Digital Manufacturing Cluster Evaluation Methodology

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Abstract

Technological development in the recent years has significantly affected the business environment. Nowadays enterprises, to remain competitive and to discover the new business opportunities are forced to find the new ways and forms of collaboration. One possible solution is establishment of business clusters that include not only enterprises, but also the academic units introducing new technologies and business models. However, one of the main concerns related to the establishment of manufacturing clusters targets aspects, such as partners selection, business opportunities identification, etc. In this paper we are aiming at representing a framework intended to provide the necessary basis for establishment of successful clusters with the support of an evaluation initiative.

Keywords 1

Business model, digital manufacturing cluster evaluation, business ecosystem

1. Introduction

In the recent years the new forms of clusters have emerged. Clusters are geographic concentrations of interconnected companies and institutions in a particular field [1]. Beside "classical" clusters that are limited to the geographical location and common industrial domain there are the "meta clusters", which can be regional, unifying companies from different sectors, but from the same regions or cross-cluster partnerships [2]. Thus, the notion of clusters or business clusters comes closer to the notion of business ecosystem, which is according to [3]: "*an economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world. This economic community produces goods and services of value to customers, who themselves are members of the ecosystem*". Such ideas may come from the term business cluster, also known as an industry cluster, competitive cluster, or *Porterian* cluster that was introduced in [4]. In [5] authors discuss the key differences of industrial clusters and business ecosystem, identifying main characteristics of business ecosystem: (i) symbiosis, (ii) platform and (iii) co-evolution. First characteristic identifies that every member of the cluster is affected by the processes in other member organisations. Second characteristic stands for platforms and tools which are delivered by some members of the cluster to enhance the productivity of the whole cluster. And the third one identifies how the members of the cluster can benefit from collaboration allowing them to be more competitive through variety of competences. These characteristics can be also applied for cross-cluster partnerships, as well as for meta-clusters. Thereby, the main aim of this paper is to propose an approach for assessment of the industrial cluster being developed within the framework of ongoing European digital manufacturing projects ZDMP, EFPF, Qu4Lity.

Proceedings of the Workshops of I-ESA 2020, 17-11-2020, Tarbes, France
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2. GQM (Goal Question Metrics) approach

The lifecycle of the cluster can be separated on three main stages [6]: (i) establishing (ii) operation and (iii) dissolution. The key factors which can potentially affect the cluster establishment and criteria to assess potential benefits of collaboration should be defined in the early stages [7]. In line to this, performance indicators may be used for assessing the functioning of a company according to their strategic and operational goals [8].

This paper mainly covers the establishing phase of a cluster supported by an evaluation method to work as catalyst to reach the operation mode, where real products may be produced or exploited. Such evaluation method analyses if the goals stated are achieved.

The evaluation process is a key phase of every project, as well as clustering initiative. As a basis for evaluation the Goal, Question, Metric approach has been chosen. It is based on three levels [9]: (i) Conceptual, on which the goals are identified, (ii) Operational to formulate the questions characterising the measured object and (iii) Quantitative, where the metrics are introduced intended to answer the questions from the previous phase. Moreover, the proposed approach is extended with the importance or weight metric, which goal is to reflect the importance of each topic to each of the collaborating partner. Let's assume, if the goal is completely achieved, the assessment is equal to 1 and if completely failed, the assessment is equal to 0. In the same time, the final result is directly affected by the importance coefficient, which is identified by each partner for every goal also differentiating from 0 to 1. Thus, the result of the evaluation can be calculated as following:

$$r = \sum_{\&}^{n} a_n \times w_n, \quad (1)$$

where r is the result, n is the number of goals/topics identified, a_n is the assessment of particular goal and w_n is the perception of importance by the collaborative partner.

Thus, the best evaluation result, which can be achieved for the current assessment is equal to eight, i.e., to the sum of all evaluated characteristics, if all the assessments and importance coefficients are equal to 1. And the lowest result, respectively, is equal to 0, if the evaluating partner either considers the goal as completely failed. To every importance coefficient a textual description is assigned, i.e. 1 stands for "Critical" importance and "Insignificant" stands for 0. Thus, utilization of importance coefficients serves the goal to indicate the focus points and assess if the set goals are achieved.

