D6.1 Co-creation, combining technological and social innovation

Project information

Project title	Coordinating Optimisation of Complex Industrial Processes
Project acronym	COCOP
Project call	H2020-SPIRE-2016
Grant number	723661
Project duration	1.10.2016-31.3.2020 (42 months)

Document information

Deliverable number	D6.1
Deliverable title	Co-creation, combining technological and social innovation
Version	Final
Dissemination level	Public
Work package	WP6
Authors	Antonius Schröder / Michael Kohlgrüber Marja Liinasuo (VTT) / Roger Ivaska (Optimation)
Contributing partners	VTT, Outotec, Sidenor, TAU, Optimation
Delivery date	31.03.2020
Planned delivery month	M42 - March 2020
Keywords	Social innovation process, co-creation

This project has received European Union's Horizon 2020 research and innovation funding

Table of Contents

Abbreviations

Abbreviation	Full name
EC	European Commission
DTI	Danish Technology Institute
ESTEP	European Steel and Technology Platform
ESSA	European Steel Skills Alliance
EUWIN	European Network for Workplace Innovation
FSF	Flash Smelting Furnace
HF	Human Factors
KPI	Key Performance Indicator
LCA	Life-cycle assessment
OECD	Organisation for Economic Cooperation and Development
P2P	Person-to-person
P2S	Person-to-system
PSC	Pierce-Smith Converter
ROBOHARSH	Robotic workstation in harsh environmental conditions to improve safety in the steel industry
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
SPIRE-CCNI	Sustainable Process Industry through Resource and Energy Efficiency - Circular and Climate Neutral Industry 2050
TRL	Technology Readiness Level
VET	Vocational education and training

Executive Summary

In this report, the process of co-creation and co-development to improve the impact of technological innovations, their implementation process and the related organisational and personnel development processes (as an intended key result of COCOP) is analysed. The co-creation process (and its effectiveness and efficiency) is reviewed, mainly focusing on factors for successful integration of key personnel and end-users in the innovation process in order to deliver a model for combined technological and social innovation in the process industry (and its transferability to other branches).

It includes the general approach of a combined social and technological innovation process based on a new innovation paradigm. The report shows how this approach was operationalised for the COCOP project. Essential part of this operationalisation is the methodology how to implement a social innovation process of co-creation and co-development within COCOP. This comprises

- Site visits, interviews and desk research to describe the (social aspects) use cases of the project (in a copper and a steel plant)
- A survey in the beginning of the project (questionnaires and interviews) with future users, developers and external experts to define a baseline by raising data on experiences with existing optimisation systems, with tasks and targets of future users, with attitudes towards and expectations for the future COCOP system
- Based on survey results human factors requirements were derived. They were transferred to an action plan for monitoring these requirements during different stages of the project.
- In the end of the project when a prototype of the COCOP system was implemented, another survey (questionnaire and interviews) was conducted to obtain feedback of future users and developers of the COCOP system.

Important finding concerning the development process was that the (future) end users expected too much from the (future) system, that was technologically not feasible. However, due to practical experiences with the prototype, the results show that the users were not disappointed. Quite the contrary, they have concrete suggestions for future improvements based on their working demands. Additionally, it is necessary to have the whole development process from the idea of the solution for the given demand (improvement of the production process and reduction of energy) over its invention and implementation to its institutionalisation in mind. Even if a new solution is accepted and used to a certain degree at the workplace, more effort has to be made to ensure the transition from the implementation to the institutionalisation phase. The usage of the new solution has to become a habit, a new social practice. The COCOP project finished within the implementation phase, by evaluating the developed prototype. In future projects of this kind an extension of the project duration and a stronger attention should be paid to the transfer from the implementation to the institutionalisation phase. The further (or continuous if needed) adjustment of the technological implementation has to finetune the operations with the help of the users (in an ongoing co-creation process).

Therefore, in future research projects an extension of the project duration and a further and a stronger attention to the transfer from the implementation to the institutionalisation phase should be in focus. This could be done by an additional funded project phase (in case the implementation of the solutions was successful). The innovation process from the challenge/idea over invention to implementation is a precondition for the institutionalisation phase: As a predetermined breaking point it could be decided if an innovation of any kind should and could be institutionalised.

Concerning lessons learned, a stronger interrelation of technological and social KPIs as well as an interlaced thinking of technological and human requirements is necessary right in the beginning (setting the framework of the innovation process in the intervention phase latest). There should be no "delegation" of social requirements to the human factor experts but a strong integration of human factor requirements in the technological development process. It appeared that cooperation between technological developers and social scientists became a mutual learning process during the project interrelating the technological and social perspective in an interdisciplinary way, mutual acknowledged.

1 Introduction

In this report, the process of co-creation and co-development to improve the impact of innovations, their implementation process and the related organisational and personnel development processes (as an intended key result of COCOP) is analysed. The co-creation process (and its effectiveness and efficiency) is reviewed, mainly focusing on factors for successful integration of key personnel and end-users in the innovation process in order to deliver a model for combined technological and social innovation in the process industry (and its transferability to other branches).

The starting point for combining technological development with the concept of social innovation (Howaldt/Schwarz, 2010) is that there is a lot of technological innovation without societal and market-related relevance. The impact of this missing link between technological innovation and societal, economic and environmental challenges is experienced by many frustrated technological developers working on technological solutions, which are not implemented in practice. To avoid this situation, COCOP was conceptualised by combining technological and social innovation in a common process. This means that a comprehensive innovation approach has to be considered, overcoming the limits of pure technological oriented developments and embedding technology in social innovation processes. This new innovation perspective (leading to a new innovation paradigm, described in the following conceptual framework) has already been reflected since the start of the Horizon 2020 programme of the European Commission. Herein, non-technological and social innovation are explicitly mentioned as relevant aspects of research and innovation within Horizon 2020.

Within the European public-private partnership SPIRE (Sustainable Process Industry through Resource and Energy Efficiency) and its funded COCOP project (Coordinating Optimisation of Complex Industrial Processes), this approach is tested by setting up a social innovation concept and process (innovation process design): considering co-creation (Ramaswamy/Gouillart, 2010), (economic, social, environmental) impact as well as organisational and personnel development right from the beginning by a consequent stakeholder and user involvement. SPIRE and therefore COCOP as well aim at (www.spire2030.eu):

- industry cross-sectoral technological solution to reduce fossil energy (e.g. through novel energy-saving processes, process intensification, energy recovery, sustainable water management, co-generation of heat-power and progressive introduction of renewable energy sources within the process cycle);
- decreasing the use of non-renewable, primary raw material intensity (e.g. by increasing chemical and physical transformation yields and/or using secondary and renewable raw materials);
- a significant contribution to the political and societal objectives of drastic efficiency improvement in CO2-equivalent.

Facing societal, economic and environmental challenges, companies in the process industry require to raise their production processes to the next level by facing critical environmental challenges, such as reducing pollution and more efficient use of resources (raw material, energy). To strengthen the competitiveness of European process industries, companies have to reduce operating costs through better process control. Therefore, skilled workers are key. To improve working conditions, to secure and promote employment and to provide companies with needed skills, social issues have to be taken into account when innovation is taking place in these industries.

Traditional approaches focus mainly on optimisation of sub-processes in process industries: targets refer to the performance of a sub-process; operators and managers are responsible for their production area, respectively installation, knowledge and experiences focus on the owned sub-process. Even if optimisation has to consider influences of previous sub-processes and effects on following sub-processes, the effects on relevant parameters of the production process as a whole (e.g. the quality of the final product) are not fully considered. Digitisation (e.g. big data, Industry 4.0) has the potential to understand and improve the relationships between the parameters of sub-processes and the results of the whole production process. This is the technological starting point of the COCOP project.

However, plant-wide optimisation is also a social phenomenon. It requires another mindset of operators and managers to take responsibility for the whole process instead of an optimisation of a limited production area. This needs closer collaboration and communication between the involved people of different processes, but also a better understanding of the whole production process. Additional skills need to become part of training for operators and managers to gain deeper insights into interrelationships between the different sub-processes. Target and bonus systems have to be adapted to the new objectives: instead of rewarding good results within the owned sub-process, the contribution to the performance of plant-wide processes should be focused. That is what is basically meant by the term "social innovation" (Howaldt & Schwarz, 2010) in this context: changing (social) practices, such as working practices and organisational practices. In COCOP some of them are reflected in social key performance indicators (e.g. "Better understanding of plant-wide processes", "Needed skills" described in Section Methodological Operationalisation, some are covered by the human factors requirements (see "New communication channels" or "Bonus systems" in Section Social Requirements).

Within the EU funded Horizon 2020 SPIRE Project COCOP (www.cocop-spire.eu), a new approach has been developed that aims at such a plant-wide optimisation. Since this challenge is too complex for a human without computing tools, COCOP is developing a software design approach that will support the operator decisions and benefit the overall plant efficiency. However, a more comprehensive innovation approach is needed to meet the requirements of societal, economic and environmental challenges mentioned above. More and more, social innovation is moving into the focus of practitioners and scientists to meet these challenges (European Commission 2014, Mulgan 2018). For example, the EU funded project SI-DRIVE has developed an "Atlas of Social Innovation" (www.socialinnovationatlas.net) (Howaldt et al., 2018) mapping social innovations all over the world, covering different policy fields (such as energy supply and climate change), practice fields and sectors of innovation in order to meet societal and social challenges. The EU Research Fund for Coal and Steel funded project "Robotic workstation in harsh environmental conditions to improve safety in the steel industry" (ROBOHARSH) deals explicitly with a new innovation paradigm that stresses the interaction of social and (disruptive) technological innovation in the steel industry (Colla et al., 2017) to advance the allocation of the particular capabilities of human and technology and to improve industrial production and maintenance processes.

COCOP valorises this approach by aiming at the best possible interplay of human and technology to reach plant-wide optimisation. "Social innovation focuses on changing social practices to overcome societal challenges, meeting social demands and exploiting inherent opportunities in better ways than done before. It represents an understanding of innovation that goes beyond pure technological and or business innovation" (Kohlgrüber & Schröder, 2019). For COCOP, this means that human factors issues are considered right from the beginning. Consequently, not only impact on social and societal issues is regarded. In fact, strong participation of future end-users and other stakeholders is taking place to make them co-creators for a new solution for a plant-wide optimisation. Beyond earlier works on social innovation, COCOP is more positioned in the application end, involving that:

- mutual learning of technical designers and human factors experts was needed;
- real interaction between the different disciplines had to take place;
- common work of both parties (engineers and human factor experts) was needed to get to solutions that are working and accepted by end-users;
- a common language, common templates, common timelines, etc. had to be defined to which both parties contribute.

Against this backdrop, this handbook is describing the contours of a new innovation paradigm and its implementation, exemplarily shown by the development of plant-wide optimisation systems piloted in the steel and the copper industry.

2 New Innovation Paradigm and Social Innovation Process (Conceptual Framework)

A new innovation paradigm is overcoming the purely technology-oriented understanding of innovation by integrating technological developments into a social innovation process (Kopp et al., 2016). Against the background of the findings in innovation research and the clear emergence of complex innovation activities, technology-oriented innovation is more and more changing to socio-technical system development. This sort of fundamental change process, involving the entire institutional structure and the associated way of thinking and basic assumptions, can be interpreted in terms of the development of a new innovation paradigm (Howaldt & Schwarz 2010): opening fundamentally new perspectives on recognized problems and thus simultaneously unlocking new possibilities for action. The approach is characterized by three key categories:

1. new comprehensive ***contents*** leading to new practices;
2. modified, not only technology demanded ***objectives***;
3. social innovation ***processes*** embedding all the relevant actors and considering the impact right from the beginning (see figure below).

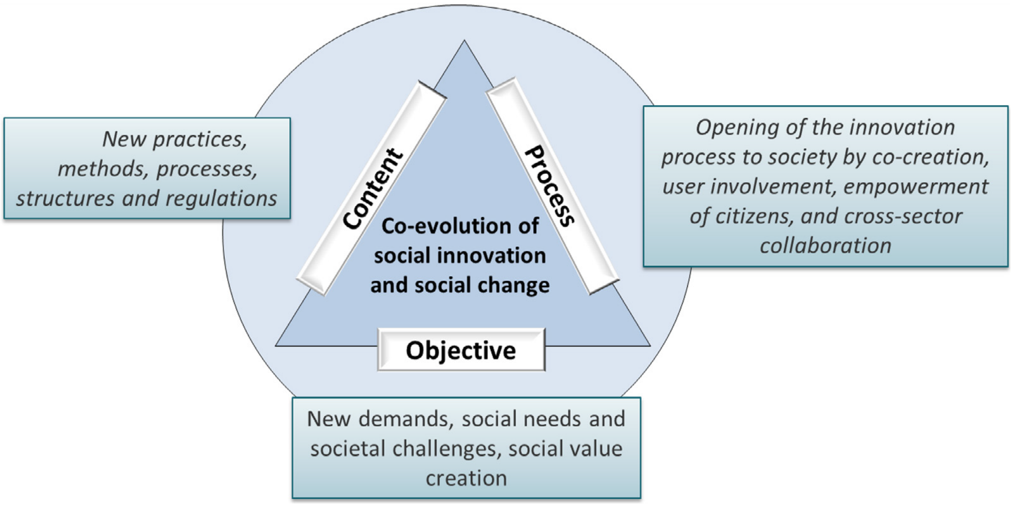

Figure 1 New innovation paradigm

Based on this, a new symbiotic technological-social/human-societal relation has to be developed within an innovation process, not just focusing on technological possibilities but on new social practices (of working, in this case). Material (technologies, assets, physical resources), competences (skills, know-how, common understanding) and meaning (ideas, motivations, emotions) have to be taken into account (Shove et al., 2012).

The new innovation perspective is combining technological innovation with social and economic innovation. It is opening the view from a narrow and purely technological view to an overarching perspective focusing on societal challenges and demands, integrating societal, environmental, economic impact right from the beginning, looking at co-creation integrating the potential, knowledge, resistance, etc. of the (end) users.

Again, this new innovation approach includes modified and more comprehensive objectives: solutions for societal challenges and impact are in focus. And it is concerning changing subjects of innovations: new technologies alone are not solving recent and upcoming societal challenges, new or modified social practices are needed as well as cross-sector embedding innovations. The solution of a social demand (also from a company perspective) is in focus and not requirements of the technology for the implementation through users and the adaptation of humans to technology.

However, it should be clarified that social innovation is not a contrast or competitor of technological innovation. Playing technological and social innovation against each other prevents fully benefit from both. Therefore, awareness is rising that a combination of both unfolds the full potential of technological and social innovation. Green and Vergragt (2002) are laying “less emphasis upon technology, rather a combination of technological, social and cultural changes is envisaged”. The approach of “Workplace Innovation” (Pot et al., 2017) accentuates technological and non-technological innovation as complementary and mutually integrated. According to this approach, it is particularly about workers’ engagement and employee-driven innovation to make the best use of new technologies within an appropriate work organisation at the workplace.

However, this understanding of social innovation is quite different from some authors that are stressing a social purpose of this kind of innovation, such as tackling poverty, climate change or improving education and health delivering social value (van der Have & Rubalcaba, 2016). The social innovation approach within COCOP is defined as a reconfiguration of social practices, which may not necessarily have a social purpose. In the sense of Howaldt and Schwarz (2010), social innovation is focusing on the renewal of social practices or configurations of practices of any kind, diffused into society and without a limitation to a need for creating social value. Social innovation can therefore also explain the emergence of new social practices in the industry and towards socio-technical systems (such as new working practices based on new skills needed by digital technologies and organisational changes leading to increase competitiveness - and in the case of COCOP also to a better environmental performance, which is a desired societal value as well).

According to Brooks (1982), management innovation is also understood as social innovation. Based on such a non-normative approach, “Lean Production” mainly discussed and implemented in the 1990s can be seen as management innovation and – according to Brooks – as social innovation because of its focus on organisational rather than on technological innovation. Teamwork, Kaizen, Kanban and other elements of Lean Production do not require high tech solutions (Womack et al., 1990) – they mainly benefit from organisational solutions.

For the current wave of digitisation, this has already been discussed in literature to a lesser or greater extent (e.g. Colla et al. 2017, Dregger et al., 2016). The discussion reflects a huge advance compared to the time when discussion on technological innovations (such as Computer Integrated Manufacturing in the 1980s) took place (e.g. Scheer, 1990; Waldner, 1992). While in the 1980s, the unmanned factory was a guiding principle for technology development, the sociotechnical system approach is nowadays widely recognised in current research and development projects on digitisation (e.g. Tüllmann et al. 2017 “Social Networked Industry”). Different disciplines (engineers, software developers, social scientists, training specialists, industrial psychologist) seem to agree about central principles of shaping new technology in the context of sociotechnical systems (Kopp et al., 2019). Nonetheless, the problem of different “languages” and “cultures” (between technological and non-technological disciplines) has still to be tackled to achieve integrated solutions (Gardner et al., 2007). Based on current results of the COCOP project, this handbook describes a process that brings the “new innovation paradigm” closer to application.

3 Operationalisation of the Social Innovation Concept in COCOP

As part of the COCOP project, social innovation means to contribute to an efficient innovation process in terms of integrating practical implementation and challenges during the development process and not during implementation of a readymade software solution. In this context, social innovations consist of three pillars:

- to widen the scope of innovation, i.e. to include social needs and societal changes in the innovation process;
- to develop innovations as a co-creation process involving relevant users and stakeholders in the development process;
- to modify social practices, i.e. to deal with new technologies and/or to use new skills and/or to give social practices (of working and organising) a new meaning. Therefore, routinised behaviour (of process control) will change.

This implies that COCOP has used technological ***and*** social (human, organisational) means to achieve plant-wide optimisation that has generated benefits in the economic, social and environmental dimension. Particular attention has to be paid to the interfaces of technological, human and organisational solutions (see figure below). These interfaces are strongly interrelated: Changes of one interface will always affect the two others as well. These interrelations have to be considered as they might support or hinder the success of the innovation. In the COCOP case this means:

- the technology - human interface is concerned by a new interaction of operators/managers with the developed COCOP system, to be integrated and considered in the daily production process; adaptivity of the software to different user groups is a further subject of technology - human interface.
- the technology - organisation perspective is imposing a new plant-wide perspective and responsibility
- the human - organisation interrelation is affecting ways of communication between people working in different sub-process and might be affecting organisational conditions, such as target and bonus systems.

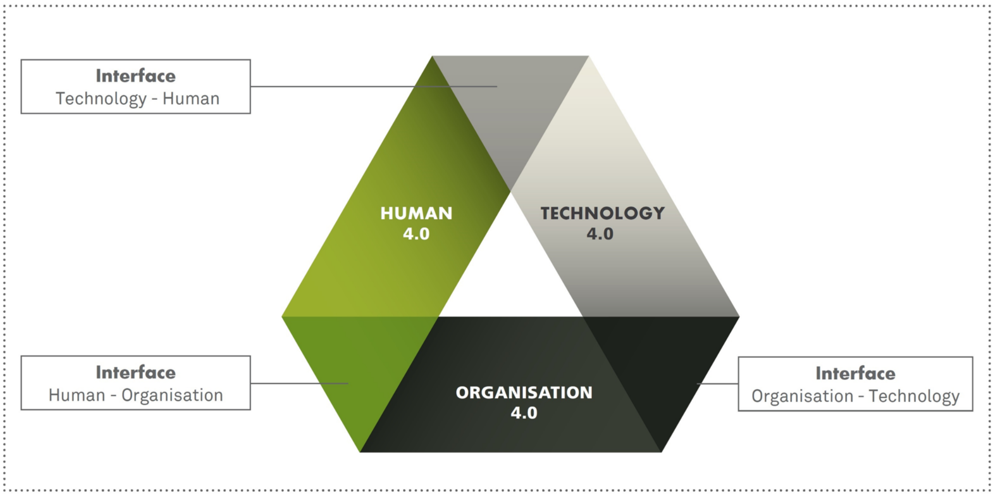

Figure 2 Interfaces of technology, organisation and human in innovation processes (Dregger et al. 2016)

As mentioned before, plant-wide optimisation is not only a technical but also a social innovation. For the COCOP project this means to consider the (end) users and all the relevant stakeholders within a co-creation process right from the beginning, combining and interrelating technological solutions with social and environmental impact. This is the ground for a more effective and more efficient innovation process. This is more than just identifying technical requirements, but requirements that cover all three dimensions of the represented socio-technical system. This approach has enabled a joint optimisation of technology, people and organisation. In order to implement this idea consistently, the methodology was operationalised and adapted to concrete use cases. The following section shows how this was done in the project.

The technological development process of the plant-wide optimisation focused on an additional monitoring and control system supporting the decision and quality improvement in the production processes and leading to a new plant-wide perspective and responsibility. This process was based on different approaches/preconditions for the use cases. While in the steel case an interactive social innovation process between the steel company, software developers and human factors / social innovation experts was possible on site, the situation in the copper case was quite different. As the copper company was not a funded partner in the project, social and human factors were considered in the beginning and at the end of the project, but with only limited direct interactions with end-users - leading to differences in Human Factor Workflow (number and characteristics of covered milestones), esp. feedback on prototypes.

3.1 Conceptual Operationalisation

The social Innovation process started as part of the definition and description of use cases for plant-wide optimisation. In a joint analysis of the participating project partners, the two pilot case factories (Sidenor as the steel case, Copper company as the copper case) presented the existing situation in the factories and the current baseline for optimisation. The first technical and social as well as development approaches for plant-wide optimisation were conducted with a description of the underlying production processes. Site visits at the involved companies took place to get familiar with the production processes, its challenges and local boundary conditions such as hardware/software restrictions and IT policies. The use case description was not only about technical issues but also about the social aspects such as key personnel, organisational/personnel development and economic and environmental issues.

The general aim for the **steel case** has been to develop a steel manufacturing plant-wide monitoring and a control advisory tool in order to reduce the surface and sub-surface defects in micro-alloyed steels in as-rolled state. The selected sub-processes have been those where the origin of defects is: secondary metallurgy, continuous casting and hot rolling. The prototype has been installed in the Basauri plant of Sidenor.

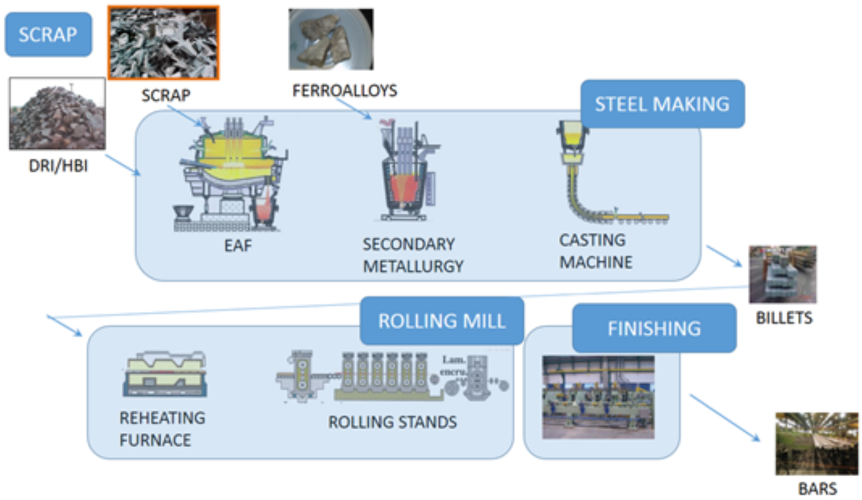

Figure 3 Flow diagram of the production of SIDENOR Basauri Works

The second case study is an example of a **copper-smelting plant**. The potential for improvement comes from increased production and reduced emissions related to more precise process control.

