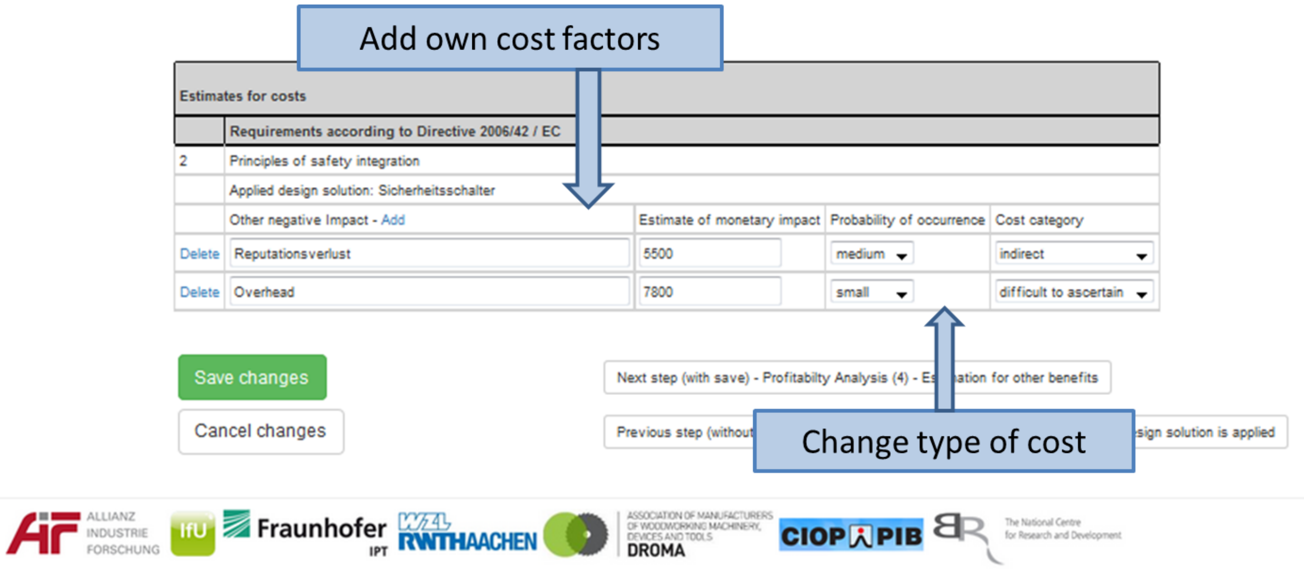

Figure19: Estimation for costs

The next step involves assigning monetary values, benefit type (direct, indirect, difficult to ascertain) and likelihood of prevention (high, middle, low) levels to risks prevented by the new safety measure). The procedure is the same as with the estimation of costs for the safety measure.

Next, monetary values are applied to the cost and likelihood of occurrence factors, which are not directly linked (indirect of difficult to ascertain) to the risks prevented by the safety measure. It is also possible to add the user's own impacts if necessary (see Figure 20).

