Development of Regional Innovative Clusters and Supply Chain Strategy in Terms of Lean Production Principles

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***Abstract*- The article considers the genesis, content and relevance of the cluster approach in socio-economic regional development. Certain aspects of the innovativeness of this approach have been discussed in a number of national strategic documents since 2008. In our opinion, their further development and updating is relevant for the upcoming international forum, "Partnership for Cluster development: Creating the future," which will be held in the Republic of Tatarstan in 2020. The key goal as part of the development of regional innovative clusters is the development of effective intra-cluster interaction to increase labor productivity. The authors introduce the hypothesis regarding the increase of production systems' efficiency. The necessity of implementing the lean production concept according to the certain cluster model is identified and justified. In relation to this, the conditions and possibilities of having a synergies-tic effect on the joint, interconnected and mutually reinforcing use of lean principles are analyzed. In addition, the model that is implemented by all the participants in the innovative cluster in the product value chain is developed. The authors refer to provisions in international and domestic documents on the sphere of cluster development, recommendations from the national standard GOST R 57524-2017 "Lean production. Value Stream," methods for calculating process performance indicators, product stocks in buffers, and cycle time of the reverse processes. According to the results of the study, it was concluded that the implementation of lean production principles for the development of innovative regional clusters is universal and effective. Moreover, it has a high degree of feasibility for any organizational model of a cluster. There is scientific and practical interest in the implementation of the entire complex of lean principles to provide for the quality of products and processes, as well as their continuous improvement.**

***Keywords*-** *innovative cluster, regional cluster, supply chain strategy, lean production, pull principle, value stream.*

1. Introduction

Current Russian economy requires the development of regional innovative clusters and a scientific clustering concept, which reflects the global trends of the successful growth of large companies [1, 2, 3]. The elements of this strategy were first formulated within the context of the national cluster policy of the Russian Federation in 2008. The fundamental basis for clustering is laid down in the provisions of the "Concept for the long-term socio-economic development of the Russian Federation up to 2020." Identifying the basic aspects of the creation and development of the cluster approach has enabled us to identify such important documents endorsed at the state level as "The Strategy for Russia's Innovative Development 2020", adopted at the end of 2011. The basic objectives of the concept and strategy are to create territorial production clusters in highly urbanized regions of Russia. It would provide the conditions for economic modernization and the realization of competitive potential of the regions [4-8]. According to the statistics data of the priority project of the Ministry of Economic Development of Russia, "Development of Innovative Clusters—Leaders in World-class Investment Attractiveness" for the period up to 2020, 40 such clusters have been established across Russia. This combines the operations of the companies of different industries.

At present, the discussion of the successful development of innovative clusters requires improvement. As a result, in October 2020, Russia will host the International Conference, "Partner-ship for Cluster Development: Creating the future". Leading researchers, representatives of innovative clusters and regional institutions to support their competitiveness, and developers of regional innovation and cluster policies will meet at the discussion platform in Tatarstan. Such an interest in the development of innovative regional clusters enables us to expand the boundaries of international scientific and business cooperation, increase competitiveness and apply the most effective clustering and innovative development methods in the region.

The development of effective intra-cluster interactions to increase cluster productivity is actively discussed at national and international scientific and practical events. Recent scientific studies are therefore devoted to the formation of a unified methodological basis for implementing the most successful experience in the development of the cluster production systems (2, 3, 4, 5, 6, 7, 8, 40, 41, 42, etc.). There is a tendency to integrate progressive production and operating management methods into a single system, due to the attempt to achieve a synergistic effect in cluster environment [9, 10]. One of the most recognized methodological approaches is the implementation of lean production principles and the analysis of their economic benefits in the context of the cluster approach to regional economic development.

The aim of this study is to develop adaptive mechanisms for the implementation of intra-cluster interaction principles for lean production. In this context, it is necessary to test the hypothesis of some restrictions and possibilities for implementing certain lean production principles in order to improve the effectiveness of regional clusters. Russian regional innovative clusters and their models are the objects of this research. The subject of the study is the conditions for the development of the production systems of cluster participants basing on the implementation of the lean production principles.

2. Methods of research

Nowadays, scientific and specialized literature, as well as the professional Internet environment, refers to the study of problems in the field of lean production. Russian scientists have been interested in this field since the early 2000s. In the context of market relations development and in-creasing competitiveness, domestic enterprises tried to craft their production systems based on effective foreign examples. The lean manufacturing concept was a part of the Toyota Production System (TPS). It was then developed in the American market and got a new interpretation, namely, Lean Production. This term was introduced by Krafcik, who worked together with Vumek, Jones and Rus to im-plement a national research project called the “International program ' Automobiles.'" The results of their work were presented in a number of well-known scientific publications [11, 12] in the field of general philosophy on lean production with approaches to certain types of production losses. The lean approach was further developed by European companies; their successful experience was adopted by Russian organizations.

The concept of lean production in different countries took on national features that took into ac-count production traditions and received corresponding terminological features. According to Salomatin, Drobyshevskaya and Isaeva [13], such an approach proved to be an effective combi-nation of European practicality and Eastern philosophy. These authors rightly point out that lean production can be considered as a philosophy, as a system, and as a tool. Nowadays, lean production comprises an integrated approach that includes process optimization, management infra-structure provisions, and employee behavior and thinking changes.

This approach is confirmed by foreign authors. In their works, lean production is regarded as a holistic management concept, applied as the basic business model of a company. The following authors are worth highlighting: Ono [14], [15], [16], [17], [18], [19], [19, 20], [21], [22], Russell [23], [24], [25-30], [31-43], [44], [45], [in 46], and others. Of the Russian research devoted to the study of lean production as a management system, the following authors can be noted: Adler [26], [27], [28].

The concept of lean production implementation for a regional cluster is not studied sufficiently in the scientific literature, although there are some scientific achievements. Zaitsev and Sedlarge [29] introduce the term “lean cluster”, which reflects the logistical integration of participants in the value chain. This is just one of a few works in this sphere. It is also worth noting that only a few works are devoted to the development of cluster members and the synergistic effect of their successful interactions. For example, Palamar and Vorontsov [30] analyze the possibilities for energy optimization in cluster enterprises. Stepovaya [31] considers the technological interactions of territorial cluster participants. Carrie [32] explores issues around operational management and IT interaction within clusters.

The institutional, financial, and organizational aspects of the innovative cluster enterprises are studied closely in the framework of the cluster approach. However, insufficient attention is still paid to the problem of their efficiency and competitiveness in the context of production man-agreement. This is partly due to the fact that cluster approach to regional politics in the Russian economy has been applied only recently. Therefore, regional experience and the problems of improving the production systems of the regional clusters will contribute to a close study of this is-sue.

3. Results

The implementation of the concept of lean production in a regional innovative cluster contributes to the necessity of determining the conditions and possibilities for a synergistic effect from the cooperative, interconnected and complementary use of the lean principles by cluster members. The key benefits of a cluster are obtained by means of cooperation opportunities development, the use of a unified infrastructure and, in the context of innovative cluster, through the development of the interaction with research structures. It helps to improve the competitiveness not only of individual cluster members, but the innovative cluster as a whole and the region where it is located. According some Russian scientists [33], the development of an innovative cluster provides regional attractiveness for businesses, investors, high-skilled workers and researchers.

Nowadays, all Russian regional innovative clusters can be divided into three groups according to their organization model:

- "Anchor" territories of a large high-tech business
- Regions of small and medium innovative business concentration
- Leading scientific and educational centers

Systematization of the research in the sphere of intra-cluster interactions development [34-40] made it possible to analyze the applied organizational models of innovative clusters (Figure 1).