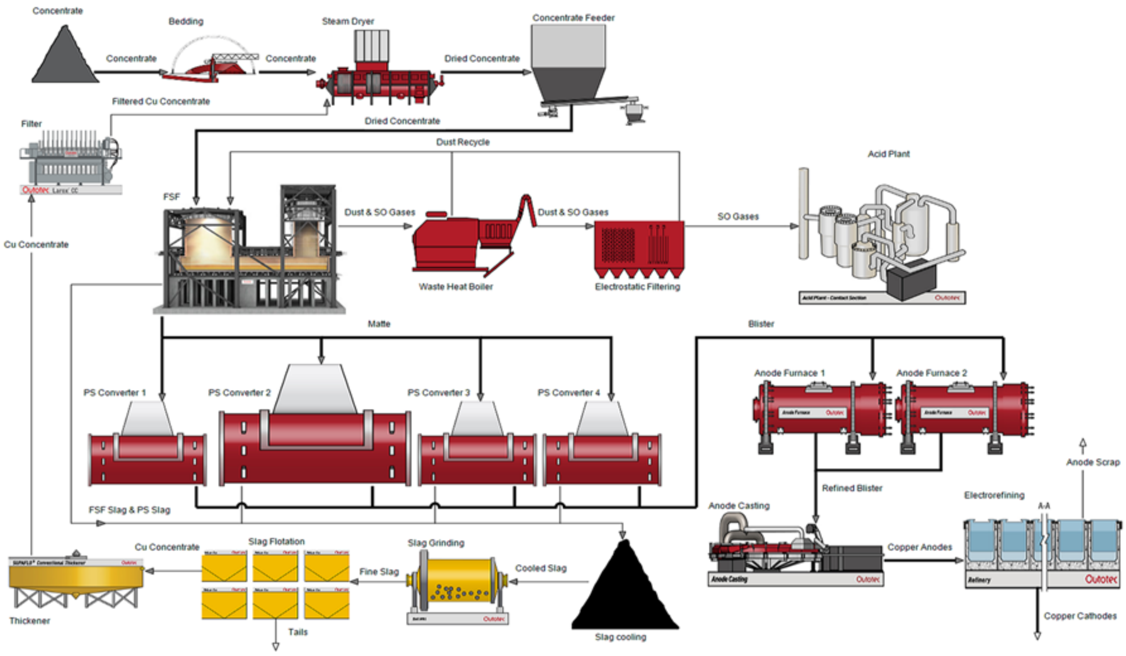

Figure 4 Flow diagram of the copper production

The use case description of COCOP included a report of the relevant characteristics of the pilot case processes and provided the basic information to be followed for developing the next stages of the project. Background for the analyses were documents, visits and workshops at the steel and the copper companies. With this, a starting point was given, the preliminary scope and the challenges of the optimisation process were defined. Concerning the social part of the use case description, the first step in the social innovation process was to identify the prerequisites for the COCOP approach of plant-wide optimisation from a socio-technical perspective: people related and organisational conditions which set the stage for the COCOP approach. People and organisation related measures of the past have been documented to get a big picture of the current status of the pilot factories. Together with previous experiences of operators with new tools, the baseline for integrating the intended COCOP software into a socio-technical system had been defined.

The people related requirements concern the understanding and skills for plant-wide optimisation. For both pilot cases (steel and copper), the awareness of potential users of the COCOP system has been discussed. There was some evidence that operators are already sensitive to the impact of their actions on subsequent sub-processes or on the results of the whole production process. A sensitisation for the impact of one's own actions on other processes has already taken place in the past through training measures or a work assignment in different sub-processes. However, these preliminary results had to be further examined and deepened (in the context of planned interviews with the people concerned). It was estimated that the COCOP system to be developed could also be used for simulation and training purposes to improve plant-wide understanding.

With regard to the question of organisational prerequisites for plant-wide optimisation, previous activities such as working groups to improve the production process, communication between the various sub-processes and job rotation were mentioned. Also, systems/methods to improve production processes were checked. Last but not least, existing organisational regulations were discussed as to whether they are conducive to plant-wide optimisation.

In addition, it was roughly outlined what experience operators already have with the introduction of new software tools and what experience exists with the participation of users in the development/implementation of new tools, including previous experience with the acceptance of new tools.

Last part of the social part of the use case description was to identify the future users of the COCOP system and how they are integrated into the organisational structure of the involved factories. Depending on the features of the software, operators and different levels of managers were identified as the future users. In addition, further departments in the companies were identified which, although not directly using the future system, were selected as (company internal) stakeholders that are affected by the new system.

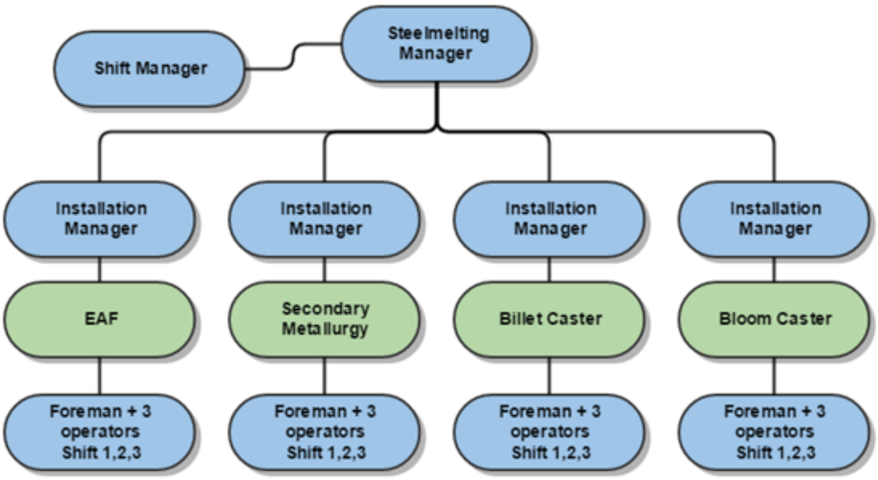

Figure 5 Organisation Chart Steelmaking (Secondary Metallurgy / Continuous Casting)

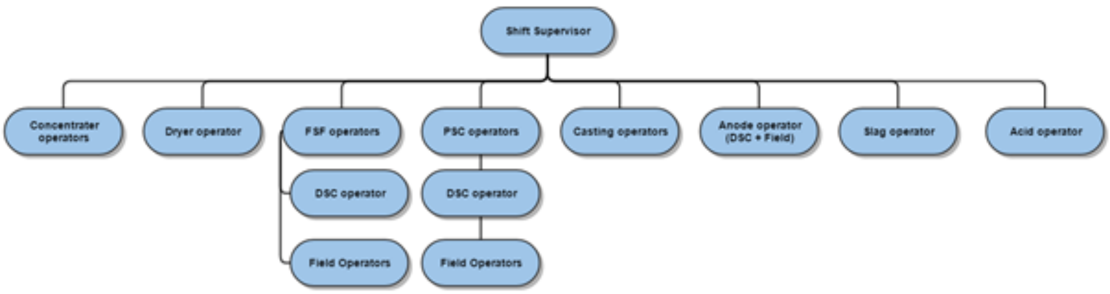

Figure 6 Supervisors and operators in the copper plant

3.2 Methodological Operationalisation

To perform the development as a co-creation process that generates not only new technologies but improved working and organisational practices, requirements of future users and (internal) stakeholders of the planned COCOP system have been taken into account. In the COCOP case, this was surveyed by questionnaires and interviews at two stages (1) depicting the starting situation of the innovation process and (2) assessing the prototype implementation phase. To do this, COCOP used a methodology that has been based on (1) social KPIs, (2) the integration of the different perspectives of people concerned, (3) a mixed-methods approach combining quantitative and qualitative research methods, and (4) a sequential measurement at important stages of the system development. It was intended to raise (and monitor) social requirements to the COCOP solution and to measure impact by social KPI. Data source for KPI were mainly the questionnaire-based surveys, social requirements were mainly elaborated based on interviews with future users and other stakeholders.

(1) Social Key Performance Indicators

At first and fundamental, the empirical research and measurement is based on the developed social KPIs (see deliverable 2.2 Impact Evaluation Criteria), which are the main reference point for all developed instruments (questionnaires, interviews) and the relevant target groups and their perspective.

Key performance indicators (KPIs) were developed (based on ISO 22400) to monitor and measure the technological, social and process impact of the whole project. The empirical research and measurement of social resp. human factor side is based on six social KPIs (see also figure below):

- KPI S1 Usage of the system
- KPI S2 Acceptance of system advice
- KPI S3 Plant-wide optimisation (as part of organisational/personnel development, training)
- KPI S4 Understanding of plant-wide processes.
- KPI S5 Influence on job satisfaction
- KPI D1 Participation, involvement in plant-wide optimisation processes.

These KPIs reflect the central social dimensions for the system development and implementation from a social perspective. They include indicators for the results of the COCOP project (S1-S5) from a worker's perspective and for the development process (D1) - each in social terms. To develop and run the optimisation system it is of high importance how far the concerned operators and managers accept and use the new system (KPI S1 and S2). The first KPI (S1) is to find out whether the operators really accept and use the advice provided by the tool (in a quantitative and qualitative way by using data from the software and asking how often users accept or deny system advices). Acceptance of the system advice (S2) is measured by the questionnaire including questions how users assess potential advantages of the system. KPI S3 (Operator training) and S4 (Understanding of plant-wide processes) are dealing with current skills of users on which the COCOP system could be based on. KPI S5 is a general social result that measures the (potential) influence of the COCOP system on the job satisfaction of users and (company internal) stakeholders. KPI D1 refers to the development process and asks whether and to what extent users feel involved. The following table shows an example how the (social) KPI are represented, developed during COCOP project based on ISO 22400-2 (again, see deliverable 2.2 Impact Evaluation Criteria).

KPI definition	
Content	
Name	Plant-wide processes as part of operator training ratio relative to baseline
ID	KPI-S3C
Description	The share of plant-wide processes as part of operator training relative to baseline Objective: to integrate the plant-wide perspective and to assess if it is adopted as an integral part of training Methodology: document analysis of training material, questionnaire for operators/shift managers (is the perspective sufficiently considered in the training?), interview of training responsible persons (how is plant wide understanding provided in trainings)
Scope	Work centre/whole site
Formula	Document analysis: part of training material (yes/no; if yes, to what extent and in which form) Questionnaire: Statement "Plant-wide understanding is sufficiently considered in trainings." Range of answers: strongly agree - agree - indifferent - disagree - strongly disagree Interview: quantitative and qualitative aspects of training Measured in the beginning and in the end.

Unit of measure	Documents: training modules related to plant-wide processes, questionnaires/interviews of training responsible persons, operators
Range	Comparison of initial (existing training programme) and final situation (after system development)
Trend	The higher the approval, participation and knowledge improvement of operators and managers, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management, personnel development responsible persons, operators
Production methodology	Continuous and Discrete
Notes	
Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Training documents, primary data via survey
Goal	Integration of all relevant employees (operators, managers, etc.) in the training programme, improvement of knowledge about plant-wide processes
Notes	Indirect assessment through the attitudes of trainees, in combination with a document analysis of existing and new training programs target-performance comparison
Impact	
Description	Better understanding of plant-wide processes Awareness for training programs to get a plant-wide perspective Higher qualification of operators
Calculation	Results from questionnaire
Evaluation Method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	Training as a human centered basis for plant-wide operation from a people perspective (in addition to the technical perspective) KPI-S3S is a basis for KPI-S4S (*Understanding* plant-wide processes)

Table 1 KPI definition (Example KPI S3 Plant-wide processes as part of Operator Training)

The social dimensions, mainly represented by the KPIs, are closely interrelated as shown in the effect model diagram below, setting up and visualising the interrelations of all the social dimensions at different levels, including the aspect of qualification and skills. The figure visualises that the COCOP system is affecting an interrelation between the individual and the company / process level by opening the individual (and work place related) rationality much more to a plant-wide and process related reference, setting-up a new mind-set for behaviour, decisions and attitudes (within a broader company rationality).

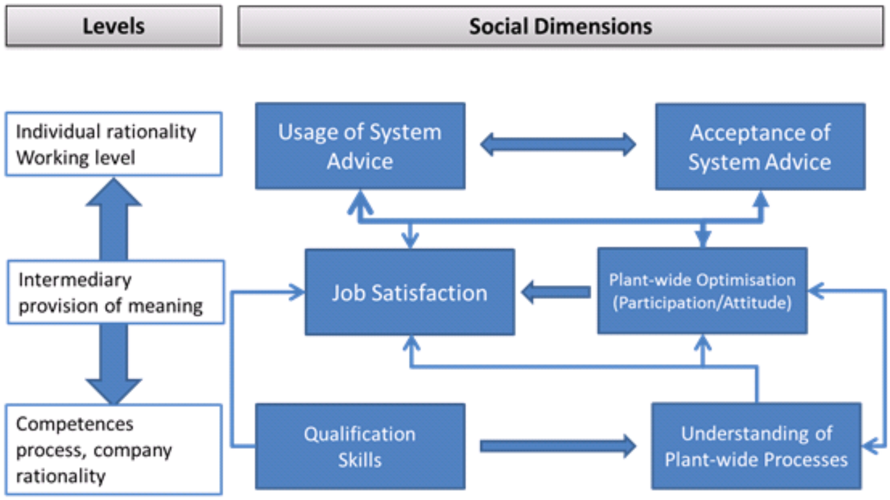

Figure 7 Levels and interrelation of social dimensions

(2) Integration of different perspectives

The empirical research and analysis were focused on three different target groups, integrating and comparing three distinct perspectives:

1. **User perspective** - information about the work of future users of the COCOP system in the steel industry and opinions related to plant-wide optimisation as well as assessment of the COCOP solution through directly concerned operators/stakeholders/managers: **Steel** Case and **Copper** Case (2017 and 2020)
2. **Engineers' and developers' perspective** - information about the work of copper smelter operators and about solutions for optimisation (mainly Advanced Control Tool - ACT) from engineers having experiences in implementing these tools as well as having knowledge about the involved copper company and/or other copper smelters (**Copper** Case 2017) and after the COCOP implementation (2020): **Copper** Case and **Steel** Case
3. **Transfer perspective** of **external experts** (2017) from different industry sectors - related assessment of plant-wide and process control optimisation from an external expert perspective.

Thereby, we could contrast the different findings of these three perspectives by having a direct user, developer/implementer and transfer related assessment. For all these three target groups we developed mainly comparable instruments (questionnaires and semi-structured interviews), allowing a comparative analysis by identifying similarities and disparities - getting an empirical based comprehensive view on optimisation systems as such and the intended COCOP solution particularly.

The indicators and variables of the developed questionnaire were based on the social KPIs. Responses to the questionnaire were received from end users and company internal stakeholders (steel case), and (as a contrasting perspective) from project external experts of different process industries. This methodology combines the operating, developing and implementing as well as the transferability perspective. End users (directly concerned operators/stakeholders/managers) assessed the COCOP solution for the steel case (Sidenor) - because of the high relevance of this direct and workplace related perspective standardised questionnaires (14 potential users at the beginning of the project and 10 end users after the implementation of the prototype) *and* semi-structured interviews in-depth interviews took place (nine potential users in the beginning and six end users after the implementation). Due to the fact that the copper company was not a funded partner of COCOP and access to the workplaces were limited, experts from OUTOTEC have been surveyed who were familiar with the copper case company. Additionally, brief interviews were conducted among four control-room operators in the copper plant. In 2020 seven developers of the copper and steel case were questioned via more or less the same items the users answered (to ensure direct comparison).

Additionally, 60 external experts from different industry sectors, not involved in the COCOP project, assessed the plant-wide optimisation from their experience and expertise answering a standardised online questionnaire with the same indicators and variables - contrasting the perspectives of the steel company internal (future) users with external experts' estimations.

(3) Mixed-methods approach

Additionally, the integration of different perspectives on the research subject was conducted as a triangulation of qualitative and quantitative data, filling the gaps and constraints of each single method in a complementary and interrelated way, validating the results in a complementary and optimised way. While the standardised questionnaires show the more quantitative distribution of opinions, the semi-structured (personal and group) interviews are delivering in-depth information, illuminating the context of the attitudes and the reasons behind the given judgements. Concerning the quantitative method (questionnaires) it has to be stressed, that the low number of respondents are not leading to a *representative* statistical dataset, but a structured and quantified summary.

(a) Questionnaires

Questionnaires provide a means to relatively easily gather information about relevant and already known matters which should be easy to verbalise. The possibility to get a broader overview of the opinions of the target groups is the advantage of this method. But the response is only given in the way the questionnaire defines and typically, the replies in questionnaire give answers to the question "what" and not "why". If the questionnaire aims at studying the reasons and context behind the statements, the options are defined beforehand and hence, the "why" is still provided in a rather restricted way. In COCOP, this disadvantage was compensated by the triangulation of the results with the findings of the in-depth interviews.

User perspective: Sidenor

One type of questionnaires is for scrutinising the operator perspective. Regarding the operator-oriented questionnaires, the first version is for supporting (Sidenor) operator interviews to acquire baseline information about the situation before implementing the plant-wide optimisation system (baseline stage). A second version was developed getting the operators' (and other stakeholders') opinions about the new system, for evaluating the plant-wide optimisation at the end of the COCOP project (prototype stage).

Objectives of this perspective were:

- To measure social KPI (usage of the COCOP system, user acceptance for the implementation process, job satisfaction related to the usage of the system, understanding of plant-wide processes, acceptance of plant-wide processes, relevance of training for plant-wide optimisation processes)
- To get deeper insights (specific issues) for acceptance of the solution and the development process
- To get feedback during the development process, monitoring and recognising whether COCOP is right on track (meeting the demands of key staff/stakeholders).

User perspective: Copper plant

The copper Company is not part of the COCOP project, which has limited the possibilities to queries in the factory. However, the company operators were delivered a brief questionnaire to get an overview of the opinions of operators in a general level. The timing of using the questionnaire was when the independent testing period of COCOP system was just finished. Responses were acquired from three operators. The objectives of this brief questionnaire are to find out

- the importance of optimisation in a copper smelter, as understood by operators
- the usefulness of COCOP system, as experienced by operators.

As the questionnaire was very short (four questions) and there were only three respondents, no quantitative results will be presented about the questionnaire for the copper case. Instead, the results are embedded in the overall analysis.

External expert and stakeholder perspective

A second version of the questionnaire was delivered online via Internet to interested external experts and stakeholders from process industry (copper, steel, chemistry and others) having experience about process optimisation. Thus, this possibility enabled acquiring of a lot of information from other (transfer relevant) perspectives. The context of answering the questionnaires is rather anonymous relative to the situation of the COCOP partners' representatives. Again, as the survey was to be personally filled in, the questions in the questionnaires had to be as clear as possible so that no further guidance was needed. The survey was delivered via email to relevant contacts of the COCOP partners and via platforms and networks they are engaged in (e.g. European Steel Technology Platform ESTEP, European Workplace Innovation Network EUWIN, and others).

Objective of integrating the external perspective was to get an insight about conceptions in the field, related to optimisation of plant-wide processes (such as user acceptance for the implementation process of optimisation system, understanding of plant-wide processes, acceptance of optimising plant-wide processes, relevance of training for plant-wide optimisation processes). The results can be used for benefit of the design and implementation of the COCOP system.

(b) Interviews and participatory observation

Beside the quantitative questionnaire-based survey, qualitative expert interviews and participatory observation at the workplace were used as an instrument to describe and assess current working practices, acceptance related issues and requirements to the COCOP software system in a more contextual and in-depth way. Expert interviews are an appropriate instrument to deepen insights of the quantitative survey and to understand complex processes. The interview partners have been experts because of their workplace and production knowledge. They are users of a production or optimisation systems or they are relevant experts that have been involved in developing and implementing optimisation systems (COCOP and others).

Interviewing was chosen because it is a means to acquire relevant and relatively trustworthy information as the interviewing process took place in a social, face-to-face situation and, contrasting to questionnaires, false assumptions and unclear expressions could be corrected. Furthermore, it was possible to extend the interview to an interesting and relevant direction if the interviewee proved to be exceptionally knowledgeable about such matters.

Additionally, in the copper case it was possible to observe the end users during their shift and working hours directly at the workplace during the implementation of the optimisation prototype.

Interviews: Sidenor

The expert interviews were conducted with semi-structured interview guidelines based on the same structure and issues of the questionnaires (COCOP KPI oriented). That ensured that all relevant dimensions of working conditions, current work with the computer, acceptance related issues and requirements were addressed in more or less the same structural way.

Depending on the particular context (such as the function of the interview partner), some kind of customising the interview guideline had taken place. Some questions were added, others were dropped due to the relevance given by the interview partners. Questions have been worded openly, so interview partners could focus on issues that seem to be most relevant for them. Furthermore, there was some scope for performing the interviews in a certain range. For example, the interview structure allowed to present examples of used software systems. Nevertheless, statements were still comparable due to the structure of the interview guidelines.

Interviews were performed to relevant actors for the COCOP concept working in a pilot factory (steel case, Sidenor). For Sidenor, nine relevant (future) users were nominated for the first interview round, ten for the second round (foremen, installation managers, supervisors and other relevant stakeholders). The interviewers had to have - beside the knowledge of the COCOP project background - necessary language skills, they were preferably experienced interviewer and had additional specific subject expertise (e.g. working practices and DCS, worker participation experiences).

The interviews were usually carried out as individual interviews. This procedure enabled statements of persons not influenced by other interview partners. There was only one exception: three members were interviewed at the same time. This took less time and it was quite reasonable, because they were working in the same department and had similar requirements.

Objectives of the in-depth interviews at the baseline stage were:

- To deepen the insights of the use case description (working practices, DCS, acceptance problems)
- To improve and enrich the results of the standardised questionnaire by qualitative information provided by experts (directly by staff of Sidenor)
- To define social requirements for the software solution and supporting technological, organisational and personnel aspects (such as training)
- To evaluate and analyse the requirements for the operator-system interface from an end user perspective
- To set the stage to get the later COCOP solution in use, discussing results with COCOP project and system development partners to derive relevant requirements for the software solution and appropriate framework conditions.

Objectives of the interviews at the end of the project (prototype implementation) were:

- To measure the acceptance and usage of the system
- The review the involvement of the end users and stakeholders
- To check the skills requirements and trainings
- To reflect the (organisational) support for system usage
- To list up system improvement possibilities from a user perspective.

Interviews and Participatory Observation: Copper case

In all copper case interviews, each interviewee was interviewed individually. As in the interview, interviewee and interviewers all shared the same mother tongue, both interviewers - the main interviewer and the supporting interviewer - could fully participate in the interviews.

Two different kinds of interviews were conducted in the copper company among operators. Firstly, brief interviews were conducted among four operators by human factors experts. In this case, a brief list of interview questions was produced and during the interview, the interviewee and two interviewers (main interviewer and support interviewer) were present. Such operators were chosen who could use, in principle, COCOP system in their work the most. The interviews took place in the copper smelter control room, during the normal working hours of the operators. As the work was not to be disturbed, the interviews were short. During the interview, operators controlled the process and had to answer the work-related phone calls, so the interviews were conducted by respecting the operator work and by disturbing it as little as possible. This means, in practice, that interviewing was interrupted from time to time. However, interviewees were experienced operators and could answer our questions while working. Four operators were interviewed in this way. The timing of these interviews was when the testing of COCOP system had just started.

The other type of getting information was performed when the COCOP system was introduced by system developers to copper smelter operators. Fourteen days were dedicated to this, so that six developers contributed to the introduction for 20 hours per day (with 10-hour shifts), totally 280 hours. Mostly one developer was present at a time, sitting in a control room, beside either of the control-room operator (in FSF or PSC). During that period, the developers observed how copper smelter operators performed their work and presented them the possibilities of COCOP optimisation system when appropriate. Developers made notes about these observations and discussions and, thereafter, answered a brief set of predefined questions set by human factors experts from COCOP project. Thus, chronologically, all operator interviews in the copper Company were conducted during the same phase of testing, when they were familiarising themselves with COCOP system, whereas the questionnaire results were acquired later, after the testing period. As a whole, 14 operators were monitored and/or discussed with.

Objectives of the interviews were:

- To improve and enrich the results of the brief questionnaire by qualitative information provided by operators (directly by the copper company operators and indirectly by Outotec and TAU experts, i.e., COCOP developers, having observed and discussed with copper company operators getting acquainted with COCOP system at the end of the project)
- To verify the results of the qualitative information provided by copper smelting experts in Outotec about the work of copper smelter operators in the beginning of the project
- To define social requirements for the software solution and supporting technological, organisational and personnel aspects (such as training)
- To set the stage to get the later COCOP-solution in use, discussing results with COCOP project and system development partners to derive relevant requirements for the software solution and appropriate framework conditions.

