BIFOCALPS Project

Boosting Innovation in Factory Of the
future value Chain in the Alps

Project Number: 510

D.T3.1.1: Set of measureable impact indicators

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EXECUTIVE SUMMARY

WPT3 aims at developing and validating an impact indicator system to track effective improvements after transfer and adoption of enabling FoF practices in manufacturing enterprises. In addition to enterprises, the results of WPT3 address regional and national public authorities aiming to enhance the innovative growth of the manufacturing sector. The impact indicator system directly builds on the findings of WPT2 and helps to improve the given methodology for innovation and knowledge transfer towards a factory of the future.

In order to address a broad range of stakeholders, the results are further subdivided into three different categories. Particularly, three sets of indicators are defined, focusing on a national, on a regional and on a company level perspective. The first two categories aim at evaluating the environment of manufacturing enterprises in the alpine space, regarding the success factors defined in WPT2. The last category presents an impact indicator system directly addressing manufacturing enterprises. The objective of this indicator system, which is based on the IPOO-framework, is to support the transformation towards a factory of the future by proposing a set of both quantitative and qualitative key performance indicators (KPI).

The impact indicator system on company level covers sets of quantitative, but also qualitative indicators. Even if all KPIs are embedded in the same impact indicator system, this paper only focuses on the presentation of quantitative indicators. The qualitative assessment is therefore presented in the deliverable D.T3.1.2.

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1 INTRODUCTION

1.1 Activities and deliverables

WPT3 covers three activities with five deliverables in total. This paper presents the first of three activities A.T3.1, including the deliverables D.T3.1.1 and D.T3.1.2. As described in the executive summary, activity A.T3.1 aims at defining key performance indicators in order to track effective improvements after successful technology and practices adoption towards the factory of the future (FoF). This activity builds upon the findings of WPT2, especially on the set of critical success factors identified, which enable the transition towards FoF. In order to track all relevant influencing factors, the impact indicator system has to include quantitative as well as qualitative measures. The following two activities A.T3.2 and A.T3.3 validate and test the proposed framework for the impact indicator system in dedicated workshops. An overview of the specific contents of each activity is given in Figure 1.

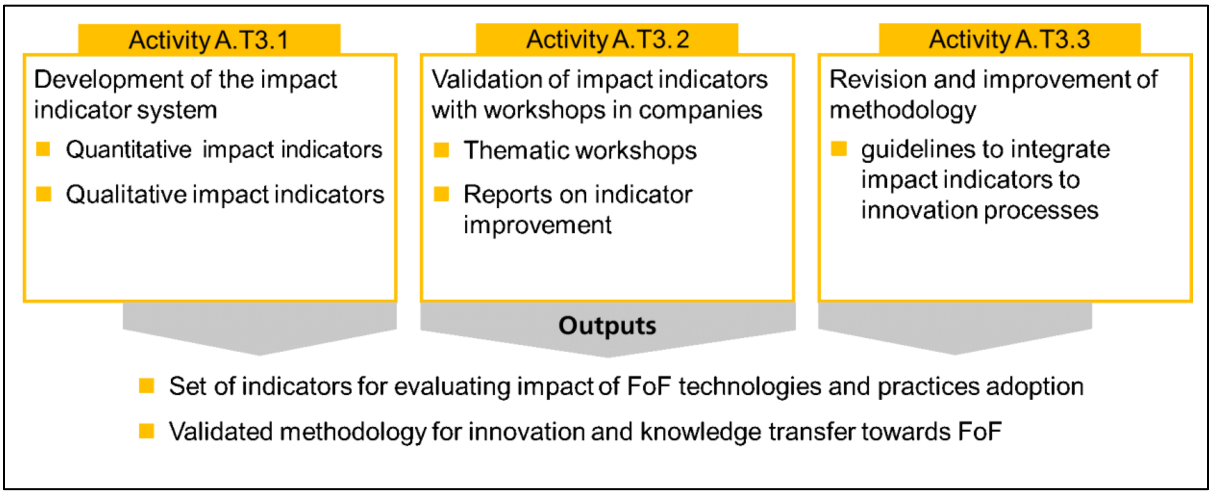

Figure 1 – Activities and deliverables in WPT3[1]

1.2 Approach

According to the specifications defined in activity A.T3.1, the indicator system has to meet a few requirements, which are described in detail in chapter 2.1. One specification defines that the indicator system has to consider different stakeholder and needs to address different parties. As it is not feasible to create a performance measurement framework simultaneously valid for enterprises and political decision makers, the approach is subdivided into three independent parts. The first two parts aim at comparing different regions and countries in the

[1] BIFOCAlps project description

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alpine space concerning the environments and conditions, which local enterprises have to work with. The analysis is built on a broad database research performed by each project member of BIFOCAlps. The last part addresses companies directly, by proposing a performance measurement framework to support the transformation towards FoF. As defined above, activity A.T3.1 relies on the results of the previous working package WPT2. The identified critical success factors deliver an essential input for all three parts.

1.3 Structure of the paper

The paper starts with a short presentation of the theoretical background in chapter 2. In more detail, the requirements and specifications are presented, which need to be fulfilled in the impact indicator system. Additionally, an introduction to the set of critical success factors is given, as these success factors play a critical role in this paper. The chapter ends with a presentation of the Input-Process-Output-Outcome (IPOO)-framework, which represents the basis for the impact indicator system on the company level.

Chapter 3 is dedicated to the presentation of results and findings of activity A.T3.1. The chapter starts with the presentation of the national and regional analysis and ends with the elaboration of the impact indicator system on company level.

A short summary of the work done together with a few recommendations for future research activities complete this paper in chapter 4.

2 IMPACT INDICATOR SYSTEM FRAMEWORK

2.1 Indicator system requirements

As defined in the project description, the WPT3-impact indicator system is subject to a set of requirements, which have to be taken into account in the model definition. These requirements guarantee that relevant stakeholders and influencing factors are considered in the indicator system, while still ensuring a broad applicability of the model. The requirements are defined below:

- **Different perspectives:** The indicator system should consider multiple perspectives such as competitiveness, smartness, innovativeness, etc.
- **Different stakeholders:** The indicator system should also include all relevant stakeholders from suppliers to final consumers.
- **Different measurement modes:** Finally, different modes of impact evaluation should be considered to ensure the collection of all necessary information. This requirement is met by defining quantitative and qualitative indicators in the model. While quantitative

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indicators represent numeric measures such as the financial performance of a company or the number of employees in a division, qualitative indicators are useful in cases where important outcomes are difficult to capture quantitatively.

2.2 Critical success factors

As defined above, the impact indicator system is based on the results and findings of the preceding work package WPT2. The results of this work package include guidelines for fostering innovation processes towards the factory of the future as well as the definition of critical success factors, which represent main enablers for FoF practices- and technology adoption. The critical success factors cover the following criteria, as shown in Deliverable D.T2.2.1:

- CSF1: Strategy
- CSF2: Technology
- CSF3: Capacity for innovation
- CSF4: Ecosystems support for innovation
- CSF5: Skills and change management

In WPT2, each success factor consists of five maturity levels, which define certain requirements an enterprise has to achieve in order to advance in their maturity levels. Referring to the impact indicator system, these maturity levels allow the formulation of company-specific objectives, which can further support the decision-making process regarding future developments and investments. The full list of critical success factors together with the corresponding maturity levels is shown in Table 1.

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Maturity level	*CSF 1: Strategy*
0	the company does not have any strategy
1	the company makes «forced» investments to test new technology and/or improve the performance of its products or processes(without a clear and defined strategy)
2	the company makes «intentional» investments to improve the performance of its products or processes
3	the company has a clear and defined strategy, questions its current and/or next business models and integrates technologies
4	the company has a complete 4.0 strategy and develops dedicated technologies
Maturity level	***CSF2: Technology***
0	the company does not invest in any 4.0 technology
1	the company invests in 3.0 technology to update its production system
2	the company tests or invests in some isolated 4.0 technology
3	the company integrates and uses 4.0 technology, it is an early adopter
4	the company anticipates new technologies and initiates new technology developments
Maturity level	***CSF3: Capacity for Innovation***
0	the company does not innovate
1	the company has an engineering office but no R&D department
2	the company develops some internal projects and use internal resources exclusively (it can collaborate with universities, technical and competence centres occasionally)
3	the company has a R&D department and participates in external national collaborative projects
4	the company has a R&D department and participates in external international collaborative projects

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Maturity level	***CSF4: Ecosystems support for innovation***
0	the company does not have any FoF support
1	the company collaborates with «isolated» and heterogeneous actors and benefits from general support programs
2	the company is part of specialized technological networks and benefits from specialized support programs
3	the company is part of multi-actors ecosystems(clusters, platforms…) and benefits from complementary, original and incentive support programs
4	the company is part of structured (regional, national or European) multi-actors ecosystems and benefits from public policies and specialized support programs
Maturity level	***CSF5: Skills and change management***
0	the issue is not addressed
1	there isn't a identified person in charge of the digital transformation, the company addresses the issue after the implementation of the technologies
2	the company evaluates internal skills when the technology is being implemented
3	the digital transformation is managed by a identified person from the management, the company designs a plan before the implementation of the technologies
4	the company implements a Human Resource Planning (HRP), there is a new culture and mind set into the company

Table 1 - Critical success factors[2]

As defined above, the list of critical success factors not only include specific FoF-technologies but also necessary skills, requirements, practices and other steps a company needs to invest in, in order to develop itself to a factory of the future. Accordingly, these critical success factors can serve as direct inputs for the impact indicator system in order to link specific FoF investments with achieved outcomes. Regarding the successful transfer and application of the identified success factors and practices, WPT2 also provides a set of guidelines assigned to each success factor. These guidelines aim at stimulating the cross-fertilization of the best practices in order to enhance a successful and sustainable growth of manufacturing sector at all levels of value chain and in all Alpine Space countries involved in the project.