All of these considerations and guidance represent what the paper authors define as the Cluster Establishment Framework (CEF). This framework represents a set of guidelines, considerations and approaches that focus all the work around evaluation and considers it as a catalyst to facilitate an effective cluster creation. This was inspired in the framework for technological research results assessment presented in [7]. The following case study has the objective to show an example of a cluster creation where evaluation works to push the success of it.

3. ZDMP Case Study

Identification of funding sources and other support, and thanks to individuals and groups that assisted in the research and the preparation of the work should be included in an acknowledgment section, which is placed just before the reference section in your document.

A case study to exemplify the CEF application consists of a set of European projects which are combined under umbrella of the Zero Defects Manufacturing Platform (ZDMP)[2] initiative. The cluster member projects within the joint imitative are: European Connected Factory Platform for Agile Manufacturing (EFPF)[3], Digital Reality in Zero Defect Manufacturing and Aligning Reference Architectures (QU4LITY)[4] and Open Platforms and Large-Scale Pilots in Digitising European Industry (CSA OPEN DEI). All of the projects are focused on designing, development and implementation of

[2] https://www.zdmp.eu/
[3] https://www.efpf.org/home
[4] https://qu4lity-project.eu/

Industry 4.0 solutions. The main aim of the ZDMP initiative is to create an ecosystem enabling the core services used to build the application that are pushed to the marketplace.

Important part of the presented framework is focused on assistance provision in evaluating the outcome, but also on identification of promising activities direction, whereas the objective is to turn the results of clustering initiative into the new business. On the current stage the framework is still in its infancy, which might require more improvement iterations and permanent feedback after being applied to the cluster. Another difficulty is that the framework is applied to a real cluster, thus in the course new aspects might appear that need to be properly addressed by the framework. However, as a part of initial stage of GQM approach, following topics or goals according to GQM approach were identified [10]:

- T.1 – Standardization stands for clustering activities facilitating the compliance of the cluster results with existing standards and contribution to new standardization activities where possible.
- T.2 – Dissemination on events stands for joint dissemination actions to communicate and promote the cluster results to technology and service providers as well as other business users and/or stakeholders.
- T.3 – Joint research activity stands for publishing activities of innovative results in leading journals and conferences.
- T.4 – Performance management and KPIs stands for an assessment framework containing core indicators to assess overall performance, including circular economy aspects, will be addressed in a common way.
- T.5 – Market Analysis and Business Models stands for a set of actions on turning the outcomes and innovation/technological developments of the cluster projects into value-creating products and services.
- T.6 – Open Calls stands for joint work to make external stakeholders aware of the available resources, to potentiate the open calls participation and to combine efforts on their evaluation.
- T.7 – Platforms stands for joint activities to exploit synergies between technology-based platforms addressing issues such as architecture, interoperability and standards approaches.
- T.8 – Pilots stands for pilot activities addressed by the three projects to increase knowledge on pilots' description, conducting, and assessment.

On the next stage, after the goals are set, questions, which help in reaching the goal and a set of metrics to answer the questions are identified. Below questions and metrics identified are presented in relation to Market Analysis and Business Models.

4. ZDMP Case Study

For the purpose of creating the new product or service which can be pushed into the real business, market analysis and the proper business model are of significant importance. The market analysis allows companies identifying and assessing the opportunities and risks of a market in order to make informed decisions regarding manufacturing investments and defining concrete marketing strategies to implement business ideas [11].

A business model describes how an organization creates, delivers and control value and how money is earned in a company [12]. It may identify a useful framework to link ideas and technologies to economic outcomes [13]. It also reflects the market research, "the chosen system of inputs, business activities, outputs and outcomes that aims to create value over the short, medium and long term [14]".

