

AGILE MANUFACTURING, COLLABORATION AND KNOWLEDGE CREATION: A PILOT STUDY FROM RUSSIA

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ABSTRACT

In the 21st century Agile Manufacturing and Knowledge Management are two realities that exist worldwide; both these realities benefit from each other and from the cooperation between enterprises. The modern knowledge-based economy is characterized by the integration of information and knowledge from different fields. So, organizations need mechanisms that are capable of generating or acquiring knowledge. The aim of this paper is to present the mechanism of collaboration of enterprises in the context of agile concept in Russian industry. Businesses should be integrated into dynamic networks formed around well-defined market opportunities so that knowledge can be shared. Through this process, knowledge is transformed into new products and services. A case study of industrial enterprises in Russia has been conducted from 2014 to the present. The study was made within a qualitative methodology based on techniques such as generalization, systematization, comparison, interpretation, using direct observation of a predefined and established pilot study. The continuously growing knowledge base is the most important result of the mechanism's action. In addition, such results as reduction of time of product creation, improvement of product quality, maximum satisfaction of customers' requests were achieved. Summing up, the use of knowledge management in the company based on flexible processes and the use of collaboration is an effective measure to maintain and improve the competitiveness of the enterprise. This study is a value for researchers in the field of industrial economics and industrial practitioners. And it might be replicated in other similar organization that might perform similar pilot studies.

Keywords: Agile Manufacturing, Knowledge Creation, Russian Industry.

INTRODUCTION

Since the early 2000s, some Russian companies have begun to introduce the concept of lean production. Over time, this example was followed by many enterprises of Russian industry. First of all, these are representatives of state corporations, large industrial groups, strategic enterprises of the Russian Federation, effectively functioning industrial enterprises. An analysis of enterprise data (about 100) revealed a number of features (Balashova & Gromova, 2017). There are two ways for Russian companies to master the above model of resource management. The first is the penetration of foreign companies into the domestic market, which are already actively applying the principles of lean production or providing consulting assistance on the implementation of the concept in enterprises representing the Russian economy. An alternative way is to self-interpret and align business processes according to this concept. It is noteworthy that the path of development is not of primary interest, since the main criterion for the

effectiveness of a particular management model is to increase the efficiency of performance indicators. In addition, the fundamental point is the set of tools used by enterprises. According to our own analysis, the distribution of enterprises according to the chosen path of implementation of the lean production concept is represented by the ratio: 84.52% - independently introducing lean production, and 15.48% - enterprises applying consulting assistance in introducing lean manufacturing. Among the organizations that assist domestic enterprises in the adoption of lean production principles are the following: Daimler, Boeing, Dupont, Renault-Nissan Alliance, Alstom Transport, McKinsey & Company, Schneider Electric, Pratt and Whitney, Snecma (SAFRAN Corporation), Lean Coaching, Lean Management Institute. The percentage ratio demonstrates the tendency of the self-introduction of this concept to prevail, based on the subjective perception and interpretation of the features of the above-mentioned business model of production organization, over the use of consulting services of third-party structures that are characterized by a well-developed and functioning resource management model questions and problems of the concept of lean production.

Turning to the analysis of lean production tools used by Russian enterprises, attention is drawn to the total superiority of such a tool as 5S (87.5%) - the applied methodology of forming and maintaining working order in the process of creating added value due to the apparent simplicity of the content of this tool and ease of implementation. Also noteworthy is the comparative variety of tools. Along with 5S, the following tools appear: Total Productive Maintenance (54.69%), Value Stream Map (39.06%), Single-Minute Exchange of Dies (34.38%), KANBAN (25%), and Total Quality Management (12.5%). Lean Production tools (26.56%) - Shop Floor Management, Hoshin Canri, Total Flow Maintenance, Total Service Management, SWIP, and Training within Industry - have been allocated to a separate group as under-demanded by Russian management.

The economic effect of the implementation of activities in the framework of the chosen development strategy is the main characteristic of the success of the enterprise (Table 1).

