DOCUMENT TITLE:

GOOD PRACTICE REPORT FOR CZECH REPUBLIC

Project: Improving RD and business policy conditions for transnational cooperation in the manufacturing industry

Acronym: Smart Factory Hub

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PU	Public	
PP	Restricted to other Programme participants	
RE	Restricted to a group specified by the consortium	X
CO	Confidential, only for members of the consortium	

Contents

1 INTRODUCTION

Regional Good Practice Report for Czech Republic contains three good practices collected using the Good Practice Template developed in D4.2.1.
The data in this report were collected during October 2017 as part of the project entitled "*Improving RD and Business Policy for Transnational Cooperation in the Manufacturing Industry – Smart Factory Hub (SFH)"*.

These three examples are the basis of the regional report, the Handbook tool report and the Good Practice Handbook, which together with the Mapping tool will allow project partners to present and promote specific smart manufacturing solutions. Based on the collected data, the Handbook tool report will be prepared by the UTC-N, WP4 leader.

The handbook will be available in electronic format on the web portal, while, for disseminating the work package, also 250 handbooks will be printed, which will be available to the participants at the closing dissemination event.

The data collected during this period will also be used for ex-ante evaluation.

University of West Bohemia collected the following good practices cases:

No.	Name of the Good Practice	Classification[1]
1	PRODUCTION CELL 4.0	Next-gen manufacturing systems
2	MONARCO HAT	Intelligent sensors/actors
3	VIRTUAL REALITY WORK INSTRUCTIONS	Digital working instruction

[1] According GOOD PRACTICE GUIDELINES

1 GP1: PRODUCTION CELL 4.0

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Keywords: Continuous measurement and adjustment, predictive diagnosis, integrated robotics, augmented reality, Edge Node, cloud processing.
Good practice applied in: (NACE code) : Machining (NACE code C25.6.2)

Production Cell 4.0 is being developed as a base unit of future smart factories. The cell is formed by interconnected devices that are involved in the partial steps of the production of metal workpieces. The motivation is to prepare a cell for easy adaptation of production for SMEs. The cell is used to test principles and develop new industry-related technologies in connection with Industry 4.0.

1.1 GOOD PRACTICE DESCRIPTION

Several subjects participated on the development of production cell 4.0. The machine was provided by TAJMAC-ZPS, measuring station by Renishaw, B + R Automation developed an open platform, a robot for the demonstration of integrated robotics was borrowed by COMAU, SMC delivered clamping elements, and thanks to Sewio Networks the movement of people around the cell can be tracked.

This solution is strongly tied with the “Smart Factory” concept, as several novel technologies (namely cyber physical systems, intelligent sensors, robotics and cloud processing) were incorporated directly and contributed to the production of a specific product. The benefits can be seen in the area of quality assurance.

The cell forms a functional production unit linking a CNC machine, a robot and a measuring station. The uniform system solves proprietary communication with each device and communicates externally with open protocols. Thanks to modular architecture the device can be easily modified and the system can be supplemented by other software applications.

The so-called production control process remains the basis of the production cell - the measuring station in the cell checks the quality of each workpiece after finishing. When a deviation is detected, the workpiece, including the necessary corrections, is sent back to the machine for repair. This

greatly reduces the need of the operator to interfere with machine settings during the manufacturing process.
Key capabilities include horizontal and vertical connectivity of the cell with other manufacturing systems. For the cell, the so-called edge node connection into the cloud platform was prepared where the data mining is being conducted to search for deeper connections. The cell is controlled by a system opened for user applications and the third-party applications. The data are displayed in augmented reality, monitoring of people movement is being done, condition monitoring of CNC machine and, last but not least, quality control of production process.

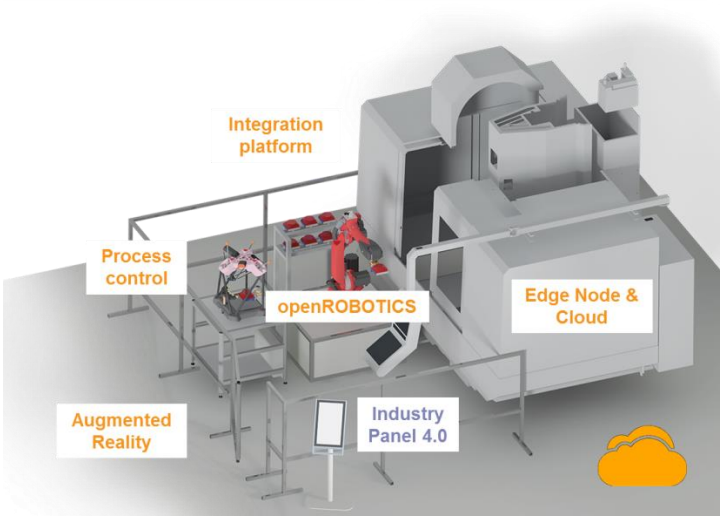


Fig. 1 – Features of Production cell 4.0

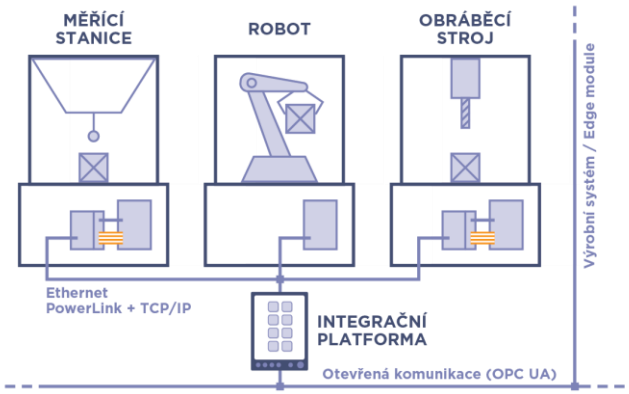


Fig. 2 – Visualization of communication and integration platform principle

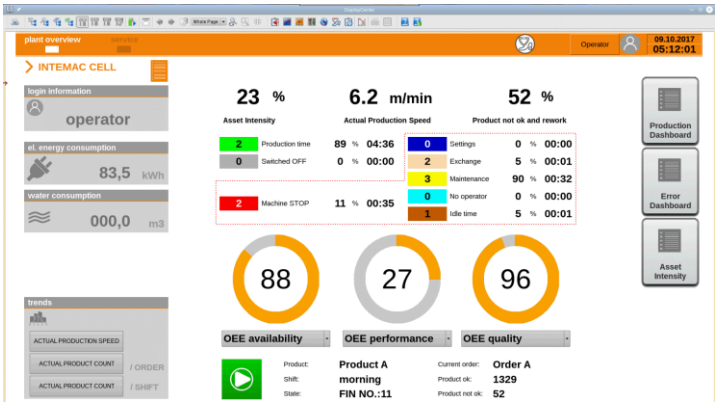


Fig. 3 – Edge Node – visualization and data processing

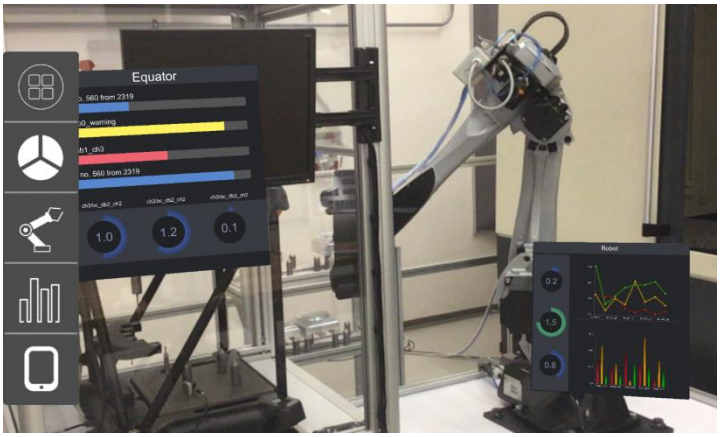


Fig. 4 – Augmented reality - all important information in one device, quick managerial reports.

Uniqueness consist in interconnection of a whole range of new technologies to a functional concept that is ready for deployment in production. Operation od the production cell is built on the principles of the so-called Testbed. The cell is opened to other industrial partners.

1.2 OBJECTIVE AND TARGET AUDIENCE

The solution described previously was developed, tested and validated in Czech Republic.
The production cell 4.0 is usable in small and medium-sized companies as well as in large companies which are focused on machining operations.

1.3 METHODOLOGICAL APPROACH

The solution minimize on-site presence of experts, reduce changing time, increase machine availability, predictive maintenance will detect a possible failure on time.
Avoid human interaction and thus human faults. Quality is further ensured by following measures.

- Control of the machining process by workpiece probe.
- Process control by the control system Renishaw Equator.
- Calibration of each manufactured part.
- The parts carry correction data and are automatically sent back for repair.

Data Security Measures have to be applied.

The methodology for implementing this solution comprised of the following steps:

1. Analysis of the production system – mapping of customer requirements on the resulting functionality, mapping of control systems and compatibility options.
2. Creating a concept for the operation of the production cell with customer approval.
3. If necessary, purchase and installation of missing devices.
4. Modification of the uniform system for mutual communication of all devices - programming of specific functions.
5. System testing and validation - functionality, accuracy, speed, data processing and visualization.

Below are the resources which are necessary for successful implementation.
Personnel: IT, technology and process department
Finance: very variable, can't be predicted
Infrastructure: machines, IT hardware, LAN
Timespan: Realization depends on complexity. It may vary for 3 to 6 months.