[2] BIFOCAlps A.T2.1 – D.T2.1.2

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2.3 Input-Process-Output-Outcome model

Performance management is an organization's essential mean to provide information to decision makers. Special frameworks for performance measurement can be used to capture and evaluate performance data, which enables the derivation of key success factors in business processes. Especially in connection with innovation-processes, such frameworks are suitable to link innovation metrics to measure the efficiency and effectiveness of R&D activities.[3]

The Input-Process-Output-Outcome (IPOO)-framework represents a process based performance management framework, which was first developed by Brown and Svenson and later expanded by several components. The IPOO-Model serves as a framework to combine relevant indicators in order to manage and control innovation activities.[4] The framework, shown in Figure 2, is based on an ideal sequence of innovation processes.

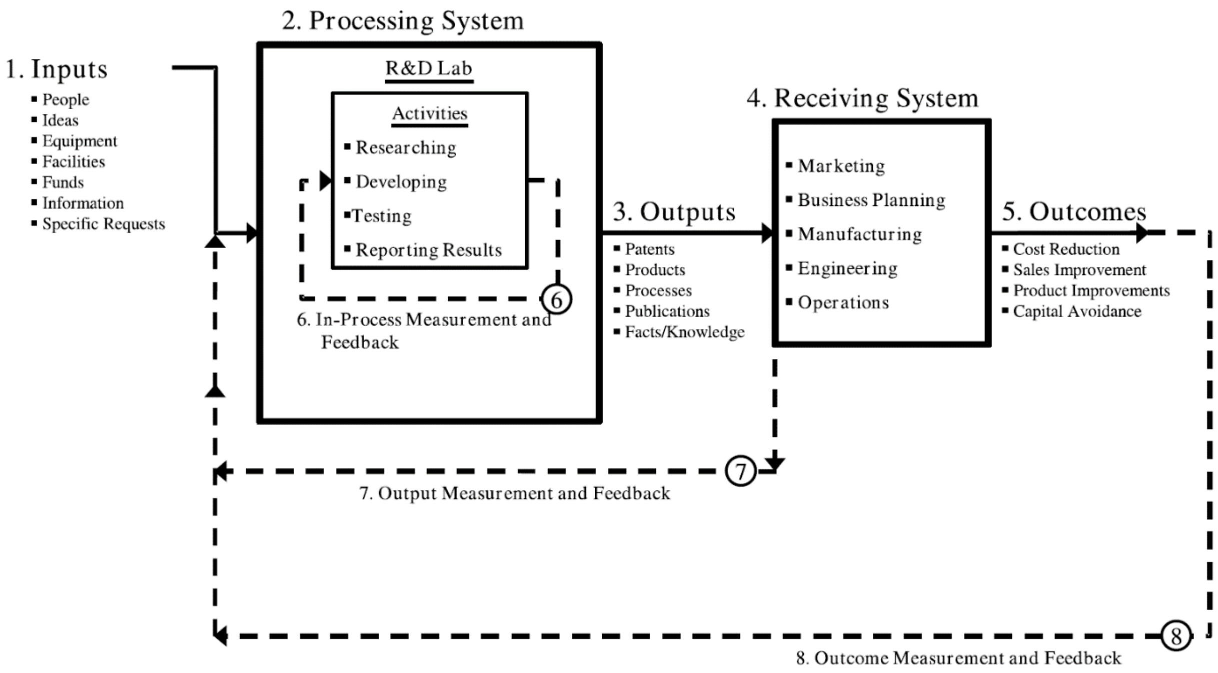

Figure 2 - IPOO- framework by Brown and Svenson[5]

[3] Cf. Janssen, Moeller and Schlaefke (2011, 110)
[4] Cf. Möller and Janssen (2011, 98)
[5] Cf. Janssen, Moeller and Schlaefke (2011, 111)

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According to the illustration, different types of inputs enter the innovation process, where these inputs are handled by the processing system. In this context, the processing system consists of all R&D-activities, which generate outputs such as new products, patents, knowledge or new methods. According to Brown and Svenson these outputs then enter the receiving system, an umbrella term for all business units that are involved in distributing and capitalizing the outputs. The receiving system itself is not a part of the IPOO-framework, but it is necessary to show the connection to outcome indicators, which represent the monetary success of all preceding innovation processes.[6] The different types of measures used in the model are described in more detail below.

Structuring innovation activities into the described process elements inputs, process, outputs and outcomes enables a classification and systematic representation of performance measures. In order to arrange such measures even more precisely, *Möller & Jannsen* propose a framework as shown in Figure 3, where these measures are further divided into quantitative, qualitative and relative indicators.[7]

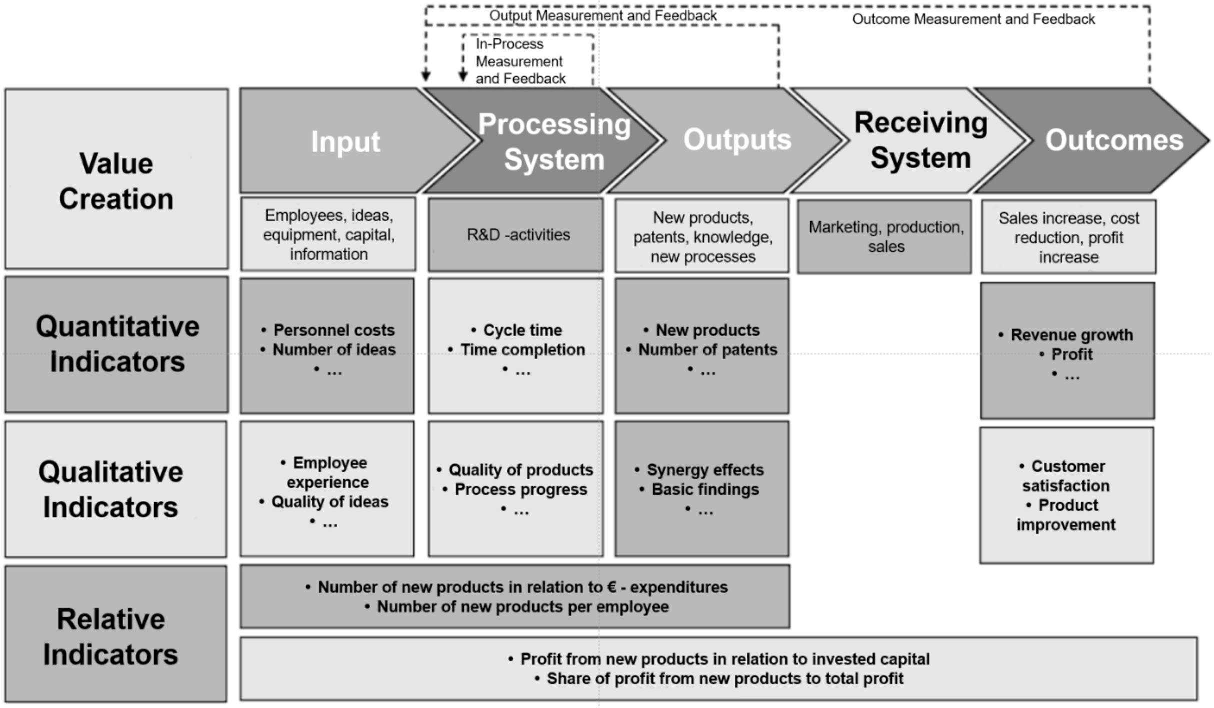

Figure 3 - Performance measurement in the innovation process[8]

[6] Cf. Möller and Janssen (2011, 98f.)
[7] Cf. Möller and Janssen (2009, 92)
[8] Cf. Gleich and Quitt (2011, 106)

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According to *Gleich*, systematically monitoring measures in these categories could be a key success factor to manage all innovation activities with regard to specific objectives and therefore to ensure the innovation success of a company.[9]

Selection of indicators

- **Input indicators**: As described above, input indicators capture resources, which enter the innovation process. In order to build a comprehensive model it is necessary to consider multiple perspectives besides costs. Therefore, input resources should include tangible as well as intangible assets of a company such as employees, equipment, information, expertise or financial resources. The significance of input measures is limited due to various reasons. For example, an increase in input resources does not necessarily result in higher outputs rates. In this context, the effectiveness of resource allocation and the processing of system inputs is far more important than just the amount of resources provided. Still, input measures should definitely be considered in a performance measurement framework, as they are relatively easy to gather and suitable for the derivation of comparative figures and reference values
- **Process indicators:** The transformation of input factors into specific outputs is the main activity in a companies' strive for innovation. As a result, guaranteeing effectiveness and efficiency of this change process, should be of greatest importance for every decision maker. Selected indicators in this category can support this goal by providing relevant information and ensuring transparency in the whole processing system. Frequently used measures include cycle time, adherence to delivery dates as well as cost- or quality related indicators.
- **Output indicators:** In general, organizational innovation activities aim at creating knowledge, new products or new processes. Output indicators are necessary to evaluate the successful achievement of these objectives. Depending on the specific objective, different types of measures can be defined. To capture the success in new product or process development, particularly quantitative measures can be utilised, such as the total number of new products or methods. A common approach to evaluate the growth of knowledge on the other hand is to count a companies' output in patents in relation to the total number of employees. This indicator can serve as an approximation, even if the quality of patents applied is more important than the quantity.
- **Outcome indicators:** By pursuing an innovation-orientated strategy, every company expects to either extend its market position, through revenue growth by new products or cost reduction with improved production methods. Therefore, besides considering the amount of new products, patents, etc. the market success of these outputs has to

[9] Cf. Gleich and Quitt (2011, 105)

be taken into account. Outcome indicators thereby are necessary to evaluate the overall success of the innovation process with respect to the business mission. Typical measures include the revenue increase or growth in terms of market share. Frequently, also the customers' perspective is considered, by measuring the average satisfaction or the customer benefit of a new or improved product.