(4) Sequential measurement at important stages of the system development

Fourthly, the triangulation and combination of quantitative and qualitative methods is embedded in sequential inquiry periods. The in-depth interviews and the standardised questionnaires to operators, operating managers, engineers and external experts and stakeholders focus on getting information for designing the user interface in an appropriate way and for supporting the acceptance of the new system. Therefore, the methodology is defined for designing, monitoring and evaluating the innovation process with two points of measurement (depending on the technological development stages):

1. Baseline, preconditions and expectations (before the development of the optimisation system, July 2017)
2. Final evaluation (after the implementation of the system at the end of the project, February 2020).

At both stages, surveys (based on interviews and questionnaires) were conducted. Feedback of users and (company internal stakeholder) were obtained by a workshop. An early prototype was presented by developers and users had the opportunity to become familiar with the system and to give feedback on the features. This feedback was taken up to develop the next release of the system.

4 Defining requirements from the social perspective

As described in the methodology section, stakeholder integration took mainly place by surveys. Interviews with users (steel case) and external experts were conducted, questionnaires were completed by end users, developers and external experts. This section presents the results of these surveys covering social KPIs and raising social requirements.

4.1 Results of quantitative research

As already mentioned the quantitative (and qualitative) research for the social requirements of COCOP was structured by the social KPIs identified. In the following, a selection of the main important KPI related results of the survey (users, developers, and external experts) is revealed mainly for the steel case:

- job satisfaction, relevance of plant-wide optimisation as a basic and general acknowledgement of the individual user (KPI S5)
- system usage and acceptance of the optimisation system (KPI S1 and S2)
- skills / training and understanding of plant-wide process as impact and precondition for an optimal usage of the system (KPI S3 and 4)
- Participation, involvement in plant-wide optimisation processes (KPI D1)

While the results of the first phase 2017 (baseline) gave the ground for the further operationalisation of social requirements (see previous chapter) the 2020 outcomes are reflecting the prototype implementation. The presentation of the results is mainly based on a scale from extremely low (-2) to extremely high (+2) rating, with a neutral option in the middle (0), presented by percentages or averages.

Relevance of plant-wide optimisation (users, developers and external experts)

In general, plant-wide optimisation across all production areas in the plant is accepted and considered to a high degree, for the workers of the company, the developers and the external experts (see figure below). While almost all of the respondents rate the system as (highly or extremely) relevant, the (potential) users had more optimistic expectation in 2017 (50% of the participants saw it *extremely* relevant) which was a little bit reduced after the first experiences with the optimisation tool in 2020 (60% rate it as *highly* relevant). The developers are more in line with the external experts expressing also a high relevance but to a lower degree. The figures underline a general result of the surveys: Although there is a high positive attitude to plant-wide optimisation and related systems in all groups, the future users expressed a higher relevance than the developers and external experts in the beginning but decreased their expectation because of the practical experiences in the implementation phase.

Conclusion: The high, overestimated expectations of the (future) users were relativised during the course of the implementation. However, *users, developers and experts more or less ended up in underlining the high relevance of plant-wide optimisation in the same wa*y.

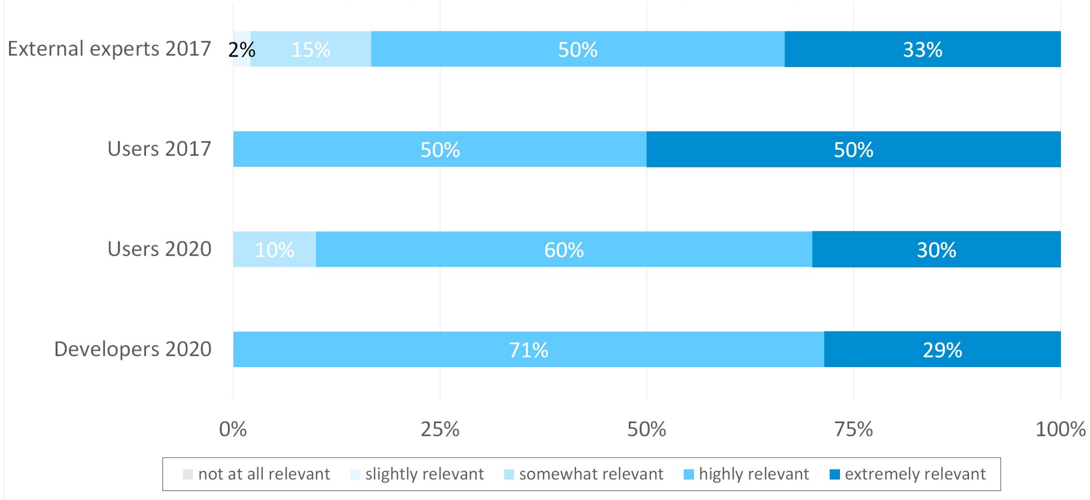

Figure 8 Relevance of plant-wide optimisation

Having a closer look at different aspects of plant-wide optimisation (see next figure) it is visualised that the *users* underline especially that they know what plant-wide optimisation means for their work, how their work affects the final product, and that their work is supported by their knowledge about plant-wide processes, also because of the supporting training. Comparing the user expectations (2017) with the concrete practical experiences of the COCOP optimisation tool in the implementation phase (2020) the understanding of plant-wide optimisation, supported by training measures and the support of their work raised considerably up to strongly relevant (average 0,86 to 1,80 / 0,93 to 1,6 / 0,36 to 1,2). However, their knowledge about the effects of plant-wide optimisation for their own work was not affected by the concrete COCOP tool experience, it is more or less the same in 2017 and 2020. Compared with the *experts* and *developers* the users have a more positive attitude to these aspects of plant-wide optimisation after getting concrete experiences during the implementation phase 2020. In this context, it has to be stressed that the developers are bit more unaware how the tools will affect the final product as the users and external experts.

In 2020, after first experiences with the COCOP tool, more users do have a “big picture” of all processes in their plant than before (in 2017). However, not astonishingly the experts and developers agreed to this item to a higher extent. Plant-wide processes are also part of the discussions with colleagues (again, rated more positive by the *developers* and *experts* than by users). Notably, the users related their knowledge about plant-wide processes drastically. After experiencing the COCOP tool they stressed that they have only little knowledge about and experience with plant-wide optimisation systems (in average from +0,14 in 2017 to -0,80 in 2020). *This is underlining that the COCOP system brings a really new perspective on plant-wide optimisation to the users, additionally to the positive effects of supporting their work and affecting the final product.*

Conclusion: The experience with the implemented COCOP optimisation system and the supporting training for it extended the recognition of the *added value and opens up a new perspective on plant-wide optimisation systems to the users*. Their knowledge what optimisation system means for their work raised, its support function and impact on the final product is seen very positive. However, based on the concrete experiences with the COCOP tool, their practical knowledge of plant-wide optimisation system is not given: This could be improved by the further usage of the system.

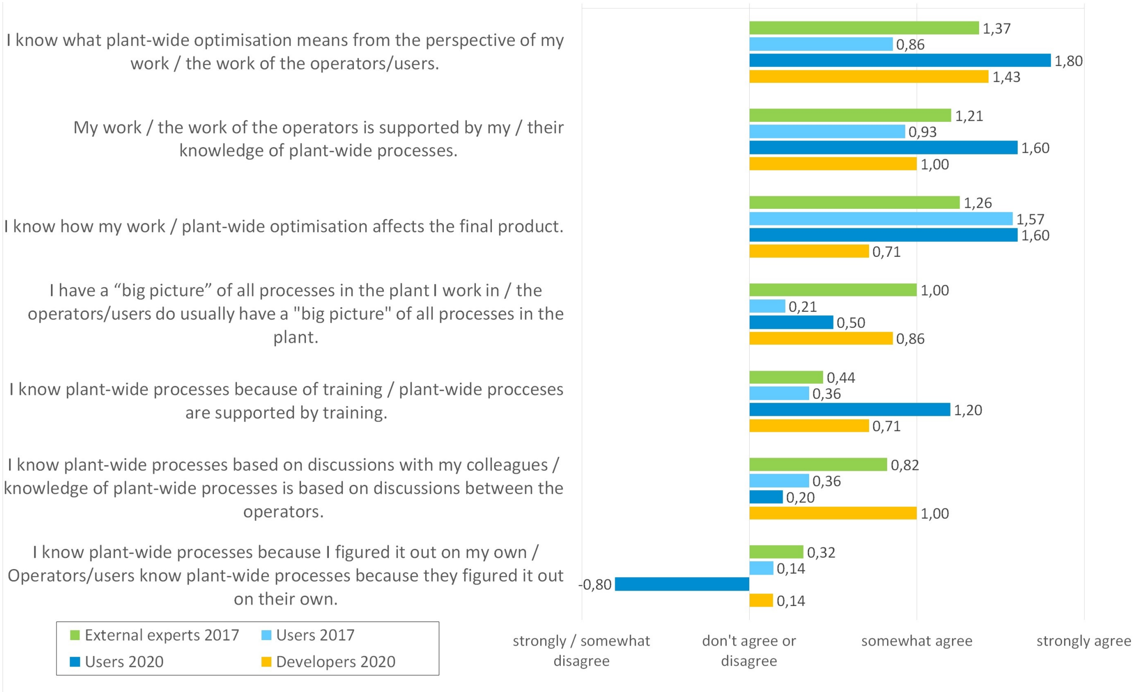

Figure 9 Different aspects of plant-wide optimisation

Impact of plant-wide optimisation on job satisfaction

Again, experience with the optimisation system led to positive views of the *users* in general (see figure below): The optimisation system have increased possibilities of the users to make decisions at the workplace, made their work more interesting and increased their job satisfaction in general (scaling on average between 0,7 and 1,2). While there is a slow reduction concerning job satisfaction from 2017 to 2020, there is a slow increasement of decision making and a bigger one on making the job more interesting by the COCOP tool implemented. However, the possibilities to reduce the workload are not seen by the users. The already low rating in 2017 was further reduced in 2020 after making real experience with the system.

Compared with the user perspective it becomes again evident that the external *experts* and the *developers* are very close to the user perspective but a bit more critical. Generally, they also state mainly positive impact of the optimisation system on job satisfaction for the users. However, the external *experts* are more expecting that optimisation systems are able to reduce the workload to a remarkable degree.

Conclusion: External experts, developers and users concluded that optimisation systems will make the work of the concerned operators and managers more interesting, increase their possibilities for decision making at the workplace, and finally increase their job satisfaction. With the exception of the external experts, developers and especially the users do not see a reduction of the workload (but there is also no remarkable intensification of the workload as stated in the qualitative interviews, see next section). However, the answers underline that the COCOP optimisation system is for increasing production quality and not workload reduction.

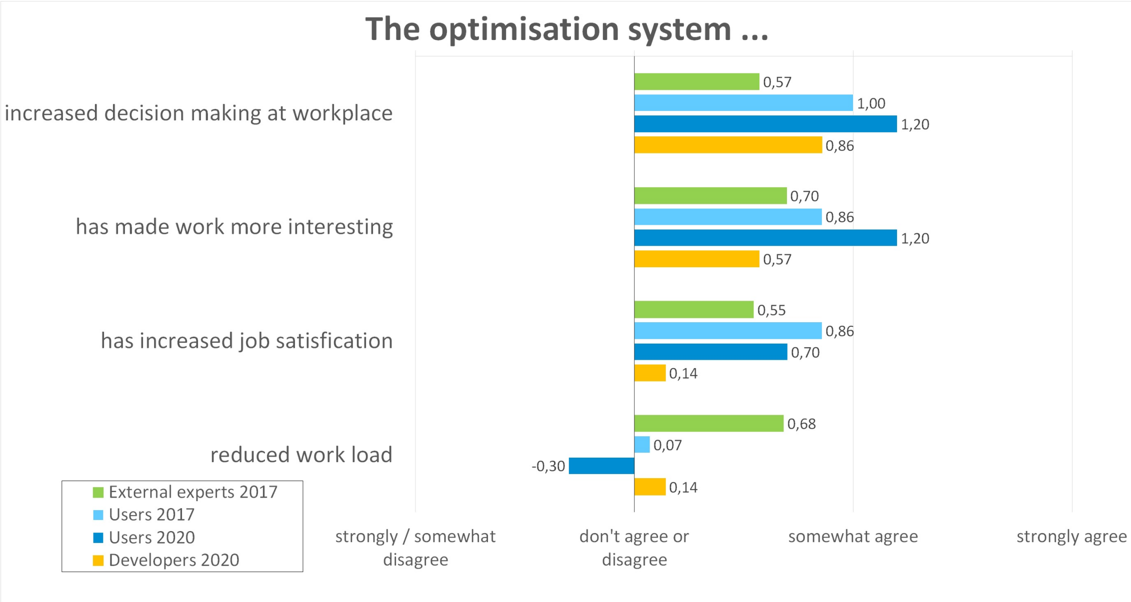

Figure 10 Influence of optimisation system on job satisfaction

System usage and acceptance

In 2017 to use optimisation tools was to a high degree a good idea, useful and interesting for the *users.* Being recommended by important people, offering recommendations for improving processes are seen as a measure to accomplish tasks more quickly and to increase productivity and work performance (more than 50% of the users totally agreed). Comparing the estimation in 2017 with the answers based on the concrete usage of the prototype optimisation system the users reduced their positive view of the effects of the system (by an average degree of about 0,4 to 1), stating a lower but still positive opinion (between somewhat and strongly agree). However, the users still find the optimisation system interesting and - based on two additional aspects asked in the implementation phase - makes the users feel more confident in their job and help them to perform better in problem situations.

However, in 2020 the users are more positive and in line with the developers concerning the following characters: Understanding the system clearly, the usage of the system is easy and pleasant, is not requiring a lot of mental effort and getting the system to do what is intended by the users has increased (as well as the other characters named here).

In general, the *developers* see the effects of the optimisation system more positive than the users (2020). However, concerning the user friendliness and its interesting use they are in line with the users.

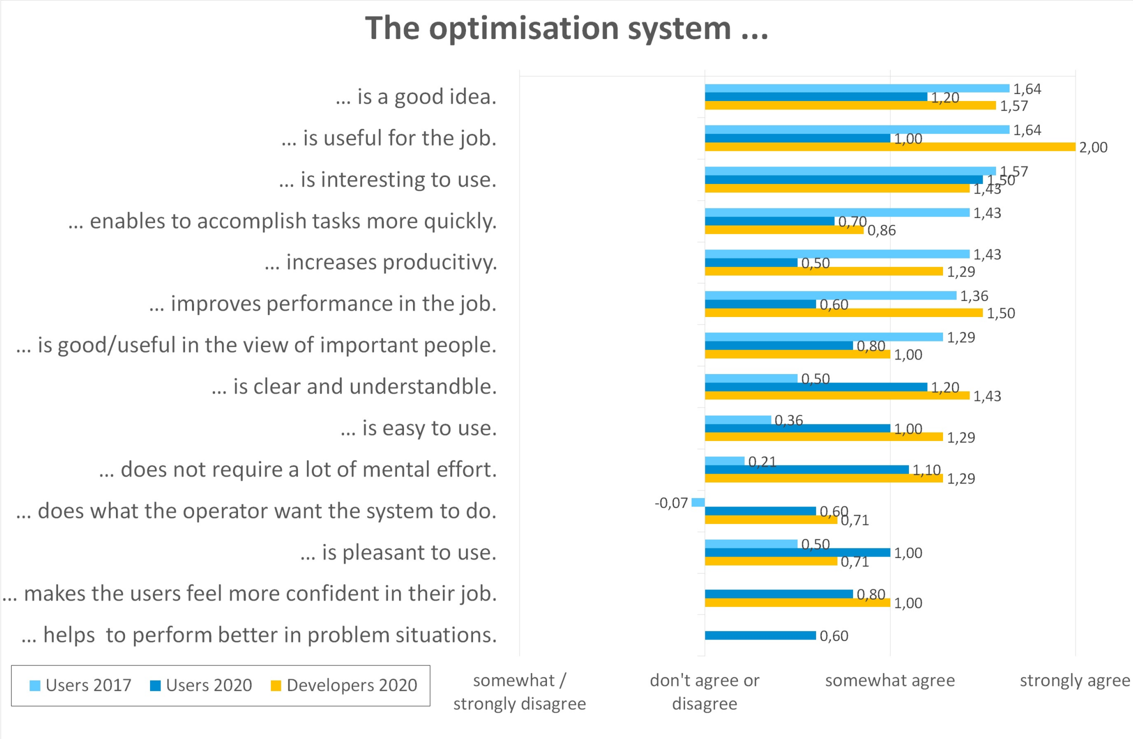

Figure 11 Effects of using the optimisation system (users and developers)

In 2017 the advices provided by the already existing software system were followed by the *users* mainly to *a slightly higher degree* than the advices of the COCOP system prototype in 2020 (average reduction from 2,29 to 1,50). This picture appears as well concerning the future usage of the system (from 3,14 to 2,75) and following the advices (from 2,71 to 2,38). The figure below shows also that users, developers and experts are more or less of the same opinion that the system and its advices will be used to a high degree in the future.

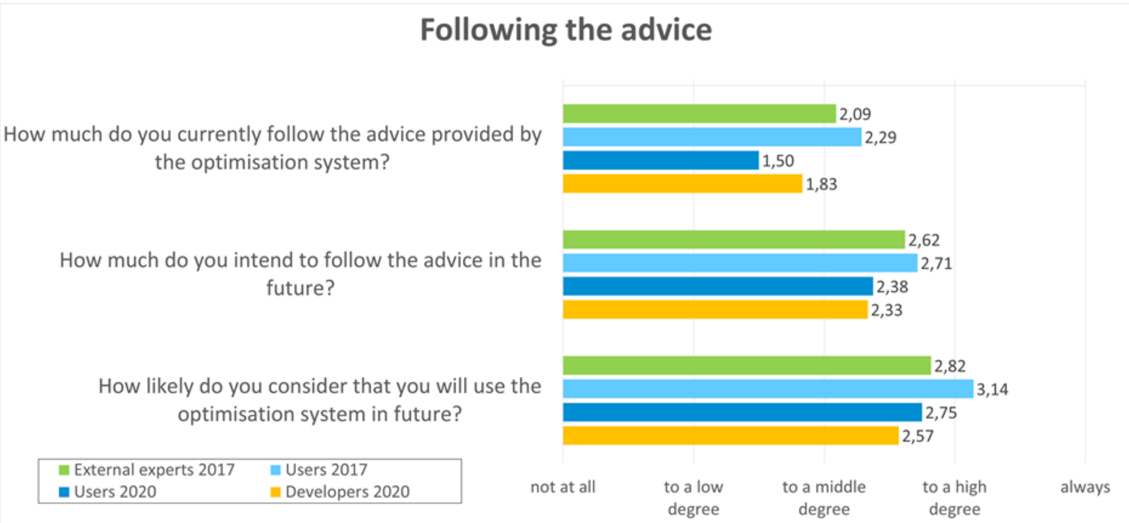

Figure 12 Current and future usage of the optimisation system

Having a look at different aspects (see next figure) the picture is also positive: Following the advices of the optimisation system makes decisions easier and work done more quickly for the users, leads to better results and cost effectiveness, produces better quality. But this has changed comparing the estimation in 2017 with the answers based on the concrete usage of the prototype optimisation system in 2020. The users reduced their positive view stating a more neutral (don't agree or disagree or somewhat degree) opinion. In particular, following the systems advices has not become a habit (esp. the developers emphasise this). The high expectations of the plant-wide optimisation system are reduced esp. concerning easier decision making and workload reduction. The effects on improvement of production, better results and quality as well as cost-effectiveness and the speed of work are rated a bit lower than 2017. However, there is still the reflection that by using the advices of the COCOP system the production is becoming more ecological in the future.

In general, the external experts and the developers have a remarkable more positive opinion (than the users 2020), in line with the estimation of the users in 2017. Exceptions: Reduction of workload is not given in the view of developers and users, following the advices becoming a habit and improved speed of the production is seen more critical by the developers.

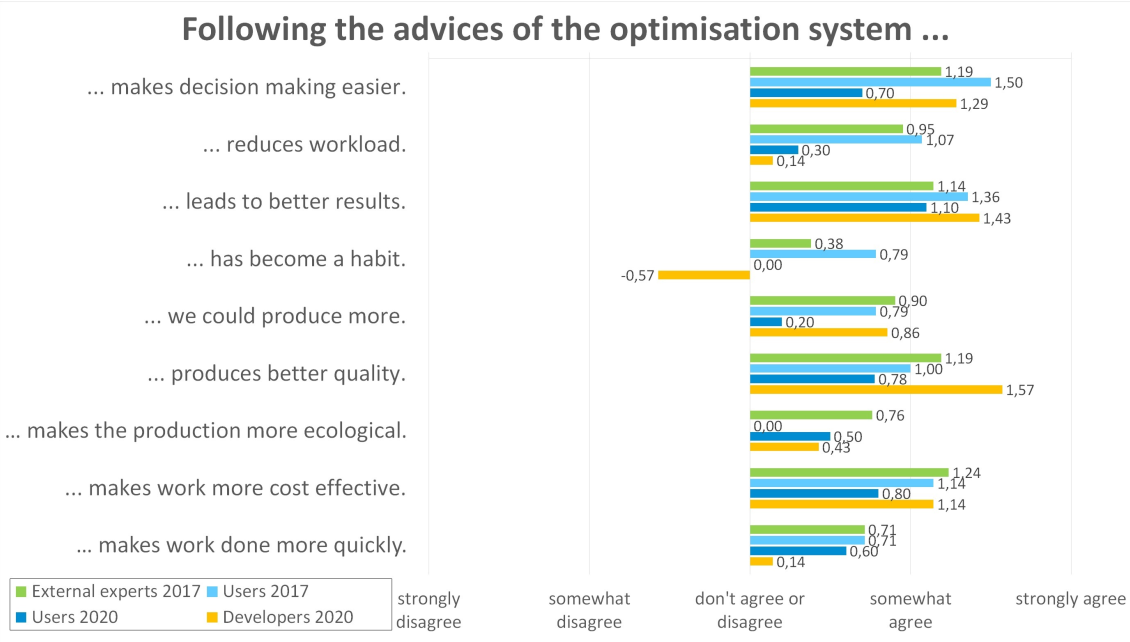

Figure 13 Assessment of different aspects for the usage of system advices

Conclusion: The COCOP system fulfilled the demands on user friendliness after its implementation (in 2020) more than expected (in 2017). Additionally, the new system 2020 makes the users feel more confident in their job and supports their performance in critical situations. Nonetheless, there is a more realistic view on the functionality for the production process (speed, productivity, performance) than estimated due to the concrete experiences after the implementation of the system. Due to the implementation phase and concrete experiences with the system, the estimations of the experts, developers and users in 2020 are more or less in line, underlining a more realistic assessment based on concrete experiences of the users and the usage. Although the expectations of the users for the COCOP system were very (or too) high in the beginning of the project (2017) they are still looking forward to an increase usage in the future. Therefore, in line with the results of the qualitative interviews (see following section), the implemented system has to be developed further in the direction of the user expectations leading to following the advices becomes a new social practice (habit).

Skills requirements

This issue concerns necessary skills for using a plant-wide (optimisation) perspective and system. It includes expectations and experiences with optimisation systems in general and the COCOP system in particular, but it is not limited only to software but also organisational and work practices.

Starting to work with a plant-wide perspective requires definitely new skills from the perspective of the *users* (and external experts) in 2017, but due to the experiences and training activities of the COCOP system the necessity was seen lower in 2020 (average from 1,64 to 0,60, more in line with the developers). This might be also due to the effect that the reflection and the presentation of plant-wide processes in the existing training has increased significantly from 2017 to 2020 as stated by the users (increase form -1,0 to 0.4 in the average mean), also endorsed by the developers' assessment (0,71). However, in 2017 and 2010 the users complain in the same way that they do not get enough training about plant-wide processes like COCOP in general (more or less in line with the experts and developers). Compared with the users and experts, the developers think that plant-wide processes are presented in training in a better way. However, when it comes to the concrete training measures for the COCOP system (2020) most of the users and developers estimate enough training for the usage of the optimisation system.