1.4 VALIDATION PROCESS

The good practise was validated with industrial clients.

1.5 RESULTS / IMPACT

The impact of the good practise is highly positive, as the scrap rates are reduced to almost 0% and the process of self-adjustment is fully automatic. Data about the machining process are displayed virtually and in time so the customer has all the necessary information for decision making.

1.6 SUCCESS FACTORS AND CONSTRAINTS

The benefit of Production Cell 4.0 is based on the interconnection of new technologies into a functional unit and in the same time openness to the technologies of other industrial partners. Those interested can even engage their devices (such as the material transport system or 3D printer), use it to test their own technologies or develop features that they would like to prefer in their business.
Thanks to the open platform the production cell is prepared also for new technology advances and thus can serve as a testbed.

1.7 LESSON LEARNED & SUSTAINABILITY

The described solution represents a great possibility to interconnect devices in one fully automated manufacturing cell however the user acceptance strongly correlates with the level of experience concerning the technologies involved. Customizing is an important requirement for user acceptance.

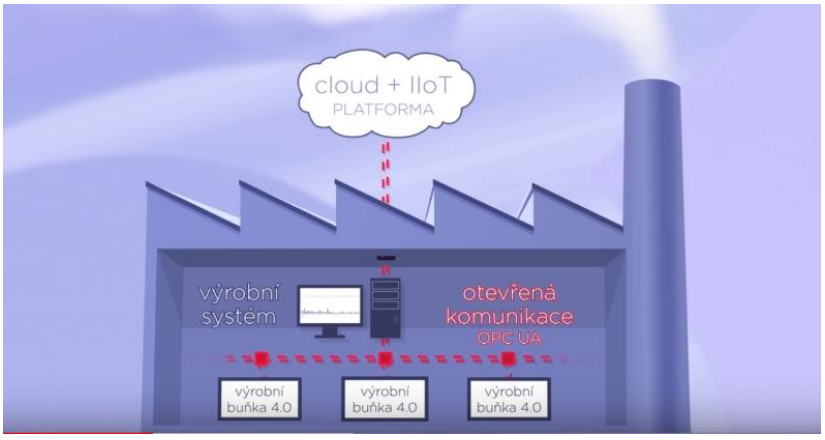
1.8 REPLICABILITY AND UP SCALING

This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch. It must be noted, however, that it initially requires a high financial commitment and the organizational culture should be open to the use of new technologies.
The benefit of Production Cell 4.0 is based on the interconnection of new technologies into a functional unit and in the same time openness to the technologies of other industrial partners. Those interested can even engage their devices (such as the material transport system or 3D printer), use it to test their own technologies or develop features that they would like to prefer in their business.

1.9 FINAL REMARKS

The core of the Production cell 4.0. is formed by a platform linking a machine with a handling robot and a measuring station. The cell enables the so-called adaptive process of production - the measuring station can evaluate the workpiece quality after completing the machining process and, when finding the imperfections, send information to the machine that will repair the workpiece.
The system can work completely automatically without human intervention, which eliminates errors. Reports and data from machines are instantly available in various display formats thanks to cloud computing.
The cell with a uniform system demonstrates the advantages of automation combined with the needs of small-scale production where one of the key requirements is the need to change the input of production several times a day.

List of attachments:
Attachment 1: Video demonstration: https://www.youtube.com/watch?v=IQJph5c7xo0



2 GP2: MONARCO HAT

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Keywords: Monitoring of machines, Monarco HAT, Raspberry Pi, REX control system.
Good practice applied in: (NACE code) : Manufacturing (NACE code C)

Monarco HAT is an add-on board which provides input-output interfaces following industrial automation standards for the Raspberry Pi (B+ and newer) minicomputer. It is designed according to the HAT (Hardware Attached on Top) specification. It enables collection of data from machines for its visualisation or evaluation.

2.1 GOOD PRACTICE DESCRIPTION

This product was created in response to the demand of SMEs for upgrading or retrofitting existing control systems of machines. Monarco HAT is based around ARM Cortex-M3 microcontroller (MCU) which provides a wide set of embedded peripherals missing on the Raspberry Pi itself. It offers PWMs for all digital outputs, versatile counters including quadrature encoder signal decoders, digital-to-analog and analog-to-digital converters, and RS-485 communication etc. ARM MCU can also provide very deterministic IO timing compared to Raspberry Pi with Linux.
This solution is strongly tied with the “Smart Factory” concept, as a novel technology, namely intelligent sensors/actors are implemented.
Below are the applications we had in mind when we designed the add-on board which we call the Monarco HAT.

- Reading and archiving data from standard industrial sensors.
- Monitoring of machines.
- Providing communication gateway between various devices.
- Feedback control in non-critical applications.

Here are a few examples of devices whose outputs can be handled by Monarco HAT digital inputs:

- utility meters (electricity, gas, water) with pulse output,
- standard quadrature encoders for position/velocity measurement,
- gear tooth sensors for position/velocity measurement,

- motor controllers with pulse/direction or quadrature position output,
- various industrial sensors (temperature, pressure, distance) with frequency output.

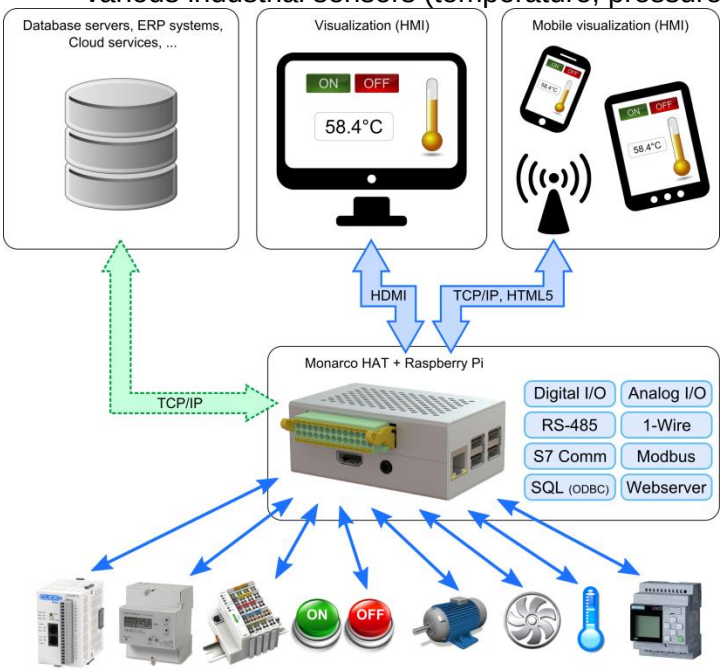


Fig. 5 Visualisation of product peripherals, inputs and outputs

The first choice for programming is the REX Control System, which is best described by the following features:

- Graphical programming without hand-coding.
- Programming control units on a standard PC or laptop.
- User interface for desktop, tablet and smartphone (HMI).
- Wide family of supported devices and input-output units (including Monarco HAT).
- Industry-proven control algorithms.
- Easy integration into business IT infrastructure (ERP/BMS).
- REST API for seamless integration into Industry 4.0 and (I) IoT solutions.

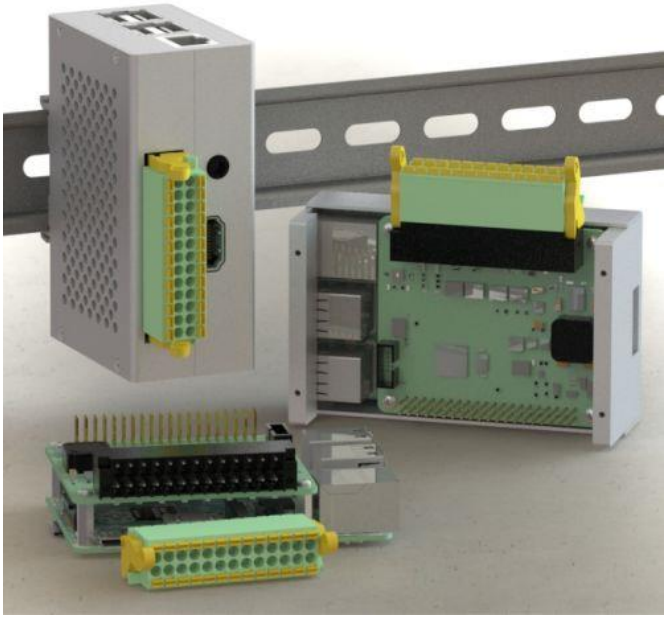


Fig. 6 Monarco HAT plain board and with housing

2.2 OBJECTIVE AND TARGET AUDIENCE

The solution described previously was developed, tested and validated in Czech Republic. The utilisation is worldwide.
Monarco HAT with its REX Control System can be applied in various scenarios in various industry fields. Its versatility ensures its uses in large as well as in small and medium size companies.

2.3 METHODOLOGICAL APPROACH

There are indirect cost savings connected with describes solution. The data which is being collected and evaluated influence the overall productivity by well-timed decision making. Furthermore the purchase cost of Monarco HAT is quite low which ensures that this solution is also affordable for SMEs.
Clear visualisation and electronical data transfer eliminates mistakes which may occur if the data was processed manually (pen and paper) by workers.
Data Security Measures have to be applied.

