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Automated identification of circular value chains and synergies

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Abstract

A human-driven procedure able to identify cross-sectorial and cross-regional circular economy value-chains was co-created by 17 European regions within the H2020 SCREEN project. This paper explains how such a procedure has been translated into an automated service able to be inserted in a digital platform overcoming current information asymmetry among value-chain stakeholders, currently under development within the H2020 DigiPrime project. The open innovation approach adopted for the translation enables local companies to directly insert their data and to be directly notified about circular business opportunities. The advantage of the automated identification mechanism consists in avoiding the support of a circular economy expert for the first identification of value chains and synergies matching, thus leaving the regional officer more freedom; the lower accuracy of the automated mechanisms will be compensated by the large number of data that will be available once the DigiPrime platform will be fully operating.

Keywords: Circular Economy; Regional Value Chains; Automated Mechanisms, Local Stakehodels, Open Innovation

1. Background

DigiPrime is an H2020 project financed under the call DT-ICT-07-2018-2019, aiming at the development of a new concept of Circular Economy digital platform overcoming current information asymmetries among value-chain stakeholders [1]. The project is creating and populating a federated platform, where stakeholders from different sectors can exploit value-chain and operational oriented IT services, for the creation and boosting of innovative business models based on the data-enhanced recovery and reuse of products' functions and materials.

A specific service of the platform has the scope to identify cross-sectorial and cross-regional circular economy value-chains, based on the methodology developed within the H2020 SCREEN project [2], where 17 European regions co-created a replicable systemic approach towards a transition to Circular Economy within the context of the Smart Specialization Strategy. The original methodologies and tools, further validated by a group of different international stakeholders [3], were conceived as a powerful instrument for supporting regional officers in charge to foster the transition towards a circular economy to have an overview of the existing and

Fig. 1. (left) SCREEN logo, (right) DigiPrime logo.

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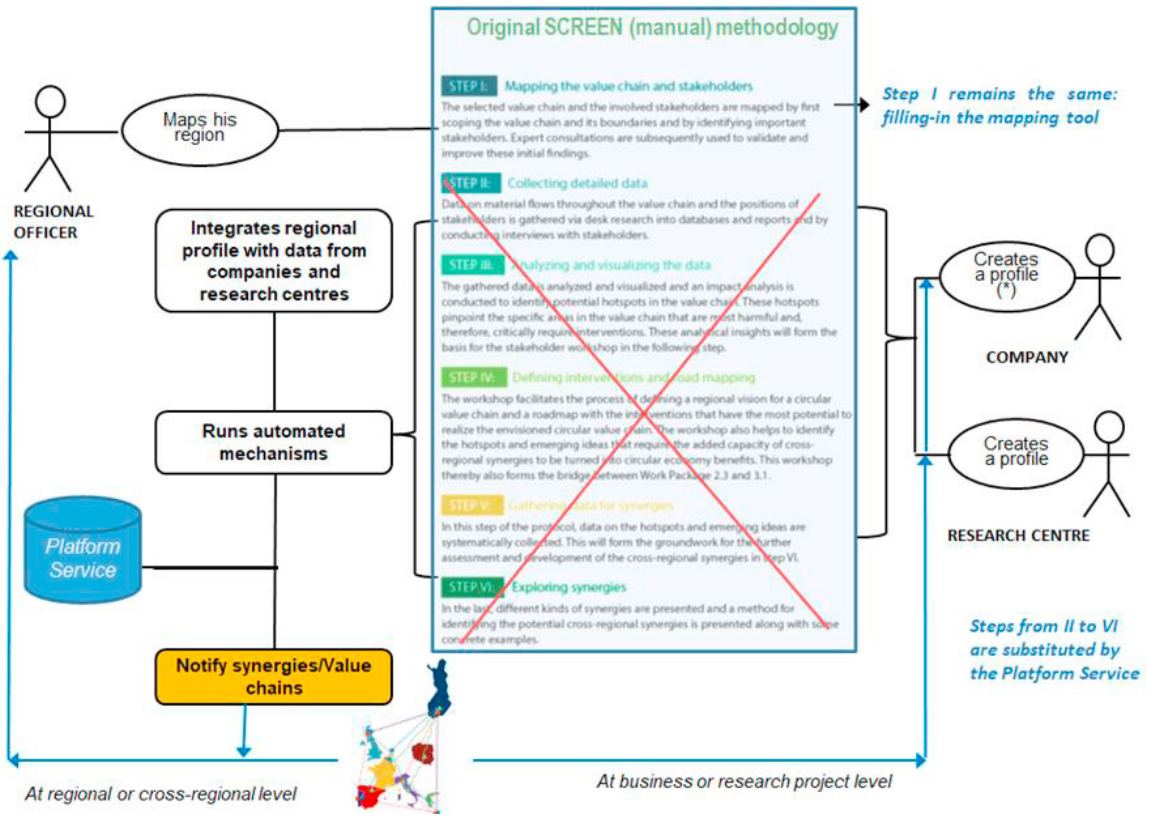