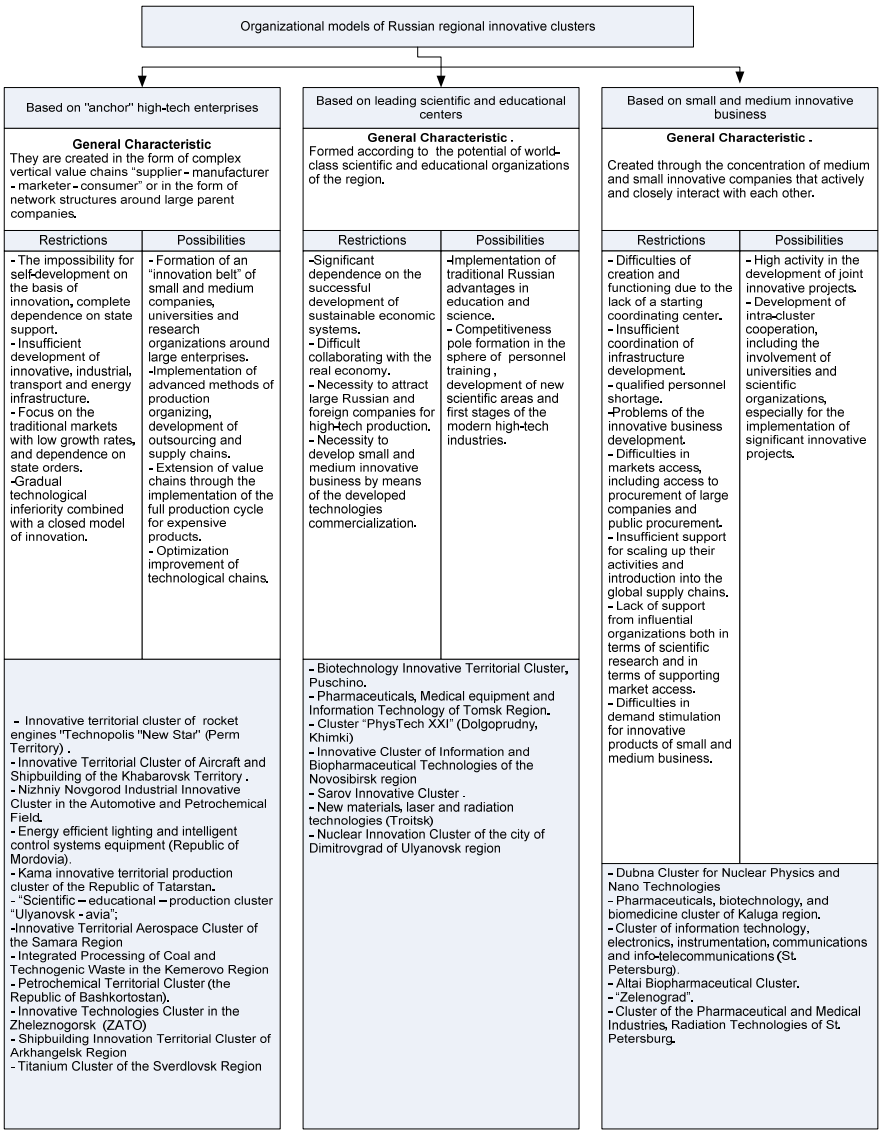

Figure 1. Characteristics of organizational models of the Russian regional innovative clusters.

Figure 1 shows that the characteristics of organizational models allow us to conclude that the largest group of Russian regional innovative clusters is based on "anchor" high-tech enterprises. This is due to the fact that the innovative potential of the Russian regions, which was largely the heritage of the country's pre-market economy, was used in the territorial clusters formation. For the

enterprises of such a cluster, there are significant restrictions for the development, connected to the necessity of improving their production systems in accordance with the modern approaches to production management. One of the possibilities of such an organizational model of the innovative cluster is also the implementation of advanced methods of organizing production. It completely corresponds to the necessity of applying the lean production principles by cluster members. This allows us to lower the cost of innovative products by means of production losses reduction. In addition, the profitability of the cluster enterprises is being improved and the restrictions connected with the dependence on state support are leveled [41-46].

At the same time, irrespective of the organizational model applied for the regional innovative cluster formation, it implements a complete innovation chain of scientific knowledge formation and business ideas development, as well as production and sale of innovative products [47-51]. In these conditions, the optimization of the value chain within the framework of the development of the lean production system is highly relevant.

The value formation for the consumer within the framework of lean production system is based on the synergy of the principles of this concept. The study requires the active use of the principles that characterize the cluster members' interactions. In the special literature, the authors introduce diverse views on the structure of lean production principles (Table 1).

Table 1. Approaches to the structure of lean production principles

Author/ Source	Principles
Womack, J.P., Jones, D.T [11]	1. Definition of value 2. Definition of value stream 3. Organization of value stream 4. Product Pulling 5. Perfection
Liker D.K. [38]	1. Decision-making according to the long-term principles 2. Organization of the process as a continuous stream to identify problems 3. Pull system implementation 4. Production shutdown to solve quality problems 5. Visual supervision implementation to identify problems 6. Encouragement of the leaders supporting company philosophy and training future leaders 7. Partnerships with associates and business suppliers 8. Making decisions basing on the analysis of all possible options and their implementation 9. Creating a training company through introspection and improvement
Salomatin, V.A., Drobyshevskaya, L.N., Isaeva, L.A [13]	1. Logistic processes optimization to minimize the time and movement of products in the production process 2. The maximum possible decrease in stock levels 3. Standardization of the enterprise operational process 4. Optimization of incomplete production basing on the output needs 5. Determination of the optimal production volume 6. Production technology improvement basing on the economy trends 7. Defects minimization by means of advanced training of employees and timely replacement of equipment 8. Staff adaptation to changes caused by the implementation of lean production; trainings
GOST R 56020-2014 "Lean Production. Fundamentals and vocabulary"	1. Focus on strategy 2. Focus on Consumer Value 3. The organization of Consumer Value flow 4. Continuous improvement 5. Pulling 6. Loss reduction 7. Visualization and transparency 8. Security priority 9. Built-in quality 10. Factual decision making 11. Long-term relationships with suppliers 12. Standards Compliance

The comparative analysis of approaches to the lean production principles in Table 1 shows that Womack and Jones offer the most concise version. The highlighted principles aim at the continuous improvement of the company's activities to achieve the product's consumer value. Liker suggests a more extended characteristic of the principles, focusing on personnel training. The approach introduced by Salomatin, Drobyshevskaya, and Isaeva is based on a comparison of lean production principles with certain types of production losses. The most complex set of principles is presented in GOST R 56020-2014, "Lean Production. Fundamentals and Vocabulary," which combines the first two approaches.

At the same time, all the studied approaches focus on the principles of value stream and pulling. In our opinion, these two principles most closely correspond to the conditions of innovative clusters. As noted, a complete innovation chain is implemented in terms of innovative clusters. At each stage, an additional product value is developed, which requires clear interactions among cluster participants based on the pulling system. Managing an innovative cluster from a single center creates wide opportunities for successful dissemination. Therefore, the value stream is optimized, and cluster companies' competitiveness is improved.

According to GOST R 56020-2014, pulling is an organization of processes where the supplier produces exactly as much as the consumer requires and only if necessary. The basis of pulling is the prompt exchange of information and long-term partnerships between consumers and suppliers. As a result, the close intracluster cooperation of its participants, their interdependence, and their focus on a single result create all the necessary conditions for pull principle implementation. A single value stream minimizes the traditional problems of satisfying the situational interests of unrelated companies.

The final product value is created in the industrial environment. However, its development is carried out throughout the whole chain, starting with the creation of a conceptual idea of the product. In the context of an innovative regional cluster, the implementation of the indicated principles of lean production can be as shown in Figure 2.

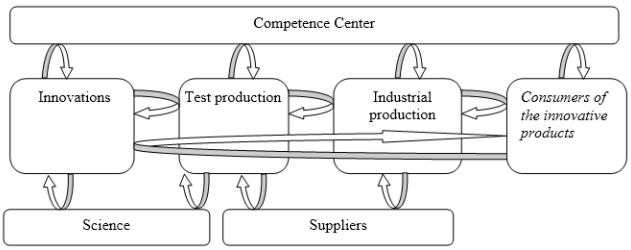

Figure 2. The model of pull principle implementation in the value stream of the product of the regional innovative cluster

It is clear that the pull system in an innovative regional cluster has fundamental differences from a similar system of the companies operating outside the cluster:

- A traditional value stream of the product (from creation and production to its consumption) is observed. There is also a significant dependence on the scientific component of the innovative cluster products. Thus, a close cooperation occurs between the production participants and science, especially at the test production stage.
- The role of the competence center is significant, since it is necessary at all stages of the product value stream. Innovations development needs not only competent product designers and personnel developing the scientific and technical ideas, but also a competent consumer. The use of a fundamentally new product may require the development of the consumer's intellectual abilities and practical skills, especially if it is a product for industrial purposes.
- There is the probability of a reverse pulling process, when a consumer does not need a product, but the producer develops such a necessity. Accordingly, firstly a fundamentally new product is created that has characteristics and properties unknown to the consumer. Then feasibility and functionality of the product is explained and it is offered to the consumer. But, at the same time, the direct pulling process is not excluded. During the innovative product testing, the consumer may have additional requirements for the product itself or its operation terms.

The identified peculiarities of the pulling system functioning in an innovative regional cluster contribute to the necessity of analyzing its applicability depending on the cluster model. Table 2 introduces the restrictions and opportunities characterizing the implementation of the lean production principles that can be applied to all organizational models of an innovative regional cluster.

Table 2. Characteristics of the implementation of the value stream and pull principles in an innovative regional cluster

Organizational model	Characteristic
On the basis of "anchor" high-tech enterprises	Restrictions. Dependence on large parent companies and state aid restrains the scientific initiative. Possibilities. Increasing the share of added value by means of value stream development and production losses reducing.
On the basis of leading scientific and educational centers	Restrictions. Significant dependence on the development of industrial participants and the suppliers' capabilities Possibilities. Innovation activity development basing on the generation of progressive scientific and technical ideas as well as on the improvement of the competence of all participants of the value stream.
On the basis of small and medium innovative business	Restrictions. Difficulties in creating sustainable relationships between cluster members and product consumers due to the lack of a coordinating center Possibilities. Significant collaboration and innovation activity of cluster members.

The restrictions and possibilities for applying the principles of lean production presented in Table 2 influence their effectiveness. This requires an economic assessment of such achievements in the general value stream in the regional innovative cluster.

In this regard, it seems appropriate to use the classical approach for the evaluation of the value stream in the lean production system, i.e. to determine the relationship between the value stream time of an innovative product and the total time spent on its production. Time indicators measurement of such an evaluation should be based on the facts that:

- Firstly, value stream implementation is aimed at achieving exclusively consumer, and no other value of the products (investment, share, tax, etc.).
- Secondly, the duration of the value stream is a comprehensive indicator that reflects the overall effectiveness of the principles of lean production implementation by all the members of innovative regional cluster involved in the value stream, beginning with the innovative idea design to its commercialization and introduction to the consumer.
- Thirdly, the total time of the value stream includes the total duration of all material and information flows [52-54].

In general, the formula for calculating the value stream efficiency for the innovative cluster product (Es) can be the following:

$Es = Tv/Ts \times 100\%$,

Where:

Tv – value added time,

Ts – total stream time, spent on product creation (the duration of the scientific production cycle).

