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Editor's office address: 190020, St. Petersburg, 43–45 Staropetrgofsky avenue, B, of.4H

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Formation of a value proposition for clients: Theoretical approaches and understanding of representatives of Russian companies

A.V. Trachuk[1, 2]
N.V. Linder[1]
V.O. Tuayev[3]
[1] Financial University under the Government of the Russian Federation (Moscow. Russia)
[2] "Goznak" JSC (Moscow. Russia)
[3] "Unilever – Russia" JSC (Moscow. Russia)

Abstract

The paper is devoted to a comparative analysis of theoretical approaches to the formation of a value proposition and its understanding by representatives of Russian companies. The existing theoretical approaches to the formation of a value proposition are considered, as well as the main tools used in its formation in practice. To determine the theoretical approaches, more than 50 articles from leading economic journals were analyzed. To analyze the understanding of the value proposition, Russian companies conducted in–depth semi-structured interviews with managers of 84 Russian and foreign companies representing customer service departments, sales departments, innovation activities, strategic management, marketing and brand management departments.

The analysis has shown that for most employees of companies, the concepts of a value approach in management and a value proposition are limited to standard categories, such as price, quality, and direct satisfaction of needs. This is especially true for representatives of Russian companies and firms that conduct their business only within Russia and CIS countries. While representatives of international companies noted the importance of the entire range of value formation tools in one way or another evenly, respondents from Russian companies clearly relied on product components and price in their answers. It should also be noted the leadership of product tools in both cases, and if Russian respondents focused only on the quality of the product in their answers, then representatives of international companies often noted the importance of the assortment and uniqueness of products.

The result of the study was to determine the importance and place in the process of forming a value proposition of such tools as joint value creation with the consumer and the involvement of personnel in joint value creation.

The author's approach to the formation of value proposition by companies is proposed in the article. The proposed matrix model allows you to quickly determine which factors and tools companies need to focus on first.

Keywords: consumer value, joint value creation, value creation models, value proposition, value innovations.

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Introduction

The current dynamics of macroeconomic indicators is characterized by a decline in GDP, an increase in inflation, a fall in real monetary incomes of the population and a reduction in effective demand. Macroeconomic trends have a negative impact on effective demand and, accordingly, change consumer behavior. This, in turn, makes it necessary to transform the value proposition of companies.

However, at the present stage there are no empirical studies of how the concept of a value proposition is defined by the management of modern companies, and what tools are used for its formation. Such a study is especially relevant in connection with the fact, that these are practitioners, who are responsible for the implementation of the value generation strategy and the choice of business models by modern companies. The study of a value proposition formation from the academic and practical point of view is significant both for research scientists and for representatives of the management in modern companies, as it allows us to develop a unified platform for understanding management practices. The results of this research will contribute to the mutual study of management practices and their wide dissemination among Russian practitioners and company management. Unity in understanding of the value proposition and the tools for its formation contributes to bridging the gap between the theory and practice of strategic management. It is especially important for companies operating in emerging markets, including Russia, where companies apply theories worked out for developed markets. Therefore, the study of the opinions among management representatives in Russian companies is of particular interest.

The purpose of this article is to identify differences in the definition of a value proposition concept by researchers and representatives of the management in Russian companies. To achieve this goal, first of all, the points of view existing in the academic literature were analyzed and current models and tools for creating a value proposition were considered. As part of the empirical study, in-depth interviews were conducted with representatives of domestic and foreign companies operating in the Russian market.

The structure of the article is as follows: in the first part, the theoretical provisions related to the concept of a value proposition, models and tools for its formation are given, then the methodology of the study is presented, in the final part the results are described and conclusions are drawn.

1. Theoretical review. Approaches to understand customer value

There are quite a few different perspectives on value and customer value creation [Windsor, 2017]. At the same time, there is still no single approach to understand the value, either in theory or among practitioners.

The first studies of value belong to A. Smith who used the paradox of water and diamond as an example and showed the importance of the difference between value in exchange, on the one hand, and value in use, on the other. Subsequently, the notion of value as exchange value introduced in “The Wealth of Nations” by Smith became the predominant definition of value in economics [Vargo et al., 2010]. According to this logic, value is created when the price consumers pay for goods or services exceeds the production.

However, the changes taking place in the economy: globalization, technological development, new methods of competition have led to a transformation in the understanding of value as an exchange value [Gummesson, Mele, 2010; Vargo et al., 2010].

The most important turning point in the evolution of the value concept was the shift in focus to a consumer. In a rapidly changing competitive environment a business can no longer consider a consumer only as a source of income and a homogeneous mass of customers. A deep understanding of customer value and, accordingly, the formation of an effective value proposition by the company are coming to the fore.

The development of marketing concepts has led to the understanding that consumers do not receive value directly from the product itself but rather from its use or consumption, as well as from interaction with other entities interested or involved in the value creation process [Katzan, 2008; Polese et al., 2017]. Later, this understanding initiated the development of value co-creation theory [Akaka et al., 2014].

M. Rokeach's theory of consumption values interprets the term "value" as a belief that any form of behavior or final state of existence for a person or society is more preferable than the opposite one [Rokeach, 1973]. This allows us to conclude that value predetermines consumer behavior model, consumption style, lifestyle, the choice of certain services and goods, on the basis of which it is possible to determine the consumer's propensity for specific brands or values.

The article [Gallarza et al., 2011] identifies two dimensions of customer value – economic and psychological. The first is connected with the price and determines the transactional value, the second relates to the value that can have an emotional and cognitive impact on the choice of a particular brand or product.

In the literature the use of the terms value proposition or customer value is quite widespread. Value proposition is a certain set of benefits that the seller can provide to the consumer in exchange for any unit of value (in monetary or other beneficial form). R. Kordupleski was the first to use the concept of customer value in his writings: “value proposition is a business or marketing statement (main position) that describes why customers should purchase a product or use a service” [Yar Hamidi, Gabrielson, 2018]. F. Kotler characterizes the value perceived by the buyer as “the difference between the total value of the product for the consumer and its total costs”. The total value for the buyer is “the totality of benefits that he expects to receive by purchasing a product or service”, and total costs are “the sum of costs expected by the buyer when evaluating, receiving and using a product or service” [Kotler, 2006]. According to the theory of J. Narver and S. Slater, the concept of consumer value is the result of comparing the benefits received by the consumer as a result of the acquisition and use of a product and the costs of getting this product [Narver, Slater, 1990].

It is important to note that the above definition of consumer value reflects to a greater extent its essence as a category that ensures the unity of price and quality due to the fact that the consumer compares the benefits that he receives from the product with its price.

The work of Nagle and R. Holden mentions that the economic benefit for consumers is the price of the best alternative for users – the reference price and the value of any differences between a product offer and an alternative one, the value of differences [Nagle, Holden, 2002]. From the point of view of J. Forbis and N. Mehta, the economic attractiveness for the recipient is the winning amount that the buyer will be willing to pay with a parallel complex of the estimated value of the product offer and other available offers [Forbis, Mehta, 1981]. M. Christopher also defines value as "the amount of money representing the difference between the monetary equivalent of perceived benefits and the price" [Christofer, 1982].

V. Zeithaml noted that consumer value is “a buyer's overall assessment of the usefulness of a product based on the perception of what he receives and what he gives in return” [Zeithaml, 1988]. This leads to the fact that the basis of customer value is a comparative analysis of the benefits and costs perceived by the consumer. A significant number of researchers adhere to this point of view. K. Monroe recommends using the value-benefit-cost formula [Monroe, 1990]. Because of the fact that this approach is one-dimensional, it partially simplifies the assessment of value and does not provide the opportunity to obtain complete data for a subsequent analysis. For this reason, other researchers adhere to the application of a multidimensional approach in which economic, functional, emotional and psychological aspects are distinguished. After all, a complex value representing a multidimensional object consists of the following elements: as the perceived price, benefits and risks on the part of the consumer, quality, brand, service, etc. Another interpretation was proposed by P. Woodruff, ex-president of the Coca-Cola Company. In his opinion, "customer value is the perceived advantage by the consumer when evaluating the properties of the product, the attributes of its presentation, as well as the consequences of its use, which contribute to the achievement of the goals and objectives of the consumer in relation to a particular case of using this product" [Woodruff, 1997].

Key approaches to understanding customer value are presented in Table 1.

It is important to note the fact that the process of identifying customer value and creating a value proposition can only be effective with the joint involvement of the maximum number of participants, company divisions, as well as with the unconditional involvement of consumers. In addition, customer-focused companies are able not only to produce goods and provide services in accordance with needs, but also to influence the formation of needs, the

Table 1
Key aspects of understanding consumer value

Key aspects of understanding consumer value	Authors
A certain form of end state or behavior for a person (consumer) or society is more preferable than another form	M. Rokeach, 1973
A value proposition is a business, statement, or positioning that helps the consumer understand why they should buy a particular product or service.	R. Kordupleski, 1980
Value is expressed as a monetary amount, being the difference between the price and the benefit that a product or service actually brings.	M. Christopher, 1982
Consumer evaluation of product or service benefits which is based on the perception of what a person gives and what he receives in return	W. Zeithaml, 1988
The result of comparing the benefits received after the acquisition of goods with material costs	S. Slater, 1990
The feeling by the consumer of that advantage in evaluating a product or service, its attributes, as well as the consequences of use, which contributes to the achievement of the original goals and satisfaction of a particular need	R. Woodruff, 1997
The whole set of benefits that a consumer expects to receive by purchasing a particular product or service	F. Kotler, 2006
The economic dimension of value in the form of transactional value, as well as the psychological aspect of value associated with the direct impact of a cognitive and emotional nature	M. Galarza et al., 2011

Source: compiled by the authors.

creation of value using all their experience and knowledge.

Woodruff in his work describes three key stages that allow to understand the essence of the value perceived and desired by the consumer [Woodruff, 1997]. At the first stage, the consumer studies a particular product or service, as well as the attributes associated with it. After purchasing and using the product, the consumer has a set of emotions, desires and preferences associated with a consumer experience from using the product, which is the second stage. In the third stage, consumers focus on achieving their specific goals with the product and satisfying needs based on desired consumer experience. This model describes desired and perceived customer value, allows you to understand exactly how the consumer evaluates a product or service, what goals he pursues, as well as what feelings and emotions he experiences in the process of consumer experience [Woodruff, 1997].

J. Simova in her works studies consumer value based on price and quality indicators, including the benefits and risks that the consumer receives in the process of using products, both tangible and intangible ones [Simová, 2009]. This structure of value based on value for money allowed Simova to expand her concept by adding new elements of value to it. The model describes the benefits that the consumer receives in the process of using the product and the risks that he may incur. Benefits can be represented by the following elements of customer value: functional (product or service quality), psychological (psychological, emotional, cognitive), epistemic value, brand value, service process value, and value associated with other secondary conditions. The following aspects can be attributed to the risks: time, price, transportation costs, ease of use, availability, resources expended, maintenance costs, as well as other opportunity costs that directly affect customer satisfaction.

Kotler describes one of the most effective types of modern brand promotion – experience marketing – as "marketing using positive life experiences and positive impressions of consumers who are prone to searching for new, unusual sensations. Sellers have to think more and more not only about selling a product or service, but also about developing and offering a positive experience to the consumer. It is necessary to take into account positive impressions that consumers already have when buying a product or service and find a way to imitate such impressions" [Kotler, 2008].

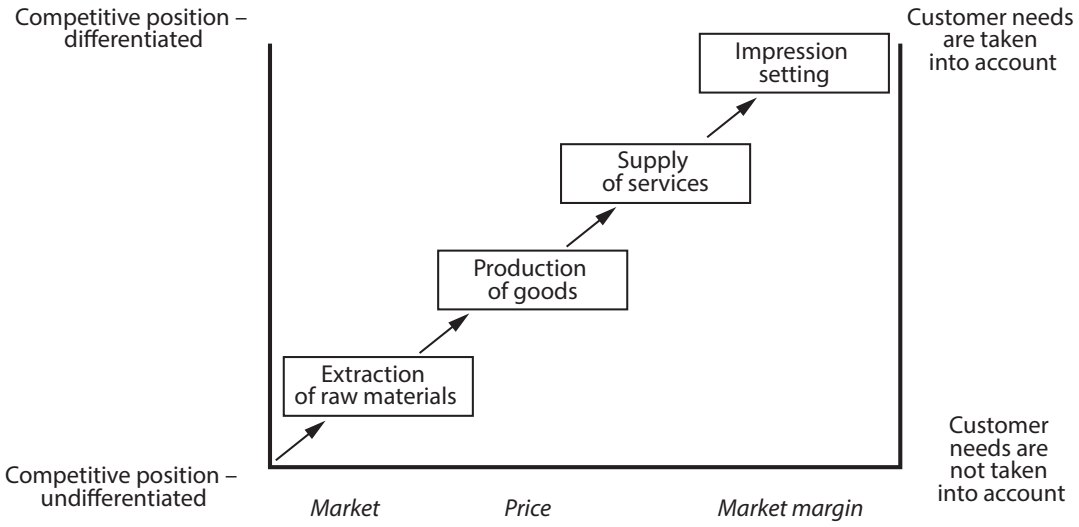
J. Pine and J. Gilmore consider impressions as the fourth economic proposition and believe that this is the key factor in effective business growth [Pine, Gilmore, 2005]. Firms claiming leadership positions in the industry simply have to use the tools of experience marketing in the current market conditions. The process of customer value evolution proposed by Pine and Gilmore is shown in Fig. 1.

Obviously, all previous types of economic proposals and approaches to value affected the inner world of a person, his emotions, while impressions are individual to a lesser extent; they are the result of indirect interaction with the buyer at an intellectual, emotional and physical level. Kotler notes that "modern companies need to understand that they produce experience, not products, and add value to customers rather than provide services. Consumers crave experiences and wish for paying money for them" [Kotler, 2006].

Despite the fact that the economic proposal is increasingly taking on an intangible form, its value is becoming more significant and tangible. Pine and Gilmore in their work note that "people save on goods to buy more services, so they save time and money on services in order to acquire more valuable experience for them" [Pine, Gilmore, 1998]. That is, companies setting themselves the goal to achieve the greatest possible satisfaction of consumers should offer exactly the experience, strive to form an emotional attachment to the brand along with rational preferences, which mainly affects the degree of need satisfaction.

Table 2 presents the key elements of the consumer value category.

Fig. 1. Evolution of consumer value



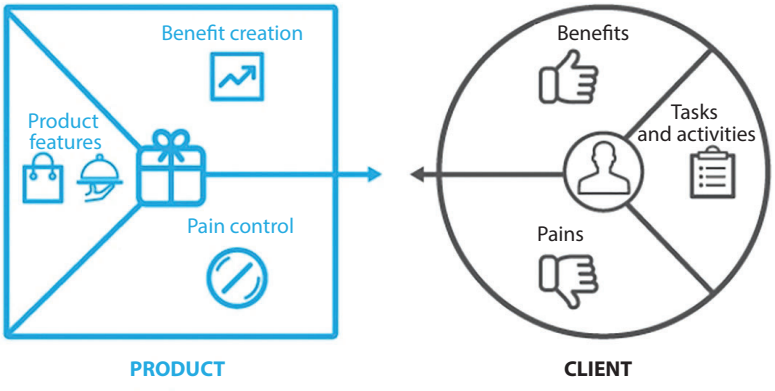
Source: [Pine, Gilmore, 2005].

Table 2
Key elements of the "Consumer value" category

The elements of consumer value	Authors
Consumer value is utility, price and quality	[Lapierre et al., 1999]
Consumer value is the best balance between price and quality of a product.	[Day, Crask, 2000]
Value for the consumer is an exclusively emotional perception of the product which is formed under the influence of consumer experience and product characteristics, the consequences of consumption, and the consumer's personal values.	[Brunso et al., 2004]
Consumer value is the functional, utilitarian, physical satisfaction of the consumer.	[Pura 2005]
Value for consumers is not only the functional conformity of the product but also the satisfaction of some social norm ("successful person", "business", etc.)	
Value for consumers is the functional, social and aesthetic satisfaction of consumption	
Value for the consumer consists of the ratio of four elements: emotional satisfaction, satisfaction of social needs, quality, price	[Sweeney, Soutar, 2001]
Value for the consumer is emotional satisfaction, satisfaction of social needs, quality, price, brand possession.	[Wang et al., 2004]
Value for the consumer is new, the possibility of obtaining new knowledge, new information, possession of something new	[Spiteri, Dion, 2004]
Customer value is the added value between the benefits and costs of using a product.	[Zeithaml, 1988]
Customer value is dynamic and situational. The consumer perceives value in many ways depending on different settings and contexts	[Sweene, Soutar, 2001]
Value for the consumer depends on the preferences and assessments of the consumer, including the degree to which his goal is achieved, the value received and further opportunities and consequences.	[Woodruff, 1997]

Source: compiled by the authors.

Fig. 2. A. Osterwalder's model of value proposition formation



Source: [Osterwalder et al., 2017].

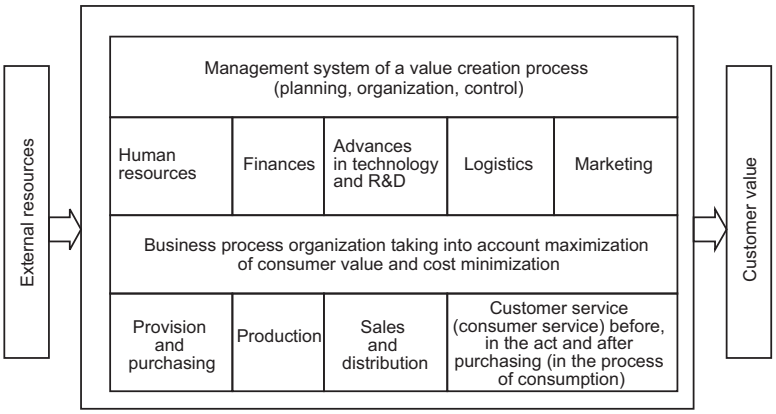
2. Models of forming a value proposition

A value proposition is most often understood as the totality of those benefits and advantages a business is ready to offer to a consumer. Examples of such benefits include novelty, customization, performance, convenience, uniqueness, design, brand, price, and many other factors.

One of the most common models for forming a value proposition is the model of value building proposed by A. Osterwalder [Osterwalder et al., 2017]. A template for the complex construction of a value proposition is shown in Fig. 2.

The model consists of two understanding blocks – a product and a client, all of which are divided into three segments corresponding to each other, with mutual consideration and comparison of which one can come to the construction of an effective value proposition. When compiling a

Fig. 3. Structure of the process of creating value for the consumer by Yudin and Yuldasheva



Source: [Yudin, Yuldasheva, 2012].

consumer profile and a value map as well as with further qualitative comparison of segments to each other, it seems possible to build an effective value proposition that allows you to meet the needs of the customer base and, if possible, even exceed the consumer's expectations from the offered products or services.

O. Yudin and O. Yuldasheva identify six key elements in the formation of a value proposition [Yudin, Yuldasheva, 2012]:

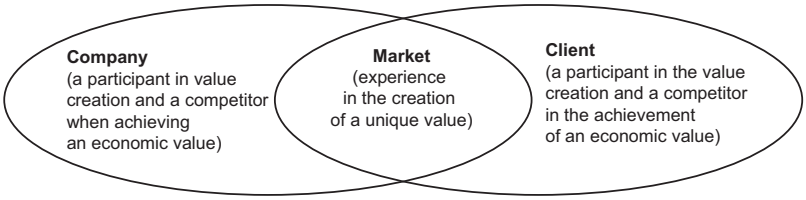
- product, service (key features);
- information characteristics (recognition, brand, positioning);
- after-sales service;
- terms of payment and purchase;
- offer price;
- product consumption technology.

These elements are of particular importance in the process of creating a value proposition, since each of them is necessary to form customer value. It is easy to imagine that the absence or low level of at least one of them can significantly destroy the whole complex of a value proposition and turn the consumer away from the company's offer.

Yudin and Yuldasheva offer in some way a more modernized and complex model of value creation, taking into account network communities (Fig. 3). An important distinguishing feature is the division of the model into four levels arranged according to the degree of their impact on a value creation process.

According to Yudin and Yuldasheva, this model is of particular importance in the process of forming a value proposition, since "these are the areas that provide long-term competitive advantages and the development of the company's competencies" [Yudin, Yuldasheva, 2012].

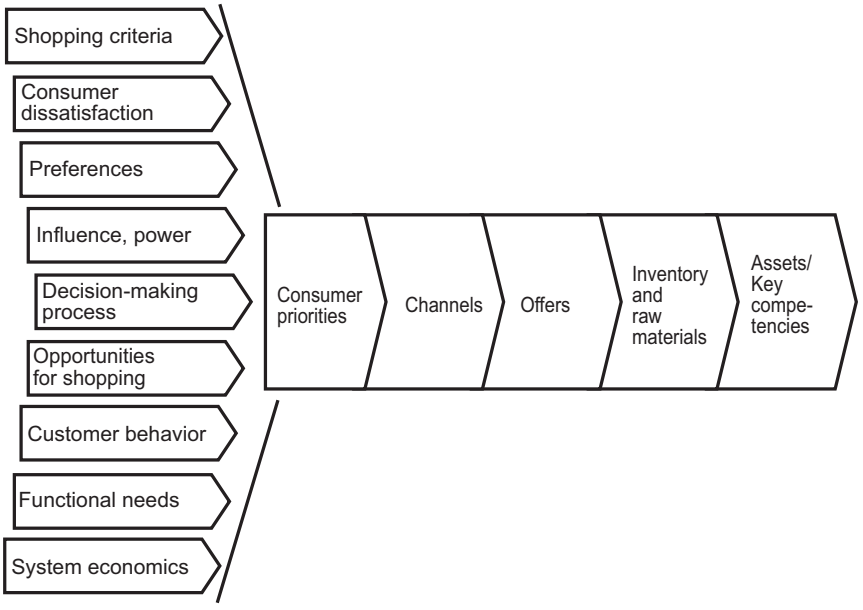
Fig. 5. The value creation model in the interaction of the company and the client, Prahalad and Ramaswamy



Source: [Prahalad, Ramaswamy, 2004].

The value creation model proposed by A. Slivotsky and D. Morrison is shown in Fig. 4. Here the chain is built in the direction from the consumer to the company, where the main source of forming a value proposition is the behavioral characteristics of the consumer, his decisions and preferences.

Fig. 4. The value chain according to Slivotsky and Morrison



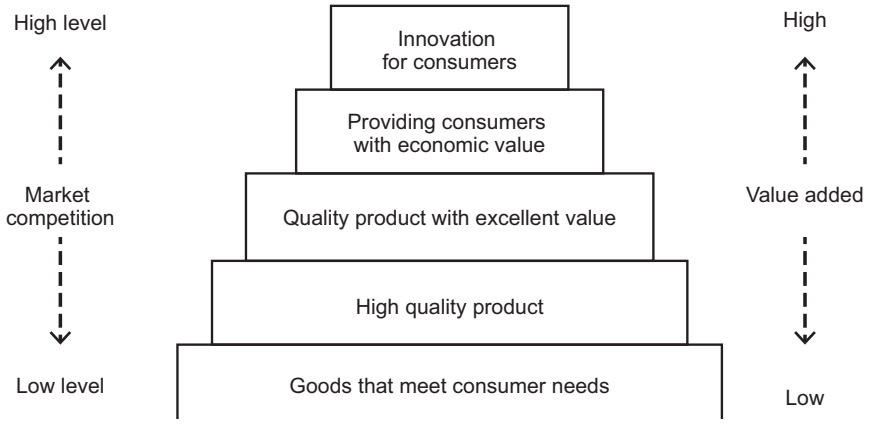
Source: [Slivotsky, Morrison, 2003].

Thus, in this model, processes such as production, resources, transportation, management, distribution channels, etc., are secondary. The source of forming a value proposition is the consumer himself, and everything else only serves his interests.

As part of a value proposition creation, the quality interaction between the company and customers is of undoubted importance. According to K. Prahalad and V. Ramaswamy, in the context of the current market competition, the key link in value formation is precisely the partnership between the consumer and business, where the market is a kind of platform for the implementation of this interaction [Prahalad, Ramaswamy, 2004].

The authors believe that the client is able to be actively involved in the process of forming a value proposition and identify

Fig. 6. The ladder of increasing the value of the product for consumers, P. Doyle



Source: [Doyle, 2001].

two important principles underlying the proposed model [Prahalad, Ramaswamy, 2000]:

1. Interaction is an important component in value creation for the company and the client.
2. Shared experience is the basis for value.

Prahalad and Ramaswami also note in their papers that "customers are part of the ecosystem, they create and extract business value; customers are co-producers of personalized experience; the company and consumers should have common goals in education, formation of impressions (experience) and in joint creation of company recognition in the market of goods and services" [Prahalad, Ramaswamy, 2000].

K. Gronros and P. Voima also consider the consumer as the main partner in value creation, calling him a key resource in the successful development and growth of the company [Grönroos, Voima, 2012]. In their opinion, the company is capable of producing only potential value, but the client himself can have a direct impact on what exactly the final product should be.

In turn, A. Helkkula and K. Kelleher also believe that "the client not only determines the value, but holistically forms it in the process of his experience" [Helkkula, Kelleher, 2010]. In their opinion, value is a fairly dynamic category and directly depends on changes in public sentiment and consumer preferences. Voima et al. in their papers say that "consumer experience is a constantly evolving process that contributes to the formation of value, taking into account past, present and future experience" [Voima et al., 2010].

According to Ramaswamy, "value is increasingly being formed together with the firm and the client, and not just within the framework of the firm" [Ramaswamy, 2011]. Today's client is looking for freedom of choice when interacting with a company through a large number of events and experiences. The market, in turn, considers the customer not as the ultimate goal for its offer, but as a key source of value creation [Ramaswamy, 2011]. Following this, Ramaswami notes:

1. Value is a function of customer experience.
2. The experience of the company is born in the process of interaction with the consumer.
3. Any firm should contribute to the value creation based on the experience.
4. The result of value creation is influenced by the process of effective and meaningful customer experience [Ramaswamy, 2011].

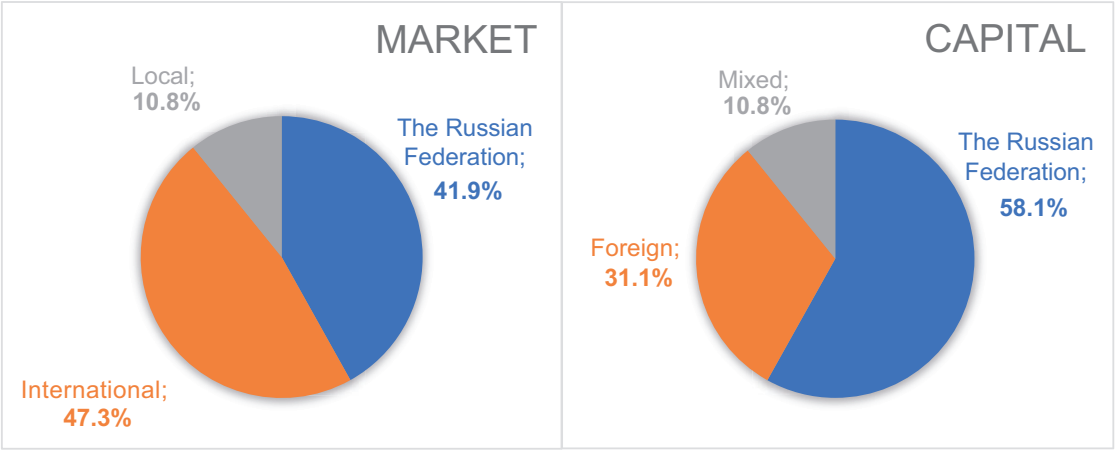
V. Ramaswamy and F. Gouillart in their work note that while the network economy is gaining momentum, it is extremely important to involve customers in the process of creating value and gaining experience [Ramaswamy, Gouillart, 2010]. To build trust, companies should be transparent and accessible to their customers, which helps them clearly identify the strengths and weaknesses of a company's value proposition.

I. Lipsits in his work distinguishes three levels of value creation factors together with the consumer [Lipsits, 2007]. The first level is related directly to the product or service including packaging, features, price, design, performance, features. The second level consists of services that accompany the product or service such as pre-sales or after-sales service, regular updates and upgrades, etc. The third level defines various intangible factors directly related to the company and product: reputation, positioning, feedback from other consumers, image, brand strength, and others [Lipsits, 2007].

The level of value for the consumer of a particular product or service directly affects the efficiency of the business, its resulting indicators such as sales, revenue, profit. A similar relation is presented by the ladder of the increase in product or service value for consumers proposed by P. Doyle [Doyle, 2001]. It is shown in Fig. 6.

The left side of the figure reflects the degree of competition effect on business, the right side shows the level of business value added. As can be seen from the figure, the higher the product or service is placed in this

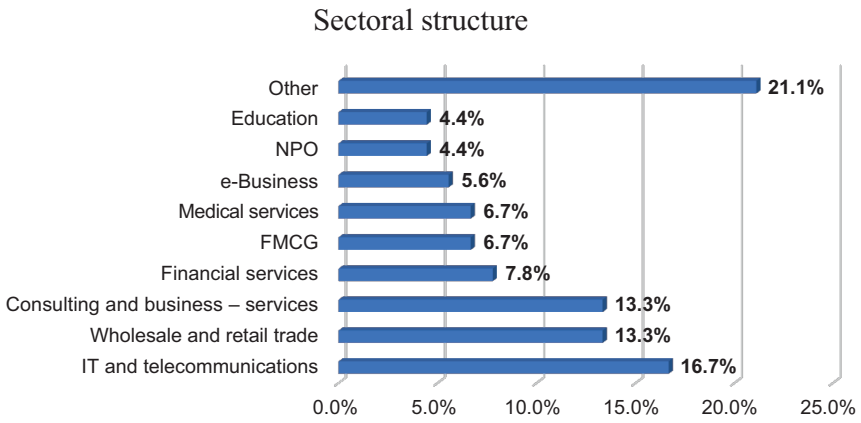
Fig. 7. The position of companies in the international market



Source: compiled by the authors.

hierarchy, the more significant benefits the company can receive. Accordingly, the more steps the proposed product corresponds to, the more effectively the value proposition realizes itself and the better the company achieves in the framework of conducting business. It is also important to note that reaching a higher stage on the value ladder also entails certain difficulties for the company in terms of responsibility and a significant contribution of additional resources. However, if all stages are successfully overcome, the subsequent benefit for the company is able to cover all intermediate costs through real growth in revenue as well as business margins.