Name of the company	Year of introduction of the lean production	The economic effect in 2019, million rubles	Revenue in 2019, million rubles	The share of economic impact in revenue, %
PJSC "Motovilikhinskiye Zavody"	2014	205	4 197,452	4.88
JSC "TGC-1"	2011	1 229	65 173	1.89
JSC "Atomenergomash"	2007	354	48 600	0.73
ZAO "Aviastar-SP"	2008	22	6 747,033	0.33
Group "the Chelyabinsk pipe-rolling plant"	2014	182	97 184,656	0.19
Group "Novolipetsk steel"	2009	543	674 648	0.08
PJSC "SIBUR holding"	2011	170	285 545,215	0.06

The data shown in this table are basically from the first decade of this century or thereabouts. And more recently, but in the realities of the Fourth Industrial Revolution, dominated by digitalization, robotization and artificial intelligence agile manufacturing comes to the fore. Indeed, as a result of this new reality, industrial enterprises must adapt to the new environment. In this new environment, knowledge is a fundamental asset (Drucker, 1999;

Nonaka & Takeuchi, 1998). Also, in the new environment, collaboration seems to be decisive because for knowledge creation (Kianto, 2007) trust (Blomqvist, 1997) and dialogue (Nonaka & Konno, 1998) are essential.

Thus, the objective of the paper is to present the mechanism of enterprises' collaboration creating knowledge in the context of agile concept in Russian industrial sector of economy. Achieving this objective will help explain how enterprises can maintain and increase competitiveness in modern conditions taking into account the Russian reality.

In order to reach this objective the paper is composed by five sections namely, Literature review, Methods and Data, Results, Discussion and Conclusions.

LITERATURE REVIEW

The Knowledge Economy

The greatest scientist in the field of management P. Drucker described the period from the end of the Second World War until 2000 as the transition to a knowledge-based economy (Drucker, 1999). Traditional factors of production - capital, natural resources become of secondary importance, and knowledge becomes a key resource of the organization. Booth (1996) argues that organizations will succeed that can “*develop knowledge and adapt to change.*” Warner & Witzel (1998) suggested that the tasks associated with the acquisition, use, creation and dissemination of knowledge in the organization are priorities for the leader. (Albert & Bradley, 1997) noted the significant role of knowledge in the creation and increment of value. The result is that organizations need mechanisms that are capable of generating or acquiring knowledge. Knowledge Management (KM) (Shrivastava et al., 2021) is a relatively new scientific field which was built around the fact that Knowledge, considered as “*understood information*” is a decisive asset for organizations, people and regions. The main model used to analyze knowledge is the SECI model from Nonaka and Takeuchi, 1995. Nowadays KM is at the forefront of the understanding of companies and organizations (Ortenblad, 2014).

Agile Manufacturing

In today's reality, an industrial enterprise faces a number of challenges. Along with those that have already become standard, which consists in achieving a high-quality indicator and minimal costs, the following are becoming topical:

1. Reduction in time to market;
2. Increase in the rate of flow of production processes;
3. Accurate customer satisfaction;
4. Wide variety of product range;
5. Use of the latest technological advances.

Due to this business challenges agile manufacturing comes to the fore (Cooper & Sommer, 2018; Huikkola & Kohtamäki, 2020). Agile manufacturing (Goldman et al., 1995; Larman, 2004; Sutherland, 2014) is a concept of production organization based on foreseeing changes in the business environment and timely responding to rapidly changing market needs through the efficient use of internal and external resources. The company's production system, which supports the agile manufacturing principles, is based on the integration of organizations,

highly qualified and knowledgeable people and advanced technologies into a coordinated system to achieve a qualitative leap forward in the competition by providing abilities that exceed those obtained from the current practice of the company. Such an enterprise is a dynamic, flexible and reliable business unit capable of rapid reconfiguration in accordance with market opportunities. According to Kidd (1994), the fundamental resource for an agile enterprise is "knowledge". People should be brought together in dynamic teams formed around clearly defined market opportunities so that they can use each other's knowledge. Through this process, knowledge is transformed into new products and services.

The theoretical and practical aspects of this concept are studied by many scholars. Among them the following scientists are highlighted: Kidd (1994), Goldman et al. (1995); Larman (2004); Sutherland (2014), Gunasekaran (1998). In Russian industry, the concept is just beginning to develop. The latest works related to the agile approaches for generating or acquiring knowledge are noteworthy for their variability. So, Davenport (2015) describes alternative process-oriented approaches to knowledge work instead of traditional engineering-based approaches. Ghobadi & Mathiassen (2016) deeply analyze the barriers to knowledge sharing in agile teams from the point of view of their main members. Yanzer Cabral et al. (2014) identify and discuss the gap between knowledge management and agile methodologies. Andriyani (2017) considers knowledge management as an important aspect of one of the agile management techniques – retrospective. And Indian researchers (Singh et al., 2014) are trying to identify the level of knowledge management adoption of Indian software organizations which are using agile practices.

Cooperation between Enterprises

The expansion of cooperation between enterprises during the product life cycle is a current trend in the global market. As a result, various forms of interfirm cooperation of economic entities are becoming important.

Collaboration is one of these variations of interaction, which has developed relatively recently, since the beginning of the 21st century (Thompson, 2021). Tapscott & Williams (2008) define this concept as the generation of shared pools of industry knowledge and processes on which new developments are based by similar companies, including competitors.

M. Hansen (2009) introduces the concept of "rational collaboration", the idea of which is succinctly concluded in one phrase: "leadership practice of proper assessment, when to cooperate and when not, education in subordinates of the desire and ability to interact in necessary cases." A comparative analysis performed by a foreign scientific group (2009), that is actively engaged in collaboration issues looks remarkable. Scientists (Camarinha-Matos et al., 2009) draw a fine line between the concepts of "cooperation" and "collaboration", pointing out the fallacy of identifying these terms. In addition to the above, we also analyzed such types of interaction as networking and coordinated networking.

Collaborative Networks

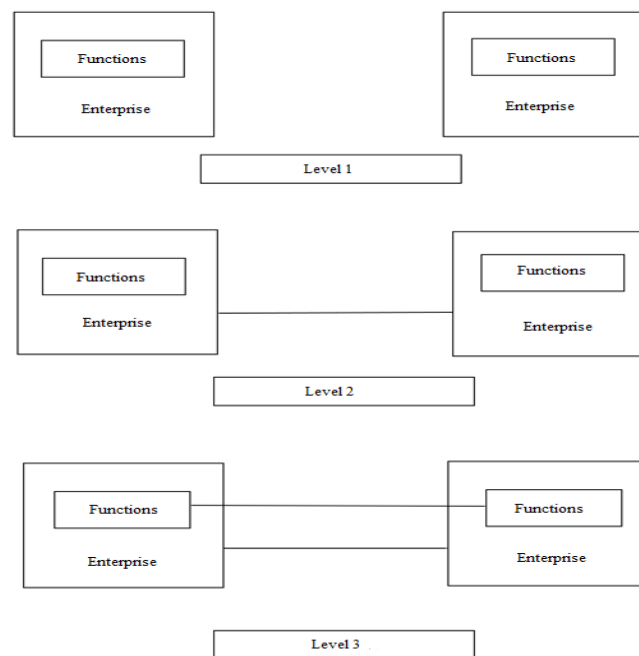
Each of the above concepts is a "building block" for the following definition. Coordination extends networking opportunities; cooperation expands coordination; and collaboration extends cooperation. Therefore, guided by this logic, the collaboration contains the entire elemental composition of these concepts. As you move from networking to collaboration,

the number of common target risks, liabilities and resources that participants must invest in joint efforts increases.

Thus, collaboration can be determined as a form of temporary cooperation of entities in which mutually beneficial cooperation takes place on the basis of agreement and trust, the exchange of knowledge and experience, production of products with likely innovative potential in order to achieve certain goals and significant cumulative effects.

The growing role of active production in the modern economy provokes the genesis of collaborative production networks that maximize the scope of activities and attract market opportunities. Collaborative networks consist of groups of objects, mainly autonomous, geographically distributed and heterogeneous, collaborating to achieve a common or compatible goal.

The nature of interaction in a collaborative network is clearly demonstrated by the dynamics of the development of partnership models Figure 1.



Source: Based on Yusuf et al. (1999)

FIGURE 1
DYNAMICS OF PARTNERSHIP MODELS DEVELOPMENT

The figure shows three levels of cooperation between enterprises, culminating in the collaborative network of enterprises. The first level represents businesses that act as isolated Islands. Interaction between companies at the corporate level with little or no communication at the operational levels is depicted on the second level. At the third level, businesses form a collaborative network and collaborate at both the corporate and operational levels. This circumstance allows the use of resources and diverse skills that are distributed through disparate organizations, which will be used and coordinated to produce products with a high degree of efficiency and in accordance with the requirements of the consumer, who becomes part of this interaction, which contributes to the maximum satisfaction of its requirements. Creating dynamic

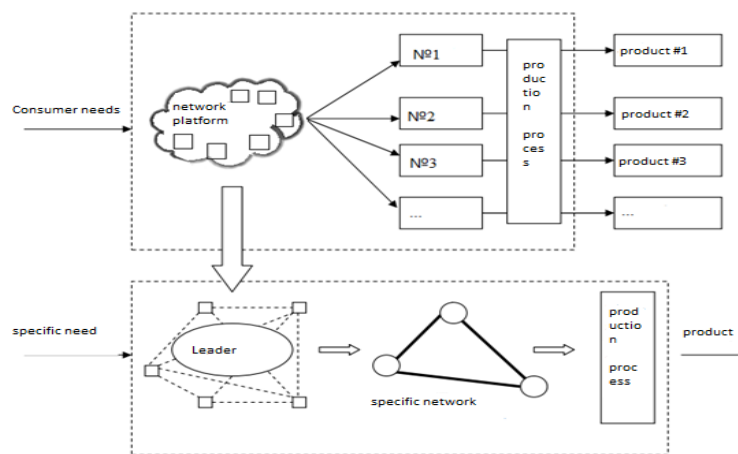
partnerships in response to changing market conditions to develop products that perhaps no individual partner could produce on their own is an important feature.

A collaborative enterprise network (Thakur-Weigold, 2021; Pirzadeh et al., 2021; Yang et al., 2021) is a mechanism that is a dynamically reconfigurable global network of enterprises sharing information, knowledge, skills, and core competencies, resources to achieve a mission or goal. This network is created as a temporary alliance to meet the rapidly changing market window of opportunity. In the network structure, a leader is singled out, that is, an enterprise that coordinates activities in order to improve management and increase the synergy effect from cooperation. Such an enterprise acts as a kind of system integrator, accelerating the organizational process, promoting cooperation between enterprises and teams from related fields of activity, and identifying the market opportunities of the business environment.

An integral attribute of this mechanism is a collaborative environment that operates in real time and unites partners through a collaborative network platform, which is considered a kind of digital platform. It contains tools for managing the production cycle and a general knowledge base (Gunasekaran, 1998). The collaborative platform expands the capabilities of the production network, providing the necessary functional potential of the software product, thus promoting innovation by incorporating knowledge management into business processes, with the goal of effectively sharing information between employees and, as a result, maximizing market opportunities. The organization of direct relationship with consumers, providing the platform’s rapid response ability to rapidly changing market conditions, plays a fundamental role.

How Does A Collaborative Network Work?

Figure 2 shows the mechanism of functioning of the collaborative network. At the top of the figure is a general view of a collaborative network platform consisting of enterprises potentially ready to form a network to meet a specific customer requirement. Each enterprise is theoretically capable of releasing a product with certain functional capabilities.



Source: Author’s own work

**FIGURE 2
THE MECHANISM OF ENTERPRISES COLLABORATION CREATING
KNOWLEDGE**

The bottom of the figure shows the principle of the mechanism of the collaborative production network. In this case, the specific market opportunity is determined. The leading enterprise initiates the formation of a partner network from the platform enterprises. The collaborative network consists of enterprises with key competencies necessary to fulfill a specific order. It is important that each partner cannot successfully act separately in the given business environment. The integration of core competencies contributes to the ability to produce the desired product.

Theoretical Model and Hypothesis

Based in all the above we speculate that in agile organizations, collaboration between companies develops knowledge management and this increases efficiency (Jaggi, 2021; Abrishamkar et al., 2021; Dao et al., 2017; Lotfi & Saghiri, 2018; Moghaddam & Nof, 2018; Ghobakhloo & Azar, 2018; Levy et al., 2021; Zhang et al., 2021).

(+AGILE --)+COLLABORATION --)+KM --)+EFFICIENCY

In the remaining of the paper we will present a pilot study that shows an application of this model in a Russian company.

METHODS AND DATA

Methodology

A pilot study conducted at PJSC Severstal and accompanied by interviews to some officials was the effective research method developed to achieve the objective of the paper. We describe the pilot study in the following section.

Data collection was carried out by studying the company's annual reports, analyzing interviews with top officials of the company (past and current Director of business system development of Severstal, managers of the center for business system development of Severstal, masters of production sites), a detailed study of the company's visual materials (videos, presentations, notes, Youtube channel materials, etc.), familiarization with materials that were presented at various scientific and practical conferences, visiting the official website of the company and specialized sites of this industry.

The Case Company

Define In this context, PJSC Severstal is of particular interest. In 2010, a set of principles and tools was formulated under the name "*Business System of Severstal*" aimed at introducing the necessary behavioral patterns among the company's employees and, as a result, the cultural transformation of Severstal and achieving the strategic goals of the company. Among the main directions of development were highlighted: labor safety, customer focus, continuous improvement, people, business standard. The business system has become a logical continuation of previous projects for the development of the company. PJSC Severstal has always paid special attention to production efficiency and has implemented several projects in this direction: "*Total Production Optimization*" (1998), "*Production Consulting*" (2000) and "*Continuous Improvement*" (2009).

In 2017, the company launched a major innovation program aimed at ensuring business growth without a significant increase in production volume (the company operates steadily with almost 100% capacity utilization). This program covers three key areas:

1. Innovative products.
2. Innovation processes.
3. Innovative business model.

It was within this innovation program that the pilot study described and analyzed in this paper was done.

RESULTS

The Pilot Study Main Features

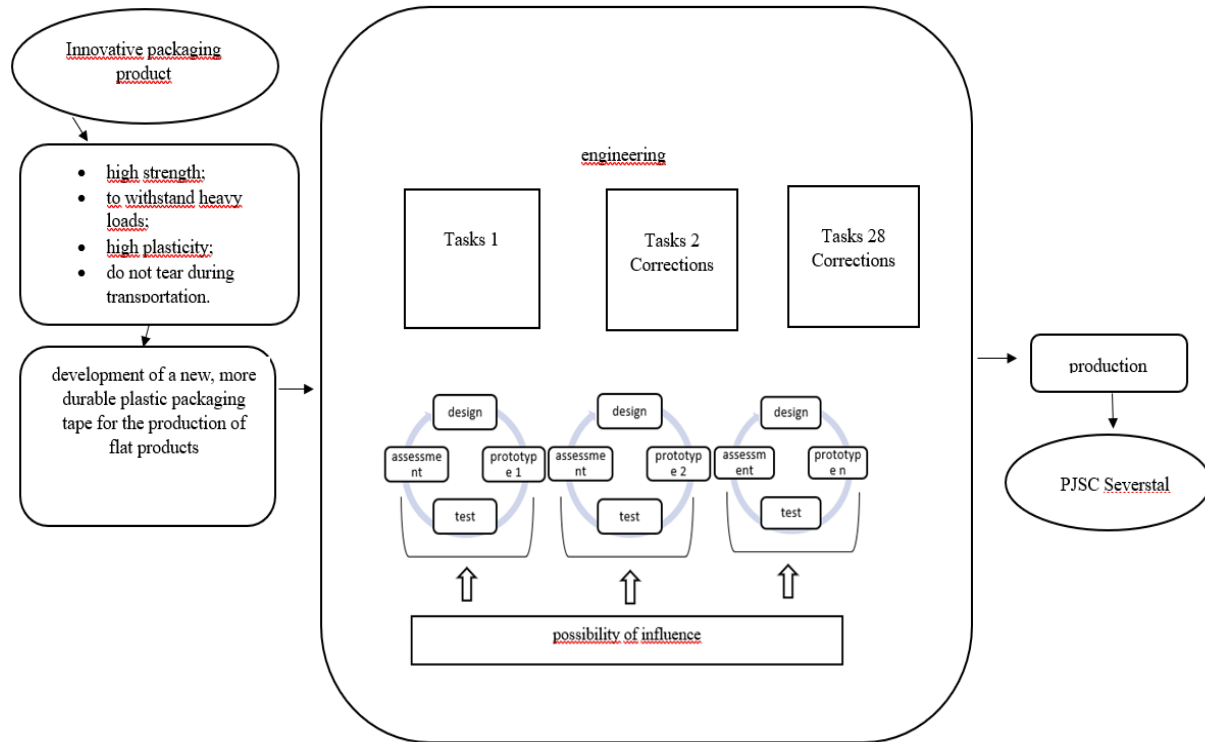
Place of approbation	Cherepovets Metallurgical Plant (PJSC Severstal)
Goal	New product development
Concept	Development of a new, more durable plastic packaging tape for flat products
Tools used	Task burnout diagram, scrum-meeting, retrospective, task board, value flow map, work in progress diagram, customer involvement
Characteristics of short cycles	Only 28 cycles, the duration of each - 2 weeks
Success criterion	The single success criterion is to bring the finished product to the customer, satisfy it, and bring the company's profit
Result	The term of the product creation was 9 months, instead of 2-3 years, obtained using traditional methods, that is, acceleration of the product launch to the market more than 3 times
Project period	2017

Source: Author's Work

The focus is on the goal of the project, the tools used, and the results achieved in the context of agile manufacturing. The indicators characterizing the result are compared with similar indicators of the result in the framework of the traditional approach to the organization of production (Table 2).

The Technical Base of the Project

Schematically, the tool - technical base of the project is reflected in Figure 3. This figure describes the logic of the organization of production in the framework of agile manufacturing with a focus on the tools used. At the beginning, the product that needs to be produced is contracted. The following are descriptions of the requirements of the external environment, which are decomposed to the basic characteristics of this product. The central part of the figure is the implementation of an incremental-iterative orientation of agile manufacturing. And further it is noted that this project is being implemented for the needs of PJSC Severstal.



Source: Developed by the author on basis of the approbation of the new production organization in PJSC severstal

FIGURE 3
THE TOOL TECHNICAL BASE OF THE PROJECT PACKAGING TAPE>>

The tool-technical base, which is used in the Severstal, has an incremental-iterative form. This form is a key feature of agile manufacturing. It is clear that in two weeks it will not be possible to bring a partially finished new product to the market and then finish building it. But significantly reduce the path leading to the emergence of a new product, it is absolutely possible. And every two weeks, it is possible to adjust the direction of its movement.

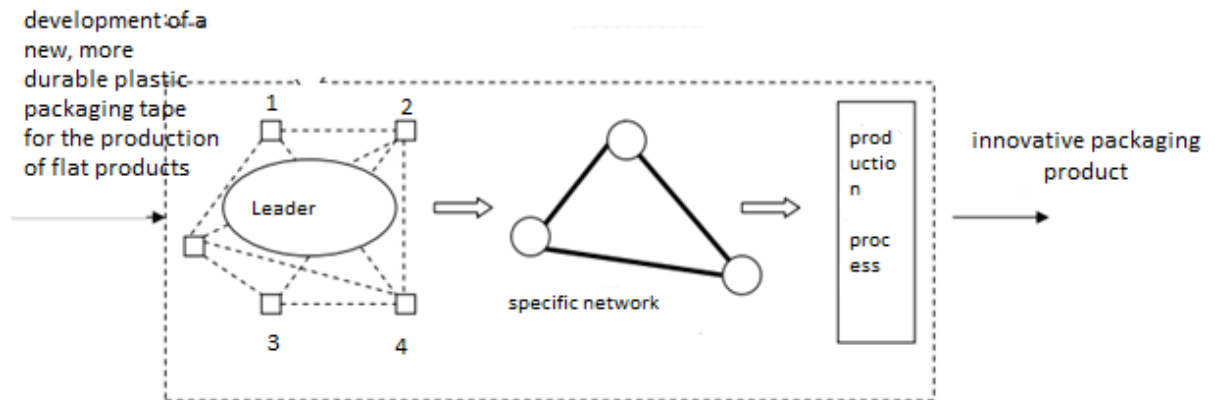
The principles underlying the project are a single cross-cutting goal, inspiring and unifying which is the result of rational collaboration; culture of trust - ensures the independence of teams; radical transparency; clear boundaries; constant experiments.

The Pilot’s Study Aim

The pilot project aim was to develop a new type of product. Namely, the development of a new, more durable plastic packaging tape for the production of flat products. The plan was to release a new product not only for internal customers, but also for external ones. One packing tape was used in almost every redistribution of metallurgical production. According to Konakov, the foreman of the site of the cutting units of the metal finishing department No. 2 of the Cherepovets Metallurgical Plant, in his workshop the packing tape is used for packing sheets of sheets, as well as for packing rolls. Therefore, the new tape should have high strength; withstand heavy loads, as well as high ductility so that it is not torn during transportation.

The Team and the Collaboration Process

The team consists of employees of the directorate for sales, marketing, technical quality development, customer support services. The leader of the team is the Business System Development Center. Schematically, the mechanism of enterprises' collaboration (bottom part) is shown in the Figure 4 (1-is directorate for sales, 2-is directorate for marketing, 3-is directorate for technical quality development, 4-is directorate for customer support services and leader is Business System Development Center).



Source: Author's own work

FIGURE 4
THE MECHANISM OF ENTERPRISES COLLABORATION IN SEVERSTAL
(BOTTOM PART)

Such a team has a single criterion of success - to bring the finished product to the client, satisfy the client, and make a profit for the company. In their work, experts used a whole range of tools: scrum-meeting, retrospective, sprint planning. These tools allow you to solve problems independently, promptly and efficiently.

The Pilot Study Results

Thanks to the scrum-approach, the experts at the beginning selected the optimal chemical composition, which should satisfy the customers' requirements for the packing tape. Next the new product was tested. After that, the customer and the cross-functional scrum team reached a final agreement, and they were engaged in the release of a new cold-rolled tape for flat-rolled products.

In the end, the increase in efficiency was clear: the product creation period was 9 months, instead of 2-3 years, obtained using traditional methods, that is, acceleration of product launch to the market by a factor of 3 times. According to Smirnov, manager of the Severstal business system development center, the speed is achieved through tools such as a retrospective, that is, discussions at the end of two-week sprints, which turned out those further actions, did not work. Kolobov, Director of Business System Development "*Severgrupp*" argues that the use of the mechanism of enterprises' collaboration in the work helps in conditions of "*very large*

uncertainties." He emphasizes constant contact with the client as an integral part of successful activity.

The pilot project was recognized as a success in the company. In 2018, about 30 projects were implemented in completely different areas.

DISCUSSION

Agile manufacturing has not yet received significant distribution in Russia both at the theoretical and at the practical level. This project is one of the first attempts to introduce the mechanism of company departments' collaboration creating knowledge in Russian industry.

The modern development of the world community, characterized by the highest speed with which changes occur, the globalization of markets, the transition from centralized business models to open ones, from forms of rivalry to cooperation, adherence to network structures, the growing importance of satisfying individual consumers, the development of information and communication technologies, dictates new conditions for the organization of successful production activities. The expansion of cooperation between enterprises during the product life cycle is a current trend in the global market. As a result, various forms of interfirm cooperation of economic entities become important.

In the new realities in competition, not the one who is larger or has a long and successful development history wins, but the one who brings the new product to the market faster and retains the customer. Borovkov (2016) confirms: *"The key thesis is time to market. We are now witnessing the window of opportunity slamming in front of entire corporations and industries. The window existed for a year or two, during which time it was necessary to have time to enter the market. If this did not work out for some reason, you will have to wait for the next window."*

Production has undergone many evolutionary stages and paradigm shifts - from the handicraft industry to mass production; then to lean production and, further, to agile manufacturing.

The above evolutionary stages are reflected in the Russian industrial sector of the economy. According to a study of industrial enterprises in Russia, which has been conducted from 2014 to the present, the government of the Russian Federation has embarked on import substitution and structural economic changes, which implies the actualization of the issues of increasing the competitiveness of Russian industry. In this regard, it is worth noting the need to implement effective models for managing industrial enterprises and organizing internal processes.

The mechanism of enterprises' collaboration creating knowledge is effective and appropriate to the agile concept tool to maintain and increase competitiveness. It was confirmed by the example of the Russian industrial sector of the economy.

The limitations of the research are not for production of standard products, but for performing a high-tech project (product, service) that is produced in small batches or single copies. Russian reality is an important feature of this paper too.

CONCLUSION

This work considered the mechanism of collaboration of enterprises in the context of the agile concept which is capable of generating or acquiring knowledge. Main conclusions are:

The essence of the mechanism of enterprises' collaboration of the production network is to create a single information space in which supply chains for a specific customer order are promptly generated based on the flexible attraction of resources from various enterprises. The supply chain is formed dynamically from a variety of alternatives, depending on the specific requirements of the customer. The objective is the ability to quickly respond to the demands of a wide range of markets and to maximize the use of resources by the enterprises involved.

In Severstal, the mechanism of enterprises' collaboration creating knowledge was implemented at the micro level, that is, between different departments of the company. The pilot project in the company was recognized as successful.

Knowledge and skills are divided into individual and collective. Individuals are partners of the collaborative production network, and collective ones refer to the network as a whole. These two types of knowledge and skills influence each other dynamically. There is a pattern: partner companies contribute to the knowledge of the collaborative production network, and the network in turn enhances the knowledge of partners. They are one of the most important sources of innovation and competitive advantage of the company. The continuously growing knowledge base is in the long term the most important result of the mechanism of enterprises' collaboration.

This pilot study confirms the possibility of building collaboration between departments of the enterprise. A possible continuation of this study consists in the presentation of the implementation of the mechanism at the macro level (between enterprises), that is, the full implementation of the theoretical model of the mechanism in practice. This is a prerequisite for Russian companies to participate in collaboration on a global scale that will create a global knowledge base.

Practical recommendations on implementing the mechanism of collaboration of enterprises in the context of agile concept in order to increase the competitiveness of industrial enterprises:

1. Monitor the current state of the enterprise;
2. Determine the goals and objectives of implementing this mechanism at the enterprise;
3. Form cross functional teams;
4. Start working within the initial cycle of the "short cycles" model and continue to adhere to the principles of this model;
5. Evaluate the results obtained.

For example, in metallurgy, mistakes are quite expensive, since the minimum batch of new goods is 350 tons.

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