The cluster vision is to bring the project's outcomes to market, thus creating jobs and enhancing Europe's economic development. Cluster activities will place strong emphasis on turning the outcomes and innovation/technological developments of the cluster projects into value-creating products and services. The main objective is to establish a joint 4DMP Market Analysis and portfolio of Business Models for DMP.

Below is an example for the topic on market analysis and business models (see Table 1):

Table 1
The goal, question, metric for Market Analysis and Business Models topic

Topic (T5)	**Market Analysis and Business Models**
Question (Q1)	***How the Market analysis helps to identify the business opportunity?***
Metrics (M1)	***Market density*** represents an estimated number of potential customers in particular area/region. This metric can be very important for small and medium enterprises regionally oriented.
Metrics (M2)	***Competitive density*** [15] represents the number of competitors in particular domain offering similar products/services.
Metrics (M3)	***Potential market volume*** represents the size of the market at specific time stamp. It can be represented through the time-dependent function.
Metrics (M4)	***Time-to-market*** represents the amount of time needed for the product to reach the market. The time includes the whole period from the idea to the ready-to-sale product/service (all phases from idea, design and development, entering the market).
Metrics (M5)	***Required resources to reach the market*** represents estimated amount of human and financial resources needed to reach the market with product/service.
Question (Q2)	**What is the impact of developed business models?**
Metrics (M1)	***Innovation to product/service conversion rate*** represents the number of products/services developed, divided through number of innovative ideas formulated.
Metrics (M2)	***Applicability of business models developed.***
Metrics (M2.1)	***General Acceptability*** – subjective assessment of the business model implementation by the partners involved in the pilots.
Metrics (M2.2)	***Success rate*** – e.g. numbers of jobs created, added value (product price - cost of producing), reduction of the ecological pressure, etc.

The metrics identified in this paper are aimed at improving the common vision and understanding of the potential of the idea that need to be turned into the real product or service. Thus, the first stage is to collaboratively generate the idea of a product or service and afterwards assess the potential market and corresponding business model for its implementation. The next phase is to answer the following questions and establish the importance weights for the metrics.

Moreover, a foreseen joint workshop meeting between the cluster projects (e.g. ZDMP; EFPF) will provide important information sharing in order to mutually help the projects, mapping of business and technological services. Next actions should be agreed after the permit to share non confidential information about business models approaches for the three cluster projects as already individual projects work has progressed. Similar approaches are expected to address the marketplace issue, based on previous research initiatives. For instance, it can make sense to have a single marketplace, or to share some of the apps. In conjunction with the importance weight for each considered topic, as well as for each single metric this should allow for the cluster projects to identify the most promising ideas and products/services for joint implementation. Thus, each idea is checked against the mentioned metrics in the previous table. As an example, if the *market density* is low for a particular concept, e.g. there are not many potential clients for the product/service, there is no reason to choose this concept for further development. And if several concepts have comparable score for the market density metric, further metrics can support the decision making. The decision making is a complex procedure taking into consideration the importance weight, so the concept with worst time-to-market metric can have an advantage over another concept with better time-to-market metric but with better market volume metric score compensating the longer R&D process. The importance weight of all the metrics is supposed to be discussed and identified with all cluster partners on the next stages of the work.

5. ZDMP Case Study

Novel technological developments and fast changing business environments force enterprises to find suitable forms for future collaboration. In this paper, we introduce the framework for the assessment and evaluation of the results of industrial ecosystems to be developed through ongoing European digital manufacturing projects, e.g. ZDMP, EFPF, Qu4Lity. The GQM approach is put in the center of the presented framework allowing for both qualitative and quantitative aspects of the evaluation process to be efficiently addressed. Our future work on the framework is to practically evaluate the projects' results throughout their lifecycle in order to guarantee an effective establishment of manufacturing ecosystems and clusters.

6. Acknowledgements

The research leading to these results received funding from the European Union H2020 Program Under grant agreement No. 825631 "Zero Defect Manufacturing Platform (ZDMP)".

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