Fig. 2. Adaptation of the SCREEN Methodology for the DigiPrime IT service; blue arrows show the different kind of notifications: regional value chains to regional officers and synergies to local stakeholders.

potential value chains, as well as to be notified about possible cross regional or cross sectorial synergies and value chains.

The original human-operated SCREEN methodology was based on several steps such as: i) Mapping existing stakeholders and value chains at regional scale using data already owned by regional authorities; ii) Collecting detailed data through dedicated workshops with local stakeholders; iii) Analyzing data; iv) Matching & synergies; v) Identification of circular value chains; vi) Exploring synergies. The outcomes of the procedure, carried out with the support of a circular economy expert, allowed the regional officers to have a clear framework of the potential development in the field of the circular economy. Since the SCREEN procedure was targeted to regional authorities, it brings only indirect benefits to private stakeholders, as outputs of the regional actions implementing the value chains notifications.

2. Objectives

The objective of the research conducted in DigiPrime was to transform the human-operated SCREEN methodology, based on excel files to be filled-in after several workshops with local stakeholders, into a software tool able to run automated mechanisms for the preliminary identification of cross-regional cross-sectorial value chains and synergies opportunities. The advantage of the automated identification mechanism consists in avoiding the support of a circular economy expert for the first identification of value chains and synergies matching, thus leaving the regional officer more freedom; the lower accuracy of the automated mechanisms will be compensated by the large number of data that will be available once the DigiPrime platform will be fully operating.

The added value provided by the Open Innovation approach is given by enabling local stakeholders, particularly SMEs and industries, to directly insert their data, more detailed than the ones provided by the regional officers, and to be directly notified about eventual circular business opportunities, thus increasing their competitiveness and sustainability. Notifications to local stakeholders happen only after a matching detected by the automated mechanisms described in the following; therefore, the chance of being notified is related to the amount of data uploaded. Since the platform will be developed at European level and the data requested to the companies are relatively simple and not related to any process detail, the potential advantages for private stakeholders are relevant with respect to the time to be dedicated to the registration. The scheme in Fig. 2 shows how the automated mechanisms replace the previous human operated ones, with the only exception of the regional mapping tool preparation. The full detail of the original methodology is available in the SCREEN project public deliverables [4,5].