Relevance of the IPOO-framework
The IPOO-framework offers a structured approach trying to connect specific inputs with outputs expressing a cause-and-effect relationship. Through application of a performance measurement system according to the IPOO-framework, decision-makers gain detailed information how inputs enable progress towards outputs and outcomes. This goal strongly resembles the objectives of WPT3 in the BIFOCAlps project, which consist in evaluating the impact of FoF- technology and practices adoption. The classification of performance measures into qualitative and quantitative indicators performed by *Möller & Jannsen* makes the framework even more suitable for the project specific needs.

3 IMPACT INDICATOR SYSTEM

This chapter is devoted to the presentation of the impact indicator system and the results obtained in WPT3. During the development of the indicator system, difficulties were recognized in an early stage, to create a single indicator system satisfying the needs of all defined perspectives. In particular, the difficulty lies in finding indicators that are not only sufficiently precise and detailed to allow the application of the model as a tool in companies, but also adequately generic, to serve as an assessment model on a regional level. Due to this reason, the decision was taken to split the indicator selection into three major categories, in order to ensure better-tailored results and findings for different target groups. Accordingly, the indicator selection complies with the following structure:

1) Indicator selection on national level
2) Indicator selection on regional level
3) Indicator selection on company level

The indicator selection at national and regional level aims at evaluating the degree to which regions in the alpine space comply with the identified critical success factors. This step will support the comparison between regions and provide valuable insights, where specific actions are required, in order to enable the development of local companies to factories of the future. This defined set of indicators will therefore mainly address and serve national, regional or local public authorities.

On the other hand, the indicator selection on company level will directly address enterprises, especially SMEs, and support the progress of these companies towards FoF. This step includes the elaboration of a management tool, which aims at helping enterprises to analyse their status regarding FoF-progress as well as to measure the direct impact of FoF-technology and practices adoption. The structure of the indicator system, together with the indicators on national, regional and company level are described in the following section.

3.1 Impact Indicator System – National level

Evaluating (infra-) structural and societal requirements in alpine regions is a critical step to gather information, if a region provides the right environment for the FoF-transformation. Looking at the list of critical success factors defined in WPT2, it is apparent, that companies are very dependent on external factors and structural conditions. Example given, regarding the success factor “Skills and change management”, an enterprise can only employ qualified workers if enough specialists are available locally. This requires the existence of educational institutions, especially concerning tertiary education. As another example, the critical success factor “Ecosystems support for innovation” already implies the dependence of enterprises on external “Ecosystems”, which are deeply influenced by governmental regulations.

3.1.1 Methodology

As stated above, the goal of this section is to provide information regarding critical success factor-requirements and related issues in the Alpine Space. Since WPT3 does not include the development or the execution of a survey in the alpine space, the necessary information has to be collected in existing statistics or databases. Therefore, the indicator selection in this chapter is based on nationwide research in national and regional databases regarding indicators with a strong relation to the critical success factors.

Before focusing at smaller regions in the alpine space, it is useful to gather some information on how the countries involved are generally performing concerning the critical success factors. The Eurostat database offers a reliable source to evaluate the environment these countries offer their enterprises. The data can be graphically processed either by using clear diagrams or by utilization of so-called statistical maps, which offer a particularly comprehensible visualization of regional differences. The visualization software *Tableau* is suitable for the development of these maps.

3.1.2 Evaluation

As stated above, the evaluation relies on an extensive database research covering requirements and fulfilment of critical success factors. Table 2 and Table 3 list all relevant indicators identified in this process. The table includes a description of these indicators

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together with practical information concerning the type of indicator and the year of investigation.

Topic		Indicator	Description	Year	Unit
CSF: Strategy	2.a	R&D-investments	Eurostat Regional Yearbook 2017, R & D intensity — gross domestic expenditure on R & D (GERD) relative to gross domestic product (GDP), by NUTS	2015	%
	2.b	R&D-investements Government	[tsc00001] - Research and development expenditure, by sectors of performance - % of GDP	2015	%
CSF: Technology	3.a	3.a Business digitization	Business Digitisation sub-dimension calculated as the weighted average of the normalised indicators: 4a1 Electronic Information Sharing	2014-2017	%
	3.b	3.b eCommerce	eCommerce sub-dimension calculated as the weighted average of the normalised indicators: 4b1 SMEs Selling Online (33%), 4b2 eCommerce Turnover (33%), 4b3 Selling Online Cross-border (33%)	2014-2017	%
	3.c	3.c Social Media	Enterprises that use two or more types of social media	2014-2017	%
	3.d	3.d RFID	Enterprises using Radio Frequency Identification (RFID) technologies for after sales product identification or as part of the production and service delivery	2014-2017	%
	3.e	3.e eInvoices	Enterprises sending e-invoices suitable for automatic processing	2014-2017	%
	3.f	3.f SMEs Selling Online	Enterprises selling online (at least 1% of turnover)	2014-2017	%
	3.g	3.g eCommerce Turnover	Enterprises' total turnover from e-commerce	2014-2017	%
	3.h	3.h Open Data	Score in the Open Data Maturity indicator. This composite indicator measures to what extent countries have an Open Data policy in place (including the transposition of the revised PSI Directive), the estimated political, social and economic impact of Open Data and the characteristics (functionalities, data availability and usage) of the national data portal.	2014-2017	%
	3.i	3.i Electronic Information Sharing	Enterprises who have ERP software package to share information between different functional areas	2014-2017	%

Table 2 - List of national CSF – indicators, part 1

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Topic		Indicator	Description	Year	Unit
CSF: Capcity for Innovation	4.a	4.a Total Number of researchers		2014	Abs
	4.b	4.b Share of Researchers to total employees		2014	%
	4.c	4.c HR in science and technology	Successfully completed an education at the third level or being employed in science and technology (% of active population)	2015	%
	4.d	Docotrate students in science and technology fields		2012	%
	4.e	Patents per year an million inhabitants		2014	Abs
	4.f	Patents per year an million inhabitants in high tech industry		2013	Abs
CSF: Skils and change management	6.a	6.a Basic Digital Skills	Individuals with basic or above basic digital skills	2014-2017	%
	6.b	6.b ICT Specialists	Persons Employed with ICT Specialist Skills	2014-2017	%
	6.c	6.c STEM Graduates	Science and technology graduates	2014-2017	%

Table 3 - List of national CSF – indicators, part 2

As shown in the table, the identification and selection of multiple measures for most of the critical success factors does not pose a problem in the analysis. Since the European Union also pursues national comparisons on a regular basis, data is widely available. Concerning the critical success factor *ecosystems support for innovation,* a low amount of data is publically available. Especially statistics about innovation-funding programs or local network-structures are missing for the comparison. In the following, a few results of the analysis are shown.

Figure 4 shows the total R&D – expenditure of an economy on relation to its gross domestic product (GDP). The indicator represents the total expenditure within the business enterprise sector, the government sector, the field of higher education as well as private, non-profit expenditures. This indicator, also called R&D-intensity, is frequently used to provide an overview of the importance, which is assigned to R&D and innovation in different countries. The indicator matches the critical success factors *strategy* as well as *capacity for innovation.* Regarding *strategy,* especially governmental and educational expenditure are significant, as these values indicate the strategic objective a country wants to achieve. On the other hand, business related expenses especially address the ability and the capacity of these enterprises to innovate. Figure 4 also enables the derivation of structural differences within economies.

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For example, the governmental expenses on R&D are relatively low in dependence of the GDP, while Austrian enterprises on the other hand show a great willingness to spend high amounts of their income on further research.

