Analysis and Assessment of Bottom-Up Models Developed in Central Europe for Enhancing Open Innovation and Technology Transfer in Advanced Manufacturing

Maria Rosienkiewicz, Joanna Helman, Mariusz Cholewa, Mateusz Molasy, and Grit Krause-Juettler

Abstract In this paper, new phenomena and models supporting innovativeness of manufacturing companies are discussed. Quadruple helix innovation model and a sharing economy concept are presented. A role of innovation as a crucial factor of sustainable manufacturing is addressed. The main aim of the paper is to analyse and assess selected bottom-up models and approaches developed for enhancing open innovation and technology transfer in industrial companies in Central Europe. Research methodology is composed of an analysis of the models which have been developed within three international projects co-funded from the Interreg Central Europe programme, namely SYNERGY, TRANS^{3}Net and NUCLEI. Five IT tools are presented and investigated. Moreover, activities supporting their implementation process are indicated to underline the new, innovative and holistic approach of creating an effective cooperation environment, with particular emphasis on the area of advanced manufacturing.

1 Introduction

According to the latest European innovation scoreboard, the EU's average innovation performance has improved [1]. Although for the first time the EU's performance has surpassed the USA, yet still China, Canada, Australia and Japan maintain a performance lead over the EU. In order to improve the innovation performance, the European countries should pay special attention to open innovation (OI)—one of the most important components of the European innovation system, "where all stakeholders need to be involved and create seamless interaction and mash-up for

M. Rosienkiewicz (✉) · J. Helman · M. Cholewa · M. Molasy
Department of Laser Technologies, Automation and Production Organization, Wrocław University of Science and Technology, Wyspiańskiego 27, 50-370 Wrocław, Poland
e-mail: maria.rosienkiewicz@pwr.edu.pl

G. Krause-Juettler
CIMTT Centre for Production Engineering and Management, Faculty of Mechanical Engineering, Technische Universität Dresden, 01062 Dresden, Germany

S. G. Scholz et al. (eds.), *Sustainable Design and Manufacturing 2020*, Smart Innovation, Systems and Technologies 200, https://doi.org/10.1007/978-981-15-8131-1_11

ideas in innovation ecosystems" [2]. A good example of companies strongly relying on external innovation is Google, Apple or Amazon— "according to BCG's, Most Innovative Companies 2019 Report, 75% of the top 50 most innovative companies use incubators, 81 per cent leverage academic partnerships, while 83 per cent partner with other companies" [3].

Experiences gained from a number of research and industrial projects carried out in Central Europe (CE) lead to a conclusion that support for innovation is still rather limited in the scope, transnational cooperation is relatively poor, and there are still many barriers hindering industrial companies (especially SMEs) from cooperating with universities and research organizations [4–6]. The traditional, "local-based", approach to innovation development and technology transfer does not support efficiently companies operating in advanced manufacturing (AM) sector. Therefore, to overcome the innovation barriers in CE regions, where AM is a strong branch of economy, it is particularly important to support industrial companies with providing the "innovation-friendly ecosystem" based on OI paradigm [7]. Development and implementation of models, tools and methods enhancing OI in advanced manufacturing is especially crucial, due to the reason that such solutions are—so far—rather limited and only fledging in Central European industrial companies. The flagship industrial examples of products developed on the OI basis include Zortrax M200—professional desktop 3D printer [8], Olli—the smart, safe and sustainable vehicle [9] or LM3D—the first highway-ready, 3D-printed car [10].

2 Literature Review on Open Innovation Phenomena in Terms of Advanced Manufacturing

One of the major challenges in modern manufacturing is the implementation of sustainable and at the same time innovative manufacturing systems [11]. According to Dassisti et al., one of the crucial goals of sustainable manufacturing (SM) is the development of innovative manufacturing processes and systems [12]. Zindani et al. indicate "three pillars that define the term sustainability: social directions, economic factors and environmental concerns" [8]. As Rauter et al. underline "innovation plays a crucial role by fostering a greater level of sustainability in company activities" [13]. "Many studies highlight the importance of innovation for sustainability as well as the goals of sustainable development" [14]. Hence, as social directions and innovation are of great importance for SM, it can be stated that, although in the literature countless ways and models for innovation development can be found, currently, in the era of Industry 4.0, it seems that the most adequate solutions supporting innovativeness of manufacturing companies are those based on OI and Open Innovation 2.0 (OI 2.0). OI can be defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively" [15], whereas according to publications of European Commission, OI2.0 is "a new paradigm based on a quadruple helix model where government,

industry, academia and civil participants work together to co-create the future and drive structural changes far beyond the scope of what any one organization or person could do alone. This model encompasses also user-oriented innovation models to take full advantage of ideas' cross-fertilization leading to experimentation and prototyping in real-world setting" [2].

Business models which are based on open innovation paradigm are still shaping, and hence, there is a requirement to perform research towards building a dedicated environment, where companies could fully benefit from the new phenomena, tools and methods based on i.a. sharing economy, crowdsourcing, crowdfunding and micro-working. This approach is also consistent with the concept of the regional innovation system, in which the innovation process is considered as a social phenomenon involving various regional actors [4]. It is based on the assumption that there is a subsystem generating the knowledge (science) as well as a subsystem exploiting the knowledge economically (economy) in order to contribute to the competitiveness of a whole region [16–19]. Important factor from the innovativeness point of view is also internationalization, due to the reason that combining different national competencies leads to release of innovation capabilities [20]. What is more, as Ahuja et al. underline, a very important element of sustainable and innovative manufacturing is human factor [21], which directly corresponds to the quadruple helix innovation model [22]. Therefore, it is expected that involving representatives of society in the manufacturing processes and facilitating them bottom-up activities will lead to enhancement of innovativeness of industrial companies. These activities may be for instance social product development [23, 24] or micro-working, which is a new form of working beyond organizational boundaries, created mostly by social media technologies, in which engagement in work is posted by organizations or individuals on a web-based and third-party platform in exchange for monetary remuneration [9, 25].

Last but not least, aspect related to open innovation environment creation is a concept of sharing economy [26], which has become widespread globally as an innovative service business model [27]. It can be defined as the "acquisition or distribution of a source coordinated by people for compensation or a certain fee" [28] or as "an umbrella term that describes an emerging consumption trend: online peer-to-peer economic activities for sharing among consumers through intermediary service firms" [27]. From an advanced manufacturing point of view, this business model is interesting not only in terms of competences and skills sharing, but especially in terms of industrial research infrastructure sharing because it may result i.a. in lowering the costs of infrastructure usage, increasing turnover, thanks to easier investment decision and testing advanced technologies without necessity to buy them first. The literature analysis and research performed within a number of European projects lead to a conclusion that creating a real living open innovation environment and supporting technology transfer in advanced manufacturing need bottom-up initiatives and activities.

3 Research Methodology

The main aim of this paper is to present, analyse and asses selected bottom-up models and approaches developed for enhancing open innovation and technology transfer in advanced manufacturing in Central Europe. In order to reach the defined goal, a research methodology has been developed and schematically presented in Fig. 1. Following the presented methodology, the research discussed in this paper is focused on analysis of three Central European projects dealing with technology transfer enhancement and support of OI environment development. According to Fig. 1, the three investigated projects will be introduced—namely SYNERGY, TRANS^{3}Net and NUCLEI (all co-funded from Interreg Central European programme).

Next, the models developed within each project and their implementation in the form of tools will be presented. Afterwards, an analysis of the tools will be performed, followed by the analysis of the event formats developed in each project. Finally, the conclusion will be formulated on the basis of the executed comparison. Each of the abovementioned projects was established as a bottom-up initiative of Central European consortium partners. In total, the analysis covers 12 regions from 8 countries. A list of countries and regions involved in each analysed project is presented in Table 1.

The first investigated project will be SYNERGY (08.2017–10.2020), which stands for "synergic networking for innovativeness enhancement of Central European actors focused on high-tech industry". SYNERGY's main goal is to enhance innovativeness in European regions through strengthening linkages and beyond border cooperation to create synergy between SMEs, industry, research, intermediaries and policy-makers. The project scope is mainly oriented on advanced manufacturing with a special focus on the most promising modern industrial technologies. SYNERGY follows the quadruple helix innovation model [22], due to the fact that project partners represent not only entities based on triple helix innovation model—4 higher education and research institutions, 1 SME, 2 business support organizations and government as an associated partner, but also the project aims at direct involvement of the society through implementation of crowdsourcing, crowd funding and micro-working tools and pilot actions [7].

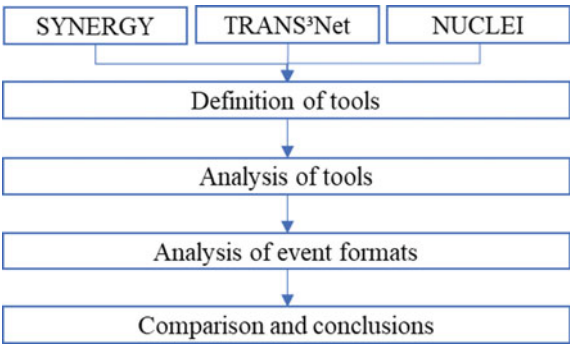

Fig. 1 Scheme presenting research methodology

Table 1 Countries and regions involved in each analysed project

No.	Country	Region	SYNERGY	TRANS^{3}Net	NUCLEI
1	Austria	Upper Austria	X		X
2	Croatia	Adriatic Croatia	X		
3	Czech Republic	Prague			X
4		Usti Region		X	
5	Germany	Baden Württemberg	X		X
6		Bavaria			X
7		Saxony	X	X	
8	Italy	Emilia Romagna	X		X
9		Veneto			X
10	Poland	Lower Silesia	X	X	X
11	Slovakia	Košice Region			X
12	Slovenia	Western Slovenia	X		

The second analysed project will be TRANS^{3}Net (07.2016–09.2019)—"Increased effectiveness of transnational knowledge and technology transfer through a trilateral cooperation network of transfer promotors". Its main objective was to shape conditions for building up a well-working innovation system in tri-national regions of border area between Germany, Czech Republic and Poland which is characterized by a low level of transnational cooperation between science and industry. TRANS^{3}Net aimed at establishing strong ties and a self-sustaining cooperation between all key players relevant for knowledge and technology transfer and development of solutions overcoming the multifaceted obstacles concerning transnational cooperation [29].

NUCLEI (07.2016–06.2019) stands for "network of technology transfer nodes for enhanced open innovation in the Central European advanced manufacturing and processing industry". The main aim of the NUCLEI project was to establish a transnational innovation management model in Central European regions and to create a transnational pool of knowledge that supports advanced manufacturing innovation beyond regional borders. Moreover, NUCLEI's purpose was to assess the "distance-to-target" between the actual needs and technological interests of advanced manufacturing industrial companies and the technology transfer services currently provided by the selected excellence nodes concerned in the project [5, 30].

4 Analysis of Models

As presented in the research methodology scheme, after short introduction of SYNERGY, TRANS^{3}Net and NUCLEI, the models developed within each project and their implementation in the form of tools will be discussed. Each model has been

Table 2 Table captions should be placed above the tables

Project	Tool	Technological area
SYNERGY	SCIP—synergic crowd innovation platform	Additive manufacturing, micro- and nanotechnology, Industry 4.0
TRANS^{3}Net	Map of transfer promotors innovation web portal	Not defined
NUCLEI	Transnational web-ATLAS technology digital periscope	Automotive, automation and robotics electronics, mechatronics, ICT

developed to support technology transfer and open innovation in advanced manufacturing in a little bit different way. Within SYNERGY project, the main tool that has been developed is synergic crowd innovation platform (SCIP). It is combined with the matchmaking tool, which enables the user to search, profile, cluster and reach innovation-oriented organizations based on their activities and experience gained from successful project realizations in order to enhance networking and linking regional actors from research, industry and intermediaries. SYNERGY's approach is based on open innovation rules and especially, the quadruple helix innovation model. TRANS^{3}Net is focusing mainly on enhancing knowledge and technology transfer in cross-border regions through direct linking "transfer promotors". The implementation of this approach was done i.a. through development of two IT tools, namely (1) map of transfer promotors and (2) innovation web portal. NUCLEI on the other hand, aiming at changing the traditional innovation management services for Central Europe advanced manufacturing industries from a "local-based" support approach to a transnational pool of knowledge supporting innovation in businesses beyond own regional borders [5], developed two supporting tools—(1) transnational web-ATLAS and (2) technology digital periscope. Table 2 presents technological areas assigned to each project.