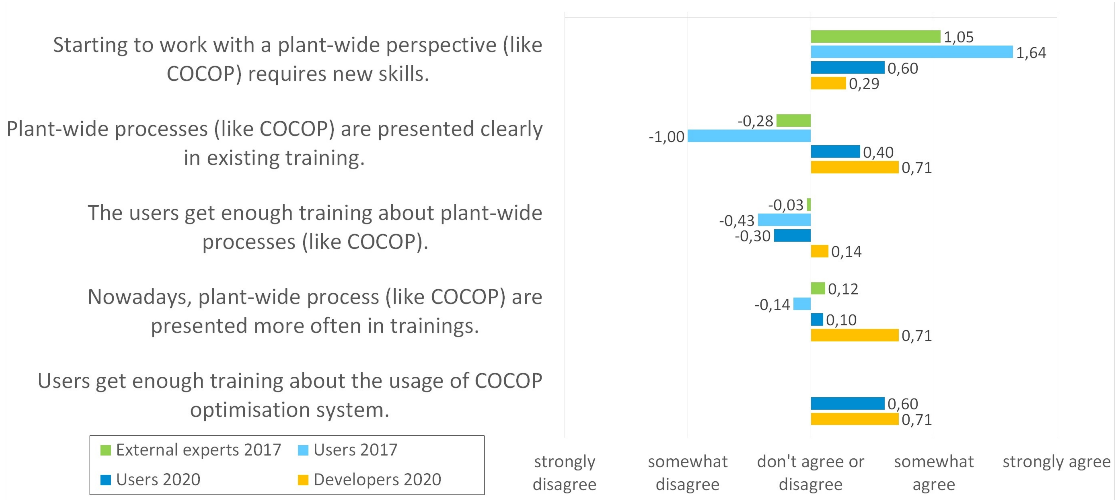

Figure 14 Skills requirements

Almost all participants stress the necessity of specific learning measures (see next figure). But the picture of the users has changed from 2017 to 2020. While in the beginning of the project every user stated (in line with the experts) that special measures for using an optimisation system are necessary. In 2020, 20% of the users and 14% of the developers think, that due to the easy usage of the system no special training is needed. In line with this result, the relevance of specific learning measures has decreased from 2017 to 2020 as well. While in 2017 for the users learning on the job, general training courses and simulation were of high relevance in general, this mix of training measures are still favoured in 2020, but to a significant lower extent. However, the users prefer still (process) simulation as the favourite learning arrangement to require the necessary skills for using new optimisation systems. Developers vote much more for (a combination) of general training courses with learning on the job. Experts are more often voting for learning on the job than for the other training measures.

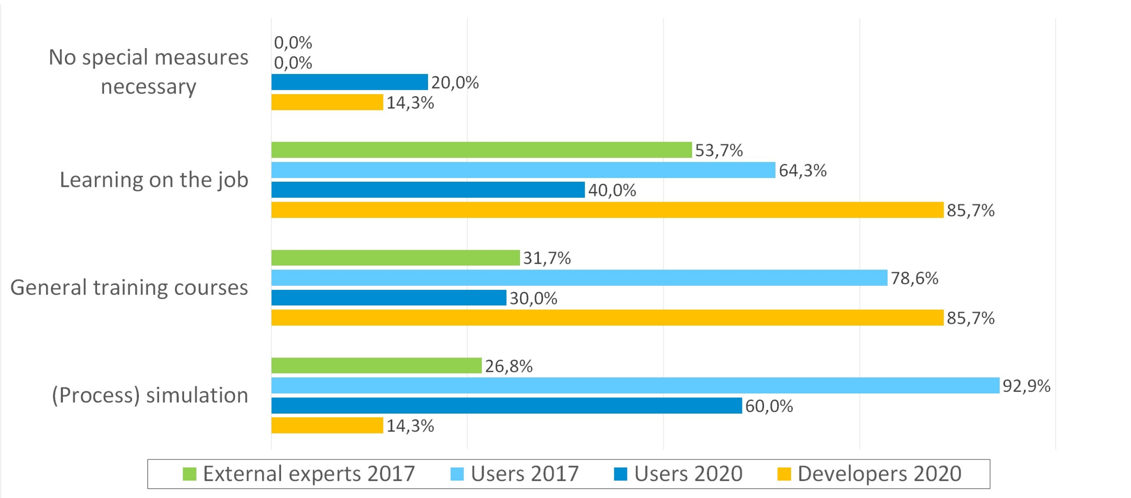

Figure 15 Preferred training measures

Conclusion: The necessity of new skills for plant-wide perspectives is important for all groups (experts, users and developers). However, for the users it is not as important as 2017 anymore. Maybe this is due to the fact, that users (and developers) underline that the users got (somehow) already some training for the COCOP system. However, although plant-wide processes are more clearly presented in existing training measures, users, developers and experts state that this could be improved in general. While a mix of different training measures is still demanded by users and developers, the most preferred training measure of the users is (process) simulation, while developers are in favour of the combination of training courses with learning on the job.

Organisational support and involvement in the developing process (co-creation)

Plant-wide optimisation processes and the COCOP system are strongly supported by organisational measures in general, management decisions and communication structures. Most of the users (somewhat or strongly) agree to this in 2017 and 2020; however, with a bit more critical assessment in 2020. In 2017, incentives and targets like bonus systems or production specifications were supporting optimisation processes in general from a user perspective as well, but concerning the COCOP system implementation 2020 this is missing. As already mentioned above in the assessment of the usage of the COCOP system the users 2020 (in line with the developers) see a bit less possibilities for more leeway concerning actions and decision making after the system was implemented. The developers state a positive but lower support by organisational, management, communication and cooperation structures than the users, but they see more incentives given to the system in 2020.

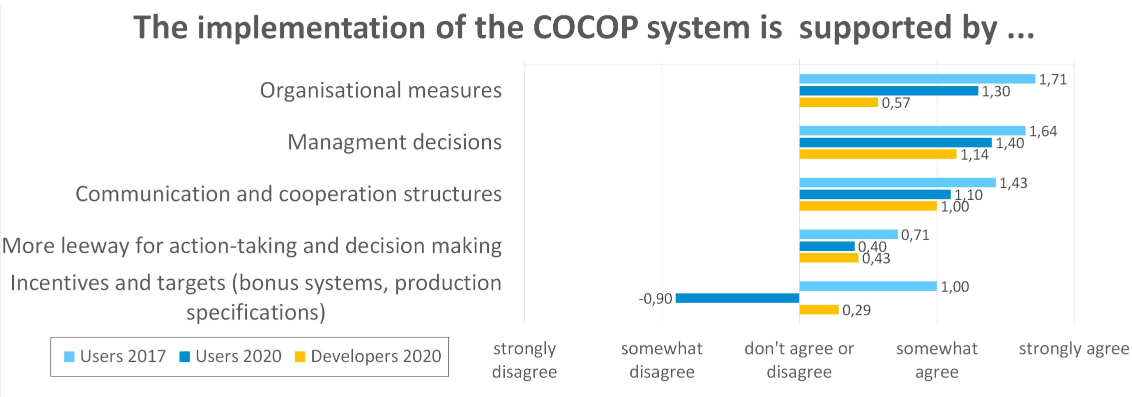

Figure 16 Support for system implementation

The involvement of the *users* in the development of the COCOP system (2020) was higher than in the optimisation systems before (2017):

- In optimisation system development before, 30% of users 2017 stated that they were not involved and 53% of them feel being somewhat involved; only 15% are strongly involved at that time.
- In the co-creation of the COCOP system 30% felt strongly, 60% somewhat involved, 10% stated they were not involved.

The *developers* stated a high involvement of all the people concerned during the software development: Two of three developers stated that they involved operators and foremen to some extent, managers and project partners were seen mainly strongly involved. Being asked how often they integrated these groups in the development process operators, foremen, managers and other persons were involved about five times, project partners about thirty times a year.

2017 most of the experts were strongly (25%) or somewhat (46%) involved in the development process of plant-wide optimisation. Only 29% are not directly included (mainly coming from the steel and chemistry sector).

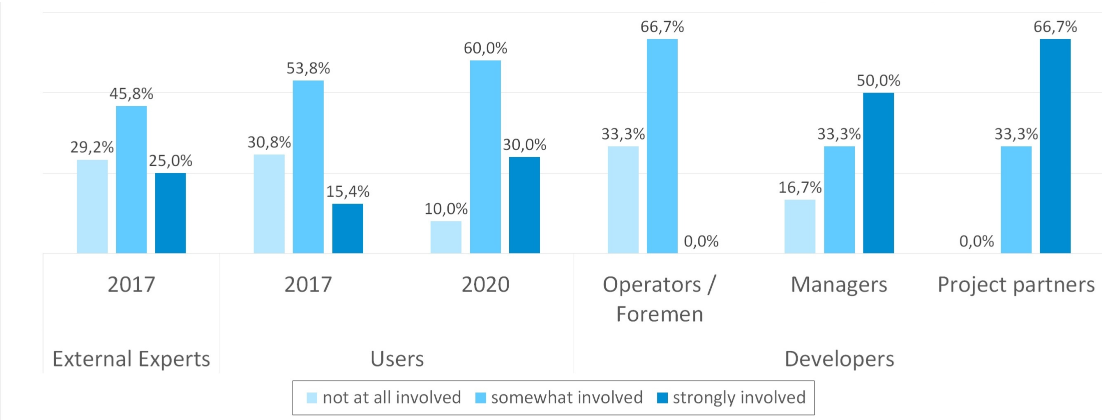

Figure 17 Involvement of different actors in the development process

Being involved in the development of the COCOP optimisation system the *users* increased their positive assessment during the course of the project. Compared with the former involvement in other optimisation systems (2017) significantly more users confirmed that their opinions were heard and the management was supporting their involvement in the COCOP development process (2020). Being sufficiently involved and getting the necessary information to support and understand the optimisation processes over the years, the recent and former involvement in optimisation processes leads to the statement that the participants are strongly or somehow eager to develop the optimisation process further.

While the external experts (2017) are very close to the opinions of the users (2018) they see leeway to improve supporting measures by the management.

The *developers* are a bit more critical about the involvement. They see more room for sufficient involvement of the users. Esp. concerning the expected user engagement in the further development of the COCOP system the developers have a wide range of opinions: from strongly disagree to somewhat agree to the statement, that the users are eager to develop the plant-wide optimisation tool further.

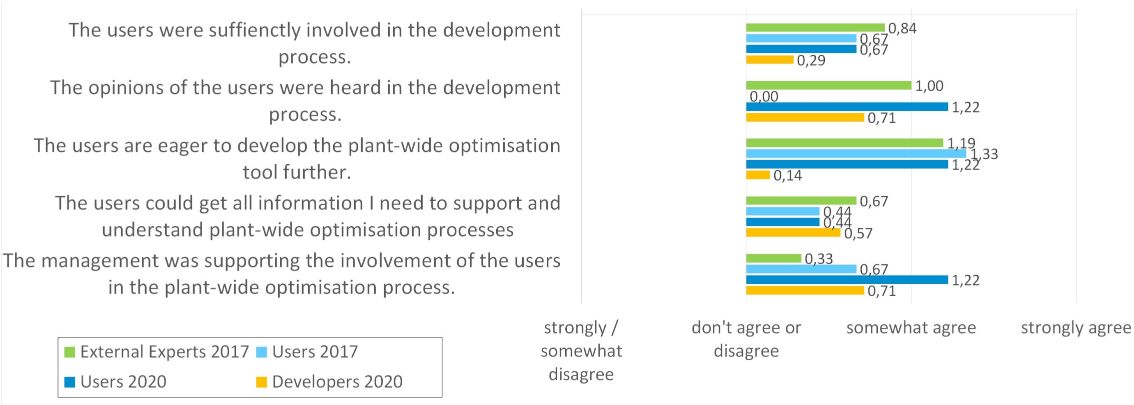

Figure 18 Specific aspects of user involvement

To conclude: Organisational measures, management support and communication structures were well recognised, supporting the implementation process of the plant-wide optimisation and the COCOP system. Users and developers stated a high involvement of different groups (foremen/operator, managers, stakeholders) in the development process. Due to this high involvement and support and the integration of users' opinions in the development process the users are being eager to develop the plant-wide optimisation system further.

Concluding remarks from the survey

Users, developers and experts stressed more or less the high relevance of plant-wide optimisation in general. Based on the experiences during the implementation of the COCOP solution the high, overestimated expectations of the (future) users in the beginning of the project were relativised, becoming a more realistic basis. Grounded on experience, optimisation systems will make work more interesting, increase possibilities for decision making, and finally improve job satisfaction. However, a reduction of the workload is not in place and was not intended (however, no additional workload as stated in the qualitative research, see following chapter).

Due to the high involvement of different groups (foremen/operator, managers, stakeholders) in the development process, supported by organisational measures, management decisions and communication structures, integrating the users' opinions the first version of the system the COCOP system fulfilled the demands on user friendliness more than expected. Moreover, the users feel more confident in their job and being supported in critical situations. Nonetheless, due to the implementation experience now a more realistic view on the functionality for the production process (speed, productivity, performance) is given in 2020 than estimated in 2017.

The experience with the implemented COCOP optimisation system and the supporting training for it led to a clear *added value of plant-wide optimisation systems in general and of the COCOP system in particular*. Knowledge about the relevance of optimisation systems for the workplace raised, valuing its support function and impact on the final product.

New skills for plant-wide perspectives are almost relevant. Although plant-wide processes in 2020 are more clearly presented in existing training measures, users, developers and experts state that this could be improved in general. While a mix of different training measures is still demanded by users and developers, the most preferred training measure of the users is (process) simulation, while developers are in favor of the combination of training courses with learning on the job.

It has to be considered that the expectations of the users for the COCOP system were too high in the beginning of the project (2017), not being aware of the technological possibilities so far. This has changed: Due to the implementation phase and concrete experiences with the system, experts, developers and users are more or less in line in 2020, underlining a more realistic assessment. However, practical knowledge and usage of the plant-wide optimisation system has to be improved by the further development and usage of the system. In line with the results of the qualitative interviews (see next chapter) the implemented COCOP system is seen as a prototype and preliminary optimisation tool, that have to be developed further in the direction of the user expectations. The users are still looking forward to be engaged in a further improvement and an increase usage in the future. Follow up of social KPI's monitoring during further developments has to be done to increase acceptance/usage and effectiveness of the new system.

4.2 Results of qualitative research

4.2.1 Steel case

Additional to the standardised questionnaires face-to-face or group interviews took place in July 2017 and February 2020 at Sidenor in Basauri, Spain. Most of the interviewees were installation managers that will be the main users of a (plant-wide) optimisation system in the steel case. Further interviewees were quality managers and manufacturing technicians (as internal stakeholders). In total, seven interviews (with 9 people) were carried out in 2017. In 2020, six people (foremen, line managers, and supervisors) from the melting shop, secondary metallurgy, and continuous casting were interviewed.

Beforehand, these people were identified as key staff that will make use of the future COCOP system. Despite the low number of interview partners, this qualitative research was very important for the project because it provided the requirements of the installation managers and quality supervisors (1) who are very familiar with the production processes, (2) who will mainly use the system and (3) will generate the main benefit of the future COCOP system. Additionally, these People gave feedback on the prototype that was introduced at the end of the project.

Interview sessions took place in Spanish language with interviewers from TU Dortmund University and representatives of Sidenor and Tecnalia to make sure that technical details were well understood by the interviewers and interviewees. The interviews were recorded and paraphrased before analysed in the present summary.

4.2.1.1 Before the installation (related to baseline) (2017)

The qualitative research is underlining the results of the standardised questionnaire 2017 and adding some important context related further information.

For all interviewed people, plant-wide optimisation is of high or extreme relevance for their work. Interviewees show a positive attitude towards advanced optimisation systems. They are anticipating advantages for the production process and for their work by using advanced optimisation systems. They are expecting that COCOP optimisation system will support the users in their original purposes, such as finding solutions for existing problems and optimising processes. Collaboration with upstream and downstream processes is already part of their current job but should be optimised, systemised and more supported.

From the interviews, cross-process analysis is currently seen as a reaction to present problems than a continuous task or information flow. Continuous plant-wide optimisation in the future could benefit in terms of speed and quality of processes. In the interviews, some people are currently missing decisions that are useful for the whole process, not only for single sub-processes. In the present situation, some of the interviewed persons state a lacking software system (like the to-be-developed COCOP solution) that provides data on interrelations between the owned process and previous/subsequent processes.

Some interviewees were explicitly interested in solutions that benefit the whole process not only single sub-processes. They have already gained experience that upstream processes have to be taken into consideration to optimise the owned process. The features of a future optimisation system seem to suit the motivating factors of their job (coping with challenges, finding new solutions, optimising processes). Some interviewees could explicitly imagine that the future (COCOP) optimisation system will increase job satisfaction. Positive experiences with existing optimisation systems have generated a high degree of acceptance for future systems. Important for this acceptance conditions are the compatibility with existing systems/tools, the reliability of the system and working with existing standards that enables tracking production results and improving them.

To accept both existing and future installation of software tools quality managers need an easy and intuitive usability and a good visualisation of the system. At least, it should make visible the effects of one sub-process on another. One person requested traceability of errors to identify their origin in upstream processes.

Most of the interviewed people stated education and training as a relevant condition for a successful implementation of a (plant-wide) optimisation system. It is important that handling of new software will be learned early on. However, existing trainings are not reflecting this necessity. There is no clear preference for a particular way of learning new skills: (process) simulation, general training courses and learning on the job are all highly relevant from the perspective of most respondents, meaning that a mixture of measures have to be combined. In the interviews, one person stated that not only installation managers should be trained but also operators.

As a result, plant-wide optimisation (not as a software system yet) is already supported by the organisational measures (such as communication and cooperation, incentives and targets, management decisions). However, interviewees stated that more organisational support is needed for the implementation of the future optimisation system. This means improving communication between different production areas (e.g. by common meetings) and providing personal support for the users. One interview partner emphasised explicitly that operators should be involved in optimisation processes correcting wrong decisions.

4.2.1.2 After the implementation of the prototype (end of project) (2020)

Acceptance of the optimisation system is generally given but critically reflected for improvements (KPI S1/S2)

The plant-wide optimisation system of COCOP is basically accepted, and a detailed description of implementations and online tests can be found in deliverable D6.2 Verification and validation report. It is technical (and functional) stable and user friendly (“nice and good looking”), easy to use, not requiring additional workload, estimating forecasting (with intrinsic information) and has a high potential the workers could benefit from. The system integrates data from different sources of the factory, for the online and offline tools. But having this stated, the workers see the system still in a developing phase: The system has still improvement potential by implementing additional utilities to the ones initially planned in the COCOP project (e.g. integration of another Ladle Furnaces is missing, making it difficult to follow complete sequences, differentiating between the different billet faces as not all of them suffer the same risk for defects or breakouts, or more interaction of online and offline tools). Main problem at this stage is that they do not have evidence and experience about the reliability of the given (forecast) information to follow the advices. They need to “trust” the tool information. To get this more time is needed (beyond the project life span). Especially at the beginning of the production (secondary metallurgy), they consider that the forecast of the number of defects on the final product is very useful but also very challenging in their view.

To increase trust in the data, comparison of the predictive data with the concrete production results would be helpful in the still given implementation phase. However, real data of the production process to verify the given system information is only available (depending on the production area) two days or months later (e.g. information about the defects can only be obtained maybe 2-3 months after the heat was produced).

Provision of background information and suggestions for actions

The workers considered useful that the system provides alarms, but they complained that the system does not provide the cause of the alarm and warnings neither present the reason for the present data on the system. In the case of a warning, the system should provide background information (to understand "why") and suggestions how to solve the problem. Negative predictions should be explained, background parameters should explain why). The connection of the offline COCOP system with the online monitoring tools should be checked to provide the users with additional information to make the correct decision (e.g. optimal values to solve the problem, influence of changing the value of a parameter in the final performance of the process).

Some of the operators are checking the system screen continuously and some of them (not technology and system affine) do not. There is an interaction with the system, mainly based on additional information but up to now not used for making decisions. As some workers are highly conscious about the potential and future advantages of the optimisation system (mainly about predicting defects), others do not see the need to consider the advices and information of the optimisation tool recently.

System improvements

In order to improve the system, the integration of a support system (online connection) is necessary. Providing online advice and suggestions to the worker could only be a part of an additional project (beyond COCOP), and needs a comparison of estimated values with real results, final production data integration (only available after several weeks or months).

At this initial stage of the implementation, the workers do not trust and use the predictive information (enabled by the system) given for the subsequent production areas. The main aim of the tool is the optimisation of production by reducing defects. Although the system gives them new and additional direct information about (possible) defects and this a critical information for them, they claim, that they need time to rely on the information provided by the tool. They need time (1) to rely on the data provided by the system and (2) trust the system. As functionality of the system will increase, the reliability and trust will also increase.

Involvement in the development process and support (KPI D1 and S3)

Involvement in the development process and support for the optimisation tool was is seen from “not at all” over “continuous” to “too much”. Although there has been organisational support from different departments of the company and feedback and training sessions of the developers (for selected workers in the development phase and about 60 people in the implementation phase) some of the workers complained that there could have been more training as well as more time and possibilities to express own ideas (KPI S3). Concerning training, learning on the job was a commonly preferred training form (because process simulation is not available yet). The documentation of the new system was assessed ranging from “did not get it” over “some parts are missing” to “helpful”. Those who felt being active involved confessed that their suggestions were taken up by the developers. However, it was stated that combining the software development with existing practical experience and knowledge (of their own production area) is challenging from the perspective of the workers, because of the plant-wide orientation of the tool.

Opening of the single own production area perception to a plant-wide perspective (KPI S4)

Most of the managers stated an already given plant-wide orientation due to their job, but they underlined (in line with the other workers) that the new optimisation system has improved and will increase the plant-wide perspective in the future much more (after improvement of the system) and will improve sensitivity for it by the continuously given (predictive) plant-wide information.

Job satisfaction (KPI S5)

No remarkable increasement (or decreasing) of job satisfaction was mentioned, due to the recent stage of the optimisation tool.

4.2.2 Copper case

The copper smelter COCOP system was tested in 2020. A detailed description of implementations and online tests can be found in deliverable D6.2 Verification and validation report. Two types of operators were interviewed, process operators who could benefit COCOP system the most and process operators to whom COCOP system can only provide some additional information. The results of the interviews reflect the fact that at the time of interviews, the (four interviewed) operators had only started to become familiar with the system - the dates are the first and second day when the COCOP system was brought in the smelter control room.

Furthermore, COCOP system developers spent several days each in the smelter, mainly or only in the control room, discussed with the operator(s) in duty and clarified the functionalities of COCOP system. In practice, COCOP developers presented especially the part of COCOP system they knew the best (i.e. the part of system they had developed). During this time, COCOP developers made notes and prepared to answer a brief set of questions produced by human factors experts. This period lasted for the two last weeks of January 2020 in a copper company. The total number of operators discussed with is 14 operators.

Three copper smelter operators also provided responses to a brief questionnaire. The responses were provided when the operators had had an opportunity to test COCOP system by themselves, without the presence of COCOP developers.

In the following, results for the two types of interviews as well as the questionnaire are presented. The results are classified in accordance with social KPIs (see explanations for the KPIs above). Additionally, as other points were raised during the interviews as well, they are reported below, after the KPI related results.

Usage of system advice (KPI S1)

In copper case, the usage and acceptance of the system could not be separated based on behaviour as during the COCOP testing period, operators were free to try the system. The usage of the system is shown by using the recommendations the system has provided, so usage directly reflects acceptance. However, in this section, the performance indicators are presented.

Having developer insight as the source of information, COCOP developers were asked how often they think operators used the COCOP system while developers sat beside them. As COCOP system did not push any advice but it was up to the operator to check how COCOP system would recommend in various situations. Regarding the amount of raw materials and additives to put in and in the timing of operations, it was not possible to evaluate how often the system's advice was used. Instead, developers could monitor how often operators followed the system recommendation, provided they had seen the recommendation. To start with, there was no general trend to be found but the way of acting seems to depend on the operator and the functionality in question. Six operators used the system hardly ever. Explanations for that, as reported by COCOP developers, were that the operator just was not interested in COCOP system; one operator was highly experienced (which can be a reason for not being interested); some thought the functionality the operator observed was unreliable. One example of unreliable functionality was the missing input data form crane scale that measured the weight of the matte ladles. The advisory system offered faulty recommendation based on missing mass measurement while the operator could take that into account in his mental model.