Fig. 8. Industry structure of the study sample

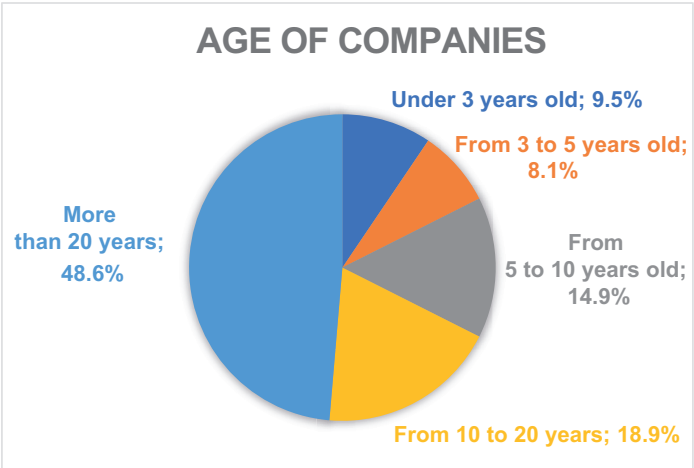


Source: compiled by the authors.

When building an effective offer, it is important to consider the key factors of a successful value proposition. Of course, it is difficult to talk about the existence of such universal factors for each specific case. However, in our opinion, it is necessary to have, in a certain sense, support in the form of factors and signs of a successful value proposition in its construction. One of these most comprehensive lists was proposed by A. Osterwalder in his work "The development of value propositions. How to create goods and services that consumers want to buy. In his opinion, a good value proposition:

- Is a part of a successful business model;
- is focused on unrealized tasks, unresolved problems and outstanding benefits;
- is focused on those tasks, problems and benefits that are most significant to the consumer;
- corresponds to the understanding of success by the consumer;
- is not limited to functional tasks and takes into account emotional and social tasks;

Fig. 9. Age structure of the sample



Source: compiled by the authors.

Table 3
Category “Value for consumers” elements

Research	Frequencies of mention			
	Russian companies	Foreign companies	Total	%
Consumer value is utility, price, and quality [Lapierre et al., 1999].	15	12	27	23.9
Consumer value is the best correlation between price and quality [Ulaga, Chacour, 2001].	11	10	21	18.6
Consumer value is a purely emotional perception of a product, formed under the influence of consumer experience and product characteristics, the consequences of consumption, and the consumer personal values [Baker et al., 2004; Brunso et al., 2004].	1	8	10	8.8
Consumer value is a functional, utilitarian, physical satisfaction of the consumer [Wang et al., 2004].	3	6	9	8.0
Consumer value is not only the functional conformity of a product, but also the satisfaction of some social norm ("successful person," "business person," etc.) [Sheth, Parvatiyar, 1995].	1	4	5	4.4
Consumer value is the functional, social and aesthetic satisfaction of consumption [Spiteri, Dion, 2004].	2	3	4	3.5
Consumer value is composed of the correlation of four elements: emotional satisfaction, satisfaction of a social need, quality, price [Sweeney, Soutar, 2001].	0	2	2	1.8
Consumer value is emotional satisfaction, satisfaction of a social need, quality, price, the possibility of having a brand [Wang et al., 2004].	1	7	8	7.1
Consumer value is something new, an opportunity to gain new knowledge, new information, to have something new [Spiter, Dion 2004].	2	7	9	8.0
Consumer value is added value between the benefits and costs of using a product [Zeithaml, 1988]	1	2	3	2.7
Consumer value is dynamic and situational. The consumer perceives value differently in different settings and contexts [Woodall, 2003; Zeithaml, 1988]	1	3	4	3.5
Consumer value depends on the preferences and assessments including the degree of achieving the goal, the value received, further opportunities and consequences [Woodruff, 1997]	5	6	11	9.7
Total	43	70	113	100

Source: compiled by the authors.

Table 4
Common and differing components of value for the consumer, identified among researchers and practitioners

Elements	Research workers	Company representatives - practitioners
Common	Physical value of the product	
	Functional compliance of the goods	
	Emotional satisfaction	
	Dynamism of value	
	Value for money	
	Satisfaction of social needs (norms)	
	Company reputation (brand)	
	Opportunity to gain new knowledge	
	Possibility of owning a brand	
Differing	Incremental value between benefits and costs from using goods	Imposing value on the consumer
	Situational value	Targeting consumer segments
	Personal values of the consumer	The sum of the components: usefulness and guarantee
	The consequences of consuming a product (service)	Evaluation and use of the company's existing experience

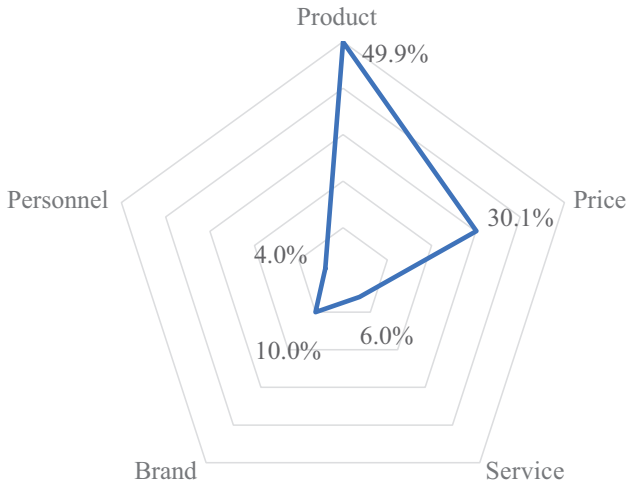
Source: compiled by the authors.

Table 5
Tools for creating a value proposition for customers

Research	Frequencies of mention		% of respondents	
	ea	%	Russian companies	Foreign companies
Improving product (service)	189	35.7	95	100
quality	118	22.3	75	96
Product range	46	8.7	47	63
uniqueness	25	4.7	14	30
Reducing the price of the product	127	24.0	88	86
Improving service	57	10.8	26	69
ease of choice	14	2.6	6	14
risk reduction	14	2.6	8	12
ease of purchase	25	4.7	20	27
ease of use	4	0.8	0	7
Brand building	81	15.3	46	88
uniqueness	6	1.1	2	10
acceptance	75	14.2	46	81
Staff	75	14.2	56	70
professionalism	33	6.2	23	37
relations	18	3.4	6	20
customer focus	10	1.9	4	16
personal qualities	14	2.6	10	10

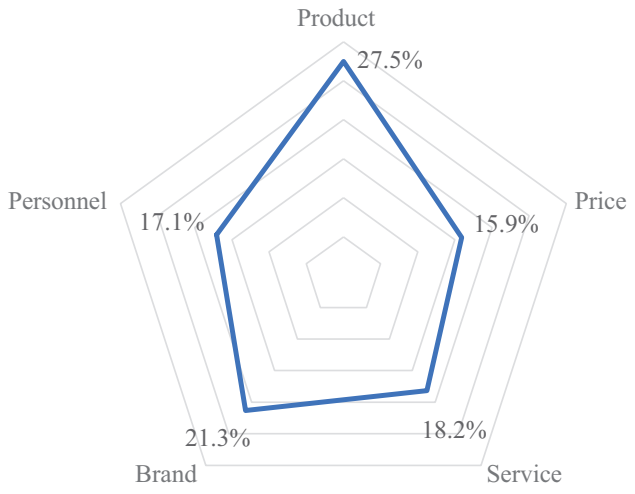
Source: compiled by the authors.

Fig. 10. Value formation tools according to representatives of Russian companies



Source: compiled by the authors.

Fig. 11. Value formation tools according to representatives of international companies



Source: compiled by the authors.

Table 6
Tools for involving customers in joint value creation

Research	Examples of respondents' answers	Frequencies of mention			
		Russian companies	Foreign companies	ea	%
Feedback – filling out a questionnaire by the consumer developed by the company, writing a review on the Internet by the consumer, etc. [Piller, Ihl, 2009]	Questionnaires, online surveys, reading consumer reviews; The opinion of consumers has always been important to us, therefore, when creating a value proposition, we in most cases interact with customers (surveys, reviews, wishes); Each client can use the phone number listed on the site as well as at each retail outlet; Questionnaires, online surveys, ratings of blacklist suppliers	17	30	47	36.2
"Co-production" is characterized by the participation of a consumer in creating joint value with the company at the final stages of creating a service (service consumption) [Shaw et al., 2011; Chathoth et al., 2013]	We involve clients in the process of discussing prepared reports and memorandums, adjust our own opinion and conclusions based on the client's comments; Collaborative development of a product that would meet the needs of this particular customer contributes to the creation of a value proposition	3	5	8	6.2
"Service innovation" [Lawer, 2006; Shaw et al., 2011; Chathoth et al., 2013]	The use of innovation, creation of an integrated offer, expansion of services; High-quality service is the basis of our company's work, we pay close attention to training our employees in customer interaction techniques	3	7	10	7.7
"Customization" [Piller, Ihl, 2009; Shaw et al., 2011; Chathoth et al., 2013]	The client is first offered a range of planned values, after which his opinion is listened to and something is added depending on the need; Each problem, as a rule, is individual, and its solution is applicable to a specific object with given requirements.	5	6	11	8.5
The interaction of a consumer with the company as well as his participation in promotions/ events initiated by both the company and consumer himself [Vivek et al., 2012]	Participation of consumers in various events within the framework of event-marketing, promotions; Companies willingly participate in our research, which we regularly conduct, and then publish the results; Every month we run a large number of promotions including digital campaigns, which involve more and more consumers and motivate them to try and buy our products more often	10	15	25	19.2
"Virtual brand community" [Brodie et al., 2011]	We have official accounts on social networks where communication takes place, mainly with potential future employees, but nevertheless, I think their work can be called effective; In addition to the virtual reception, there are pages on social networks, where work is also carried out to track complaints and suggestions; In social networks there are groups ("VK", "Facebook"), as well as promotions on forums visited by the target audience	10	19	29	22.3
Total		48	82	130	100%

Source: compiled by the authors.

Table 7
Common and different signs of a successful value proposition, highlighted among researchers and practitioners

Elements	Research workers	Company representatives – practitioners
Common	Poorly copied	
	Orientation specifically to problems and benefits that are significant for most people, and for which they are willing to pay	
	Outperforms competitors in at least one aspect	
	Accounting for emotional and social aspects	
	Solve problems significantly better than competitors	
	Orientation to the most important and essential needs of a client	
Differing	Part of a successful business model	Ability to compete on price based on successful cost minimization by optimizing production processes
	Aligns with the consumer's understanding of success	Great potential in terms of life cycle, i.e. it will be in growing demand for a long time
	Orientation to unsolved problems and consumer problems	Taking into account the concept of sustainable development

Source: compiled by the authors.

- is focused on those tasks, problems and benefits that are significant to many people or for which some are willing to pay a lot of money;
- outperforms competitors in at least one aspect;
- solves the problems of consumers much better than the proposals of competitors;
- is difficult to copy [Osterwalder et al., 2017].

Thus, adhering to the described features, the company significantly increases the chances of building a successful value proposition – after all, each of them is a fundamental aspect of effective business in most areas. With the development of the economy and society as a whole, it is important for companies to understand that at present the key factor of success is precisely the construction of a successful value proposition and its competent integration into the business model. This fact constantly imposes new requirements for determining and creating value that correspond to the current level of the society development and competitive environment in the economy.

Therefore, value having gone through various stages in its evolution is currently the basis for the formation of organizational culture and value proposition, business modeling and the overall functioning of the organization. However, it is important to note a significant difference in approaches to define and understand value and a value proposition.

3. Methodology of sample study and description

To collect the opinions of company representatives on what they mean by a value proposition, an in-depth interview method was used on the basis of a semi-structured guide. The guide included questions that were aimed at understanding of a value proposition and its formation in companies, for example: “What do you understand by a value proposition?”, “What components of a value proposition are most important for the company?”, “What tools does the company use to form a value proposition?” suggestions?" In addition, questions on the activities of the company in which the respondent works were added to the guide.

Respondents were selected based on their best knowledge of product management and value proposition building. Since the design of the study involved the participation of one or two representatives from the company, a total of 113 in-depth interviews were conducted with representatives from 83 companies. The interview took place from October, 2021 to March, 2022. The duration of the interview ranged from 25 minutes to 1 hour, the average interview time was 40 minutes[1].

An analysis of the market in which the respondents work showed the following: 43.2% of the companies included in

[1] The authors express their gratitude to the students of the Master's program "Innovation Management and Entrepreneurship", Graduate School of Management of the Financial University, for their help in conducting interviews with respondents.

the sample operate in the B2B market, 37.8% – in the B2C market, 18.9% – in both markets. 31.1% of the companies offer their customers goods, 54.1% – services, and 14.9% – both goods and services. The data allow us to state that the sample is quite representative and all types of companies are proportionally represented in it according to the specified parameters. In capital structure, 58.1% have only Russian capital, 31.1% have only foreign capital, 10.8% have mixed capital, of which 47.3% work on the international market, 10.8% on the local market and 41.9% – at the national level (Fig. 7). The sectoral structure of the sample is shown in Fig. 8.

The study presents a wide range of companies from various industries to exclude the influence of a particular industry on the results of the study.

The sample is divided into two equal parts according to the threshold value of 20 years. A large number of young companies are represented – up to 5 years of activity, the total share of which is 17.6% (Fig. 9).

Thus, in the presented sample, companies of various sizes and organizational designs are proportionately represented, covering most types of organizations operating in the Russian market.

4. The results of the empirical study

After transcribing the in-depth interviews, the materials were studied by using content analysis. The elements of value for the consumer highlighted in the respondents' answers to the question "What do you understand by value for customers?" are presented in Table 3.

The results presented in the table allow us to determine the most common characteristics of consumer value: price, quality. Also, in a significant number of cases, respondents emphasized such value characteristics as emotional perception and benefits for the consumer. In some ways, this is due to stereotyped and formulaic thinking towards the creation of a company's value proposition.

At the same time, characteristics of customer value, such as the dynamic nature of value, the social mission of the brand/company, added value were mentioned once or not mentioned at all.

Thus, the analysis of "value for the consumer" concept allows us to conclude that for most employees of companies from various business areas the concepts of a value approach in management and a value proposition are limited to standard categories, such as price, quality, direct satisfaction of needs. This is especially true for representatives of Russian companies and firms that conduct their business only within our country. As can be seen from Table. 3, the number of responses from representatives of Russian companies exceeds or is equal to similar responses from representatives of international companies only in the first two cases, when it comes to the price/quality ratio or the direct usefulness of the product, that is, the most standard and primitive understanding of a value proposition. In other, more non-standard elements of a value proposition, Russian respondents are represented in a relatively insignificant manner.

Table 8
The degree of influence of factors on the formation of a successful value proposition

№	Factors that form a successful value proposition	Degree of importance
		%
1	Focused on unmet tasks, unresolved problems and unrealized benefits	23.4
2	Solve consumer problems significantly better than competitors' offerings	19.6
3	Outperforms competitors in at least one aspect	12.8
4	Focused on those tasks, problems and benefits that are most significant to the consumer	10.6
5	Part of a successful business model	8.4
6	Focuses on those tasks, problems and benefits that are significant to many people or for which some are willing to pay a lot of money	8.2
7	Goes beyond functional tasks and takes into account emotional and social tasks	6.5
8	Hard to copy	6.0
9	Corresponds to the consumer's understanding of success	4.4

Source: compiled by the authors.

The analysis allows to compare common and different characteristics in determining value for customers.

Tools of value creation most frequently named by respondents are presented in Table. 5.

According to the respondents, the most significant value creation tools are quality, acceptance and price. At the same time, tools such as ease of use and brand uniqueness are almost never used in the practice of Russian companies, which can be explained by the insufficient level of Russian personnel's knowledge of the entire spectrum of creating a value proposition, and especially its most complex tools. It is even more interesting to see the distribution of answers from representatives of Russian and international companies (Figures 10 and 11).

As can be seen from the figures, the distribution is very different in the first and second cases. While representatives of international companies noted the importance of the entire range of value-creating tools more or less evenly, respondents from Russian companies clearly relied on product components and the price in their answers. In this case, we see a repetition of the importance of the price / quality indicator on the part of practitioners – representatives of Russian business, while in international companies the price

Table 9
Matrix model of value proposition formation

№	Factors to form a successful value proposition	Value proposition tools																
		Improving the product				Improving service				Brand			Personnel				Additional tools		
		Quality / functionality	Product offering	Uniqueness	Price regulation (lowering the price)	ease of choice	Reduced risks	Ease of purchase	Ease of use	Uniqueness	Communication	Recognition	Professionalism	Attitude	Focus on customer	Personal qualities	Co-creation of value with the staff	Involving the consumer in the co-creation of value	The concept of sustainable development
1	Oriented at unsolved problems, unrealized tasks and benefits	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Solves the tasks of consumers much better than competitors	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3	Outperforms competitors in at least one aspect	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	Oriented at those tasks, problems and benefits which are more important for a consumer	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
5	Is a part of a successful business-model	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	Oriented at those tasks, problems and benefits which are important for many people or for which people are ready to pay more	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
7	Is not limited by functional tasks and takes into account emotional and social tasks	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
8	Hard to copy	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
9	Corresponds to the consumer's understanding of success	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

■ Direct influence

■ Indirect influence

■ Minimum/no connection

Source: compiled by the authors.

indicator plays a smaller role and the distribution is almost uniform. The leadership of product instruments in both cases should also be noted, and if the Russian respondents in their answers focused only on the quality of the product, then the representatives of international companies often noted the importance of the range and uniqueness of products.

When asked about value creation together with their staff, most Russian companies admitted that they rarely involve staff in this process. In foreign companies, on the contrary, personnel is one of the key sources of forming a value proposition. Companies often develop and encourage internal entrepreneurship, when each employee can put forward their own innovative ideas, and after the analysis and approval from managers these ideas can be turned into real projects with full support and resources from the company.

When asked about co-creating value with customers, most companies admitted that they involve customers whenever possible using mostly questionnaires and surveys that help learn about customer preferences, desires, and customer satisfaction. At the same time, it is important to note that a greater variety of tools and methods of interaction with consumers is found in foreign companies. However, in recent years, Russian companies have been increasingly focusing on business development through interaction with customers.

The most common tools for involving customers in joint creation of value are presented in Table. 6.

It can be seen from the data in the table that the most used tools for engaging consumers in joint value creation are such standard methods as the analysis of reviews, questionnaires, telephone surveys as well as a virtual brand community and participation in promotions and events jointly with the company. Note that absolutely all of the presented tools are used more often in international companies. At the same time, it is important to note that most of the non-standard tools for involving the consumer in the joint creation of value were also offered by international companies, which could be seen in the process of content analysis of the real answers from the respondents. All this indicates a significantly deeper involvement of the consumer and the use of the entire range of tools by foreign companies and the backlog of Russian companies in this aspect. Also, during the analysis, it was possible to notice that it is precisely those companies that use the maximum number of tools for interacting with their customers and consumers in their arsenal that actually have the greatest market success at the moment (Microsoft, Unilever, P&G, EFES, IBM, Reckitt Benckiser, Citi and others).

Signs of a successful value proposition for customers from the perspective of researchers and practitioners are presented in Table. 7.

Here, to a greater extent, I would like to note the frequent mentioning about the concept of sustainable development by representatives of Western companies. This fact is extremely rarely referred to in the theoretical literature while nowadays, especially in developed markets, this aspect is a key link in the formation of a successful value proposition. It is also important that, statistically, brands with a social mission that support the concept of sustainable development have higher rates of growth and development, which, in turn has a positive effect both on the owners of these brands and on the society and the environment as a whole.

Table 8 presents a ranked list of factors in the formation of a value proposition in terms of their importance and influence on a successful result.

As can be seen from the results, the key factors in a successful value proposition, according to the respondents, is the ability to solve customer problems and satisfy their needs, as well as to do it better than their main competitors.

5. Discussion of the research results

A comparative analysis of the respondents' answers made it possible to see the correlation between the thoroughness and complexity of the use of tools and methods to form a value offer and the company's position in the market and the success of its financial and economic results. Thus, representatives of Russian companies that are in the position of “catching up” often use only a part of the most obvious and simple tools, while their key competitors – market leaders – approach customer value with greater efficiency.

An analysis of the concept of "value for the consumer" allows us to conclude that for most employees from various business areas, the concepts of a value approach in management and a value proposition are limited to standard categories, such as price, quality, direct satisfaction of needs. This is especially true for representatives of Russian companies and firms that conduct their business only within Russia and CIS countries.

The key feature and result of the study was to determine the importance and place in the process of forming a value proposition of such tools as joint value creation with the consumer and the involvement of personnel in joint value creation. If in the most successful companies these tools are considered critically important, then in catching up and more often Russian companies they are used rather pointwise – or even “for show” in some cases.

The differentiation described above is especially pronounced when it comes not to standard tools for involvement, but to various innovations. Thus, most of the non-standard tools for involving consumers and staff in the joint creation of value were proposed by international companies, which could be seen in the process of content analysis of the real answers of respondents.

Another important result of the study was that the factor of taking into account the concept of sustainable development is mentioned quite often by respondents-practitioners, while in the theoretical literature it is indicated very rarely. Here we see a situation where it is the theoretical provisions that need some refinement and revision of factors and tools. And here, to a greater extent, I would like to note the frequent mention of the concept of sustainable development, again by representatives of the most successful Western companies.

An important result of the study was the ranking according to the degree of importance and influence of various factors of a successful and effective value proposition, according to the respondents. It was found that the most important

and key factors in a successful value proposition, according to practitioners, is the ability to solve customer problems and satisfy their needs, as well as to do it better than their main competitors. It should be noted that in this case, the opinions of representatives of Russian and international companies often converged. True, representatives of international companies often put in a high place in terms of the degree of influence such a factor in the formation of a value proposition as "is part of a successful business model", which, of course, corresponds to most theoretical provisions, especially the works of A. Osterwalder.

6. Practical application of the obtained results

Summarizing the results of the study, we can draw key conclusions: the use of tools and models for the formation of a value proposition is limited or temporary; in the approaches to building a business model and an offer there is often no complexity in the aspects of value management. In other words, business representatives and especially newcomers or small players in the market often simply do not understand what specific tools need to be used to develop one or another factor of a successful value proposition.

Thus, a significant need has been identified to bring together the factors of a successful value proposition and the tools for its formation into a single model. A feature of our model is that it clearly indicates what specific tools should be used to form and develop the key factors of a successful value proposition, taking into account the priority and importance of a particular tool in relation to the selected factor. The model presents both a classic set of tools to form a value proposition proposed by A. Osterwalder, and additional tools the need for which was identified in the course of the study. The convenience of the proposed model also lies in the fact that the factors for creating a successful proposal in it are arranged in the order of importance and influence on the final result, so that the practitioner – the user of the model can quickly form the sequence of specific steps to improve the business model and a value proposition. The proposed model is presented in Table. 9.

Thus, this matrix can help a business adjust or create a successful value proposition for its company or a particular product / service. By identifying the most important tools for developing a particular value proposition driver, the practitioner can compare the level of their use or development in their business and take appropriate measures. The proposed matrix model allows you to determine quickly which factors and tools companies need to focus on first.

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About the authors

Arkady V. Trachuk
Doctor of Economic Sciences, Professor, Dean of Faculty "Higher School of Management", Financial University under the Government of the Russian Federation, General Director of "Goznak" JSC (Moscow, Russia). https://orcid.org/0000-0003-2188-7192.
Research interests: strategy and management of the company's development, innovation, entrepreneurship and modern business models in the financial and real sectors of the economy, dynamics and development of e-business, operating experience and prospects for the development of natural monopolies.
ATrachuk@fa.ru

Natalia V. Linder
Doctor of Economic Sciences, Professor, Head of Department of Management and Innovations, Deputy Dean of Faculty "Higher School of Management" of the Financial University under the Government of the Russian Federation (Moscow, Russia). https://orcid.org/0000-0002-4724-2344.
Research interests: strategy and development management companies, formation of development strategy of industrial companies in the context of the fourth industrial revolution, innovation transformation of business models, dynamics and development of e-business development strategies of companies in the energy sector in the fourth industrial revolution, exit strategies of Russian companies on international markets.
NVLinder@fa.ru

Valery O. Tuayev
Brand manager of the «Unilever in Russia» JSC (Moscow, Russia).
Research interests: formation of the valuable offer for clients, marketing practicians in Russia, creation of brands by the Russian and foreign companies.
t.valera.o@mail.ru

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Estimation of economic effects from product customization of Russian industrial enterprises

S.A. Titov[1]
N.V. Titova[2]
[1] Financial University under the Government of the Russian Federation (Moscow, Russia)
[2] State University of Management (Moscow, Russia)

Abstract

The development of digital production technologies, taking place within the framework of the global fourth industrial revolution, creates conditions for increasing the level of customization of industrial production, i.e. the ability to manufacture products that reflect the preferences of small groups of consumers and even individual customers. Product customization, as one of the most important aspects of the fourth industrial revolution, is of great interest for researchers and has been becoming one of the promising trajectories for the development of new production technologies and methods of organizing production. But at the same time, the economic effect of increasing the customization of products remains not fully understood. This study is aimed at identifying various economic effects arising from customization in industrial enterprises, and their quantitative assessment in relation to the manufacturing industries of the Russian industry. Using a systematic review of available scientific research and analytical reports, the study quantifies the economic effects of customization in various sectors of the Russian economy. The results show the colossal effect of further customization in Russian enterprises. The authors conclude that the annual effect of revenue growth in all industries, even under the most pessimistic scenarios and estimates, is 1.9 trillion rubles, and the effect of cost reduction – 1.4 trillion rubles. The results obtained can form the basis of government measures to stimulate the customization of products of Russian industrial enterprises.

Keywords: digital technologies, digital transformation, customization, industrial production.

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Introduction

The development of digital production technologies in the conditions of the global fourth industrial revolution creates conditions for the increase in the level of product customization, that is, match of its functional, ergonomic and aesthetic characteristics to the tastes and preferences of small groups or even individual consumers [Industry transformation..., 2018]. Additive technologies make it possible to produce according to individual projects without significant restructuring of production lines. 3D modeling offers the opportunity to create complex, highly accurate product models that reflect the preferences of individual customers. Collaborative design platforms create conditions for involving consumers in the development of new products, their rapid testing and prototyping. Cloud

information services can unite a large number of participants in the same supply chain within a single space of activity. Digital technologies form flexible manufacturing systems that produce customized products on a mass basis.

The customization of industrial production is of great interest on the part of researchers and is becoming one of the promising trajectories for the development of new production technologies and methods of industrial management [Popadyuk, 2008]. At the same time, the economic effect of increasing product customization remains poorly understood [Piller et al., 2004]. This study is aimed at identifying various economic effects arising from customization in industrial enterprises, and their quantitative assessment in relation to the manufacturing industries in Russia. The first section presents the results of the scientific literature review, based on which the research task is formulated. Next, the research methodology is described, followed by the main results which consist of the economic assessment of various effects from customization in the context of types of production activities, various scales of these effects and scenarios for the development of the Russian economy. In conclusion, the main findings are formulated, the limitations of the study are given, and the directions for further research are determined.

1. Mass customization in the age of digital transformation

The rapid development of production technologies and methods of industrial management in the direction of increasing its flexibility and responsiveness to consumer needs is accompanied by an increase in the average level of product customization. Product customization can be viewed as the correspondence of engineering, functional, style and other characteristics to the preferences of specific consumers. Customized products and services are meant to meet the needs of relatively small groups or even individual customers [Kudryavtseva, 2016]. Product customization can be understood as a set of processes for its development, production and sale and related included in it services [Piller, Reichwald, 2002].

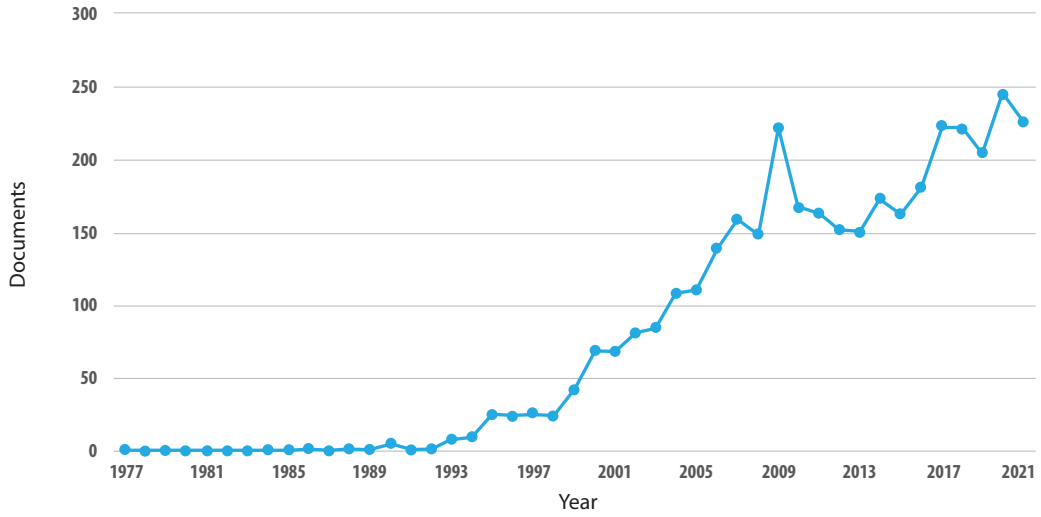
Customization affects almost all sectors of the economy and spheres of public activity. Customization is subject not only to consumer goods traditionally focused on a specific customer, such as clothing or furniture, but also to products of industrial enterprises. The dynamics of publications in the Scopus database with the term customization in the title, keywords, and abstract grew steadily until 2009 (Fig. 1), after which there was a decline in the number of publications, and then a new, somewhat fluctuating, but stable growth arose until 2021. The second wave of interest in customization can be explained by the fact that new digital technologies, which are currently rapidly transforming the landscape of economic activity, have enormous potential to increase the level of customization of products and services.

Traditionally, the production of customized products was accompanied by the creation of more value for the customer, but at the same time, the increase in product diversity significantly enhanced the value of such products. This led to the fact that effective customization arose only in narrow market niches. However, with the development of modern digital technologies and the new approaches to the organization of production on their basis, customization began to be characterized by decreasing costs, which led to the emergence of the phenomenon of mass customization, that is, the possibility of producing customized products for a large number of customers.

Technologies aimed at the production of customized products usually include:

- additive technologies (for example, 3D printing), which allow to create products with a variety of design solutions without noticeable changes in the production line;
- 3D scanning and modeling, creation of digital models and twins (for example, a digital model of a specific

Fig. 1. Annual dynamics of publications on the topic of customization in scientific areas of management and business



person's foot) that accurately reflect and use the specifications of individual customers in production;
- Platforms and applications for collaborative design that can involve consumers, designers, and technologists in the product development process at the same time;
- social networks and big data analysis and machine learning algorithms that allow to collect large amounts of customer data and identify group patterns in their consumer behavior and preferences;
- artificial intelligence that implements flexible dynamic pricing systems; flexible digital production systems that allow you to change the parameters of manufactured products quickly;
- distributed and cloud information systems that can unite the activities of a large number of suppliers, contractors and manufacturers within a single information space in real time;

etc. [Saniuk et al., 2020].

Organizational methods and customization tools often include:
- modular production, which makes it possible to achieve a wide variety of products within a limited set of components on the principle of Lego sets;
- product life cycle management, thanks to which it is possible to build in mechanisms for adapting products to new conditions, to carry out customization in the course of product operation;
- lean production;
- production service;
- co-design, involving deep customer involvement in product development processes;

and others [New production technologies, 2015].

The use of digital technologies leads to the emergence of mass customization, when customized products are produced in large volumes and personalization of products and services, when they are created for a specific consumer. Customization began to be characterized by various levels and implementation options (assembly to order, production to order, development to order, etc.), described by different breadth and depth of customization. Narrow customization involves adapting products to the requirements of individual customers. Broad customization usually means adapting products to the requirements of different customer groups. Narrow customization tends to create more value for the customer, but comes at a higher cost. Deep customization affects the project (design) of products, the processes of production or assembly, the processes of product sales. More superficial customization may concern only product packaging. Even more superficial customization occurs within retail sales and customer relationship management. Most researchers hold the opinion that deeper customization has the greatest economic effect [Matulik, 2008].

Given the interest to the development of customization, its economic effect in the context of various economy sectors remains insufficiently considered. In the Scopus database, 59 reviews of publications on the topic of customization were identified, and none of them addressed the economic assessment of the customization effect in the context of economic sectors. Most studies deal with the qualitative effect of customization at the level of individual enterprises or in the context of the development of certain technologies [Piller et al., 2004]. At the same time, the assessment of the economic effect of customization seems to be a rather important scientific task, since the state incentives for strengthening customization through the use of digital technologies are declared in some policy documents, but at the same time, the effectiveness of these incentive efforts does not seem obvious [New production technologies, 2015].

By the fact that the greatest economic effect from customization is expected from deep customization within the framework of industrial production using digital technologies, in this article the research task is as follows: to quantify the economic effect of the development of production technologies and methods of industrial management that provide an increase in the customization of products in the context of the manufacturing industries.

2. Research methodology

This study is based on the analysis of secondary sources via the review of consulting and analytical companies and scientific articles, aimed at qualitative identifying the economic effects of customization and summarizing the quantitative assessment of these effects. The assessment of the positive effect is summarized in the form of the effects of cost reduction and revenue growth of enterprises. The effects of customization are evaluated taking into account the maturity levels of customization on enterprises in various industries. It is also taken into account that the available data relate to economies that are ahead of the Russian in their digital development. Due to the lack of systematic data on customization costs, the study estimates these costs based on the percentage of failed digital transformation projects of companies. The parameters obtained in the course of summarizing the available data are applied to statistical data on the volume of activity in the context of manufacturing industries. In this case, three levels of effect are formed: maximum, average and minimum, as well as three scenarios for the development of the economy: optimistic, realistic and pessimistic.

3. Research results

3.1. Qualitative identification of economic effects from customization on industrial enterprises

In the scientific research and analytical reviews, two groups of economic effects arising from customization at the level of manufacturing enterprises can be identified. Cost reductions include:
- reduction of direct switching costs – companies spend a significant amount of resources on finding suppliers that best meet their requirements; the ability to adapt products as much as possible to customer requirements helps to reduce these costs [Riemer, Totz, 2003];
- reduction of opportunity costs – increasing the adaptability of supplies involves investing resources in establishing long-term relationships with suppliers,

which leads to the fact that these resources are not used in other, more profitable areas; customization leads to a reduction in the cost of resources for the development of relationships with suppliers [Riemer, Totz, 2003];
- reduction of sunk costs – often investments in the development of relations with suppliers are characterized by a limited ability to reuse the results that have arisen in the case of relations with other suppliers; customization, while reducing supplier relationship costs, also reduces sunk costs [Piller, Reichwald, 2002];
- optimization of product design – reducing the cost of functionality and features that do not create proper value for the client, due to faster information communication with the client and a better understanding of it, arising in the framework of customization [Jeffrey et al., 2015];
- better matching of supply and demand – increasing the predictability of demand leads to a reduction in costs associated with inventory, excess production or underutilization of resources [Jeffrey et al., 2015];
- reduction of used capital costs: the reduction in capital requirements due to the decline in stocks also comes with the possibility of full or partial prepayment of products by the buyer; this reduces the costs associated with financing activities [Matulik, 2008];
- economies of scale and diversity – reduction of costs through the economies of scale and economies of scope arising from the use of flexible manufacturing technologies that allow the production of customized products in large volumes [Jeffrey et al., 2015];
- reduction of commercial costs – an improvement in the understanding of the client as part of the customization process reduces the cost of retaining him, as well as the reduction of the client base and, accordingly, attraction of more new clients [Kudryavtseva, 2016];
- increase in the efficiency of innovation – short relationships with customers allow you to respond faster to changing of their preferences, test new products faster and more often, thereby reducing unproductive costs in the course of innovation [Hinz, 2013];
- increase in acceptable waiting time – customers who ordered products to their specifications are willing to wait longer, which is accompanied by a decrease in revenue losses due to unwillingness to wait, a decrease in the cost of emergency supplies of materials, and a reduction in errors in the supply chain [Piller et al., 2004].

The group of revenue growth effects includes the following:
- increased willingness to pay – customization is accompanied by the creation of higher value and perceived quality of products, which leads to the willingness of buyers to pay a higher price [Guneshka, 2021];
- increasing the customer's lifetime value – customization creates added knowledge about the customer, which leads to the ability to keep him longer and stimulate repeat purchases [Kudryavtseva, 2016];
- increased customer satisfaction – creating added value through the implementation of personal specifications leads to increased customer satisfaction, accompanied by repeat purchases, as well as an increase in the number of recommendations of the company to other customers [Dessler, 2021];
- improving competitive positions – customization allows you to increase the differentiation of the company's products, increase brand loyalty and thereby protect your segment from the possible impact of competitors, stabilize your market share and performance [Mass customization.., 2020].

Considering the industry as a set of enterprises producing similar products, we can conclude that the identified two groups of effects at the level of enterprises form generalized effects on the scale of industries and industrial production as a whole.

3.2. Estimation of cost reduction and revenue growth effects from product customization

The cost reduction effect of customization was found in [Piller et al., 2004], where it is estimated at 30% for the garment industry. Naturally, customization is not able to realize this potential fully in any company and industry, even within the framework of a super-optimistic scenario. The introduction of the "Customized Product" technological complex is an initiative for the digital transformation of the enterprise. The success of digital transformations is estimated at 24% [Unlocking success.., 2018], 20% [Morakanyane et al., 2020], and even 10% [Ramesh, Delen, 2021] of all initiatives. An intermediate value of 20% gives the maximum achievable cost reduction effect from customization of 30% × 0.20 (i.e. 20%) = 6% of revenue.

There are noticeably more quantitative estimates of the effect of growth in revenue from customization in open sources, but they are all heterogeneous and also require the formulation of a number of assumptions. Thus, according to a study by BCG, personalization of consumer experience through advanced digital technologies has allowed companies to increase revenue by 5 to 10% per year [Abraham et al., 2019]. It concerned only advanced companies in terms of customization. According to the results of the survey, the authors of the research [Boudet et al., 2019] conclude that personalization leaders have 5–15% more revenue than the industry on average. Deloitte has found that 50% of shoppers are interested in customized products, and that different proportions of shoppers are willing to pay different price premiums for personalized products [Jeffrey et al., 2015]. For example, the share of those willing to pay 50% or more on top of the price is 11% among shoe buyers and 3% among drink buyers.

In this mixed picture, it is assumed that, despite the diversity of customer preferences and industries, the growth in revenue from customization is determined by the ability of companies to realize this effect. To streamline quantitative estimates of the effect of revenue growth, you can use the

Table 1
Key parameters of the BCG customization (personalization) maturity level model (%)

Indicator	Customization level			
	lagging	basic	innovative	leading
Average revenue growth per year	0	10	25	40
Share of companies	41	40	19	0

model of customization maturity levels (in the original – personification) proposed by BCG [Abraham et al., 2019]. Four levels were formed; each of them was characterized by certain content aspects, the share of companies with these aspects identified in the course of the survey and an indicator of revenue growth from customization. The main parameters of the model are presented in Table 1.

The metrics proposed by BCG should be adjusted for the percentage of digital transformation initiatives that fail, and thereby, the cost of customization initiatives should be taken into account at least in this crude form. Average revenue growth per year is also multiplied by 0.20, as it was done for cost reduction. Adjusted figures are given in Table. 2 (line B).

3.3. Differentiation of customization effects by industries based on the concept of customization maturity

It should be noted that the BCG model was built primarily for retail and therefore has the ability to transfer to companies involved in the production of food, beverages and tobacco products. As sources of additional data, the work of [Matulik, 2008] was used which also provides a grouping

Table 2
Indicators of industry effects from customization (%)

№	Indicator	Customization maturity level			Industry-based effect	
		lagging	basic	innovative	Revenue growth	Cost reduction
	Customization effects					
B	Average revenue growth per year	0	2	5	—	—
Z	Cost reduction per year	0	1.50	3.75	—	—
	Amount of activity					
1	Manufacture of food products, drinks, tobacco products	41	40	19	1.75	1.31
2	Manufacture of clothes	43	36	21	1.77	1.33
3	Vehicle manufacturing industry	49	26	25	1.77	1.33
4	Printing	32	35	33	2.35	1.76
5	Manufacture of computers, electronic and optical products	61	7	32	1.74	1.31
6	Furniture production	52	27	21	1.59	1.19
7	Manufacture of paper and paper products	35	0	65	3.25	2.44

Table 3
Indicators of sectoral effects from customization for the Russian Federation (%)

№	Industrial activity	Industry-based effect	
		Revenue growth	Cost reduction
1	Manufacture of food products, drinks, tobacco products	1.31	0.98
2	Manufacture of clothes	1.33	1.00
3	Vehicle manufacturing industry	1.33	1.00
4	Printing	1.76	1.32
5	Manufacture of computers, electronic and optical products	1.31	0.98
6	Furniture production	1.19	0.89
7	Manufacture of paper and paper products	2.44	1.83

of companies by customization levels but in the context of individual industries. The number of levels in the model from [Matulik, 2008] is the same as the BCG model, but the grouping methodology is different. This model is based on the volume (or in terms of the author, intensity) of customization in the industry at various levels rather than on the number of companies. Despite methodological differences, the data from the two models are combined.

More complete parameters for the distribution of companies by customization levels are shown in Table. 2. Due to the fact that companies at the leading level were not identified in both models, the corresponding column was excluded.

Returning to the effect of cost reduction, it should be assumed that the maximum effect (6% of revenue, see 3.2 of this article) can only be assumed at the highest level of customization, in terms of the BCG model – the leading one. Based on this, the achievement of the cost reduction effect is differentiated by customization levels in the same proportion as the revenue growth indicator in the BCG model which is shown in line 3 of Table. 2.

To determine the industry-wide effects from customization in terms of revenue growth and cost reduction, it is necessary to find their average value, weighted by the volume of activities at different levels of customization. In other words, the sum of pairwise products of the effect by levels and the share of activity by levels is found. So, for example, the average effect of revenue growth in the clothing industry will be found as $0 \times 0.43 + 2 \times 0.36 + 5 \times 0.21 = 1.77\%$ (highlighted in Table 2 by light shading). The average cost reduction effect in the vehicle manufacturing industry will be calculated as $0 \times 0.49 + 1.50 \times 0.26 + 3.75 \times 0.25 = 1.33\%$ (highlighted in Table 2 by dark shading).

All calculated indicators are given in Table 2 in the "Industry Effect" columns.

3.4. Adaptation of the effects to the level of the Russian economy

It should be noted that [Matulik, 2008; Abraham et al., 2019] were based on the consideration of fairly advanced economies. It is problematic to transfer them without adjustment to the Russian economy. At the same time, there are no mechanisms for adapting the obtained values to Russian realities in the scientific and analytical literature. To solve this problem, it is proposed to assume that since customization largely involves digital transformation, the effect of it to a certain extent will depend on the level of the economy digitalization. If you look at the digital development indices of the Russian Federation in comparison to other countries[1], it turns out that the best results for Russia are characterized by ranking at the end of the second ten best countries (for example, according to the E-Government Development Index – 36th place out of 193, according to the Inclusive Internet Index – 25th out of 120). The worst ones are on the verge of the last third of countries (for example, according to the World Digital Competitiveness Ranking – 43rd out of 63 countries). In most cases, Russia is closer to the lower border of the first third of the countries.

The research [Matulik, 2008; Abraham et al., 2019] covered companies from various countries, which were most often within the top ten countries in many rankings. From this we can assume that Russia differs from the considered countries by an average of 25 points out of an average rating

[1] Digital Economy: 2022. Brief Statistical Collection. Moscow: НИУ ВШЭ. ISBN 978–5-7598-2599–9. DOI: 10.17323/978–5-7598-2599–9.

Tab. 4. Effect of customization by industry of manufacturing companies for 2022–2026 (mln rubles)

				2021	2022		2023		2024		2025		2026		2027		2022–2027		
Type of activity	Table 2	Size of revenue growth effect (%)	Size of cost reduction effect (%)	Scope of activity	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth (million rubles)	Cost reduction effect (million rubles)	The effect of revenue growth over 6 years (million rubles)	Effect of cost reduction over 6 years (million rubles)	Overall effect over 6 years (million rubles)
Food production	1	1.31	0.98	8 134 791	106 566	79 721	116 157	86 896	126 611	94 717	138 006	103 242	150 427	112 534	163 965	122 662	801 732	599 772	1 401 504
Beverage production	1	1.31	0.98	950 689	12 454	9 317	13 575	10 156	14 797	11 070	16 129	12 066	17 581	13 152	19 163	14 336	93 699	70 097	163 796
Tobacco production	1	1.31	0.98	263 744	3 455	2 585	3 766	2 818	4 105	3 072	4 474	3 348	4 877	3 649	5 316	3 977	25 993	19 449	45 442
Textile production	2	1.33	1.00	332 834	4 427	3 328	4 825	3 628	5 259	3 955	5 732	4 311	6 248	4 699	6 810	5 122	33 301	25 043	58 344
Clothes manufacture	2	1.33	1.00	212 816	2 830	2 128	3 085	2 320	3 363	2 529	3 666	2 757	3 996	3 005	4 356	3 275	21 296	16 014	37 310
Manufacture of leather and leather goods	2	1.33	1.00	83 291	1 108	833	1 208	908	1 317	990	1 436	1 079	1 565	1 176	1 706	1 282	8 340	6 268	14 608
Wood processing and product manufacturing	6	1.19	0.89	1 070 775	12 742	9 530	13 889	10 388	15 139	11 323	16 502	12 342	17 987	13 453	19 606	14 664	95 865	71 700	167 565
Manufacture of paper and paper products	7	2.44	1.83	1 291 817	31 520	23 640	34 357	25 768	37 449	28 087	40 819	30 615	44 493	33 370	48 497	36 373	237 135	177 853	414 988
Printing	4	1.76	1.32	314 994	5 544	4 158	6 043	4 532	6 587	4 940	7 180	5 385	7 826	5 870	8 530	6 398	41 710	31 283	72 993
Production of coke and oil products	–	0	0.00	11 944 585	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Production of chemical substances	–	0	0.00	5 112 962	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Production of medicines	3	1.33	1.00	1 375 658	18 296	13 757	19 943	14 995	21 738	16 345	23 694	17 816	25 826	19 419	28 150	21 167	137 647	103 499	241 146
Manufacture of rubber and plastic products	3	1.33	1.00	1 721 425	22 895	17 214	24 956	18 763	27 202	20 452	29 650	22 293	32 319	24 299	35 228	26 486	172 250	129 507	301 757
Manufacture of other non-metallic mineral products	–	0	0.00	2 071 496	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Metallurgical production	–	0	0.00	10 438 092	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manufacture of finished metal products	3	1.33	1.00	3 163 606	42 076	31 636	45 863	34 483	49 991	37 586	54 490	40 969	59 394	44 656	64 739	48 675	316 553	238 005	554 558
Manufacture of computers, electronic and optical products	5	1.31	0.98	1 625 925	21 300	15 934	23 217	17 368	25 307	18 931	27 585	20 635	30 068	22 492	32 774	24 516	160 251	119 876	280 127
Production of electrical equipment	5	1.31	0.98	1 259 660	16 502	12 345	17 987	13 456	19 606	14 667	21 371	15 987	23 294	17 426	25 390	18 994	124 150	92 875	217 025
Manufacture of machinery and equipment	3	1.33	1.00	1 590 216	21 150	15 902	23 054	17 333	25 129	18 893	27 391	20 593	29 856	22 446	32 543	24 466	159 123	119 633	278 756
Vehicle manufacturing	3	1.33	1.00	3 194 663	42 489	31 947	46 313	34 822	50 481	37 956	55 024	41 372	59 976	45 095	65 374	49 154	319 657	240 346	560 003
Manufacture of other vehicles	3	1.33	1.00	2 246 438	29 878	22 464	32 567	24 486	35 498	26 690	38 693	29 092	42 175	31 710	45 971	34 564	224 782	169 006	393 788
Furniture manufacture	6	1.19	0.89	373 284	4 442	3 322	4 842	3 621	5 278	3 947	5 753	4 302	6 271	4 689	6 835	5 111	33 421	24 992	58 413
Manufacture of other finished products	3	1.33	1.00	315 937	4 202	3 159	4 580	3 443	4 992	3 753	5 441	4 091	5 931	4 459	6 465	4 860	31 611	23 765	55 376
Repair and installation of machinery and equipment	3	1.33	1.00	1 245 481	16 565	12 455	18 056	13 576	19 681	14 798	21 452	16 130	23 383	17 582	25 487	19 164	124 624	93 705	218 329
Total for manufacturing industries				60 335 179	420 441	315 375	458 283	343 760	499 530	374 701	544 488	408 425	593 493	445 181	646 905	485 246	3 163 140	2 372 688	5 535 828

Tab. 5. Effect of customization by manufacturing industries across three scenarios (mln rubles)

Economic development scenario	Total production activity	9% increase in effects			11.25% increase in effects			13.5% increase in effects		
		The effect from revenue growth	Cost reduction effect	Mass effect	The effect from revenue growth	Cost reduction effect	Mass effect	The effect from revenue growth	Cost reduction effect	Mass effect
Optimistic (the level of 2021)	60 335 179	3 163 140	2 372 688	5 535 828	3 347 958	2 511 319	5 859 277	3 543 662	2 658 110	6 201 772
Realistic (80% from 2021)	48 268 143	2 530 496	1 898 136	4 428 632	2 678 371	2 009 055	4 687 426	2 834 942	2 126 500	4 961 442
Pessimistic (60% from 2021)	36 201 107	1 897 867	1 423 621	3 321 488	2 008 782	1 506 802	3 515 584	2 126 183	1 594 901	3 721 084

scale of 100 points. Thus, taking into account indicators calculated in Table 2, it makes sense to reduce them by 25%. The obtained indicators are given in Table 3.

3.5. Evaluation of the dynamic effect changes from customization

Further, it should be assumed that the size of the found effects will change over time as companies move between different levels of customization because the market will favor more and more customized products and companies will invest more in customization. Unfortunately, there is not much temporal analytics in open sources, which allows to build dynamic scenarios, and it is very fragmented.

Thus, the study [Abraham et al., 2019] found that the best companies allocate investments for customization in the amount of 0.9% of turnover, while on average all the studied companies invest 0.7%. Going forward, top companies are expected to spend 30% of their turnover on customization, with an average customization investment of 18%. Unfortunately, the fact about predicting this future is not specified in [Abraham et al., 2019].

[Wilson, 2007] found that most executives expected (as of 2007) an increase in demand for customized products at the level of 25 to 50% per year. A study [Kanama, 2018] finds less impressive growth. The author studied the growth of the customized drinks segment in Japan and concluded that sales volumes in these segments in the period 2010–2015 increased steadily by 1.2% per year. The share of this segment in the indicated period also grew and at a faster pace – 2.1% per year. This happened at the time when the beverage industry as a whole was shrinking.

You can also pay attention to secondary trends that reflect the interest of companies in the development of customization. For example, the work of [Mourtzis, Doukas, 2014) analyzes the number of articles in the Scopus database with the terms “mass customization” and “personalization” as keywords. The dynamics of the number of articles reproduces the classic hype cycle with a characteristic peak in 2003 and a return to the main trend already in 2004. The average increase in publications in the period 2000–2012 was 12.2% per year.

As another proxy trend we can consider the one in the field of 3D printing which, of course, does not exhaust the whole variety of technological solutions for customization, but in most cases they act as the main one. [Roberts, 2021] summarizes 11 forecasts for the period 2020–2026 and concludes that 3D printing market growth of 11.7% per year can be considered as a consensus forecast. In [Crozet V., 2018] the development of additive technologies for the automotive industry in the period 2020–2028 is estimated at 16.4% growth per year.

We can discard the 25–50% and 2.1% growth rates as extreme and consider the 12–18% customization growth corridor as the main one with 15% as the average and use these indicators for the period 2022–2028. With regard to the growth indicator there is a decrease of 25% due to the fact, that the range of 12–18% is identified on the basis of advanced economies, from which Russia is noticeably behind

in digital development ratings. Thus, to assess the growth of effects from customization, it is proposed to use the range of 9–13.5%, with an average value of 11.25% effect growth per year.

3.6. Definition and calculation of scenarios for achieving the social effect of customization

For the basic scenario,[2] we will consider statistics on the volume of shipped goods by the type of economic activity in the context of manufacturing industries for 2021. For each industry, we determine separately the effect of revenue growth and the effect of cost reduction according to Table. 3 (Columns "Industry effect") for 2021, and then calculate the indicators for the period 2022–2027 based on the forecast of 11.25% annual growth in effects. The calculations are presented in Table 4.

Unfortunately, it was not possible to determine the effects of customization for all industries of industrial production, and perhaps these effects do not make sense to expect for all industries. In the course of the study, not a single case of customization was found in such industries as the production of coke and petroleum products, metallurgical production, the production of chemicals and chemical products and the production of other non-metallic mineral products. These industries were excluded from the calculations. For industries where the cases were found in the literature, but the effects in Table. 3 were not calculated, a decision was made to apply the effect size out of those defined in Table. 3 based on the expert judgment of the authors of this study. The decision was made based on the similarity of customization potentials arising from the specifics of the product (how differentiable it is) and demand (how sensitive consumers are to creating additional value through customization). In Table. 4, column "Tab2", the line of Table 3 is indicated, from which the indicators of the customization effect were taken.

Under the baseline scenario, the effect of customization due to revenue growth over 6 years for all manufacturing industries amounted to 3.3 trillion rubles, and due to cost reduction – 2.5 trillion rubles. Note that these effects only take into account the costs associated on average with failed customization initiatives.

As industries with the greatest absolute effect, the production of food products, paper and paper products, finished metal products, motor vehicles and other vehicles should be noted. The industries with the greatest relative effect include the production of paper and products from it, printing activities.

The basic scenario calculated in Table 3 builds upon the fact that the volume of activity in 2021 can be considered as an average for the next 6 years. However, this scenario in the current geo-economic conditions seems to be optimistic. Therefore, in general, for the branches of industrial enterprises, it is advisable to consider other scenarios, also taking into account the different levels of a certain corridor of effect growth from customization (12–18% per year).

As a basis for the second, realistic, scenario, the indicator of activity volumes of 80% from the level in 2021 will be taken into account. As a basis for the third, pessimistic, scenario, an activity volumes of 60% from the level in 2021 will be used. The calculation results are shown in Table 5.

The effect of revenue growth for various combinations of scenarios and growth estimates varies from 1.9 trillion rubles up to 3.5 trillion rubles. The effect of cost reduction varies from 1.4 trillion rubles up to 2.7 trillion rubles.

Conclusions

Thus, an increase in the level of product customization in the Russian industry is characterized by a group of effects leading to a reduction in the costs of industrial enterprises (optimization of product architecture, economies of scale and diversity, an increase in the efficiency of innovation, reduction in the cost of switching between suppliers, etc.) and growth revenue (increased willingness to pay, satisfaction, customer lifetime value, etc.). Despite the lack of systematic data to assess the identified groups of effects from customization for the Russian economy, based on the available fragmentary information and the assumptions adopted in the study, quantitative indicators of the effects for the Russian manufacturing industries were calculated. The assessment of the customization effects is built in relation to the volume of production activity in the manufacturing industries of the Russian economy. An optimistic scenario considers the volume of production for 2021, realistic – 80% of this volume and pessimistic – 60%. Within each of the scenarios, the effect is estimated in the context of a corridor from 9 to 13.5% with an average value of 11.25%.

The effect of revenue growth, even at the lowest value, is estimated at 1.9 trillion rubles, and the effect of cost reduction is 1.4 trillion rubles. The figures obtained, even taking into account fairly aggregated estimates of the costs of customization and the probabilistic nature of many assumptions, indicate a huge economic effect from the introduction of digital customization technologies at Russian industrial enterprises. The presented calculations do not take into account other socio-economic effects, the assessment of which is even more difficult: an increase in the quality of life due to growing perceived quality of products as a result of its customization. Among them is job creation with advanced digital and out of the box skills and stimulation of entrepreneurial activity in the field of implementing customized technologies and analytics, improvement of Russian industrial companies' positions in foreign markets. These aspects can be attributed to the most significant limitations of the present study.

However, for the full realization of the effects estimated above, active actions of producers and a change in consumer behavior are required. Identification of mechanisms for changing the behavior of producers and consumers and the formation of proposals to stimulate the development of these mechanisms seem to be a promising direction for further research in the field of product customization at industrial enterprises.

[2] Rosstat. Industrial production (2022). https://rosstat.gov.ru/enterprise_industrial.

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About the authors

Sergei A. Titov
Candidate of Economic Sciences, MBA, Associate Professor, Higher School of Management of Financial University under the Government of the Russian Federation (Moscow, Russia). ORCID: 0000-0001-6857-579X, SPIN-code: 8251-9053, Author ID: 451272.
Research interest: project management, entrepreneurship, innovation management.
SATitov@fa.ru

Natalya V. Titova
Candidate of Economic Sciences, Senior Lecturer, Department of Project Management, State University of Management (Moscow, Russia). ORCID: 0000-0001-9676-7203, SPIN-code: 6873-7681, Author ID: 640334.
Research interest: project management, team management, innovation management.

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Influence of the trigger levels in pricing of the Maize Index insurance in Zimbabwe

B.W. Mazviona[1]

[1] National University of Science and Technology (Bulawayo, Zimbabwe)

Abstract

Agriculture has always been a risky practice and this has been increased by the continuously changing and unpredictable weather patterns. These changes have left smallholder farmers exposed to food insecurity and high levels of chronic poverty due to the unavailability of expensive agriculture insurance. To cushion the farmers from these risks index insurance contracts that provide Insurance to the farmer in the case when there is shortage of rainfall and when there is excessive rainfall were designed, as the materialisation of either of the two scenarios compromise the expected maize yields of the farmers. Maize index insurance price was using the Black-Scholes framework as the contract resembles a cash-or-nothing straddle option. The estimate premiums of the contract were compared at different trigger levels to determine the effect of changes in the trigger levels in the price of the contract.

Kewords: agricultural insurance, pricing, trigger levels, Maize Index, Zimbabwe.

JEL: D4, D10, G1, G2, G13.

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Introduction

The uncertainty in the weather conditions has left farmers exposed to several production risks. The World Bank indicated that these risks are specific to mainly local agriculture production and socioeconomic development [Weather index insurance.., 2011]. Zimbabwe experienced floods, droughts and extreme temperatures, which in turn has reduced the agriculture production. Majority of the population in the country gets its income from agricultural activities, however this income has recently become very volatile due to the randomness of rainfall. 90% of variation in the crop production level is deeply rooted in the variation of rainfall roughly impacted by global change patterns. M.R. Carter and R.S. Janzen [Carter, Janzen, 2012] found that droughts affect the largest group of farmers and cause the highest damage costs. As a result, the contribution of agriculture to the GDP of Zimbabwe has been compromised.

In response to these net results of natural risks, the government has introduced ad hoc food aid programs. This initiative has however faced several challenges. Firstly, inadequate distribution of infrastructure as some of the recipients of these aids are usually

asked to pay for transportation of the aid to their locations which is a burden to the already poverty-stricken population who cannot afford to meet these expenses resulting in them being unable to receive the aid. Secondly, these aid programs are vulnerable to mismanagement in the form of political abuse resulting in inequitable benefit distribution.

Despite these challenges, the programs have only met the one side of the net results of risks, it attempted to solve the food insecurity of the population but pretermitting that farmers farm also for income that covers the other needs of the family such as school fees and clothing amongst others. Exposure to chronic poverty is not addressed by these programs. Above all, these programs have created a culture of dependency which is a slow poison to the well-being of households and the economy of the country at large as agriculture contributed 12.8% of the country's GDP in 2018 according to The Global Economy[1].

To address the small scale farmers' exposure to food insecurity and vulnerability to chronic poverty, there is a need for access to affordable agricultural insurance, this access will encourage farmers to use scarce resources efficiently and reduce the dependence on inadequate food aid programs. The introduction of index insurance products has been considered handy in protecting the farmers from these adverse effects of weather changes. The indemnity of these contracts depends on the trigger levels that appear at the onset of the contract as well as the estimation of the premiums of the index insurance. Therefore, there is need to assess the effect of the changes of the trigger levels in the premium estimation, hence this article focuses mainly on this evaluation.

1. Literature review

In an attempt to respond to this challenge and fill void insurance insurers, agricultural economists, and researchers have developed an interest in the development of other insurance vehicles that will meet the needs of the small-scale farmers and benefit both parties of the contract. Such vehicles are the index insurance contracts, where the farmer is indemnified contingent on the performance of a variable or index, unlike the formal insurance contracts that pay indemnity based on the individual specific outcomes.

There are several indices which are correlated to the farm losses, that can be used to design index insurance contracts. These include rainfall, temperature, NDVI, and El Nino-Southern Oscillation indices amongst others, this ideology is supported by the International Fund for Agricultural Development [Weather index-based insurance.., 2011] who highlights that index insurance functions more effectively if there exists a strong correlation between insured losses and the selected index. Index insurance principles address the challenges that are faced by formal insurance in many ways. First, the value of the index cannot be influenced by the farmers, and the insurer therefore effectively frees of moral hazard and adverse selection respectively. It is cost-effective as it does not require field loss assessments and on-farm inspections like formal insurance. It however has some limitations. The greatest limitation is that it does not cover idiosyncratic losses such as those resulting from fire or conflicts.

According to [Hazell et al., 2010], index-based insurance is a financial product that indemnifies the farmer when pre-specified conditions of an aggregate index, or indicator are triggered.

According to [Clarke et al., 2012] triggers are developed using historical and current data and also monitored at weather stations that are closer to the insured farmer. The trigger values are selected for weather indices. The indemnity from the insurance contracts commence at these trigger values [Jensen N., Barrett C, 2016]. T.J. Lybbert and M.R. Carter calibrated rainfall index insurance with different trigger values using the percentiles of the rainfall data [Lybbert, Carter, 2014]. The contract payout is triggered for all farmers who bought the contract when the cumulative seasonal rainfall data received is above the trigger levels or below another trigger level.

[Okine, 2014; Filiapuspa et al., 2019] concluded that the price of the crop index insurance increases with an increase in trigger levels for contracts that cover shortage of rainfall. [Filiapuspa et al., 2019] found that the lowest trigger level (25th percentile) resulted in the cheapest premium (IDR 680,318.305 /ha/season), and the use of the highest percentile resulted in the most expensive premium (IDR 3,096,600.871/ha/season) and hence concluded that the premiums for rainfall index insurance covering rice farmers in the case of drought increase with increase in trigger levels. [Okine, 2014] observed that an increase in the trigger level from10.13 mm to 13.45 mm resulted in a 789.5% increase in premiums and that an increase in the trigger level from 13.45 mm to 19.42 mm produced 789.5% increase in premiums. [Kath et al., 2018] found that the cheapest premiums ($ 12.06 AUD/ha) for the excess rainfall index insurance for sugar cane was at the highest trigger level (95th percentile) and the most expensive premium($ 57.25AUD/ha) was at the lowest trigger level applied (70th percentile).

2. Data and methodology

The maize yields and rainfall data used were obtained from AGRITEX and NASA website respectively. The data used for the study range from October 2009 to May 2019 for rainfall data and 2010 to 2019 for the maize yields data. The black-Scholes option pricing framework was used to evaluate the contract in the study. Normalized yields and seasonal rainfall data for the region were used in the premium estimation process. Regional data were obtained from averaging the data for the districts in the corresponding regions. The prices were estimated at different trigger levels. The changes in the estimated premiums were then computed and conclusions were made.

3. Empirical results and discussion

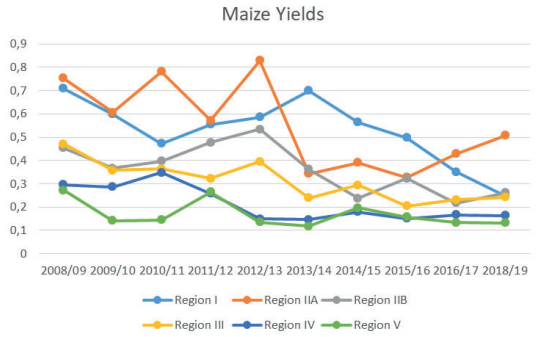
This section summarises the descriptive statistics (means, standard deviation, minimum and maximum) of the data used in the research. According to [Mushore, 2013] the Zimbabwean rainfall season ranges from mid of November to mid of March of the following year, therefore the cumulative seasonal rainfall in this study was taken as the cumulative rainfall for the period from the beginning of October to the beginning of May to account for the late planted crops contradicting with [Mushore et al., 2017] whose period ranged from the 1st of October to the 31st of

[1] The Global Economy - 2018: https://reports.weforum.org/global-competitiveness-report-2018/country-economy-profiles/.

Table 1
Regional descriptive statistics

Region		Mean	Median	Standard Deviation	Sample Variance	Minimum	Maximum
I	Seasonal Rainfall	701.389	656.706	139.733	19525.398	483.984	971.904
	Maize Yields	0.528	0.559	0.144	0.021	0.249	0.709
IIA	Seasonal Rainfall	759.959	816.996	129.910	16876.645	556.884	924.360
	Maize Yields	0.532	0.508	0.182	0.033	0.328	0.829
IIB	Seasonal Rainfall	743.446	756.750	128.616	16542.184	526.104	996.252
	Maize Yields	0.363	0.365	0.106	0.011	0.217	0.535
III	Seasonal Rainfall	660.025	683.316	129.782	16843.320	441.924	828.456
	Maize Yields	0.312	0.309	0.085	0.007	0.205	0.471
IV	Seasonal Rainfall	468.251	447.216	121.503	14762.917	308.592	675.000
	Maize Yields	0.169	0.143	0.056	0.003	0.117	0.272
V	Seasonal Rainfall	324.954	587.700	105.583	11147.836	504.564	835.620
	Maize Yields	0.214	0.173	0.075	0.006	0.146	0.347

Fig. 1. Maize Yields



March of the next year. The seasonal descriptive statistics for the respective regions during the period 2010-2019 are summarised in the table 1.

The average rainfall received in region I, IIA, IIB, III, IV and V is 701.39 mm, 759.96 mm, 743.45 mm, 660.02 mm, 468.25 mm and 324.95 mm respectively. The average rainfall generally decreases across the regions.

The graph below shows the trend between the maize yields and time. A downward trend is observed for all regions thus justifying the need for index insurance to cover the smallholder farmers in the event of either shortage or excess of rainfall, which occurrence leads to reduced yields.

3.1. Analysis of relationship between maize yield and seasonal rainfall

The relationship between the maize yields and rainfall was examined with the use of different regression models that include linear, log linear and quadratic schemes. The maize yields data were detrended and normalized to remove the effects of heteroskedasticity and time trends when using model 1 and 2. The normalized maize data are presented in the appendix. To test the relationship between the variables the original seasonal data were used in the case of independent variable and normalized maize yields were used in the place of dependent variable. The correlation coefficients R^2 were compared. The results from the regression models analysis are summarized in the table 2.

The relationships between maize yields and rainfall were modelled better using the quadratic regression model (for all regions) compared to linear regression and nonlinear regression for the region I, IIA, IIB, III, IV, V respectively. This is indicated by the highest R^2 values of 0.01, 0.07, 0.22, 0.03, 0.26 and 0.01 for regions I, IIA, IIB, III, IV and V respectively being obtained from the quadratic regression model; This showed that the maize yields increase with rainfall to a limit point where it start to decrease with excessive rainfall. Beyond this point, the maize yields begin to decrease, hence the need for index insurance will cover both drought and floods. This is similar to the findings of [Mushore et al., 2017], who concluded that the relationship between maize

Table 2
Regression model results

	Region	I	IIA	IIB	III	IV	V
Linear model	R^2	0.00	0.05	0.18	0.02	0.16	0.00
	Intercept	717.90	841.66	484.46	783.43	789.95	461.61
	X Coefficient	-24.40	-127.90	597.30	-266.64	-580.07	26.12
Log Linear model	R^2	0.00	0.03	0.20	0.02	0.13	0.00
	Intercept	691.14	725.42	966.87	563.94	461.15	474.36
	X Coefficient	-24.29	-65.60	260.67	-122.93	-126.70	4.33
Quadratic model	R^2	0.01	0.07	0.22	0.03	0.26	0.01
	Intercept	857.25	630.15	-5.18	1452.05	362.08	688.91
	X Coefficient	-505.03	559.39	2965.48	-3285.75	3036.82	-1939.94
	X^2 coefficient	385.66	-508.46	-2745.61	3330.90	-7022.84	3908.56

Table 3
Trigger levels (percentiles)

Percentile	Region I	Region IIA	Region IIB	Region III	Region IV	Region V
10th	594.770	644.753	593.431	493.084	518.885	334.415
25th	621.459	680.625	687.630	580.734	558.972	380.112
50th	656.706	786.940	756.750	683.316	587.700	447.216
60th	690.022	818.359	772.423	693.067	630.934	470.345
75th	767.382	858.510	796.482	752.370	690.402	569.811
90th	869.876	879.518	839.533	816.360	741.217	605.351

Source: author's analysis.

yields and rainfall in Mt Darwin is better modelled by a quadratic regression model with R^2=0.630. The figures in this research differ from the findings as the study sampled different districts but however they both exhibit similar relationships between the variables. These findings are also in contradiction with those of [Poudel et al., 2016] who found that the crop yields were linearly related to the rainfall data. This is due to the difference in the crop type examined and the sample population.

3.2. Premium Rate estimation

Determination of trigger values

The trigger levels for drought coverage were the lower percentiles i.e. (10th, 25th, and 50th percentiles) whereas the upper percentiles i.e. (60th, 75th, and 90th percentiles) were used as the trigger levels of the floods coverage. Therefore, the trigger values for the contract will be (10th and 60th), (25th and 75th) and (50th and 90th). The percentiles for each region are summarized in table 3.

Lognormal test of seasonal rainfall data

When pricing the options using the Black-Scholes framework, it is assumed that $\frac{S_T}{S_0}$ follows a lognormal distribution. Hence, examine if $\frac{I_T}{I_0}$ follows a lognormal distribution. Q-Q plots for the rainfall data were plotted to indicate that the data follow a lognormal distribution, the plots are presented in the appendix. To further prove that the data follow a lognormal distribution, Kolmogorov-Smirnov Test and Shapiro-Wilk Tests were carried out using SPSS.

H_0 = the ln (seasonal rainfall) follows Normal distribution.

H_1 = the ln (seasonal rainfall) does not follow Normal distribution.

The p- values of the both the Kolmogorov test and Shapiro - Wilk test are both greater than 0.05, therefore we conclude that the natural logarithm of the seasonal rainfall data with maize follows a normal distribution, hence the data follow a lognormal distribution, therefore, we accept H_o. The results of these tests are presented in the table 4.

Table 4
Normality test results

	Kolmogorov - Smirnov[a]			Shapiro - Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Region 1	0.196	10	0.200[b]	0.967	10	0.864
Region 2A	0.214	10	0.200[b]	0.932	10	0.465
Region 2B	0.167	10	0.200[b]	0.961	10	0.796
Region 3	0.198	10	0.200[b]	0.936	10	0.513
Region 4	0.196	10	0.200[b]	0.941	10	0.561
Region 5	0.152	10	0.200[b]	0.965	10	0.836

[a] Lilliefors significance correction.
[b] This is a lower bound of the true significance.

The scatter plots below show that the log of seasonal rainfall data follows a normal distribution and hence the seasonal rainfall data follow a lognormal distribution. This similar to [Okine, 2014] findings.

Pricing

In this case, we consider a contract that pays out indemnity at a rate of 1 in the event of either drought or floods. Therefore:

Pay-out = Pay-out rate x the insured amount of yields x the preagreed value of 1 unit of maize yields.

The contract resembles an exotic combination option which consist of a cash or nothing put option struck at the lower percentiles and a cash or nothing call option struck at the upper percentiles. Therefore, the premiums paid by the insured will be the total of the premiums paid if the farmer was to purchase these options separately (drought and floods insurance separately).

Premiums = Premium of long cash or nothing put option + premium of a long cash or nothing call option

The premiums paid by a farmer from region 3 are calculated as follows:

Fig. 2. Normal Q-Q plot of Regions

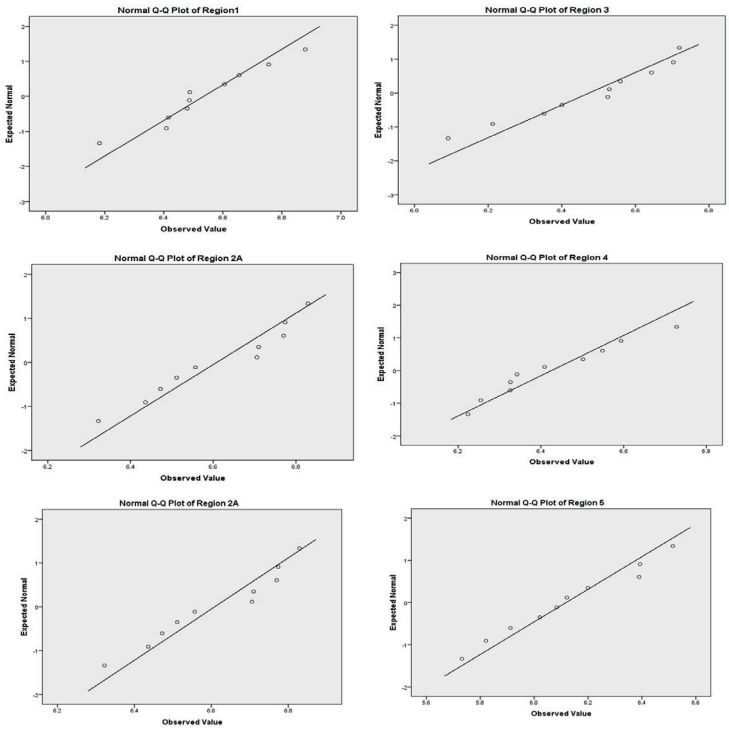


Table 5
Estimated Premiums

	Trigger	Region I	Region IIA	Region IIB	Region III	Region IV	Region V
Premiums of drought cover (1)	10th	0.1946	0.2195	0.4476	0.4651	0.5365	0.5705
	25th	0.2347	0.3022	0.6409	0.6677	0.6490	0.7015
	50th	0.2906	0.5618	0.7472	0.8189	0.7166	0.8266
Premiums of floods cover (2)	60th	0.6059	0.3212	0.1844	0.1224	0.1547	0.0967
	75th	0.4796	0.2450	0.1572	0.0751	0.0823	0.0309
	90th	0.3311	0.2105	0.1170	0.0433	0.0459	0.0203
Overall premiums (1+2)	10th and 60th	0.8005	0.5407	0.6320	0.5876	0.6911	0.6672
	25th and 75th	0.7143	0.5472	0.7981	0.7428	0.7313	0.7324
	50th and 90th	0.6218	0.7723	0.8642	0.8621	0.7625	0.8469

Source: author's analysis.

$$d_2 = \frac{\ln(\frac{I_0}{I_T}) + \mu t}{\sigma\sqrt{t}}.$$

$$\mu = \frac{1}{n-1} \times \ln(\frac{I_n}{I_1}).$$

$\sigma = \frac{1}{n-1}\sum_{i=1}^{n}(u_i - \bar{u})^2$; where $u_i = \ln\left(\frac{I_t}{I_t - 1}\right)$ and $\bar{u} = \frac{1}{n}\sum_{i=1}^{n} u_i$

I_0= the last entry of the cumulative seasonal rainfall as it is the most recent, in the case of region IIB = 600.912

t = 1

$$\mu = \frac{1}{n-1} \times \ln(\frac{I_n}{I_1}) = \frac{1}{10-1} \times \ln(\frac{600.912}{701.292}) = 0.008251$$

σ = 0.281087

r = 0.05 (assumed)

Price of cash or nothing put option = Payout × $e^{-rt} \times N(-d_2)$

$$d_2 = \frac{\ln(\frac{I_0}{I_T}) + \mu t}{\sigma\sqrt{t}} = \frac{\ln\left(\frac{600.912}{593.4312}\right) + 0.008251)}{0.281087} 0.073921$$

$N(-d_2)$= 0.470537

I_T = the 10th percentile = 593.4312

Payout rate = 1

Premium of put option = $1 \times e^{-0.05} \times 0.470537 = 0.447588$

Price of cash or nothing call option = Payout × $e^{-rt} \times N(d_2)$

$$d_2 = \frac{\ln(\frac{I_0}{I_T}) + \mu t}{\sigma\sqrt{t}} = \frac{\ln\left(\frac{600.912}{772.4232}\right) + (0.008251)}{0.281087} = -0.86391$$

$N(d_2) = 0.19382$

I_T = the 60th percentile = 772.4232

Payout rate = 1

Price of cash or nothing call option = Payout × $e^{-rt} \times N(d_2)$ = $1 \times e^{-0.05} \times 0.19382 = 0.184367$

Overall premium = Price of cash or nothing put option + Price of cash or nothing call option = 0.447588 + 0.184367 = 0.631955.

There premium rate paid for both drought and floods cover is 0.631955 for a payout rate of 1 in the event of either floods or drought.

Effects of trigger levels of premium price

The premium rates for other regions at different trigger levels, i.e. percentiles are summarised in table 5. From this table it can be deduced that for region 3 the premiums increase with an increase in trigger value, hence highlighting the importance of trigger values when pricing the contract. The premium for the drought cover increased by 30.34% when the trigger increased from 493.084 mm (10th percentile) to 580.734 mm (25th percentile). When the trigger increased from 693.067 mm (60th percentile) to 752.37 mm (75th percentile), the premium rate for the floods scenario cover decreased by 62.98%. The overall premium increased by 20.89%. The percentage changes of premiums as the trigger values increase are summarized in table 6.

We concluded that, on average, when the trigger value for the drought cover is increased the price of the contract also increases as the probability of rainfall being lower than the trigger value increases hence the higher chances of loss materialization to the insurance company. This conclusion is also similar to that made by [Filiapuspa et al., 2019] who found out that the price of drought index insurance increases with trigger levels. The cost of floods insurance cover decreases with increase in the trigger levels of the contract. This is due to the decrease in the probability of the payment triggered by the lower expectation of costs.

Table 6
Changes in the premium rates

	Trigger	Region I	Region IIA	Region IIB	Region III	Region IV	Region V
Premiums of drought cover((1)	10th	-	-	-	-	-	-
	25th	17.062	27.376	30.159	30.335	17.345	18.677
	50th	19.261	46.204	14.232	18.464	9.429	15.134
Premiums of floods cover(2)	60th	-	-	-	-	-	-
	75th	-26.330	-31.104	-17.274	-63.056	-88.047	-213.125
	90th	-44.830	-16.417	-34.407	-73.580	-79.059	-52.061
Overall premiums (1+2)		-	-	-	-	-	-
		-12.074	1.194	20.815	20.894	5.490	8.906
		-14.872	29.139	7.649	13.845	4.098	13.523

Source: author's analysis.

4. Conclusions and policy recommendations

It was found out that the overall premium rates increased with the increase in trigger levels for the contract. The contract is a combination of drought and floods insurance cover. It was noted that the price of the drought cover separately grew with an increase in trigger levels as the probability of occurrence of the insured event increased. The price of the floods cover was decreasing with the increase in the trigger levels as the probability of the payments being triggered reduced since a majority of the rainfall entries from the collected data were much below these triggers. The overall premium of the contract that covers both droughts and floods generally increased with an increase in trigger levels. This was due to the higher probability of droughts occurence compared to that of floods. It was also found that the price of the contract increased with the increase in the trigger levels of the contract. This was in line with the observations of Okine (2014) who noted that the price of the drought insurance increased with the increase in trigger levels. The price of the contact varied linearly with the price of the drought cover and inversely with the price of the floods cover if these were purchased separately. This was found to be due to the lower likelihood of floods occurrence, which was overpowered by the likelihood of droughts in the period considered in this research.

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About the author

Batsirai Winmore Mazviona
National University of Science and Technology (Bulawayo, Zimbabwe).
winmoreb@gmail.com

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Optimum Routing of Aerial Vehicles and Ambulances in Disaster Logistics

Z. Mahmat[1]
L.S. Sua[2]
F. Balo[1]
[1] Firat University (Elazig, Turkey)
[2] American University of Central Asia (USA)

Abstract

One of the most vital aspects of emergency management is planning and improving post-disaster rescue activities and treatment facilities. Reaching the survivors in the shortest time possible and planning the logistics aspect of post-disaster efforts is one of such issues to be handled when performing these operations. This research involves development of mathematical models for both the debris scanning by the utilization of Unmanned Aerial Vehicles in a disaster area and consequently carrying the injured individuals to the treatment facilities by the available ambulances in the shortest possible time. The mathematical model developed for the ambulance routing problem includes unique constraints that are introduced for the first time in the literature. The proposed model is tested on benchmark problems created by using the real data which belongs to the region under investigation. Computational results indicate the efficiency of the proposed model, particularly in small and medium sized problems.

Keywords: disaster logistics, cluster coverage, multi-depot vehicle routing problem, ambulance routing problem, mathematical modeling.

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Introduction

It is often very difficult to project the outcomes of natural disasters. That is why, taking precautions in advance and improving the logistic infrastructure is imperative. Disaster management encompasses all these activities that must be planned ahead. The field attracts many researchers due to its significant impact.

In terms of their nature of occurrence, the disasters can be classified under natural and human disasters [Sahin and Sipahiohlu, 2003]. Natural disasters are caused by the own actions of the nature while human disasters are initiated by the human impact and/or obstruction on nature. Hurricanes, earthquakes and major accidents can be mentioned as such disasters. Earthquakes, among the others are very difficult to foresee as well as their potential impacts in terms of both financial losses and casualties. Thus, taking precautions and improving the applicable infrastructure is particularly important when it comes to the earthquakes. Unlike earthquakes, disasters like hurricanes are a lot easier to forecast through meteorological data which makes it easier to plan and manage. As a result, especially major earthquakes have the potential of resulting with structural collapses and disruption of transportation activities which makes it even more difficult to reach to the survivors during rescue activities while it is imperative to coordinate such activities as fast as possible.

Advanced technology that is available today makes it possible to scan the disaster area in relatively short duration which is important to see the damage and guide the rescue teams. The east region of Turkey that was hit by an earthquake in 2020, was quickly scanned by Manned Reconnaissance Aircraft and Unmanned Aerial Vehicles. The images were transmitted to the Command Center as they were taken. The vehicles scanned 275 locations within a 3-hour time window, significantly contributing to the rescue teams which were able to reach the survivors within the debris caused by the earthquake.

Another critical issue during and after rescue efforts is the transportation of the survivors to the hospitals within the shortest distance. This paper proposes a mathematical model and solution scheme to scan the disaster location using unmanned aerial vehicles and consequently routing the ambulances and other related vehicles to the appropriate hospitals/treatment centers in shortest time possible. The methodology involves two steps. The first step involves the mathematical formulation of vehicle routing to scan the area an initiate the rescue activities as fast as possible in the most efficient manner. The problem is modelled as a cluster coverage problem to route the aerial vehicles. The subsequent step involves routing the ambulances and a mathematical model is proposed by utilizing a multi-warehouse VRP to suggest the quickest transportation of the injured people to the hospitals. Various scenarios are applied to the proposed model, using GAMS software. The data used for the scenarios are generated by visiting the earthquake sites.

The paper is structured in the following way. The first part presents the scope of the study along with the related studies in the literature. The first major contribution of this research is to present a comprehensive review of related literature summarized in Table 1. In the next section, theoretical framework in disaster management is presented. The third section includes problem details as well as the mathematical models formulated for the problem. The last section involves experimental results and the discussion over the findings along with the future direction for subsequent research efforts.

In this study, the problem of ambulance routing has been taken into consideration. This issue can be associated with the following topics in the related literature; disasters, natural disasters, disaster management, disaster logistics, emergency logistics, emergency logistics, humanitarian aid logistics, and earthquake logistics. There are many studies in the literature on the mentioned issues, some of which are given in Table 1

Table 1
Literature review

Author	Method	Content
Yi and Ozdamar [2007]	Mixed integer commodity network flow model	Coordinating logistical support and evacuation processes in disaster response
Gormez [2008]	Model Development	Disaster response and aid center location selection
Gul[2008]	Mixed integer programming	Post-disaster casualty transportation logistics for a possible earthquake
Yuan and Wang [2009]	Model Development – Dijkstra – Ant colony algorithm	Choosing the best way in emergency logistics management
Tanrıoven [2010]	Simulation	Ambulance guidance after disaster
Ozbek [2011]	Bayesian Networks	Prediction system of pre-disaster mitigation and preparedness studies based on Bayesian networks
Unal [2011]	P-median, Floyd Algorithm and AHP	Post-disaster nutrition and shelter location selection model
Hong and Xiaohua [2011]	AHP	Emergency logistics centers location selection
Lin et al. [2011]	Integer Programming Model-Heuristic Approach-Genetic Algorithm	Logistics design for delivery of priority items in disaster relief operations
Doyen [2012]	Random integer programming	Humanitarian supplies logistics
Zhang J. et al. [2013]	Steiner tree-Intelligent algorithm	Multi-objective location model review
Zhang X. et al. [2013]	Amoeboid algorithm	Route selection in emergency logistics management
Roh et al. [2013]	AHP	Humanitarian depot location
Agdas et al. [2014]	SMAA-2	Location of disaster distribution centers
Kalkanci [2014]	Edge Routing	Assigning and routing snow plows to priority routes
Sahin et al. [2014]	Model Development	Containers of relief supplies to run [mobile-temporary] in s possession, the location and number of
Sheu and Pan [2014]	Mixed Integer Linear Programming Model	Design an uninterrupted central emergency supply network
Liberatore et al. [2014]	RecHADS Model	Recovery of transport infrastructure elements and aid distribution planning

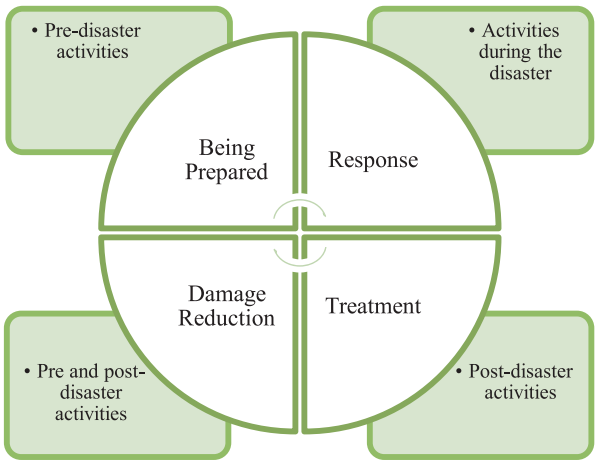
Table 1 *(ending)*

Author	Method	Content
Khojasteh [2014]	Stochastic optimization model	Determining the settlements of medical aid material stores to be used after a disaster
Konu [2014]	Model Development	Multi-product warehouse location determination and pre-positioning of humanitarian elements
Vafaei and Oztaysi [2014]	AHP	Determination of the optimum location of the field hospital
Arslan and Ertem [2015]	Model Development	Using containers, determining the number and location of disaster relief materials instead of stocking them in warehouses
Topal [2015]	Model Development	Transport of disaster relief supplies as soon as possible
He and Liu [2015]	SEIR Model Prediction-Model Development	Building a logistics model with emergency medical demand estimation and aid distribution over the SARS epidemic
Huang et al. [2015]	Uncertainty Theory-4PLROP uncertain programming model	A fourth-party logistics routing optimization with uncertain delivery time in emergencies
Ahmadi et al. [2015]	Stochastic Programming	Multi-store location routing
Ozkapici [2015]	Model Development	Intermodal aid material distribution [sea and road transport]
Peker et al. [2016]	AHS-VIKOR	Location of disaster distribution centers
Ayvaz and Aydin [2016]	Cluster Coverage and P-Median	Disaster logistics warehouse location selection
Uslu [2016]	Stochastic demand multi-warehouse vehicle routing -Model development	Delivering relief supplies as soon as possible after disasters and determining vehicle routes
Tofighi et al. [2016]	Developing a probabilistic-stochastic programming approach	Logistic network design of multiple central warehouses and local distribution centers for potential earthquakes
Ransikarbum and Mason [2016]	Target Programming	Strategic supply distribution and integrated response and recovery for early stage network restoration decisions
Kavlak [2016]	Integer Linear Programming Model	Providing aid materials without handling by a flexible intermodal transport system
Kucuk [2016]	Stochastic programming	Temporary-disaster-response facilities location
Demirdogen et al [2017]	SMAA-2	Location of disaster distribution centers
Ofluoğlu et al. [2017]	ENTROPY-TOPSIS	Disaster logistics warehouse location selection
Yaprak and Merdan [2017]	Stock Control-Demand Analysis	Stock levels of aid materials to be kept in disaster logistics warehouses
Sahin [2017]	Fuzzy VIKOR-Fuzzy TOPSIS	Selection of temporary shelter in case of disaster
Boonmee et al. [2017]	Deterministic , dynamic, stochastic and robust plant location problems	Facility location before and after the disaster
Baskaya et al. [2017]	Model Development	Lateral transfer [number] opportunities, disaster relief facility locations and number, number of relief supplies
Sebath [2017]	Decision Support System	Disaster response facilities [GAM] placement
Haghi et al. [2017]	Multi-purpose programming model	Determination of the locations of health centers and distribution centers
Kaya [2018]	Model Development	Number and location of aid stations in disasters
Kucuk and Cavdur [2018]	Route generation-elimination algorithm and Integer Programming	Post-disaster relief material handling, routing and assigning vehicles to routes
Konu et al. [2018]	Model Development	Pre-positioning aid materials
Wang et al. [2018]	Ideal point algorithm-Ant colony	Urgent material shipment and transportation
Zhang et al. [2018]	Uncertainty Model Development	Multi-area emergency facilities location selection
Roh et al. [2018]	Fuzzy AHP-Fuzzy TOPSIS	Choosing the most suitable warehouse location for international humanitarian organizations
Loree and Aros-Vera [2018]	Model Development	Determining the location of distribution points and allocation of inventory in post-disaster humanitarian logistics
Vahdani et al. [2018]	Model Development-NSGAII and MOPSO algorithms	Two multi-purpose and multi-period geolocation – inventory models for three-level relief chain

Table 1 *(ending)*

Author	Method	Content
Trivedi [2018]	DEMETAL	Choosing a place of shelter for disaster planning
Ozbay [2018]	Mixed integer modeling	Tent – city location selection after the earthquake
Samarah [2018]	Model Development	Warehouse location selection before disaster
Abbasoglu [2019]	Demand Forecast-Facility Layout Model	Location of disaster distribution centers
Sozen [2019]	Model Development- AHP-Conic target programming	Choosing the most suitable disaster logistics system
Zhang et al. [2019]	Stochastic programming model	Emergency resource allocation
Temur et al. [2019]	AHP and P-median Model	Establishing a humanitarian aid distribution center after an earthquake
Suzuki [2019]	Material Convergence [p-method, m-method]	The effect of material convergence on last mile distribution in humanitarian logistics
Cotes and Cantillo [2019]	Model Development	Plant layout for material positioning in the flood area
Maharjan and Hanaoka [2019]	Model Development	Developing a multi-objective location allocation model for disaster response facilities
Acar and Kaya [2019]	Stochastic programming	Network design taking into account the displacement and displacement of mobile hospitals for an expected earthquake
Cavdur and Sebatlı [2019]	Decision Support System - Stochastic programming	Temporary disaster response facility allocation for relief supplies distribution under demand uncertainty
Davoodi and Goli [2019]	Model Development	Prevention of late arrival of aid vehicles to disaster areas in critical situations
Keser [2019]	AHP	Disaster logistics warehouse organization location selection
Dorum [2019]	Model Development	Multi-period , multi-material optimal inventory positioning and routing after natural disaster
Mostajabdaveh [2019]	Mixed integer programming-Genetic algorithm	Selection of shelter in disaster and distribution of aid materials to shelters
Feng et al. [2020]	Model Development	Location of emergency material pools
Budak et al. [2020]	Fuzzy DEMETAL-Fuzzy ANP-Fuzzy TOPSIS	Application of real-time location systems to humanitarian logistics
Oksuz and Satoglu [2020]	Stochastic programming	Determining the location and number of temporary medical centers in case of disaster

Fig. 1. Phases in Disaster Management



Source: [Uslu, 2016].

1. SCIENTIFIC FOUNDATIONS

Although the causes of disasters vary, they all have the potential to have significant life and property damages which require carefully planned and coordinated efforts spanning pre-disaster and post-disaster time window. While pre-disaster measures have the greatest impact in minimizing the casualties and property damages, post-disaster measures are also critical towards the same goal. Disaster management includes the planned efforts to increase awareness of people on the natural conditions in their regions, recognition of the reasons for occurrence, and helping the residents of the region not to be affected if similar situations repeat in the future [Erkal and Degerliyurt, 2009]. Tanyas et al. claims that disaster management should focus on minimizing the damage rather than optimizing the events [Tanyas et al.2013].

Pre-disaster planning and disaster logistics are critical components in disaster management and they will eventually evolve into post-disaster practices [Agdas et al.2014]. Disaster logistics can be defined as the group of studies on the delivery of first aid materials, food supplies, and rescue teams to various

points affected by the disaster, transporting the injured people from the area as fast as possible and reaching hospitals for the required treatment [Barbarosoglu et al. 2002].

2. MATERIALS AND METHODS

Erzincan city located on the Northern Anatolia Fault Line is taken into consideration for this research. Post-disaster activities following a destructive earthquake start with scanning the area with the aim of determining the collapsed buildings. The earthquake took place in Elazig in the same region on 2020 is where the aerial vehicles were successfully used and resulted in significant benefits. This study aims to assess the performance of the unmanned aerial vehicles in cluster coverage problem to calculate the optimal number of vehicles to cover the area. The number of aerial vehicles needed to scan the area was calculated for 68 neighborhoods in Erzincan province. Consequently, assignment of injured people to the six hospitals within the same region and ambulance routing problem is discussed in this section.

2.1. Coverage Problem

Cluster coverage problems are usually associated with location decisions. The purpose of using this type of mathematical models is to determine the number of supply facilities that can meet the demand of a set of demand facilities in a way that will minimize the total cost or maximize the area covered. Below is a list of coverage problems (Kara, 2014):

- Highest Space Coverage Problem [Sarikaya et al. 2020]
- Cluster Coverage Problem [Aktas et al. 2011, Sezen and Erben 2019, Ozturk et al. 2013]
- Double Coverage Problem [Catay et al. 2008]
- Reserve Coverage Problem [Catay et al. 2008].

Indices:

i = Index indicating the demand points i = 1, 2, 3, …., T

j = Index indicating facility points j = 1, 2, 3, ….. , S

Parameters:

$a_{ij}=\begin{cases}1 & \text{if the facility j meets the demand of demand i}\\ 0 & \text{otherwise}\end{cases}$ $\forall$ i, j

M_j = fixed of facility j $\forall$ j

Decision Variables:

$x_j=\begin{cases}1 & \text{if facility is is to be established at j}\\ 0 & \text{if not}\end{cases}$ $\forall$ j

Objective Function:

$$\text{Min} \sum_{j=1}^{S} M_j * x_j \quad (2.1.1.1)$$

Constraints:

$$\sum_{j=1}^{S} a_{ij} * x_j \geq 1 \quad \forall i \quad (2.1.1.2)$$

$$x_j \in \{0,1\} \quad \forall j \quad (2.1.1.3)$$

If the costs are the same for each facility to be opened, the objective function is:

$$\text{Min} \sum_{j=1}^{S} x_j \quad (2.1.1.4)$$

2.1.1. Cluster Coverage Model

These types of problems are mainly used to determine the number of emergency aid locations and distribution centers in disasters. Mathematical model of the cluster coverage problem is presented as it follows [Aktas et al. 2011]. The provided model is formulated for S facility points and T demand points.

While the aim in Equation 2.1.1.1 is minimizing the total cost, the aim is minimizing the number of facilities to be opened in Equation 2.1.1.4 since facility opening costs are equal. Equation 2.1.1.2 represents the constraint which cuts the inclusion of each demand point of the facilities to be opened. Constraint 2.1.1.3 ensures the decision variables have integer values.

2.1.2. Cluster Coverage Model to Determine the Number of Aerial Vehicles

Number of aerial vehicles to be utilized for scanning purposes after the earthquake, the model presented below is built on the mathematical model discussed in the previous section.

Determining the optimum number of aerial vehicles to be utilized to screen the disaster area is the objective of using this model in the implementation study presented in Section 3.

Indices:

i = Index indicating the neighborhood i = 1, 2, 3 ,…., T

j = Index indicating the neighborhood to be centered for UAVs j = 1, 2, 3 ,… .., S

Parameters:

$a_{ij}=\begin{cases}1 & \text{if the center neighborhood at point j is covering the neighborhood i}\\ 0 & \text{otherwise}\end{cases}$

$\forall$ i, j

Decision Variables:

$x_j=\begin{cases}1 & \text{j point center neighborhood is chosen}\\ 0 & \text{otherwise}\end{cases}$ $\forall$ j

Objective Function:

$$\text{Min} \sum_{j=1}^{S} x_j \quad (2.1.2.1)$$

Constraints:

$$\sum_{j=1}^{S} a_{ij} * x_j \geq 1 \quad \forall i \quad (2.1.2.2)$$

$$x_j \in \{0,1\} \quad \forall j \quad (2.1.2.3)$$

2.2. Vehicle Routing Problem

Compared to the Traveling Salesman Problem, Vehicle Routing Problem is more challenging due to more constraints and multiple tools. Vehicle routing problems are classified as NP-Hard [Demirtas and Ozdemir, 2017]. This problem type was first introduced by [Dantzig and Ramser 1959], and later this study was developed by [Clarke and Wright 1964] and the classical saving method was introduced. Although there are variations in terms of constraints [Duzakın and Demircioglu 2009], 3 areas emerge. These are:

Constraints on current clients

- Constrained time windows for distribution of product/ service claims
- Each client has one or more demand constraints

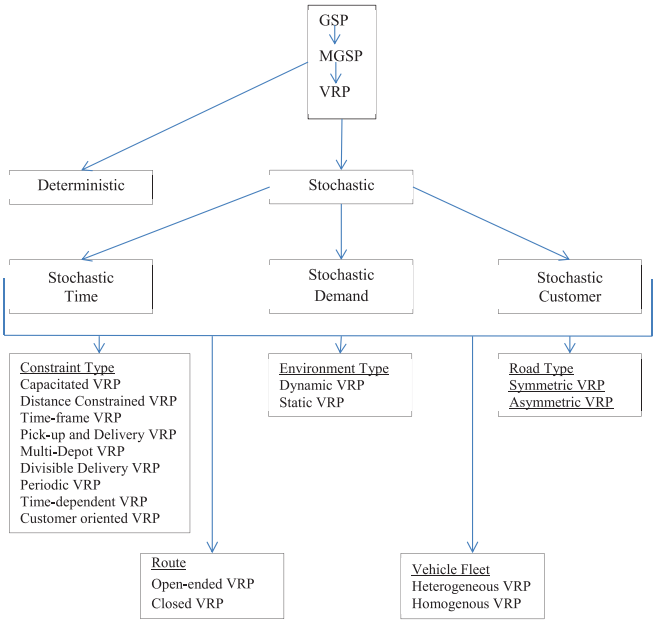
Constraints on the planned vehicles to be utilized

- Limitations on total vehicle time

– Weight or volume constraints of vehicles
– Constraints on legal working hours of vehicle drivers

Other constraints
– Tours exceeding one day length
– Number of tours of the vehicles is more than one restrictions
– Number of facilities to be used is more than one.

Fig. 2. Vehicle routing problem types



Sets;

I: Depots

J: Customers

K: Vehicles

Parameters;

N: Total number of customers

c_{ij}= distance between i and j points i, j Є I U J

v_i= capacity of the depot I, i ЄI

d_j= demand from customer j, j ЄJ

q_k= capacity of vehicle k, k ЄK

Decision variables;

$x_{ijk}=\begin{cases}1, & \text{if using vehicle k from point i to point j} \\ 0, & \text{otherwise}\end{cases}$ I ,j Є IUJ

$z_{ij}=\begin{cases}1, & \text{if customer j is assigned to depot} \\ 0, & \text{otherwise}\end{cases}$

U_{lk}= dummy variable, which is the sub-tour elimination constraint on vehicle/route k

Mathematical Model;

$$\text{Min } Z = \sum_{i\in IUJ}\sum_{j\in IUJ}\sum_{k\in K} x_{ijk}\, c_{ij} \quad (2.2.1.1)$$

$$\sum_{k\in K}\sum_{i\in IUJ} x_{ijk} = 1 \qquad \forall j\in J \quad (2.2.1.2)$$

$$U_{lk} - U_{jk} + N x_{ijk} \le N-1 \qquad \forall\, l, j \in J, \forall\, k \in K \quad (2.2.1.3)$$

$$\sum_{j\in IUJ} x_{ijk} - \sum_{j\in IUJ} x_{jik} = 0 \qquad \forall k\in K, i\in IUJ \quad (2.2.1.4)$$

$$\sum_{k\in K}\sum_{i\in IUJ} x_{ijk} \le 1 \qquad \forall k\in K \quad (2.2.1.5)$$

$$\sum_{i\in IUJ}\sum_{j\in J} d_j x_{ijk} \le q_k \qquad \forall k\in K \quad (2.2.1.6)$$

$$\sum_{j\in J} d_j z_{ij} \le v_i \qquad \forall i\in I \quad (2.2.1.7)$$

$$-z_{ij} + \sum_{u\in IUJ} (x_{iuk} + x_{ujk}) \le 1 \qquad \forall i\in I, j\in J, k\in K \quad (2.2.1.8)$$

$x_{ijk}\in\{0,1\}$ $\forall i\in I, j\in J, k\in K$ (2.2.1.9)

$z_{ij}\in\{0,1\}$ $\forall i\in I, j\in J$ (2.2.1.10)

$U_{lk} \ge 0$ $\forall l\in J, k\in K$ (2.2.1.11)

The problem investigated within the scope of this research is closely related to the Multi-Depot Vehicle Routing Problem (MD–VRP), thus MD–VRP is explained in the following section.

2.2.1. Multi-Depot VRP

MD–VRP is a particular case of VRP problem and it aims providing service to multiple clients using multiple facilities in the shortest time and minimum cost possible while finding optimum vehicle routes. Some studies using this problem type appear as follows. [Yilmaz, 2008] made the modeling of the multi-depot VRP with an ant colony algorithm and proposed a solution. [Yildiz, 2011] discussed the problems of VR charts in logistics industry. [Onder, 2011] discussed the bread distribution of Istanbul Public Bakery Facilities as a multi-depot VRP. In his study, [Ozer, 2016] modelled a multi-depot VRP (MD–VRP) to trasport liver transplantation to transplant centers in the shortest time. [Kiziloglu, 2017] studied the stochastic multi-depot VRP with heuristic solutions using a chance constraint approach. [Sadatizamanabad, 2018] utilized a multi-depot VRP in supply chain networks aiming to protect critical facilities. [Ozen, 2020] proposed a mathematical model for an open-ended MD–VRP for the feeder bus network design.

Assigning vehicles to the facilities and clients to the vehicles while ensuring that the demands do not exceed the vehicle capacities are the main constraints for the mathematical model introduced in this study. It is the objective to determine which clients being served from which facility and using which vehicle. It is imperative to decide which patients should be treated in which hospital and transported to the hospital using which vehicle. In the ambulance routing problem discussed in this study, hospitals are referred as depots, the injured people as clients and ambulances as vehicles.

The problem is solved using the mathematical model introduced by [Mirabar, 2010] for the MD–VRP:

The objective function of the model is minimizing the distance traveled. Constraint (2.2.1.1) refers to the assignment of each customer to a single route. (2.2.1.3) expresses the sub-route elimination. (2.2.1.4) shows that each node in the routes has one entry and exit. (2.2.1.5) indicates that each vehicle is dispatched from one and only depot. (2.2.1.6) shows that the demands of the clients on each route are not more than the capacities of the vehicles on the routes. (2.2.1.7) indicates that each customer demand is not more than the capacity of the depot to which it is assigned. The constraint (2.2.1.8) shows that each customer is on the route of the depot to which it is assigned. (2.2.1.9, 10, 11) are the sign constraints of the decision variables.

2.2.2. Mathematical Model Developed for Ambulance Routing Problem

Following the model that [Mirabi, 2010] has proposed for MD–VRP, the mathematical model that is introduced here is provided under this section. The model itself is one of the main contributions of this study to the available literature. Another contribution is the development of another model named ambulance routing problem which is formulated based on this problem. To the best of our knowledge there is no study on the in

the literature on ambulance routing problem. Thus, the study is unique in the sense that both the problem itself and the developed mathematical model are new.

Ambulance routing problem discussed within the context of this research aims moving the injured people to the nearest treatment facilities in the fastest way possible given the existing constraints. On the other hand, considering the capacities of the ambulances, it is critical that ambulances make multiple trips and deliver people to the hospitals. Meanwhile, it is considered that ambulances will transport the injured people to different hospitals in case the capacities of the hospitals are full. Fig. 3 illustrates the network of hospitals, ambulances, and wreckage areas in certain areas of the city.

Fig. 3. An example solution to the problem

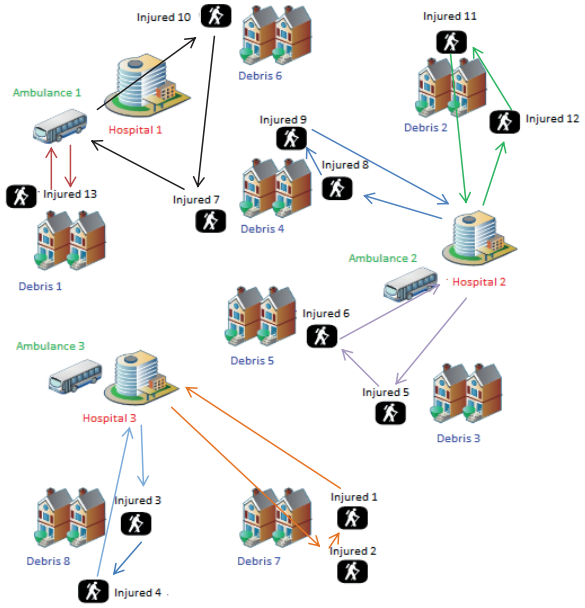


Fig. 3 indicates that there are three hospitals, three ambulances, and thirteen individuals to be taken to the hospitals. The model assumes the hospital capacities are defined and ambulances can transport two individual together. The solution scheme provided in the figure shows that two trips are assigned to the first ambulance, while three trips are assigned to the second, and two trips are assigned to the third ambulance. Another observation is that the seventh and tenth individuals are transported in the first trip while the thirteenth individual is transported on the second trip. Similarly, the remained assignments of injured people to the trips can also be observed in the figure. The solution takes the hospital and ambulance capacities were also taken into account.

The model shown in fig. 3 incorporates various assumptions, constraints, and parameters which are specified as below:

- All injured individuals must be carried to a hospital.
- Suggested solution should satisfy the ambulance and hospital.
- Capacities of the ambulances are assumed to be the same.
- Ambulances can be assigned multiple trips.
- An ambulance can carry the injured individual to the hospitals other than the one that it belongs, but it arrives at the next incident point after stopping at the hospital to which it will carry the patient in the first place to take the necessary equipment.

Index sets;
I: Hospitals
J: Injuries
K: Ambulances
M: Trips

Parameters;
N: Total number of injuries
c_{ij}= distance between i and j points i, j Є I U J
v_i= capacity of hospital i, i ЄI
d_j= demand of injury j, j ЄJ
q_k= capacity of ambulance k, k ЄK
b_m= cost of trip m, m ЄM

Decision variables;

$x_{mijk}=\begin{cases}1, & \text{if ambulance k is used from point i to point j with trip m}\\ 0, & \text{otherwise}\end{cases}$ i,j Є IUJ

$z_{mij}=\begin{cases}1, & \text{if injured j is transported to hospital i with trip m}\\ 0, & \text{otherwise}\end{cases}$

$p_{mijk}=\begin{cases}1, & \text{if ambulance k goes to hospital j from hospital i with trip m}\\ 0, & \text{otherwise}\end{cases}$

U_{mlk}= dummy variable of sub-tour elimination constraint at k ambulance/route
h_m= variable showing the availability of trip m

Mathematical Model;

$$\text{Min } Z = \sum_{m\in M}\sum_{i\in IUJ}\sum_{j\in IUJ}\sum_{k\in K} x_{mijk}\, c_{ij} + \sum_{m\in M}\sum_{i\in I}\sum_{j\in I}\sum_{k\in K} p_{mijk}\, c_{ij} + \sum_{m\in M} h_m b_m \quad (2.2.2.1)$$

$$\sum_{m\in M}\sum_{k\in K}\sum_{i\in IUJ} x_{mijk} = 1 \qquad \forall j\in J \quad (2.2.2.2)$$

$$U_{mlk} - U_{mjk} + N x_{mljk} \le N-1 \quad \forall l,j\in J,\ \forall k\in K,\ \forall m\in M \quad (2.2.2.3)$$

$$\sum_{j\in IUJ} x_{mijk} - \sum_{j\in IUJ} x_{mjik} = 0 \qquad \forall k\in K,\ i\in IUJ,\ m\in M \quad (2.2.2.4)$$

$$\sum_{k\in K}\sum_{i\in IUJ} x_{mijk} \le 1 \qquad \forall k\in K,\ m\in M \quad (2.2.2.5)$$

$$\sum_{i\in IUJ}\sum_{j\in J} d_j x_{mijk} \le q_k \qquad \forall k\in K,\ m\in M \quad (2.2.2.6)$$

$$\sum_{j\in J} d_j z_{mij} \le v_i \qquad \forall i\in I,\ m\in M \quad (2.2.2.7)$$

$$-z_{mij} + \sum_{u\in IUJ} (x_{miuk} + x_{mujk}) \le 1 \qquad \forall i\in I,\ j\in J,\ k\in K,\ m\in M \quad (2.2.2.8)$$

$$-1 + \sum_{j\in J} x_{mijk} + \sum_{j\in J} x_{wtjk} - \sum_{o\in M}\sum_{j\in J} x_{oijk} \le p_{mitk} \quad (2.2.2.9)$$
$$\forall i\in I,\ t\in I,\ k\in K,\ (m,w,o)\in M,\ \ i\neq t, m>o>w, m>1$$

$$x_{mijk} = 0 \quad \forall i\in I,\ j\in I,\ k\in K,\ m\in M \quad (2.2.2.10)$$

$$\sum_{i\in I}\sum_{j\in J} z_{mij} = h_m \quad \forall m\in M \quad (2.2.2.11)$$

$$\sum_{i\in I}\sum_{j\in J} z_{mij} * 1000 \ge \sum_{i\in I}\sum_{j\in J} z_{(m+1)ij} \quad (2.2.2.12)$$

$$x_{mijk}\in\{0,1\} \quad \forall i\in I,\ j\in J,\ k\in K,\ m\in M \quad (2.2.2.13)$$

$$z_{mij}\in\{0,1\} \quad \forall i\in I,\ j\in J,\ m\in M \quad (2.2.2.14)$$

$$U_{mlk} \ge 0 \quad \forall l\in J,\ k\in K,\ m\in M \quad (2.2.2.15)$$

IMathematical model developed based on the above-mentioned assumptions is provided as it follows:

In the objective function of the model (2.2.2.1), the total travel time, the cost of ambulances going to distant hospitals, and the costs resulting from the additional trips were aimed to be minimized. Constraint (2.2.2.2) implies assigning a single route for each injured. Constraint (2.2.2.3) represents the sub-tour elimination. Constraint (2.2.2.4) means that each node in the routes has a single entry and exit. Constraint (2.2.2.5) means that each ambulance leaves a single hospital. Constraint (2.2.2.6) limits the demands of the injured individuals on each route with the capacities of the ambulances on the routes. Constraint (2.2.2.7) ensures each injured individual demand does not exceed the capacity of the hospital to which it is assigned. Constraint (2.2.2.8) means that each injured person is on the route of the hospital to which they are assigned. Constraint (2.2.2.9) ensures that ambulances are directed to the same and nearest hospital, if possible. Constraint (2.2.2.10) ensures that the transfer between hospitals is not assigned to each other at the relevant time. Constraint (2.2.2.11) allows the trips to be activated gradually. Constraint (2.2.2.12) ensures the assignment of injured people to be transported in the initial trips to a large number of hospitals. (3.2.2.13–2.2.2.14–2.2.2.15) are the constraints limiting the signs of the decision variables.

The developed model is tested on several scenarios and its results are analyzed within the next section.

Table 2.
District clusters obtained from the cluster inclusion problem

Cluster Number (Representation)	Central Clusters	District Numbers Covered
1 (A)	6. Davarlı	6
2 (B)	8. Büyük Çakırman	8
3 (C)	11. Bayrak	11
4 (D)	24. Gazi	1, 2, 5, 10, 12, 14, 15, 16, 20, 21, 22, 24, 31, 43
5 (E)	39. Mengüceli	9, 13, 27, 32, 36, 39, 48, 49, 51, 54, 56, 60, 61, 62, 63, 64
6 (F)	50. Sarıgöl	3, 4, 7, 17, 18, 19, 23, 25, 28, 30, 34, 35, 37, 38, 40, 41, 44, 50, 52, 53, 55, 57, 58, 59, 65, 66
7 (G)	67. Terzibaba	26, 29, 33, 42, 45, 46, 67, 68

3. Research findings

Central district of Erzincan province is used as a benchmark in this research and based on the most recent earthquake in the same region, debris scanning and the most efficient transportation of the injured people to the hospitals are searched. Mathematical models are developed (Sections 3.1.1. and 3.2.1.) for debris scanning and transporting people from incident locations to the hospitals. The following section presents the data used to test the models as well as the information on the implementation.

3.1. Ideal number aerial vehicles

Cluster coverage problem for 68 districts of Erzincan was investigated and the necessary number of UAVs was calculated. The main goal of this problem type is to cover the maximum number of areas using the minimum number of facilities. Treating the unmanned aerial vehicles as facilities, it is aimed to determine the required number of them. To find out the required number of aerial vehicles, the distance matrix of the neighborhoods is generated using Google Maps. The distance values indicate the minutes of the distance traveled by vehicles. The number of aerial vehicles needed to scan the area was determined using the mathematical model in Section 3.1.2, assuming that the aerial vehicles scan distances of 5–10–15–20 minutes.

The solution scheme obtained from Gams software indicates that 17 UAVs are needed for a 5-minute scanning distance while 7 UAVs are required for a 10-minute distance, 2 UAVs for a 15-minute scanning distance, and 2 UAVs for a 20-minute scanning distance. Taking the need for a more detailed scanning after an earthquake into account, 7 UAVs are assumed to be needed in developing datasets in the application stage of ambulance routing problem and the injured individuals are transported to the appropriate districts considering such clusters. The district clusters that occur when 7 UAVs are used are given in table 2.

Datasets are developed based on the mathematical model developed for the ambulance routing problem was tested and presented in the following section.

Table 3
Random distribution of the injured by the district clusters

Trial	Number of Injured	Cluster + District (Number of Injured)
1	10	A6(1)-B8(1)-C11(1)-D1(1)-D2(1)-E9(1)-E13(1)-F3(1)-F4(1)-G26(1)
2	10	A6(1)-B8(1)-C11(1)-D5(1)-D10(1)-E27(1)-E32(1)-F7(1)-F17(1)-G29(1)
3	10	A6(1)-B8(1)-C11(1)-D12(1)-D14(1)-E36(1)-E39(1)-F18(1)-F19(1)-G33(1)
4	10	A6(1)-B8(1)-C11(1)-D15(1)-D16(1)-E48(1)-E49(1)-F23(1)-F25(1)-G42(1)
5	20	A6(1)-B8(1)-C11(1)-D20(1)-D21(1)-E51(2)-E54(2)-E56(2)-F28(2)-F30(2)-F34(2)-F35(2)-G45(1)
6	20	A6(2)-B8(4)-C11(1)-D22(1)-E60(2)-E61(2)-F37(2)-F38(2)-F40(2)-G46(2)
7	20	A6(3)-B8(1)-C11(3)-D24(1)-E62(3)-F41(1)-F44(1)-F50(1)-F53(1)-F55(1)-G67(3)
8	20	A6(4)-B8(4)-C11(4)-D31(1)-D43(1)-E63(1)-E64(1)-F57(1)-F58(1)-F59(1)-G68(1)
9	30	A6(1)-B8(1)-C11(4)-D1(3)-D2(3)- D5(3)- D10(3)-E9(1)-E13(1)-E27(1)- E32(1)-F65(2)-F66(2)-G26(2)-G29(2)
10	30	A6(1)-B8(1)-C11(2)-D12(4)-D14(4)-E36(2)-E39(2)-E48(2)- E49(2)-F3(1)-F4(1)- F7(1)- F18(1)-F19(1)- F23(1)-G33(2)- G42(2)
11	30	A6(1)-B8(1)-C11(1)-D15(3)-D16(3)-D20(3)-E51(3)-E54(3)-E56(3)-F23(1)-F25(1)- F28(1)-G45(3)-G46(1)-G67(1)-G68(1)
12	30	A6(1)-B8(1)-C11(1)-D21(4)-D22(4)-D24(4)-D31(4)-E60(1)-E61(1)-E62(1)-E63(1)-F30(1)-F34(1)-F35(1)-F37(1)-G26(1)- G29(1)-G33(1)
13	40	A6(1)-B8(1)-C11(1)-D1(5)-D2(4)-D5(3)-E9(4)-E13(5)-E39(4)-E51(4)-F65(2)-F66(2)-G45(3)-G46(1)
14	40	A6(2)-B8(4)-C11(2)-D15(4)-D16(4)-D20(4)-D24(4)-E48(2)-F25(4)-F28(4)-F30(4)-G67(2)
15	40	A6(1)-B8(1)-C11(1)-D12(3)-D14(3)- D31(3)- D43(3)-E32(1)-E36(1)-E39(1)- E48(1)-F30(3)-F34(3)-F35(3)-F37(3)-F38(3)-G33(6)
16	40	A6(4)-B8(4)-C11(1)-D20(1)-D21(1)-D22(1)-E60(4)-E61(4)-E62(4)-E63(4)-E64(4)-F17(1)-F18(1)-F19(1)-F23(1)-G68(4)

Table 4
Number of hospitals and their total capacities

Trial	Number of Hospitals	Total Hospital Capacity
1	1	15
2	1	15
3	1	15
4	1	15
5	2	30
6	2	30
7	2	30
8	2	30
9	3	45
10	3	45
11	3	45
12	3	45
13	3	60
14	3	60
15	3	60
16	3	60

Table 5
Capacity distribution among three hospitals

Trial	H1	H2	H3
1	15	X	X
2	X	15	X
3	X	X	15
4	15	X	X
5	10	20	X
6	X	14	16
7	12	X	18
8	10	20	X
9	15	15	15
10	10	20	15
11	15	12	18
12	12	15	18
13	20	20	20
14	20	36	4
15	21	3	36
16	4	40	16

Table 6
Distribution of ambulance numbers and capacities and the number of injuries-trips

Trial	Number of Ambulances	Ambulance Capacity	Number of Injured	Number of Trips
1	2	1	10	5
2	2	2	10	3
3	2	3	10	2
4	2	4	10	2
5	4	1	20	5
6	4	2	20	3
7	4	3	20	2
8	4	4	20	2
9	6	1	30	5
10	6	2	30	3
11	6	3	30	2
12	6	4	30	2
13	8	1	40	5
14	8	2	40	3
15	8	3	40	2
16	8	4	40	2

3.2. Routing Ambulances

Seven district clusters were obtained by applying the mathematical model in section 2.1.2 for 68 districts of Erzincan. The mathematical model in section 2.2.2 has been tested based on these district clusters. The parameters addressed during the model trial are:

- Number of ambulances
- Ambulance capacity
- Number of hospitals
- Hospital capacity
- Number of trips
- Number of injured.

The mathematical model that was developed along with all these datasets and the assumptions was solved using the GAMS software and the computational results are presented in the following section.

4. Conclusion and recommendations

The proposed model was tested and ambulance routing for Erzincan was investigated for smaller examples. In the trial studies, the number of injured was changed to 10–20–30–40 and four trial studies were conducted for each injury cluster. Hospital capacities, ambulance capacities and number of trips varied in each injury cluster. At the same time, the responses of the system were examined by changing the ambulance capacities and the number of trips for the same injured locations in some trial studies. Solution times of the model that was solved with the help of the GAMS and explanations for the solution are provided in table 7.

The findings obtained as a result of the experiments are as follows. As a result of the first trial, the program gave a solution very quickly and the result was the optimum solution. However, in the second attempt, although the program ran for about an hour, it gave an acceptable solution, not an optimum. At the end of the third trial, the program again worked for about an hour, but gave an optimum solution. In the fourth trial, the ambulance capacity was gradually increased and the solution time of the program remained as one hour. The result was not an optimum but an acceptable value. As a result of the increase in the number of injured, only the fifth trial was solved in a short time and gave the optimum solution. However, other trial periods

Table 7. Results and solution times of ambulance routing in GAMS program

Trial	Result	Solution Time (sec)	Solver Status	Model Status
1	22508	0.170	1	1
2	437	3600.024	3	8
3	201	3339.551	1	1
4	202	3600.014	3	8
5	44794	1.093	1	1
6	772	3600.124	3	8
7	295	3600.143	3	8
8	263	3600.078	3	8
9	67170	5400.505	3	8
10	1048	5400.299	3	8
11	499	5400.309	3	8
12	460	5400.305	3	8
13	89509	10801.429	3	8
14	—	—	—	—
15	595	10800.394	3	8
16	—	—	-	—

increased in direct proportion as a result of the increase in the number of injured. The results obtained were not optimum but acceptable values. The trials were considered as 40 wounded and 3 hospitals at most, but the program did not provide solutions within reasonable periods (around 3 hours for 40 injured) in 14 and 16 trials for randomly assigned injured numbers and locations. According to the trials, the increase in the number of injured and other variables prolonged the solution period of the program. At the same time, almost all of the obtained results received an acceptable value, not an optimum. And again, in case the system becomes complicated, the program could not get results within a reasonable time.

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About the authors

Zeliha Mahmat
Department of Industrial Engineering, Firat University (Elazig, Turkey). https://orcid.org/0000-0003-0717-7880.

Lutfu S. Sua
School of Entrepreneurship and Business Administration, American University of Central Asia (USA). https://orcid.org/0000-0003-0717-7880.
lutsua@gmail.com

Figen Balo
Doctor of Industrial Engineering, Professor, Department of Industrial Engineering, Firat University (Elazig, Turkey). https://orcid.org/0000-0001-5886-730X.

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Reducing the risks of illicit trafficking in industrial products to achieve sustainable development goals

A.L. Lisovsky[1]

[1] "NPO Krypten" JSC (Moscow, Russia)

Abstract

Achieving the Sustainable Development Goals is impossible without the active participation of business, including contributing to the environment, improving the quality of human capital, supporting significant initiatives in the field of ensuring economic growth and creating new jobs; ensuring the well-being and health of citizens; ensuring responsible consumption and production. A significant task for achieving the Sustainable Development Goals is the development of mechanisms to protect the domestic market from illegal trafficking of industrial products, which will lead to the protection of public health and increase jobs. And the increase in tax collection will strengthen the social protection of the population.

In Russia in 2021, the turnover of counterfeit products amounted to 7.2 billion rubles and, according to experts, will continue to grow. In this regard, it is necessary to analyze the risks of existing mechanisms of protection against counterfeit products and develop measures to reduce them.

The object of research in this article is labeling, which is the application of a special DataMatrix code to the packaging and the entry of this unit of goods into the database.

The purpose of the article is to develop recommendations on the use of additional visual control tools on the material carriers of the DataMatrix code, protected from forgery, and to assess the probability of the level of risk reduction and the level of possible losses when using them.

The novelty of this study was: identification and analysis of risks of possible threats to the security of the mandatory labeling system for various categories of goods; development of a risk register of possible threats to the security of the system with a grouping of qualitatively assessed and quantifiable risks; development and verification of a model for assessing the probability and possible losses for a group of quantifiable risks; assessment of the probability of risks and possible budget losses from non-payment of taxes and excise duties; assessment of the probability of risks and possible losses for a bona fide manufacturer and end user; formation of management measures aimed at reducing the likelihood of risks and reducing the consequences of the potential implementation of risks; assessment of the residual level of probability and exposure to risks when using additional means of visual control on the material carriers of the DataMatrix code; assessment of the residual level of probability and exposure to risks when using additional visual inspection tools on tangible media protected from counterfeiting in similar systems and Track&Trace marking systems implemented in foreign countries.

The results obtained can be applied by federal executive authorities in the formation of state policy in the field of increasing the level of security of Russians, significantly reduce the amount of counterfeit and low-quality analogues, effectively combat smuggling, protect legal businesses and consumers, and also allow the state to increase tax collection.

Keywords: sustainable development, illegal turnover of products, industrial companies, risks of sustainable development, environmental and social responsibility.

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Introduction

The events of the last few years clearly demonstrate that the changes taking place in all sectors of the economy and public life will only accelerate and radically affect the existing social ties. The demand for the active participation of business in the implementation of sustainable development goals is constantly growing, which includes contribution into the environment, improvement of the human capital quality, support of significant initiatives in the field of economic growth and the creation of new jobs. It also ensures the well-being and health of citizens, responsible consumption and production. These goals are reflected in the Russian Federation Presidential Decree No. 204 dated by May 7, 2018 "On National Goals and Strategic Objectives for the Development of the Russian Federation for the period up to 2024", strategic documents of the

Government of the Russian Federation as well as in national and federal projects. They were put into practice within a few years. An important task for achieving the goals of sustainable development is the development of mechanisms to protect the domestic market from illicit trafficking of industrial products.

In the modern economy, the problem of ensuring the protection of markets from illegal circulation of industrial products is international in nature, and crimes in the production of counterfeit and fake products are among the most serious economic crimes[1].

According to the WTO, the global turnover of counterfeit goods is about 500 billion USD, the OECD estimates the global market for counterfeit products at 650 billion USD. At the same time, there is a tendency for a steady and significant increase in the turnover of fake products.

In Russia the turnover of counterfeit products amounted to 7.2 billion RUB in 2021 against 4.7 billion RUB a year earlier. The growth of counterfeit products is facilitated by factors such as the spread of online trading, a decrease in the income level of the population and the inability to visually distinguish a fake from a real product. In the future, the increase in the uncertainty of the external environment and the possible decline in the well-being of the population will also contribute to an increase in illicit trafficking of industrial products.

The Russian authorities consider mandatory labeling of goods to be the most effective measure to combat counterfeit goods [Bogdanov et al., 2012; Bogdanov et al., 2013]. According to V. Zaslavsky, deputy director of the system for digital marking of goods and legalization of product turnover of the Ministry of Industry and Trade of the Russian Federation, "the marking system has almost completed integration with all control systems of supervisory authorities. This will become the most effective tool for controlling illegal circulation of products" [2]. At the same time, many professional community members do not consider the current labeling system to be reliable [Bludov et al., 2015].

The purpose of this work is to study the risks that the current system of labeling industrial products entails and to develop the necessary measures to reduce them.

1. Theoretical review of the literature

To protect consumers from counterfeiting, the Government of the Russian Federation decided to take under state control all products that are produced in Russia and imported into the country. To this end, since 2019, universal mandatory labeling of goods has been introduced. By 2024, each unit will have a unique label.

The first group of goods that began to be labeled back in 2016 is fur coats and fur products. The process of working with this product is debugged, so no changes are planned in the near future. Since 2021, goods subject to labeling have been replenished with several new groups.

Tobacco: since July 2019, tobacco manufacturers have not put unlabeled products into circulation. The circulation of unmarked cigarettes was discontinued on July 1, 2020. On January 11, 2021 an experiment on labeling nicotine-containing products started.

Shoes: from July 1, 2020, the production and sale of unmarked shoes is prohibited, the remains had to be marked before September 1, 2020.

Medicines: Medicines related to Seven Nosologies Program have been labeled since July 2019, other medicines - from July 1, 2020.

Photo products: the circulation of unmarked cameras, flashes and lenses are prohibited from October 1, 2020. It was necessary to mark the remains until December 1, 2020.

Tires and covers: from December 15, 2020, the circulation and withdrawal of unmarked tires from circulation is prohibited, the remains were marked until March 1, 2021.

Light industry goods (clothing and underwear): from January 1, 2021, the circulation of unmarked textile goods is prohibited; at the same time, the remains had to be marked before February 1, 2021.

Perfume: from October 1, 2020, labeling of all perfume products is mandatory, unlabeled remaining products had to be sold by September 30, 2021. Until October 31, 2021, labeling of remains produced or imported into the Russian Federation before October 1, 2020 was allowed.

Milk and dairy products: Mandatory labeling began on January 20, 2021.

The following product groups are in the experimental stage:

- beer and beer drinks;
- wheelchairs;
- bicycles;
- drinking water.

The marking itself is the application of graphic signs or symbols to an object for its further identification.

Within the framework of the state project, this means that each unit of goods must have its own unique identification mark. It can be used to track the path of the product from the production line to the consumer basket.

All participants in the commodity circulation market are involved in the marking process, therefore it is called a set of measures[3] – this is not just applying a code to a product. Information about the product and all actions with it are entered into a single information system for product traceability[4].

The chain of product movement from the production line to the consumer involves all organizations and enterprises through which it passes (Fig. 1)

In addition to pharmacies, the drug labeling system includes medical organizations and organizations that have a medical license and use medications in their activities.

[1] On additional measures to counter illegal circulation of industrial products// Russian Federation Presidential Decree of January 23, 2015 No 31. http://www.kremlin.ru/acts/bank/39365.
[2] Counterfeit is spreading like a virus // Rosbusinessconsulting. https://plus.rbc.ru/news/5f87765a7a8aa9d887869d34?.
[3] The concept of creation and functioning of a system for labeling goods by means of identification and traceability of the movement of goods in the Russian Federation. Approved by the Decree of the Government of the Russian Federation by December 28, 2018 No. 2963-r..
[4] Bogdanov, Vikhlyantsev, Simonov et al. Eurasian Patent No. 002516; Bludov, Bogdanov, Vikhlyantsev, Simonov et al. RF patent for utility model No. 129673; GOST R 54109-2010. Protective technologies. Production 137 polygraphic protected. General technical requirements. M.: Standartinform2011.

Fig. 1. Product movement chain

*In addition to pharmacies, the drug labeling system includes medical organizations and organizations that have a medical license and use medications in their activities.

Labeling provides benefits seeing that:

- *For the buyer,* authenticity and declared quality are one of the most important aspects of the purchased goods. The labeling system confirms these criteria by tracing the product from the producer to the consumer. Any buyer can independently scan the marking code and find out all the information about the product even before the purchase itself;
- *For business,* the benefit is not only gaining access to the full path of goods transportation but also in reducing costs. The labeling system will help protect the brand and trademark and, as a result, reputation. A decrease in the revenue of illegal producers will lead to an increase in the revenue of legal ones;
- *It is important* for the state to ensure labor productivity and budget savings. Labeling in this case is directly involved, as the gray market will be significantly reduced. Tax and customs fees are also increasing due to the introduction of the system [Ruegg, Voloshchinovsky, 2010; Expired identification technology.., 2014; Przyswa, 2015].

However, the existing labeling that uses the DataMatrix code system is subject to many risks [Rfid smart labels.., 2007].

The purpose of this study is to identify the register of risks and assess the possibility of reducing them by changing the labeling system.

Risk management measures are designed to change either its probability or the degree of the consequences, or the probability and degree of influence at the same time. As a rule, activities can be aimed at:

- risk avoidance;
- acceptance of the existing level of risk;
- elimination of the source of risk;
- change in the probability of risk occurrence;
- change in risk exposure;
- sharing the risk with another party (e.g. by insuring the risk) (ISO 31000).

A promising risk management measure affecting most of the risk reduction methods listed above could become the introduction of additional visual controls on material media of the DataMatrix code that are protected from forgery.

2. Research methodology

At the first stage, to identify the risk register when labeling with the help of the DataMatrix code, two in-depth interviews were conducted with experts - heads of IT labeling departments of two companies: a manufacturer of tobacco products and a manufacturer of dairy products.

At the second stage, the counterfeit risk register was assessed for various types of goods.

The probability assessment scale for risks from the counterfeit risk register for various types of labeling is presented in Table 1.

The scale for assessing the consequences for risks from the register of risk falsification for various types of labeling is presented in Table 2.

In order to assess the risks from the register of risk falsification for the DataMatrix code, as well as to prepare recommendations on the use of additional means of visual control on material carriers of the DataMatrix code and risk reductions listed in the register, a questionnaire was developed in which experts were asked to determine the levels of the likelihood and consequences of risk falsification for various types of labeling. It was sent to 178 experts from companies in various industries.

3. Research results

Based on the results of the first study phase, the following risk registers were formed: a register of falsification risks for various types of labeling (Table 3) and a register of risks for a bona fide manufacturer, end consumer, and budgetary risks (Table 4).

To verify the register of risk falsification for various types of markings, as well as to prepare for the future development of recommendations on the use of additional means of visual control on material carriers of the DataMatrix code and reduce the risks listed in the register, a questionnaire was developed in which experts were asked to correlate various types of markings with the risks of falsification to which they may be exposed. The questionnaire was sent to 139 experts from companies across the variety of sectors. The processing

of the questionnaires made it possible to verify the generated risk register and move on to the next stages - analysis and comparative risk assessment.

4. Risk matrix

Within this work, for the preparation of the matrix it is proposed to use scales limited to five points for both probability and consequences.

To form the scales, the methodological recommendations of GOST R ISO / IEC 27005-2010 "Information technology. Methods and means of ensuring security. Information security risk management", GOST R ISO/IEC 31010-2011 "Risk management. Risk Assessment Methods" as well as a review of materials on the DataMatrix code and its crypto security and two in-depth interviews with experts were used.

It should be noted that in order to assess risks from the register of risk falsification for various types of labeling (Table 3) and the register of risks for a bona fide manufacturer, end consumer and budgetary risks (Table 4) separate scales were formed due to the different nature of these risks.

The probability assessment scale for risks from the counterfeit risk register for various types of labeling is presented in Table 1.

The scale for assessing the consequences for risks from the register of risk falsification for various types of labeling is presented in Table 3.

5. Results of the assessment for the counterfeit risk register for different types of labeling

The results of processing questionnaires for the DataMatrix code are presented in Table. 5. For different expert assessments for the same risk the average value of the score rounded to the nearest whole number was used.

Table 1
Probability score table for risks of the Falsification Risk Register for various types of labeling

Score value	Estimated probability corresponding to the score
1	• Probability of risk realization is extremely low • The risk realization history may represent the occurrence of unique/rare events • Expensive highly specialized equipment is required to realize the risk
2	• Probability of risk realization is low • There are cases of risk realization, there are few precedents • Risk realization requires highly specialized equipment
3	• The probability of risk realization is average • There is or forecast a history of repeated and regular risk realization. • Risk realization requires equipment that is not highly specialized
4	• Probability of risk realization is high • There is or is predicted a history of frequent risk realization. • Widely available hardware is required to realize risk
5	• Probability of risk realization is extremely high • There is or is predicted a history of multiple risk occurrences • No additional equipment is required to realize the risk

Source: compiled by the author.

Table 2
Table of the score assessment of the consequences for the risks of the Falsification Risk Register for various types of labeling

Score value	Estimated probability corresponding to the score
1	The realization of the risk allows you to falsify piece volumes of goods
2	Realization of risk allows to falsify a small quantity of goods
3	Realization of the risk allows to falsify about half of the consignment stock
4	The realization of the risk allows you to falsify most of the goods in the whole
5	Realization of the risk allows you to falsify the entire batch of goods

Source: compiled by the author.

Table 3
Falsification Risk Register for various types of labeling

№	Risk	Risk realization consequences
1. Risks of labeling falsification through information compromising		
1.1	Risk of labeling falsification through unauthorized copying of information to removable media	Use of information to generate counterfeit labels and subsequent sale
1.2	Risk of marking falsification through unauthorized use of corporate information systems (software)	Use of information to generate counterfeit labels and subsequent sale
1.3	Risk of marking falsification through cryptotail falsification	Sale of counterfeit goods if the malefactor has the serial number of the goods
1.4	The risk of labeling falsification through attacks on information systems for the purpose of unauthorized access to information	Use of information to generate counterfeit labels and subsequent sale
2. Risks of counterfeit labeling through unauthorized actions		
2.1	Risk of counterfeit labeling through unauthorized use of labeling equipment	Marking printing for the purpose of applying to counterfeit products
2.2	Marking falsification risk by distorting the data contained in the labeling	Inability to read data from the marking Selling goods with a barcode
2.3	The risk of opening the aggregated packaging	Withdrawal from circulation of goods remaining in aggregate packaging
2.4	The risk of selling counterfeit products through mobile sales from a mobile shop (vending, market stalls)	
3. Risks of counterfeit labeling through duplication		
3.1	Risk of marking falsification through scanning and duplication of markings	Marking copying and printing for the purpose of applying to counterfeit products
3.2	Risk of label falsification by photographing and label duplication	Marking copying and printing for the purpose of applying to counterfeit products
3.3	Risk of counterfeit labeling through the use of special equipment to duplicate the label	Marking copying and printing for the purpose of applying to counterfeit products
4. Risks of damage to the applied marking		
4.1	Risk of deliberate damage to the applied marking leading to the impossibility of reading	Inability to read data from the marking Sale of goods with a barcode
4.2	Risk of exposure to the environment damaging the marking and making it impossible to read	Inability to read data from the marking Sale of goods with a barcode

Source: compiled by the author.

Table 4
Register of risks for a bona fide producer, end user, as well as budget risks

№	Risk	Risk realization consequences
1. Risks for a bona fide producer		
1.1	The risk of reputation loss for a bona fide producer	Decreased reputation of a producer The threat of leaving the market in case of irreparable reputational losses
1.2	The risk of lower profits for a bona fide producer	Revenue decline Decrease in business profitability Loss of competitive advantage relative to an bona fide producer
2. Risks for the consumer of the goods		
2.1	The risk of purchasing low-quality counterfeit goods by the consumer	Dissatisfaction of needs and loss of funds due to the acquisition of low-quality goods
2.2	The risk of harm to the life and health of the consumer due to counterfeit goods	Causing harm to the life and health of the consumer of varying severity The death of consumers
3. Risks of budget losses		
3.1	The risk of losing the budget from non-payment of taxes	Budget losses from non-payment of taxes
3.2	The risk of losing the budget from non-payment of excise taxes	Budget losses from non-payment of taxes

Source: compiled by the author.

Based on the data presented in Table 5, a matrix of consequences and probabilities for the falsification risk register for the DataMatrix code is formed and shown in Fig. 2.

The matrix demonstrates that most of the risks lie in the red zone, which shows a high risk component for labeling systems based on DataMatrix codes.

Risks 1.1-1.4 which characterize "Risks of marking falsification by compromising information" group and fall entirely into the red zone of the matrix, describe the potential for falsified DataMatrix codes when attackers gain access to the data on generated codes stored in enterprise information systems. The most vulnerable point is the ability to sell counterfeit goods as legitimate if the DataMatrix code is copied before the legitimate goods are sold and applied to the counterfeit. This risk is exacerbated by the inability to verify the crypto-tail in DataMatrix at the time of sale. Also, the DataMatrix labeling system is notification-based, while USAIS is permissive. Thus, if an intruder gets hold of the serial codes of goods, he has an opportunity to "scan" the goods using a normal barcode.

Risk 2.1 "Risk of marking falsification through unauthorized use of marking equipment" and risk 2.2 "Risk of marking falsification through distortion of data contained in the marking" also received high scores because of potential ease of marking reprint and its application due to the access to the equipment by an intruder.

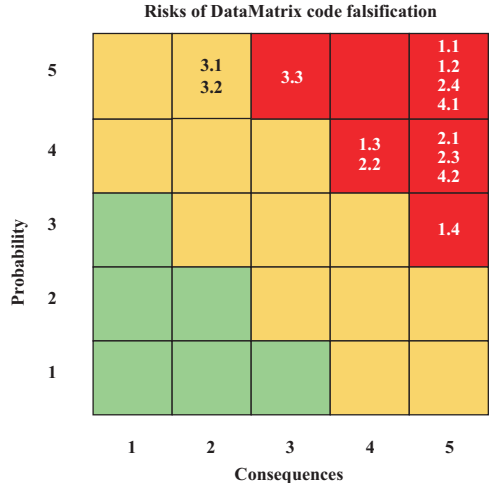
Risk 2.3 "Risk associated with opening of aggregated packaging" and its high score are explained by the vulnerability of the system to uncontrolled disaggregation

Table 5
Result of risk assessment of the Falsification Risk Register for DataMatrix code

№	Risk	Probaility, score	Consequences, score
1. Risks of marking falsification through information compromising			
1.1	Risk of marking falsification through unauthorized copying of information to removable media	5	5
1.2	Risk of marking falsification through unauthorized use of corporate information systems (software)	5	5
1.3	Risk of marking falsification through cryptotail falsification	4	4
1.4	Risk of marking falsification through attacks on information systems for the purpose of unauthorized access to information	3	5
2. Risks of counterfeit labeling through unauthorized actions			
2.1	Risk of counterfeit labeling through unauthorized use of marking equipment	4	5
2.2	Risk of falsification of marking by distorting the data contained in the labeling	4	4
2.3	The risk of opening the aggregated packaging	4	5
2.4	The risk of selling counterfeit products through mobile sales from itinerant trade (vending, market stalls)	5	5
3. Risks of counterfeit labeling through duplication			
3.1	Risk of marking falsification through scanning and duplication of markings	5	2
3.2	Risk of label falsification by photographing and label duplication	5	2
3.3	Risk of counterfeit labeling through the use of special equipment to duplicate the label	5	3
4. Risks of damage to the applied marking			
4.1	Risk of deliberate damage to the applied marking leading to the impossibility of reading	5	5
4.2	Risk of exposure to the environment, damaging the marking and making it impossible to read	4	5

Source: compiled by the author.

Fig. 2. Matrix of consequences and probabilities for the Falsification Risks Register for the DataMatrix code



Source: compiled by the author.

of shipping cartons. Sale of counterfeit pack of goods with a serial number that coincides with the one of the legal pack leads to displaying the whole box of products as disaggregated.

Risk 2.4 "Risk associated with sales of counterfeit goods through itinerant trade from stalls and market stands" is due to the very nature of such trade, where control over compliance with the law on mandatory labeling is minimal.

Risks 3.1 "Risk of falsification of markings through scanning and duplication of markings" and 3.2 "Risk of falsification of markings through photographing and duplication of markings" were assessed by experts as highly probable, but with relatively low impact scores due to the difficulty of copying, photographing and preparation for further application of large amounts of markings. Risk 3.3 "Risk of falsification of markings through the use of special equipment to duplicate markings" received a higher consequence assessment as it could potentially result in the compromise of a larger volume of goods.

Table 6
Table of the score assessment of the consequences for the risks of the Register of Risks for a bona fide manufacturer, end user, as well as budget risks

Project performance	Score				
1. Assessing the consequences for a bona fide producer					
The quality of counterfeit goods relative to genuine ones	Unnoticeable deterioration in quality	Deterioration in the quality of a small part of goods	Significant deterioration in the quality of goods	Decreased quality undermines the brand of a bona fide producer	Decreased quality makes a bona fide manufacturer's brand completely uncompetitive
Reputation as a bona fide producer	The level reputation loss is almost invisible	The level of reputation loss will be restored over a short period of time	The level of reputation loss will be restored over a moderate period of time	The level of reputation loss will be restored over a long period of time	Irreplaceable reputational losses resulting in closure
Forecast value of lost profit, billion rubles	< 1	1–5	5–10	10–15	> 15
2. Assessment of the consequences for the final consumer of goods					
The quality of counterfeit goods relative to genuine ones	Unnoticeable deterioration in quality	Deterioration in the quality of a small part of goods	Significant deterioration in the quality of goods	Decreased quality undermines the brand name of a bona fide producer	Decreased quality renders a bona fide producer's brand completely uncompetitive
The cost of goods for the end consumer	Does not affect the amount of funds of the end user	Insignificant amount in the total consumer spending	Moderate amount in total consumer spending	The cost of acquiring counterfeit goods makes up a large part of the budget	To purchase a counterfeit product the consumer has to save or borrow money
Life and health of the end user	Does not harm the life and health of the consumer	Causes minor harm to the life and health of the consumer	Causes minor harm to life and health of a group of consumers	Significant bodily harm to one or two consumers	Mass loss of consumers
3. Assessment of possible budget loss consequences					
Budget losses from non-payment of taxes, billion rubles	< 10	10–25	25–50	50–100	> 100
Budget losses from non-payment of excise duties, billion rubles	< 10	10–25	25–50	50–100	> 100

Source: compiled by the author.

Risk 4.1 "Risk of intentional damage to applied markings resulting in impossibility of reading" is also due to notification nature of the DataMatrix code marking system. Similar to the other risks, if an intruder takes possession of the serial codes of goods, he has the ability to "scan" the goods using a normal barcode. Moreover, intentional mislabeling or poor quality can encourage consumers to "scan" merchandise through a normal barcode without checking the DataMatrix. Risk 4.2 focuses on damage to the DataMatrix due to environmental factors.

The risk analysis showed a high risk component for DataMatrix-based labeling systems. After assessing all identified risks and placing them on the consequence and likelihood matrix, measures should be developed to reduce the level of risk.

The risk probability assessment scale from the risk register for a bona fide manufacturer, end user, as well as budgetary risks presented in Table. 1.

Risk assessment scale for a bona fide manufacturer, end user, as well as budgetary risks is presented in Table. 6.

The results of processing the questionnaires are presented in Table. 7. For different assessments of experts for the same risk, the average value of the score, rounded up to a whole number, was used.

The results of the scoring showed that the marked goods are mostly counterfeited quite often, especially tobacco products, perfumes and toilet water, clothes and footwear.

At the same time, the greatest consequences such as loss of profit for bona fide producers, as well as the largest share of unpaid taxes and excise payments, are concentrated on alcohol and tobacco products. The turnover of other groups of goods is relatively small. Some commodity groups, such as perfumes and shoes, have rather low consequences for lost profits by bona fide producers, since most of the expensive assortment is imported to Russia.

The greatest reputational risks from the sale of counterfeit goods are expected on the side of alcohol and tobacco producers, moderate ones - among producers of fur coats and fur products, the smallest - among water and dairy products.

A high risk of harm to the life and health of a consumer due to counterfeit goods was noted by experts among producers of medicines and alcoholic products, a moderate risk - for tobacco products.

6. Additional means of visual control and technologies of Track&Trace marking systems: assessment of the residual risk level

A questionnaire was analyzed to assess residual risks from the counterfeit risk register for different types of labels.