Practically, in order to simplify the calculation of the indicator, the value added time is equated to the processing time. However, such a calculation is not accurate. Processing time is the sum of the cycle time of each operation. Value added time is the sum of the time of the operations, resulting with products with the consumer properties for which the client agrees to pay. Accordingly, not each processing time adds value to the product, as the manufacturer can develop such properties that will not be consumed, although increase the value of the product.

Thus, it becomes necessary to concretize the formula according to the criterion for identifying the true value of innovative products of a regional cluster in the process of its processing:

$Es = Tv/ Tpr \times 100\%$,

Where:

Tpr - product processing time of the research and production cycle.

Alongside with the effectiveness indicator, it seems appropriate to implement other indicators characterizing the value stream. Russian national standard GOST R 57524-2017 "Lean production. Value stream" defines the following main characteristics [39]:

1. Process effectiveness
2. Times of takts and cycles
3. Product stocks of in buffers
4. Cycle time of reverse processes

5. Process availability factors

In our opinion, due to the specific features of the functioning, it is reasonably to use only the indicators that reflect the interaction of all processes in the value stream with all involved cluster participants. There can be implemented the process effectiveness, product stocks in buffers, and cycle time of reverse processes. Their characteristics are presented in Table 3.

Table 3. Indicators characterizing the value stream in the innovative regional cluster

Indicator	Indicator Characteristic	Calculation formula	Explanation of Symbols
Process effectiveness (V)	Speed of value stream and movement	$V = \frac{C_2 - C_1}{\Delta t}$ $V = Tpr \ / \ Ts$	C2 – value on entry of the consumer process; C1 – value on entry of the supplier process; Δ_t – value-creating time – time between two consecutive process entries.
Product stocks of in buffers	The time of process if there is no supply at the right time, in the proper amount, to the right place	Tnorm = Tcur+ Ttr + Tac+ Tprep	Tnorm – stock norm, time; Tcur – current stock norm, i.e. storage time from delivery to supply; Ttr – delivery time; Tac – acceptance time; Tprep – preparation time.
Reverse cycle time (Tct)	Time for nonconforming products processing	Tct = m* Toc + n* Tob	m – number of operations in reverse processes; Tpc – average cycles duration of nonconforming products processing; n – the number of interoperation breaks within reverse processes; Tob – average interoperation breaks duration within reverse processes.

It should also be noted that beside the characteristics presented in Table 3, the consumer can be interested in such parameters as quality, safety, time of the related services provision, reliability, etc.

In our opinion, the indicators of the stream efficiency and its productivity, as well as the time of products stocks formation in buffers, and the time of nonconforming products processing should be regarded as universal indicators characterizing the value stream of the product of innovative regional cluster. Other characteristics are individual. They depend on the characteristics of the products and their application at cluster enterprises (commercialization level), intra-cluster inter-actions of the participants, organizational mechanisms for scientific and technical ideas, supply of the material and technical resources, and products.

4. Conclusion

Despite the fact that each participant of the innovative regional cluster has both restrictions and developing opportunities, the implementation of such principles of lean production as value stream and pull has a high degree of feasibility for any organizational model of the cluster. Practical use of these principles will allow for the development of value streams that reduce all types of production losses within the general cluster. In addition, it will create the necessary basis for increasing the share of added value from the cluster product and cluster effectiveness. The introduced system of indicators that characterize the value stream of innovative regional cluster products will create the basis for assessing the implementation of lean production principles.

The study focuses only on two lean production principles. However, the implementation of other principles is not excluded and may also have a high degree of importance both for individual companies in the regional innovative cluster and for the entire cluster as a whole. In our opinion, such principles of built-in quality and continuous improvement can also be scientifically significant. Investigation into the context of applicability for the regional innovative cluster requires further study. Accordingly, within the framework of new experience and the objective problems in the sphere of production systems development and increasing the effectiveness of cluster members, such issues can be developed in both theoretical and practical research.

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