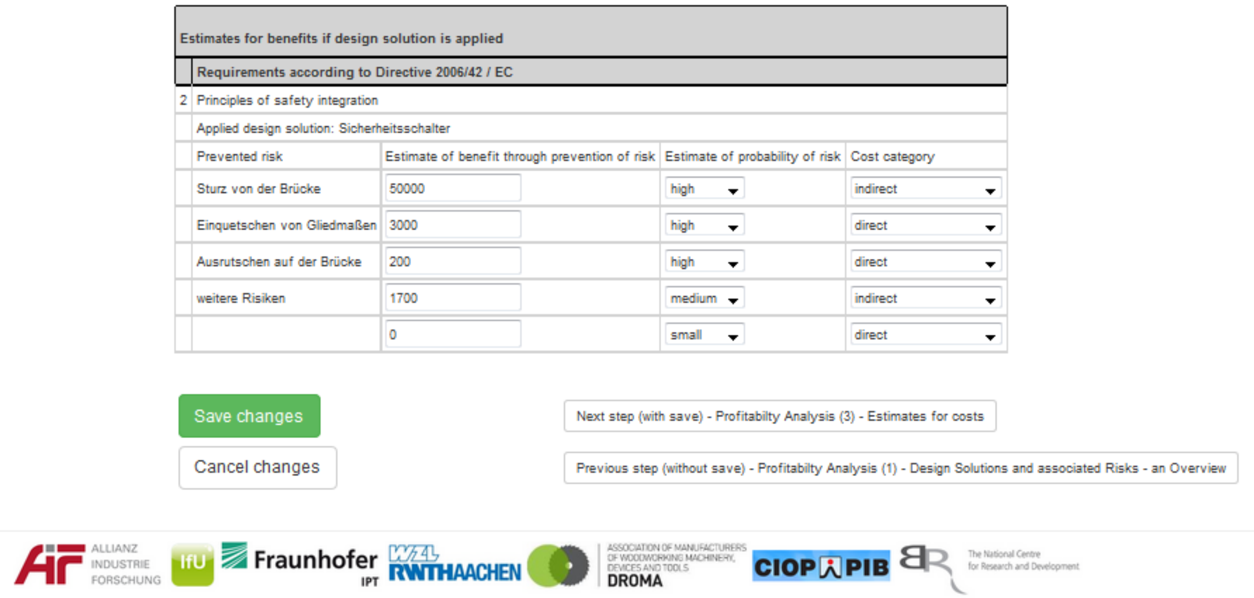

Figure 20: Estimation of other benefits

The next step depicts the PEFB-method cost and benefit matrices and summarises the previous inputs. Following this, the cost benefits according to the PEFB-method are depicted based on the matrices seen earlier. The profitability of the selected safety measure can be deduced by identifying where the intersection point of the cost- and benefit curves is (if left of level 5, the investment tends to be advantageous). In the next step the desired design safety measure solution is selected, and the assessment process starts over again. It is also possible to choose alternative design solutions for a certain safety measure and in this case, more profitable solutions can be chosen.

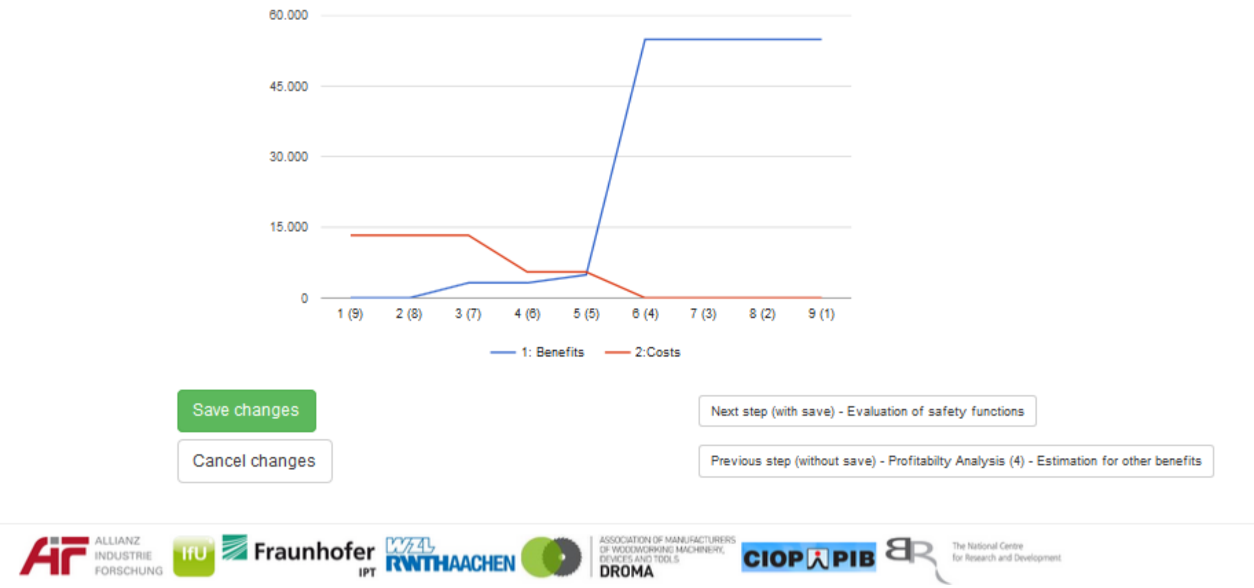

Figure 21: Cost-benefit curve

The best solution is selected after the profitability of all the design solutions has been assessed. The result of each Profitability Estimation Focused on Benefits calculation for all of the alternatives found using the tool can be viewed as a qualitative term (advantageous or disadvantageous) or a quantitative value. As a result of this tool, the alternatives can be compared and selected easily.

Cooperation

IfU was the WP leader and thus organised and maintained all tasks in this work package. IfU also conducted the basic research and the formatting of the relevant data. IPT inputted their knowledge obtained in earlier Work Packages (WP2-4) and assisted IfU in the analysis of existing concepts and the quantification of key risk-factors. IfU and IPT worked together on the implementation of the general assessment manual, which was mainly written by IfU. IfU then oversaw the implementation of steps leading to the successful cost-benefit analysis.

All deliverables and milestones of WP 7 have been fulfilled.

3.9 Overall conclusion

All deliverable and milestones of the project TeSaMa have been fulfilled.

