C-Engineering Based Industry 4.0 Innovation Networks Sustainable Development

Vitaliy Omelyanenko[†, ††], Oksana Braslavska[†††], Nataliia Biloshkurska[††††], Mykola Biloshkurskyi[†††††], Natalia Kliasen[††††††], and Olena Omelyanenko[†]

[†] Department of Business Economics and Administration, Sumy State Pedagogical University named after A. S. Makarenko, Sumy, Ukraine
[††] Department of Regulatory Policy and Entrepreneurship Development, Institute of Industrial Economics of National Academy of Sciences of Ukraine, Kyiv,
[†††] Department of Geography and Methods of Teaching, Pavlo Tychyna Uman State Pedagogical University, Uman, Ukraine
[††††] Department of Marketing, Management and Business Management, Pavlo Tychyna Uman State Pedagogical University, Uman, Ukraine
[†††††] Department of Finance, Accounting and Economic Security, Pavlo Tychyna Uman State Pedagogical University, Uman, Ukraine
[††††††] Department of Project Activity, State Scientific Institution "Institute of education content modernization" of Ministry of Education and Science of Ukraine, Kyiv, Ukraine

Abstract
The article deals with problems of innovation development on a network basis, which require effective mechanisms of innovation communications. In research the organizational aspects of ICT infrastructure development for innovation networks sustainable development based on cooperative marketing principles is considered. The proposed research idea is based on the idea that ICT implementation is based not only on the operational approach for innovation management as a factor of efficiency of internal communications, but also on knowledge economy and post-industrial economy trends. Therefore, the purpose of study is to develop an ICT model of innovation infrastructure to improve its effectiveness (strategic character) and efficiency (operative character) through increasing the efficiency of network communication interactions. Creation of information space and communication tools to support innovation network sustainable development and cooperation activities in research is proposed to be solved with the help of specialized ICT platform. It is shown, that ICT platform of innovation cooperation innovation network is important tool for common work of participants. ICT platform is considered as an integrated information system designed to automate business processes related to the sustainable development of innovation network, segment management and integration with HEI information systems and industrial cooperation. The main factors that determine the need to use a special ICT platform for innovation network cooperation were considered. The main issues of concurrent engineering (C-technology) application in high-technology industries and innovation cooperation for integrated product development were studied.

Key words:
Innovations, Technology Transfer, C-Technology, ICT, Strategy, Industry 4.0 Innovation Networks.

1. Introduction

Innovation networks are effective mode of beneficial interaction between R&D institutions, start-ups and innovation business, interested in implementation of scientific & technological projects. In the conditions of intensified competition in partner interaction, the choice of potential customers (partners) of the innovation project is based on the analysis of information from various sources (specialized databases, publications, advertising materials, assessments of reputable experts, industry information platforms, etc.). To solve the problems of innovation development on a network basis, an effective mechanism to promote the results of scientific research to the innovation market is needed. In the conditions of innovation development paradigm shift and tougher competition for ideas, developers and owners of new technologies face with the difficulties in organization the marketing of their developments and finding the partners to create joint ventures. This is largely caused to the lack of an extensive technology transfer infrastructure, which would include specialized centres and information systems for the exchange of technological requests. This necessity is also caused by cooperative marketing role in Industry 4.0 conditions. A typical feature of Industry 4.0 is efficiency from interaction [1]. Thus, the organizational aspects of ICT infrastructure development for innovation networks based on cooperative marketing principles are an important task. ICT implementation is based not only on the operational approach for innovation management as a factor of efficiency of internal communications, but also on knowledge economy and post-industrial economy trends.

In these conditions, the issues of sustainable industrial development and technological progress become relevant. Given the rapidly changing global economic landscape and growing inequalities, progressive growth must include industrialization, which, firstly, gives all people access to

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opportunities and, secondly, relies on innovation and sustainable infrastructure.

2. Theoretical Consideration

The report devoted to Industry 4.0 trends [1] contain the conclusions that development strategies should be based on the completely new approach for production as a network of major academics, industrialists, experts, economists. Therefore, the question about the development of tools for designing relevant networks for cooperation that will form synergies of interaction arises. This approach is also relevant for open innovation context [2]–[4] and open innovation networks development [5]. This interaction synergy can be created within the innovation systems with interaction of actors operating in single environment and creating the value that none of them could not produce alone [6], [7]. From the point of [8], the innovation system consists of partners, on whom your success depends in the creation of innovation.