The methodology for implementing this solution comprised of the following steps:

1. Feasibility study (establish whether the solution can be implemented – checking electrical compatibility at signal level, checking availability of sensors and actuators, studying the programming tools, budget analysis, potential benefits and weak points);
2. Acquire the hardware platform and programming tools;
3. Develop software based on the solution (programming the mini PLC to collect the required data, perform the requested operations and);

4. Deploy the resulting controller/data logger/communication gateway at floor level of the factory;
5. Verify the impact (compared to historical data and/or evaluate benefits of collecting new data).

Below are the resources which are necessary for successful implementation.
Personnel: IT, PLC programmers
Finance: Plain board with optional housing – 129 €, Automation kit with RexCore Plus – 279 €, Automation kit with RexCore Pro – 359 €
Infrastructure: IT Hardware, LAN
Timespan: Delivery time is about 3-5 business days within Europe and 10-12 days outside Europe. Realization on the spot in one day for single implementation.

2.4 VALIDATION PROCESS

The good practise was validated with industrial clients worldwide. (USA, Australia, Taiwan, Republic of South Africa, Germany, Austria, Belgium, Norway, etc.)

2.5 RESULTS / IMPACT

The impact of the solution was highly positive, the new collected data and interconnection between individual machines led to an increase in productivity and lowering failure rates in final quality tests on production lines.

2.6 SUCCESS FACTORS AND CONSTRAINTS

The solution cannot be directly mounted on moving parts of machines. The reason is the memory card holder, which is not designed for use in vibrating environments.
Monarco HAT was developed by control engineers for control engineers. So far it is the only board aimed at industrial automation and following the HAT standard. Years of experience in automation domain and electronics design were put into the product design. Although Monarco HAT is a very young product, our records indicate very low failure rates. Hundreds of satisfied customers are enjoying the benefits of using the solution. The device is universal and can be used for all tasks in automation and cybernetics. Low entry costs make it attractive also for SMEs and even end customers.

2.7 LESSON LEARNED & SUSTAINABILITY

Operating temperature and vibrations are known to be the most critical. What happens when the Raspberry Pi fails? Not having real-time data on displays at floor level can hurt, but certainly not as much as stopping the whole production line. If necessary, will it be possible to switch to another hardware platform without starting software development from scratch? Those are the types of

questions you should be asking before deploying the solution in the field. In short, using this platform gives you freedom, but keep in mind that freedom comes with responsibilities.

2.8 REPLICABILITY AND UP SCALING

This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch.
The Monarco HAT is upgraded continuously in its functions regarding the needs of industrial practice. The upgrades are mainly on software basis.

2.9 FINAL REMARKS

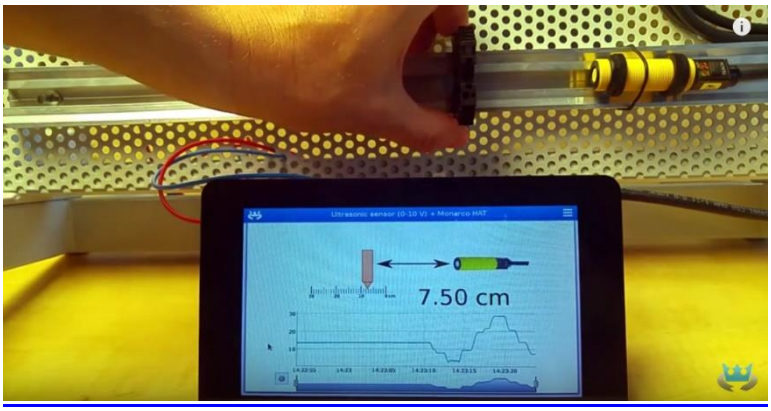
The use of Raspberry Pi and the Monarco HAT in industrial automation opens new possibilities for IoT and Industry 4.0 projects. This platform has proven to work well in symbiosis with existing control systems and controllers, providing additional CPU power, memory, storage and communication capabilities, which the traditional platforms are missing.

List of attachments:

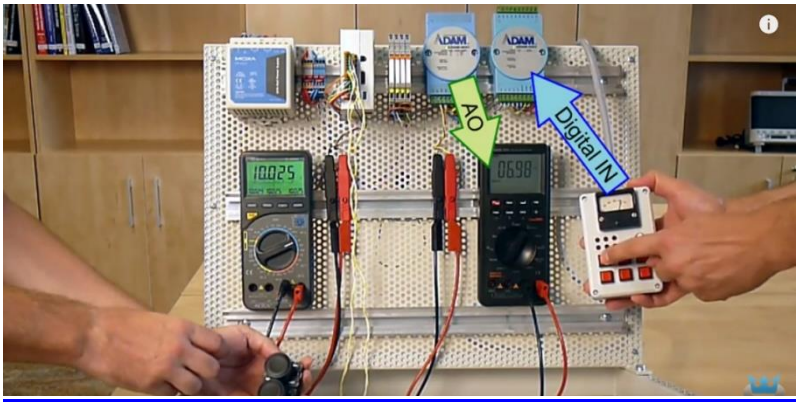
Attachment 1: Video demonstration: Raspberry Pi as a 1-Wire data bridge for Siemens LOGO
https://www.youtube.com/watch?v=rdosVtdxJac

Attachment 2: Video demonstration: Raspberry Pi controlling a frequency inverter
https://www.youtube.com/watch?time_continue=74&v=APXEFQKF5Tw

Attachment 3: Video demonstration: Raspberry Pi reading a 0-10 V ultrasonic sensor
https://www.youtube.com/watch?time_continue=45&v=oXTaTk1jbEY



Attachment 4: Video demonstration: Extending I/O of the Monarco HAT via RS-485
https://www.youtube.com/watch?v=3G5M0xRgNss



3 GP3: VIRTUAL REALITY WORK INSTRUCTIONS

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REGIONAL TECHNOLOGICAL INSTITUTE

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Keywords: Virtual work instructions, augmented reality, assistive technology, operator empowerment.

Good practice applied in: (NACE code) : Manufacture of consumer electronics (NACE code C26.4.0)

The goal was to create a virtual work instructions that will shorten the time needed to train new employees to improve work performance, reduce mistakes, and ease work by eliminating inappropriate assembly and further disassembly of parts. The shorter the training of new employees is, the sooner they will be able to perform their work and produce flawless products. These instructions are also useful if the operator gets into an unfamiliar situation and if he have to do some work for the first time.

3.1 GOOD PRACTICE DESCRIPTION

A first prototype was created in the course of a master thesis. The system was further developed within the research work conducted in the RoRTI project from National Sustainability Programme funded by the Ministry of education and then validated and improved with lead customers.
This solution is strongly tied with the “Smart Factory” concept in concrete with mobile workforce. The workers are provided with virtual working instruction presented on LCD display.
The innovative nature of this solution is that it provides animated instructions for the operators training and work which makes their activities more efficient. The instruction can be performed as fully virtual or in mixed reality (augmenter reality). The visualisation with smart glasses (Vuzix) was tested however the satisfaction was very low. Thus the simple visualisation on LCD display – tablet, smartphone was provided. The system was developed with aid of Unity 3D software package.

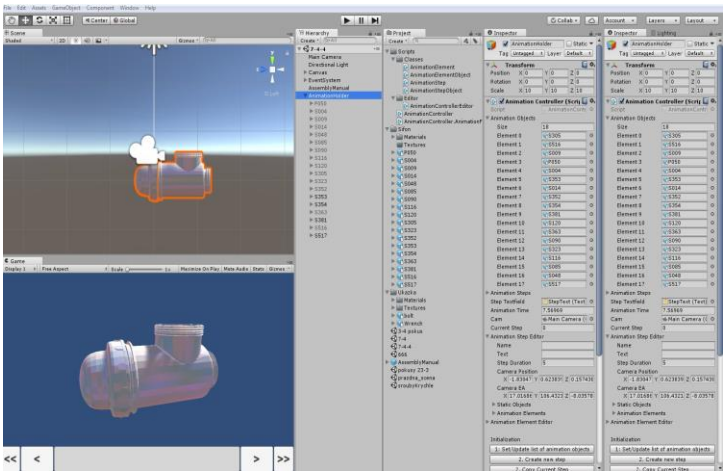


Fig. 7 Preparation of virtual assembly in Unity 3D

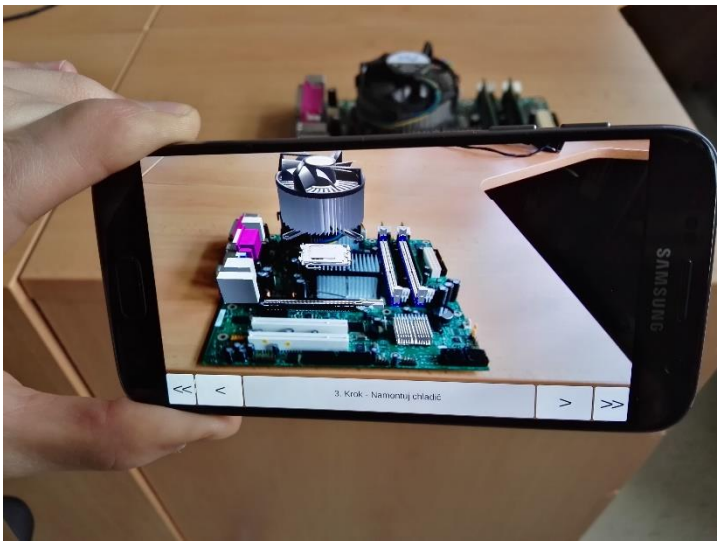


Fig. 8 Augmented reality work instruction

The application of the current technology extended over to other industry branches, but its use differed in nature from this type of application (e.g. Daimler applied Vuzix glasses for quality-control and other type of product inspection activities, while UPS (United Parcel Service Inc.) used it for reducing labelling on packages). In both of these cases the AR glasses are required however the comfort by using the AR glasses is not very high. The technology has still its limitation. For our solution we choose simple visualisation on display.

3.2 OBJECTIVE AND TARGET AUDIENCE

The solution described previously was developed, tested and validated in Czech Republic. Solution can be applied by other companies that are willing to integrate virtual reality or augmented reality technology into their manufacturing process, especially those that have operators involved in product assembly activities. The practice has a high degree of portability and can be adapted to companies operating in various industry branches.

3.3 METHODOLOGICAL APPROACH

If a company recruits new workers, they have to be trained and the faster they learn, the sooner they can effectively perform the necessary tasks. Virtual guides are not only suitable for training of new employees, but they can be effectively used if there is a wide range of products in the company. If the employees don't perform these processes daily, they do not need to remember the exact procedures and steps.
In addition to promptly training of new employees and thus increasing their performance, the errors are reduced or completely eliminated, and the resulting ease of work due to inappropriately mounted parts and subsequent removal of faulty components occurs. Virtual working instructions can be easily done in language versions and therefore are also suitable for foreign agency workers. There is also no possibility for operators when using virtual instructions to skip a step and thus create a scrap. In the case of virtual instructions, every step after completion has to be confirmed by pressing the button and therefore can't be omitted by mistake.

The methodology for implementing this solution comprised of the following steps:

1. Analysis phase – decision about form of work instruction (VR or AR), selection of work instructions and products to be processed, budget analysis, mapping of company's IT infrastructure and databases;
2. Development phase – digitisation of products and its components (creation of 3D models), creation of animations, in case of AR mapping the 3D models on real object;
3. Implementation phase – upload to company's database, fine-tune the visualisation, train the operators.

Below are the resources which are necessary for successful implementation.
Personnel: IT department, technology and process department
Finance: Depends on no. of products and thus number of work instruction to be prepared, also on the complexity of the products and finally the type of work instruction (VR, AR). One working instruction costs around 550 €. If more instruction are being prepared than the costs for one instruction is being lowered as the 3D components may be interchangeable.
Infrastructure: IT Hardware, LAN, database entry.
Timespan: Time also depend on the complexity of the project. Timeframe is usually around 1-3 months also with implementation on the spot.

3.4 VALIDATION PROCESS

Twelve workers (6 males and 6 females) tested the assembly of two complex products of a similar type, of which they had previously no information. The product was assembled according to both paper and virtual instructions. They have always done four repetitions of the assembly. With every further round, work has accelerated (see chart). The results show that the virtual instruction was much more efficient than paper in the first round, and this was repeated in the following rounds also.

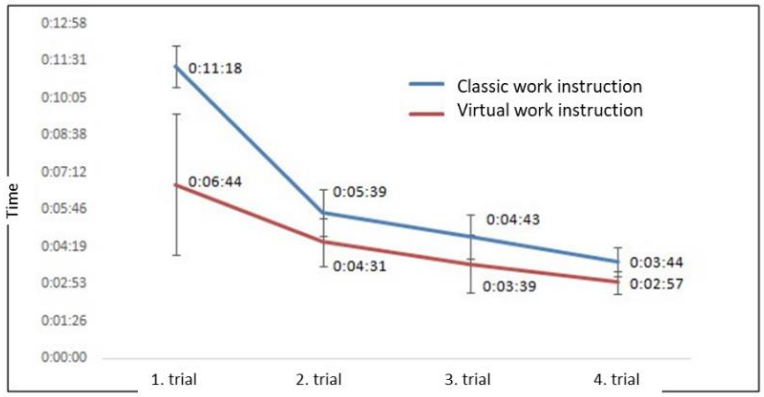


Fig. 9 Results from validation of time demands

3.5 RESULTS / IMPACT

The impact of the solution was highly positive, as the assembly time was reduced by 40% in the first trial round, by 22% in the second trial round, by 23% in the third trial round and by 20% in the fourth trial round. From these results can be seen that the virtual work instructions enables around 20% faster assemblies.
Moreover as the printed documentation is reduced significantly the reduction is also in the printing costs.

3.6 SUCCESS FACTORS AND CONSTRAINTS

The technology is universal however the software is programed directly for specific products. If the product is updated or modified the same goes also for the software which needs to be updated as well. The quality of company's internal databases and also the speed of connection is essential.
The augmented reality work instructions has still many limitations. Marker technology is sensitive for the distance from marker and vison angle. The object fitting technology is limited by the size of the product which can maximally be around 30x30 cm.
The solution and technology is not brand new. The virtual reality and augmented reality work instructions are implemented also in other companies. But it is usually domain of larger companies. Our solution and its development is rather cheep a thus can be implemented also in SMEs.

3.7 LESSON LEARNED & SUSTAINABILITY

The success of the implementation depends on the capability of overcoming the resistance of workers regarding the technological change. If they give it a try usually they are more satisfied. During the testing phase most of the workers followed the animations. The accompanying text was read only when assembly was difficult or if there was another problem.
The technology has still some limitations in these days however due to future technological progress the development can be foreseen.
Moreover the system reduces the need for printed documentation and thus is environmental friendly.

3.8 REPLICABILITY AND UP SCALING

This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch. The technology is transferable however the work instruction preparation must be taken into account which requires a medium financial commitment. Also the workers must be open to utilize new technologies.
The technology is limitation for now especially in augmented reality application. With technology development we will be able to track greater objects without markers.

3.9 FINAL REMARKS

The virtual work instructions are promising new technology of work organisation. Either the full virtual reality solution or augmented reality solution can be applied. The AR still has some technology limitation but fully VR instructions works fine. Validation showed time reduction of assembly in comparison to classical work instructions by around 20%. The costs for printing are reduced or eliminated totally. The solution can be used widely through many industrial sectors. Also it is very effective in those types of productions where high variability occurs, where the production is running in small batches or where often changes of products portfolio appears.

List of attachments:
Attachment 1: The animation of virtual assembly

4 LESSON LEARNED

This section contains the learned lessons related to the good practice collection activity from the perspective of the partner and who provided the data for each good practice.

Lessons learned from the perspective of the companies who provided the good practice information

The responders were questioned about the learned lessons from their point of view and asked to provide information about the most important aspects. These are summarized as follow:

- **Intemac** – We have a brand new solution which was developed just recently. The SFH project could help to promote our solution and popularize the Industry 4.0 topic between the Czech companies, thus it is interesting for us. The project idea is very good. We want to stay in touch for the rest of the project. As we are also partially funded by the public finances we also would like to take place at the Stuttgart academy for facilitators.
- **REX Controls** – Our company has already a good experience in international trade. The Monarco HAT was already sold worldwide but we are still looking for different communication channels. The mapping tool platform could serve us as another communication channel and spread the information about our solution via Europe.
- **Regional Technological Institute** – The idea of mapping tool platform is very good. We see the potential in it and we can imagine how it can helps us in communication with potential customers.

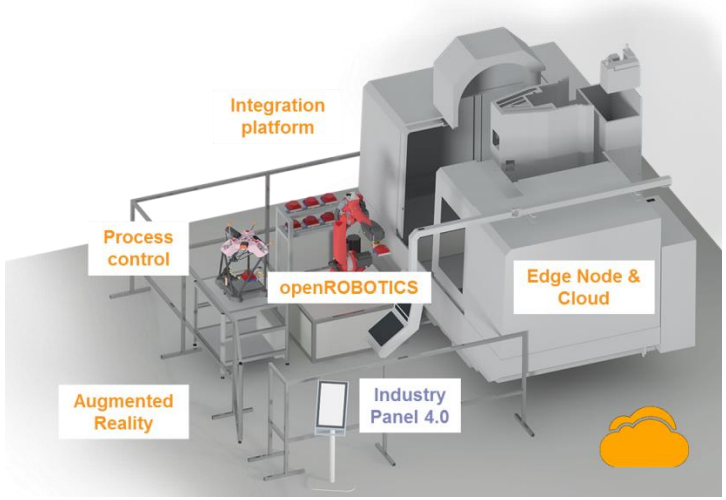
Lesson learned from the perspective of the UWB

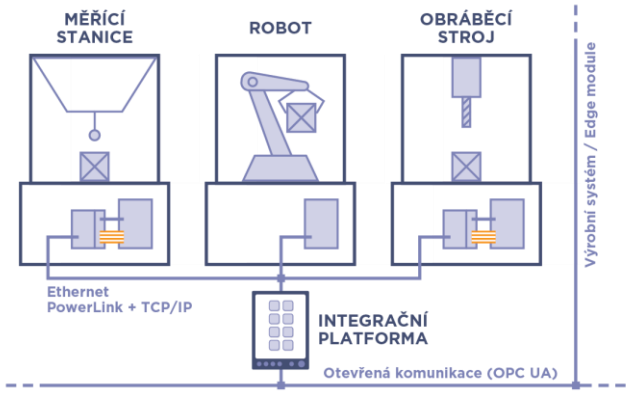
Collecting all the good practices was not an easy task, that's also why the goal was not met in desired time. Not many companies who have been addressed with cooperation refused but this wasn't contributing to the success anyway. The biggest problem was the aspect of time. Especially bigger companies has their inner process of confirmation if they can provide the data and participate but this process was sometimes so time consuming and confusing for the outsider that sometimes we even didn't know where the confirmation process stopped. Some companies who wanted to participate during the first meeting declined later due to time reason when they were asked to fill in the datasheet. Even the good practices presented in this document haven't been filled directly by the companies. We asked them for different information material regarding theirs solutions. We harvested the necessary information and filled the datasheets for good practices and the companies was then asked to check the info, correct it a fill in the missing fields. Some of the companies was not able to cooperate of god practices due to lack of personal. We were told that many of the skilled workers are assigned with more important tasks (projects, reports) that needs to be done before end of the year, however they said that after the New Year they want to participate on the project.
Presentation of mapping tool platform validated as interesting tool. During the meetings all the companies were presented with the mapping tool platform. Everybody likes it and seems a potential in it. In many cases it was the decision reason for cooperation.