Developed within SYNERGY project SCIP (http://synergyplatform.pwr.edu.pl) is a platform ensuring crowdfunding and crowdsourcing for innovative solutions for the Central European society. The platform is also implementing micro-working, which is an approach where community solves smaller tasks which are then reassembled into an overall result at the end. The SCIP enables its users to take part in a number of pilot actions including: "Simulated crowd funding", "Vouchers for research and innovation projects", "Rent-a-robot", "Crowd innovation for companies", "Design and prototype a model"—presenting a social product development approach. What is more, the tool contains the database of the high-tech infrastructure located in Central European regions and offers a possibility of infrastructure sharing through matchmaking the owners with those looking for the easy access to the advanced technologies.

Developed within TRANS^{3}Net project, the map of transfer promotors (http://map.trans3net.eu) is an online tool including descriptions of transfer-promoting institutions that support science and industry in the implementation of collaborative research projects and in transferring knowledge and technology. It provides an overview about which of these actors are available in a geographical area and what they can contribute

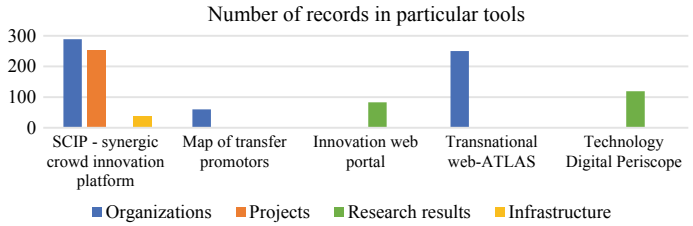

Fig. 2 Number of records in particular tools

to such collaboration processes [31]. The second tool, the innovation web platform, includes the so-called technology profiles that describe available research results in a short, understandable and application-oriented way targeting mainly SMEs. Technology profiles serve as starting points for collaboration between science and industry [32].

Transnational web-ATLAS developed within NUCLEI project is a map that consists of the selected research institutions, small, medium, large enterprises and intermediaries. All entities are displayed with a pin on the map of Europe. The project has decided to colour code the pins according to the business field and to the technology field, respectively. The first map shows an overview of the entities, and the different colours mark the five technologies field addressed by NUCLEI. The tool has been created on the basis of pool of excellence. The second NUCLEI solution is technology digital periscope, being a "tool to support and speed-up the access to the existing state-of-the-art R&D results and products by their systematization and exportability. Results included in the periscope are from the field of advanced manufacturing and processing industry. Results cover highly important key enable technologies (KET) such as robots, production processes, ICT, electronics, modelling and visualization" [33]. If analyse all types of information which have been collected and then introduced to the abovementioned tools, they can be grouped into four main categories: organizations, projects, research results and infrastructure. Current records registered in the discussed tools are presented in Fig. 2.

Analysis of Fig. 2 shows that the biggest number of records can be found in the SYNERGY's tool—579 (289 organizations, 253 projects and 37 infrastructures). Second score refers to organizations which can be found in NUCLEI's web-ATLAS (250). TRANS^{3}Net project has identified 83, while NUCLEI 119 ready to commercialize research results. It needs to be clearly underlined however that all the abovementioned tools need users (critical mass) to be successful. As number of different platforms in Central Europe and worldwide is increasing rapidly, meta platforms creation should be considered. It would be much easier for a company if the knowledge and information which is so far dispersed in many sources could be approached from one meta platform. Nevertheless, bottom-up approach represented in all three projects shows that different types of organization see a common problem of hidden information locally and define a need of sharing this knowledge transnationally through online channels. Thus, particular networks of partners and their stakeholders

Table 3 Number of participants in particular events

Event type	Number of events	Number of participants	Average
Design thinking idea meeting	7	132	19
Simulated sharing networking workshop	7	123	18
Open seminar	21	727	35
Transnational working table	10	342	34
TRANS^{3}Net.visit	6	168	28
TRANS^{3}Net.show	2	119	60
TRANS^{3}Net.training	2	53	27
TRANS^{3}Net.dialogue	2	49	25

start to become more open to international collaboration. It is especially important in advanced manufacturing sector which is quite specific and by definition rather reluctant to openness. All three discussed projects followed a holistic approach of creating an effective and innovative cooperation environment, therefore not only tools have been developed, but also dedicated event formats. Hence, another bottom-up approach investigated in this research is different event prototypes which were designed, developed and tested within the presented projects. Their role was i.a. to support efficient implementation of the abovementioned tools. Apart from other types of events, SYNERGY project developed and tested design thinking idea meetings and simulated sharing networking workshops, TRANS^{3}Net project designed and implemented—TRANS^{3}Net.visit, TRANS^{3}Net.show, TRANS^{3}Net.training and TRANS^{3}Net.dialogue, whereas NUCLEI project proposed and validated–Open Seminars and Transnational Working Tables. Table 3 presents statistics of the particular events.