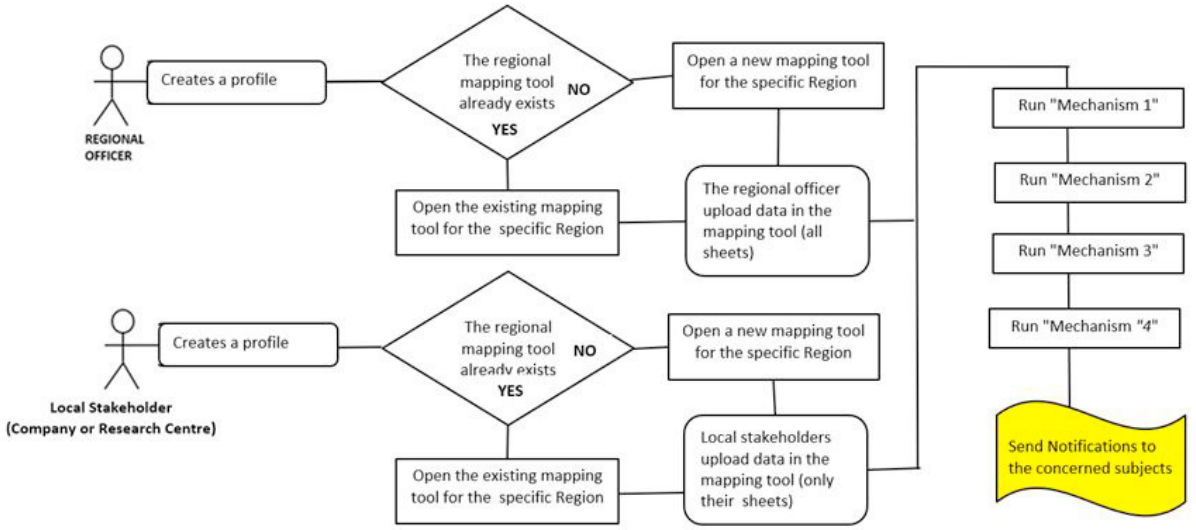

Fig. 3. Logical process chain of the SCREEN-DigiPrime methodology adaption.

3. Methods

The method adopted, summarized in the scheme of Fig. 3 is composed by:

- A system of notifications (blue arrows in Fig. 2).

The main differences in terms of potentialities and limitations of the original human driven SCEEN methodology and the IT service developed in DigiPrime are mostly related to the different degrees of freedom given by the automation of the four identification mechanisms on the right of the logical flow presented in Fig. 3.

For space reasons this paper provides only a general overview of *mechanism one*, together with a more detailed description of *mechanism two*, which is the most relevant for

the information directly notified to single companies. Nevertheless, this single detailed example is enough to provide relevant considerations about the potentialities provided by the DigiPrime driven human-to-IT methodology transfer.

Mechanism one operates a first identification of regional and cross regional value chains in the same sector; it is based on the first three fields of the *"Companies"* data sheet (Table 1): i) *NACE code*; ii) *Position in the circular value chain*; and iii) *Application Domain of the CE activities*.

NACE (Nomenclature of Economic Activities) codes indicate the various statistical nomenclatures of economic activities developed since 1970 in the EU [6]. The universe of economic activities is broken down in such a way that a NACE code can be associated with a statistical unit carrying out the activity it designates.

With reference to a generic circular value chain, its linear part is represented in Table 2 by the *"Positions"*, while the circular part is defined by the *"Application domains"*. The same company may occupy different positions in different value chains.

Table 1. *"Companies"* data sheet. Companies which want to have access to the described services are asked to fill-in this table with their data.

Area	Field	Input required
Company positioning	NACE code	From fixed list of NACE codes
	Position in the circular value-chain based on the framework	From list in Table 2: *"positions"*
	Application domain of Circular Economy activities (if any), based on the framework	From list in Table 2: *"application domains"*
	Technological capabilities	Free
INPUT	Type	From list: "*Product; Component; Material; Overall"*
	Short description by using up to five keywords	Free
	Quantity	[tons / year]
OUTPUT to the market	Type	From list: "*Product; Component; Material; Overall"*
	Short description by using up to five keywords	Free
	Quantity	[tons / year]
NOT USED (Circular entities or discarded)	Type	From list: *"Product; Component; Material; Overall"*
	Short description by using up to five keywords	Free
	Quantity	[tons / year]

Table 2. Positions and Application domains in a circular value chain.

Positions	Application domains
1. Gathering of core resources	8. Maintenance
2. Primary material processing	9. Repair
3. Production	10. Re-use/Refurbish.
4. Packaging & Distribution	11. Re-manufacturing
5. Use /service.	12. Recycling (open loop)
6. Collection	13. Recycling (closed loop)
7. Disposal	14. Biochemical Feedstock Recovery

Mechanism one reads the three data of a company and places it in the right position in one or more of the 22 pre-identified sectorial value chains for each European Region. When sufficient data are uploaded, the mechanism notifies the status of each value chain in each region through the following information:

- Number of companies present in each of the 14 fields of each pre-identified sectorial value chain.
- In case of one or more empty fields, number of companies found in the same value chain in other regions.

Mechanism one is important for regional officers in charge of fostering a transition towards a circular economy, because it provides, together with the further three ones, an overview of the situation at regional level and the possibility to search the *"missing rings"* of a certain circular value chain in other regions. It also provides to the regional policy makers an instrument for the decisions on which sectors or value chains should be supported; and support to decision makers on which sectors are most likely to be successfully supported.