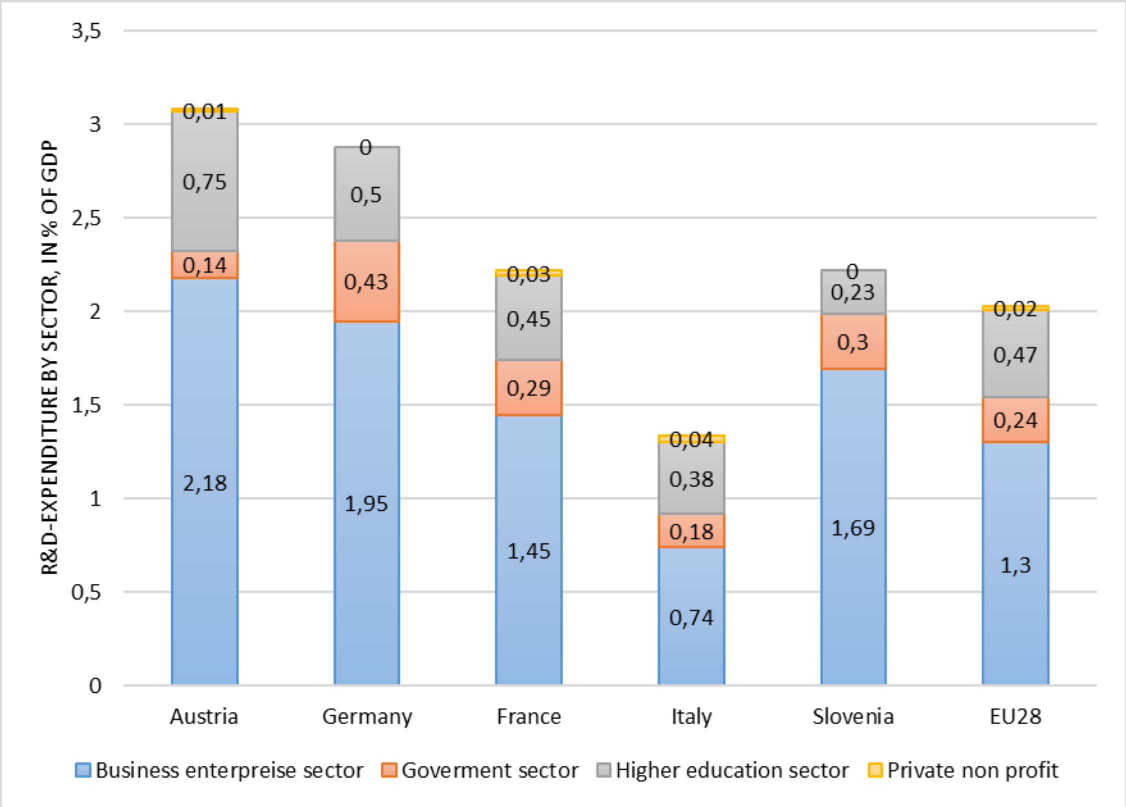

Figure 4 - R&D – expenditure by sector, in percentage of GDP

Figure 5 shows the visual representation of a second indicator regarding the critical success factor *technology,* in form of a statistical map created with the software *Tableau.* The image demonstrates the integration of digital technologies in the business enterprise sector, which is calculated as the average of the sub-dimensions business digitization (electronic information sharing, RFID, social media, cloud usage, etc.) and eCommerce (online sales). The colours in the statistical map indicate the current level of technology integration, changing from gold to red as a higher percentage of companies invests in digital technologies. According to the image, companies in Slovenia are particularly technology orientated, while enterprises in Italy and France still need to catch up in this international comparison.

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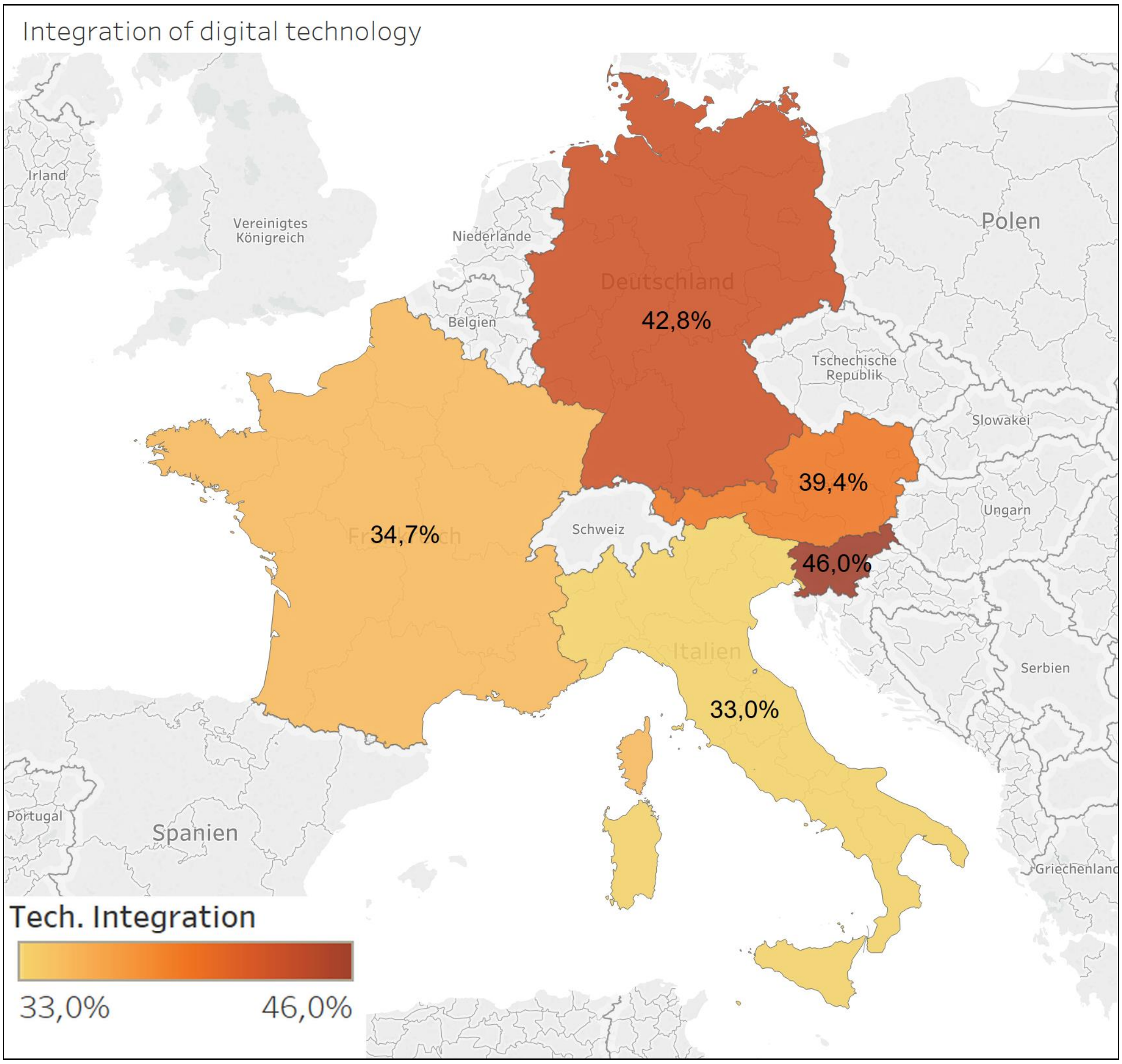

Figure 5 - Digital technology integration in the business enterprise sector

Figure 6, the last figure in the national analysis, addresses the critical success factor skills and change management. The data represents a countries' human capital in the field of technology, which is a critical success factor for the transformation towards a factory of the future. The indicator includes individuals employed with ICT specialist skills as well as graduates in science and technology. The image illustrates, that Austrian and French companies can rely on a rather large pool of skilled human resources, while education in Italy has to be pushed forward, especially regarding technical studies.

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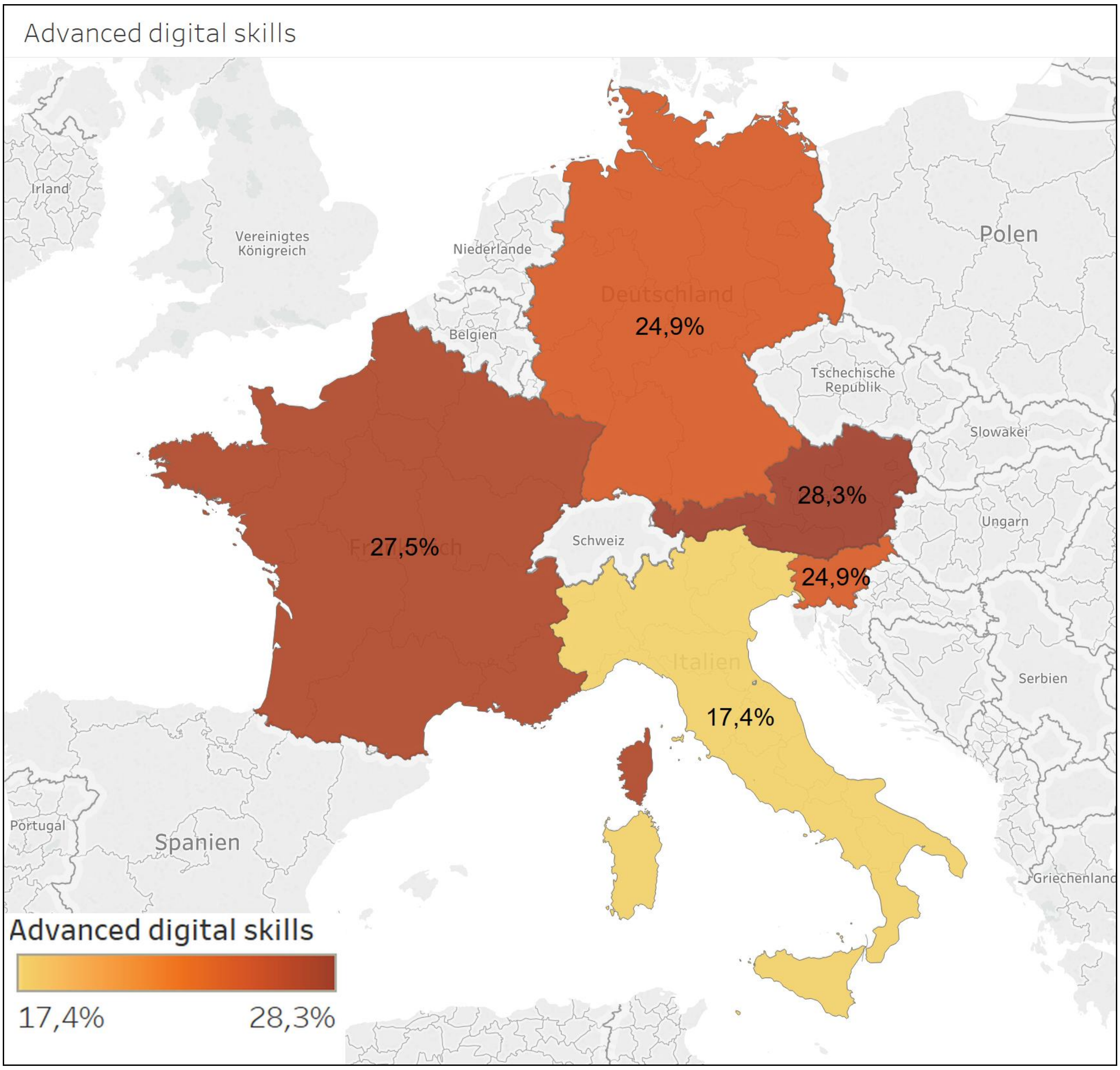