In these conditions from the education-based approach it is necessary to form the technology transfer management culture [9] as a key element of undergraduate's entrepreneurial skills [10], [11] through the prior experience of collaboration [12]. Study [13] considers issues of how knowledge and skills acquired through various disciplines are to be integrated into the learning practices. Networks formed by global companies.

In studies [14]–[16] cooperation between higher education institutes HEIs and other stakeholders as a source of economic growth and competitiveness in all knowledge societies is considered. Also, the most significant limiting factors of these types cooperation are highlighted. The research [17], [18] aims to analyse how the knowledge transfer takes place. The empirical results show that the cooperation between companies and HEIs, which translates into the tech transfer, is conducive to greater innovation.

The paper [5] builds an agent-based simulation model of open innovation network dynamics in search of technological development partnership. Within innovation network development we can underline the role of S2B-B2S cooperation.

An integrated approach to the analysis of innovation ecosystems requires the study of institutions, and participants, and their interaction networks, and the specifics of the environment: culture, resources, technology, etc. [5], [19]–[21], especially within the collaborative community planning [22].

Based on a literature review, the role of ICT in the development of S2B-B2S innovation network cooperation can be considered in such aspects:

i) searching the ways how various disciplines can be integrated into the teaching and learning practices [23] especially through the multidisciplinary cooperation;

ii) variety of activities involving representatives from various organizations: industry, investors, experts, students, and so on [24]–[26];

iii) development of web infrastructure tools [27] of databases, analysis and mapping of networks (in particular, it is based on a thorough analysis of networks that the management of the innovation ecosystem of Stanford University is built);

iv) cooperation participation in network structures and projects, both national and international [14], [15], [28].

Among the main trends of mentioned aspects, it is possible to single out the development of information portals that provide interactive interaction of interested participants at all stages of the innovation cycle. However, the problem of communications is in the absence of communication channels between disparate communities, the absence of a common communication strategy – these activities are carried out by v6arious government authorities and development institutions, but are not coordinated. In some of the reviewed papers, it was pointed out the need to solve the problem of information transfer by creating an information support tool, and the need for a tool to search for partnerships, cooperation and coordination of innovation activities.

Study [29] deals with the issues of government promotion of academia-industry cooperation, various matching events, networks activities, established to return results of researches to society. The paper [30] aims to contribute to the identification of relationship between R&D cooperation and innovation performance (product and process) of firms by using difference-in-difference approach. The paper [31] explores the R&D-marketing and R&D-sales cooperation within the new product development. It is noted that the effect of R&D-marketing and R&D-sales cooperation varies depending on market, company and R&D characteristics. This requires the development of individual solutions.

In our previous studies [32]–[35] an analysis of ICT application in technology transfer management within Industry 4.0 based on an education approach was done. It was underlined, that the industrial revolution encourages everyone to adapt faster [36], [37]. Therefore, the development of ICT support model based on network mechanism is a relevant scientific and practical task.

The purpose of current study is to develop an ICT model of innovation infrastructure to improve its efficiency through increasing the efficiency of network communication interactions based on C-technology.

Transformation of innovation conceptual model based on active cooperative strategies is proposed to be studied in such way: the identification of specifics of activities in "education – science – practice" relationship and analysis of its value-semantic content within the innovation marketing. Another approach can be also based technology

management assessment procedure, technology audit model and technology assessment.

The research is structured according to the stages of any R&D project as a cooperative innovation and is covered in three interdisciplinary aspects: strategical; managerial; creative & technological.

The first aspect characterizes the state of formation of structural and functional components of ICT based R&D strategies.

The second aspect is considered from the point of view of marketing and management of ICT innovations and provides a justification of the strategy of creating an environment for the advanced sustainable development of intellectual resources.

The third aspect of the study deals with the analysis of the main issues of some types of ICT application for processes in innovation networks and digital educational.

The impact of ICT on the formation of an innovation culture of future specialists is seen in the creation of an educational environment, where the means of interaction with stakeholders in innovation networks will play a leading role.

3. Experimental Consideration

Creation of information space and communication tools to support innovation network cooperation activities is urgent task solved with the help of specialized ICT platform. The ICT platform of innovation network is important tool for common work of participants and can provide the following functions [38]:

i) information system (technological offers and requests profiles databases, remote information management interface, website);

ii) communication system (tools for organizing the interest tracking and correspondence with customers, participant's forum, tools for collaborative education projects);

iii) training system (methodical materials library, regulatory documents, samples);

iv) monitoring system (statistical reports on performance indicators).

Generally, ICT platform is an integrated information system designed to automate business processes related to the sustainable development of innovation network, segment management and integration with information systems and industrial cooperation.

The following factors can be identified that determine the need to use a special ICT platform for innovation network cooperation. The ICT platform functionality is primarily intended for organizing communications among a large number of innovation network participants (Fig. 1). Companies and innovative intermediaries can use various means of communication. Effective tracking of contacts even with 3 counterparties is a difficult task in practice. In the technology transfer network of such contacts (interactions) each participant is orders of magnitude larger.

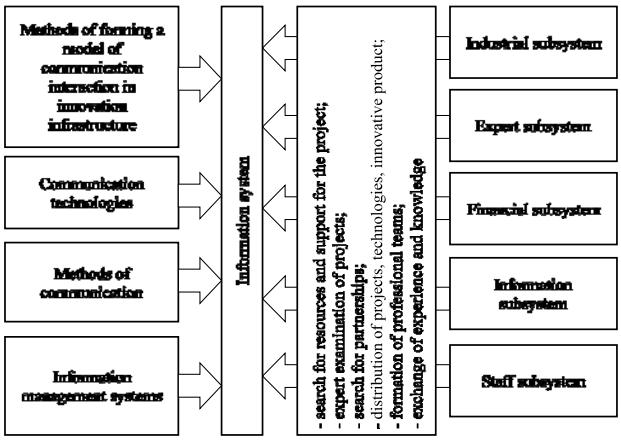

Fig. 1 Innovation infrastructure ICT support model

Source: *Developed by authors.*

As innovations become more complex the amount of information, exchanged by network members, increases exponentially. For example, in the Enterprise Europe Network the number of actual requests and proposals for scientific and technical cooperation is about 3,000 (total for 2008–2015 – more than 15,000 units). Processing such a large amount of information requires ICT application.

In order to increase the degree of conversion (transition from expressions of interest to negotiation stage), information on technological inquiries and proposals should be described and structured in a certain way. The ICT platform allows maintaining of uniform standards of information presentation by defining description formats and automating the process of information validation (checking compliance with specified requirements). The effectiveness of the search for partners and the organization of subsequent cooperation is largely determined by the quality of the initial information presented in the descriptions of the technology request or proposal. So, we came to two aspects of information aspect: (1) availability and quality of the information and (2) readiness and stimulus for using the information. In this regard, in the innovation network, great attention is paid to ensuring the quality of the disseminated information.

It is also important that the structure of innovation network, in particular the presence of participants with different roles and rights to access information. For example, the three main groups of participants in technology transfer network (coordinator, network members and network participants) can include up to 10–15 different subtypes. Additional complications arise if several registered users with different access rights to information can be from the same organization

participating in network, as well as creating regional or thematic subnets and forming working groups from among the representatives of the network members.

The process of organizing the validation of information objects (checking for compliance with formal requirements and confirmation of placement for wide access) is one of the key processes automated by the ICT platform. For example, the Enterprise Europe Network has a quality control system for profiles when all new profiles are checked by the coordinator before they are placed in the database. And only the centres of the Enterprise Europe Network, which have shown consistently high-quality profiles, are given the right to post them without authorization.

We propose to consider ICT platform development based on concurrent engineering (C-technology), which in high-technology industries and innovation cooperation is based on integrated product development. At the core of C-engineering development is the concept of the possibility of a hierarchical representation of the object systems and the concept of the possibility of a hierarchical representation of the goals and objectives of designed complex system.

The application of C-technology is based on the fact that the task of creating a new product imposes the highest demands on reliability and is complex. The degree of uncertainty of estimates of project costs varies depending on the stage of the project at which such an assessment is carried out, and the possible magnitude of the error varies greatly depending on the subject area.

Additionally, the cost of making changes to the project exponentially increases until the end of the project, and, therefore, the implementation of all risky work must be planned at the early stages of the project. If at the design stage mistakes were made, then they are very difficult or impossible to correct as a result of accidents, which lead to large economic losses. Therefore, we believe that the best way to form a technology package is to use the method of parallel engineering development.

Concurrent engineering provides information interaction of many remote participants in the design of complex technical systems. At the same time, information is exchanged at all design stages, which allows organizing a reduction in terms due to parallelization of project tasks. Therefore, concurrent engineering allows creating the cooperative innovation space with minimization the time and maximization the value.

The principle of C-technology involves the implementation of development and design processes simultaneously with the modelling of manufacturing and operating processes. This also includes the simultaneous design of various components of a complex product. In parallel engineering, many problems that may arise at the later stages of the life cycle are identified and solved at the design stage. This approach allows to improve the product quality and to reduce the time of its development.

The differences of C-technology from the traditional approach to the organization of engineering activity, which makes it useful for education, are:

i) elimination of traditional barriers between the functions of individual specialists and organizations through the creation of multidisciplinary working groups, including geographically distributed;

ii) iterative process of desired result approaching.

Based on this, we will highlight three models for the development of innovative products based on sustainable development principles:

1) *Combination model*: existing technologies (R&D results) from various industries adapting for application in new conditions;

2) *Model of target development*: technologies are specially developed;

3) *Mixed model of technological development*: existing technologies and specially developed technologies are used together (improvement of product modules, custom manufacturing).

The analysis shown that in the practice in developing countries this method is not used because of the isolation of research and the lack of cooperative marketing to participate in innovative projects, which leads to a loss of innovative potential due to time lag and increasing transaction costs and costs of technology modification (unification). In addition, it is necessary to note the gap in education and practice.

On the basis of J. Holland's classifying systems, we propose to consider the process of forming a technological package of a project as part of three interrelated subsystems: classifier, learning system and genetic algorithm. The classifier receives information about existing technologies. The classifier contains the rules by which the effective assessments of technologies are formed. The training system evaluates the selection rules used. The genetic algorithm is designed to modify the rules.

It is assumed that the C-engineering project team should simultaneously solve various special design tasks ensuring the achievement of education and innovation (project) development goals. Each such task is associated with the implementation of certain vital requirements, which in turn affect a number of other requirements. It is these relationships that are often overlooked in the traditional (sequential) approach to the development of new products.

An increase in share of ICT application in R&D activities within C-engineering contributes to the formation of process, which in practice contributes to:

i) simplify the explanation the concept of the project (product) by modelling, isolation and abstraction;

ii) establishing differences and consistency with previous knowledge and ways of activity, as well as the possibility of transition to them;
iii) selection of changing and conserved parameters, the establishment of a relationship between them;
iv) maximum disclosure of the essence of the subject of explanation through cause-effect, functional, structural and genetic patterns.

Generally, product information is a set of data that is generated and used on all of its life cycle and includes information about the configuration and structure of the product, characteristics and properties, organizational information (description of the processes associated with changes in product data and necessary resources), information on control tests carried out, documents that are connected with the product from the moment of its design to its sale and further maintenance, etc.

The integrated information environment of innovation project is a specially organized data repository, which is a collection of distributed databases, in which there are uniform, standard rules for storing, updating, searching and transmitting information, through which paperless information interaction between all participants of the life cycle of the product takes place. At the same time, once created information is stored in an integrated information environment, it is not duplicated, it does not require any recoding in the exchange process, it remains relevant and integrity.

Integrated information environment of innovation project includes infrastructure, tools and interaction protocols.

CALS is the main technology, elements of which should be included in the integrated information environment of innovation networks. CALS is a continuous integrated information support for participants in a product's life cycle with data about products, related processes and the environment, mainly in electronic form. CALS ideology is a set of principles based on ICT achievements:
i) representation, processing, exchange and management of data in e-form;
ii) data reuse with minimal changes and costs;
iii) optimization and unification of methods for presenting, processing and transmitting data about a product, process, environment;
iv) integration and optimization of information interaction of all participants in the product life cycle.

Application of CALS in innovation networks should lead to the emergence of so-called virtual productions within the innovation networks. Virtual production is a type of production that does not have a fixed organizational and territorial structure, in which the process of creating information for software-controlled manufacturing equipment and the manufacture of a product itself can be distributed in time and space between many participants. A virtual enterprise is a form of combining the organizations involved in supporting the life cycle of a common product and connected by common business processes on a contract basis.

Ensuring the competitiveness of the enterprise is currently impossible without the introduction of integrated product life cycle support (IPI-technology). Effective implementation of the principles of IPI-technologies in an enterprise is achieved by creating an integrated corporate collaboration environment on a product (PDM-system), which, in turn, provides:
i) creating an environment for joint parallel product development;
ii) creation of a structured electronic product description;
iii) configuration management at all stages of product life cycle (design, preproduction, production, post-production support);
iv) reduction of time and cost reduction of design and technological design and coordination of technical documentation through electronic document management.

These approaches are also important for HEI that the creating specifications for technological equipment, sufficient for some product, can be distributed among many project studios (student groups, labs).

4. Conclusion

Creation of information space and communication tools to support innovation network cooperation activities is urgent task solved with the help of specialized ICT platform. The ICT platform of cooperation in innovation network is important tool for common work of participants.

Generally, information technology platform is an integrated information system designed to automate business processes related to the development of innovation network, segment management and integration with HEI information systems and industrial cooperation. The main factors that determine the need to use a special ICT platform for network cooperation were identified. It was shown that application of C-technology is based on the fact that the task of creating a new product imposes the highest demands on reliability and is complex.

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Vitaliy Omelyanenko, Ph.D. (Economics), Associate Professor.
Associate Professor at the Department of Business Economics and Administration. Faculty of Physics and Mathematics.
Sumy State Pedagogical University named after A. S. Makarenko, 87 Romenska Street, Sumy, 40002, Ukraine.
Doctoral Student at the Department of Regulatory Policy and Entrepreneurship Development.
Institute of Industrial Economics of National Academy of Sciences of Ukraine, 2 Maria Kapnist Street, Kyiv, 03057, Ukraine.
E-mail: omvitaliy@gmail.com
ORCID ID: 0000-0003-0713-1444
Scopus ID: 56624321000

Oksana Braslavska, Doctor of Sciences (Pedagogy), Professor. Head of the Department of Geography and Methods of Teaching. Faculty of Nature and Geography.
Pavlo Tychyna Uman State Pedagogical University, 2 Sadova Street, Uman, Cherkasy Region, 20300, Ukraine.
E-mail: oksana.braslavska@udpu.edu.ua
ORCID ID: 0000-0003-0852-686X
Researcher ID: ABG-6203-2020
Scopus ID: 57216752379

Nataliia Biloshkurska, Ph.D. (Economics), Associate Professor. Associate Professor at the Department of Marketing, Management and Business Management. Educational and Scientific Institute of Economics and Business Education.
Pavlo Tychyna Uman State Pedagogical University, 2 Sadova Street, Uman, Cherkasy Region, 20300, Ukraine.
E-mail: biloshkurska.n@udpu.edu.ua
ORCID ID: 0000-0002-7617-7836
Researcher ID: P-3368-2018
Scopus ID: 56595222400

Mykola Biloshkurskyi, Ph.D. (Economics), Associate Professor. Associate Professor at the Department of Finance, Accounting and Economic Security. Educational and Scientific Institute of Economics and Business Education.
Pavlo Tychyna Uman State Pedagogical University, 2 Sadova Street, Uman, Cherkasy Region, 20300, Ukraine.
E-mail: biloshkurskyi.m@udpu.edu.ua
ORCID ID: 0000-0002-2826-3983
Researcher ID: B-4501-2018
Scopus ID: 57205639656

Natalia Kliasen, Ph.D. (Pedagogy). Head of the Department of Project Activity.
State Scientific Institution "Institute of education content modernization" of Ministry of Education and Science of Ukraine, 36 Mytropolyt Vasyl Lypkivskyi Street, Kyiv, 03035, Ukraine.
E-mail: kliasenn2014@gmail.com
ORCID ID: 0000-0002-7919-4690

Olena Omelyanenko, Ph.D. Student (Economics) at the Department of Business Economics and Administration. Faculty of Physics and Mathematics.
Sumy State Pedagogical University named after A. S. Makarenko, 87 Romenska Street, Sumy, 40002, Ukraine.
E-mail: elnikkrasnaya@gmail.com
ORCID ID: 0000-0001-8993-806X
Scopus ID: 57216657012