The person months used by each Institute are the following according to each year:

IfU	**Person Months**
Granted person months by notice of approval	**19**
Deployed in 2013	2,7
Deployed in 2014	10,5
Deployed in 2015	5,8
Deployed overall	**19**

CIOP-PIB	**Person Months**
Granted person months by notice of approval	**120**
Deployed in 2013	0
Deployed in 2014	41,27

Deployed in 2015	59,29
Deployed overall	**100,56**

IPT	**Person Months**
Granted person months by notice of approval	**36**
Deployed in 2013	1,59
Deployed in 2014	22,92
Deployed in 2015	10,31
Deployed overall	**34,82**

DROMA	**Person Months**
Granted person months by notice of approval	**6**
Deployed in 2013	0
Deployed in 2014	0
Deployed in 2015	0
Deployed overall	**0**

4 Valorisation of the research results

a. Dissemination Strategy

Dissemination, reference cases, training and technological advice are key issues to achieve a successful adoption by SMEs. The project result is basically a newly developed tool that is assisting SMEs in machinery assessment for both production (bought machinery) and development (developed machinery) to an unmatched extent. To maximise the effects of dissemination, the project partners followed a strategy of diverse dissemination in a tripartite way: The first phase actions were focused on early adopters in Poland and Germany outside of the User Committee. These actions were implemented in the first and second year of the project and focused on information sources for early adopters like science magazines, association meetings, conferences, technological fairs and the internet. In the second phase that mainly happened in the second project year, the actions were expanded to access a wider range of SMEs (the early majority). Publications in popular technical magazines and the collaboration with networks and associations outside the User Committee and the project consortium prepared for the third phase, which is timely located after the end of the project. During the project, the partners have developed the dissemination material that can be used for the purpose of establishing the tool on the market. To attract a wider European take-up of the tool, the consortium intends to collaborate with other regional knowledge and technology transfer centres which exist throughout Europe.

TeSaMa Dissemination Activities

During Project Phase

Measure	**Objective**	**Timeline**
Kick Off Meeting - 1st German User Committee meeting	Detailed discussion of project realisation. Presentation of the work plan to all partners and the German User Committee. Development of the requirements for product and production safety concepts.	05.11.2013
Project presentation Promotion of the project on the websites of IfU and IPT	Information for external interested parties.	11.2013
Project presentation Promotion of the project on the websites of CIOP-PIB and DROMA	Introduce project towards targeted SMEs: needs, objectives and expected results	11.2013
Project Website, Newsletter and Wiki in German, Polish and English language	Communication between consortium partners and to User Committee Presentation of project's progress, contact data for interested SMEs	12.2013

Measure	Objective	Timeline
Publication in RWTH Aachen University Magazine "Angedacht" Publication on safety measures selection methodologies for safety at work and machine safety	Create awareness about opportunities and added value Information for external interested parties. Publication of intermediate results.	12.2013
1st Polish User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Presentation of the work plan to all partners and the Polish User Committee. Development of the requirements for product and production safety concepts.	03.2014
Visit at Company site	Requirements for product and production safety concepts.	25.03.2014
Seminar for the DROMA members	Presentation of the project idea for the DROMA members. Discussion on the technical safety problems.	03.2014
DREMASILESIA fair Presentation of TeSaMa research result at fair	Dissemination of TeSaMa research results in industry Presentation of the project idea for the external interested parties	04.2014
Conference for the maintenance engineers Presentation of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Presentation of the project idea for the external interested parties. Discussions on the technical safety maintenance problems	05.2014

Measure	Objective	Timeline
Publication in Institute for Management Cybernetics Magazine Publication of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Information for external interested parties. Publication of intermediate results.	07.2014
Poster Presentation at IHKL Potentiale 2014 Publication of intermediate results on industry-related conferences	Dissemination of TeSaMa research results in industry Information for external interested parties, mainly SMEs.	13.05.2014
Poster Presentation at Aachener Werkzeugmaschinen-kolloquium (AWK) Publication of intermediate results on industry-related conferences	Dissemination of TeSaMa research results in industry Information for external interested parties.	22./23.05.2014
2nd German User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Presentation on safety at the workplace. Presentation of first concept. Discussion on needs of UC.	28.08.2014
2nd Polish User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Presentations of the first TeSaMa concept. Discussion on user needs.	08.2014
DREMA fair, European Found area Presentation of TeSaMa research result at fair	Dissemination of TeSaMa research results in industry Presentation of the project idea for the external interested parties	08.2014