Figure 6 - Human capital – advanced digital skills

The presented indicators offer a good first impression of the environment SMEs are working in. While the indicators derive from a reliable source, one has to bear in mind that these measures only represent national averages, resulting in smaller significance, as local differences are not considered. Since the BIFOCAlps project focuses especially on alpine regions, it is necessary to refine the analysis on smaller areas, which is done in the following chapter 3.2.

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3.2 Impact Indicator System – Regional level

This chapter presents the critical success factor analysis on a geographically more detailed level, considering regions in the alpine space. The methodology as well as the elaboration of identified data corresponds to the analysis in chapter 3.1.

3.2.1 Methodology

The amount of publicly available data is greatly dependent on the size of the region, which lies in the centre of the analysis. The smaller the region, the less information is available on statistical databases. On the other hand, the size of the region also determines the accuracy of the analysis. To ensure a good balance between availability and accuracy of data, the analysis focuses on **NUTS – 2** regions, according to the geocode standard for referencing the subdivisions of countries for statistical purposes in the European Union. The exact alpine regions included in the analysis are listed in Table 4.

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Figure 7 - NUTS – 2 regions in the European Union[10]

[10] Cf. Wikipedia (10/2017), last checked on 30.01.2018

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Country	Region	NUTS - Code
Germany	Stuttgart	DE11
	Karlsruhe	DE12
	Freiburg	DE13
	Tübingen	DE14
	Oberbayern	DE21
	Niederbayern	DE22
	Oberpfalz	DE23
	Mittelfranken	DE25
	Schwaben	DE27
France	Champagne-Ardenne	FR21
	Bourgogne	FR26
	Lorraine	FR41
	Alsace	FR42
	Franche-Comté	FR43
	Rhône-Alpes	FR71
	Provence-Alpes-Côte d'Azur	FR82
Italy	Piemonte	ITC1
	Valle d'Aosta/Vallée d'Aoste	ITC2
	Lombardia	ITC4
	Provincia Autonoma di Bolzano/Bozen	ITH1
	Provincia Autonoma di Trento	ITH2
	Veneto	ITH3
	Friuli-Venezia Giulia	ITH4
Austria	Burgenland (AT)	AT11
	Niederösterreich	AT12
	Wien	AT13
	Kärnten	AT21
	Steiermark	AT22
	Oberösterreich	AT31
	Salzburg	AT32
	Tirol	AT33
	Vorarlberg	AT34
Slovenia	Vzhodna Slovenija	SI03
	Zahodna Slovenija	SI04

Table 4 - Selected NUTS – 2 regions

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3.2.2 Evaluation

Indicators

Table 5 and Table 6 show an extract from the complete list of identified indicators for Austrian regions. As stated in this list, specific measures are mostly available concerning the critical success factors *capacity for innovation*, *ecosystems support for innovation* and *skills and change management*. More precisely, the success factor *capacity for innovation* includes all indicators related to R&D in a regional economy as well as in enterprises. For the success factor *ecosystems support for innovation,* data was found regarding the funding provided for innovation projects in the enterprise sector. Finally, *skills and change management* includes information about the level of education and the fields of specialisation in a region.

Topic		Indicator	Description	Unit	Year
CSF: Capcity for Innovation	4.a	Employees in R&D in the enterprise sector	Total Number of Employees in R&D including internal R&D Employees and Employees in cooperative projects	Abs	2015
	4.b	Expenditure for R&D in the enterprise sector	Total Expenditure for R&D including Expenditures for internal and cooperative R&D projects	€	2015
	4.c	Estimated Number of Employees in R&D in SMEs	= 4.a * 1.h	Abs	2015
	4.d	Estimated Number of Employees in R&D per SME	= 4.c / 1.b	Abs	2015
	4.e	Estimated Expenditure for R&D in SMEs	= 4.b * 1.h	Abs	2015
	4.f	Estimated Expenditure for R&D per SME	= 4.e / 1.b	€	2016
CSF: Ecosystems Support for innovation	5.a	Total Fundings (grants, loans, liabilities) of Enterprises regarding Base-Programs	Base Programs include application-oriented individual projects as well as special instruments for SMEs	€	2012
	5.b	Total Fundings (grants, loans, liabilities) of Enterprises regarding Structure-Support for innovation	Structural support enables enterprises to build innovation networks, create new knowledge and expand core strength	€	2012
	5.c	Total Fundings (grants, loans, liabilities) of Enterprises regarding R&D-Activities	Escpecially adressing R&D-Activities in the technology policy	€	2012
	5.d	Total Fundings (grants, loans, liabilities)	= 5.a + 5.b + 5.c	€	2012
	5.e	Total Fundings related to total Number of enterprises	= 5.d / 1.d	€	-

Table 5 - List of regional CSF – indicators, part 1

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Topic		Indicator	Description	Unit	Year
CSF: Skills and change management	6.a	Coutry level of education - Natural sciences, Math and statistics	Number of population (age 25 - 64) with graduation in Natural sciences, Math and statistics according to ISCED-F 2013	Abs	2015
	6.b	Coutry level of education - Information - Communication Technologies	Number of population (age 25 - 64) with graduation in Information - Communication Technologies according to ISCED-F 2013	Abs	2015
	6.c	Coutry level of education - Engineering, manufacturing industry and construction	Number of population (age 25 - 64) with graduation in Engineering, manufacturing industry and construction according to ISCED-F 2013	Abs	2015
	6.d	Total number of Population with higher completed education	Number of population (age 25 - 64) with higher education according to ISCED-F 2013	Abs	2015
	6.e	Coutry level of education - Total	= 6.a + 6.b + 6.c	Abs	2015
	6.f	Coutry level of education - Total in relation to population	= 6.e / 6.d	%	2015

Table 6 - List of regional CSF – indicators, part 2

The missing critical success factors *strategy* and *technology* cover topics that are difficult to evaluate in quantitative terms as strategy alignment or technology integration have to be evaluated in detail for every company. For this reason, datasets available internationally are too limited and incomplete to be integrated in the analysis.

Results

The data analysis was performed for all regions stated in Table 4. However, not every indicator listed in Table 5 was identified for regions outside of Austria. In general, data available internationally mostly involves R&D-related topics as well as information concerning the level of education, as these measures are frequently used in country comparisons. Some results of the analysis are presented below in statistical maps. The datasets are taken from the Eurostat research and innovation statistics.[11]

Figure 8 shows the R&D intensity in alpine regions, defined as the gross domestic expenditure on R&D (GERD) relative to the gross domestic product (GDP). While the indicator does not differentiate between public or business related R&D-activities, it is easy recognisable, that regions in south Germany are generally more orientated towards innovation than regions in France or Italy.