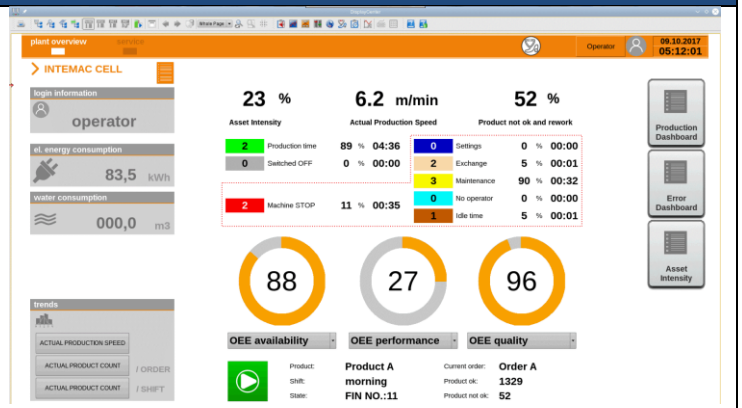
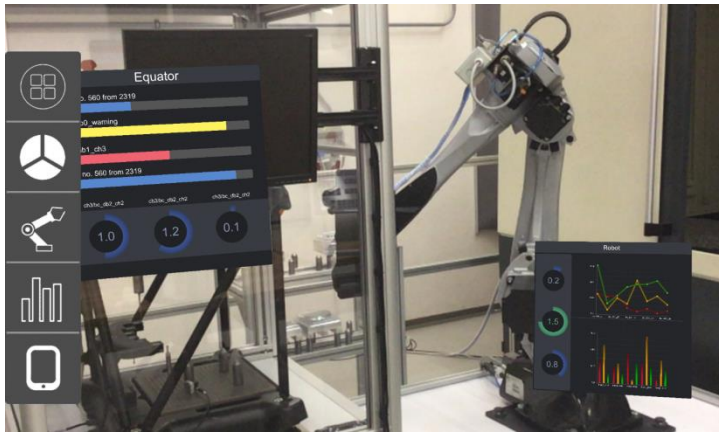
5 TEMPLATE FOR GOOD PRACTICE DOCUMENTATION

Element	Guiding questions	Answers
INTRODUCTION		
Company information	Data identification, logo, contact person, possible representative image(s).	Data identification : Intemac Solutions, s.r.o., Logo: Contact person: Ing. Zdeněk Fiala, Ph.D. Blanenská 1288/27, 664 34 Kuřim, Czech Republic, Phone: +420 606 097 793 E-mail: fiala@intemac.cz Website: www.intemac.cz
Name and brief description.	Name or acronym: what is the name that captures the essence of the good practice	PRODUCTION CELL 4.0
	Provide a concise description of the good practice being addressed	Production Cell 4.0 is being developed as a base unit of future smart factories. The cell is formed by interconnected devices that are involved in the partial steps of the production of metal workpieces. The motivation is to prepare a cell for easy adaptation of production for SMEs. The cell is used to test principles and develop new industry-related technologies in connection with Industry 4.0.
GOOD PRACTICE DESCRIPTION		
Detailed description	How did the SME create good practice / new product?	Several subjects participated on the development of production cell 4.0. The machine was provided by TAJMAC-ZPS, measuring station by Renishaw, B + R Automation developed an open platform, a robot for

Element	Guiding questions	Answers
		the demonstration of integrated robotics was borrowed by COMAU, SMC delivered clamping elements, and thanks to Sewio Networks the movement of people around the cell can be tracked.
	What is the relationship to SFH approach: novel technology, production processes, HRM or cost efficiency, quality assurance, risk management?	This solution is strongly tied with the “Smart Factory” concept, as several novel technologies (namely cyber physical systems, intelligent sensors, robotics and cloud processing) were incorporated directly and contributed to the production of a specific product. The benefits can be seen in the area of quality assurance.
	Describe what are the technical solutions and innovations: of the good practice	The cell forms a functional production unit linking a CNC machine, a robot and a measuring station. The uniform system solves proprietary communication with each device and communicates externally with open protocols. Thanks to modular architecture the device can be easily modified and the system can be supplemented by other software applications. The so-called production control process remains the basis of the production cell - the measuring station in the cell checks the quality of each workpiece after finishing. When a deviation is detected, the workpiece, including the necessary corrections, is sent back to the machine for repair. This greatly reduces the need of the operator to interfere with machine settings during the manufacturing process. Key capabilities include horizontal and vertical connectivity of the cell with other manufacturing systems. For the cell, the so-called edge node connection into the cloud platform was prepared where the data mining is being conducted to search for

Element	Guiding questions	Answers
		deeper connections. The cell is controlled by a system opened for user applications and the third-party applications. The data are displayed in augmented reality, monitoring of people movement is being done, condition monitoring of CNC machine and, last but not least, quality control of production process. 
	Highlights (or keywords) of the Best Practice	Specific keywords: continuous measurement and adjustment, predictive diagnosis, integrated robotics, augmented reality, Edge Node, cloud processing.
	Good practice applied in : (NACE code)	Good practice applied in the field of: Machining (NACE code C25.6.2).
Benchmarking	How does your solution related to others provided by competitors	Uniqueness consist in interconnection of a whole range of new technologies to a functional concept that is ready

Element	Guiding questions	Answers
		for deployment in production. Operation od the production cell is built on the principles of the so-called Testbed. The cell is opened to other industrial partners.
Additional information's / materials	Provide additional information if existing such as case studies, datasheets, whitepapers, awards and other relevant information. Electronic sources (websites, social media, pictures, videos) are encouraged to be included in this section. Training manuals, guidelines, technical fact sheets, posters, pictures, video animations, audio documents, 3D files, and/or other material about the Good practice implementation (if existing).	Visualization of communication and integration platform principle.  Edge Node – visualization and data processing

Element	Guiding questions	Answers
		 Augmented reality - all important information in one device, quick managerial reports. 

Element	Guiding questions	Answers
		Video material that presents how the solution work is provided here: https://www.youtube.com/watch?v=IQJph5c7xo0
OBJECTIVE AND TARGET AUDIENCE		
Geographical coverage and target audience	What is the geographical range where the good practice has been used / tested / validated: country, region, Danube Region if is relevant and possible	The solution described previously was developed, tested and validated in Czech Republic.
	Specify also the target audience/potential customers and stakeholders (stakeholders can affect or be affected)	The production cell 4.0 is usable in small and medium-sized companies as well as in large companies which are focused on machining operations.
Targeted customers and scale of use	Select the target group of customers: 1. SMEs (<250 employees) 2. Large companies 3. Public institutions 4. End customer (Business to Customer) Other, please specify	1. SMEs (<250 employees) 2. Large companies
METHODOLOGICAL APPROACH		
Managerial aspects	Cost efficiency of the good practice, if applicable	Minimize on-site presence of experts, reduce changing time, increase machine availability, predictive maintenance will detect a possible failure on time.
	Quality assurance aspects, if applicable	Avoid human interaction and thus human faults. Quality is further ensured by following measures. - Control of the machining process by workpiece probe. - Process control by the control system Renishaw Equator.

Element	Guiding questions	Answers
		- Calibration of each manufactured part. - The parts carry correction data and are automatically sent back for repair.
	Risk management aspects, if applicable	Data Security Measures have to applied.
Implementation guidelines	How can the Good practice be implemented?	The methodology for implementing this solution comprised of the following steps: 6. Analysis of the production system – mapping of customer requirements on the resulting functionality, mapping of control systems and compatibility options. 7. Creating a concept for the operation of the production cell with customer approval. 8. If necessary, purchase and installation of missing devices. 9. Modification of the uniform system for mutual communication of all devices - programming of specific functions. 10. System testing and validation - functionality, accuracy, speed, data processing and visualization.
	What resources are necessary for implementation (personnel, finance, infrastructure and timespan)?	**Personnel**: IT, technology and process department **Finance**: very variable, can't be predicted **Infrastructure**: machines, IT hardware, LAN **Timespan**: Realization depends on complexity. It may vary for 3 to 6 months.
VALIDATION PROCESS		
Validation	Provide a brief description of the good practice validation process.	The good practise was validated with industrial clients.

Element	Guiding questions	Answers
RESULTS / IMPACT		
Solution impact	What has been the impact (positive or negative) of this good practice on the beneficiaries	The impact of the good practise is highly positive, as the scrap rates are reduced to almost 0% and the process of self-adjustment is fully automatic. Data about the machining process are displayed virtually and in time so the customer has all the necessary information for decision making.
SUCCESS FACTORS AND CONSTRAINTS		
Limitations and Strong points	Describe limitations, both from the technical and implementation point of view	NA
	Selling points – list the real or perceived benefit of a good practice that differentiates it from the competing brands and gives its client a logical reason to prefer it over other brands	The benefit of Production Cell 4.0 is based on the interconnection of new technologies into a functional unit and in the same time openness to the technologies of other industrial partners. Those interested can even engage their devices (such as the material transport system or 3D printer), use it to test their own technologies or develop features that they would like to prefer in their business.
Need assessment	What else would be needed in order to improve the impact of the Good practice	Thanks to the open platform the production cell is prepared also for new technology advances and thus can serve as a testbed.
LESSON LEARNED		
Lessons learned	What are the key messages and lessons learned to take away from the good practice experience	The described solution represents a great possibility to interconnect devices in one fully automated manufacturing cell however the user acceptance

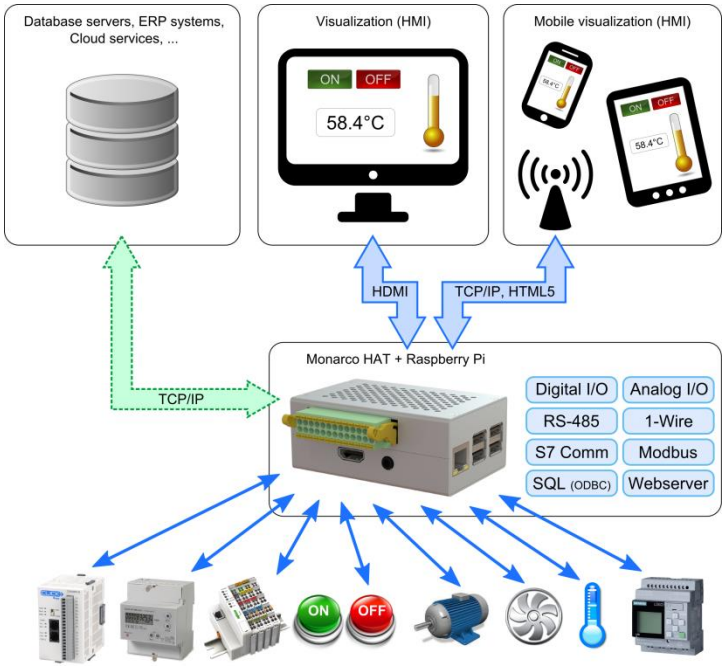
Element	Guiding questions	Answers
		strongly correlates with the level of experience concerning the technologies involved. Customizing is an important requirement for user acceptance.
SUSTAINABILITY		
Sustainability of Good Practice	Describe aspects related to sustainability of the Good Practice, if applicable	NA
REPLICABILITY AND UP SCALING		
Replicability and further application	How can the solution / good practice be useful for other SMEs?	This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch. It must be noted, however, that it initially requires a high financial commitment and the organizational culture should be open to the use of new technologies.
	What are the possibilities of extending the good practice more widely?	The benefit of Production Cell 4.0 is based on the interconnection of new technologies into a functional unit and in the same time openness to the technologies of other industrial partners. Those interested can even engage their devices (such as the material transport system or 3D printer), use it to test their own technologies or develop features that they would like to prefer in their business.
FINAL REMARKS		
Conclusion	Conclude specifying / explaining the impact and usefulness of the good practice.	The core of the Production Cells 4.0. is formed by a platform linking a machine with a handling robot and a measuring station. The cell enables the so-called

Element	Guiding questions	Answers
		adaptive process of production - the measuring station can evaluate the workpiece quality after completing the machining process and, when finding the imperfections, send information to the machine that will repair the workpiece. The system can work completely automatically without human intervention, which eliminates errors. Reports and data from machines are instantly available in various display formats thanks to cloud computing. The cell with a uniform system demonstrates the advantages of automation combined with the needs of small-scale production where one of the key requirements is the need to change the input of production several times a day.
Disclaimer / Acknowledgements	Address any legal loose ends or limitations for dissemination, certify the use of this information for dissemination, online and printed (Yes/No)	We are agree with on-line and printed dissemination of the information from this questionnaire.

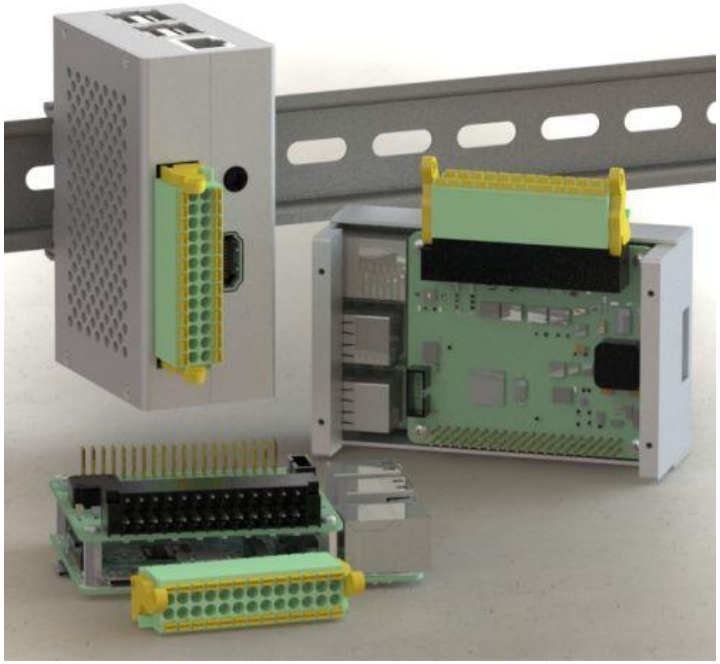
6 TEMPLATE FOR GOOD PRACTICE DOCUMENTATION

Element	Guiding questions	Answers
INTRODUCTION		
Company information	Data identification, logo, contact person, possible representative image(s).	Data identification : REX Controls s.r.o., Logo: Contact person: Ing. Pavel Balda, Ph.D. Jeřabinová 30, 326 00 Plzeň, Czech Republic, Phone: +420 605 212 971 E-mail: info@rexcontrols.cz Website: www.rexcontrols.cz Product website: www.monarco.io
Name and brief description.	Name or acronym: what is the name that captures the essence of the good practice	Monarco HAT
	Provide a concise description of the good practice being addressed	Monarco HAT is an add-on board which provides input-output interfaces following industrial automation standards for the Raspberry Pi (B+ and newer) minicomputer. It is designed according to the HAT (Hardware Attached on Top) specification. It enables collection of data from machines for its visualisation or evaluation.
GOOD PRACTICE DESCRIPTION		
Detailed description	How did the SME create good practice / new product?	This product was created in response to the demand of SMEs for upgrading or retrofitting existing control systems of machines. Monarco HAT is based around

Element	Guiding questions	Answers
		ARM Cortex-M3 microcontroller (MCU) which provides a wide set of embedded peripherals missing on the Raspberry Pi itself. It offers PWMs for all digital outputs, versatile counters including quadrature encoder signal decoders, digital-to-analog and analog-to-digital converters, and RS-485 communication etc. ARM MCU can also provide very deterministic IO timing compared to Raspberry Pi with Linux.
	What is the relationship to SFH approach: novel technology, production processes, HRM or cost efficiency, quality assurance, risk management?	This solution is strongly tied with the “Smart Factory” concept, as a novel technology, namely intelligent sensors/actors are implemented.
	Describe what are the technical solutions and innovations: of the good practice	Below are the applications we had in mind when we designed the add-on board which we call the Monarco HAT. - Reading and archiving data from standard industrial sensors. - Monitoring of machines. - Providing communication gateway between various devices. - Feedback control in non-critical applications. Here are a few examples of devices whose outputs can be handled by Monarco HAT digital inputs: - utility meters (electricity, gas, water) with pulse output, - standard quadrature encoders for position/velocity measurement, - gear tooth sensors for position/velocity measurement,

Element	Guiding questions	Answers
		- motor controllers with pulse/direction or quadrature position output, - various industrial sensors (temperature, pressure, distance) with frequency output.  The first choice for programming is the REX Control System, which is best described by the following features: - Graphical programming without hand-coding.

Element	Guiding questions	Answers
		- Programming control units on a standard PC or laptop. - User interface for desktop, tablet and smartphone (HMI). - Wide family of supported devices and input-output units (including Monarco HAT). - Industry-proven control algorithms. - Easy integration into business IT infrastructure (ERP/BMS). - REST API for seamless integration into Industry 4.0 and (I)IoT solutions.
	Highlights (or keywords) of the Best Practice	Specific keywords: Monitoring of machines, Monarco HAT, Raspberry Pi, REX control system.
	Good practice applied in : (NACE code)	Good practice applied in the field of: Manufacturing (NACE code C).
Benchmarking	How does your solution related to others provided by competitors	Uses normal and quite common Raspberry Pi minicomputer but supplement it with additional normally not available interfaces, effectively turning it into a PLC or a mini industrial PC (IPC).

Element	Guiding questions	Answers
Additional information's / materials	Provide additional information if existing such as case studies, datasheets, whitepapers, awards and other relevant information. Electronic sources (websites, social media, pictures, videos) are encouraged to be included in this section. Training manuals, guidelines, technical fact sheets, posters, pictures, video animations, audio documents, 3D files, and/or other material about the Good practice implementation (if existing).	 Video material that presents how the solution work is provided here: Raspberry Pi as a 1-Wire data bridge for Siemens LOGO https://www.youtube.com/watch?v=rdosVtdxJac Raspberry Pi controlling a frequency inverter

Element	Guiding questions	Answers
		https://www.youtube.com/watch?time_continue=74&v=APXEFQKF5Tw Raspberry Pi reading a 0-10 V ultrasonic sensor https://www.youtube.com/watch?time_continue=45&v=oXTaTk1jbEY Extending I/O of the Monarco HAT via RS-485 https://www.youtube.com/watch?v=3G5M0xRgNss
OBJECTIVE AND TARGET AUDIENCE		
Geographical coverage and target audience	What is the geographical range where the good practice has been used / tested / validated: country, region, Danube Region if is relevant and possible	The solution described previously was developed, tested and validated in Czech Republic. The utilisation is worldwide.
	Specify also the target audience/potential customers and stakeholders (stakeholders can affect or be affected)	Monarco HAT with its REX Control System can be applied in various scenarios in various industry fields. Its versatility ensures its uses in large as well as in small and medium size companies.
Targeted customers and scale of use	Select the target group of customers: 5. SMEs (<250 employees) 6. Large companies 7. Public institutions 8. End customer (Business to Customer) Other, please specify	3. SMEs (<250 employees) 4. Large companies
METHODOLOGICAL APPROACH		
Managerial aspects	Cost efficiency of the good practice, if applicable	There are indirect cost savings connected with describes solution. The data which is being collected and evaluated influence the overall productivity by well-

Element	Guiding questions	Answers
		timed decision making. Furthermore the purchase cost of Monarco HAT is quite low which ensures that this solution is also affordable for SMEs.
	Quality assurance aspects, if applicable	Clear visualisation and electronical data transfer eliminates mistakes which may occur if the data was processed manually (pen and paper) by workers.
	Risk management aspects, if applicable	Data Security Measures have to be applied.
Implementation guidelines	How can the Good practice be implemented?	The methodology for implementing this solution comprised of the following steps: 11. Feasibility study (establish whether the solution can be implemented – checking electrical compatibility at signal level, checking availability of sensors and actuators, studying the programming tools, budget analysis, potential benefits and weak points); 12. Acquire the hardware platform and programming tools; 13. Develop software based on the solution (programming the mini PLC to collect the required data, perform the requested operations and); 14. Deploy the resulting controller/data logger/communication gateway at floor level of the factory; 15. Verify the impact (compared to historical data and/or evaluate benefits of collecting new data).
	What resources are necessary for implementation (personnel, finance, infrastructure and timespan)?	**Personnel**: IT, PLC programmers

Element	Guiding questions	Answers
		Finance: Plain board with optional housing – 129 €, Automation kit with RexCore Plus – 279 €, Automation kit with RexCore Pro – 359 € **Infrastructure**: IT Hardware, LAN **Timespan**: Delivery time is about 3-5 business days within Europe and 10-12 days outside Europe. Realization on the spot in one day for single implementation.
VALIDATION PROCESS		
Validation	Provide a brief description of the good practice validation process.	The good practise was validated with industrial clients worldwide. (USA, Australia, Taiwan, Republic of South Africa, Germany, Austria, Belgium, Norway, etc.)
RESULTS / IMPACT		
Solution impact	What has been the impact (positive or negative) of this good practice on the beneficiaries	The impact of the solution was highly positive, the new collected data and interconnection between individual machines led to an increase in productivity and lowering failure rates in final quality tests on production lines.
SUCCESS FACTORS AND CONSTRAINTS		
Limitations and Strong points	Describe limitations, both from the technical and implementation point of view	The solution cannot be directly mounted on moving parts of machines. The reason is the memory card holder, which is not designed for use in vibrating environments.
	Selling points – list the real or perceived benefit of a good practice that differentiates it from the competing brands and gives its client a logical reason to prefer it over other brands	Monarco HAT was developed by control engineers for control engineers. So far it is the only board aimed at industrial automation and following the HAT standard.

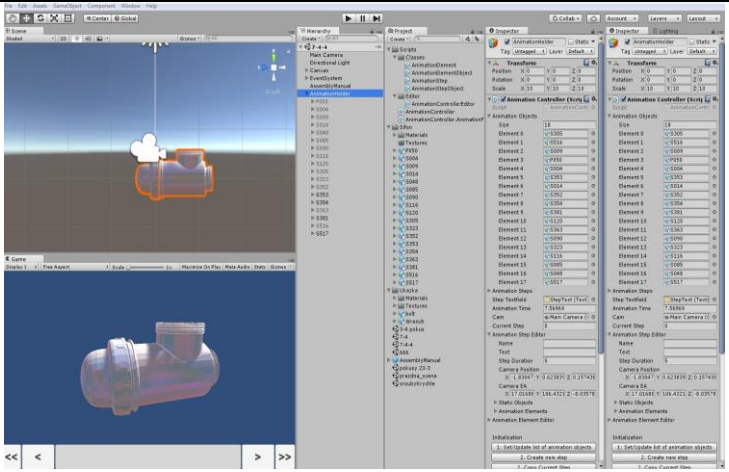
Element	Guiding questions	Answers
		Years of experience in automation domain and electronics design were put into the product design. Although Monarco HAT is a very young product, our records indicate very low failure rates. Hundreds of satisfied customers are enjoying the benefits of using the solution. The device is universal and can be used for all tasks in automation and cybernetics. Low entry costs make it attractive also for SMEs and even end customers.
Need assessment	What else would be needed in order to improve the impact of the Good practice	NA
LESSON LEARNED		
Lessons learned	What are the key messages and lessons learned to take away from the good practice experience	Operating temperature and vibrations are known to be the most critical. What happens when the Raspberry Pi fails? Not having real-time data on displays at floor level can hurt, but certainly not as much as stopping the whole production line. If necessary, will it be possible to switch to another hardware platform without starting software development from scratch? Those are the types of questions you should be asking before deploying the solution in the field. In short, using this platform gives you freedom, but keep in mind that freedom comes with responsibilities.
SUSTAINABILITY		
Sustainability of Good Practice	Describe aspects related to sustainability of the Good Practice, if applicable	NA

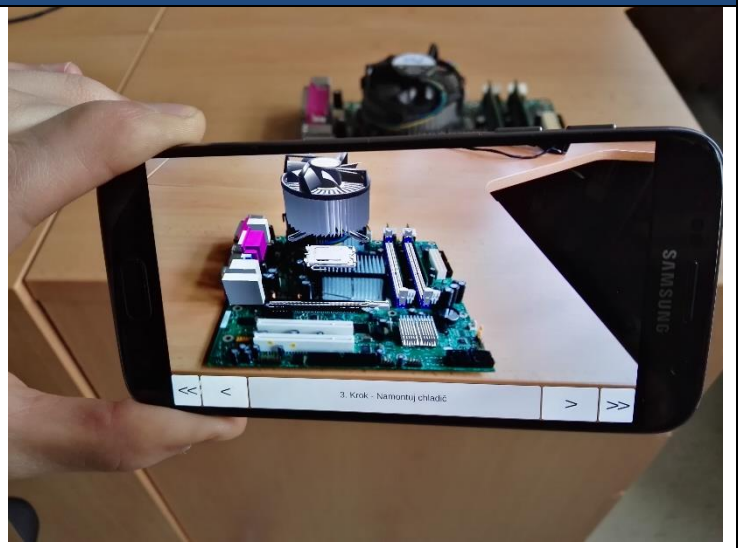
Element	Guiding questions	Answers
REPLICABILITY AND UP SCALING		
Replicability and further application	How can the solution / good practice be useful for other SMEs?	This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch.
	What are the possibilities of extending the good practice more widely?	The Monarco HAT is upgraded continuously in its functions regarding the needs of industrial practice. The upgrades are mainly on software basis.
FINAL REMARKS		
Conclusion	Conclude specifying / explaining the impact and usefulness of the good practice.	The use of Raspberry Pi and the Monarco HAT in industrial automation opens new possibilities for IoT and Industry 4.0 projects. This platform has proven to work well in symbiosis with existing control systems and controllers, providing additional CPU power, memory, storage and communication capabilities, which the traditional platforms are missing.
Disclaimer / Acknowledgements	Address any legal loose ends or limitations for dissemination, certify the use of this information for dissemination, online and printed (Yes/No)	We are agree with on-line and printed dissemination of the information from this questionnaire.