In total, within these events, the presented projects reached 1713 participants representing different target groups—i.a. SMEs, large companies, regional and national authorities, business support organizations (BSO) and higher education and research institutions. It can be stated that such initiatives are required to create living and working linkages of actors operating in advanced manufacturing in Central Europe. Especially, BSO and research organizations should be the responsible for creating trustworthy environment where together with companies' innovations can be developed and technology efficiently transferred.

5 Conclusions

The main conclusion from the presented research is that different types of organizations see the common need to share the information about their resources, competences and experience transnationally. To answer this requirement, a number of tools and events have been created and validated within Central European projects. Next

step should be an integration of this knowledge to make it easily available from one source for all potentially interested actors. What also needs to be underlined is that "cross-cultural understanding is the key to open innovation in an increasingly international setting" [3]. Participation of Central European entities in international or transnational networks can significantly enhance their level of innovativeness. It is expected that the tools and events presented in this paper will contribute to development of OI environment, technology transfer and support of sustainable manufacturing in Europe by:

- closing the knowledge gap: due to a lack of both financial and human resources, the target groups (mainly SMEs) are struggling to track developments in advanced manufacturing,
- promoting of new technologies and integration in new value chain,
- supporting companies in becoming factories of the future by providing the necessary tools for responding to changing conditions and business model levels,
- sharing knowledge, resources and exchanging experiences as an important basis for mutual learning, networking and efficient cooperation.

Acknowledgement The research leading to these results has received funding from Interreg Central Europe programme priority innovation and knowledge development under grant agreement No. CE258 for TRANS^{3}Net and No. CE1171, project SYNERGY as well as from funds for science of Polish Ministry of Science and Higher Education for the implementation of an international co-financed project.

References

1. Hollanders, H., Es-Sadki, N., Merkelbach, I.: European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs: European Innovation Scoreboard 2019. https://ec.europa.eu/docsroom/documents/38781/attachments/1/translations/en/renditions/native (2019)
2. http://ec.europa.eu/digital-single-market/en/open-innovation-20 Last Accessed 26 Feb 2020
3. www.asianscientist.com/2020/01/features/ipi-techinnovation-secrecy-synergy-open-innovation/. Last Accessed 26 Feb 2020
4. Krause-Juettler, G.: Promoting cross-border cooperation between science and small businesses as a source of innovation. In: Intelligent Systems in Production Engineering and Maintenance. pp. 118–127. Springer International Publishing, Cham (2019)
5. www.interreg-central.eu/Content.Node/NUCLEI-Handbook-2.pdf. Last Accessed 27 Feb 2020
6. Cholewa, M., Helman, J., Molasy, M., Rosienkiewicz, M.: Identification of Challenges to be Overcome in the Process of Enhancing Innovativeness Based on Implementation of Central European Projects Funded from Interreg Programme. In: Intelligent Systems in Production Engineering and Maintenance. pp. 185–194. Springer International Publishing, Cham (2019)
7. Rosienkiewicz, M., Helman, J., Cholewa, M., Molasy, M.: SYNERGY Project: Open Innovation Platform for Advanced Manufacturing in Central Europe. In: Intelligent Systems in Production Engineering and Maintenance. pp. 306–315. Springer International Publishing, Cham (2019)