[11] Cf. Eurostat (01/2017)

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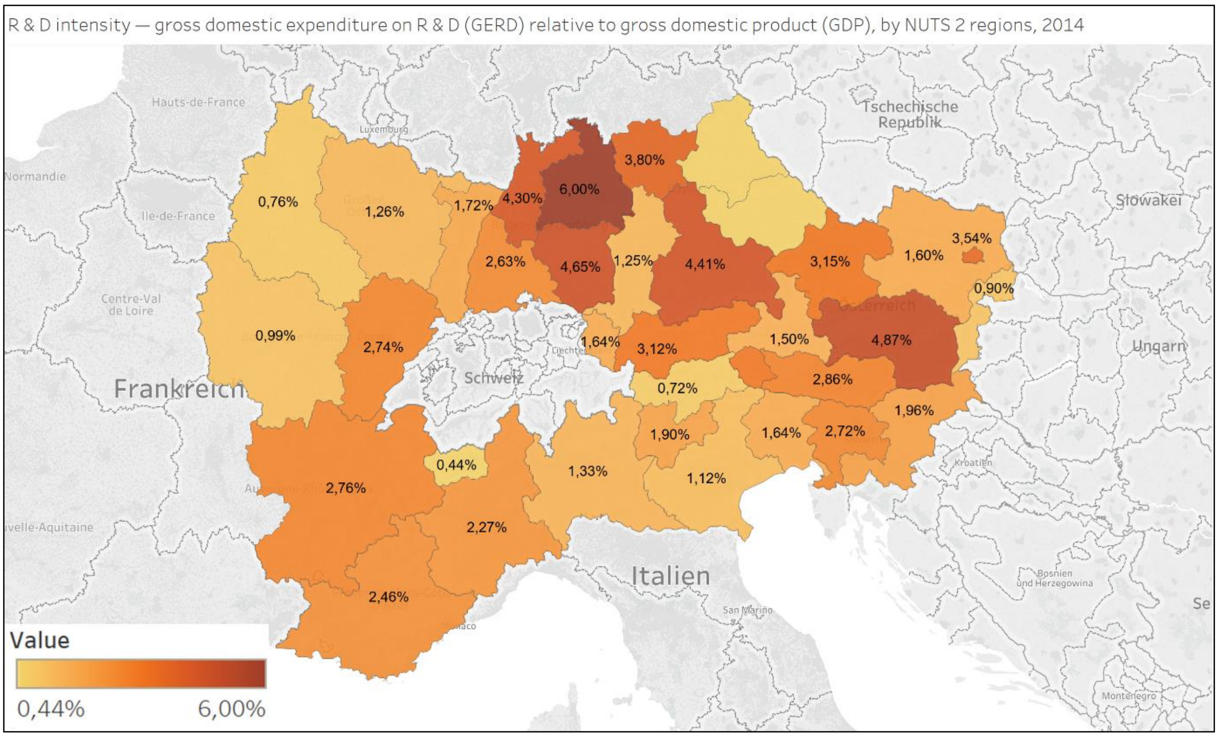

Figure 8 - R&D intensity, 2014

Figure 9 highlights the share of R&D researchers in the total number of persons employed in the year 2014. Again, one look at the map is enough to reveal the outstanding importance assigned to R&D in some regions. The image not only offers an international comparison, but also is useful to evaluate differences within economies. For example, the share of researches in the south of France is partly more than three times higher than in northern-eastern part of France.

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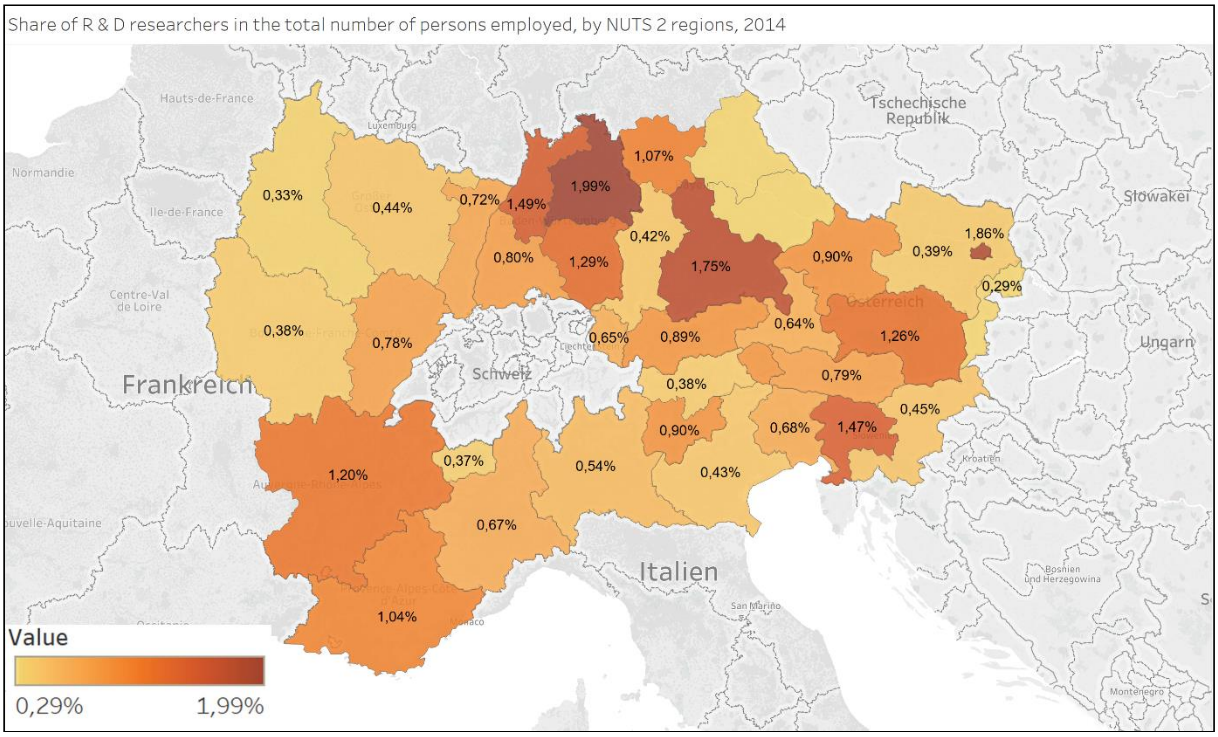

Figure 9 - Share of R&D researchers

The last image (Figure 10) addresses the critical success factor *skills and change management*. The figure shows the percentage of human resources in science and technology within the economically active population. This measure is particularly important to indicate the level of knowledge and the availability of skilled workers in alpine regions, which are critical for a successful transformation towards a factory of the future.

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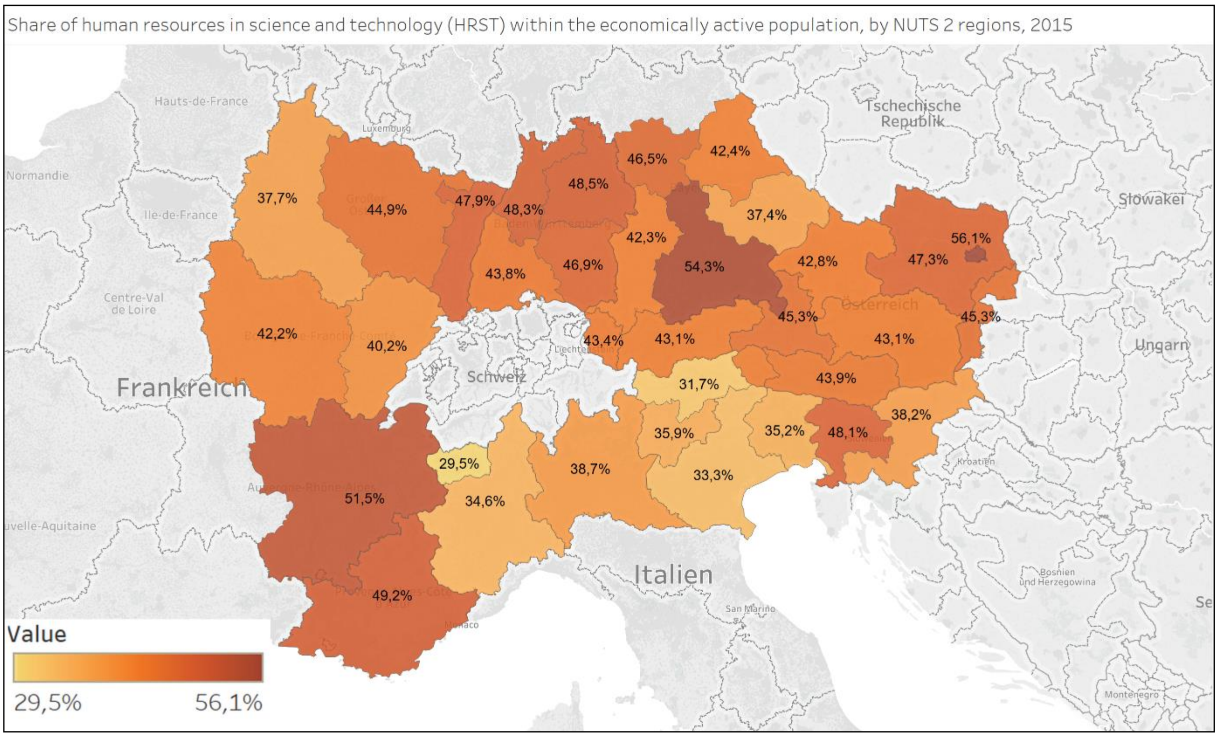

Figure 10 - Share of human resources in science and technology

Processing regional datasets to statistical maps offers a good method to highlight differences between regions visually. Concerning the degree to which regions in the alpine space comply with the identified critical success factors, it can be concluded that some regions offer a more favourable environment for enterprises in terms of workforce and innovation while other regions still need improvement. The analysis is constrained due to the low availability of standardized data across international regions.

3.3 Impact Indicator System - Company level

3.3.1 Methodology

The impact indicator system on company level is build according to the requirements defined in chapter 1. Due to similarities of the described IPOO-Model objectives to the specific objectives in this project, the IPOO-Model will serve as a framework for the development process of the impact indicator system. As foreseen by the creators, the IPOO-framework is applicable for various processes and activities where performance measurement is needed, which makes it an optimal starting point for the impact indicator system. According to the framework described in Chapter 2.3, as a first step, the model elements input, processing system, output and outcome have to be defined. In the following, specific indicators have to be assigned to each of these model elements. Corresponding to the IPOO-framework and the given BIFOCAlps-deliverables, the indicators are classified into a quantitative and a qualitative set of indicators.