The types of possible markings were analyzed based on [Bogdanov et al., 2005; Bogdanov et al., 2007; A technical study.., 2012; Zhelev et al., 2012; Expired identification

Table 7
Result of risk assessment of the Register of Risks for a bona fide manufacturer, end user, as well as budget risks

№	Name of product category	Name of risk	Probability, score	Consequences, score
1	Milk and dairy produce	The risk of reputational loss for a bona fide producer	4	1
		The risk of lower profits for a bona fide producer	4	4
		The risk of purchasing low-quality counterfeit goods by the consumer	4	2
		The risk of harm to the life and health of the consumer due to counterfeit goods	4	2
		The risk of losing the budget from non-payment of taxes	4	2
		The risk of losing the budget from non-payment of excise duties	–	–
2	Packaged drinking water	The risk of reputational loss for a bona fide producer	4	1
		The risk of lower profits for a bona fide producer	4	4
		The risk of purchasing low-quality counterfeit goods by the consumer	4	1
		The risk of harm to the life and health of the consumer due to counterfeit goods	4	1
		The risk of losing the budget from non-payment of taxes	4	2
		The risk of losing the budget from non-payment of excise duties	–	–

Table 7 *(ending)*

№	Name of product category	Name of risk	Probability, score	Consequences, score
3	Tobacco (tobacco goods)	The risk of reputational loss for a bona fide manufacturer	5	3
		The risk of lower profits for a bona fide manufacturer	5	5
		The risk of purchasing low-quality counterfeit goods by the consumer	5	4
		The risk of harm to the life and health of the consumer due to counterfeit goods	5	3
		The risk of losing the budget from non-payment of taxes	5	5
		The risk of losing the budget from non-payment of excise duties	5	5
4	Pharma-ceuticals	The risk of reputational loss for a bona fide manufacturer	4	2
		The risk of lower profits for a bona fide manufacturer	4	2
		The risk of purchasing low-quality counterfeit goods by the consumer	4	5
		The risk of harm to the life and health of the consumer due to counterfeit goods	4	5
		The risk of losing the budget from non-payment of taxes	4	2
		The risk of losing the budget from non-payment of excise duties	–	–
5	Light industrial goods	The risk of reputational loss for a bona fide producer	5	1
		The risk of lower profits for a bona fide producer	5	1
		The risk of purchasing low-quality counterfeit goods by the consumer	5	2
		The risk of harm to the life and health of the consumer due to counterfeit goods	5	1
		The risk of losing the budget from non-payment of taxes	5	2
		The risk of losing the budget from non-payment of excise duties	–	–
6	Footwear	The risk of reputational loss for a bona fide producer	5	3
		The risk of lower profits for a bona fide producer	5	2
		The risk of purchasing low-quality counterfeit goods by the consumer	5	3
		The risk of harm to the life and health of the consumer due to counterfeit goods	5	1
		The risk of losing the budget from non-payment of taxes	5	2
		The risk of losing the budget from non-payment of excise duties	–	–
7	Fur coats and goods	The risk of reputational loss for a bona fide producer	3	4
		The risk of lower profits for a bona fide producer	3	2
		The risk of purchasing low-quality counterfeit goods by the consumer	3	4
		The risk of harm to the life and health of the consumer due to counterfeit goods	3	1
		The risk of losing the budget from non-payment of taxes	3	1
		The risk of losing the budget from non-payment of excise duties	–	–
8	Perfume and toilet water	The risk reputational loss for a bona fide producer	5	1
		The risk of lower profits for a bona fide producer	5	1
		The risk of purchasing low-quality counterfeit goods by the consumer	5	1
		The risk of harm to the life and health of the consumer due to counterfeit goods	5	1
		The risk of losing the budget from non-payment of taxes	5	1
		The risk of losing the budget from non-payment of excise duties	–	–
9	Alcoholic and alcohol-containing products	The risk of reputational loss for a bona fide producer	4	3
		The risk of lower profits for a bona fide producer	4	4
		The risk of purchasing low-quality counterfeit goods by the consumer	4	3
		The risk of harm to the life and health of the consumer due to counterfeit goods	4	5
		The risk of losing the budget from non-payment of taxes	4	4
		The risk of losing the budget from non-payment of excise duties	4	4

Source: compiled by the author.

Table 8
Result of the risk assessment of the Falsification Risk Register for various types of labeling, point

№	Name of risk	DataMatrix-code		DataMatrix code supplemented with security features based on visual elements (optical variables)		DataMatrix code supplemented with polygraphic security elements and RFID mark		Optical half-tone code		Optical half-tone code supplemented with security features based on visual elements (optical-variables)	
		Probability	Conse-quences	Probability	Conse-quences	Probability	Conse-quences	Proba-bility	Conse-quences	Probabil-ity	Conse-quences
1. Risks of counterfeit labeling through compromising information											
1.1	Risk of counterfeit labelling through unauthorized copying of information to removable media	5	5	–	–	–	–	–	–	–	–
1.2	Risk of counterfeit labelling through unauthorized use of corporate information systems (software)	5	5	–	–	–	–	–	–	–	–
1.3	Risk of counterfeit labelling through cryptotail falsification	4	4	–	–	–	–	–	–	–	–
1.4	The risk of counterfeit labelling through attacks on information systems for the purpose of unauthorized access to information	3	5	–	–	–	–	–	–	–	–
2. Risks of counterfeit labelling through unauthorized actions											
2.1	Risk of counterfeit labelling through unauthorized use of labeling equipment	4	5	2	2	2	2	2	2	1	2
2.2	Risk of counterfeit labelling by distorting the data contained in the labeling	4	4	2	2	2	2	2	3	1	2
2.3	The risk of opening aggregated packaging	4	5	2	4	2	3	2	4	1	3
2.4	The risk of selling counterfeit products through itinerant trade from a mobile shop (trade from portable stalls, market stalls)	5	5	5	5	5	5	5	5	5	5
3. Risks of counterfeit labelling through duplication											
3.1	Risk of counterfeit labelling through scanning and marking duplication	5	2	–	–	–	–	–	–	–	–
3.2	Risk of label falsification by photographing and label duplication	5	2	–	–	–	–	–	–	–	–
3.3	Risk of counterfeit labelling through the use of special equipment to duplicate the label	5	3	2	2	2	2	2	2	1	1
4. Risks of damage to applied markings											
4.1	Risk of deliberate damage to the applied marking leading to the impossibility of reading	5	5	2	4	2	4	1	4	1	3
4.2	Risk of exposure to the environment, damaging the marking and making it impossible to read	4	5	2	4	2	4	1	4	1	3

Source: compiled by the author.

technology protects.., 2014; Winemakers turn to NFC.., 2014; Barabas, 2015;], as well as the RF patent for invention No. 2272319 "Method for protecting the unique sign marking of a serial product using an interactive database", RF patent for invention No. 2309453 "Method for identifying the authenticity of items put into circulation."

The results of processing questionnaires for various types of labeling are presented in Table. 8. For different assessments of experts for the same risk, the average value of the score rounded to the nearest whole number was used.

Based on the data presented in Table. 8, matrices of consequences and probabilities are formed for the register of falsification risks for various types of marking.

Residual risks from the falsification risk register for the DataMatrix code, supplemented with security features based on visual elements (optical variables), are shown in Fig. 3.

Residual risks from the risk falsification register for the DataMatrix code, supplemented by polygraphic security elements and RFID mark, are shown in Fig. 4.

Residual risks from the falsification risk register for the optical half-tone code are shown in Fig. 5.

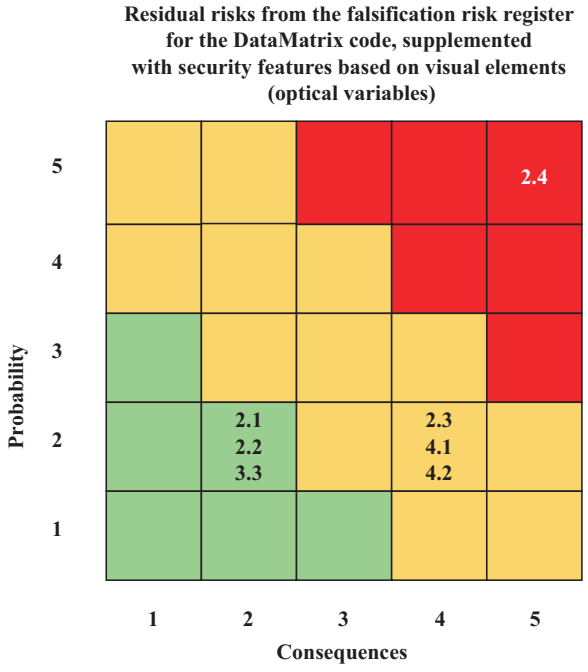
Residual risks from the falsification risk register for an optical half-tone code supplemented with security features based on visual elements (optically variable) are shown in Fig. 6.

The matrix shows that most of the risks have shifted from the red zone to the yellow and green ones, which reflects the high efficiency of the introduction of additional protective features.

As noted above, additional protection technologies, including those based on visual elements, are able to mitigate the risks of group 1 “Risks of falsification of markings through compromising information”, since it is not enough to gain access to data to falsify markings using these technologies, specialized equipment capable of reproducing additional security features is also required.

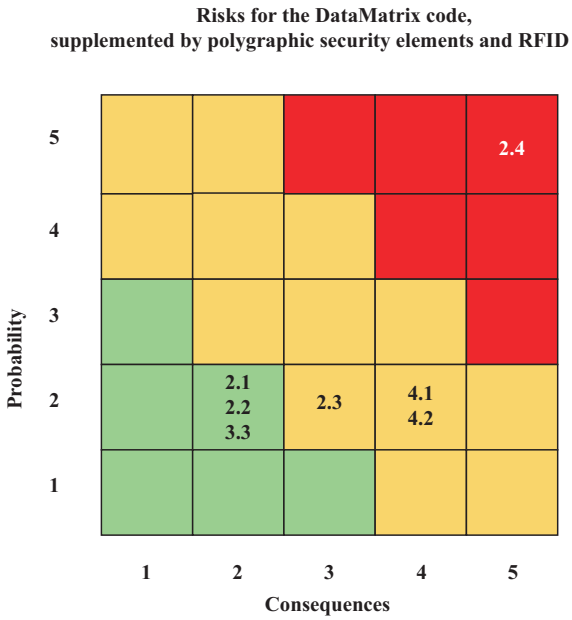
Risk 2.1 “Risk of label falsification through unauthorized use of labeling equipment” and risk 2.2 “Risk of label falsification through misrepresentation of data contained in

Fig. 3. Residual risks of the Falsification Risk Register for DataMatrix code supplemented with security features based on visual elements (optically-variables)



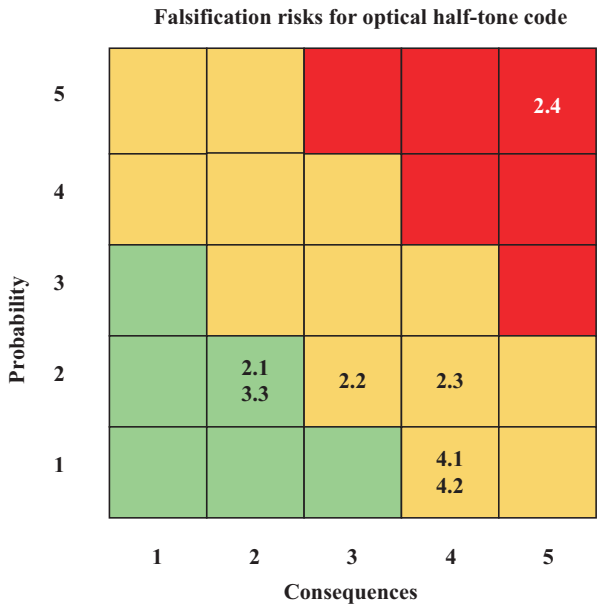
Source: compiled by the author.

Fig. 4. Residual risks of the Falsification Risk Register for the DataMatrix code supplemented with polygraphic security elements and an RFID tag



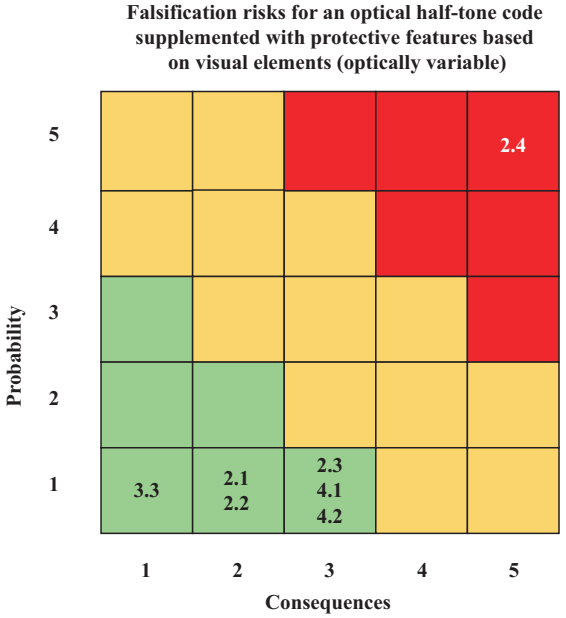
Source: compiled by the author.

Fig. 5. Residual risks of the Falsification Risk Register for optical halftone code



Source: compiled by the author.

Fig. 6. Residual risks of the Falsification Risk Register for an optical halftone code supplemented with protective features based on visual elements (optically variable)



Source: compiled by the author.

the label" received lower scores due to much greater labor costs for the production of labels and more control over production equipment.

Risk 2.3 "Risk of opening aggregated packaging" has shifted predominantly to the yellow zone and remains at a moderate level, since the sale of a counterfeit package with a serial number that matches the serial number of a legal package can still result in the display of the entire product box as disaggregated.

Risk 2.4 "Risk of counterfeiting through itinerant trade from a mobile shop (trade from portable stalls, market stalls)" did not change its estimates and remained in the red zone due to the nature of trade from portable stalls and market stalls, where enforcement of the law on mandatory labeling is minimal.

At the same time, the risks 3.1 "Risk of falsification of markings by scanning and duplicating markings" and 3.2 "Risk of falsifying markings by photographing and duplicating markings" are leveled due to the impossibility of copying visual security features by scanning or photographing.

Risk 3.3 "Risk of falsifying labels through the use of special equipment to duplicate labels" received markedly lower scores due to the use of more highly specialized equipment, which is more controlled by enterprises.

Risk 4.1 "Risk of intentional damage to the applied marking, resulting in the impossibility of reading" is also due to the advisory nature of the marking system. Similar to other risks, if an attacker gets hold of the serial codes of goods, he has the opportunity to "break through" the goods using a regular barcode. Moreover, deliberate incorrect or poor-quality labeling can push the consumer to "break through" the product using a regular barcode without checking the labeling. Risk 4.2 deals with marking damage due to environmental factors. At the same time, these risks received lower estimates due to the much greater resistance of optical half-tone codes and holographic protection to intentional or accidental damage and erasure.

The analysis of residual risks confirmed the high potential of using additional visual control tools on material carriers used in the product labeling system. Part of the risks turned out to be inapplicable to such protection systems; the rest received significantly lower risk ratings. At the same time, some of the vulnerabilities of the product labeling system cannot be solved only by improving labeling and require additional organizational actions, for example, to combat the problem of package disaggregation or trade from portable stalls.

In order to quantify the level of risk reduction and the level of possible losses when using various marking means, the register of falsification risks for various types of marking was additionally analyzed.

For each type of label, the exposure to risk of fraud was calculated as the average product of the likelihood score and the consequence score for the risks inherent to this marking type.

The relative reduction in exposure to the risk of fraud was then calculated for different types of labels. The calculation results are presented in Table. 9.

In conclusion, a quantitative analysis of the probability of risk level reduction and the level of possible losses is presented with a positive experience of using additional means of visual control on material media.

According to the Monte Carlo modeling methodology, the input values for the Monte Carlo model will be the shares of illegal produce distributed by product groups and given with triangular distribution of a random variable. The output data for further analysis are the magnitude of budget losses from non-payment of tax and excise payments as well as the lost profits of bona fide producers.

To model each of the risks, three scenarios are considered.

1. "Current labeling systems" - in this scenario DataMatrix codes are used to protect tobacco products, packaged water, medicines, dairy products and clothing, for alcohol products - DataMatrix codes supplemented by holographic protection, for fur coats and fur products - DataMatrix codes supplemented by polygraphic protection and RFID mark.

2. "Holographic security everywhere" - in this scenario DataMatrix codes supplemented by holographic security are used to protect tobacco products, packaged water, medicines, dairy products and clothing; for alcohol products DataMatrix codes supplemented with holographic security are used for fur coats and fur products – DataMatrix codes supplemented by printing protection and RFID mark.

3. "The widespread introduction of optical half-tone codes supplemented by holographic security" - in this scenario optical half-tone codes supplemented with holographic security are used for all product groups.

To assess the risks of budget losses from non-payment of tax and excise payments as well as the risks of shortfall in profits by bona fide producers, modeling was carried out based on the above scenarios. Six calculations were carried out: three scenarios for each risk. 10,000 iterations were used

Table 9
Relative reduction of exposure to the risk of falsification for various types of labeling, %

Comparable marking types	Reduced exposure to risk of falsification
Reduction when using DataMatrix-code supplemented by holographic protection relative to DataMatrix	53
Reduction when using an optical half-tone code supplemented by holographic protection against the DataMatrix	70
Reduction when using an optical half-tone code supplemented by holographic protection against DataMatrix supplemented by printing security and RFID mark	33
Reduction when using an optical half-tone code supplemented with holographic protection relative to a DataMatrix code supplemented by holographic protection	36

Source: compiled by the author.

to model the triangular distribution of a random variable (share of illegal products).

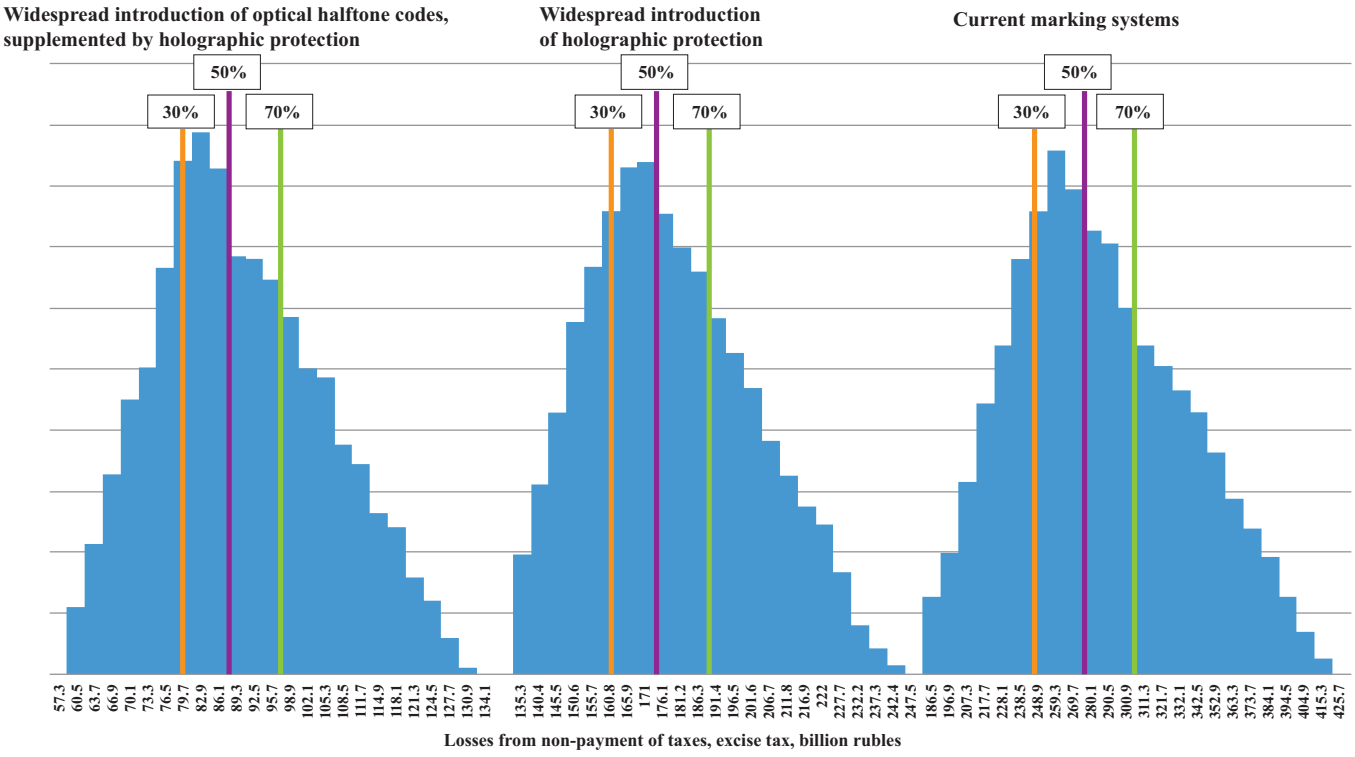
The simulation results were the distribution of the amount of budget losses from non-payment of tax and excise payments (Fig. 7), as well as the distribution of lost profits of bona fide producers for three scenarios.

In the figures, colored lines indicate percentiles (in mathematical statistics, values that a given random variable does not exceed with a fixed probability).

The value of percentiles for the distribution of the amount of budget losses from non-payment of tax and excise payments, as well as for the distribution of lost profits by bona fide producers are presented in Tables 10 and 11 respectively.

Thus, the wording "30th percentile for the distribution of the budget loss amount from non-payment of tax and excise payments is 248.9 billion rubles" means that with a 30% probability the budget losses will be less than or equal to

Fig. 7. Distribution of the amount of budget losses from non-payment of tax and excise payments



Source: compiled by the author.

Table 10
Percentile values for the distribution of the amount of budget losses from non-payment of tax and excise payments, billion rubles

Percentile values for the distribution of budget losses from non-payment of tax and excise payments in 2022.	Current marking systems	Widespread introduction of holographic protection	Widespread introduction of optical halftone codes, supplemented by holographic protection
Probability of budget losses is less by 30%	248.9	160.8	79.7
Probability of budget losses is less by 50%	274.9	173.5	87.7
Probability of budget losses is less by 70%	306.1	188.85	97.3

Source: compiled by the author.

248.9 billion rubles, and with a 70% probability they will be higher than this value.

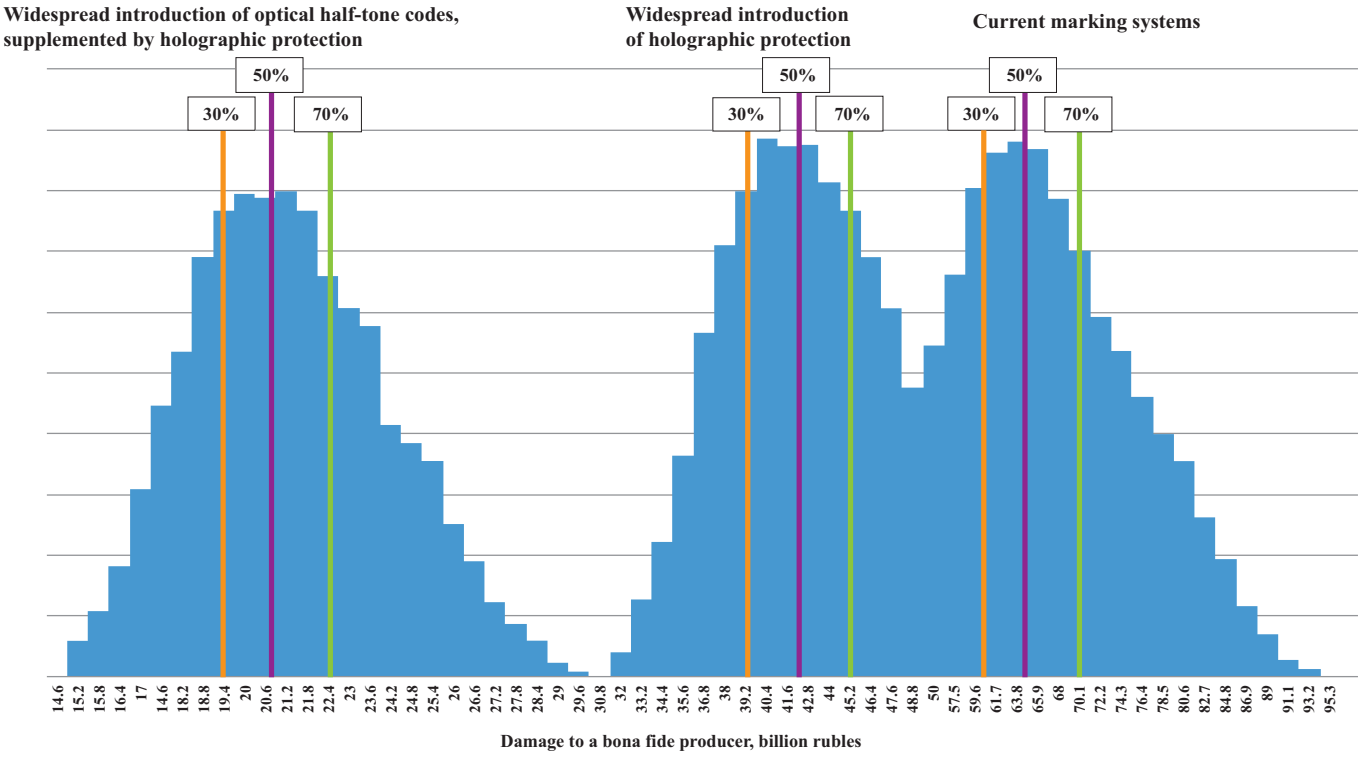
Thus, the introduction of holographic protection can significantly reduce the expected budget losses at all levels of probability. In turn, the introduction of optical half-tone codes supplemented by holographic protection will achieve even greater results.

It should be noted that, despite the use of 10,000 iterations in the simulation, the shape of the distributions tends to be triangular. This feature is characterized by the largest contribution to the distribution of tax and excise payments on tobacco products. The second place in terms of payments is occupied by alcohol products. The remaining groups of goods make a significantly smaller contribution to the form of distribution.

Based on the above materials, it follows that the introduction of holographic protection can significantly reduce the expected lost profit of bona fide producers at all levels of probability. In turn, the introduction of optical half-tone codes, supplemented by holographic protection, will achieve even greater results.

The overlap of distributions for "Current labeling systems" scenario and "Public introduction of holographic protection" scenario is due to the fact that alcohol products make the largest contribution to the lost profits of bona fide producers. In these two scenarios, alcohol products are protected using DataMatrix codes supplemented with holographic security. Accordingly, the remaining product groups contribute to the distribution shift.

Fig. 8. Distribution of lost profits of bona fide producers



Source: compiled by the author.

Table 11
Percentile values for the lost profits of bona fide producers, billion rubles

Percentile values for the lost profits of bona fide producers in 2022	Current marking systems	Widespread introduction of holographic protection	Widespread introduction of optical halftone codes, supplemented by holographic protection
Probability of budget losses is less by 30%	60.7	39.8	19.4
Probability of budget losses is less by 50%	64.9	42.2	20.9
Probability of budget losses is less by 70%	70.1	45.2	22.4

Source: compiled by the author.

Conclusion

In Russia in 2021 the turnover of counterfeit products amounted to 7.2 billion rubles and according to experts will continue to grow. The growth of counterfeit products is facilitated by the factors such as the spread of online trading, a decrease in the income level of the population and the inability to visually distinguish a fake from a real product.

The Russian authorities recognize the mandatory labeling of goods as the most effective measure to combat counterfeiting. However, many professional community members do not consider the current labeling system to be reliable.

The work carried out a comprehensive comparison of the risks of the existing labeling of goods. The results showed that the labeled goods are mostly often counterfeited, especially tobacco products, perfumes and toilet water, clothes and shoes.

At the same time, the greatest consequences in the form of loss of profit for bona fide producers, as well as the largest share of unpaid taxes and excise payments, are concentrated on alcohol and tobacco products. The turnover of other groups of goods is relatively small. Some commodity groups, such as perfumes and shoes, have rather low consequences for lost profits by bona fide producers, since most of the expensive assortment is imported to Russia.

The greatest reputational risks from the sale of counterfeit goods are expected on the side of manufacturers of alcohol and tobacco products, moderate ones - among manufacturers of fur coats and fur products, the smallest - among water and dairy products.

A high level of risk of harm to the life and health of the consumer due to counterfeit goods was noted by experts on the side of manufacturers of medicines and alcoholic products, a moderate risk for tobacco products.

To assess the risks of budget losses from non-payment of tax and excise payments, as well as the risks of shortfall in profits by bona fide producers, modeling was carried out based on the above scenarios. Six calculations were carried out: three scenarios for each risk. 10,000 iterations were used to model the triangular distribution of a random variable (share of illegal products).

The proposed implementation of holographic protection can significantly reduce the expected loss of profits of bona fide manufacturers at all levels of probability. In turn, the introduction of optical halftone codes, supplemented by holographic protection, will achieve even greater results.

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About the author

Alexandr L. Lisovsky
Candidate of Economic Sciences, the Director General of "NPO Krypten" JSC (Moscow, Russia).
Research interests: sustainability management, ESG strategies, formation of strategy of development of the industrial companies, management of changes, transformation of industrial production.
al@aspp.ru

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Stages of transport corridor development: Mechanisation, robotisation, intellectualisation and digitalisation perspectives

I.V. Anokhov[1]
O.N. Rimskaya[1]
[1] Railway Research Institute (Moscow, Russia)

Abstract

The aim of the article is to investigate the perspectives of transport corridors digitalisation. The subject of the study is rail freight transport.

The authors use the Theory of Inventive Problem Solving (TIPS) methodology, which forms the basis of transport industry development stages: mechanisation, intellectualisation, robotisation (automation) and digitalisation. The transition from one stage to another is shown by the comparison between the two documents of significant importance for Eurasian transport: Agreement on International Goods Transport by Rail and Convention concerning International Carriage by Rail (CIM-COTIF). They are fundamentally different at the stages of mechanisation and robotisation that makes the digitisation of international transport corridors impracticable. The article clearly identifies the factors preventing digitalisation, as well as the ways of its neutralising.

The research proves that a fully digitalised transport will represent an isolated system, aimed at meeting the most predicted part of human demands. The article presents the transport corridors digitalisation model.

The authors state that modern transport is at the stage of automation and robotisation and has not yet approached digitalisation. The pipeline transport is the only transport mode that has closely reached the digital frontier. Railway transport also has favourable prerequisites and perspectives.

Keywords: transport corridor, convention concerning international carriage by rail (CIM), RZhD, digital railway, path dependence.