8. www.kickstarter.com/projects/zortrax/zortrax-m200-professional-desktop-3d-printer. Last Accessed 04 Mar 2020
9. www.localmotors.com/meet-olli/. Last Accessed 04 Mar 2020
10. www.forbes.com/sites/tjmccue/2015/11/13/worlds-first-3d-printed-road-ready-car-lm3d-by-local-motors/#21a5333b2aa0. Last Accessed 04 Mar 2020
11. Zindani, D., Kumar, K., Davim, J.P.: Sustainability Manufacturing Systems Design. In: Encyclopedia of Renewable and Sustainable Materials. pp. 512–518. Elsevier (2020)
12. Dassisti, M., Chiarello, F., Fantoni, G., Priarone, P.C., Ingarao, G., Campana, G., Matta, A., Cimatti, B., Colledani, M., Frigerio, N., Forcellese, A., Simoncini, M.: Benchmarking the sustainable manufacturing paradigm via automatic analysis and clustering of scientific literature: A perspective from Italian technologists. Procedia Manuf. **33**, 153–159 (2019)
13. Rauter, R., Perl-Vorbach, E., Baumgartner, R.J.: Sustainable Open Innovation and its influence on economic and sustainability innovation performance. Presented at the The XXVI ISPIM Conference —Shaping the Frontiers of Innovation. Budapest (2015)
14. Kuzma, E., Padilha, L.S., Sehnem, S., Julkovski, D.J., Roman, D.J.: The relationship between innovation and sustainability: A meta-analytic study. J. Cleaner Prod (2020)
15. Chesbrough, H.W.: Open innovation: the new imperative for creating and profiting from technology. Harvard Business School Press, Boston, Mass (2003)
16. Krause-Juettler, Grit: Cross-border Collaborations between Science and SMEs: Empirical Findings and Strategic Considerations Illustrated by the Example of the Saxon-Czech Border Region, in: UIIN (ed.), University-Industry Interaction: Chal-lenges and solutions for fostering entrepreneurial universities and col-laborative innovation, 6–15, (2017)
17. Cooke, P.: Regional innovation systems—an evolutionary approach. In: Regional innovation systems, pp. 1–18. Routledge, London (2004)
18. Cooke, P.: Regional innovation systems: competitive regulation in the new Europe. Geoforum **23**, 365–382 (1992)
19. Doloreux, D., Parto, S.: Regional innovation systems: current discourse and unresolved issues. Technol. Soc. **27**, 133–153 (2005)
20. Lundquist, K.-J., Trippl, M.: Towards cross-border innovation spaces. A theoretical analysis and empirical comparison of the Öresund region and the Centrope area. SRE Discussion Papers, 2009/05, WU Vienna University of Economics and Business, Vienna (2009)
21. Ahuja, J., Panda, T.K., Luthra, S., Kumar, A., Choudhary, S., Garza-Reyes, J.A.: Do human critical success factors matter in adoption of sustainable manufacturing practices? An influential mapping analysis of multi-company perspective. J Cleaner Prod (2019)
22. McAdam, M., Debackere, K.: Beyond 'triple helix' toward 'quadruple helix' models in regional innovation systems: implications for theory and practice: Beyond 'triple helix' toward 'quadruple helix' models. R&D Manage. **48**, 3–6 (2018)
23. Forbes, H., Schaefer, D.: Social product development: the democratization of design. Manuf. Innov. Procedia CIRP. **60**, 404–409 (2017)
24. Bertoni, M., Larsson, A., Ericson, Å., Chirumalla, K., Larsson, T., Isaksson, O., Randall, D.: The rise of social product development. Int. J. Netw. Virtual Organisat. **11**, 188 (2012)
25. Cherry M.A.: Beyond Misclassification: The Digital Transformation of Work (February 18, 2016), Legal Studies Research Paper No. 2016–2, Comparative Labor Law & Policy Journal, Forthcoming; Saint Louis (2016)
26. Sari, R., et al.: Sharing economy in people, process and technology perspective: a systematic literature review (September 12, 2019). Int. J. Mech. Eng. Technol. **10**(3), 1008–1024 (2019)
27. Hwang, J.: Managing the innovation legitimacy of the sharing economy. Int. J. Q. Inn. 5 (2019)
28. Belk, R.: You are what you can access: Sharing and collaborative consumption online. J. Bus. Res. **67**, 1595–1600 (2014)
29. http://interreg-central.eu/Content.Node/TRANS3Net.html. Last Accessed 26 Feb 2020
30. http://interreg-central.eu/Content.Node/NUCLEI.html. Last Accessed 26 Feb 2020
31. TRANS^{3}Net report Development and implementation map of transfer promotors
32. TRANS^{3}Net report Development and implementation of innovation web platform (IWP)
33. http://transfertech.eu. Last Accessed 27 Feb 2020