3.1. Digital mechanism two detailed overview

Mechanism two is based on material-driven analysis: it reads the information contained in the *"Company"* data sheet on input and output material classification and types for each company, identifies possible upstream/downstream material links and notify the results to the concerned companies.

The specific section of the company data sheet is divided in three main areas, as shown in Table 1: i) *Input*; ii) *Output to the market*; and iii) *Not used*, meaning a potential Circular entity or wasted material. Each area is composed by three fields:

- *Type*: a drop-down menu with four possible choices (Product, Component, Material and Other).
- *Short description*: up to five keywords specifying the characteristics of the voice chosen in the *"Type"* field.
- *Quantity*: the estimated yearly amount in tons.

The mechanism operates as in the following (graphically summarized in Fig. 4).

For each company listed in the mapping tool of a specific Region, sheet *"Companies"*:

- Read the data in the field *"Type"* and *"Quantity"* in the *"Not used"* area of *Company x*.
- Search for the same data in the *"Input"* area in the other rows of the table.
- For each matching (e.g.: component/component, material/material, overall/component, material/overall), compare the text in the short description fields [search for equal keywords].
- In case of equal keywords found, notify the following message.

"Regional material driven possible synergy between:
Company x: Not used material [Keyword1, Keyword 2, etc] quantity/year
AND
Company y: Input material [Keyword1, Keyword 2, etc], quantity/year"

- Go to the next regional mapping tool.
- Repeat the steps explained in the first four bullet points for all the existing regional mapping tools. In case of equal keywords, notify the following message.

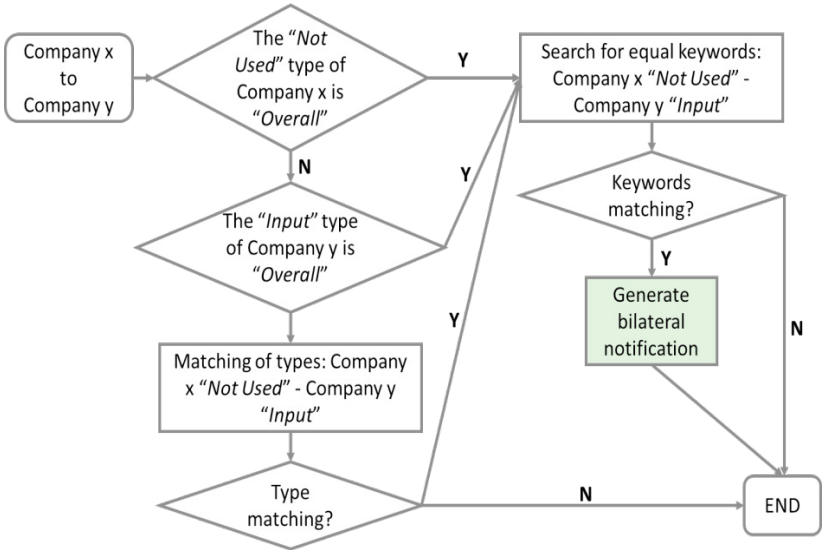

Fig. 4. Material driven automated matching, *mechanism two*. Iterated for each company both in the same Region and in different Regions.

"Cross-regional material driven possible synergy between:
Company k: Not used material [Keyword1, Keyword 2, ...] quantity/year
AND
Company z: Input material [Keyword1, Keyword 2, ...], quantity/year"

The software application capable to run this mechanism has been developed exploiting Python coding and the Spyder - IDE programming environment [7]. The software is launched and provides notifications to the DigiPrime DB by REST calls [8].

3.2. Evaluation of the SCREEN automation potentialities

The above presented mechanism can be evaluated to assess the potentiality of the software-based automation transfer of the SCREEN synergies identification tools.

Strengths and weaknesses of this automated approach are firstly listed in Table 3 and Table 4 and then further commented. Impacts which these strengths and weaknesses can have on the overall effectiveness of the DigiPrime cross-sectorial, cross-regional circular economy value-chains identification service are divided into *M* major impacts and *m* minor impacts.

Table 3. SCREEN mechanism automation: strengths.