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Introduction

Experts consider the prospects for the digitalization of transport today rather optimistic. Indeed, unmanned vehicles are already moving on public roads, self-driving locomotives are being tested, the use of mail drones, etc. has become commonplace. However, in our opinion, such examples indicate the intellectualization of transport rather than its digitalization, since it requires a radically different technology of transport connectivity.

The very concept of "transport digitalization" does not have a generally accepted interpretation and, as a rule, is reduced to a list of practical technologies (both in scientific publications and in official documents). Thus, the long-term development program of Russian Railways provides for the transition to the "digital railway" and the introduction of the following technologies: platform solutions integrated with the production systems of Russian Railways; internet of things; big data processing; blockchain; digital modeling; artificial intelligence; a new generation of mobile workstations; electronic document management, etc.[1] The digitalization of transport in this sense looks like a set of digital solutions that do not have a clear systemic integration.

The concept of transport corridors' digitalization is even less defined. For example, Decree of the Eurasian Intergovernmental Council No. 4 dated by January 31, 2020 approved the plan to form an ecosystem of digital transport corridors of the EAEU which includes: a digital map, a reservation system for infrastructure facilities, an electronic international waybill system used for rail and road transportation, etc.[2]

The definition of the European Commission on the development of transport corridors does not add clarity: "An

[1] Decree of the Government of the Russian Federation dated by March 19, 2019 No. 466-r "On approval of the development program of Russian Railways until 2025". http://www.consultant.ru.

[2] Decree of the Eurasian Intergovernmental Council No. 4 dated by January 31, 2020 "On the Formation of an Ecosystem of the Eurasian Economic Union Digital Transport Corridors". http://www.consultant.ru.

international transport corridor is the presence of road, rail, water and mixed modes of transport that operate in close proximity to each other or are remote for many kilometers, but oriented in one common direction" [Efremov et al., 2019].

In this regard, it seems that before anything else the terminological certainty of transport corridors' digitalization is necessary.

1. Terminology and the concept of digitalization

In our opinion, the digitalization of transport corridors can be considered most adequately with regard to the Theory of Inventive Problem Solving (TRIZ), which was developed by the Soviet inventor G. Altshuller [Altshuller, 2011; Shpakovsky and Novitskaya, 2011].

In accordance with TRIZ, any technical system, including transport, in its most expanded form includes the following elements (Fig. 1):

- "working body"; the main function of this element is the physical impact on the object of labor to obtain the desired product;
- "transmission"; the main function is the transfer of energy from the "engine" to the "working element";
- "engine"; the main function is the transformation of energy received from the "energy source";
- "computer"; the main function is to control the "engine", "transmission" and "working body".

If cargo transfer occurs only due to the muscular strength of a person, then from the point of view of TRIZ, this person solely performs the functions of all these elements ("working body", "transmission", "engine" and "computer"). The evolution of this system will take place according to the following algorithm: the appearance of transportation mechanisms leads to the allocation of the "working body" subsystem; the emergence of labor and conveyor division system (including transport) involves the allocation of the "transmission" subsystem; the appearance of motors makes for the allocation of the "engine" subsystem (Fig. 2).

Let us take a closer look at the stages of transport corridors' digitalization in Fig. 2 and clarify the terminology.

1. *Mechanization.* In this study, it is perceived as the addition or replacement of human physical labor by the work of mechanisms according to the algorithm: a person → a mechanism → an object of labor (freight traffic). The mechanism corresponds to the "working body" element in Fig. 1.

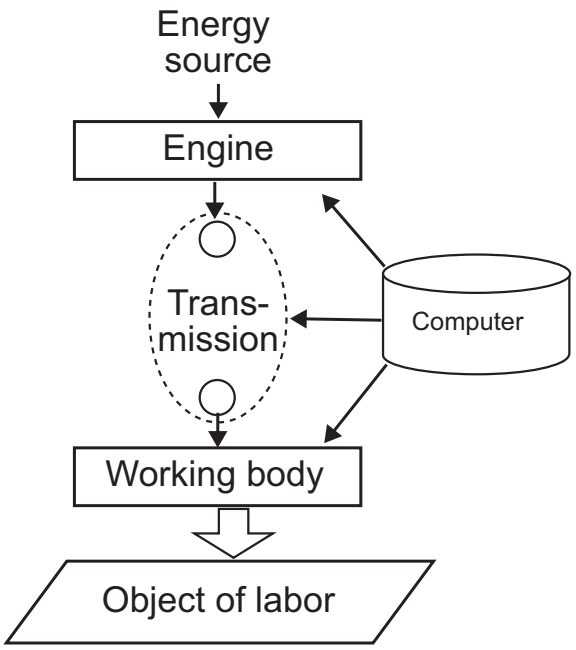
Mechanization is possible if two conditions are observed:

1) labor is of a routine nature, that is, it is repeatedly reproduced according to the same program;
2) the volume of routine work is significant, which makes it appropriate to develop and use special mechanisms.

In the transport industry, examples of mechanization include various types of wheeled equipment, lifting devices, communication lines, etc.

2. *Robotization.* We understand it as a process of organizing a single production chain from physical

Fig. 1. Internal structure of technical system according to TIPS (theory of inventive problem solving)



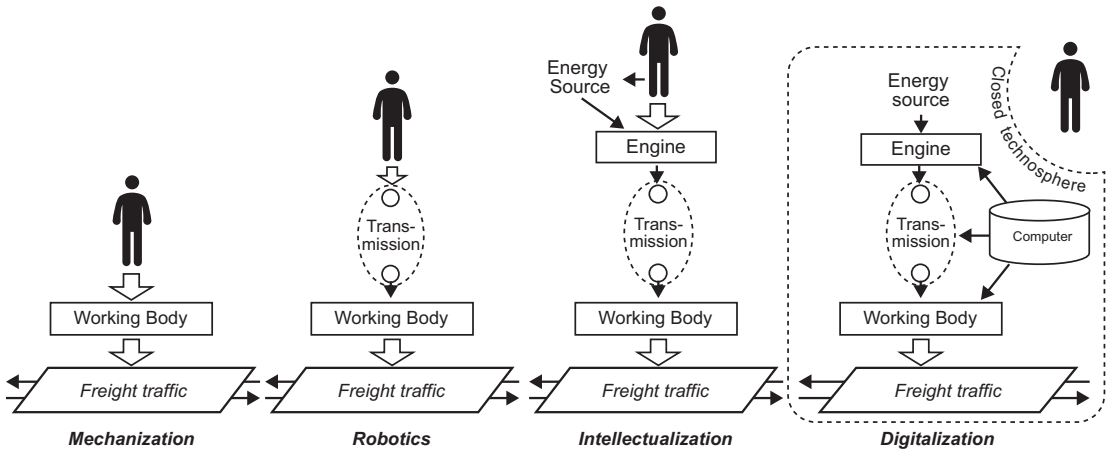
mechanisms that sequentially perform work on the object of labor and are activated by a signal from a certain trigger (for example, by a human command or when a measurement sensor is activated). Such robotic production chains are organized in accordance with the stages of the labor division and correspond to the "transmission" element in Fig. 1, since one or another set of mechanisms is sequentially activated. If the work is carried out only with the help of computer programs, then such a process, in our opinion, should be called automation.

With robotization (automation), in contrast to mechanization, a person transfers the entire production cycle to the technical system during which a number of not uniform in quality operations are sequentially performed on the object. Because of this, the transport process is a kind of conveyor operating according to the principle: a person → an energy source → a mechanism 1 → an object of labor → a mechanism 2 → an object of labor → ... → a mechanism n → an object of labor. The control of the technological process in this case is carried out by mechanisms according to a predetermined and, which is of fundamental importance, an unchanged program.

In the transport industry, examples of robotization can be a car, a ship, a locomotive, as well as railway lines of communication in which a sequence of operations is performed on the flow of goods within the framework of labor system division (transportation, storage, loading/unloading, packaging, distribution, etc.).

3. *Интеллектуализация* Intellectualization in the framework of this article is understood as the transfer of the ability to calibrate and even completely change the program being executed from a person to a technical system (that is, to determine the work scope of the "transmission" and "working body" elements in Fig. 1). As a result, a person is

Fig. 2. Stages of transport system evolution according to TIPS



exempted from participating in the operational management of the transportation process, which is now carried out according to the principle: a person (situational) → an energy source → a computer program → equipment → an object → a computer program → a person (situational). In other words, the transport system in this case is already able to perceive and interpret the signals of the external environment restructuring the entire transportation process respectively.

In the transport industry, examples of intellectualization are systems that can operate without the direct presence of a person: smart traffic control systems, unmanned vehicles, mail shuttles (drones, rovers, etc.), as well as intelligent transport payment systems, analyst robots, etc.

4. *Digitalization,* which in its most simplified form can be understood as the complete removal of a person from the transportation process (that is, dehumanization) and the transfer of all its functions to cyber-physical systems, is "smart systems that include interactive engineering networks from physical and communication components" [CPS PWG Draft , 2015]. In our opinion, these systems should be able to perform at least the following functions:

- forecasting the need for cargo movement;
- advanced planning of production capacities for the physical cargo movement (i.e. renewal, modification or even replacement of the "working body", "transmission", "engine" in Fig. 1);
- combination of production capacities to solve current problems of physical cargo movement;
- control over the transportation process;
- ensuring energy supply;
- adjustment of forecasting, planning and physical transportation processes.

It should be noted that the formation of each new stage in the development of the transport industry from the above (mechanization, robotization, intellectualization, digitalization) does not completely destroy the dominant technology of the previous stage and icludes it as a subsystem.

Digitalization requires the fulfillment of a number of conditions:

1. Complete predictability of traffic flows.
2. Effective tools for neutralizing the instability of the external environment.
3. Information symmetry, that is, a situation in which all participants in the transportation have the same maximally complete amount of latest data.
4. Means of cargo transportation technologically capable of operating in the automatic mode of cyber-physical systems.
5. Significant market demand for systematic and unlimited transportation of homogeneous cargoes.
6. Full complementarity of the activities among all participants in the transportation process. The concept of complementarity will be discussed later.

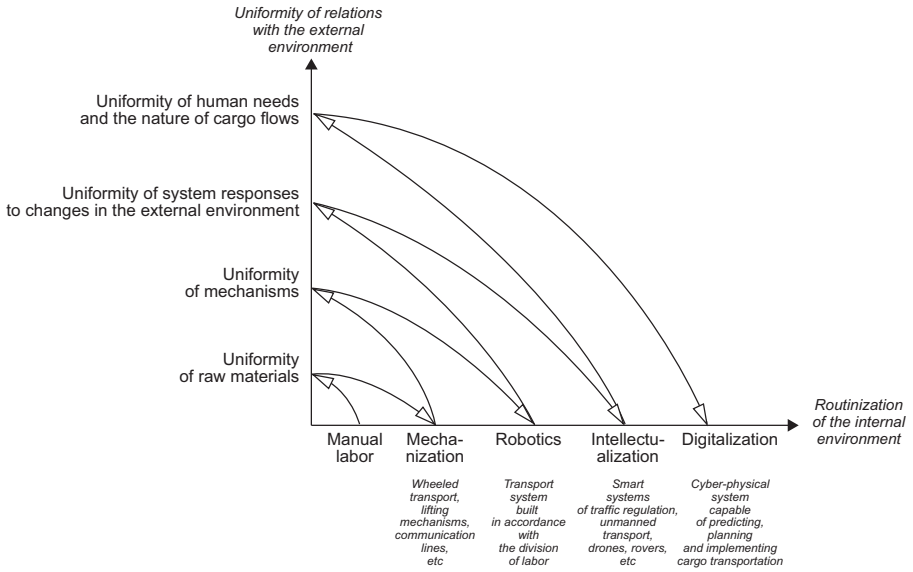
Thus, fully digital transport must acquire all the logical functions of a person, including the control function, because "digit is a control signal in information and computer systems" [Katasonov, 2019]. As a result, the transportation process should be carried out without any human participation according to the principle: cyber-physical system → cargo → cyber-physical system → human (as the final consumer of the cargo).

Based on the foregoing, within the framework of this article, the digitalization of transport corridors is understood as the process of transferring all human transportation functions to cyber-physical systems culminating in the complete dehumanization of the transport process.

In this article, a transport corridor is understood as a geographical route on which the resistance of the external environment to the process of transporting goods is minimal and which, therefore, is demanded by carriers.

The transition to each subsequent, more complex stage in the development of transport corridors occurs with the utmost uniformity, predictability, homogeneity and routine of operations at the previous level. Indeed, by virtue of Sedov's

Fig. 3. Uniformity as a criterion for transport system development



law (the law of hierarchical compensations), in a complex hierarchically organized system the growth of diversity at the upper level of the system is ensured by the restriction of diversity at the previous levels, and, conversely, the growth of diversity at the lower level destroys the upper level of the organization (that is, the system dies by itself) [Sedov, 1993].

Thus, the uniform, routine, often repetitive human labor is capable of giving rise to mechanization; the same set of applied mechanisms is well positioned to generate robotization and automation, immutability and uniformity of the external environment and responses of the transport system – intellectualization, immutability and uniformity of human needs and cargo flows - digitalization.

In view of the foregoing, we can imagine the following stages of preparing the technical system of transport for digitalization (Fig. 3).

Fig. 3 shows that according to Sedov's law achieving uniformity in relations with the external environment (vertical axis) makes possible a qualitative leap in the evolution of production activity (horizontal axis). In turn, the achievement of predictability, uniformity and routine in production opens up new prospects for transferring relations with the external environment to a higher level of uniformity.

In other words, digitalization by default requires one critical condition: the absolute stability of human needs, which results in the linear nature of all changes in the transport system and the full predictability of trade, transport and production processes. This provides the possibility of carrying out transportation without direct and constant human participation.

Of course, this condition is not feasible in the current state of affairs. It is only possible to classify different modes of transport according to their readiness for potential digitalization in terms of two factors (Fig. 4):

- degree of dependence on an unstable external environment;
- freight turnover of homogeneous product units over a long distance. Such homogeneous cargoes include, for example, oil, gas, coal, grain, fertilizers, etc.

Fig. 4. Readiness of different transport modes for potential digitalization

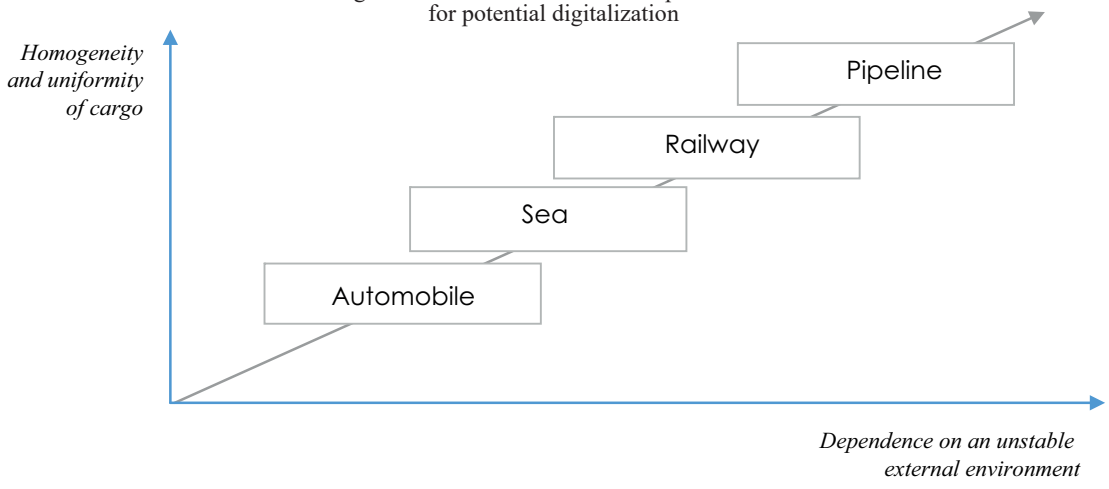


Fig. 4 shows that pipeline and railway modes of transport are most suitable for digitalization, since they use specially allocated channels and ways for moving goods, and they are also focused on working mainly with homogeneous types of goods.

Ideally, for the full deployment of digitalization, impersonal units of homogeneous cargo should move endlessly and en masse along the transport corridors. At the same time, fully digitized transport must be multimodal and global in nature, that is, it must freely cross all spaces, countries and continents. To do this, all participants (including shippers and consignees) must interact on the basis of the same compatible (that is, identical) digital technologies.

2. Non-complementarity of European and Russian railways

To make digitalization become reality, there must be complementarity in the interaction of two or more carriers which in this case means the ability of all participants in the transportation to maintain free circulation of material, information and energy flows among themselves, due to which their own technical systems both remain intact (according to TRIZ, Fig. 1) and preserve the ability to further internal complication.

Complementarity is not observed in interstate railway communication today. This is most clearly manifested in the different gauges on railways and in the difference relating to basic international agreements: the Agreement on International Freight Transport by Rail (SMGS), which is used in Russia, China and a number of other countries, and the Convention on International Rail Transport (CIM-COTIF; often referred to as CIM in Russian literature), which is used in a number of European countries. These agreements have serious differences, and "SMGS clearly protects the interests of the carrier more, while CIM is more in the interests of the sender and recipient" [Kolodyazhny, 2018]. In addition, "CIM provides quite a lot of freedom to the parties to the transport agreement in exercising their rights and obligations. Unlike CIM, the provisions of the SMGS are strictly regulated" [Kolodyazhny, 2018]. Thus, SMGS and CIM have fundamental differences regarding the most important legal aspects: "the terms of the transport agreement, the legal status of the recipient, the rules for service payment under the contract, the acceptance and delivery of cargo, the calculation of the amount and limits of the railway (carrier) liability, the rules for filing claims and lawsuits" [Budzinskaya, 2013]. As a result, "it is impossible to deliver cargo, for example, from Germany to Russia using one waybill. It is necessary to re-register transportation documents" [Budzinskaya, 2013].

In our opinion, the fact of a fundamental difference in document management systems is associated not only with political factors, but has deeper, systemic reasons. Let us consider them in more detail.

It is a common fact that in the world the width of the railway track ranges from 1000 to 1675 mm, and in Europe historically there were railway tracks with different gauges in parallel. Only with the passage of time a single standard for the gauge of 1485 mm appeared, which, "as historians note ... was used by Roman craftsmen who made carts" [3]. However, even today there is still no complete technical uniformity of railway tracks in Europe: "Today, in the EU, three states - Latvia, Lithuania, Estonia - have a 1520 mm gauge, Finland has a 1524 mm gauge, Poland and Slovakia have separate railway lines with a 1520 mm gauge; there are also small sections in Hungary and Romania. We should not forget about the presence of the "Iberian" gauge in Europe - 1668 mm in Spain and Portugal" [1520-1435: prospects for cooperation, 2011]. In addition, it should be noted, that "one of the obstacles to the creation of a single railway network is the lack of technical compatibility between the railway networks of the EU countries. For example, in European countries, various types of alarm systems and contact network voltages are used. As a result, "the creation of a single railway space is still an unattained goal for European countries, which is due to the lack of technical compatibility between the railway networks of the EU countries" [Rynok rail freight traffic.., 2020]. It was only in April 2004 that the European Railway Agency was established to coordinate technical specifications for technical and operational compatibility and traffic safety and to create a competitive European railway system.

At the same time, in Europe, the importance of "rail transport in passenger and freight traffic is relatively small: in 1970–2000, in 15 EU countries, the share of rail transport in passenger traffic decreased from 10.2 to 6.3%, in freight traffic - from 20.1 up to 8.1%" [Rail freight market.., 2020]. Competition from road transport is growing: "...increase in the competitiveness of road transport: market liberalization has created a mechanism in which licensed road carriers freely deliver goods from one EU country to another" [Rail freight market .., 2020]. Road transport in Europe "gained the opportunity (with a license) to deliver cargo between any cities of the European Union countries. At the same time, in railway transport for international transportation it is necessary to conclude contracts and agreements between all countries and railway companies" [Rail freight market.., 2020].

At the same time, competition within the railway system itself is actively stimulated: "by concluding state contracts and ... opening up access to infrastructure and freight traffic" [Rail freight market ..., 2020]. As a result, in Europe "... direct carriers of goods or passengers, whose activities are carried out on the same infrastructure compete with each other" [Rail freight market.., 2020].

The listed facts about railways in Europe suggest that they are an auxiliary mode of transport. Relatively short haul distances provide a competitive advantage to road freight transport, which is able to benefit from economies of scale at much lower volumes than rail. The consequence of this is monopolistic competition in the transportation market.

In our country, initially there was a different situation: "Unlike Europe, in Russia a single standard for the gauge was immediately adopted and since 1851 the "wide" gauge

[3] Railway gauge in different countries. https://pzb-online.ru/novosti/zh/d-koleya-v-raznyix-stranax/#/.

has become a unified gauge during the construction of all railways in Russia itself and in all parts of the empire, and then in the Soviet Union" [1520-1435: prospects for cooperation, 2011].

Let us note this fact: the Russian railway system was designed and created according to uniform standards established centrally. In turn, different widths gave rise to different dimensions of the rolling stock: on the 1520 mm gauge space it is significantly wider and higher than in Europe. Such decisions always have important technological implications for many industries, including, for example, the space industry. So, NASA was forced to take into account the overall limitations of American railways when developing the technology for delivering their aircraft to the launch site - "150-ton segments 12 feet wide to the launch pad." [4]. In other words, the dimensions of modern American spacecraft are determined by the standards of ancient Roman roads - the average dimensions of a wagon and the bodies of two horses.

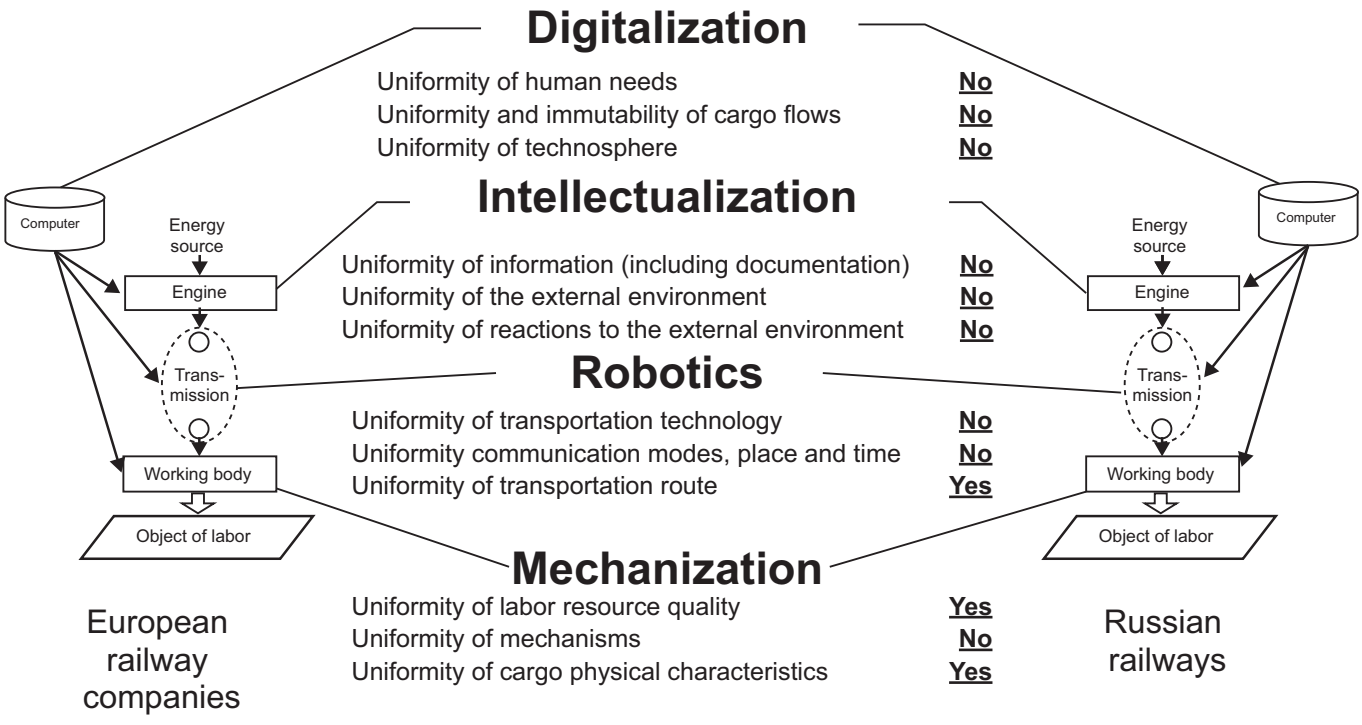
In Russia, however, the special conditions (harsh climate, large territories, significant transportation distances, low density of economic activity) led to the fact that railway lines of communication immediately became the backbone of the entire national economy: communication was carried out mainly with the help of railways focused on large volumes of transportation. Such volumes, in turn, could be provided only by large manufacturers or territorial production complexes. In other words, Russian railways have been and remain the main tool for connecting large technological zones. Due to the vast length of the paths, obtaining a positive effect of scale requires the concentration of all production within one company. Only under this condition a deep division of labor and the efficiency of railway transport is achieved. This property of Russian roads gave rise to a natural monopoly, plus SMGS as a tool for observing its interests.

Thus, the following cause-effect link is observed: different natural, geographical and demographic conditions → different standards of mechanisms, for example, gauges, wagons, etc. (mechanical level) → different technologies for interfacing mechanisms (robotics level) → different ways of reconciling the interests of carriers, sellers , buyers and the state, including in the legal sphere (the level of intellectualization).

In other words, there is a lack of complementarity between Russian railways and European railways on several levels:

1. The level of the natural environment and social institutions: different geographical, climatic, demographic and economic conditions, as well as ways of organizing production. The degree of instability of the external environment (natural and social) in Russia is significantly higher, and the density of economic activity is much lower.
2. Level of mechanization: mechanical technologies are fundamentally different since their inception.
3. The level of robotics: the movement of goods between Russia and Europe cannot be carried out seamlessly, as it requires the constant participation of a person

Fig. 5. Mutual discrepancy of Russian and European railways



[4] Heiney A. NASA railroad keeps shuttle's boosters on the right track. www.nasa.gov/mission_pages/shuttle/flyout/railroad.html.

in the readjustment of wagon bogies for a gauge of a different size.

4. The level of intellectualization: the incompatibility of transportation technologies in Russia and in most of Europe requires a semi-manual process of crossing the border of technological zones, including rearranging wagons to other wagon bogies, semi-manual transmission of information (including in the form of SMGS and CIM) and cash settlements. In addition, the slightest change in the external environment (macroeconomic situation, government activities, international political situation, etc.) requires a laborious process of manual adjustment of the transportation and transshipment process.

Thus, international transport corridors have not yet overcome the stage of intellectualization and in the foreseeable future will not be able to move to the actual digitalization of transportation.

Digitalization as the mainstream of modern transport development requires the complete identity of European and Russian railways at all levels. However, if the activities of Russian and European carriers are modeled using TRIZ, then their non-complementarity can be represented as follows (Fig. 5).

Non-complementarity of Russian and European railways is largely related to the phenomenon that is called the “path-dependence problem” in economics: it is not so important which standard is fixed (for example, railway gauge), but it is important that “then it is impossible to get off this path” [Auzan, 2015]. In this case, the " path-dependence problem " can be understood both in the literal sense (as a historical difference in the gauge width) and figuratively (as the effect of the dependence of new actions on past decisions).

This means that the complementarity of railways and the digitalization of global transport corridors can be achieved on a qualitatively different technological platform (for example, magnetic levitation), which will remove irresolvable contradictions at the mechanical level.

Secondly, non-complementarity is related to the difference in the external environments in which the Russian railway and European railways operate: the higher the instability of the external environment, the more difficult it is to advance intellectualization and digitalization. It is for this reason, for example, that pipeline transport operators prefer long-term contracts rather than pursuing short-term tariff and price maximization.

Thus, it is still very premature to talk about the digitalization of transport corridors. There are some prerequisites for digitalization within the railways (for example, within the Russian Railways), but digital technologies are not complementary for carriers, consignors and consignees, since each of them works in its own technological environment. In addition, government agencies (for example, customs) are not ready either to use the digital documents of these transport entities, or to work in a single information ecosystem. This means that in transport corridors today there are paperless technologies rather than digital ones, since the transportation process still cannot do without human participation.

Conclusion

The globalization of transport flows is an objective global trend. To assess the prospects for the digitalization of transport corridors, the SMGS and CIM agreements are considered. They set an eloquent example of the fact that the digitalization of railway transport is blocked at the level of intellectualization behind which, in turn, unresolvable contradictions between the levels of mechanization and robotics are found.

Different gauges affecting the wear of rolling stock wheel sets, the carrying capacity of wagons, the quality of the superstructure of the track, etc. entail many other consequences, which is especially evident when transporting non-standard cargo. Technological differences determine different economies of scale and, as a result, different institutional environments. All this ultimately results in a different market configuration (seller's market or buyer's market) and determines the prospects for digitalization.

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About the authors

Igor V. Anokhov
Candidate of Economic Sciences, Associate Professor, Head of the Scientific and Publishing Department. Research Institute of Railway Transport (Moscow, Russian Federation). ORCID: 0000-0002-5983-2982, Researcher ID: AAF 9428 2020, SPIN-code: 1444-3259, Author ID: 260787.
Research interests: labor, economic interests, theory of firms, transport.
i.v.anokhov@mail.ru

Olga N. Rimskaya
Candidate of Economic Sciences, Associate Professor, Head of the Scientific and Educational Complex of the Research Institute of Railway Transport (Moscow, Russian Federation). ORCID: 0000-0002-1548-0815, Researcher ID: 583440, SPIN-code: 4185-4532, AuthorID: 583440.
Research interests: world economy, digital economy, labor economics, education economics, lifelong education, European systems and models of education, human resource management, motivation and stimulation of labor, economic and political problems of the humanitarian crisis.
olgarim@mail.ru

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