3.3.2 Impact indicator system – model design

Process elements

1. **Input**

According to the description of the IPOO-framework in chapter 2.3, input indicators capture resources, which enter the innovation process. As such, these indicators should include tangible as well as intangible assets of a company such as employees, equipment, information, expertise or financial resources. Correspondingly, input indicators can be seen as an extensive range of requirements enterprises need to improve in order to be successful in their innovation activities. In context of BIFOCAlps, these requirements can perfectly be summarised by the list of critical success factors defined in WPT2. In particular, these critical success factors can be evaluated using the set of guidelines proposed for each success factor in WPT2.

2. **Process indicators**

The IPOO-framework has a clear focus on the innovation process and R&D-related activities. On the contrary, the impact indicator system takes a broader view, putting the focus on innovation, but also in competitiveness, new technologies, overall efficiency, etc. Accordingly, process indicators in the impact indicator system can be summarised under the term *Operations & Innovation.*

3. **Output indicators**

Output indicators are necessary to evaluate the results of the processing system. As innovation is a key element of the analysis, such measures can be represented by innovative results of an enterprise including new products, patents, applications, processes etc. Enterprises also profit from intangible outputs such as the increase in knowledge or synergy effects, which have to be evaluated by qualitative measures.

4. **Outcome indicators**

By investing and adopting FoF-technologies and practices, enterprises expect to extend their market position, to be more sustainable and to gain overall competitiveness. These goals are usually tracked by indicators such as cost reduction, increase in market share or revenue growth. Generally, outcome indicators need to be in line with the mission of an enterprise. Therefore, results are frequently also measured from a customer's perspective. The impact indicator system offers a set of relevant outcome indicators with a focus on FoF-goals, which then can be adjusted according to specific objectives of the companies.

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Set of measures

The IPOO-framework offers a perfect model for the impact indicator system regarding the process-based structure as well as the distinction between quantitative and qualitative indicators. What is missing for the purposes of the impact indicator system is the possibility to derive measures and list of actions in the model directly. Since all manufacturing enterprises differ from each other regarding the status of FoF-implementation, the objectives or the environment, business-critical goals that are generally valid cannot be defined. Similar to the balanced scorecard, one of the most known performance measurement systems, it is useful to link the selected indicators to company-specific long-term and short-term goals. Therefore, the IPOO-framework is extended by an additional category for the derivation of goals.

Quantitative vs. Qualitative indicators

According the IPOO-framework the impact-measurement of FoF technology and –practices adoption requires information about current status, investments, etc. of the respective company which are expressed through the input category in the framework. The current status regarding the path towards FoF can be evaluated using the set of critical success factors presented in chapter 2.2 in terms of a qualitative assessment of the company. As this paper focuses on the presentation of quantitative indicators, the assessment of qualitative input factors in the impact indicator system is presented in the deliverable D.T3.1.2.

Regarding the evaluation of the impact in the three categories process, output and outcome, especially quantitative measures are suitable. Quantitative performance measures regarding processes, products, costs, financials, etc. are widely available and already implemented in all divisions of enterprises. These measures are perfectly suitable for the evaluation of the progress as subjective answers are excluded from the analysis. Therefore, in contrast to the IPOO-framework, the impact indicator system does not define quantitative and qualitative indicators for every stage in the value creation. Instead, the distinction is made between these stages. While input indicators are expressed through a qualitative scoring model, the stages process, output and outcome cover a set of quantitative measure. The structure of the impact indicator system according to the stated specifications, is shown in Figure 11 below.

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Basic structure

Figure 11 shows the fundamental structure of the impact indicator system according to the specifications and the requirements defined above. In contrast to the IPOO-framework, relative indicators are not defined in a particular division, as they can be included in the list of quantitative and qualitative indicators directly. As evident from the figure, each critical success factor has its own list of indicators which together form the inputs undertaken in the path towards FoF. The following three columns processing system, outputs and outcomes then mainly aim at evaluating the impact of CSF-related investments and improvements on different levels. After the structure is built, the next step is to determine relevant indicators for each column of the model.

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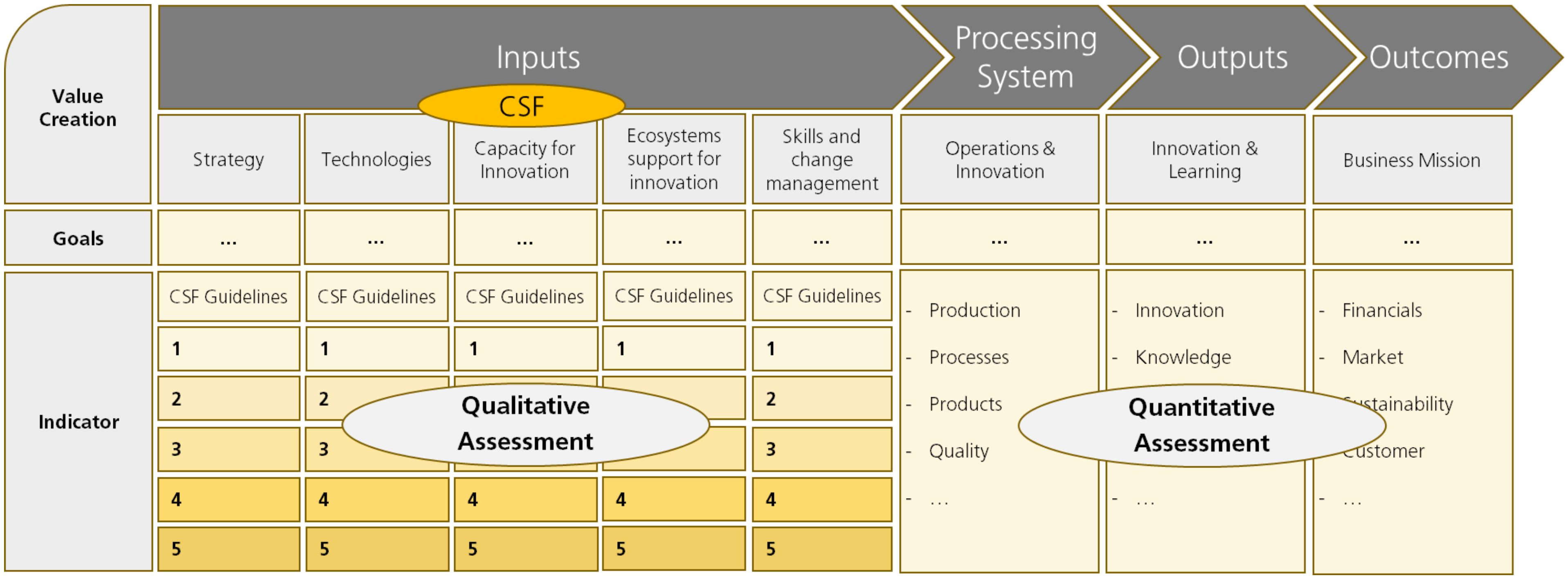

Figure 11 - Impact indicator system – structure

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3.3.3 Quantitative indicator selection

The definition of indicators for the impact indicator system in this paper follows a few guidelines, guaranteeing a useful output for enterprises. Firstly, it is important not to define too many indicators, as the impact indicator system should be clearly arranged and easily applicable. Simultaneously, the identified indicators should cover the respective circumstances as complete as possible. Therefore it is necessary not to focus on too many details, but to define generally valid indicators. Taking into consideration that indicators have to be assigned to three columns processing system, outputs and outcomes, between 6 and 10 measure should be reasonable in order to avoid a high degree of complexity in the application. Additionally, the information necessary for the calculation of the indicators has to be collectable without too much effort or costs. This requirement ensures that progress can be monitored on a regular basis, which further guarantees the applicability of the indicator system as a strategical management tool.

3.3.3.1 Processing system indicators

Area	Indicator	Description
Production planning	*Lead time*	Defined as the time it takes for a workpiece to complete a process or a value stream. By improving lead times, it is possible to increase punctuality, flexibility and thus customer satisfaction.[12]
	Degree of automation	Defined as the proportion of automated functions to overall functions in a production system[13] The indicator directly indicates the development towards FoF.
	Employee productivity	Defined as the total value added in relation to the number of employees.[14] In combination with a before and after-comparison, the impact of FoF-practices adoption on productivity can be evaluated.
	Space productivity	Defined as the price-adjusted turnover in relation to the production area[15] The indicator tracks improvements in use of the available space, especially addressing process innovations.

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[12] Cf. Rother and Shook (Oktober 2015, 19)
[13] Cf. Voigt (05.02.2018)
[14] Cf. Havighorst (2006, 20)
[15] Cf. Dangelmaier (1999, 331)

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	Order fulfilment cycle time	Refers to the average time required to fulfil a customer order. The indicator measures the time between ordering and delivery.[16]
	Relative process time reduction	Defined as the achieved process time reduction relating to the previous process time.[17] This indicator directly shows the impact of process innovations and FoF-technology adoption on the manufacturing process.
Process quality	*OEE*	The overall equipment effectiveness is a measure to evaluate how effectively a manufacturing operation is utilized.[18]
	Rejection rate	The rejection rate measures the percentage of rejected products per period during quality control.[19]
	Delay time	Defined as the share of delayed production hours to total production hours.[20]
R&D	*Time to market*	Defined as the average time required in the product development process from the product idea to the finished product.[21] This measure indicates the innovation capacity and efficiency of the R&D department.
	Go rate	The Go rate calculates the share of successfully realized innovations to the total amount of innovation proposal.[22] The measure is useful to quantify the quality of strategic portfolio management, as well as the quality of the ideas submitted.