Seven operators used COCOP recommendations in about half of the situations they had seen the recommendation. Explanations for that, as reported by COCOP developers, were that suggestions were interesting but not always realistic; operators often made a compromise between own conception and COCOP recommendation; one operator utilised the values COCOP system provided, even if the system did not directly recommend anything; and one new operator first followed all recommendations but after colleagues' critique, his manager advised him not to follow at all. Finally, one operator, a trainee, followed almost always the recommendations COCOP system provided.

In the brief questionnaire with predefined response alternatives, it was asked how often COCOP system was looked at and regarding those instances, how often the recommendation was used. The operators not in the core of the usage of COCOP system (operator in the local control room and the one responsible for the whole process) had evaluated they had looked at the system only seldom and, based on those occasions, had only seldom used the recommendation. Converter operator, whose work COCOP system could support the most, had stated that (s)he had looked at COCOP occasionally (not seldom or often) and in those instances, had used the recommendation occasionally. Again, remembering that the system could not get 100% reliably input data from plant’s sensors and is not fully trustworthy yet, the result is rather good. It is especially positive that the roles (see following section "Roles benefiting from COCOP system"), whose opinion is the most important, had also the most positive one.

Acceptance of system advice (KPI S2)

Regarding COCOP system acceptance and the potential usage of it, it appeared that at least part of copper smelter operators could be ready to truly try and learn the system (developer insight as the source of the information). Before that, the COCOP system should constantly receive reliable input data (crane measurements, SO2 content of gases) and operators should be shown what the practical benefits of the system are, from the proceeding of the process and process output points of view. The type of operator not interested in COCOP system, according to interviews performed by human factors experts, is the one with long experience in copper smelting operations. They probably have a complex and extensive knowledge of the smelting process and its interdependencies. One challenge in introducing any new system to such operators is to really show that the new system is not only as good as they are but that in some cases, it can provide information beyond human capabilities. Here it becomes also obvious that the acceptance of the system by the experienced workers could have been higher as well as the performance of the system, if they and their experience would have been involved in the development process from the beginning. Contrasting to this, some operators were highly interested and provided suggestions to develop it further.

During all operator interviews (both developer-based insight and interviews made by human factors experts), COCOP system was not finalised and it produced information that did not take into account all the restrictions of local equipment. Because of that, operators could not trust the system and it had its consequences. It can be taken for granted that operators are experts in their work. Any new system must show how well it is to be trusted. As the operators are responsible for work results, it is highly understandable that they do not want to rely on unrealistic recommendations. To be precise, being experts, they are not supposed to rely on such recommendations either. Otherwise the situation can be seen, like one operator said, that "everything is done twice - first the machine does it and then you do it yourself. The human has to think it through". According to developer insight on operator opinions, the logic and functionalities of COCOP system appear or can be appropriate but the exact values require fine-tuning not performed yet. Had the instrumentation been more finalised during testing and interviews, the results could have been much better (from the perspective of accepting the system readily into operation).

As a sign of acceptance, operators named to COCOP developers various points in the copper smelting process, in which COCOP system might support the work of the operators. The points named varied according to the operator and probably depending on how much they had been shown about the functionalities of the COCOP system.

Operators were also inquired in the questionnaire, how much they considered COCOP facilitates decision making at work. Again, the role which is the most relevant as a COCOP system user had the most positive opinion: In the five-point scale from "not at all" to "a lot", field operator responded "not remarkably", process operator to whom COCOP system can only provide some additional information replied "maybe" and process operator who could benefit COCOP system the most chose the alternative "to some extent".

Plant-wide optimisation and personnel/organisational development (KPI S3)

According to interviews made by human factors experts, operators were accustomed with new systems. New systems are brought to the smelter every now and then so the operators had an open state of mind to renewals in their work. From that perspective, the implementation of COCOP system would not cause special issues. However, being as complex as it is, the deployment of COCOP system would require systematic training. Otherwise it is possible it would not be used enough and in that case, the full potential of the system would not be utilised in the smelter. The training related to COCOP system would not require extensive training related to plant-wide processes as it is well known by most operators working in the control room.

Understanding of plant-wide processes (KPI S4)

The interviewees (interviewed by human factors experts) had gained control over the process through their work experience. Like most operators in the smelter, they had started from simple tasks and continued in their career to the more demanding ones. This means that those working in the control room and having the possibility to use controlling and monitoring systems had the experience of working physically and manually in other areas of the process. As a result, operators in the control room had a clear conception of the plant-wide processes. The way of getting this knowledge, on the job, makes this knowledge vivid and profound. Assumable, training of plant-wide operations should be provided so that the experience of smelter operators is acknowledged - not everything is needed to tell in detail. This is the level of understanding of plant-wide operations in at least in the copper smelter of our Copper case.

In the brief questionnaire made to the copper company operators, all three operators, all from various parts of the smelter (local control, converter control, main control) agreed (separately from each other) that process optimisation is important in the smelter.

Influence on job satisfaction (KPI S5) and participation in plant-wide optimisation processes (KPI D1)

COCOP system was a preliminary version of a potential fully developed version, still having bugs and values to tune. Due to this, it is not possible to evaluate the influence of system recommendations to job satisfaction. Regarding plant-wide optimisation process, the personnel seems to be rather knowledgeable about plant-wide processes, probably at least knowing how the output of the part of the process they are responsible for affects the next phase. Regarding the participation on the development of COCOP system, operators were not involved in it. COCOP developers had visited the plant but, as the copper company was not a project member, did not disrupt operators' work but tried to model the smelting process by themselves as well as they could.

Roles benefiting from COCOP system

Based on information acquired through interviews made by human factors experts, there are roles in the control room having a wider responsibility on the smelting process, with control-room systems to support the monitoring and controlling of the system. From that perspective, control-room operators are the ones able to utilise COCOP system in the copper smelter. However, control-room operators work in close contact with operators all over the smelter - people come for exchanging information with them and telephone is used frequently. Field operators in the local control rooms probably would not need the information COCOP system would provide as such, but the operators would have a broader overview on the smelting process with it. Furthermore, operators from other places may substitute a control-room operator during his/her absence. This fact supports the idea of having COCOP system in the local control rooms as well. Still another group of potential COCOP system users are those working in the copper smelter only during vacation period. They are not permanent operators and do not know the process as well as those having worked there for several years. Having a supporting system like COCOP system would ease their work, providing grounds for decisions to be made.

User interface related feedback

According to interviews conducted by human factors experts, user interface of the COCOP system appeared clear for some operators, at least at first glance (remembering that during the interviews, the operators were not familiar with the system). Others claimed that the user interface was unclear. In practice, COCOP system was presented to operators in one dedicated display, among other displays of the control room. From the usage point of view, it is good that the monitor is not separate but is part of the control panel in front of the operator. It would be even better, if the functionalities of COCOP system could be implemented in their "correct" locations, so that the monitors which deal with some specific functionalities would have the related COCOP system functionalities there as well.

4.3 Conclusion

The system is working and giving stable information, offers innovative data to support the production work. However, this technological stability has to be added by a functional improvement (e.g. background information, online advice and suggestions, interaction with existing tools) and experience based trust. This further development and improvement will increase the acceptance and usage of operators in general and lead to *new social practices*, which are not given yet. Combining the online tools with predictive (off-line) tools might improve trust and reliability of the COCOP system and lead to suggestions for action beyond the pure information level. Therefore, further reciprocal learning between operators and developers / implementers is necessary. Giving the workers the possibility to get positive and reliable experiences as well as further integrating the workers' experience will improve the optimisation system in its functionality and reliability in a mutual way (see figure below): Within a Roadmap "Optimising the Optimisation System" functionality and reliability will increase mutually. The results of the interviews with the workers makes additionally evident that plant and production area specific settings have to be considered for transferability of the COCOP system to other companies and sectors.

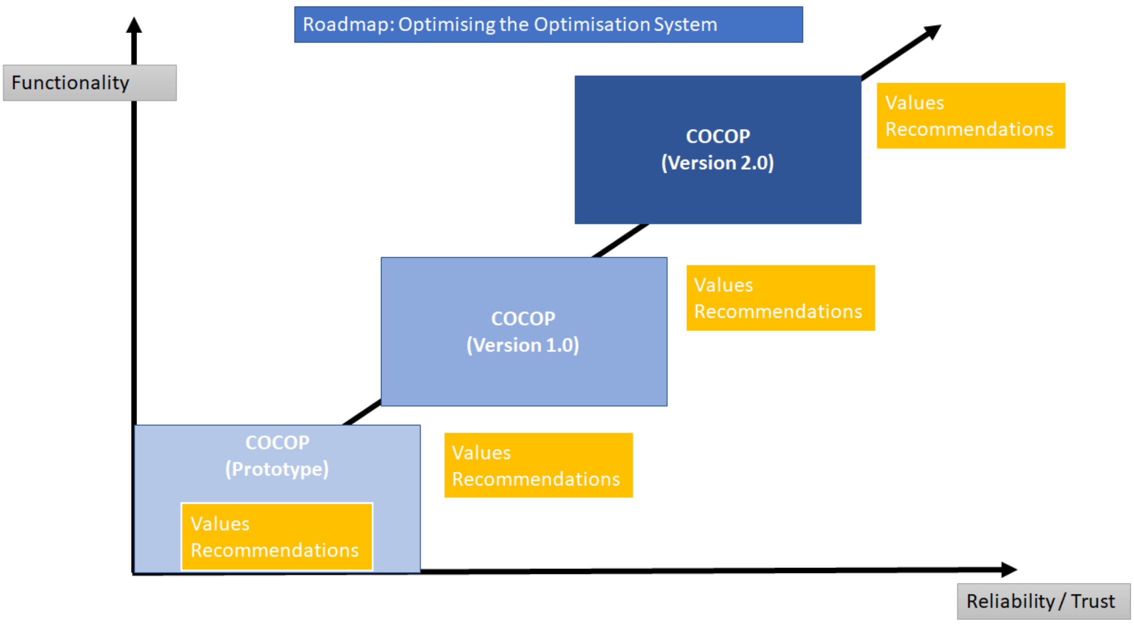

Figure 19 Roadmap: Optimising the optimisation system

5 Making social requirements and the technical development process compatible

Based on the results of the quantitative and qualitative surveys, requirements of future users and company internal stakeholders were defined - in COCOP called “Human Factors Requirements”. These requirements (deriving from the theoretical and empirical analysis) covered all elements of a sociotechnical system: technology, organisation and people. However, since the COCOP Project has been close to application, some further challenges had to be met to truly influence software development.

A team of human factors experts, KPI experts and software developers elaborated on the criteria for describing the human factors requirements to find a common interdisciplinary understanding and to bridge the different “culture” and language of the social and technological perspectives. This was done in a way that was understandable, helpful and workable for the technical oriented disciplines in the project. Therefore, human factors requirements should be clear, measurable and – in the end – validated; meaning, it can be clearly assessed whether a requirement is fulfilled or not. Answers to interview questions or to questionnaires are usually not formulated as requirements – they are expressed as statements, general descriptions/needs or questions etc. Therefore, the first step is to translate these answers into requirements that indicate to the members of the development team, how a (sociotechnical) system has to be designed to fulfil the given requirements. The criteria for a clear, measurable and validatable requirement is: Does the (sociotechnical) solution fulfil the human factors requirements – and to what extent? If defined in another, more open manner, technical designers take notice of the users’ and stakeholders’ needs, but they are not capable to process this information in their further work.

A framework was created that divides the requirements based on if they were result (R) or process (P) oriented. A result oriented requirement has a measurable goal which is typically true when end users can test and use the system. The process oriented requirement goal is more difficult to measure, and it typically considers aspects during the development. Furthermore, the requirements are divided into two categories, the ones between the user and the new system (person-to-system requirements, i.e., P2S), and the ones between users and the usage context (person-to-person requirements, i.e., P2P).

	Person-to-person requirements	**Person-to-system requirements**
Process-oriented requirements	It should be estimated if the COCOP system needs to be supplemented by further communication channels (e.g. face-to-face) that are needed by the (future) users.	The COCOP system should be improved with practical knowledge during the development, e.g. by excluding non-realistic solutions.
Result-oriented requirements	The project should measure plant-wide processes as part of operator training ratio relative to baseline.	The system should measure the acceptance ratio of how often the plant personnel follow the advice given by the system.

Table 2 Matrix of human factors requirements (examples)

Depending on the kind of human factors requirements, they will be treated in a different way. Person-to-system requirements that are related to the final system (e.g. user interface requirements) could be integrated into cases and be defined in project management tools (such as JIRA) familiar to technical designers. The more complex process orientated requirements have to be handled differently. They do not describe features of a finished (sociotechnical) system but processes that have to take place to concretise requirements. Therefore, actions were defined to fulfill HF requirements. In the following we give an example of requirement P-P2P-2.1. The process oriented requirement (P) is of type person-to-person (P2P) and has an identification number (2.1). The requirement description is as follows:

Trainings SHOULD be defined and developed to close the skills gap between needed and existing skills.

Action to be performed is as follows:

A workshop with human factors team, developers, end user representative, process expert and training expert.

Note that the use of term SHOULD, among other capitalized words, has a precise definition that is given in the COCOP deliverable D2.3 System Requirements Specifications. The categorization was performed in order to obtain a better overview and find synergies between the actions.

5.1 Milestones

One or more actions are specified for each requirement that aims to fulfil the requirement. The actions are organised on a milestone based timeline and the following list defines the milestones:

1. Setting up the project (building a project team)
2. Use case definition and requirement specification. During this milestone key persons are identified, attitudes of future users are analysed and an HF action plan is made.
3. A final or mature version of a mock-up or similar is sent to the customer. No functionality is required in the mock-up and it should be sent before the main software development (coding) effort starts.
4. Introduction of a prototype with some functionality.
5. Testing period of the release candidate that is expected to be final. The testing period should be initiated with an evaluation of the system by HF experts. Most or all functionalities are included.
6. Final system delivery
7. Maintenance

The milestones are defined in order to ease the burden to track when actions should be executed. Actions should be executed at latest immediately after a milestone is reached, but in many cases it is preferable to execute them during the milestone activity. The actions can and should be synchronised with the other project activities so that synergies can be utilized. Milestone 1 was predefined at the start of the implementation of the COCOP project and therefore does not contain any actions. However, we acknowledge the importance of this milestone and recommend to give it attention when implementing the COCOP concept in other areas in the future. For example, time should be reserved for HF work throughout the project and commitment of relevant stakeholder participation should be guaranteed. In the following table, an action plan is presented done for the COCOP steel case.

In the table, the status column contains abbreviations with the following interpretation:

1. (U) - Unhandled
2. (I) - In progress
3. (C) - Completed
4. (P) - Partially completed
5. (F) - Failed to execute
6. (N) - Will Not be executed

The following table shows an example for the steel pilot case, when the HF milestone 2 was almost completed and milestone 3 contained the next actions to be executed. For each milestone ID, an action type is given, which is of one of the following 5 types:

1. COCOP internal work or triggering an activity
2. Questionnaires
3. Interviews
4. Skype Meeting
5. Regular meetings or workshops

Mile-stone-ID	Action	Requirement-ID	Estimated time	Status
M2-1	Kick-off workshop at pilot plant.	P-P2P-7 (Common understanding) R-P2S-3.1 (UI related) R-P2S-3.2 (UI related) R-P2S-3.3 (UI related) R-P2S-3.4 (UI related)	2 days	P-P2P-7 (C) R-P2S-3.1 (I) R-P2S-3.2 (I) R-P2S-3.3 (I) R-P2S-3.4 (I)
M2-2	Interviews	P-P2P-1.1 (Future work content) P-P2P-1.2 (New skills) P-P2P-6.2 (End users' needs)	2 days (up to 1 hour per interview)	P-P2P-1.1 (C) P-P2P-1.2 (C) P-P2P-6.2 (C)
M2-3	Questionnaires	R-P2P-1.1 (Operator training) R-P2P-1.2 (Understanding processes) R-P2P-2 (Job satisfaction) P-P2P-6.1 (End user involvement) P-P2P-6.2 (End users' needs)	20 min per person	R-P2P-1.1 (C) R-P2P-1.2 (C) R-P2P-2 (C) P-P2P-6.1 (C) P-P2P-6.2 (C)
M2-4	Workshop	P-P2P-3 (Organisational practices)	0,5 day	P-P2P-3 (C)
M3-1	COCOP internal work	R-P2S-3.1 (UI related) R-P2S-3.2 (UI related) R-P2S-3.3 (UI related) R-P2S-3.4 (UI related) R-P2S-8 (UI related)	0	R-P2S-3.1 (U) R-P2S-3.2 (U) R-P2S-3.3 (U) R-P2S-3.4 (U) R-P2S-8 (U)
M3-2	Workshop	P-P2P-6.3 (Feedback on mock-up) P-P2S-2.1 (Effects of decisions)	0,5 day	P-P2P-6.3 (U) P-P2S-2.1 (U)
M3-3	Regular meetings	P-P2S-1.1 (Practical knowledge)	0,5 day	P-P2S-1.1 (U)
M4-1	Workshop	P-P2P-1.1(New skills) P-P2P-1.2 (New skills) P-P2S-2.1 (Effects of decisions)	1 day	P-P2P-1.1 (I) P-P2P-1.2 (I) P-P2S-2.1 (I)
M4-2	Workshop	P-P2P-2.1 (Plan training)	1 day	P-P2P-2.1 (U)

Mile-stone-ID	Action	Requirement-ID	Estimated time	Status
M4-3	Triggering decisions of the company	P-P2P-4 (Scope of decisions)	To be discussed	P-P2P-4 (U)
M4-4	Triggering level of flexibility	R-P2S-7 (Flexibility of use)		R-P2S-7 (U)
M4-5	Triggering decision about detailed information	R-P2S-11.1 (Detailed information)	To be discussed	R-P2S-11.1 (U)
M4-6	Regular meeting	P-P2S-1.1 (Practical knowledge) P-P2S-1.2 (Reliability of practical knowledge)	1 day	P-P2S-1.1 (U) P-P2S-1.2 (U)
M4-7	Internal COCOP work	R-P2S-6 (Memory supporting features)	0	R-P2S-6 (U)
M4-8	Triggering decision about detailed information	R-P2S-11.1 (Detailed information)	To be discussed	R-P2S-11.1 (U)
M5-1	Skype Meeting	P-P2P-2.2 (Education)	0,25 days	P-P2P-2.2 (U)
M5-2	Skype Meeting	P-P2P-3 (Organisational practices)	0,25 days	P-P2P-3 (U)
M5-3	COCOP internal work	P-P2P-4 (Validation scope of decision) R-P2S-1.1 (Acceptance ratio) R-P2S-6 (Memory supporting features) R-P2S-8 (UI related) R-P2S-12 (Differences between shifts)	0	P-P2P-4 (U) R-P2S-1.1 (U) R-P2S-6 (U) R-P2S-8 (U) R-P2S-12 (U)
M5-4	Interview	P-P2P-5 (Communication channels) P-P2P-3 (Organisational practices) R-P2P-1.1 (Operator training) R-P2P-1.2 (Understanding) R-P2P-2 (Job satisfaction) R-P2S-1.2 (Acceptance)	2 days (1 hour per interview)	P-P2P-5 (U) P-P2P-3 (U) R-P2P-1.1 (U) R-P2P-1.2 (U) R-P2P-2 (U) R-P2S-1.2 (U)

Mile-stone-ID	Action	Requirement-ID	Estimated time	Status
M5-5	Questionnaire	P-P2P-6.1 (Involvement tracking) R-P2P-1.1 (Operator training) R-P2P-1.2 (Understanding) R-P2P-2 (Job satisfaction) R-P2S-1.2 (Acceptance)	20 min per questionnaire	P-P2P-6.1 (U) R-P2P-1.1 (U) R-P2P-1.2 (U) R-P2P-2 (U) R-P2S-1.2 (U)
M5-6	Questionnaire	P-P2P-6.4 (Training)	20 min per questionnaire	P-P2P-6.4 (U)
M5-7	Regular meeting	P-P2S-1.1 (Practical knowledge) P-P2S-1.2 (Practical knowledge)	1 day	P-P2S-1.1 (U) P-P2S-1.2 (U)
M5-8	Workshop	P-P2S-2.1 (Prototype evaluation) R-P2S-3.1 (UI related) R-P2S-3.2 (UI related) R-P2S-3.3 (UI related) R-P2S-3.4 (UI related) R-P2S-7 (Flexibility and efficiency) R-P2S-9 (System errors) R-P2S-10.2 (Help documentation) R-P2S-11.2 (Detailed information)	1 day	P-P2S-2.1 (U) R-P2S-3.1 (U) R-P2S-3.2 (U) R-P2S-3.3 (U) R-P2S-3.4 (U) R-P2S-7 (U) R-P2S-9 (U) R-P2S-10.2 (U) R-P2S-11.2 (U)
M5-9	Triggering	P-P2S-2.2 (Simulate process) P-P2S-2.3 (Track process) R-P2S-2 (Provide relevant data) R-P2S-9 (System errors)	0	P-P2S-2.2 (U) P-P2S-2.3 (U) R-P2S-2 (U) R-P2S-9 (U)
M6-1	Interview	P-P2P-6.1 (Involvement) R-P2P-1.1 (Operator training) R-P2P-1.2 (Understanding) R-P2P-2 (Job satisfaction)	2 days (1 hour per interview)	P-P2P-6.1 (U) R-P2P-1.1 (U) R-P2P-1.2 (U) R-P2P-2 (U)
M6-2	Questionnaire	P-P2P-6.1 (Involvement) R-P2P-1.1 (Operator training)	20 min per questionnaire	P-P2P-6.1 (U) R-P2P-1.1 (U)

Mile-stone-ID	Action	Requirement-ID	Estimated time	Status
		R-P2P-1.2 (Understanding) R-P2P-2 (Job satisfaction)		R-P2P-1.2 (U) R-P2P-2 (U)
M7-1	Triggering	P-P2P-5 (Communication channels) P-P2S-1.3 (Practical knowledge) R-P2P-3 (Support team)	To be discussed 30 min	P-P2P-5 (U) P-P2S-1.3 (U) R-P2P-3 (U)
M7-2	Interview	P-P2P-3 (Organizational practices) R-P2S-1.2 (Acceptance) R-P2S-2 (Relevant data)	1 hour per interview	P-P2P-3 (U) R-P2S-1.2 (U) R-P2S-2 (U)
M7-3	COCOP internal work	R-P2S-1.1 (Acceptance)	0	R-P2S-1.1 (U)
M7-4	Questionnaire	R-P2S-1.2 (Acceptance)	20 min	R-P2S-1.2 (U)

Table 3 Action plan for human factors work at the steel pilot plant

6 Lessons Learned: How to Improve Combining Technological and Social Innovation

Based on the experience of this process we will describe a Social Innovation Process Prototype for combining technological development with a social innovation process including Human Factor requirements but also further non-technological concerns. This will be done in a generic way, illustrated by the COCOP (*incremental* technological change in production) and - if relevant and contrasting - by the ROBOHARSH (*disruptive* technological change in maintenance) project (cf. Colla et al. 2017).

It is important to differentiate between *incremental* (COCOP: adding a control system to existing production systems) and *disruptive* technological changes (ROBOHARSH: replacing manual work via robotic assistance with a new control and monitoring system). While in COCOP new skills are dedicated to gather additional information from a plant-wide perspective, in ROBOHARSH completely new digital skills are needed, mainly gathered via the co-creation of the robot assistance. Both processes were designed as co-creation but different needs and ways to integrate operators and workplace experience is given as well as a different impact on skills and training.

After the description of a prototype development process we will give an outlook of the relevance of combining technological and social innovation and embedding technological innovation in a social innovation process.