7 TEMPLATE FOR GOOD PRACTICE DOCUMENTATION

Element	Guiding questions	Answers
INTRODUCTION		
Company information	Data identification, logo, contact person, possible representative image(s).	Data identification : Regional Technological Institute, Logo:  Contact person: Ing. Pavel Žlábek, Ph.D. Univerzitní 8, 306 14 Plzeň, Czech Republic, Phone: +420 377 638 711 E-mail: zlabek@rti.zcu.cz Website: www.rti.zcu.cz
Name and brief description.	Name or acronym: what is the name that captures the essence of the good practice	VIRTUAL REALITY WORK INSTRUCTIONS
	Provide a concise description of the good practice being addressed	The goal was to create a virtual work instructions that will shorten the time needed to train new employees to improve work performance, reduce mistakes, and ease work by eliminating inappropriate assembly and further disassembly of parts. The shorter the training of new employees is, the sooner they will be able to perform their work and produce flawless products. These instructions are also useful if the operator gets into an unfamiliar situation and if he have to do some work for the first time.
GOOD PRACTICE DESCRIPTION		
Detailed description	How did the SME create good practice / new product?	A first prototype was created in the course of a master thesis. The system was further developed within the

Element	Guiding questions	Answers
		research work conducted in the RoRTI project from National Sustainability Programme funded by the Ministry of education and then validated and improved with lead customers.
	What is the relationship to SFH approach: novel technology, production processes, HRM or cost efficiency, quality assurance, risk management?	This solution is strongly tied with the “Smart Factory” concept in concrete with mobile workforce. The workers are provided with virtual working instruction presented on LCD display.
	Describe what are the technical solutions and innovations: of the good practice	The innovative nature of this solution is that it provides animated instructions for the operators training and work which makes their activities more efficient. The instruction can be performed as fully virtual or in mixed reality (augmenter reality). The visualisation with smart glasses (Vuzix) was tested however the satisfaction was very low. Thus the simple visualisation on LCD display – tablet, smartphone was provided. The system was developed with aid of Unity 3D software package. Preparation of virtual assembly in Unity 3D

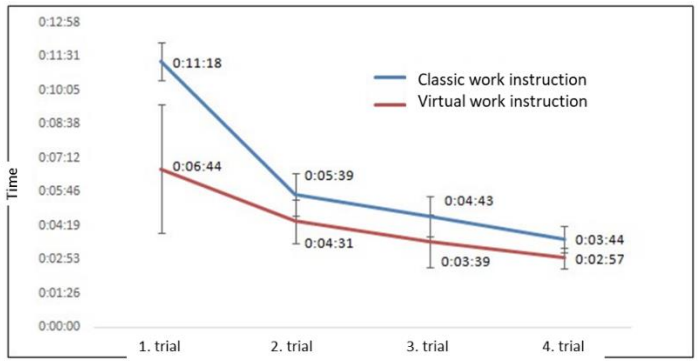
Element	Guiding questions	Answers
		 Augmented reality work instruction

Element	Guiding questions	Answers
		
	Highlights (or keywords) of the Best Practice	Specific keywords: virtual work instructions, augmented reality, assistive technology, operator empowerment.
	Good practice applied in : (NACE code)	Good practice applied in the field of: Manufacture of consumer electronics (NACE code C26.4.0).
Benchmarking	How does your solution related to others provided by competitors	The application of the current technology extended over to other industry branches, but its use differed in nature from this type of application (e.g. Daimler applied Vuzix glasses for quality-control and other type of product inspection activities, while UPS (United Parcel Service Inc.) used it for reducing labelling on packages). In both of these cases the AR glasses are required however the

Element	Guiding questions	Answers
		comfort by using the AR glasses is not very high. The technology has still its limitation. For our solution we choose simple visualisation on display.
Additional information's / materials	Provide additional information if existing such as case studies, datasheets, whitepapers, awards and other relevant information. Electronic sources (websites, social media, pictures, videos) are encouraged to be included in this section. Training manuals, guidelines, technical fact sheets, posters, pictures, video animations, audio documents, 3D files, and/or other material about the Good practice implementation (if existing).	The animation of virtual assembly is provided.
OBJECTIVE AND TARGET AUDIENCE		
Geographical coverage and target audience	What is the geographical range where the good practice has been used / tested / validated: country, region, Danube Region if is relevant and possible	The solution described previously was developed, tested and validated in Czech Republic.
	Specify also the target audience/potential customers and stakeholders (stakeholders can affect or be affected)	Solution can be applied by other companies that are willing to integrate virtual reality or augmented reality technology into their manufacturing process, especially those that have operators involved in product assembly activities. The practice has a high degree of portability and can be adapted to companies operating in various industry branches.
Targeted customers and scale of use	Select the target group of customers: 9. SMEs (<250 employees) 10. Large companies 11. Public institutions 12. End customer (Business to Customer)	5. SMEs (<250 employees) 6. Large companies

Element	Guiding questions	Answers
	Other, please specify	
METHODOLOGICAL APPROACH		
Managerial aspects	Cost efficiency of the good practice, if applicable	If a company recruits new workers, they have to be trained and the faster they learn, the sooner they can effectively perform the necessary tasks. Virtual guides are not only suitable for training of new employees, but they can be effectively used if there is a wide range of products in the company. If the employees don't perform these processes daily, they do not need to remember the exact procedures and steps.
	Quality assurance aspects, if applicable	In addition to promptly training of new employees and thus increasing their performance, the errors are reduced or completely eliminated, and the resulting ease of work due to inappropriately mounted parts and subsequent removal of faulty components occurs. Virtual working instructions can be easily done in language versions and therefore are also suitable for foreign agency workers. There is also no possibility for operators when using virtual instructions to skip a step and thus create a scrap. In the case of virtual instructions, every step after completion has to be confirmed by pressing the button and therefore can't be omitted by mistake.
	Risk management aspects, if applicable	N/A
Implementation guidelines	How can the Good practice be implemented?	The methodology for implementing this solution comprised of the following steps:

Element	Guiding questions	Answers
		16. Analysis phase – decision about form of work instruction (VR or AR), selection of work instructions and products to be processed, budget analysis, mapping of company's IT infrastructure and databases; 17. Development phase – digitisation of products and its components (creation of 3D models), creation of animations, in case of AR mapping the 3D models on real object; 18. Implementation phase – upload to company's database, fine-tune the visualisation, train the operators.
	What resources are necessary for implementation (personnel, finance, infrastructure and timespan)?	**Personnel**: IT department, technology and process department **Finance**: Depends on no. of products and thus number of work instruction to be prepared, also on the complexity of the products and finally the type of work instruction (VR, AR). One working instruction costs around 550 €. If more instruction are being prepared than the costs for one instruction is being lowered as the 3D components may be interchangeable. **Infrastructure**: IT Hardware, LAN, database entry. **Timespan**: Time also depend on the complexity of the project. Timeframe is usually around 1-3 months also with implementation on the spot.
VALIDATION PROCESS		
Validation	Provide a brief description of the good practice validation process.	Twelve workers (6 males and 6 females) tested the assembly of two complex products of a similar type, of

Element	Guiding questions	Answers
		which they had previously no information. The product was assembled according to both paper and virtual instructions. They have always done four repetitions of the assembly. With every further round, work has accelerated (see chart). The results show that the virtual instruction was much more efficient than paper in the first round, and this was repeated in the following rounds also. 
RESULTS / IMPACT		
Solution impact	What has been the impact (positive or negative) of this good practice on the beneficiaries	The impact of the solution was highly positive, as the assembly time was reduced by 40% in the first trial round, by 22% in the second trial round, by 23% in the third trial round and by 20% in the fourth trial round. From these results can be seen that the virtual work instructions enables around 20% faster assemblies.

Element	Guiding questions	Answers
		Moreover as the printed documentation is reduced significantly the reduction is also in the printing costs.
SUCCESS FACTORS AND CONSTRAINTS		
Limitations and Strong points	Describe limitations, both from the technical and implementation point of view	The technology is universal however the software is programed directly for specific products. If the product is updated or modified the same goes also for the software which needs to be updated as well. The quality of company's internal databases and also the speed of connection is essential. The augmented reality work instructions has still many limitations. Marker technology is sensitive for the distance from marker and vison angle. The object fitting technology is limited by the size of the product which can maximally be around 30x30 cm.
	Selling points – list the real or perceived benefit of a good practice that differentiates it from the competing brands and gives its client a logical reason to prefer it over other brands	The solution and technology is not brand new. The virtual reality and augmented reality work instructions are implemented also in other companies. But it is usually domain of larger companies. Our solution and its development is rather cheep a thus can be implemented also in SMEs.
Need assessment	What else would be needed in order to improve the impact of the Good practice	NA
LESSON LEARNED		
Lessons learned	What are the key messages and lessons learned to take away from the good practice experience	The success of the implementation depends on the capability of overcoming the resistance of workers regarding the technological change. If they give it a try

Element	Guiding questions	Answers
		usually they are more satisfied. During the testing phase most of the workers followed the animations. The accompanying text was read only when assembly was difficult or if there was another problem.
SUSTAINABILITY		
Sustainability of Good Practice	Describe aspects related to sustainability of the Good Practice, if applicable	The technology has still some limitations in these days however due to future technological progress the development can be foreseen. Moreover the system reduces the need for printed documentation and thus is environmental friendly.
REPLICABILITY AND UP SCALING		
Replicability and further application	How can the solution / good practice be useful for other SMEs?	This solution can be implemented to a wide range of companies, without being tied specifically to a certain industry branch. The technology is transferable however the work instruction preparation must be taken into account which requires a medium financial commitment. Also the workers must be open to utilize new technologies.
	What are the possibilities of extending the good practice more widely?	The technology is limitation for now especially in augmented reality application. With technology development we will be able to track greater objects without markers.
FINAL REMARKS		

Element	Guiding questions	Answers
Conclusion	Conclude specifying / explaining the impact and usefulness of the good practice.	The virtual work instructions are promising new technology of work organisation. Either the full virtual reality solution or augmented reality solution can be applied. The AR still has some technology limitation but fully VR instructions works fine. Validation showed time reduction of assembly in comparison to classical work instructions by around 20%. The costs for printing are reduced or eliminated totally. The solution can be used widely through many industrial sectors. Also it is very effective in those types of productions where high variability occurs, where the production is running in small batches or where often changes of products portfolio appears.
Disclaimer / Acknowledgements	Address any legal loose ends or limitations for dissemination, certify the use of this information for dissemination, online and printed (Yes/No)	We are agree with on-line and printed dissemination of the information from this questionnaire.