Table 7 - Proposal of indicators for the processing system

Table 7 lists a set of suitable key performance indicators to measure the impact of FoF-technology and practices adoption on the processing system of an enterprise. As stated in the previous chapter, the processing system covers operational activities as well as processes in the R&D department. To evaluate the performance of operational activities and production processes, a wide range of indicators are applicable. Frequently used measures include those related to efficiency and productivity, to the quality as well as indicators measuring the time between the beginning and the end of a process. The indicator *Time to market* is particularly convenient to evaluate the performance capability of the R&D department.As evident from the list of indicators, these measures especially address and evaluate advances regarding the critical success factors *Technology* and *Capacity for innovation.* FoF-technology investments primarily affect production processes in a manufacturing enterprise. To evaluate the impact of

[16] Cf. Supply Chain Council (2012)
[17] Cf. Gleich and Schimank (2011, 100)
[18] Cf. Erlach (2010, 67)
[19] Cf. Ossola-Haring (2009)
[20] Cf. Werner (2014)
[21] Cf. Ossola-Haring (2009, 149)
[22] Cf. Gleich and Schimank (2011, 96)

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these investments it is reasonable to apply the indicators stated in Table 7 in combination with before- and after comparisons.

3.3.3.2 Output indicators

Area	Indicator	Description
Innovation	*Patents per employee*	Defined as the number of patent applications per employee.[23] This indicator states the innovative activity of a firm.
	Innovation proposals per employee	Defined as the average number of product- and process innovation proposals per employee.[24] As patents are often attributed to the R&D department, this measure is more suitable to evaluate the usage of the creative potential of all employees.
	R&D – cost to revenue ratio	Defined as the Revenue from innovations in relation to the R&D-expenses for these innovations.[25]
	New product rate	Sales from products developed during the last 5 years in relation to total revenue. This measure determines, how fast a company can respond to customer requests.[26]
Employees	*Qualification structure*	Is defined as the percentage of employees meeting a certain qualification.[27] For example regarding FoF, the measure can be used to determine the share of employees having ICT-skills.
	Fluctuation of qualified employees	Defined as the share of terminations of employees with a specific qualification to the total number of qualified employees. This measure assesses the ability of a firm to hold its employees.
	Commitment Index	The commitment index evaluates the share of the workforce that feels prepared for transformation,[28] such as the digital change. It is particularly suitable to evaluate the success of the communication efforts undertaken by the firm.
Knowledge transfer	*Knowledge transfer from organization to employees*	Defined as the time to adjust a (new) employee to the given processes within the company. The time decreases as the necessary knowledge is available easier.[29]

[23] Cf. Reichert (2013, 98)
[24] Cf. Gleich and Schimank (2011, 95)
[25] Cf. Werner (2002, 120)
[26] Cf. Albach (2001, 339)
[27] Cf. Ossola-Haring (2009, 489)
[28] Cf. Personalmanagementwissen Online (06.02.2018)
[29] Cf. Resatsch and Faisst (20)

	External knowledge spillover	Defined as the time required for corporation to match the newest product of the competitor divided by the time required for competitor to match firm's newest product benefits. This indicates the ability of the corporation to maintain a leadership position or to match technology moves by the competition.[30]
	Knowledge transfer from organization to projects	Defined as the ration between actual reuse content compared to opportunities. This measure indicates how well an organization manages to apply available knowledge in different projects.[31]

Table 8 - Proposal of output - indicators

Table 8 lists indicators to evaluate to output and the results of input investments in combination with the processing system. These results can represent tangible outputs like new products, patents, applications, processes as well as intangible outputs such as the increase in knowledge or the availability or skilled workers. Regarding employees, the qualification structure is a suitable indicator to evaluate if necessary skills are available in the organization. The qualification structure for the FoF-transformation can be influenced directly by focused staff recruitment or through development of the existing workforce. These activities directly fall within the critical success factor *Skills and change management.* Besides recruiting qualified personnel, a company has to be able to hold its employees over a long term by offering a good working environment. The indicator *Fluctuation of qualified employees* is suitable to measure this ability. Concerning the category *Knowledge transfer*, Table 8 suggests a set of indicators which measure the ability of a company to gain and utilize new knowledge. As knowledge itself is difficult to evaluate in quantitative terms, the time required to apply this knowledge offers a good starting point for the analysis. Indicators in this category can be applied to analyse the impact of improvements regarding the critical success factors *Ecosystems support for innovation* and *Capacity for innovation.*

[30] Cf. Resatsch and Faisst (21)
[31] Cf. Resatsch and Faisst (20)

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3.3.3.3 Outcome indicators

Area	Indicator	Description
Customer	*Customer satisfaction*	The percentage of customers satisfied with the company, its products and services. This indicator shows how far a company is able to fulfil the expressed and implied expectations of customers.[32]
	Share of new customers	Defined as the share of new customers in a time period to all customers.[33] New customers indicate the success of new products or the marketing strategy of a company.
	Customer retention period	Defined as the average time span of a business relationship or a customer-supplier relationship in a customer segment. A longer relationship reduces customer acquisition costs along with falling communication costs.[34]
Financials	*EBIT*	Show the operative earning capacity of a firm, independent of its capital structure and income tax burden.[35]
	ROI	The return on investment provides insight on how well a company has used invested assets to generate earnings.[36] The indicator is especially interesting in relation with FoF-investments.
	Innovation share in turnover	Defined as the revenue from innovations relating to the total revenue in the observation period.[37] This measure states the economic success of a company's innovation activity. The indicator can also be applied to evaluate digital businesses.
Market measures	*Market Share*	Defined as the share of a company's sales at the total sales of all suppliers on a market.[38]
	Distribution coverage level	Defined as the density of market presence in a given product or brand within a given market are.[39] The indicator can further be evaluated in combination with an innovative product to assess the market success of the innovation.
Sustainability	*Resource consumption efficiency level*	This measure evaluates the period relevant or volume driven usage of particular resources in a firm referred to the previous period.[40] This measure is suitable to track the direct impact of a FoF-technology investment on the sustainability of a firm.

[32] Cf. Krause and Arora (2010, 143)
[33] Cf. Schneider and Hennig (2008, 252)
[34] Cf. Krause and Arora (2010, 137)
[35] Cf. Krause and Arora (2010, 16)
[36] Cf. Krause and Arora (2010, xlv)
[37] Cf. Gleich and Schimank (2011, 92)
[38] Cf. Wübbenhorst and Mecke (05.02.2018)
[39] Cf. Krause and Arora (2010, 182)
[40] Cf. Krause and Arora (2010, 265)

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	Emission volume of production-related pollutants	This indicator measures the volume of pollutants released in the environment per period or per unit of output. This measure is suitable to evaluate the application of the sustainability principle at firm level.[41]

Table 9 - Proposal of outcome indicators

Table 9 proposes a set of indicators that can be applied to measure long term achievement trough FoF-technology and practices adoption. The indicators are in line with typical goals and missions of manufacturing enterprises, including customer results, financial accomplishments, market objectives and sustainable development. A series of indicators can be used to evaluate the impact and success of innovative activities at company level. For example, the success of a new product introduction is reflected through new customers, increased revenue or through a higher market share. As defined in the previous chapter, outcome related indicators are suitable to track the overall achievements following FoF-investments. As such, the measures in Table 9 also indicate if the defined strategy has been rewarded.

3.3.4 Application of the impact indicator system

When used correctly, the impact indicator system offers a practical reference system to pave the way towards the factory of the future. By linking strategical inputs to outputs and outcomes, the indicator system creates a clear "line of sight" to desired results, which further helps to improve strategic and daily decision making. In combination with guidelines and success factors defined in WPT2 the impact indicator system additionally offers the possibility for a company to identify performance improvement opportunities that span traditional organizational structures and boundaries. In order to be effective, the indicator system has to be aligned to objectives and specific structures of the respective enterprises. This applies in particular to the selection of quantitative indicators to measure the impact of FoF-technology and practices adoption. Chapter 3.3.3 offers a set of easy understandable, informative and frequently used indicators that can help to evaluate the impact on three different levels. These indicators only represent a proposal which can be adjusted and/or modified any time according to company specific preferences. For example if a company wishes to increase the customer focus by reshaping their processes towards more flexible systems, the list of measures can be expanded by more relevant, customer-orientated indicators.

[41] Cf. Krause and Arora (2010, 273f.)

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4 CONCLUSIONS

This deliverable presents the results of activity A.T3.1, providing a reference system to track effective improvements after transfer and adoption of enabling FoF practices in manufacturing enterprises. Besides providing an indicator system on company level, this paper also aims at comparing alpine regions regarding structural requirements and environments enabling the path towards FoF, which are represented by the set of critical success factors defined in WPT2. The analysis was performed through publically available statistics following an extensive literature research covering national and regional databases. During the analysis it was found that many indicators selected for Austrian regions were not available in other alpine countries, resulting in an incomplete comparison. In order to derive measures of action on a political level, better data is necessary concerning the critical success factors.

The impact indicator system addressing firms directly, includes the methodology developed in the previous working package WPT2. The methodology is further tested and validated in the ongoing activities and workshops.

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