6.1 Social Innovation Process Prototype: Technological Innovation as a Social Innovation Process

Following the new innovation paradigm described in the beginning there is a shift from the pure technological to a broader societal perspective:

- from a technological to an objective and solution-oriented process perspective seeing technology as an enabler to solve a societal challenge
  in the COCOP case: to improve energy efficiency, reduce waste and emissions, reduction of rejection, ensure competitiveness in a global market, improving qualification and employability of the workforce
- to new overall and comprehensive structural principles of the innovation system
  in the COCOP case: to integrate the human competences, experiences, and requirements in the technological development within a co-creation process as much as possible
- organised in a comprehensive social innovation process
  to shape the technological development with non-technological issues taking impact on diverse areas (workforce, organisation, acceptance, mutual learning (developers and end-users) into account
  in the COCOP case: combining the technological development with a social innovation perspective.

This means that technological solutions have to improve, change, and create *new social practices* concerning roles, relations, norms and regulations, going beyond existing borders and consider impact in each direction.

Following the aim of a strict end-user focus workplace experience, acceptance and barriers should be the starting and reference point for every technological development, fulfilling specific end-user needs, considering and accepting formal, non-formal and informal competences, supporting professional transmissions.

Improvement of developing and implementing technological innovations is not only a system-related approach but a far-reaching and continuous social innovation process, including all the relevant stakeholders, not only within the organisation where the development takes places, but also including further institutions and policy makers as well as the inhabitants of the region and its related localities if needed.

It has to be seen as a social innovation process going beyond a systemic perspective and traditional innovation concepts (following Howaldt/Schwarz 2010), characterized by

- coordination and mediation between various different groups of stakeholders,
- interdisciplinarity, heterogeneity, recursivity and reflectivity of the processes of implementation
- emphasis on historical, cultural and organisational preconditions,
- increased involvement of users/citizens in processes of “co-development”,
- systemic perspective on innovation optimising research, development, production and marketing simultaneously in an interactive process,
- a kind of “hybridization” at the boundary between society (practitioners/users) and science (experts/developers).

Following the three elements of the new innovation paradigm (see figure in the related section) and the concept of the five Ws (Who, What, When, Where, Why) added by “How”, we will describe the COCOP Prototype of Combining Technological and Social Innovation inspired by the systematic of the “4 I Process of Social Innovation” of Hochgerner (2013). In a subsequent way, the process is starting with the (1) challenge and idea, which will be followed by the (2) intervention, (3) the implementation process (if valuable) and (4) impact / institutionalisation of the solution:

1. Idea: new solution for an existing societal challenge (technological, economic, social, environmental)
2. Intervention: funding, scientific support, core coordination structures, normative settings, common framework
3. Implementation of the innovation: open innovation process, development in partnership, new structures
4. Impact / Institutionalisation of the solution: improvement of quantitative and qualitative deployment, key competitive factor, professionalisation, efficiency and effectiveness, new social practices and production activities.

The figure below shows that the innovation process should start with a clear definition of the societal challenge (baseline) to be solved by a specific idea (starting point). This idea could/should be changed during the innovation process if at any point in the intervention, implementation and impact phase it becomes evident that the proposed way or invention is not effective and efficient and other solutions are better fitting the needs of the end-users or leading to better results and outcomes (feedback loops) - in an extreme case starting with a new idea and invention.

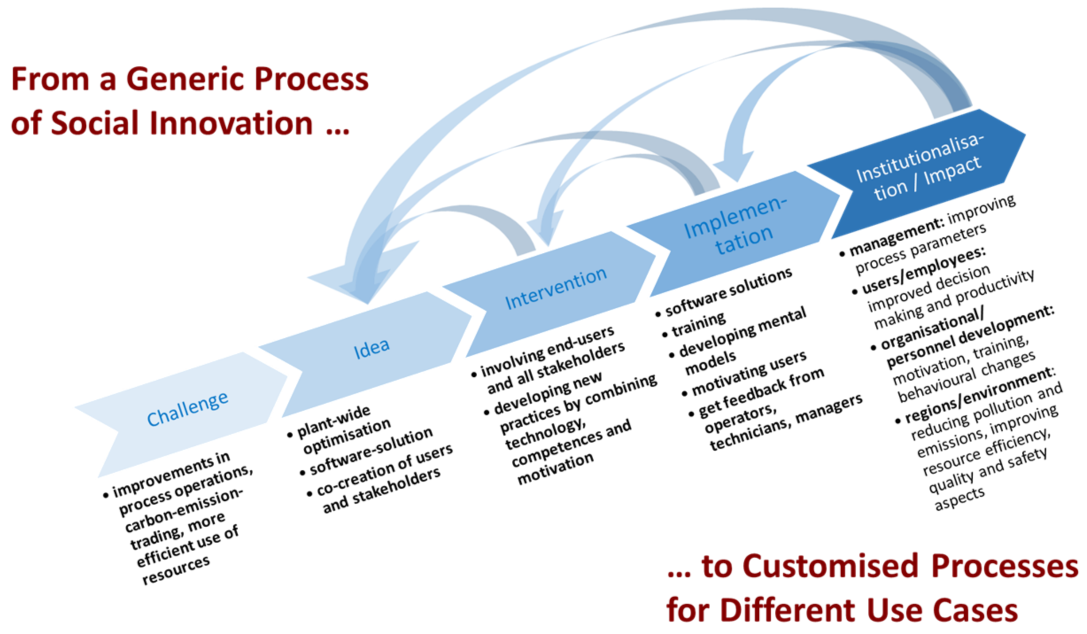

Figure 20 Innovation Process of COCOP

In the following the prototypical process will be described, illustrated by

- the COCOP experience (incremental, additional improvement) and solution,
- contrasted by the ROBOHARSH experience (disruptive change) if relevant

summarising the main challenges, barriers and enablers.

1. Challenge / Idea (objective):
Optimisation of the Production in Terms of Product Quality, Productivity and Competitiveness, and Environmental Protection

Why do we undertake this innovation? What is the main challenge to be solved? What is the objective? Which demand, social need or societal challenge is touched? What kind of social value creation is intended?

What idea is envisioned to solve the problem? (technological, economic, environmental and social)

The COCOP experience:

Main Challenge: improvement of production processes to improve competitiveness, reduction of emissions, efficient use of resources through

- Environmental objectives: increase the sustainability of the process industry i.e. reduction of pollution, greenhouse gas emissions and energy/raw materials consumption
- Social objectives: improve the working conditions of plant operators by developing new process-control tools supporting operative work by providing new ways to control the process, including new skills and competences development
- Economic objectives: strengthen the competitiveness of the European process and automation industry, resulting in job retention, exportable high-value IT products for the industry and corresponding jobs, and wellbeing in Europe.

Technological solution: digital plant-wide optimisation system to monitor the production process in order to optimise the quality of products, complex process industry plants optimally run by the operators with the guidance of a coordinating, real-time optimisation system, by taking into use the model based, predictive, coordinating optimisation concept in integration with local control systems.

Social innovation: To strengthen the societal and personnel development perspective the designed technological innovation was included in a concept of a social innovation process. Therefore, the technological development process was integrated into a broader innovation strategy integrating all relevant stakeholders and end users in a co-creation process, and thinking of the implementation and impact right from the beginning of the course.

The ROBOHARSH experience:

Main challenge: Reduction of hazardous and heavy weight situations and improvement of health and safety at the (maintenance) workplace. Idea is the installation of a robotic cell in the steel shop to support the technical personnel in the control of the tap hole and replacement of the sliding gate and related refractory material at the bottom of the ladle.

Barriers:

If partners of the project are not fully involved (e.g. not funded), access to and integration of end users in the development process is not guaranteed. To consider users' requirements via the developers instead, does only indirectly cover the social perspective. Users participation has to be permitted by the management and - depending on the on-site situation - by the workers' representatives (sometimes the employees are represented by different trade unions). However, such a participation and co-creation process is always a matter of trust in advance. Beneath the user and company stakeholder integration, a common view on the project and process by engineers and social scientists but could not be expected. The technological developers have to be open for the social perspective (often seen as "propaganda"), and the social scientists have to be open for technological vocabular and processes (mutual learning process, developing a new common innovation culture).

Enablers:

Joint agreement: All the relevant stakeholders have to support the development process. A strong commitment between management and worker's representatives is the basis for a successful innovation process with all its possible modifications, changes and challenges.

Cooperation of engineers and social scientists: An important enabler for the social innovation process is its early integration in the project idea and the definition what social innovation could contribute to the success. For instance, in a common process technological and social disciplines could collaborate by defining concrete use cases and how to innovate solutions in these use cases from a common, interrelated view.

User involvement: A joint endorsement of management and worker's representatives / unions is not only giving a perfect ground for the co-creation process. It also underlines the relevance of the innovation process and the importance of the user involvement to the highest degree. Such a basic agreement is also setting the ground for trustworthy cooperation, which is additionally given more and more during the course of the innovation process / project.

2. Intervention: Optimisation System Development Frame

How should the idea / invention be realised? What has to be concerned (e.g. advancement of existing or adding new production factors)? Who has to be integrated in the start of the intervention? Which structures are affected?

The COCOP experience:

Software development (invention) for optimisation of plant-wide production processes (intervention) was conceptualised as a social innovation process, identifying the stakeholders and end-users, integrating human factor requirements via experiences, skills and attitudes of the people concerned right from the beginning, contrasting different perspectives (developers, end-users, and external experts), defining milestones and critical events (see chapter Operationalisation).

An ideal workflow of social innovation was planned and integrated as the basis for learning effects collected during the project, starting with (step 1) setting up an interdisciplinary team of HF experts, KPI experts and software developers elaborating a workflow that covers all milestones of a software development process.

The ROBOHARSH experience:

Design and adaptation of the robotic cell to the special needs of the particular application. Integration of the technological development within a social innovation process, implementing technological innovation with the social perspective right from the beginning involving all the relevant actors and parties effected, concerning impact right from the beginning. All the (manual) tasks of the operators for the maintenance were divided and listed, looking for a substitution by the robot.

Barriers:

The collaboration of different disciplines in such a project does not guarantee integrated solutions, if working is characterised by strong task sharing between the different fields of operation. Additionally, different “languages” and “cultures” between technological and non-technological disciplines in the project represent a barrier, if they lead to separated lists of (technical and social) requirements and KPIs. This can lead to situations in which human factors requirements are delegated to separated human resources development, affecting software development only to a limited extent (and vice versa).

Overestimated expectations of the (future) users in the beginning of the project might lead to unrealistic expectation concerning the technological feasibility. However, this can be compensated by the integration of the end-users, experiencing technological possibilities and limits within the co-creation process.

Enablers:

The social innovation process is enabled if personnel and organizational issues are considered in a very early phase of the project - best during use case description as done in the COCOP project. Defining key staff of the involved company (end users, stakeholders) and conducting surveys with them shows an overview of current objectives, tasks of the future users and of experiences with IT tools introduced in the past. It proved very helpful for the COCOP project to derive such requirements from the perspective of end users and stakeholders. Thereby, human factors requirements to the COCOP system could be defined and monitored during the whole course of the project. Appropriate personnel and organisational measures (developing skills, communication channels, target and bonus systems) could be prepared. It is helpful to integrate user feedback on prototypes early to provide the opportunity for users to gain experiences with the system and to give substantial feedback on it. Integration of the end users will lead to a more realistic view of technological possibilities (latest in the implementation phase).

Co-creation right from the beginning as much as possible is key. Especially when it comes to disruptive changes (like in ROBOHARSH) the workplace experience of the workers has a high value to be combined with the technological knowledge of the developers (workplace innovation).

3. Implementation of the innovation (process)

How is the development process installed and organised? What kind of development process is most relevant to achieve the objectives and progress the idea further (e.g. how to open innovation to co-creation, user involvement and empowerment, cross-sector collaboration)? Who are the process key players? Which (production) areas are affected? Where and how is the solution implemented and tested?

The COCOP experience:

The COCOP implementation process is characterised by a detailed and comprehensive detection of human factor requirements leading to an increased potential for technological development. A social KPIs approach is addressing and monitoring the employees' professional competences, creativity, and willingness to cooperate. This included an incremental improvement of existing skills and job profiles: punctual training and operator integration; added to existing, used control systems; main co-creation part becomes relevant in the implementation phase (fine tuning of the prototype).

Following step 1 (see Intervention phase) step 2 of the social innovation process defined human factors requirements (incl. HF activities assigned to each milestone), deriving in an action plan (step 3) (incl. bundled HF activities to be executed at certain milestones, needed participants, estimated time consumption) as well as a tracking progress adding status information to the action plan (step 4). The final status information was used for validating HF requirements (incl. social KPI) (step 4).

In this important and success influencing phase the cooperation between technological developers, engineers and social scientist as well as with company stakeholders and end users (operators, shift managers etc.) was of high relevance. Main challenge was the transfer, interpretation of human factor requirements to technological relevant implications, not only because of "cultural, language differences" but because of falling back of the developers and end users to routines: Via "pedagogical repetition" the integration of human factor requirements in the innovative solution has to be continuously demanded as well as encouraging the usage of the new technology by the operators (fallback in existing routines). In this stage the development of new (social) practices comes into play as a precondition for the following institutionalisation phase.

The ROBOHARSH experience:

This was the main disruptive change in the workplace and its functioning / operations. Integration and installation of the robot system on the plant at a test workplace led to a development from scratch in a co-creation process of the developers and operators. Extensive tests of the system during the operations took place improving the robot assistance step by step. The implementation phase was conducted as a continuous improvement process with mutual learning of the operators (how to use the digital monitoring and control system) and the developers (how to integrate the worker's experience in the new task distribution between robot and operator. Digital Human-Robot-Interaction was taking over hard and hazardous work: In a mutual developing and learning process 39 operator tasks depicted at the beginning are now done mainly by the robot and the operator from inside the pulpit (esp. the heavy weight and hazardous ones), only eight tasks remained manually.

Barriers:

In general, it is a challenge to integrate production staff into development processes of new software. If not, every relevant people could be involved, some disadvantages in the development process can emerge: When some users are facing the system quite late (e.g. only some months before end of project), their requirements could not be uptaken in time. Testing a prototype only at the end of an innovation project (and this seems to be the usual way nowadays), operators have only a vague idea of what the system could provide. It is difficult to obtain essential feedback from (future) users, if they are not yet familiar with using a system in their everyday work for a longer period.

Enablers:

The social innovation process is enabled if personnel and organisational issues are considered in a very early phase of the project - best during use case description as done in the COCOP project. Defining key staff of the involved company (end users, stakeholders) and conducting surveys with them shows an overview of current objectives, tasks of the future users and of experiences with IT tools introduced in the past. It proved very helpful for the COCOP project to derive requirements from the perspective of end users and stakeholders. Thereby, human factors requirements to the COCOP system could be defined and monitored during the project. Appropriate personnel and organisational measures (developing skills, communication channels, target and bonus systems) should be prepared as well.

Direct integration of the operators in the implementation phase, leading to learning by doing for both developers and operators is improving acceptance and usage of the new solutions and its performance to a high degree.

4. Institutionalisation of the solution / Impact

How could the new solution be deployed after the implementation and research? What is the impact of the solution for daily work and life? What can be done to institutionalise the invention that it is integrated in routines and becomes a routine itself?

It is important to have in mind when planning the innovation process that just implementing an innovation in the end of an innovation project is insufficient! Being a crucial part of the innovation process the implementation phase have to be transferred to an institutionalisation and new social practices. In this stage the new product, process, method, process, structure, or regulations should become a new (social) practice, routine, as a part of everyday work (or life).

Additionally, in this phase the exploitation possibilities have to be checked. How to exploit the new solutions to other companies, sectors and areas? Business models, exploitation plans, ways to increase the TRL, etc. come into play – setting the ground for further improvements, adjusting and implementing the new solutions in similar or other working frameworks.

The COCOP experience:

Within COCOP the technological development was continuously covered by the perspective of new social practices. This comprised the integrating end-users into the prototype development and validation: Monitoring technical and social KPI, measuring to what extent the technological and environmental objectives were reached as well as end-users were involved in the system development and validating to what extent human factors requirements were fulfilled. Exploitation plans to other companies, sectors and areas as well as business models to increase the TRL were done delivered (see Deliverable 7.5).

The ROBOHARSH experience:

While already having installed one robotic cell at the workplace, the added value for an extension to other workplaces in the company is drastically shown by technical and social KPIs: increased health and safety by reducing physical, heavy weight activities, times confronted with high temperatures, and hazardous situations, reduction of critical situation to a high degree: from about 63% to about 15%, reduction of failures and incorrect operations, increasing job performance and productivity. The given solution in place could be easily improved depending on technical preconditions (e.g. with a different sliding gate the automation increases from 68% up to 88%) and transferred to other steel companies. New social practices were directly learned and institutionalised during the implementation process emerging with a new role of the concerned workers: from manual operating to digital supervising.

Barriers:

The innovation process often stops after the implementation of the solution, not taking into account its further improvement and institutionalisation at the workplace. But even in a co-creation process done so far, the new system has to show its usability in everyday work. The usage of the innovation by the users has to be improved based on the practical experiences and the ongoing monitoring of its results and added value. Users have to get more familiar, experience the reliability of the given information and advices of the system, robustness of data and quality improvement included.

Enablers:

Software and innovation development should not stop after the implementation phase. To monitor social KPIs further, gives an impression on how the system and the development process is perceived by the users. A positive attitude towards plant-wide optimisation and the new system is a base for further development. At least, users have an idea how the system could support them to execute their targets more successfully and therefore they are eager to (co-)develop the system further. Additionally, the social KPIs show what framework conditions (in terms of training and organizational measures or additional features of the system) are needed to make the use of the system more successful. The earlier a prototype (with functionalities) can be presented the earlier end users can give their feedback what can be uptaken until the end of the project.

Against this backdrop, showing that the new solution works could be done by the process-involved operators acting as "ambassadors" and promoters for the new solution.

Conclusion

Important finding concerning the development process was that the (future) end users expected to much from the (future) system, technological not feasible. However, due to practical experiences with the prototype, the results show that they were not disapointed but that they have concrete suggestions for future improvements based on their working demands. Additionally, it is necessary to have the whole development process from the idea to its institutionalisation in mind. Even if a new solution is accepted and used to a certain degree at the workplace more effort has to be made to ensure the transition from the implementation to the institutionalisation phase. The COCOP project finished within the implementation phase, by evaluating the developed prototype and looking for further deployment also to other sectors.

In future research projects an extension of the project duration and a further and a stronger attention to the transfer from the implementation to the institutionalisation phase should be in focus. This could be done by an additional funded project phase (in case the implementation of the solutions was successful). The innovation process from the challenge/idea over invention to implementation is a precondition for the institutionalisation phase: As a predetermined breaking point it could be decided if an innovation of any kind should and could be institutionalised. Up to now: only limited, "virtual impact", prove of concept is given, impact measurement is limited. Additional impact could be reached based by user demanded further suggestions. Only with the further improvement of the COCOP system the solution will change given and usual practices and routines, leading to new practices if functional for the improvement of the production. Efficiency and effectiveness of the co-creation process and the new optimisation tool is therefore still depending on the further integration of key personnel as well on following up social KPI's during development to increase acceptance/usage of the new system.

Concerning lessons learned also a stronger interrelation of technological and social KPIs as well as an interlaced thinking of technological and human requirements is necessary right in the beginning (setting the framework of the innovation process in the intervention phase latest). There should be no "delegation" of social requirements to the human factor experts but a strong integration of human factor requirements in the technological development process. It appeared that cooperation between technological developers and social scientists became a mutual learning process during the project interrelating the technological and social perspective in an interdisciplinary way, mutual acknowledged.

Concerning impact, a holistic interpretation of innovation outcomes (Hochgerner 2011) has to be conducted, considering:

- all types of innovation: products, processes, marketing, organisation, roles, relations, norms, values
- all functional systems: economy, culture, politics, law (when it comes to exploitation)
- all intervention levels, e.g. in relation to COCOP:
  - micro level: acceptance, usage, behaviour of end users
  - meso level: managerial, structural and organisational changes
  - macro level: integration of the COCOP system in the production line
- integrative and binding usage: more than complementary, subsidiary or supporting
- setting of a new (cultural framework): common orientations, objectives and their practical implementation, responsibility for the whole production process
- with increased demands for the organisational model and the management focusing on a plant-wide (production) framework and overarching support structure and common product development.

6.2 Outlook: Relevance of combining technological and social innovation

To get technological innovations implemented and change social routines and company performance combining technological and social innovation is key. “All innovations are socially relevant” (Hochgerner 2013) and therefore people and non-technological aspects are key factors for success or failure of technological innovations (see an illustration of key aspects in the figure below). They are relevant for improving (a) the effectiveness, implementation and sustainability of technological innovations and (b) the competitiveness of companies.

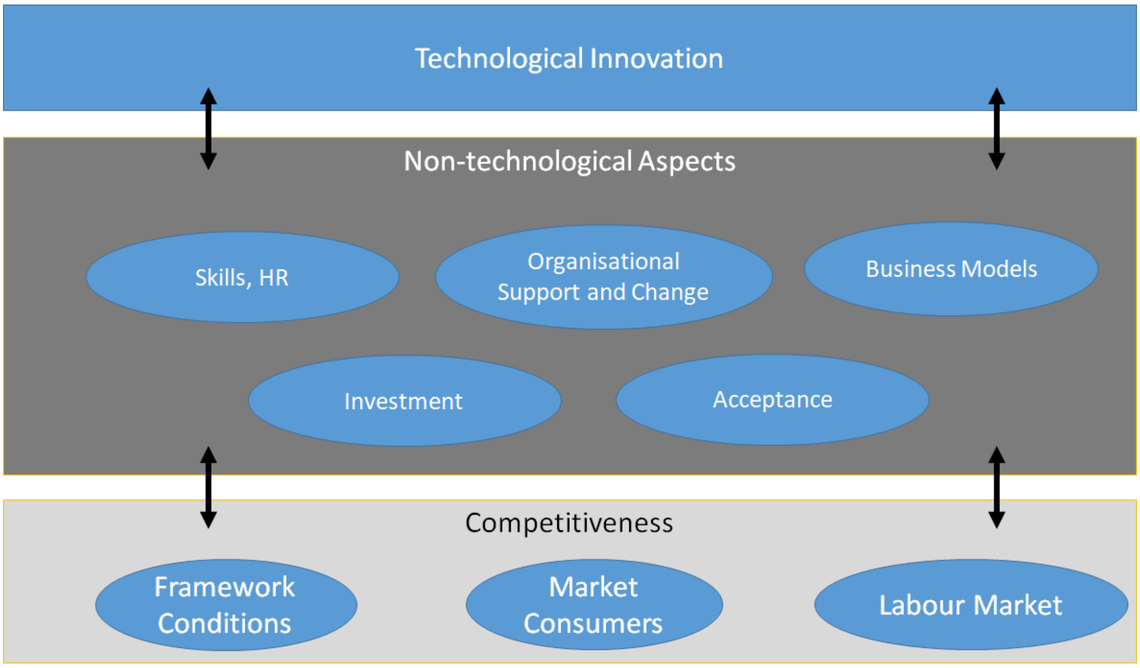

Figure 21 Relevance of non-technological and competitiveness aspects

However, every innovation development is a specific process because of the company environment and specificities. Not at least because of its embedding in a social innovation process: depending on the framework, integrated stakeholders, human and organisational impact, and other issues identified by their relevance for specific innovation processes. The table below is a non-exhaustive list and illustration of non-technological areas and their relevant activities for improving competitiveness and supporting technological innovation discussed in the new SPIRE 2050 Roadmap.

Category	Potential activities
Framework conditions **(Global / European** **National / Regional)**	Proactive (and uniform) European, national, regional and local frameworks to support innovation acceptance, implementation and transition: • Promote uniform norms and regulations regarding innovative implementations (e.g. energy and waste regulation and directives across EU member states to facilitate cross border business development and efficient infrastructures) • Identify and overcome regional, national and European bottlenecks hindering the implementation of new technologies (e.g. concerning reuse, recycling, and recirculation of material streams) • Create the best conditions to accelerate investments to deploy the innovative solutions • Stimulate sustainability investments in longer term ROI solutions (e.g. energy savings in energy intensive process industry) • Create conditions to attract “green” investments in Europe • Facilitate access to funding and private investments needed beyond company ventures (e.g. to support new energy and recycling concepts within civil society) • Formulate (new and politically addressed) key regulations to foster demand for climate-neutral products and support cost-competitiveness • Creating market penetration (pan European standards)

Category	Potential activities
	• Creating space for innovative start-ups and scale-up of SMEs that generate solutions for the sustainable European process industry • Transparent and harmonized global framework for CO2 emissions • Ensuring the security of supply (availability of resources, logistics, etc.) and needed infrastructure • Ensuring that innovations from one sector will be adapted and taken-up by another to speed-up the acceleration towards sustainable process industries • Set-up of (connected) regional ecosystems of stakeholders from industry, policy, science, VET and HE institutions, and civil society • Considering the impact of process industry transformation on the regional and local level • Considering regional impact: economic, policy, framework conditions, labour market, skills level needed, environmental, societal challenges and demands, …) • Improve civil society information, acceptance and commitment • And others.
Market / Consumers	Value chain approach (upstream, midstream and downstream; creating a market), developing a vision on the implications of consumer products from “greener” process: • Connecting across the value chain: upstream, midstream and downstream • Support to improve societal acceptance of (greener) products and to integrate consumer demands for new generation of materials, products and services • Creation of markets for climate-neutral, circular economy products • Developing climate-neutral and circular solutions and financing their uptake • Access to resources and deployment • Supporting green industry by public procurement • Piloting new value chain collaboration, organisation and business models • Developing and demonstrating new business models for new economic opportunities (e.g. driving circular economy business through digital resource platforms, new business opportunities for value chain orchestrators, new financial models for servicing the process industry i.e. for emerging energy carriers) • Creation of lead markets (e.g. on energy reduction, recycled materials as feedstock, industrial symbiosis, energy exchange like carbon to chemicals) • Reflection and integration of consumers’ demands • Developing show cases to emphasise the benefits of a greener process industry for the citizens • And others.

Category	Potential activities
Human resources, skills and labour market	New ways to close skills gaps and mismatches, improving the capacity of the process industry to unfold the potential of digitalisation and innovation: • Considering impact of the transformation of the process industry on new skills required • Developing new education and training schemes responding to regional, pan European workforce planning within the (digital and ecological) transformation • Recruit and retain talents needed by the companies, how to attract talents to the production industry in Europe • Transforming of training supply (company internal and external) and the labour market • Creating the innovators of the future: combining technology innovation and business model innovation for the process industry • Cooperation with local / regional education and training providers on the regional / local level, bridging with schools and universities, developing new teaching materials • Investments in education and training (division of responsibilities for industry, public VET institutions / universities, and the individuals), new learning models for “learning to learn” • Change management within the companies to upskill the existing workforce • Integrate experience and competences of the experts of the workplace (operators) within technological innovation development • And others.

Table 4 Check List for non-technological aspects combining technological and social innovation

Additionally, innovation processes might be supported by a tool box database of good examples, identifying and further developing tools with relevance to combine technological with social innovation, stimulating a cross-sector transfer of solutions and foster transferability and exploitation of innovations, stocktaking of innovative solutions all over the industries (and beyond). For instance, supporting by:

- Overview of possible business models
- Governance Approaches (e.g. ecosystem approach on the regional level)
- Tools for combining social and technological innovation (e.g. Societal Readiness Levels, social KPIs, etc.)
- Overcoming knowledge barriers, exchange of knowledge for new solutions, mapping of existing relevant activities for the sectors and regions
- Cross-sectoral transfer of innovative solutions
- Stocktaking of similar important activities / programmes / projects
- Common strategies for specific challenges (e.g. consumer information activities, joint recruitment and image strategies and tools)
- Topic relevant tools (e.g. LCA models)
- And others.

Beside the general framework and competitiveness perspective, the main objective on the company level is to improve the effectiveness of the technological solution by integrating the end users' and other relevant stakeholders' know-how and considering feasible (organisational, societal, environmental) impact right from the beginning. Therefore, a better cooperation and mutual understanding of developers (engineers) and beneficiaries (end users, society) of the innovative solution is a precondition. Such an innovation process is always a mutual learning process (for the benefit of all, win-win situation). The COCOP project showed that this is not an easy task.

Every innovation project has to check which non-technological factors are affected and should be integrated. Example: For processing of side, waste streams (materials, water, energy and gas) relevant non-technological aspects which have to be considered might be the integration of regional stakeholders from policy, economy, civil society and science ("quadruple helix") setting up a regional ecosystem for the governance of a regional roadmap to improve the processing of side/waste streams beyond the company involvement and responsibility. This should lead to new social practices based on new market models and consumer behavior as well as new skills development to unfold the potential of new process technologies within the companies and the region.

Although there might be some fundamental research without a recent possibility to oversee the non-technological necessities the combination with social innovation will help to prove the possible impact (in a negative or positive way) in an early stage, with an outlook on implementation and sustainability right from the beginning. Getting a feeling for non-technological demands will lead to more effectiveness within the development phase and to more efficiency on the long run (reducing costs for implementation failures and subsequent costs for adjustments).

Framework and market conditions, human resources and skills, and customer and consumer behaviour have to be adjusted. The culture within the companies, sectors and regions, where the companies are placed might have to change as well. Policy makers have to uptake the impact of relevant innovations for regional development.

Ideally, an interconnected process of technological and social innovation will bring together relevant stakeholders from science/research, business, policy/government and civil society to improve agenda setting, research, technological development, testing and implementation (see figure below, source: Schraudner et al., 2018).

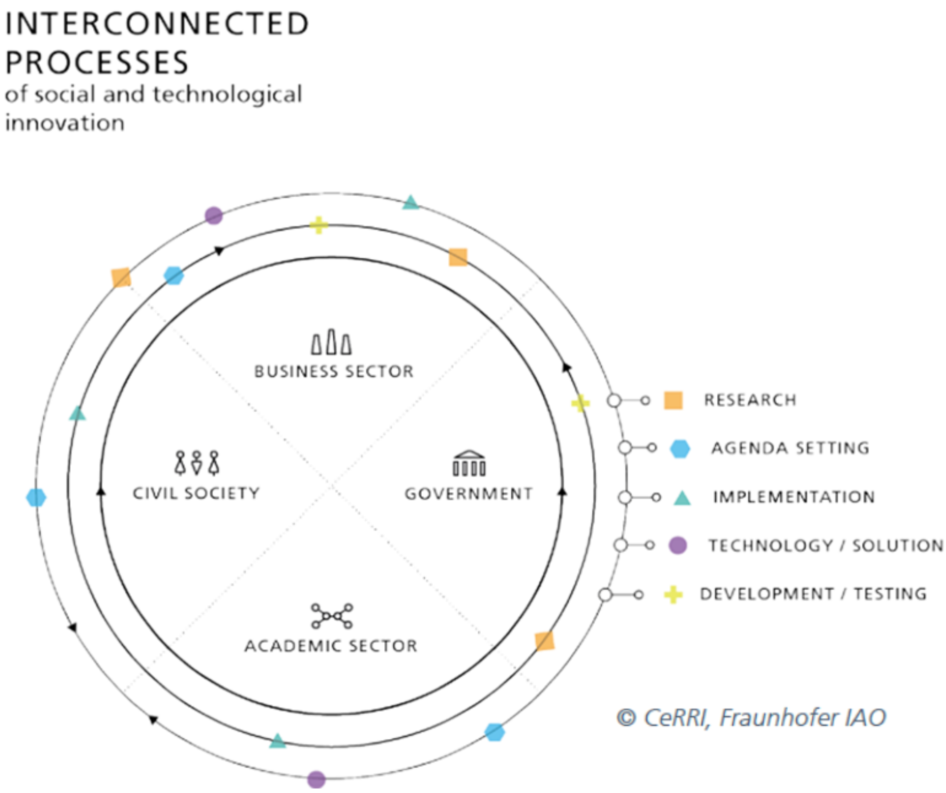

Figure 22 Interconnected process of social and technological innovation

Such an interconnected process of social and technological Innovation (Schraudner et al., 2018) leads also to the suggestion not only to look at the improvement of the Technological Readiness Levels but to combine it with Societal Readiness Levels as developed by the Danish Technology Institute (DTI):

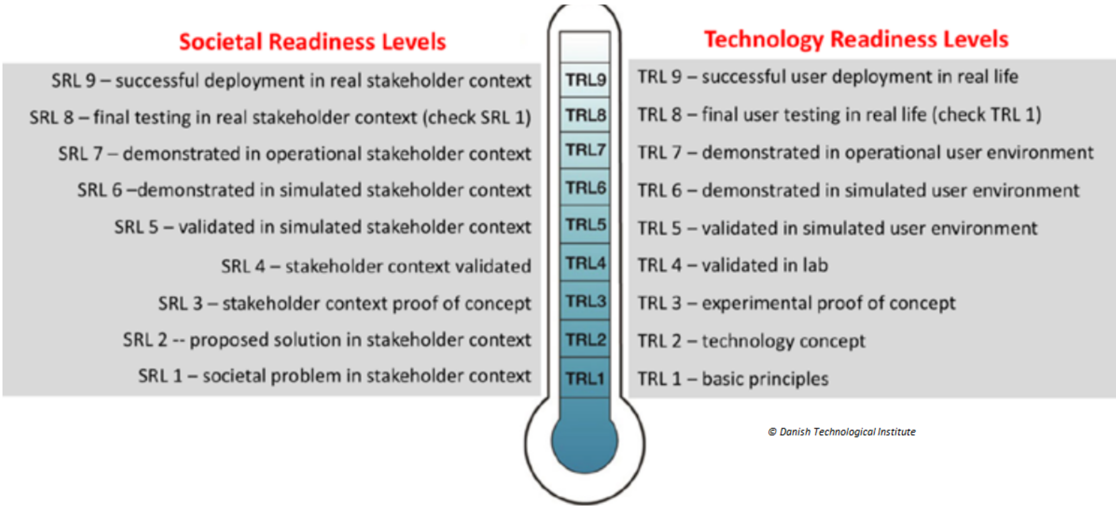

Figure 23 Combining Societal and Technology Readiness Levels (© Danish Technology Institute) (Schraudner et al., 2018)

Important research topics focusing on the social and non-technological aspects should be part of the research agenda as well as technological basic research. Within this kind of arrangements, proactive adjustment of Human Resources and Skills for technological development and implementation and for unfolding the technological potential in industry sectors, companies, and regions are key. Only with high and tailored up- and reskilled people technological solutions will unfold their full potential (in the companies and regions). New ways of cooperation between industry and VET-systems is needed, up-taking industry skills and qualification demands in a dynamic and short term (see the New Skills Agenda of the EC and related Sectoral ERASMUS+ Blueprints like the Skills Alliance on Industrial Symbiosis (SPIRE-SAIS)" and the European Steel Sector Alliance (ESSA, https://www.estep.eu/essa/)). A specific focus could be on new learning arrangements (digital, cooperation of education systems with companies, e.g. "dual system", short-termed implementation of new skills demands/occupations), digitalisation as attracting and recruiting measure (attracting new target groups, e.g. women), cross-sectoral worker pools (to close mismatches), and others.

Conclusion

The underlying process combining technological with social innovation

- widened the scope of innovation (by including the human factor requirements in the innovation process)
- developed innovations as a co-creation process involving relevant users and stakeholders;
- modified social practices, to integrate the new optimisation system in the daily work, adding a new meaning to the former workplace.

However, routinised behaviour (of process control) and decision making still have to be changed - but this will only happen in line with the remarked improvements of the workers for the software tool.

In combining technological innovation with a social innovation process awareness for the relevance of non-technological factors will be raised to improve effectiveness of the solution by co-creation processes, reflecting relevant aspects for the implementation of technological innovations and considering environmental and societal impact right from the beginning. Although such an approach might be seen as too programmatic, it will ground technological innovation to the needs of companies, industry sectors, and society - directing technology as an enabler of innovation (FORA 2009): A New Nature of Innovation). Or to say it with the words of Klaus Schwab (Founder of the World Economic Forum) to calls for leaders and citizens to “together shape a future that works for all by **putting people first**, empowering them and constantly reminding ourselves that all of these **new technologies are first and foremost tools made by people for people.”** (Schwab 2016)

To integrate technological development within an overarching social innovation process there are different key factors:

1. A high willingness of cooperation of various technological innovation developers, areas, programmes, projects to integrate non-technological concerns.
2. The integration of (company) internal but also (if relevant) external stakeholders, projects and activities.
3. The openness for feedback loops and recalibrating the technological objectives and solutions.

There are a lot of research and technology topics which need to align and join forces, driven by industry but with the need of support and coordination of external stakeholders and authorities. Collective problems and needs addressed by market and society players could be commonly turned into solutions and opportunities (for instance regional technology or business centre of the future). European, sectoral, national regional industrial eco-systems and governance structures, based on existing cooperation (e.g. like in region like Innobasque in the Basque Country or smart industrial parks) are developed to get a positive environmental impact up to solve economic and environmental and social challenges together: e.g. a cleaner, less polluting and more efficient production leading to an increased competitiveness, new and more jobs, new social practices of citizens.

Agile engineering and co-creation processes will lead to new industrial standards concerning the organisation of innovation and the observance of social and societal impact (circular economy, sustainability, regional development, and human resources development). Foreseeable and unforeseeable effects on society, economy and environment will be considered solving technological, economic, and social problems with the engagement of relevant stakeholders within and beyond industry – and the embeddedness in European, national and regional/local framework conditions to improve global competitiveness.

References

Brooks, H. (1982). Social and technological innovation. In S. B. Lundstedt & E. W. Colglazier (Eds.), *Managing innovation: The social dimensions of creativity, invention, and technology* (pp. 9–10). New York: Pergamon Press.

Colla, V., Schröder, A., Buzzelli, A., Abbà, D., Faes, A., & Romaniello, L. (2017). Introduction of symbiotic human-robot-cooperation in the steel sector: an example of social innovation. *Matériaux & Techniques*. (105), 505.

Dregger, J., Niehaus, J., Ittermann, P., Hirsch-Kreinsen, H., & Hompel, M. t. (2016). *The Digitization of Manufacturing and its Societal Challenges: A Framework for the Future of Industrial Labor*. Retrieved from http://www.neue-industriearbeit.de/fileadmin/templates/publikationen/Dregger_et_al_2016_Digitization_of_Manufacturing_and_its_Societal_Challenges_IEEE_Proceedings.pdf

European Commission (2014). Social Innovation: A Decade of Changes. A BEPA Report. Retrieved from https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/social_innovation_decade_of_changes.pdf

FORA (2009). *New Nature of Innovation.: Report to the OECD*. Copenhagen. Retrieved from https://web.archive.org/web/20160426045708/http://www.tem.fi/files/24835/New_Nature_of_Innovation.pdf

Gardner, C. A., Acharya, T., & Yach, D. (2007). Technological and social innovation: A unifying new paradigm for global health. *Health Affairs (Project Hope)*, *26*(4), 1052–1061. https://doi.org/10.1377/hlthaff.26.4.1052

Green, K., & Vergragt, P. (2002). Towards sustainable households: a methodology for developing sustainable technological and social innovations. *Futures*, *34*(5), 381–400. https://doi.org/10.1016/S0016-3287(01)00066-0

Hirsch-Kreinsen, H. (2016). Digitization of industrial work: Development paths and prospects. *Journal for Labour Market Research*, *49*(1), 1–14. https://doi.org/10.1007/s12651-016-0200-6

Hochgerner, J. (2011). “Die Analyse sozialer Innovationen als gesellschaftliche Praxis,” in *Pendeln zwischen Wissenschaft und Praxis: ZSI-Beiträge zu sozialen Innovationen*, 173–189.

Hochgerner, J. (2013). Social innovation and the advancement of the general concept of innovation. In C. Ruiz Viñals & C. Parra Rodriguez (Eds.), *Social Innovation: New forms of organisation in knowledge-based societies* (pp. 12–28). New York: Routledge.

Howaldt, J., & Schwarz, M. (2010). *Social Innovation: Concepts, research fields and international trends*. Retrieved from http://www.sfs.tu-dortmund.de/odb/Repository/Publication/Doc/1289/IMO_Trendstudie_Howaldt_Schwarz_englische_Version.pdf

Howaldt, J., Kaletka, C., Schröder, A., & Zirngiebl, M. (Eds.) (2018). *SI-DRIVE deliverable: Vol. 12.6. Atlas of Social Innovation: New Practices for a better future*. Retrieved from https://www.socialinnovationatlas.net/fileadmin/PDF/Atlas_of_Social_Innovation.pdf

Kohlgrüber, M., & Schröder, A. (2017). A New Innovation Paradigm Based on Social Innovation. Retrieved from https://www.cocop-spire.eu/content/new-innovation-paradigm-based-social-innovation

Kohlgrüber, M., & Schröder, A. (2019). Innovation Reloaded: The Social Character of Digitalisation in Industry. In J. Howaldt, C. Kaletka, A. Schröder, & M. Zirngiebl (Eds.), *Atlas of Social Innovation: 2nd Volume: A World of New Practices*.

Kopp, R. (2016). *Industrie 4.0 und soziale Innovation: Fremde oder Freunde?*

Kopp, R., Dhondt, S., Kreinsen, H. H., Kohlgrüber, M., & Preenen, P. (2019). Sociotechnical perspectives on digitalisation and Industry 4.0. *International Journal of Technology Transfer and Commercialisation*, *16*(3), 290. https://doi.org/10.1504/IJTTC.2019.099896

Mulgan, G. (2018). Social Innovation: The Last and Next Decade. In J. Howaldt, C. Kaletka, A. Schröder, & M. Zirngiebl (Eds.), *SI-DRIVE deliverable: Vol. 12.6. Atlas of Social Innovation: New Practices for a better future* (pp. 194–197). Retrieved from https://www.socialinnovationatlas.net/fileadmin/PDF/einzeln/04_Future-Challenges-and-Infrastructures/04_01_SI-the-last-and-next-decade_Mulgan.pdf

Pot, F. D., Rus, D., & Oeij, P. R.A. (2017). The Need to Uncover the Field of Workplace Innovation. In P. R.A. Oeij, D. Rus, & F. D. Pot (Eds.), *Aligning Perspectives on Health, Safety and Well-Being. Workplace Innovation: Theory, Research and Practice* (pp. 1–8). Cham, s.l.: Springer International Publishing. 1–8.

Ramaswamy, V., & Gouillart, F. J. (2010). *The power of co-creation: Build it with them to boost growth, productivity, and profits*. New York, NY: Free Press.

Scheer, A.-W. (1990). *CIM Computer Integrated Manufacturing*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-61510-8

Schraudner, M., Schroth, F., Jütting, M., Kaiser, S., Millard, J., & van der Graaf, S. (2018). Social Innovation: The potential for technology development RTOS and industry. Retrieved from http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-534927-16.pdf

Schwab, K. (2016). *The Fourth Industrial Revolution*. World Economic Forum, Geneva, Switzerland.

Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. Los Angeles: SAGE.

Tüllmann, C., ten Hompel, M., Nettsträter, A., & Prasse, C. (2017). *Social Networked Industry ganzheitlich gestalten.* https://doi.org/10.24406/IML-N-462112

Van der Have, R. P., & Rubalcaba, L. (2016). Social innovation research: An emerging area of innovation studies? *Research Policy*, *45*(9), 1923–1935. https://doi.org/10.1016/j.respol.2016.06.010

Waldner, J.-B. (1992). *Cim: Principles of computer-integrated manufacturing*. Chichester: Wiley.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The Machine That Changed the World: The Story of Lean Production*: The Free Press.

Annex

Social KPIs

KPI-S1 Usage of system advice

KPI definition	
Content	
Name	Usage of system advice
ID	KPI-S1
Description	How often does the plant personnel follow the advice given by the system
Scope	Work centre / whole site
Formula	Usage of system advice = number of accepted advice / total number of advice
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher, the better
Context	
Timing	On-demand and/or periodically
Audience	Supervisor, management
Production methodology	Continuous and/or discrete
Effect model diagram	Graphical overview of usage overtime, periodically or/and at critical milestones
Notes	The acceptance ratio should if possible be measured in the solution itself automatically. It should be a requirement to T2.2 when design of optimisation system. For e.g. by an acceptance button.
Assessment	
Data source	Number of presented advice Number of followed advice Generated in the COCOP solution.
Data availability	Frequency
Goal	High usage of the system
Notes	Quantitative and qualitative assessment of the usage. The usages could have quantitative (how often) and qualitative (improvement of the production activities) effects.
Impact	
Description	KPI impact evaluation description.

	· Productivity improvement · Reduction of energy use · Reduction of CO2/SO2 emissions · Economic impact · Oil usage due to low feed-rate Increase of productivity and quality (quantitative and qualitative usage of the system advice) Higher quality of the production and decrease of defects Reduction of energy use and CO2 emissions Economic advantages: cost effectiveness, lower costs
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	Indirect impact, through lower amount of losses/emissions/energy consumption caused by minor operator errors. This is based on the hypothesis, that the new system is having these technical based possibilities, effects.

KPI-S2 Acceptance of system advice

KPI definition	
Content	
Name	Acceptance of system advice
ID	KPI-S2
Description	How accepted is the advice given by the system
Scope	Work centre/whole site
Formula	Acceptance of system advice: to be operationalised in a questionnaire, such as: Do you agree with the following statements: · The system gives reliable advices · It makes decisions easier · It reduces workload · It is easy to handle · It is adaptable to individual requirements
Unit of measure	% of acceptance
Range	Min: Strongly disagree Max: Strongly agree
Trend	The higher the agreement, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete

Effect model diagram	Graphs of the percentage of acceptance, based on the questionnaire results
Notes	Questionnaire: "Acceptance" will be operationalised by criteria of the system developers and the users of the system. Co-creation of the indicators for acceptance.
Assessment	
Data source	Questionnaire, interviews
Data availability	New data, primary data survey: interviews, questionnaires
Goal	High acceptance (mind-set)
Notes	Qualitative assessment of the system by the operators
Impact	
Description	Increase of Productivity and Quality (quantitative and qualitative usage of the system advice) Higher quality of the production and decrease of defects Reduction of energy use and CO2 emissions Economic advantages: cost effectiveness, lower costs. · Productivity improvement · Reduction of energy use · Reduction of CO2/SO2 emissions · Economic impact · Oil usage due to low feed rate
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	Through a higher acceptance the usage of the system is improved, increasing (improving KPI-S1C)

KPI-S3 Plant-wide processes as part of operator training ratio relative to baseline

KPI definition	
Content	
Name	Plant-wide processes as part of operator training ratio relative to baseline
ID	KPI-S3
Description	The share of plant-wide processes as part of operator training relative to baseline Objective: to integrate the plant-wide perspective and to assess if it is adopted as an integral part of training Methodology: document analysis of training material, questionnaire for operators/shift managers (is the perspective sufficiently considered in the training?), interview of training responsible persons (how is plant wide understanding provided in trainings)

Scope	Work centre/whole site
Formula	Document analysis: part of training material (yes/no; if yes, to what extent and in which form) Questionnaire: Statement "Plant-wide understanding is sufficiently considered in trainings." Range of answers: strongly agree - agree - indifferent - disagree - strongly disagree Interview: quantitative and qualitative aspects of training Measured in the beginning and in the end.
Unit of measure	Documents: training modules related to plant-wide processes, questionnaires/interviews of training responsible persons, operators
Range	Comparison of initial (existing training programme) and final situation (after system development)
Trend	The higher the approval, participation and knowledge improvement of operators and managers, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management, personnel development responsible persons, operators
Production methodology	Continuous and Discrete
Notes	
Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Training documents, primary data via survey
Goal	Integration of all relevant employees (operators, managers, etc.) in the training programme, improvement of knowledge about plant-wide processes
Notes	Indirect assessment through the attitudes of trainees, in combination with a document analysis of existing and new training programs target-performance comparison
Impact	
Description	Better understanding of plant-wide processes Awareness for training programs to get a plant-wide perspective Higher qualification of operators
Calculation	Results from questionnaire
Evaluation Method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	Training as a human centered basis for plant-wide operation from a people perspective (in addition to the technical perspective) KPI-S3S is a basis for KPI-S4S (*Understanding* plant-wide processes)

KPI-S4 Level of understanding the plant-wide processes relative to baseline

KPI definition	
Content	
Name	The level of understanding the plant-wide processes of operators
ID	KPI-S4
Description	The level of understanding the plant-wide processes of operators Objective: to assess whether the plant-wide optimization has truly enlarged operators' perspective on their work Methodology: operator questionnaire analysing the relation of own work to plant-wide processes
Scope	Work centre/whole site
Formula	The level of understanding the plant-wide processes of operators' ratio, concerning the processes before and after the own working area. Statement such as: "I know the impact of my decisions on the product quality, assessed at quality control/finishing line." Adding some details, such as: · because of the new system · because of training · because of better communication with staff of other sub-processes Measured at different stages of the project (e.g. after providing prototypes, improved trainings or communication channels) Integration of plant-wide perspective contents/issues in everyday work (e.g. number of meetings with this issue)
Unit of measure	% of agreement, number of events accentuating plant-wide processes
Range	Min: Strongly disagree Max Strongly agree
Trend	The higher the agreement/accentuation, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Mainly operationalised by a questionnaire, integrating numbers of events (operationalised in the questionnaire)
Assessment	
Data source	Questionnaires, interviews Training programs and documents
Data availability	Primary data: questionnaires, interviews
Goal	Improvement of understanding of plant-wide processes higher awareness of and responsibility for the whole production process
Notes	Other indicators to be assessed: e.g. number of meetings with plant-wide perspective contents, issues

Impact	
Description	Better understanding of and orientation at a plant-wide process perspective Optimisation of plant-wide processes by a human factor, leading to the improvement of the central impact indicators: · Increase of productivity and quality · Higher quality of the production and decrease of defects · Reduction of energy use and CO2 emissions · Economic advantages: cost effectiveness, lower costs · Productivity improvement · Reduction of energy use · Reduction of CO_2/SO_2 emissions · Economic impact · Oil usage due to low feed-rate
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Impact evaluation	Task where impacts are evaluated.
Notes	Indirect affecting the central indicators

KPI-S5 Operators' job satisfaction relative to baseline

KPI definition	
Content	
Name	Operators' job satisfaction
ID	KPI-S5
Description	Operators' job satisfaction relative to baseline Objective: assessment of the effect of optimization on job satisfaction (e.g. its effects on work load, the meaning of reduced autonomy in deciding about operations, the effect of broader understanding of the plant-wide processes) Questionnaire with several questions related to the effect of optimization on job satisfaction - to be specified in relation to COCOP system and measures, operationalised along main dimensions, such as: satisfaction with (mental) workload
Scope	Work centre/whole site
Formula	Operators' job satisfaction ratio = average of questionnaires (0 -100%, relative to baseline) Measured in the beginning to get baseline, at critical events and/or periodically, in the end
Unit of measure	%
Range	Min: 0% Max 100%
Trend	The higher, the better

Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Done by questionnaire, interviews
Assessment	
Data source	Primary data: survey, questionnaires, interviews
Data availability	Primary data: questionnaires, interviews
Goal	Higher job satisfaction, leading to a higher acceptance and usage of the system
Notes	Relevant: focus on the effects caused by the new system
Impact	
Description	Higher job satisfaction leading to · Higher productivity and quality · Lower energy usage · Better cost-effectiveness
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	This kind of secondary (indirect) impact based on higher job satisfaction could not be directly measured in a causal way indirect improvement of the central impact indicators of COCOP

KPI Development Process

KPI-D1, Participation ratio: plant-wide optimization

KPI definition	
Content	
Name	Participation and attitude ratio in the plant-wide optimization
ID	KPI-D1
Description	Participation of the key personnel and relevant stakeholders in the plant-wide optimization related innovation process Attitudes of key personnel and relevant stakeholders towards the development process for plant-wide optimization
Scope	Work centre/whole site
Formula	Participation ratio: · Number of involved (groups of) users / number of relevant groups of users (shift managers, foremen of hot mill, operators etc.)

	· Number of involved (groups of) stakeholders / number of relevant groups of stakeholders · Number of times users/stakeholders are involved in the development process / stages of system/measures development (e.g., first design ideas, mock-up, first prototype, ...) Indirect assessment of attitudes/perception of the development process with statements, such as: "I feel sufficiently involved in the development process of systems/measures for a plant-wide optimisation" or "I was involved in the following stages of the development: ..."
Unit of measure	% (ratio) / questionnaire
Range	Min: 0% (low integration) Max 100% (high integration)
Trend	The higher, the better resp. the more agreeing, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Continuous and Discrete
Notes	Questionnaire users/stakeholders, (document) analysis of the process Objective: are these persons truly involved in the innovation process or only in the beginning and at the end of the project (co-creation ratio) Attitudes and perception of key personnel and relevant stakeholders towards the process for plant-wide optimization
Assessment	
Data source	Questionnaire, document analysis (minutes of meetings, agreements, etc.)
Data availability	Primary data (survey), secondary data (minutes, etc.)
Goal	Comprehensive and effective involvement of users and stakeholders, co-creation process
Notes	
Impact	
Impact description	Effective and efficient process of plant-wide optimisation Reduction of feedback loops, adjustments afterwards and aberrations Integrating and considering impact from the users' and stakeholders' perspective.
Calculation	Calculation of the KPI impact.
Evaluation method	Impact can be evaluated, for example · Related to baseline · During test periods · End of project.
Notes	Can contain additional information related to the impact.

Full list of Human Factors Requirements

Process oriented requirements

In the below tables process oriented human factor requirements are given. A yellow background color is used to denote a person-to-person requirement and a blue background color is used to denote person-to-system requirement. Prefix <x>-<x2x> denotes the following: <x>=process(p) or result(r) oriented, <x2x>= person-to-person(p2p) or person-to-system(p2s) requirements.

ID	Person-to-Person Requirement; process-oriented (with a more complex way to fulfill the requirement)	General/ Technical classification	Other comments	Activity	Milestone(s) to execute activity	Benefit
P-P2P-1.1	Present work and future changes of work content of users (end users, internal stakeholders) due to the new COCOP system and due to organisational changes for plant-wide optimisation (processes, labor division, tasks) SHOULD be estimated.	General requirement (case-independent)	For the steel sector, this will be a topic of the New Skills Agenda for Europe. So, we should coordinate our activities. (EU project starting in January 2019, if funded)	Milestone 2: HF Interviews Milestone 4: HF, developer and end user workshop to identify new working practices/ organisational practices.	2,4	• Enables the end users to use the COCOP system effectively. • Input for future training. • Helps to focus (limited) training budget
P-P2P-1.2	New skills needed for the changed work content SHOULD be identified.	General requirement	see P-P2P-1.1.	see P-P2P-1.1	2,4	see P-P2P-1.1
P-P2P-2.1	Trainings SHOULD be defined and developed to close the skills gap between needed and existing skills.	General requirement		Workshop: HF, developers and end user representative, process expert, training expert.	4	• Makes COCOP more acceptable • Future end users can make the best use of COCOP

P-P2P-2.2	Education controlling SHOULD be used to monitor participation in trainings and learning outcomes.	General requirement		Agreement between HF and HR/training expert of how to use current education controlling tools.	5	• Ensure effectiveness of training
						  ○ participation
						  ○ quality

P-P2P-3	Advices of the COCOP system SHOULD not be in conflict with organizational practices/policies e.g. target and bonus system, safety, security	General requirement	Who are the customer managers at SIDENOR and Copper Company?	Milestone 2: workshop between HF and HR Management: Analysing current target and bonus systems for end users, quality supervisors and (installation) managers.
				Milestone 5: Developer, HF, COCOP project manager and HR, plant manager and customer manager produces a report about conflicts to COCOP project manager and customer manager.
				For each conflict the COCOP project manager and customer manager agree, who corrects it.
					2, 5	• Commitment to COCOP by
						  ○ end users
						  ○ internal stakeholders
						  ○ (authorities)
						• Ensure that other benefits of COCOP are not undermined

P-P2P-4	The scope of decision (follow COCOP-advice fully, follow partly, not follow) of end users that is needed for plant-wide optimisation SHALL be clearly defined.	General requirement	"follow partly" SHALL lead to re-optimization in which end user preferences are taken into account. This leads to a new technical requirement.	Milestone 4: Scope of decision will be specified by the implementing company (customer project manager). Milestone 5: Validation should be performed by HF experts of COCOP project.	4, 5	• minimize end user errors by novice end users • Limited options improves novice end user experience by giving a safe feeling in making decisions.

P-P2P-5	It SHOULD be estimated if the COCOP system needs to be supplemented by further communication channels (e.g. face-to-face) that are needed by the (future) users.	General requirement.		Milestone 5: Estimate need for further communication by HF experts, e.g. with end user survey.
				Milestone 7: The customer project manager performs the estimation, regularly e.g. every 6 months, or e.g. if the system advice is not followed adequately.
					5, 7	• Better process operation via
						  ○ Best fit between technological tools and organizational practices
						  ○ Enhances on-site learning (less cost, better quality)

P-P2P-6.1	It SHOULD be measured to what extent relevant users and internal stakeholders are involved in the development process. TUTCOCOPDEV-127 - REQ-KPI-060: Participation ratio: plant-wide optimization **Description** The project SHOULD measure to what extent relevant users and stakeholders are involved in the development process by measure Participation ratio: plant-wide optimization. Goal: Higher the better. KPI-D1C, Participation ratio: plant-wide optimization	General requirement:	See also P-P2S-1.1.	Invite end users/ internal stakeholders to the development process. The social KPI Participation Ratio can be measured by HF. Number of times end users, internal stakeholders and/or customer project manager are involved in the development process. For example, by parsing meeting notes, e.g. confluence meetings section.	2, 5, 6	• Ensure system fit to user needs • Improved user acceptance • Collect improvement ideas • Make better workload estimates for subsequent implementation projects

P-P2P-6.2	Before the software development phase begins, the end users SHOULD be asked about their needs, expectations and visions about the future optimisation system.	General requirement.		Surveys based on interviews and questionnaires by HF with end users of the system.	2	• Ensure that the system fulfills the end user needs • Make system more acceptable • Ensure that other benefits materialize
P-P2P-6.3	During the development, a mock-up (or similar) SHOULD be presented to the end users in order to collect feedback.	General requirement.		HF facilitates a workshop where the mock-up is discussed in order to collect feedback from developers and end users. HF will analyze feedback and refine the results to developers.	3	• Ensure that the system fulfills the end user needs • The feedback may result in reasonable (sociotechnical) system changes.
P-P2P-6.4	During system training end user feedback SHALL be collected.	General requirement.		HF creates a questionnaire that retrieves feedback on training and system quality from the end users during the testing period.	5	• The feedback may result in minor system or training changes.

P-P2P-7	A common understanding of functionalities of the COCOP system SHALL be defined from the technical & HF perspectives.	General requirement.		Plan implementation project kick-off HF aspects with developers.
				Participate to kick-off, where HF aspects include:
				• effects to the end user are spelled out
				• have initial contact with customer project manager
				• familiarization with the plant and its sub-processes and why they are there
					2	• Precondition for integration of technical & social aspects
						• Starts & keeps the development to the correct direction
						  ○ results in useful system
						  ○ helps to fulfill the other HF requirements

				• define the plant-wide goal e.g. spell out the need for COCOP		

ID	Person-to-System Requirement process-oriented (with a more complex way to fulfill the requirement)	General/ Technical classification	Other comments	Activity	Milestone(s) to execute activity	Benefit
P-P2S-1.1	The COCOP system SHALL be improved with practical knowledge during the development, e.g. by excluding non-realistic solutions.	General requirement	See also P-P2P-6.1.	Regular meetings with developers, process experts and possible a subset of end users will take place. They will evaluate whether the COCOP system is appropriate from a practical point of view. Developers will implement the new features that are agreed upon. These processes continue until an agreement between developers and process experts is reached that the COCOP system is appropriate and COCOP solution will help to reach improvements of plant-wide processes.	3,4, 5	• Ensures that plant-wide optimization brings the envisioned benefits
P-P2S-1.2	The COCOP system SHOULD provide advices to improve the reliability of practical knowledge of the users.	General requirement		Same as P-P2S-1.1, facilitated by HF	4, 5	• Ensure that the system fulfills the end user needs. • Enhances end user expertise

P-P2S-1.3	The COCOP system SHALL be improved with practical knowledge of the end users during its operation.	General requirement		The customer manager and COCOP project manager agree on regular communication.	7	• Ensure that the system fulfills the end user needs • Improves reliability and quality of the COCOP system. • The COCOP system will be kept up-to-date and continues to provide benefits. • The COCOP will be used
P-P2S-2.1	The optimization system SHOULD make visible the effects of decisions, including sustainability aspects, of an end user in their own sub-process on (the relevant parameters of) the subsequent process and on the final product.	General requirement.	End users should be informed by the system of the consequences (predicted by the system and realised) of his/her decision regarding the taken action (follow/follow partially/not follow). See P-P2S-2.2 and P-P2S-2.3	Evaluation will be facilitated by HF in a workshop with end users.	3, 4, 5	• Ensure that the system fulfills the end user needs • Improved user acceptance • Supports learning of end users
P-P2S-2.2	The system SHALL be able to predict the effect of end user actions.	General requirement.		Developers implement this technical requirement.	5	• Provides deeper insight on the plant operation
P-P2S-2.3	The system SHALL be able to log realised effects of end user actions.	General requirement.		Developers implement this technical requirement.	5	• System Fault/Error detection
P-P2S-3	Deviations from system advices by end users SHOULD be analysed.	General requirement.		Appreciative inquiry with end users by HF expert and developer: Asking end users for reasons for deviation from	5, 7	• Ensure that the system fulfills the end user needs

		Requires requirement R-P2S-1.1 See also R-P2S-1.2		system advices. This might include how they set priorities in decision making when there is a dilemma between sub-process optimisation and plant-wide optimisation.		• Improves reliability and quality of the COCOP system. • The analysis may improve the sociotechnological system, e.g. reveal training need.

Result oriented requirements

In the below tables result oriented human factor requirements are given. A yellow background color is used to denote a person-to-person requirement and a blue background color is used to denote person-to-system requirement.

ID	Person-to-Person Requirement; result oriented (with a simple way to verify the fulfillment)	General/ Technical classification	Other comments	Activity	Milestone(s) to execute activity	Benefit
R-P2P-1.1	The project SHOULD measure plant-wide processes as part of operator training ratio relative to baseline (meant as the starting point of the project; REQ-KPI-030). TUTCOCOPDEV-124 - REQ-KPI-030: Plant-wide processes as part of operator training ratio relative to baseline	General requirement.		Milestone 2: HF sends questionnaire, and conducts interview to end users and internal stakeholders. Milestone 5,6: HF sends questionnaire, and conducts interviews to end users and internal stakeholders.	2, 5, 6	• To ensure that end users are getting enough training of plant wide processes that ensures that the COCOP system is used up to its potential.

	Description The project SHOULD measure Plant-wide processes as part of operator training ratio relative to baseline for e.g by a questionnaire. Goal: Higher the better. KPI-S3C/S Plant-wide processes as part of operator training ratio relative to baseline in Deliverable D2.2					
R-P2P-1.2	The project SHOULD measure the level of understanding of plant-wide processes relative to baseline (REQ-KPI-040). TUTCOCOPDEV-125 - REQ-KPI-040: The level of understanding the plant-wide processes relative to baseline **Description** The project SHOULD measure the level of understanding the plant-wide processes relative to baseline for e.g by a questionnaire.	General requirement.		Milestone 2: HF sends questionnaire, and conducts interview to end users and internal stakeholders. Milestone 5,6: HF sends questionnaire, and conducts interviews to end users and internal stakeholders.	2, 5, 6	• To ensure that end users having a deeper understanding of plant wide processes that ensures that the COCOP system is used up to its potential.

	Goal: Higher the better. See KPI-S4C/S The level of understanding the plant-wide processes relative to baseline in Deliverable D2.2					
R-P2P-2	The project SHOULD measure end users' job satisfaction relative to baseline (REQ-KPI-050). TUTCOCOPDEV-126 - REQ-KPI-050: Operators' job satisfaction relative to baseline **Description** The project SHOULD measure Operators' job satisfaction relative to baseline for e.g. by a questionnaire. Goal: Higher the better. KPI-S5C/S Operators' job satisfaction relative to baseline.	General requirement. Other requirements should guarantee that job satisfaction increases with the usage of COCOP system.		Milestone 2: HF sends questionnaire, and conducts interview to end users and internal stakeholders. Milestone 5,6: HF sends questionnaire, and conducts interviews to end users and internal stakeholders.	2, 5, 6	• To become informed how COCOP system has affected job satisfaction.
R-P2P-3	A support team SHOULD be available that provides support in case of emerging problems with the system or in case of necessary changes of the system.	General requirement.		A support team is created by COCOP project manager and customer project manager. The support team consists of developers, customer project manager, process expert and HF experts from the COCOP consortium. The support can be delivered in a hierarchy: 1) expert from	7	• The COCOP system will be kept up-to-date and continues to provide benefits. • The sociotechnical system will work properly, e.g. end users

				the company, e.g. process expert 2) support team, e.g. developer, HF experts.		keep on using the system and job satisfaction is on sufficient Level.

ID	Person-to-System Requirement; result oriented (with a simple way to verify the fulfillment)	General/ Technical classification	Other comments	Activity	Milestone(s) to execute activity	Benefit
R-P2S-1.1	The system SHOULD measure the acceptance ratio of how often the plant personnel follow the advice given by the system TUTCOCOPDEV-119 - REQ-KPI-010: Usage of system advice **Description** The system SHOULD measure the acceptance ratio of how often the plant personnel follow the advice given by the system. This MAY be measured in the solution itself automatically when design of optimisation system. For e.g. by an acceptance button Goal: Higher the better.	General requirement.		This requirement should be fulfilled by developers. HF provides explanations/reasons why usage is low, performed in P-P2P-3.	5, 7	• To be informed about the extent of COCOP system usage. The information can be used to improve reliability and quality of the COCOP system. • The analysis may improve the socio-technological system, e.g. reveal training need.

	Calculation: Usage of system advice = number of accepted advice / total number of advice KPI-S1C Usage of system advice					
R-P2S-1.2	The project SHOULD measure the acceptance of system advice, also other system advice except COCOP. TUTCOCOPDEV-123 - REQ-KPI-020: Acceptance of system advice **Description** The project SHOULD measure the acceptance of system advice for e.g. by a questionnaire. Goal: Higher the better. KPI-S2C/S Acceptance of system advice	General requirement.		Milestone 2: HF sends questionnaire, and conducts interview to end users and internal stakeholders in order to measure current technological attitude and acceptance level. Milestone 5,7: HF sends questionnaire, and conducts interviews to end users and internal stakeholders about the acceptance of COCOP system.	2, 5, 7	• To be informed about the extent of COCOP system acceptance. The information can be used to improve reliability and quality of the COCOP system. • The analysis may improve the socio-technological system, e.g. reveal training need.
R-P2S-2	The system SHALL provide relevant data for end users about previous and subsequent sub-processes to take this information into account when defining parameters for their own process.	General requirement.		Milestone 5: Developers implement the feature. Milestone 7: HF conducts end users interviews to evaluate the relevance and availability of data.	5, 7	• Helps end users in gaining a plant-wide view of plant processes. This improves plant operation.

R-P2S-3.1	REQ-UI-010: Meaning of colors on UI. The meaning of the colors in the new user interface SHALL be the same as with the one in currently used interfaces.	General requirement.	HF expert can evaluate this requirement but it is easier if it is asked from the end users during testing period. Note that, it is possible that they may have various, different user interfaces and the answer is not straightforward.	Milestone 2: HF and developers familiarize with current end user interfaces in use. Milestone 3: The developer sends the mock-up for HF for evaluation. HF reports the result to developer for corrections. Milestone 5: The developer sends the mock-up for HF for evaluation. HF organizes a workshop with end users to reveal potential misunderstandings. HF reports the result to developer for corrections. Only thereafter, the end user evaluation can take place.	2,3,5	• Improved user acceptance and clarity of the UI, which results in improved plant operation.
R-P2S-3.2	If R-P2S-3.1 cannot be fulfilled, • red SHALL only be used as an alerting color • green SHALL be used as a color to indicate the status is ok	General requirement.		Same as R-P2S-3.1	2, 3, 5	Same as R-P2S-3.1.
R-P2S-3.3	The symbols in new user interface SHALL be the same as used in current user interfaces (e.g., the appearance of symbols for technical components such as pipes, valves and the like).	General requirement.	Same as R-P2S-3.1	Same as R-P2S-3.1	2,3,5	Same as R-P2S-3.1.

R-P2S-3.4	The same definition of terms, concepts and other vocabulary as currently used in the factory SHALL be used in the UI.	General requirement.		Same as R-P2S-3.1	2, 3, 5	Same as R-P2S-3.1.
R-P2S-4	The system's status (optimization running, idle, …) SHOULD be visible.	Technical requirement.		Developer implements this requirement.	3	• Increases usefulness of the COCOP system
R-P2S-5	COCOP system control SHALL include a possibility to undo initiation of calculation.	Technical requirement.		Developer implements this requirement.	3	• Increases usefulness of the COCOP system
R-P2S-6	The UI SHOULD have memory supporting solutions so that end users does not have to remember everything (for instance, instructions must be visible or easy to retrieve, unless the system is extremely simple).	General requirement.		The developer sends the mock-up for HF for evaluation. An iterative correction procedure between the developer and HF may take place.	4,5	• Increases usefulness of the COCOP system
R-P2S-7	There MAY be flexibility and efficiency of use so that experienced users can speed up the interaction (e.g. shortcuts, if possible and relevant). .	General requirement.	It may be a good idea to follow major software trends, like leading DCS systems.	Milestone 4: The COCOP manager and customer project manager discusses about the level of flexibility. Milestone 5: HF facilitates the evaluation of flexibility features performed by end users.	4,5	• Increases usefulness of the COCOP system, for experienced end users

R-P2S-8	There SHALL be aesthetic and minimalistic design, meaning that each view is not overcrowded with text or visual components.	General requirement.		The developer sends the mock-up for HF for evaluation. Milestone 3: HF sends improvement suggestions to developers. Milestone 5: An iterative correction procedure between the developer and HF may take place. Only thereafter, the end user evaluation can take place.	3,5	• Increases usability of the COCOP system
R-P2S-9	User interface SHALL help users to recognise, diagnose and recover from COCOP-system errors; for instance, error messages must be clear and understandable.	General requirement.		Milestone 2: Developers implement a feature that can retrieve a list of error messages. Milestone 5, Step 1: COCOP project manager organizes a workshop with process expert to reveal potential misunderstandings and reports about correction needs to developers. Milestone 5, Step 2: HF organizes a workshop with end users to reveal potential misunderstandings. HF reports the result to developer for corrections.	2,5	• Enables coherent, and useful handling errors • Increases usability of the COCOP system
R-P2S-10.1	HELP documentation SHALL be written.	Technical requirement.		Developers writes help documentation: included in the system, pdf or similar.	4	• Increases usability

R-P2S-10.2	Help documentation SHALL be understandable.	General requirement.		The developer sends the mock-up for HF for evaluation. HF organizes a workshop with end users to reveal potential misunderstandings. HF reports the result to developer for corrections. Only thereafter, the end user evaluation can take place.	5	• Increases usability
R-P2S-11.1	The optimization system MAY have the option of providing detailed information about the process that is provided by the process expert for the end users on demand. The access to the information is provided with an information button (or similar).	General requirement.		Developer and process expert implement this feature.	4	Helps the end user to use the COCOP system more effectively Supports the learning of end users.
R-P2S-11.2	The optimization system MAY have the option of providing detailed information about the process that is provided by the process expert for the end users on demand. The access to the information is provided with an information button (or similar).	General requirement.		HF organizes a workshop with end users to reveal flaws. HF reports the result to developer for corrections.	5	Same as R-P2S-11.1.

R-P2S-12	Differences of performance between the shifts SHALL NOT be shown in the user interface.	General requirement.		HF checks fulfillment of this requirement and suggest corrections to developers.	5	• Avoid competition between the shifts which easily reduces the quality of work • Reduces risk of short sighted end user actions that undermines plant-wide optimization