Measure	Objective	Timeline
VII Industrial Safety Conference Publication of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Presentation of the project idea for the external interested parties	12.2014
Poster presentation at Business Forum Qualität (BFQ) Publication of intermediate results in the popular science journals	Dissemination of TeSaMa research results in industry Information for external interested parties.	24./25.09.2014
Publication in RWTH Aachen University Magazine “Angedacht” Publication on safety measures selection methodologies for safety at work and machine safety	Create awareness about opportunities and added value Information for external interested parties. Publication of intermediate results.	12.2014
3rd Polish User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Discussion on methods for risk analysis and inspections of the work equipment.	01.2015
Interim Report for the AiF	Compilation of research results. Control of project’s progress.	03.2015
Interim Report for the NCBiR	Compilation of research results. Control of project’s progress.	03.2015
DREMASILESIA fair Presentation of TeSaMa research result at fair	Dissemination of TeSaMa research results in industry Presentation of the project idea for external interested parties	04.2015

Measure	Objective	Timeline
4th Polish User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Discussion on risk reduction by machinery manufacturer and user.	05.2015
Seminar “Tools and technology for the safety of the firm”	Presentation of the project idea for the external interested parties	05.2015
3rd German User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Finalising of systemisation of costs and benefits of technical safety measures.	06.2015
Conference on Assessment Methodology in Coimbra, Portugal Publication of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Presentation of the project idea for the external interested parties	06.2015
Publication in Institute for Management Cybernetics Magazine Publication of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Information for external interested parties. Publication of intermediate results.	07.2015
Participation on conference ESREL Presentation of intermediate results on scientific conferences	Dissemination of TeSaMa results in science Presentation of the project idea for the external interested parties	07.-10.09.2015

5th Polish User Committee meeting	Ensuring the practical relevance of the project results. Present results to the UC, select future and present realised test cases, elicit feedback, report project progress Presentations and discussion on the project progress. Discussion on testing of the TeSaMa by users.	09.2015
Poster presentation at Business Forum Qualität (BFQ) Publication of intermediate results in the popular science journals	Dissemination of TeSaMa research results in industry Information for external interested parties.	17./18.09.2015
DREMA fair, Science and advisory Presentation of TeSaMa research result at fair	Dissemination of TeSaMa research results in industry and science Presentation of the project idea for the external interested parties	08.2014
User Committee 4: Public Seminar	Presentation of final results and lessons learned. Advice on necessary organisational changes to support take-up by SMEs	12.2015
Presentation at Partnering Event IraSME & Cornet Presentation of final results on scientific conferences	Dissemination of TeSaMa research results in industry and science Presentation of the project idea for the external interested parties	28.01.2016
White paper on safety measures selection methodologies for safety at work and machine safety (publication online, downloadable)	Introduce the opportunities, challenges and added value towards SMEs provided by the approach and tooling developed in the project	2015, integrated in the Tool
Studien-, Diplom-, Bachelor- and Masterthesis at RWTH Aachen	Academic education, Preparing the basis for the TeSaMa project	BA-Thesis: June 2015

After project closure

Measure	Objective	Timeline
Integration of the results in the lecture Quality Management at RWTH Aachen University (Prof. Schmitt)	Dissemination of TeSaMa research results in the academic education	Starting Wintersemester 2016/2017
User guide about TeSaMa	Provision of TeSaMa research results for independent use by SME	2015, integrated in the Tool
Final Project Report	Academic Preparation of the TeSaMa research results Free online publication of project results in a final report.	03.2016
Workshops concerning the TeSaMa-concept	Dissemination of the TeSaMa concept and qualification of SME	Planned workshop in Poland 2016
Dissertation at RWTH Aachen	Construction an scientific elaboration of the TeSaMa concept	Working Title: “Technical Safety Maintenance System in Mechanical Engineering”, 2018.
Consulting of SME concerning machine development processes	Dissemination of the TeSaMaconcept and qualification of SME	Continuous consulting
Consulting of SME concerning OSH risk assessment processes	Dissemination of the TeSaMaconcept and qualification of SME	Continuous consulting
Supplement of DGUV Vorschrift 2 and other DGUV rules and regulations	Considering the TeSaMa results in the DGUV Vorschrift 2 and other DGUV rules and regulations	Planned
Consecutive research proposal	Deepening the results obtained for the TeSaMa	Planned

Publications and Research:

- von Cube, Philipp; Volmert, Julian; Schmitt, Robert: Technical Safety Maintenance Systems. An Integrative Approach. In. Podofillini, Luca; Sudret, Bruno; Stojadinovic, Bozidar; Zio, Enrico; Kröger, Wolfgang: Safety and Reliability of Complex Engineered Systems. London: Taylor & Francis Group. 2015. S. 473.
- BA-Thesis: Eva Rosenkranz: Entwicklung einer Vorgehensweise zur integrierten Risikobeurteilung der Arbeits- und Produktsicherheit im Maschinenbau. June 2015.
- Promotion float have been developed and printed in 10 000 pages and distributed in newspapers and on the conferences and fairs.

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