Impact	Strength
M	Multiplication: the most powerful potentiality of this software-based automation approach is the capability to iterate the matching algorithms in near-to-zero time.
M	Simplicity: being just a keywords oriented matching tool, it is easy to propose possible synergies among companies, which are then let free to evaluate cooperation possibilities.
M	Granularity: this software and platform-based application enables any company from any Region to apply for the matching tool without the need of dedicated workshops or interactions with Regional officers. The need of a critical mass to justify a Regional subscription is therefore not an obstacle.
m	Costs: human-to-IT transition dramatically lowers the costs per algorithm iteration. Economic sustainability is therefore preserved in case of exponential growth of algorithm runs needed.

Table 4. SCREEN mechanism automation: weaknesses.

Impact	Weaknesses
M	Misalignments: one of the major risks attached to the automation of this synergies finding mechanism is the possibility that two companies define the same product family with different keywords.
m	Redundancy: companies which use to manage common products, or which describe their products with too general keywords might be overexposed to notifications. In this case it is easy to lose evidence of the few really interesting synergies found between the many others.

As shown in Table 3 and Table 4, the transition from human based to software-based iterations of SCREEN mechanism two brings both opportunities and risks. Nevertheless, this automation step is mandatory to make the SCREEN methodology potentiality available for all the interested stakeholders of different European regions. Moreover, the limitations of this approach can be mitigated:

- The SCREEN methodology based cross-sectorial and cross-regional circular economy value-chains identification service is not the only one which DigiPrime offers to its stakeholders for demand-supply matchings. Misalignments in keywords can be overcome by a more structural definition of the company products and technologies portfolio which enables the full exploitation of all the DigiPrime value-chain oriented services available.
- Through the active maintenance of the service, the developers might decide to implement more rigid, specific and customized synergies finding mechanisms in case of multiple redundancy advises from the users.

3.3. Validation of the software

At the time of submitting this paper, the validation of the software has been organized but not implemented yet; it is composed by the following operations: i) preliminary test of the mechanisms with fake data populating the database; ii) uploading real data coming from the previous SCREEN project and comparing the results generated by the software against those obtained manually; iii) uploading real data coming from companies and research centers that are part of the DigiPrime project and from some regional authorities and discussing the outcomes.

4. Conclusions

In this paper, a part of the automated mechanisms for the identification of cross-regional and cross sectorial circular value chains has been presented. The overall procedure is based on a methodology co-created by 17 European regions for supporting regional officers to fostering the transition towards a circular economy; it has been translated into an automated service ready to be inserted in a digital platform overcoming current information asymmetry among value-chain stakeholders. The adoption of the Open Innovation approach in the procedure enables local stakeholders (and particularly industries) to directly insert their data, and to be directly notified about circular business opportunities, thus increasing their competitiveness and sustainability and making the service relevant not only for regional officers and policy makers but also for local companies. The mechanism allowing the direct notification to companies is presented in more details; it allows companies in different regions to realize industrial symbiosis by exchanging not -used materials/product/components.

Further research is still ongoing within the H2020 DigiPrime project to optimize the combination of the outputs of the four mechanisms and then validate the software. In particular, the assumption regarding the compensation of the lower accuracy of the automated mechanisms by the large amount of data provided by the European platform is logic and reasonable, but still to be proven. While the interest of regional authorities in the research output has been already proven, the interest of

companies in this service should be accurately evaluated, in order to identify and solve possible barriers.

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References

[1] DigiPrime, DigiPrime – Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks, 2021. https://www.digiprime.eu/.
[2] Screen, SCREEN Laboratory, (2020). http://www.screen-lab.eu/index2.html.
[3] M. Chiaraluce, QUESTIONNAIRE ASSESSMENT CRITERIA, Fourth Policy Lab. (2018) 17.
[4] F. Albè, M. Colledani, N. Picone, C. Catgiu, Screen Mapping Tool: Scope and Guidelines, 2018. http://www.screen-lab.eu/deliverables/SCREEN-D2.1.pdf.
[5] B. Volkers, A ROADMAP FOR BUILDING CIRCULAR VALUE CHAINS. A Guideline for regional research and identifying synergies. - with synergie examples -, 2018. http://www.screen-lab.eu/deliverables/D3.1.pdf.
[6] EUROSTAT, NACE rev. 2, Office for Official Publications of the European Communities, Luxembourg, 2008.
[7] Spyder IDE, Home — Spyder IDE, (2021). https://www.spyder-ide.org/.
[8] R.T. Fielding, Representational State Transfer (REST), 2000. https://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm.