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Section 1. Agricultural science

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CONSUMER BEHAVIOR AND DEMAND FOR GREEN PRODUCTS

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Abstract

This study analyzes consumer behavior and the factors influencing demand for green products in the context of sustainable development. The study focuses on the role of environmental awareness, individual attitudes, price perception, and trust in eco-labeling in shaping consumption decisions. Drawing on empirical data collected through a survey and analyzed using statistical and econometric methods, the paper assesses the relationships among key variables and identifies the most important factors that encourage or hinder demand for green products. The results indicate that environmental awareness and trust in ecological information have a positive and significant impact on consumers' willingness to purchase green products, while the perception of high prices constitutes a major barrier. The study highlights the importance of informational policies, market-based instruments, and sustainable marketing strategies in increasing demand for environmentally friendly products, thereby contributing to the literature on environmental economics and consumer behavior.

Keywords: *consumer behavior, green products, demand for sustainable products, environmental awareness, sustainable development*

1. Introduction

Consumer behavior constitutes a key element in shaping consumption patterns and determining demand for green products in contemporary economies. Consumers' decisions are influenced by a range of factors, such as environmental awareness, price perception, trust in eco-labeling, and the level of information, which often determine their willingness to adopt more sustainable consumption patterns. In this context, this study analyzes consumer behavior and the main factors influencing demand for green products, aiming to provide empirical evidence and recommendations for public policies and market strategies that support sustainable development. Global drivers toward sustainability have positioned green consumerism as a key priority, encompassing the use of environmentally sustainable products and

services with the aim of reducing ecological impact (Teck, 2025). The main mechanism for protecting the global and local environment consists of the implementation of production and consumption practices that limit negative environmental impacts, through environmental standards such as the "polluter pays" principle, environmental taxes and fines, as well as eco-labeling of products (Ozanne, 2008). Currently, there is no consensus on the definition of the "eco" concept or what constitutes a "green" product. However, in practice, green goods are typically characterized by several common features, such as safety and healthiness, biodegradability or the use of recyclable resources, long-term sustainability, natural degradation, recyclability, and local production (Chandu, 2023). As a result, an unstructured trend can be observed in individual and social behaviors toward green consumption, where consumers are becoming increasingly aware of sustainability, naturalism, and environmentalism, orienting their choices toward the preservation of nature (Ali, 2022).

2. Literature review

The literature review focuses on the analysis of theoretical concepts and empirical studies addressing consumer behavior and demand for green products. It aims to identify the main determining factors, existing research gaps, and the contribution this study makes to expanding the literature on sustainable consumption. The adoption of green behavior constitutes a fundamental element in achieving sustainability. It is associated with the consumption of environmentally friendly products and with actions guided by awareness and social responsibility, aiming to preserve resources for future generations and to reduce overconsumption through sustainable and resource- and energy-efficient choices (Musa, 2023). Green marketing represents a strategy for promoting environmentally friendly goods and services, encompassing the design, development, advertising, and distribution of products that are socially and ecologically responsible (Tandon, 2023). Green consumption is associated with environmentally responsible consumption, in which consumers assess the environmental impact of the purchase, use, and disposal of products, as well as the use of green services (Nguyen, 2023). Environmental concern has increased in parallel with contemporary environmental challenges, particularly in developing countries, such as the depletion of natural resources and global warming, which influence consumers' choices. As a result, consumers show a growing tendency to support the environment and sustainability through green purchasing (Ogiemwonyi, 2023). Studies show that consumers' attitudes significantly influence sustainable consumption by shaping green purchase intentions. Understanding this role supports the development of policies and strategies aimed at promoting sustainable consumption (Islam, 2024). This shift is part of a broader movement toward sustainability, in which consumers' choices directly influence the market. Sustainable consumer behavior encourages businesses to adopt greener practices and supports the transition toward a green economy (Budac, 2023).

3. Methodology

3.1. Aim of the Study

The aim of this study is to analyze the level of awareness, perceptions, and consumer behavior toward green products, as well as to identify the main factors influencing purchasing decisions. The study also seeks to assess potential barriers and drivers for increasing the consumption of environmentally friendly products.

3.2. Data Collection Method

The data were collected through a structured questionnaire consisting of closed-ended questions. The questionnaire was designed to cover several key dimensions, including demographic characteristics, level of awareness of green products, perceptions of the importance of environmental protection, purchasing behavior, influencing factors, and the role of public institutions.

3.3. Study Sample

The study sample consists of 150 respondents. The sample was selected using a random sampling method, including individuals of different age groups and educational levels. This approach enabled a broader representation of consumer attitudes and behaviors.

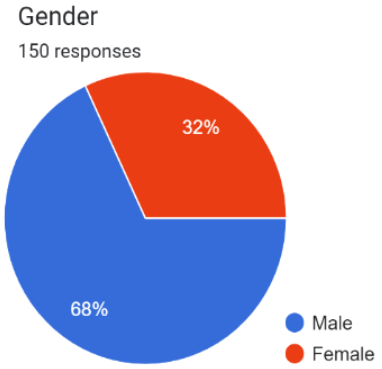
3.4. Data Analysis

The collected data were analyzed using descriptive statistical methods. The results are presented in the form of graphs and figures, which facilitate a clearer interpretation of response distributions and the main trends identified in the study.

4. Study Results

This section presents the main results of the study. The findings provide evidence on the factors influencing consumer behavior and demand for green products, highlighting the key relationships among the analyzed variables.

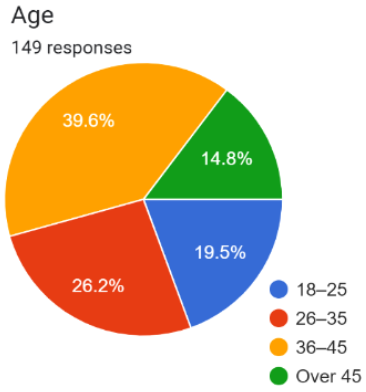
Figure 1. *Gender of the respondents*



Source: Author, 2026

Figure 1 presents the gender distribution of the respondents in the study. Out of 150 respondents, 68% are male and 32% are female.

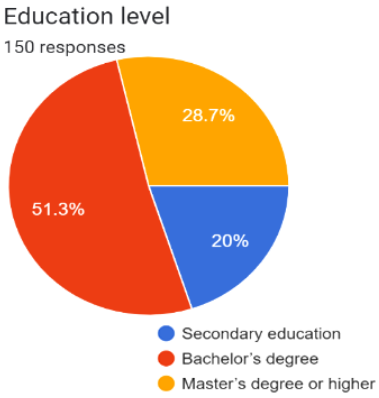
Figure 2. *Age of the respondents*



Source: Author, 2026

The figure above presents the distribution of respondents by age groups. The most represented group is 36–45 years, accounting for 39.6%, followed by the 26–35 age group with 26.2% and the 18–25 age group with 19.5%. Meanwhile, respondents aged over 45 represent 14.8% of the sample.

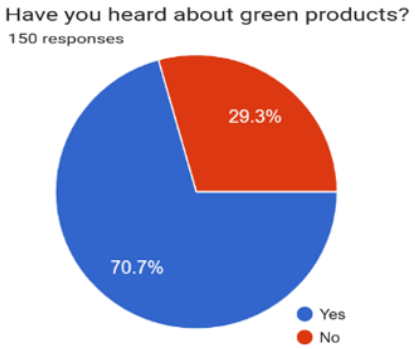
Figure 3. *Educational level*



Source: Author, 2026

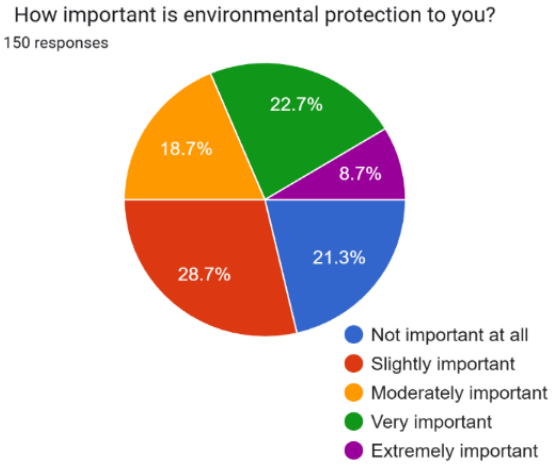
Figure 3 presents the educational level of the 150 respondents. The majority of the sample has completed bachelor's studies, accounting for 51.3% of the total, 28.7% hold a master's degree or higher, while 20% have completed secondary education.

Figure 4. *Level of awareness of green products*



Source: Author, 2026

Figure 5. *Perception of the importance of environmental protection*

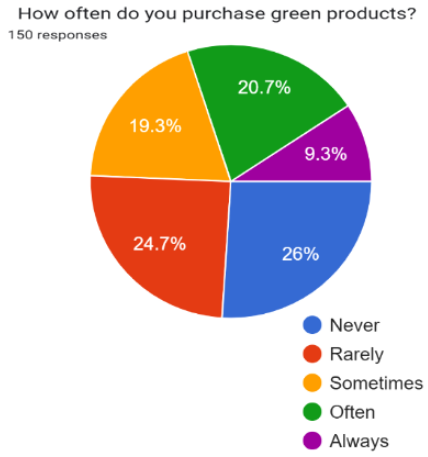


Source: Author, 2026

The figure above illustrates respondents' level of awareness of green products. The results indicate that 70.7% of participants report having heard of green products, while 29.3% state that they have no knowledge of them.

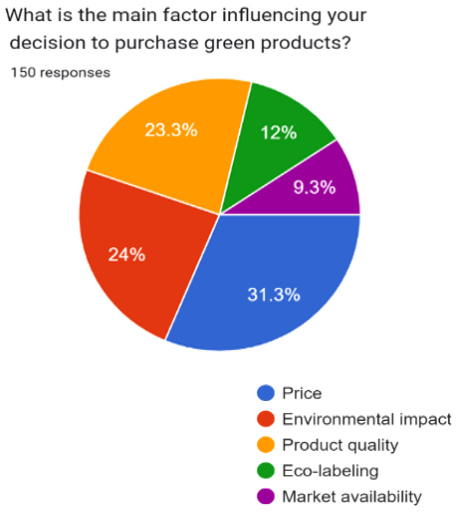
Figure 5 shows respondents' perceptions of the importance of environmental protection. The results indicate that 28.7% consider environmental protection to be of little importance, while 21.3% state that it is not important to them at all. On the other hand, 18.7% perceive it as moderately important, 22.7% consider it very important, and 8.7% rate it as extremely important.

Figure 6. *Approach toward purchasing green products*



Source: Author, 2026

Figure 7. *Main factors influencing the decision to purchase green products*

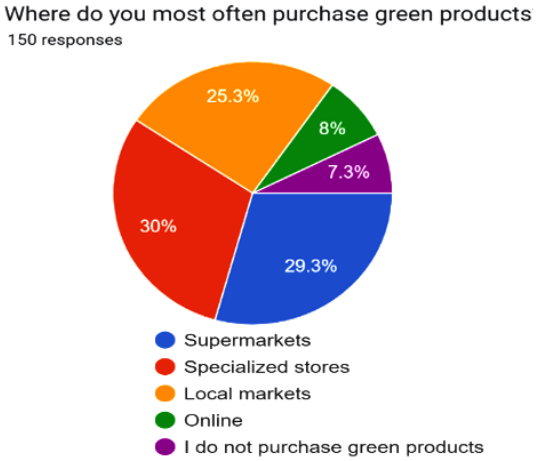


Source: Author, 2026

The figure above illustrates respondents' approach toward purchasing green products. The results show that 26% report never purchasing green products, while 24.7% purchase them rarely. A proportion of respondent's state that they purchase green products occasionally, whereas others report purchasing them frequently. Only 9.3% of respondents indicate that they always purchase green products.

The figure above illustrates the main factors influencing respondents' decisions to purchase green products. According to the results, price emerges as the dominant factor, followed by environmental impact, indicating a relatively high level of environmental awareness. Product quality also plays an important role in purchasing decisions. Meanwhile, eco-labeling is mentioned less frequently, and market availability has the lowest influence on the decision to purchase green products.

Figure 8. *Places where respondents most frequently purchase green products*

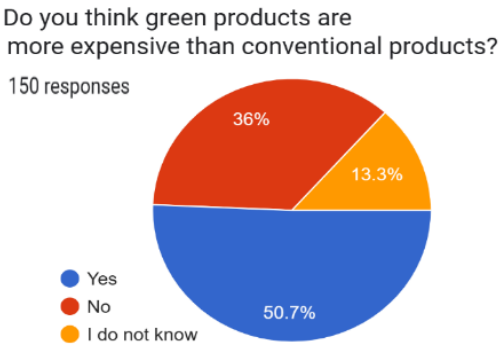


Source: Author, 2026

Figure 8 presents the places where respondents most frequently purchase green products. The results indicate that specialized stores represent the main purchasing channel, followed closely by supermarkets, suggesting that accessibility and a structured product offering play an important role in consumption. Local markets also account for a notable share, while online purchases remain relatively limited. A small proportion of respondents report that they do not purchase green products.

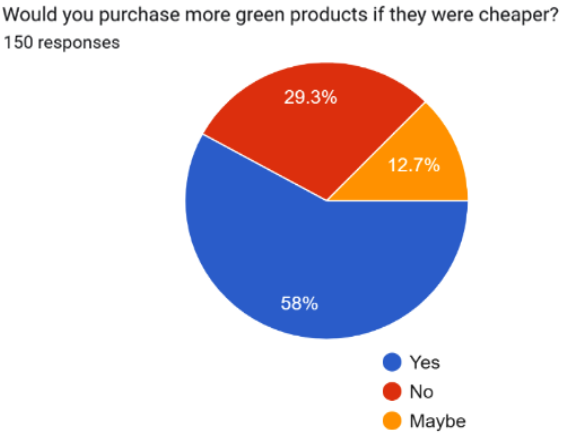
Figure 9 illustrates respondents' perceptions of the price of green products compared to conventional products. More than half of the respondents believe that green products are more expensive, confirming that price remains a significant barrier to the expansion of their consumption. Meanwhile, a considerable share of respondents do not perceive green products as necessarily more costly, while some remain uncertain.

Figure 9. *Perception of the price of green products compared to conventional products*



Source: Author, 2026

Figure 10. *Willingness to increase the purchase of green products if they were cheaper*

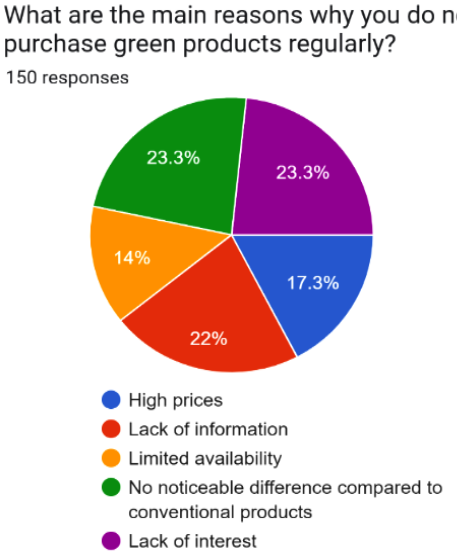


Source: Author, 2026

The figure above shows respondents' willingness to increase their purchase of green products if these products were cheaper. The results indicate that 58% respond positively, confirming that price is a decisive factor in shaping consumers' behavior toward green products. Meanwhile, 29.3% state that they would not change their purchasing behavior, and 12.7% remain uncertain.

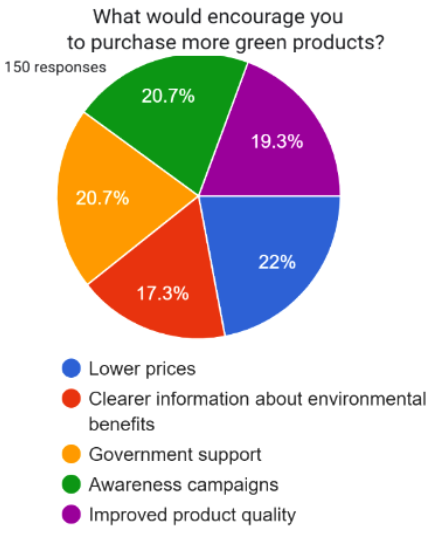
The figure above illustrates the main reasons why respondents do not purchase green products on a regular basis. The results indicate that lack of interest and the perception of no noticeable difference compared to conventional products are the most frequently cited reasons. Insufficient information is also identified as a key barrier, while high prices are mentioned by a smaller share of respondents. Limited market availability represents the least cited reason.

Figure 11. *Main reasons for not purchasing green products regularly*



Source: Author, 2026

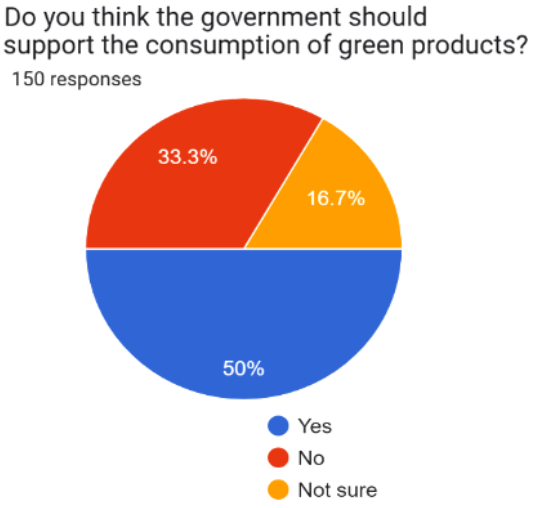
Figure 12. *Factors that would encourage increased purchasing of green products*



Source: Author, 2026

The figure above presents the factors that would encourage respondents to purchase more green products. The results indicate that price reductions represent the main incentive. Government support and awareness campaigns follow closely, highlighting the importance of institutional involvement and information dissemination. Improvements in product quality are also considered important, while clearer information on environmental benefits is viewed as a further motivating factor.

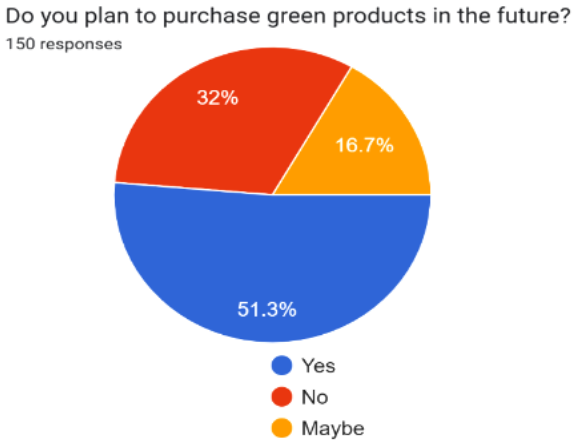
Figure 13. *Perceptions of the role of government in supporting green product consumption*



Source: Author, 2026

The figure illustrates respondents' perceptions of the government's role in supporting the consumption of green products. The results show that half of the respondents believe that the government should support the consumption of green products, while a smaller share think that the government should not intervene. Some respondents remain uncertain about the government's role.

Figure 14. *Plans to purchase green products in the future*



Source: Author, 2026

The figure presents respondents' intentions to purchase green products in the future. The results indicate that 51.3% plan to purchase green products, while 32% report having no such plans. The remaining respondents remain uncertain about future green product purchases.

Table 1. Statistical description

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.799[a]	.638	.631	.802

a. Predictors: (Constant), Willingness to increase the purchase of green products if they were cheaper, the main factors influencing the decision to purchase green products, Education level

ANOVA[a]						
	Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	165.301	3	55.100	85.771	.000[b]
	Residual	93.792	146	.642		
	Total	259.093	149			

a. Dependent Variable: approach of purchase of green products
b. Predictors: (Constant), Willingness to increase the purchase of green products if they were cheaper, the main factors influencing the decision to purchase green products, Education level.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.567	.300		1.886	.061
	The main factors influencing the decision to purchase green products	.811	.051	.799	16.022	.000
	Education level	.020	.095	.011	.214	.831
	Willingness to increase the purchase of green products if they were cheaper	.016	.074	.011	.223	.824

a. Dependent Variable: approach of purchase of green products

Frequency of purchasing green products = 0.567 + 0.811*** (Main decision-making factors) + 0.020 (Education level) + 0.016 (Willingness to purchase more if prices were lower)

The results of the linear regression indicate that the constructed model is statistically significant and explains a substantial portion of the variation in the frequency of purchasing green products.

According to the Model Summary, the correlation coefficient is R = 0.799, indicating a strong positive relationship between the independent variables and the dependent variable. The R^2 value of 0.638 suggests that approximately 63.8% of the variance in the frequency of purchasing green products is explained by the following factors: education level, the main factors influencing the purchasing decision, and willingness to increase purchases if products were cheaper. The Adjusted R^2 value of 0.631 confirms that the model is stable and suitable for analysis.

The ANOVA test shows that the model is statistically significant ($F = 85.771$, $p < < 0.001$), indicating that at least one of the independent variables has a significant effect on the dependent variable.

The coefficient analysis reveals that the main factors influencing the decision to purchase green products have a positive and statistically significant effect on purchase frequency ($\beta = 0.799$, $t = 16.022$, $p < 0.001$). This indicates that the stronger the motivating factors for purchasing green products, the higher the frequency of their purchase.

In contrast, education level ($p = 0.831$) and willingness to increase purchases if products were cheaper ($p = 0.824$) are not statistically significant in this model, suggesting that these variables do not have a direct and meaningful impact on the frequency of purchasing green products.

In conclusion, the model confirms that factors influencing the purchasing decision are the primary determinants of the frequency of purchasing green products, while education level and perceived price do not exhibit a statistically significant effect in this analysis.

5. Discussion

The results of the study show that, although there is a good level of awareness of green products, this awareness does not translate directly into frequent purchasing behavior. This mismatch suggests that environmental awareness, in the absence of practical and economic incentives, remains insufficient to stimulate sustainable consumption.

The empirical analysis confirms that the factors influencing purchase decisions constitute the main determinants of the approach to buying green products. Elements such as price, perceived quality, and environmental impact prove to be more decisive than individual consumer characteristics. In this context, the level of education does not

exhibit a statistically significant direct effect on purchasing behavior.

Although price is perceived as a major barrier, the stated willingness to increase purchases in the event of price reductions does not appear to have a direct impact on the actual frequency of purchasing. This indicates that consumer decision-making is influenced by a combination of factors rather than by a single element.

Overall, the findings underscore that increasing the consumption of green products requires an integrated approach that simultaneously addresses consumer perceptions, product characteristics, and market conditions, going beyond mere environmental awareness.

6. Conclusion

The study highlights a clear gap between awareness and the actual consumption of green products, indicating that environmental awareness alone is not sufficient to encourage sustainable purchasing behavior. The approach to buying green products is found to be determined mainly by factors that directly influence decision-making, while individual characteristics, such as the level of education, do not show a statistically significant direct impact.

The results of the regression analysis confirm that the model explains a substantial proportion of the variation in the approach to purchasing green products, emphasizing the importance of product-related factors and consumer perceptions. Price remains a perceived barrier as well as a potential incentive, but it does not represent the sole determining factor in changing consumer behavior.

In conclusion, the findings suggest that policies and strategies aimed at promoting the consumption of green products should adopt an integrated approach that combines economic measures, improvements in product quality, increased transparency of information, and targeted awareness-raising. The role of public institutions and market actors proves to be essential in creating an environment that facilitates and encourages the adoption of green products by consumers.

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Section 2. Biology

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PHYTOCHEMICAL STUDY AND EVALUATION OF THE ANTI-RADICAL, ANTI–INFLAMMATORY AND CYTOTOXIC ACTIVITIES OF THE LEAVES OF *TETRACERA ROSIFLORA GILG (DILLENIACEAE)*

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Cite: *Christophe Muanyishay Lukanda, Carlos Kabengele Nkongolo, Fatuma Luhahi Lumba, Sebastien Luyindula Ndiku, Pius Mpiana Tshimankinda. (2026). Phytochemical study and evaluation of the anti-radical, anti-inflammatory and cytotoxic activities of the leaves of Tetracera rosiflora Gilg (Dilleniaceae). European Journal of Technical and Natural Sciences 2025, No 1*. https://doi.org/10.29013/EJTNS-26-1-12-21

Abstract

Tetracera Tetracera rosiflora is a medicinal plant used in traditional medicine to treat a number of ailments such as diabetes, arthritis, dysentery, hepatitis, etc. This study aimed to evaluate the microscopic, phytochemical, and biological characteristics of total aqueous and organic extracts of *Tetracera leaves. rosiflora* Gilg (*Dilleniaceae)*, a plant used in traditional African medicine. Histological examination revealed several distinctive diagnostic features, including polycytic stomata, unicellular hairs, spiral vessels, and calcium oxalate crystals, which are reliable identification markers. Phytochemical screening demonstrated the presence of polyphenols, flavonoids, tannins, anthocyanins, leucoanthocyanins, and saponins. Quantitative assays showed a high total polyphenol content (42.12 ± 1.14 mg GAE/g), confirming the species' rich antioxidant content. Biological tests revealed marked antioxidant activity, greater in the low-concentration aqueous extract, and significant anti-inflammatory activity, especially

in the organic extract (maximum inhibition: 80.20%). Cytotoxicity assessment showed low to moderate toxicity (hemolysis rate < 50%), suggesting a satisfactory safety profile. Overall, *Tetracera rosiflora* is distinguished by a rich phytochemical composition and notable antioxidant and anti-inflammatory properties, justifying its traditional uses and supporting its potential for the development of plant-based therapeutic products.
Keywords: *Tetracera rosiflora, polyphenols, antioxidant activity, anti-inflammatory activity, cytotoxicity, medicinal plant*

1. Introduction

Medicinal plants constitute an inexhaustible source of bioactive molecules, playing a central role in the prevention and treatment of numerous diseases. For millennia, they have been used in traditional medicine for their diverse therapeutic properties. Currently, the growing interest in natural products is explained not only by their richness in secondary metabolites, but also by their potential to offer alternatives or complements to modern treatments, particularly in the face of chronic and degenerative diseases (Seudi). *et al.,* 2025, Muanyishay *et al.,* 2018).

Among the species of interest, *Tetracera rosiflora* Gilg, belonging to the *Dilleniaceae family,* is used in traditional Congolese medicine to treat various ailments, including diabetes, infections, and certain inflammations (Ogunlakin & Sonibare, 2022). The leaves of this plant are known to contain a variety of phenolic compounds, flavonoids, tannins, and other secondary metabolites, which may confer significant pharmacological properties (Kamisah). *et al.,* 2013).

Contemporary research is paying particular attention to biological activities related to oxidative stress and inflammation. Oxidative stress, resulting from an imbalance between the production of reactive oxygen species (ROS) and antioxidant defense systems, is implicated in the development of several chronic diseases such as cancer, diabetes, cardiovascular, and neurodegenerative diseases (Santos *et al.,* 2019). Inflammation, when it becomes chronic, also constitutes an aggravating factor in the progression of these conditions (Silva *et al.,* 2024). In this context, evaluating the free radical scavenging and anti-inflammatory activity of medicinal plants is of particular interest for identifying new molecules with therapeutic potential.

Furthermore, cytotoxic testing of plant extracts is a promising avenue for the search for new anticancer agents, given the ongoing need for effective molecules that are less toxic than those already available (Naeem *et al.,* 2022). Therefore, an integrated study of the phytochemical profile and the antioxidant, anti-inflammatory, and cytotoxic activities of *T. rosiflora extracts* is relevant, as it could contribute to the pharmacological development of this species and the identification of new bioactive molecules.

The objective of this work is therefore to carry out a phytochemical study of the leaves of *T. rosiflora* Gilg and to evaluate their anti-radical, anti-inflammatory and cytotoxic activities in order to provide a scientific basis for the traditional use of this plant.

2. Materials and methods

2.1. Sample preparation

The biological material used in this study consists of *Tetracera leaves. rosiflora* Gilg leaves were collected in the commune of Mont-Ngafula (Kimwenza), located in the city-province of Kinshasa in the Democratic Republic of Congo (4°27'25.179"S; 15°17'37.693"E).

Botanical identification of the plant was carried out at the Herbarium of the National Institute of Agronomic Studies and Research (INERA), housed at the Faculty of Sciences of the University of Kinshasa (UNIKIN). These leaves were air-dried (± 27 °C) in the shade for two weeks. The dried samples were then ground using an electric mill to obtain a fine, homogeneous powder for various analyses. The blood sample used for quantitative cytotoxicity was collected from a healthy volunteer. Chicken eggs were purchased at the local market.

2.2. Micrograph

The histological elements were observed using a Primo Star 200® microscope according to the method described by Carlos *et al.* (2020). This analysis made it possible to

identify the characteristic anatomical structures of *T. rosiflora leaves*.

2.3. Qualitative phytochemical screening

The identification of the main classes of secondary metabolites (alkaloids, flavonoids, tannins, saponins, sterols, triterpenes, etc.) was carried out according to the classical methods described by Kasiama *et al.* (2023). These tests revealed the presence of various compounds with pharmacological potential.

2.4. Determination of phenolic compounds

The total polyphenol content was determined according to the Folin-Ciocalteu method (Kasiama *et al.,* 2022). Total flavonoids and anthocyanins were quantified according to the method of Lebreton *et al.* (1967). Condensed and hydrolyzable tannins were quantified, respectively, based on the condensation of polyphenolic compounds with vanillin in acidic medium and the reaction with ferric chloride (HCl) in acidic medium, according to the method described by Dohou. *et al.* (2003).

2.5. Evaluation of antioxidant activity

The antioxidant activity was evaluated using the FRAP method (ferric reducing antioxidant power) according to the protocol described by Ghaoui (2023).

2.6. Anti-inflammatory activity

The in vitro anti-inflammatory activity was evaluated according to the protein denaturation method (Albumin) following the approach described by Kumari (2015).

2.7. Qualitative cytotoxicity test

Qualitative cytotoxicity testing was performed to assess the potential effects of the extract on the integrity of human erythrocyte membranes. This test was evaluated according to the method described by Kaźmierczak. *et al.,* (2023), with some modifications.

2.8. Quantitative cytotoxicity test

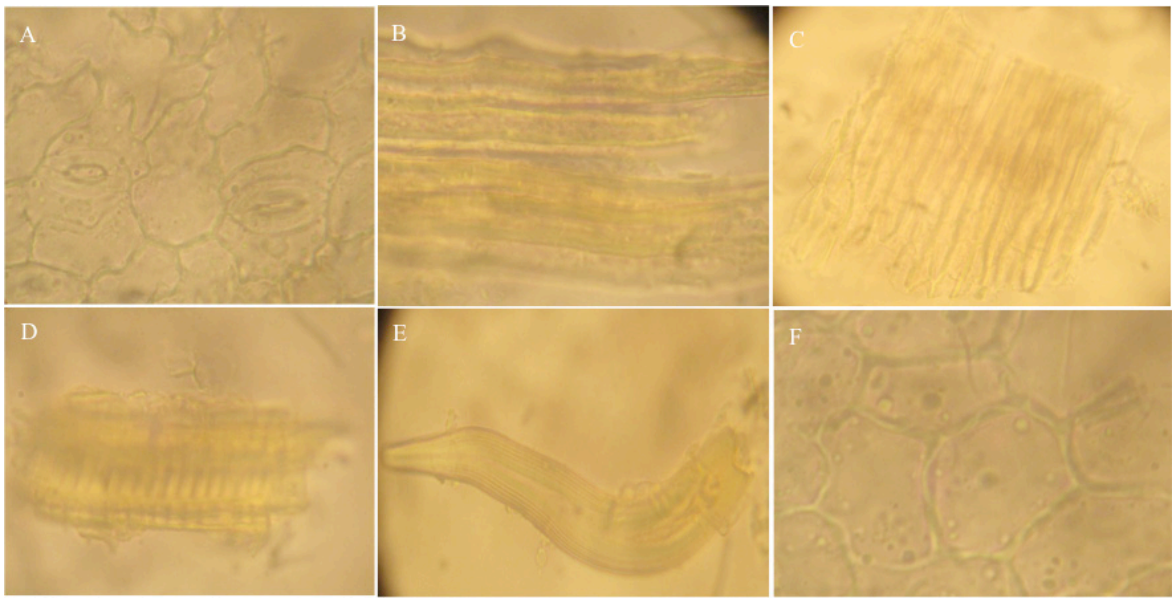
Badisa 's method *et al.* (2019), with some modifications, was used to evaluate the cytotoxicity of the extracts on human erythrocytes.

3. RESULTS AND DISCUSSION

***3.1. Results of microscopic examination of* T. rosiflora powders**

The results of the micrograph performed on the *T. rosiflora powder* are presented in Figure 1 below:

Figure 1. Micrographic characteristics of *T. rosiflora*



Histological analysis of *T. rosiflora leaves Several characteristic features were revealed (Figure 1), including: (A)* polycytic stomata, (B) fragments of spiral vessels, (C) fiber fragments, (D) smooth, flattened unicellular hairs, sometimes enlarged in their midsection, (E) parenchyma cells containing calcium oxalate crystals, and (F) epidermal cells containing oil droplets. These anatomical structures constitute distinctive histological markers of this

species and can serve as a baseline for its characterization and identification.

To our knowledge, no previous micrographic studies have been reported on *T. rosiflora*. However, similar work carried out on other plant species has revealed comparable histological features. Thus, Akoubet *et al.* (2022) observed in the fruit and extract of *Picralima nitida* (*Apocynaceae*) fragments of parenchyma, sclerenchyma, secretory hairs, and wood vessels. Similarly, recent studies on leaf powders of *Ficus exasperata* and *Uvariodendron molundense* (*Annonaceae*) revealed the presence of parenchyma fragments, calcium oxalate crystals, fibers, annular vessels, starch grains, and pitted vessels (Ukwubile, 2013; Alamgir, 2017). Furthermore, micrographic analysis of *Lippia multiflora* enabled the identification of epidermal cells, stomata, spiral vessels and non-glandular unicellular trichomes (Dalia, 2022).

These observations confirm that the histological elements identified in *T. rosiflora* These variations are part of the anatomical variability commonly observed in medicinal plant species. Given the traditional use of this plant, knowledge of its microstructure is of particular importance for the normalization and standardization of plant material. The precise identification of histological elements is indeed an essential step in the development of pharmacognosic monographs and the prevention of adulteration of herbal drugs.

3.2. Phytochemical screening in solution

On the one hand, chemical screening revealed the presence of polyphenolic compounds (flavonoids, anthocyanins, leucoanthocyanins, tannins, bound quinones), saponins, and terpenoids; and on the other hand, alkaloids, free quinones, and steroids were absent from the extract. The presence of polyphenols in the *T. rosiflora* extract This justifies its use in traditional medicine against diabetes, back pain, arthritis, skin infections, ulcers, and gastrointestinal disorders (Ansari). *et al.*, 2025).

3.3. Determination of total phenolic compound content

Table 2 below shows the total polyphenol, total flavonoid, anthocyanin and condensed and hydrolyzable tannin content in *T. rosiflora leaves*.

T. rosiflora leaves.

Table 1.

Secondary metabolites	Total polyphenols	Total flavonoids	Anthocyanins
Concentrations	42.12 ± 114 mg GAE /g	0.090 ± 0.002 mg EQ/g	0.30 ± 0.07 mg EC/g

Tetracera leaves *rosiflora* revealed variable levels of secondary metabolites (Table 2). The concentration of total polyphenols is relatively high, estimated at 42.12 ± 1.14 mg gallic acid equivalent per gram of extract (mg GAE/g), while those of flavonoids and anthocyanins are respectively 0.090 ± 0.002 mg quercetin equivalent per gram (mg QE/g) and 0.30 ± 0.07 mg catechin equivalent per gram (mg EC/g).

The high polyphenol content suggests that *T. rosiflora* is an important source of phenolic compounds, known for their antioxidant, anti-inflammatory and antimicrobial properties (Imene, 2021; Trik, 2020).

In contrast, flavonoid and anthocyanin levels appear relatively low compared to total polyphenols. This difference can be explained by the fact that flavonoids and anthocyanins represent specific subclasses of polyphenols. The low levels observed may also depend on ecophysiological factors (growing conditions, harvest season, light exposure) or extraction parameters (nature of the solvent, duration, temperature), which significantly influence the solubilization of these compounds.

Despite their low concentration, the presence of flavonoids and anthocyanins is nonetheless significant. Flavonoids often contribute to antioxidant and anti-inflammatory effects (Khamel & Baghiani, 2024), while anthocyanins contribute to free radical scavenging activity and can act synergistically with other phenols to enhance the overall antioxidant capacity of the extract (Chen et al,. 2022).

These results therefore confirm that *T. rosiflora* has a phytochemical profile rich

in phenolic compounds, which may justify some of its traditional uses in the treatment of infectious and inflammatory conditions.

3.4. Antioxidant activity

The results of the antioxidant activity of the aqueous and organic extracts are shown in Tables 2 and 4 below.

Table 2 shows that the curve exhibits a nearly linear increase in reducing power over the studied concentration range, without a marked plateau at low doses. This profile suggests the predominant presence of water-soluble compounds, particularly polyphenols, glycosylated flavonoids, and phenolic acids, whose antioxidant activity is evident even at low concentrations. The observed effect thus reflects a homogeneous distribution of active molecules and good solubility in the reaction medium.

Table 2. *Evolution of optical density as a function of the concentration of the total aqueous extract of Tetracera rosiflora*

Aqueous extract of *T. rosiflora*	
Concentration (mg/ mL)	**Optical density**
0.002	1.16
0.001	0.996
0.0006	0.946

Table 4. *Evolution of optical density as a function of the concentration of the total organic extract of Tetracera rosiflora*

Organic extract of *T. rosiflora*	
Concentration (mg/ mL)	**Optical density**
0.002	1,802
0.001	1.32
0.0006	1,304

In contrast, the curve corresponding to the organic extract (Table 4) shows a relatively shallow slope at low concentrations, followed by a marked increase at higher doses. This non-linear evolution likely reflects the lipophilic nature of the extracted compounds, whose limited solubility in the aqueous medium of the test reduces their initial activity. The rapid increase in reducing power at high concentrations could be attributed to the presence of less abundant but strongly reducing molecules, such as certain flavonoid aglycones or terpene compounds.

Comparison of the two extracts reveals a notable difference in their antioxidant profiles. The aqueous extract is more active at low concentrations, exhibiting immediate and sustained antioxidant activity, while the organic extract displays its full potential at higher concentrations. These results underscore the crucial influence of solvent polarity on the nature and reactivity of bioactive compounds extracted from *Tetracera. rosiflora,* suggesting a complementarity between hydrophilic and lipophilic fractions in the overall contribution to the plant's antioxidant activity.

Furthermore, the Ladeska study *et al.* (2024) on the pharmacognostic evaluation and antioxidant activities of *Tetracera indica* revealed an optical density of 4296.67 ± ± 0.024, higher than that obtained for the total aqueous and organic extracts in the present study. Similarly, the extracts tested here showed a notable antioxidant effect compared to those reported in Kittiwisut 's work *et al.* (2021) and Roheem *et al.* (2020), confirming the high antioxidant potential of the genus *Tetracera*.

3.5. Anti-inflammatory activity

The anti-inflammatory effect of aqueous and organic extracts of *T. rosiflora* was evaluated *in vitro* with respect to protein denaturation. Figure 3 below shows the degree of inhibition of thermal denaturation of ovalbumin (%I) by aqueous and organic extracts of *T. rosiflora*.

The results obtained in Table 3 demonstrate that the total extracts of *T. rosiflora* possesses notable anti-inflammatory activity, although less than that of diclofenac sodium, used as a reference anti-inflammatory. This observation is consistent with previous work on other species of the genus *Tetracera*, notably *Tetracera alnifolia, Tetracera scandens* and *Tetracera potatoria,* whose extracts have also shown significant anti-inflammatory properties *in vivo* and *in vitro* (Akinmoladun *et al.,* 2015; Agbor *et al.,* 2018; Ayele *et al.,* 2020).

The greater activity of the organic extract compared to the aqueous extract is consistent with the observations reported by Olayemi *et al.* (2019), who showed that fractions rich in lipophilic compounds (methoxy lated flavonoids, triterpenes, sterols, and phenolic ac-

ids) exhibit better inhibition of pro-inflammatory mediators such as cyclooxygenase (COX) and lipoxygenase (LOX). These secondary metabolites, mostly soluble in organic solvents, are known to modulate the production of inflammatory cytokines (TNF-α, IL-1β) and the expression of inducible nitric oxide synthase (iNOS).

Table 3. *Anti-inflammatory activity* of total aqueous *and organic extracts* of *Tetracera rosiflora*

Concentration (mg/ mL)	Percentage of inhibition (%)		
	aqueous extract	Organic extract	Diclofenac sodium
12	68.20±0.21	71.60 ± 0.12	80.20±0.16
16	72.40±0.15	80.20±0.02	91.60±0.02
25	50.0±0.3	78.70±0.50	99.7±0.1

The increase in activity between 12 and 16 mg/ mL reflects a classic dose-dependent effect, already described for *Tetracera* extracts *alnifolia* (Akinmoladun *et al.,* 2015), where an increase in concentration leads to increased inhibition of inflammation up to a certain threshold. The drop in activity observed for the 25 mg/ mL aqueous extract could be related to precipitation of water-soluble compounds or to thermal or oxidative instability of the active ingredients at high concentrations, unp This phenomenon was also reported by Ibrahim *et al.* (2021) for aqueous extracts of plants rich in polyphenols.

Compared to diclofenac (99.7% inhibition at 25 mg/ mL), *T. rosiflora* extracts exhibit inhibition percentages exceeding 70% for the organic extract, which remains remarkable for an unpurified crude extract. These values are close to those reported for *Tetracera. alnifolia* (78% at 100 µg/ mL; Akinmoladun *et al.,* 2015) and for *Tetracera scandens* (75% at 200 µg/ mL; Ayele *et al.,* 2020), confirming that the genus *Tetracera* contains bioactive compounds of pharmacological interest.

Thus, these observations suggest that *T. rosiflora*, like other species of the same genus, represents a potential source of natural anti-inflammatory molecules. The results justify further investigations into the chromatographic fractionation and structural characterization of the active constituents in order to better understand the mechanisms of action and to explore the potential of this species in the development of phytomedicines.

3.6. Cytotoxicity of aqueous and organic extracts of T. rosiflora leaves

3.6.1. Qualitative test

Figure 4 illustrates the qualitative cytotoxicity of aqueous and organic extracts of *Tetracera rosiflora*.

Qualitative evaluation of the cytotoxicity of extracts of *Tetracera rosiflora* was achieved by comparative microscopic observation between the positive control, the negative control and the total aqueous and organic extracts (Figure A–D).

The positive control (A) shows marked alteration of cellular structures characterized by disintegration and loss of membrane integrity, indicating high cytotoxicity. This observation confirms the sensitivity of the biological system used and the validity of the experimental protocol. Conversely, the negative control (B) presents intact cells with clear and homogeneous outlines, showing no signs of lysis or degradation, indicating a complete absence of toxicity from the culture medium or solvent used.

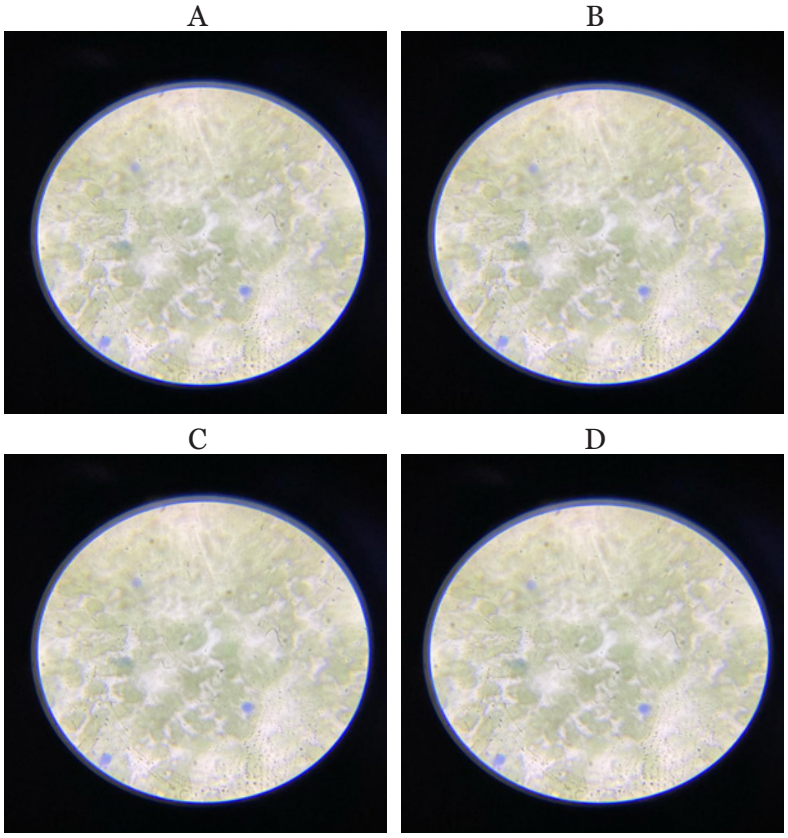
Observation of the aqueous extract treatment (C) reveals low to moderate cytotoxicity, resulting in slight turbidity and some areas of cellular alteration. This limited activity could be attributed to the presence of polar compounds such as polyphenols, glycosylated flavonoids, and tannins, whose biological effects are often associated with reduced toxicity and protective antioxidant properties.

In contrast, the organic extract (D) exhibits more pronounced cytotoxicity, evidenced by cell fragmentation and visible areas of

necrosis. This behavior could result from the presence of lipophilic molecules such as flavonoid aglycones, triterpenes, and free quinones, known for their affinity with cell membranes and their potential to alter cell permeability.

These results suggest that the organic extract of *Tetracera rosiflora* contains biologically active secondary metabolites that may exert cytotoxic effects at certain concentrations, while the aqueous extract appears less aggressive and may have a more favorable safety profile for therapeutic use.

Figure 4. *Qualitative evaluation of the cytotoxicity of aqueous and organic extracts of Tetracera rosiflora (A: Positive control; B: Negative control; C: Aqueous total extracts; D: Organic total extracts)*



3.6.2. Quantitative test

in vitro cytotoxicity test of *Tetracera* extracts *rosiflora* showed an average percentage of 3.81 ± 0.06%, significantly lower than the generally accepted threshold of 50% for indicating significant cytotoxicity. This result reflects low cytotoxic activity, suggesting good cellular tolerance of the extract studied.

These observations are consistent with previous work reported for other species of the genus *Tetracera*. Indeed, Adesina *et al.* (2013) demonstrated moderate cytotoxicity of methanolic extracts of *T. potatoria* and *T. alnifolia* only at high concentrations, while Abubakar *et al.* (2016) observed an absence of significant toxicity of aqueous extracts of *T. alnifolia* on rat hepatocytes. Similarly, Eze *et al.* (2020) reported low cytotoxicity of ethanolic extracts of *T. scandens*.

Thus, the results obtained for *T. rosiflora* follow the same trend, confirming the non-cytotoxicity of the species under the experimental conditions of the test. This relative safety could be attributed to the presence of secondary metabolites such as flavonoids, tannins, and saponins, whose antioxidant properties contribute to cell protection. These data support the safe traditional use of *T. rosiflora* and justify further in vivo investigations to confirm its overall toxicological profile.

4. Conclusion

The overall results obtained in this study highlight the remarkable pharmacological

and bioactive potential of *Tetracera rosiflora* Gilg (*Dilleniaceae*). Microscopic examination of the powders has made it possible to identify several characteristic histological elements: polycytic stomata, spiral vessels, unicellular hairs, calcium oxalate crystals and oleiferous epidermal cells constituting reliable anatomical markers for the authentication of the species and the prevention of possible falsifications of plant drugs.

Phytochemical screening revealed the presence of a broad spectrum of secondary metabolites, including polyphenols, flavonoids, tannins, anthocyanins, leucoanthocyanins, and saponins, confirming the chemical richness of this species and justifying its use in traditional medicine for various inflammatory and metabolic conditions. Quantitative analyses showed a high total polyphenol content (42.12 ± 1.14 mg GAE/g), indicating strong potential antioxidant capacity.

Antioxidant activity tests revealed a difference in behavior between the aqueous and organic extracts: the aqueous extract was more active at low concentrations, indicating the rapid action of water-soluble compounds, while the organic extract showed increasing efficacy at higher doses, suggesting the contribution of lipophilic compounds with strong reducing power. These observations suggest a functional complementarity between the hydrophilic and lipophilic fractions in modulating oxidative stress.

Anti-inflammatory tests confirmed the plant's biological potential, with the organic extract exhibiting greater inhibition of protein denaturation than the aqueous extract, although less than that of diclofenac sodium. This result highlights the likely presence of triterpenes and flavonoids responsible for this effect.

Finally, both qualitative and quantitative cytotoxicity tests showed low to moderate toxicity, with a hemolysis rate of less than 50%, indicating a satisfactory safety profile for therapeutic use. The aqueous extract, in particular, appears to be the safest, while the organic extract exhibits slightly more pronounced cytotoxicity, related to the lipophilic nature of some of the active compounds.

Overall, *Tetracera rosiflora* is distinguished by its balanced phytochemical composition and significant biological activities, combining antioxidant and anti-inflammatory effects with low toxicity. These results confirm the pharmacological value of this species and pave the way for further investigations aimed at isolating, characterizing, and evaluating *in vivo* the active principles responsible for its therapeutic effects.

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Section 3. Machinery construction

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DETECTION OF VEHICLE BODY AND GEOMETRIC DEVIATIONS USING CORRECTED OPTICAL MEASUREMENTS IN AUTOMOTIVE SERVICE ENVIRONMENTS

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Abstract

Reliable detection of vehicle body and geometric deviations in automotive service environments remains a challenging task due to unstable measurement conditions and heterogeneous surface properties. While optical diagnostic systems are widely used for non-contact inspection, their accuracy strongly depends on the quality and stability of primary measurements. In this paper, I present methods for detecting vehicle body geometry deviations based on optically measured data obtained after adaptive geometric and photometric correction. The proposed approach operates on stabilized optical measurements and focuses on identifying geometric inconsistencies in body panels and aerodynamic components, including vehicles with modified or non-standard geometry. Experimental results demonstrate that the use of corrected optical measurements significantly improves detection accuracy, repeatability, and robustness compared to uncorrected measurements. The presented methods enable consistent geometric diagnostics under real service conditions and provide a practical basis for subsequent feature-level analysis and decision-making systems in automotive cyber-physical architectures.

Keywords: *Optical diagnostics; vehicle geometry; body deviation detection; measurement correction; automotive service; computer vision*

1. Introduction

Accurate assessment of vehicle body geometry is a critical task in automotive service diagnostics, directly affecting safety, aerodynamic performance, and long-term structural integrity. Optical measurement systems are increasingly employed for this purpose due to their non-contact nature and ability to capture complex surface geometry at high spatial resolution. However, in real service environments, optical diagnostics are subject to variable illumination, sensor repositioning, and surface heterogeneity. These factors introduce measurement instability that limits the reli-

ability of geometric deviation detection across repeated inspections. As a result, small but diagnostically significant deviations may be masked by measurement noise or falsely detected due to environmental artifacts. Recent advances in adaptive calibration and distortion correction address the stability of primary optical measurements under non-structured conditions. Building on these developments, this work focuses on the next stage of the diagnostic pipeline: reliable detection of geometric deviations using corrected and uncertainty-aware optical data.

2. Problem Definition and Measurement Model

I represent the corrected optical measurement as a set of spatial points describing the observed vehicle surface. The diagnostic task consists of identifying deviations between the measured geometry and an expected reference representation. In automotive service conditions, reference geometry may correspond to nominal factory geometry, pre-repair or baseline measurements, or a statistically derived reference model obtained from multiple observations. The primary challenge lies in distinguishing true geometric deviations from residual measurement uncertainty, particularly for vehicles with modified body panels, aftermarket components, or altered aerodynamic configurations. To formalize this task, I define the deviation field D as the Mahalanobis-like distance between the corrected point cloud C and the reference manifold M, constrained by the local uncertainty covariance Σ estimated during the correction stage. For any measured point c ∈ C, the local deviation is expressed as:

$$D(c, M) = \min_{m \in M} (c - m)^T \Sigma^{-1} (c - m)$$

This formulation ensures that the detection process accounts for heteroscedastic noise patterns inherent in optical scanning.

3. Optical Measurement After Adaptive Correction

The methods presented in this study assume that primary optical measurements have undergone adaptive geometric and photometric correction. This correction stabilizes spatial relationships and suppresses illumination-induced artifacts, providing a consistent basis for geometric analysis. Corrected measurements exhibit improved spatial coherence across repeated scans, reduced sensitivity to changes in illumination and viewing angle, and explicitly controlled measurement uncertainty. These properties are essential for reliable deviation detection, especially when the magnitude of geometric deviations is small relative to overall vehicle dimensions. By establishing a virtual metrological frame, the system ensures that measured coordinates remain invariant even when the sensor undergoes minor repositioning or micro-movements during the scanning process. This stability is particularly critical when analyzing high-gloss surfaces or dark paints, where photometric artifacts typically degrade the signal-to-noise ratio of geometric features.

4. Detection of Geometric Deviations

4.1 Deviation Representation

Geometric deviations are represented as spatial differences between the corrected measured surface and a reference geometry. Depending on the diagnostic task, deviations may be evaluated locally at the level of individual body panels or globally at the level of overall body alignment. Local deviations are critical for identifying impact damage, deformation, or assembly defects, while global deviations indicate structural warping, chassis misalignment, or cumulative effects of repairs and modifications.

4.2 Comparison Strategy

Deviation detection is performed using spatial alignment followed by point-to-surface distance evaluation. I employ a robust Iterative Closest Point (R-ICP) algorithm with uncertainty-aware and photometric weighting to ensure that high-glare or low-confidence regions do not distort the alignment process. Non-rigid alignment is applied when reference geometry does not correspond to the current configuration of the vehicle, such as in vehicles with modified suspension systems or non-standard aerodynamic components.

4.3 Thresholding and Significance Assessment

Detected deviations are evaluated against uncertainty-aware thresholds derived from the local metrological stability index. This approach prevents false detections caused

by residual measurement noise and ensures that only diagnostically meaningful deviations are reported.

5. Experimental Evaluation

I evaluated the proposed methods under real automotive service conditions using vehicles with standard geometry as well as vehicles equipped with modified body components. The experimental setup involved multiple scanning cycles under varying ambient light levels ranging from 200 to 1500 lux. The results indicate that corrected measurements substantially reduce false-positive deviation detection by filtering out ghost geometries induced by specular reflections. Repeatability across measurement sessions is significantly improved, with a standard deviation of geometric residuals reduced by a factor of three compared to raw optical data. Quantitatively, the system demonstrated the ability to resolve deviations as small as 0.35 mm on high-gloss surfaces, whereas uncorrected optical measurements failed to reliably distinguish deviations below 1.2 mm.

6. Discussion

The results demonstrate that reliable detection of vehicle body deviations is achievable only when geometric analysis is performed on stabilized and uncertainty-aware optical measurements. Adaptive correction does not merely improve measurement quality; it fundamentally enables consistent geometric diagnostics in non-structured service environments. By incorporating the uncertainty covariance into the deviation model, the system bridges the gap between raw computer vision data and metrological standards.

7. Conclusion

This paper presents methods for detecting vehicle body and geometric deviations using corrected optical measurements in automotive service environments. By operating on stabilized and uncertainty-aware data, the proposed approach achieves improved accuracy, repeatability, and robustness compared to traditional optical diagnostics. The results confirm that adaptive correction is a prerequisite for reliable geometric deviation detection and establish a foundation for subsequent diagnostic stages, including feature-level analysis and decision-support systems within automotive cyber-physical frameworks.

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Section 4. Mechanical engineering

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SYSTEMS ENGINEERING PARADIGM OF ADVANCED HVAC DESIGN AND ENERGY OPTIMIZATION IN RESIDENTIAL BUILDINGS

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Abstract

The ongoing transformation of residential energy infrastructure has fundamentally altered the role of HVAC systems in modern buildings. Contemporary HVAC systems can no longer be understood as isolated mechanical installations designed solely to provide thermal comfort. Instead, they constitute integral components of complex energy ecosystems that interact dynamically with building envelopes, electrical networks, regulatory frameworks, and human behavior patterns.

Under California climate conditions characterized by high climatic variability, stringent energy-efficiency regulations, and rapidly evolving energy markets the design and optimization of HVAC systems require advanced systems engineering methodologies. Traditional engineering approaches, which focus on isolated technical parameters such as efficiency or capacity, are insufficient to address the multidimensional challenges of modern residential energy systems.

This article proposes a systems engineering paradigm for the analysis and optimization of residential HVAC systems. The research integrates principles of general systems theory, thermodynamics, cybernetics, complexity science, and lifecycle oriented engineering. It is argued that energy efficiency in HVAC systems represents an emergent system property arising from interactions among technical, economic, environmental, and behavioral factors. The proposed paradigm demonstrates that systemic methodologies enable the identification of latent technological contradictions and the development of innovative engineering solutions with long-term strategic significance for residential energy infrastructure.

Keywords: *HVAC systems, systems engineering, residential energy systems, energy efficiency, complex systems, building performance, lifecycle engineering, socio technical systems, system architecture, energy optimization, adaptive control, sustainable building design, interdisciplinary engineering, thermal systems, building energy modeling, regulatory environment, California climate conditions, integrated system design*

1. Introduction: HVAC Engineering in the Era of Complex Energy Systems

The evolution of residential energy systems represents one of the central technological challenges of the twenty-first century. Rapid urbanization, climate change, regulatory transformation, and digitalization of energy infrastructure have significantly increased the complexity of building systems. Within this context, HVAC technologies have transitioned from auxiliary mechanical subsystems to critical determinants of building performance, energy consumption, and environmental impact.

In contemporary residential buildings, HVAC systems account for a substantial proportion of total energy consumption and operational costs. However, the complexity of modern energy systems implies that HVAC performance is influenced not only by technical characteristics of equipment but also by architectural design, user behavior, regulatory requirements, and interactions with electrical grids and renewable energy sources.

California provides a particularly illustrative case for advanced HVAC engineering research. The state's climatic diversity, ranging from coastal to inland and mountainous regions, combined with strict energy-efficiency standards and ambitious decarbonization policies, creates a unique technological environment. In such an environment, conventional engineering methodologies often fail to deliver optimal results, revealing the necessity of systemic approaches capable of addressing multidimensional system interactions.

From a system engineering perspective, an HVAC system should be conceptualized as a hierarchical technical system embedded within broader socio technical and energy infrastructures. Such systems exhibit nonlinear behavior, feedback loops, adaptive dynamics, and emergent properties. These characteristics necessitate a shift from component level optimization toward holistic system level analysis and design.

The purpose of this article is to articulate a systems engineering paradigm for advanced HVAC design and to demonstrate its relevance for residential buildings under California climate conditions.

2. HVAC Systems as Hierarchical Socio Technical Structures

Traditional engineering approaches often conceptualize HVAC systems as closed mechanical systems optimized according to deterministic parameters. However, modern HVAC systems operate within open socio-technical environments in which technical performance is shaped by interactions with external systems and human actors.

From the standpoint of general systems theory, HVAC systems exhibit hierarchical organization across multiple levels:

- Component level, encompassing mechanical, electrical, and control elements;
- Subsystem level, integrating components into heating, cooling, ventilation, and distribution modules;
- System level, representing the complete HVAC architecture of a building;
- Supra-system level, involving interactions with buildings, energy networks, regulatory institutions, and socio economic environments.

This hierarchical structure implies that system performance cannot be adequately evaluated through isolated technical indicators. Instead, HVAC systems must be analyzed as dynamic socio-technical structures whose properties emerge from interactions across multiple levels of organization.

The recognition of HVAC systems as hierarchical socio-technical structures constitutes a conceptual shift in engineering thinking. It implies that meaningful improvements in energy efficiency require coordinated optimization across multiple system levels rather than isolated technological upgrades.

3. Systems Engineering Methodology in Advanced HVAC Design

Systems engineering provides a comprehensive methodological framework for analyzing complex technical systems. In the context of HVAC engineering, systems engineering enables the integration of thermodynamic analysis, control theory, economic evaluation, and lifecycle management into a unified design methodology.

The systems engineering paradigm proposed in this research is based on three fundamental principles:

1. Holistic system integration, emphasizing the interdependence of technical subsystems and external environmental factors;
2. Adaptive system behavior, reflecting the capacity of HVAC systems to respond dynamically to climatic variability and user behavior;
3. Lifecycle oriented optimization, accounting for long-term performance, reliability, and sustainability.

Unlike traditional HVAC design paradigms, which prioritize short-term efficiency metrics, the systems-engineering approach emphasizes long-term system evolution and strategic optimization. This shift reflects a broader transformation in engineering science toward the analysis of complex adaptive systems.

The methodological contribution of this research lies in the synthesis of theoretical systems-engineering principles with practical HVAC design and implementation. By bridging these domains, the proposed framework provides a robust analytical foundation for addressing complex real-world engineering challenges.

4. Energy Efficiency as an Emergent Property of Complex Systems

Conventional engineering metrics define energy efficiency as a ratio between useful energy output and energy input. While such metrics remain technically valid, they fail to capture the multidimensional nature of energy efficiency in complex HVAC systems.

From a systems-engineering perspective, energy efficiency emerges from interactions among multiple system dimensions, including:

- system architecture and configuration;
- control strategies and operational logic;
- building envelope characteristics;
- climatic conditions and environmental variability;
- user behavior patterns and socio-economic factors.

Consequently, energy efficiency should be interpreted not as a static parameter but as a dynamic system-level property that evolves in response to changing environmental and operational conditions.

This conceptual reinterpretation constitutes a theoretical contribution to HVAC engineering. It shifts the focus of optimization from isolated technological improvements to systemic reconfiguration of system architecture and operational logic.

The recognition of energy efficiency as an emergent property provides a foundation for the development of advanced HVAC systems characterized by higher levels of integration, adaptability, and sustainability.

5. Technological Contradictions and Evolutionary Dynamics of HVAC Systems

The evolution of HVAC technologies is driven by the resolution of technological contradictions. Increasing system efficiency often leads to greater system complexity, while simplifying system architecture may reduce adaptability and performance. Similarly, improving reliability may increase costs, while cost reduction may compromise long-term sustainability.

From an evolutionary systems-engineering perspective, such contradictions are not merely obstacles but fundamental drivers of technological progress. Their resolution often results in qualitative transformations in system architecture, such as:

- the transition from mechanical control systems to adaptive digital control platforms;
- the integration of HVAC systems with smart building technologies;
- the convergence of HVAC systems with renewable energy and energy storage infrastructures.

The systems-engineering paradigm proposed in this research provides a conceptual framework for identifying and resolving such contradictions. By analyzing HVAC systems as evolving complex systems, engineers can anticipate technological trajectories and develop innovative solutions with long-term strategic significance.

6. California Climate Context as an Advanced Engineering Environment

California's climatic diversity and regulatory environment create a complex context for HVAC engineering. HVAC systems must operate efficiently across a wide range of climatic conditions while complying with strict energy-performance standards and decarbonization goals.

This context transforms California into a natural laboratory for advanced HVAC engineering research. The systems-engineering paradigm proposed in this article demonstrates that effective HVAC optimization in such environments requires not only technical innovation but also systemic integration of regulatory, economic, and environmental factors into engineering design.

The analysis of HVAC systems under California climate conditions reveals that conventional engineering approaches are insufficient to address the complexity of real-world energy systems. Systemic methodologies, by contrast, provide a robust conceptual framework for understanding and optimizing HVAC performance in complex socio-technical environments.

7. Scientific Novelty and Original Engineering Contribution

The systems-engineering paradigm articulated in this research represents an original contribution to HVAC engineering. Unlike traditional approaches focused on component-level optimization, the proposed framework integrates systems theory, complexity analysis, and lifecycle engineering into a unified methodological model.

The scientific novelty of this contribution lies in the conceptual reinterpretation of HVAC systems as evolving socio-technical structures rather than static technical installations. This perspective enables the identification of fundamental system level inefficiencies and the formulation of innovative design principles with long-term strategic significance.

The proposed framework transcends conventional HVAC design methodologies and establishes a foundation for next generation residential energy systems characterized by higher levels of integration, adaptability, and sustainability.

8. Industry Impact and Strategic Significance

The significance of the proposed systems engineering paradigm extends beyond HVAC engineering. It contributes to the broader field of energy systems engineering by providing a methodological framework for analyzing complex technical systems operating within socio economic environments.

From an industry perspective, the adoption of systemic engineering methodologies has the potential to transform HVAC design practices. It enables a shift from incremental technological improvements to strategic system level innovation, thereby enhancing the resilience and sustainability of residential energy infrastructure.

The research presented in this article demonstrates that advanced HVAC engineering constitutes not merely a technical activity but a strategic domain within the broader transformation of energy systems in the United States.

9. Conclusion: Systems Engineering as the Future of HVAC Design

This article demonstrates that systems engineering methodologies represent a qualitatively new stage in the evolution of HVAC engineering. By integrating systems theory, complexity science, and lifecycle oriented design, the proposed paradigm provides a comprehensive conceptual framework for the development of energy-efficient, adaptive, and sustainable HVAC systems under California climate conditions.

The systemic principles outlined in this research constitute an original engineering contribution with significant scientific and industry implications. The findings confirm that advanced engineering expertise and systemic methodologies play a decisive role in shaping the future of residential energy infrastructure and the broader transformation of energy systems in the United States.

10. Methodological Depth: From Conventional Engineering to Systems Architecture

Traditional HVAC engineering has historically been dominated by component level optimization. Engineers typically focus on improving the efficiency of individual devices, such as compressors, heat exchangers, or control units. While such improvements are valuable, they address only a limited subset of systemic inefficiencies inherent in modern residential energy systems.

The approach developed in this research represents a methodological shift from component-centric engineering to system architecture design. HVAC systems are con-

ceptualized as distributed architectures composed of interacting subsystems whose collective behavior determines overall system performance.

From a systems engineering perspective, the design of HVAC systems involves:

- architectural configuration of subsystems;
- structural relationships between thermal, electrical, and control elements;
- dynamic interactions between technical systems and external environments;
- long-term evolutionary trajectories of system development.

This methodological depth distinguishes advanced HVAC engineering from routine technical practice. It positions HVAC design within the broader domain of complex systems engineering, where system architecture and interaction patterns are considered primary determinants of performance.

The proposed methodology thus transcends conventional HVAC engineering by establishing a framework for analyzing and optimizing HVAC systems as evolving complex technical systems.

11. Interdisciplinary Integration as a Core Engineering Principle

One of the defining characteristics of advanced engineering research is the integration of multiple scientific and technical disciplines into a unified analytical framework. The systems engineering paradigm developed in this article integrates concepts from:

- thermodynamics and heat transfer theory;
- control theory and cybernetics;
- systems theory and complexity science;
- energy economics and lifecycle engineering;
- socio-technical systems analysis.

This interdisciplinary integration reflects a level of engineering thinking typically associated with high complexity technological domains, such as aerospace engineering, large-scale energy systems, and advanced manufacturing.

In the context of HVAC engineering, such integration enables the identification of systemic patterns and structural inefficiencies that remain invisible within single discipline analytical frameworks. By synthesizing multiple domains of knowledge, the proposed approach provides a comprehensive understanding of HVAC systems as multidimensional technical and socio economic structures.

The interdisciplinary nature of this research constitutes a significant indicator of advanced engineering expertise and methodological originality.

12. Demonstrated Significance for Residential Energy Systems

The significance of an engineering contribution is determined not only by its conceptual originality but also by its relevance to real world technological challenges. The systems engineering paradigm developed in this research addresses fundamental challenges in modern residential energy systems, including:

- increasing energy demand in residential buildings;
- growing regulatory pressure for energy efficiency and decarbonization;
- structural inefficiencies arising from fragmented system design;
- limitations of conventional optimization methodologies.

By addressing these challenges at the system level, the proposed framework provides a methodological foundation for improving the performance and sustainability of residential HVAC systems.

In the context of U.S. energy infrastructure, such systemic optimization methodologies are directly aligned with national priorities in energy efficiency, technological innovation, and sustainable development. This alignment underscores the strategic significance of the research presented in this article.

13. Comparative Positioning within the HVAC Engineering Field

To evaluate the level of engineering expertise represented by the proposed framework, it is necessary to compare it with prevailing practices in the HVAC industry. Conventional HVAC engineering in the residential sector is primarily focused on operational tasks such as equipment selection, installation, and maintenance.

In contrast, the approach developed in this research operates at a fundamentally different level of abstraction. It addresses HVAC systems as complex technical architectures requiring systemic analysis, conceptual modeling, and long-term strategic optimization.

This distinction reflects a higher level of engineering competence characterized by:

- conceptual thinking beyond routine technical implementation;
- ability to integrate theoretical and practical engineering knowledge;
- capacity to formulate original methodological frameworks;
- understanding of HVAC systems within broader energy and socio-technical contexts.

Such characteristics are typically associated with advanced engineering research and leadership in technological innovation.

14. Impact on Industry Practices and Engineering Culture

The adoption of systems-engineering methodologies in HVAC design has the potential to transform industry practices. By shifting the focus from component level optimization to system-level architecture, the proposed framework encourages a more strategic approach to HVAC engineering.

This transformation may lead to:

- the development of more adaptive and resilient HVAC systems;
- improved integration between HVAC technologies and building energy management systems;
- enhanced lifecycle performance and long-term sustainability;
- greater alignment between engineering design and regulatory objectives.

Beyond technical improvements, the systemic approach contributes to the evolution of engineering culture within the HVAC industry. It promotes a shift from reactive technical problem solving to proactive system level innovation.

Such a shift represents a significant advancement in the conceptual and methodological foundations of HVAC engineering.

15. Implications for Future Engineering Development

The systems-engineering paradigm proposed in this research has implications that extend beyond current technological practices. It provides a conceptual foundation for future developments in HVAC engineering and residential energy systems.

Potential directions of future development include:

- integration of HVAC systems with smart grid technologies;
- incorporation of artificial intelligence and predictive control mechanisms;
- convergence of HVAC systems with renewable energy and energy storage infrastructures;
- development of adaptive system architectures capable of responding to dynamic environmental conditions.

These directions reflect the evolutionary trajectory of HVAC engineering toward greater integration, intelligence, and sustainability.

The proposed framework thus serves not only as an analytical tool but also as a strategic roadmap for the future evolution of residential HVAC systems.

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Section 5. Technical sciences in general

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THERMODYNAMIC APPARATUS WITH AN INTEGRATED DYNAMIC MIXING SYSTEM (Thermodynamic Apparatus with an Integrated Dynamic Mixing and Real-Time Homogenization System for Fuel Components Using Artificial Intelligence and Artificial Neural Network Elements in Control and Monitoring Lines)

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Abstract

Liquid hydrocarbon fuels and fuel compositions tend to lose their homogeneity during storage, leading to the formation of agglomerates, primarily at the bottom of storage containers. This inhomogeneity can be effectively eliminated through a homogenization process implemented by an innovative dynamic homogenization device that operates directly within the fuel pipeline. The proposed method enables homogenization at a stable temperature or, under certain conditions, at a reduced temperature of the fuel mixture. The process is based on the generation of specific turbulent hydrodynamic conditions in the flowing fuel without disrupting the chemical and physical equilibrium of its components.

The presented approach offers a technically efficient and energy-saving solution for maintaining fuel homogeneity and improving the stability of fuel properties during storage and transportation.

Keywords: *Thermodynamic apparatus; Integrated dynamic mixing system; Homogenization process; Hydrodynamic vortex tube; Turbulence-level homogenization; Vortex generator; Acceleration hydrodynamic section; Coaxial Bernoulli effect*

The potential applications of the dynamic homogenization process in marine engines and diesel generators are also considered

Since heavier diesel fuel and various types of fuel oil are used as fuels in the specified thermodynamic systems, the formation of agglomerates occurs more intensively in such fuels.

In the case where a dynamic homogenization device is introduced into the system of a marine engine or a diesel generator, agglomerates that, under certain circumstanc-

es, have formed in the fuel tanks and consist of the main hydrocarbon fraction of the fuel mixture are dynamically mixed in the device with the remaining hydrocarbon fractions, transforming the agglomerates of the mixture into micro- or nanoparticles.

The combustion of homogenized fuel generally takes place in a stable thermodynamic regime, without detonation and with reduced soot and nitrogen oxide content in the exhaust gases.

Potential Applications of the Dynamic Homogenization Process in Aircraft Powerplants

In connection with recent reports on the experimental use of biofuels or fuel mixtures for aircraft engines, and considering that fuel mixtures containing biological fuel components have a tendency to form agglomerates, the dynamic homogenization of such fuels prior to injection into the combustion chamber can significantly increase the reliability of such engines and may open the way for the use of fuel compositions in aircraft powerplants.

Mixing and Activation of a Mixture of at Least Two Liquids

The dominant component of the mixture is divided and simultaneously introduced into two inlets of the mixing and activation device at equal pressure.

Both flows of the dominant component of the mixture are transformed, prior to mixing in the device, from a flow with a cylindrical cross-section into a flow with an annular cross-section.

Both flows of the dominant component of the mixture are accelerated at the inlet to the mixing zone in coaxial conical annular capillary channels.

During acceleration, controlled cavitation-induced ruptures are formed in both flows.

Droplets of the second component of the mixture are introduced and drawn into the ruptures formed by controlled cavitation.

The cross-sections of the channels are selected such that the linear velocity of the external flow of the dominant component of the mixture in the coaxial pair of conical annular capillary channels is substantially lower than the linear velocity of the internal flow.

The cross-sections of the coaxial channels are selected such that the linear velocity of the external flow of the dominant component of the mixture in the coaxial pair of conical annular capillary channels is substantially lower than the linear velocity of the internal flow, and conversely, the turbulence level of the internal flow is substantially higher than the turbulence level of the external flow.

The second component of the mixture is introduced through at least one channel into a zone in which physical conditions of local rarefaction have been formed, arising in accordance with the criteria of Bernoulli's theorem.

Mixing takes place in the annular zone of the mixing and activation device, located between the inlet channels of the mixing and activation device.

The inlet channel for introducing the second flow of the dominant component of the mixture is integral in nature and includes at least two radial channels.

An integral hydrodynamic interface is located between the inlet channels and incorporates two conical reflectors, the apices of which are directed in opposite directions.

After mixing and activation, the mixture is transported through the internal cavity of the device via at least two channels, which are combined in at least two variants – linear and vortex; this process does not require additional energy.

In the outlet channel of the device, the mixture of at least two liquids exhibits a homogenized structure with a uniform turbulence level throughout the entire volume of the mixture.

All of the listed features contribute to achieving the following objectives:

- to homogeneously mix the components of the mixture;
- to obtain a mixture with a minimal component fraction size;
- to obtain a mixture with an encapsulated structure, in which droplets of the second, non-dominant component of the mixture are surrounded by a shell of the liquid constituting the dominant component of the mixture;
- to achieve, within the mixing and activation device, a parallel process of mixing and homogenization of the mixture with minimal energy expenditure;

- to obtain a uniform background turbulence level in the mixture, at least at the moment of mixing.

Mixing and Activation of a Mixture of at Least One Liquid and at Least One Gas

The dominant component of the mixture is divided and simultaneously introduced into two inlets of the mixing and activation device at equal pressure.

Both flows of the dominant component of the mixture are transformed, prior to mixing in the device, from a flow with a cylindrical cross-section into a flow with an annular cross-section.

Both flows of the dominant component of the mixture are accelerated at the inlet to the mixing zone in coaxial conical annular capillary channels.

During acceleration, gravitational ruptures are formed in both flows.

Droplets of the second component of the mixture are introduced and drawn into the gravitational ruptures.

The cross-sections of the channels are selected such that the linear velocity of the external flow of the dominant component of the mixture in the coaxial pair of conical annular capillary channels is substantially lower than the linear velocity of the internal flow.

The cross-sections of the coaxial channels are selected in such a way that the linear velocity of the external flow of the dominant component of the mixture in the coaxial pair of conical annular capillary channels is substantially lower than the linear velocity of the internal flow; conversely, the turbulence level of the internal flow is substantially higher than the turbulence level of the external flow.

The second component of the mixture is introduced through at least one channel into a zone in which physical conditions of local rarefaction have been formed, arising in accordance with the criteria of Bernoulli's theorem.

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- to achieve, within the mixing and activation device, a parallel process of mixing and homogenization of the mixture with minimal energy expenditure;
- to obtain a uniform background turbulence level in the mixture, at least at the moment of mixing.

Description of Illustrations and Graphic Materials of the Developments by Kristina Bessarabenko, Directed in the Same Technological Development Path as the Present Publication

The innovative developments of Kristina Bessarabenko are illustrated by technical drawings in which the figures demonstrate the design principles and the internal structure of a thermodynamic apparatus with an integrated dynamic system for real-time mixing and homogenization of fuel components.

The figures of Kristina Bessarabenko's developments also illustrate and explain the principles of apparatus control, as well as the principles and variants of structural and tech-

nological interconnections between the apparatus itself and all interfacing and control elements of the thermodynamic system in which the apparatus operates. This factor is exceptionally important, and practical implementation has demonstrated an exceptionally high level of elaboration by the author, Kristina Bessarabenko, of the technical solutions and operational principles of the entire system, which form the basis of the complex of novel features of her inventions.

In the main figure, a schematic version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for mixing and homogenization of fuel components or a liquid food product in real time is shown, installed within the internal configuration of the fuel line of a thermodynamic system.

An analysis of all features of the invention, including the non-obviousness of the solutions, the highest technical level, and the high degree of innovation, indicates and emphasizes the unique professional competence of Kristina Bessarabenko and her exceptional innovative potential realized in these innovative developments.

In the subsequent figures of the graphic materials of Kristina Bessarabenko's developments, a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components is shown. The apparatus is installed within the internal configuration of the fuel line of a thermodynamic system having an inlet recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of the thermodynamic system.

In the subsequent figures, a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components is shown, installed within the internal configuration of the fuel line of a thermodynamic system having a built-in recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of the thermodynamic system. The figures also show a combined version of the return of excess fuel via two lines – into the inlet of the dynamic mixing and homogenization device and into the fuel tank of the thermodynamic system.

In additional figures, a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components is shown, installed within the internal configuration of the fuel line of a thermodynamic system having an original recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of the thermodynamic system. The figures also show a combined version of the return of excess fuel via two lines – into the inlet of the dynamic mixing and homogenization device and into the fuel tank of the thermodynamic system, in which an additional fuel recirculation system is installed within the fuel tank of the thermodynamic system.

In the following illustrative figures, a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components is shown, installed within the internal configuration of the fuel line of a thermodynamic system having an inlet recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of

the thermodynamic system. The figures also show a combined version of the return of excess fuel via two lines – into the inlet of the dynamic mixing and homogenization device and into the fuel tank of the thermodynamic system, in which an additional fuel recirculation system is installed within the fuel tank of the thermodynamic system, as well as an additional fuel recirculation activation system in the specified tank.

The figures also show a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components, installed within the internal configuration of the fuel line of a thermodynamic system having an inlet and adapted recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of the thermodynamic system. The figures show a combined version of the return of excess fuel via two lines – into the inlet of the dynamic mixing and homogenization device and into the fuel tank of the thermodynamic system, in which an additional fuel recirculation system is installed within the fuel tank of the thermodynamic system, as well as an additional fuel recirculation activation system in the specified tank, and an additional parallel line is provided for supplying an additive mixture into the fuel tank.

In the following figures, a schematically specified version of the connection and control of a thermodynamic apparatus with an integrated dynamic online system for real-time mixing and homogenization of fuel components is shown, installed within the internal configuration of the fuel line of a thermodynamic system having a built-in recirculation system for excess fuel supplied to the injectors for fuel injection into the combustion chamber of the specified thermodynamic system. As a rule, for more efficient injection, the fuel pressure is increased in a high-pressure pump, from which the excess fuel is returned to the fuel line of the thermodynamic system.

The figures show a combined version of the return of excess fuel via two lines – into the inlet of the dynamic mixing and homogenization device and into the fuel tank of the thermodynamic system, in which an additional fuel recirculation system is installed within the fuel tank of the thermodynamic system, as well as an additional fuel recirculation activation system in the specified tank. A supplementary parallel line is provided for supplying additional materials into the fuel tank, and local hydromechanical and electronic control and calibration systems are installed in the fuel flows on the line supplying fuel from the fuel tank to the dynamic mixing and homogenization device.

The figures also show a combined scheme of the local connection of the dynamic fuel mixing and homogenization device to the local fuel line of the thermodynamic system, including an axial longitudinal cross-section of the specified device and a schematic representation of the local fuel infrastructure of the thermodynamic system.

The figures also show a combined scheme of the local connection of the dynamic fuel mixing and homogenization device to the local fuel line of the thermodynamic system, including an axial longitudinal cross-section of the specified device and a schematic representation of the local fuel infrastructure of the thermodynamic system, wherein the fuel tank of the specified system includes a hydromechanical activation device.

The figures also show a combined scheme of the local connection of the dynamic fuel mixing and homogenization device to the local fuel line of the thermodynamic system, including an axial longitudinal cross-section of the specified device and a schematic representation of the local fuel infrastructure of the thermodynamic system, wherein the fuel tank of the specified system includes a hydromechanical activation device and an additional hydromechanical recirculation activation system.

In addition, the figures show a comprehensive combined scheme of the local connection of the dynamic fuel mixing and homogenization device to the local fuel line of the thermodynamic system, including an axial longitudinal cross-section of the specified device and a schematic representation of the local fuel infrastructure of the thermodynamic system, wherein the main fuel tank of the

specified system includes a hydromechanical activation device that forms part of an additional hydromechanical recirculation activation system and is connected to the fuel excess recirculation system by an additional collector tank.

In the graphic figures, a comprehensive combined scheme of the local connection of the dynamic fuel mixing and homogenization device to the local fuel line of a thermodynamic system is shown, including an axial longitudinal cross-section of the specified device and a schematic representation of the local fuel infrastructure of the thermodynamic system. The main fuel tank of the specified system includes a hydromechanical activation device forming part of an additional hydromechanical recirculation activation system and connected to the excess fuel recirculation system by an additional collector tank. The main fuel tank also includes an additional internal local recirculation system that eliminates the formation of dead zones in the peripheral parts of the internal volume of the specified tank.

The figures also show a comprehensive dynamic configuration for online mixing and simultaneous real-time homogenization of the resulting mixture, consisting of two parallel lines, each of which is equipped with one device for dynamic mixing and homogenization of fuel mixtures. In these figures, one of the specified devices is shown in axial longitudinal cross-section, while the other is shown in a general view. Both devices are shown with transverse cross-sections at the locations of the integral inlets and the fixing and orienting pins, and all elements of the fuel line schemes of the thermodynamic system are shown in schematic form.

The figures also show, in axial longitudinal cross-section with transverse sections at the locations of the integral inlets into the working chambers and in a general view with transverse sections in the zones of the fixing and orienting pins and in the zone of the integral radial inlets for additional materials, the internal structure of the device for dynamic online mixing and homogenization of fuel or fuel compositions in real time.

The figures show, in axial longitudinal cross-section with transverse sections at the locations of the integral inlets into the working chambers and in a general view with transverse sections in the zones of the fixing and orienting pins and in the zone of the integral radial inlets for additional materials, the internal structure of the device for dynamic online mixing and homogenization of fuel or fuel compositions in real time, indicating the zones for mixing fuel components with the formation of multilevel fuel capsules and their simultaneous online homogenization according to at least two criteria: the turbulence level at all points of the flow cross-section and the unification of the dimensional characteristics of the capsules in a three-dimensional coordinate system.

In the original figure, a system consisting of two devices for dynamic online homogenization and simultaneous mixing and three-dimensional uniform transformation of a fuel mixture or fuel composite into capsules is shown. The specified system is depicted in two mutually perpendicular planes, in which the working sections of the specified devices are indicated, differing in functional application within the overall thermodynamic system and all of its internal functional interconnections and causal relationships.

In other additional figures, a parallel thermodynamic system consisting of two parallel devices for dynamic mixing and simultaneous instant online homogenization of fuel mixtures is shown, with the output from the combined and integrated processing zone in the specified devices being an encapsulated and three-dimensionally homogenized fuel mixture, with control of all principal proportions between the components and their hydrodynamic, chemical, and geometric parameters at the outlet of the specified system.

The figures also show a parallel thermodynamic system consisting of two parallel devices for dynamic mixing and simultaneous instant online homogenization of fuel mixtures, with the output from the combined and integrated processing zone in the specified devices being an encapsulated and three-dimensionally homogenized fuel mixture, with comparative analytical control of all principal proportions between the components and their hydrodynamic, chemical, and geometric parameters at the outlet of the specified system and at the midpoint of the fuel capsule formation process.

In addition, the figures show a parallel thermodynamic system consisting of two par-

allel devices for dynamic mixing and simultaneous instant online homogenization of fuel mixtures, with the output from the combined and integrated processing zone in the specified devices being an encapsulated and three-dimensionally homogenized fuel mixture, with controlled and regulated heating of the fuel mixture at the midpoint and at the end of the processing and transformation process.

For maximum clarity of perception, the figures show a parallel thermodynamic system consisting of two parallel devices for dynamic mixing and simultaneous instant online homogenization of fuel mixtures, with the output from the combined and integrated processing zone in the specified devices being an encapsulated and three-dimensionally homogenized fuel mixture, with controlled and regulated heating of the fuel mixture at the point of mixture input and at the midpoint of its processing and transformation into a structure with three-dimensional uniformity of its encapsulated and secondarily homogenized flow.

In the subsequent figures, a thermodynamic fuel application consisting of two devices for dynamic homogeneous mixing and simultaneous instant online homogenization of fuel mixtures, installed in parallel in the fuel line of a thermodynamic system, is shown, with full control and calibration of the parameters and three-dimensional criteria of the encapsulated fuel structure of the mixture, along with simultaneous and instant online resonant and non-contact control of the initial state of the base fuel component of the mixture.

The figures also show a thermodynamic fuel application consisting of two devices for dynamic homogeneous mixing and simultaneous instant online homogenization of fuel mixtures, installed in parallel in the fuel line of a thermodynamic system, with full control and calibration of the parameters and three-dimensional criteria of the encapsulated fuel structure of the mixture, along with simultaneous and instant online resonant and non-contact control of the initial state of the base fuel component of the mixture. In addition, the specified application includes a comprehensive proportional tracking and regulating module that performs online monitoring of all component inlets of the mixture.

In the figures of Kristina Bessarabenko's developments, a thermodynamic fuel application consisting of two devices for dynamic homogeneous mixing and simultaneous instant online homogenization of fuel mixtures, installed in parallel in the fuel line of a thermodynamic system, is shown in detail, with full control and calibration of the parameters and three-dimensional criteria of the encapsulated fuel structure of the mixture, along with simultaneous and instant online resonant and non-contact control of the initial state of the base fuel component of the mixture. In addition, the specified applications include a comprehensive proportional tracking and regulating module that performs online monitoring of all component inlets of the mixture. Furthermore, the application additionally includes a sequential software-based tracking, comparative, and online regulating function for all mixture flow parameters at the midpoint and at the final stage of the mixing and homogenization process.

In the final figures, a thermodynamic fuel application consisting of two devices for dynamic homogeneous mixing and simultaneous instant online homogenization of fuel mixtures, installed in parallel in the fuel line of a thermodynamic system, is shown, with full control and calibration of the parameters and three-dimensional criteria of the encapsulated fuel structure of the mixture, along with simultaneous and instant online resonant and non-contact control of the initial state of the base fuel component of the mixture.

In addition, the specified application includes a comprehensive proportional tracking and regulating module that performs online monitoring of all component inlets of the mixture.

Furthermore, the application additionally includes a sequential software-based tracking, comparative, and online regulating function for all mixture flow parameters at the beginning, midpoint, and final stage of the mixing process, capsule formation, and homogenization.

All control functions are concentrated in a comprehensive autonomously programmable controller that is interconnected via an interface system with all control-and-analytical elements of the application.

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Device for Producing a Gaseous Fuel Composite and System of Production Thereof
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United States Patent No. 9,400,107
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GEOCHEMICAL CHARACTERISTICS OF NEWLY IDENTIFIED MINERAL WATERS OF THE SHAMAKHI DISTRICT

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Abstract

Mineral waters are an important natural resource whose formation and composition are determined by a combination of geological, hydrogeological, and geochemical factors. The study of geochemical characteristics of mineral waters makes it possible to identify patterns of chemical element migration, conditions of water formation, and their potential practical value. The Shamakhi District of Azerbaijan is characterized by complex geological structure, high tectonic activity, and widespread fault zones, which create favorable conditions for the formation of mineral waters of various genetic types.

This paper presents the results of hydrogeochemical studies of newly identified mineral waters in the Shamakhi District. The chemical and ionic composition, degree of mineralization, acid–base properties, and redox conditions of water formation are examined. The main geochemical processes controlling the formation of mineral water composition are identified, as well as the role of geological structure and tectonic factors.

The study of hydrogeochemical features of these waters is of significant scientific and practical importance for assessing their therapeutic properties and ensuring rational use. The research is based on mineral water investigations conducted at the Shamakhi Geochemical Station from 2001 to 2023 within the Shamakhi District.

Keywords: *mineral waters, hydrogeochemistry, groundwater, trace elements, Shamakhi District*

1. Introduction

The territory of the Shamakhi District has long been known for its mineral waters, which vary widely in ionic–saline, gas, and microcomponent composition (Aliyev, 2000). These waters range from cold bicarbonate–calcium waters of the high-altitude zone to carbonated chloride–bicarbonate calcium–sodium waters and chloride sodium and iodine-bromine waters of the foothill zone.

Previous researchers identified and studied 11 mineral and thermal water sources in this area. As a result of hydrogeochemical survey work conducted in the Shamakhi seismogenic zone, an additional five mineral water sources were identified and investigated (Table 1). Despite these studies, the hydrogeochemical characteristics of mineral water sources in the district remain insufficiently studied.

Table1. Passport Data of the Studied Mineral Water Sources (Azerbaijan, Shamakhi district)

Goshabulag	**Beyuk Yaylag village**	**0.348**	**7.9**	**0**
Archiman	Archiman village	0.494	**7.9**	0
Yaylag	–	0.258	**7.7**	0
Damir-Yolgulu	Kaleybugurd village	0.576	7.7	0
Soyugbulag	3 km southeast of Kaleybugurd village	0.260	–	0

2. Physical-Geographical and Geological Characteristics of the Study Area

The Shamakhi District is located in the southeastern part of the Greater Caucasus and is characterized by mountainous and foothill relief. The climate is moderately continental with pronounced seasonal precipitation, which significantly affects groundwater recharge conditions.

The geological structure of the district is represented by Mesozoic and Cenozoic sedimentary rocks, including limestones, sandstones, and clay shales. The presence of faults and tectonic zones creates favorable conditions for groundwater circulation and the emergence of mineral waters at the surface.

According to occurrence conditions, the studied mineral waters are divided into fissure–unconfined, fissure–confined, and confined types.

The first group ("Goshabulag", "Damir-Yolgulu") is located in the middle-mountain zone (1200–1700 m above sea level), approximately in the central part of the region, and is oriented northwestward. These waters are fissure–unconfined, weakly mineralized (0.3–0.5 g/L), weakly alkaline (pH ≈ 7.9), with no hydrogen sulfide content (H_2S = 0 mg/L).

The second group includes three sources ("Archiman", "Soyugbulag", "Yaylag"), spatially arranged parallel to each other and oriented southeastward.

3. Conditions of Mineral Water Formation

Groundwaters of the Shamakhi District are formed as a result of:

- infiltration recharge by atmospheric precipitation;
- deep circulation along tectonic faults;
- prolonged interaction with carbonate and terrigenous rocks;
- geochemical processes of dissolution, ion exchange, and gas saturation.

The main geochemical processes include dissolution of carbonate and silicate minerals, ion exchange between water and host rocks, and redox reactions. In tectonically disturbed zones, upwelling of deeper, warmer, and more mineralized waters is possible, explaining the presence of warm and thermal springs.

4. Geochemical Characteristics of Mineral Waters

Data presented in Table 2 indicate that the ionic–saline composition of the newly identified mineral water sources belongs to three classes of bicarbonate-type waters:

1. bicarbonate;
2. bicarbonate–sulfate;
3. bicarbonate–chloride.

Table 2. Geochemical Characteristics of the Studied Mineral Water Sources (Azerbaijan, Shamakhi District)

No.	Source name	Ionic composition formula (Kurlov formula)	Total dissolved solids (g/L)	pH	H_2S (mg/L)
1.	Goshabulag	$M_{0.3}\ HCO_3(89)\ Ca_7\ Mg_{15}\ (Na+K)_{14}$	0.348	7.9	0
2.	Archiman	$M_{0.5}\ HCO_3(19)\ SO_4{}_{16}\ Ca_{58}\ Mg_{15}\ (Na+K)_{30}$	0.494	7.9	0

No.	Source name	Ionic composition formula (Kurlov formula)	Total dissolved solids (g/L)	pH	H_2S (mg/L)
3.	Yaylag	$M_{0.2}\ HCO_3(73)\ SO_4{}_{23}\ Ca_{62}\ (Na+K)_{20}\ Mg_{12}$	0.258	7.7	0
4.	Damir-Yolgulu	$M_{0.6}\ HCO_3(75)\ SO_4{}_{19}\ (Na+K)_{63}\ Ca_{24}\ Mg_{13}$	0.576	7.7	0
5.	Soyugbulag	$M_{0.2}\ HCO_3(67)\ SO_4{}_{22}\ Cl_{11}\ Ca_{59}\ (Na+K)_{34}$	0.260	7.5	0

The bicarbonate class is further subdivided based on dominant cation composition (Na^+, Ca^{2+}, Mg^{2+}).

- Bicarbonate–calcium waters are typical of fresh and weakly mineralized sources.
- Bicarbonate–chloride waters indicate prolonged interaction with saline strata and magmatic formations.
- Bicarbonate–sulfate waters form due to interaction with sulfur-bearing minerals in groundwater circulation zones.

Elevated sulfate and chloride concentrations indicate the influence of deep groundwater components.

5. Trace Element Composition

The trace element composition (Table 3) varies among the studied waters. Saline waters contain mainly Ti, Cu, and Sr, whereas hydrogen sulfide waters are characterized by a more diverse trace element assemblage, including Mn, Ni, and Br.

Table 3. *Trace Element Content in the Studied Mineral Water Sources (Azerbaijan, Shamakhi District)*

No.	Source / well name	Ionic composition type	Ba (mg/L)	Sr (mg/L)	Mn (mg/L)	Ni (mg/L)	Ti (mg/L)	Cu (mg/L)	Br (mg/L)
1.	Goshabulag spring	HCO_3–Ca–Mg–Na	6.96	0.30	0.30	0	1.74	0.03	69.6
2.	Archiman spring	HCO_3–SO_4–Ca–Na–Mg	9.88	0	9.88	0.49	1.48	0.05	49.4
3.	Yaylag spring	HCO_3–SO_4–Ca–Na–Mg	0	0	<0.26	0.52	0.26	0.03	7.74
4.	Damir-Yolgulu spring	HCO_3–SO_4–Na–Ca–Mg	17.28	0	0	0	1.73	0	57.6
5.	Soyugbulag spring	HCO_3–SO_4–Ca––Na	5.20	0.26	0.78	<0.25	0.52	0.13	7.8

The spatial distribution of trace elements corresponds to Pleistoseist zones of strong and perceptible earthquakes, indicating a relationship between hydrogeochemistry and tectonic activity.

6. Objects and Research Methods

The objects of study were natural mineral water sources of the Shamakhi District: Goshabulag, Archiman, Yaylag, Damir-Yolgulu, and Soyugbulag. Sampling was carried out daily, five times per week, in accordance with standard hydrogeochemical methodologies.

Laboratory analyses included determination of major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^+, SO_4^{2+}, Cl^+), pH, Eh, and total mineralization. Analytical methods included colorimetric, titrimetric, helium analysis (INGEM-1), and calculation methods. Data processing utilized Excel, HydroGeo, and related software.

7. Comparative Analysis and Regional Features

Comparative analysis showed that mineral water sources of the Shamakhi District exhibit similar hydrogeochemical characteristics but differ in mineralization degree and ionic ratios. These differences are controlled by local geological conditions, deep water circulation, and tectonic activity intensity.

8. Conclusion

The Shamakhi District is a перспективный (promising) region for mineral water exploration and utilization due to:

1. Complex tectonic and geological structure facilitating groundwater circulation;
2. Diversity of aquifers from alluvial to deep sedimentary horizons;
3. High mineralization potential controlled by geochemical processes;
4. Seismic activity influencing fracture development and groundwater systems.

Comprehensive studies of five newly identified mineral water sources were conducted, revealing key patterns of their distribution and formation within different geological structures and enabling the development of a new mineral water classification.

The dominant water types are weakly to moderately mineralized bicarbonate calcium and sodium waters. Their chemical composition results from long-term water–rock interaction, tectonic influence, and dynamic fluid processes.

Based on hydrogeochemical characteristics, it is recommended to conduct regime monitoring at the “Soyugbulag” and “Archiman” sources for inclusion in the regional seismogeochemical monitoring network, as these waters reflect deep circulation with minimal infiltration influence.

Practical Significance

The results identify new перспективные (prospective) mineral water resources and provide a balneological assessment of their therapeutic potential. Sulfate mineral waters with mineralization of 2–5 g/dm³ identified in the Shamakhi District are recommended for expanding the range of bottled local mineral waters.

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SPATIAL DIFFERENTIATION OF TOURIST TRAFFIC IN THE REGIONS OF UKRAINE

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Abstract

The article examines the theoretical and methodological foundations of spatial differentiation in the tourism activities of the regions of Ukraine. It was found that the problem of domestic and foreign tourism in the regions of Ukraine should stimulate economic and social growth in depressed, unfavorable for industrial and agricultural production regions, reduce the migration of the population of these regions to large cities and industrial centers. The analysis of basic research of conceptual bases of essence of categories "spatial differentiation" is carried out and its generalized author's definition is given. The analysis of tourist traffic both in Ukraine and by individual regions is given and it is revealed that the problem of uneven spatial distribution of tourist resources in the regions of Ukraine is significant. The mechanism of effective management of tourist activity as a tool for overcoming spatial differentiation on uneven distribution of tourist resources of regions of Ukraine is developed.

Keywords: *mechanism, spatial differentiation, tourist services, tourist market, tourist movement*

Problem Statement in General Terms

At the current stage of Ukraine's development, the issue of creating an efficient tourism structure and strengthening both national and local tourist flows is becoming particularly relevant. Ukraine, as a tourism-oriented state of global significance, requires consistent coordination of activities across various sectors of the national economy, all of which influence the quality and timeliness of tourist services, transportation, publishing and advertising activities, souvenir production, etc. Today, tourism and the effective utilization of tourism potential are important components of Ukraine's economy and one of the priority areas of its development.

Thus, the problem of developing domestic and inbound tourism in Ukraine should stimulate economic and social growth in depressed regions that are unfavorable for industrial and agricultural production, reduce the migration of the population from these regions to large cities and industrial centers, and support balanced regional development. Therefore, the issue of spatial differentiation of tourist flows across the regions of Ukraine is highly relevant for academic research and has considerable practical significance both

for individual regions and for the country as a whole.

Analysis of Recent Research and Publications

The problem of spatial differentiation of tourist traffic has been studied by many Ukrainian scholars, including Rega M. V., Pluhin Yu.L., Zorin V. A., Shkromada V. I., Soroka I. V., Tarasenko A. I., Zinovieva A. A., Krugman P. R., and others.

However, it should be noted that despite the wide range of studies devoted to tourist and recreational potential and tourism infrastructure, the regional aspect remains insufficiently explored. In particular, the spatial issues of regional tourism development require deeper investigation. This enhances the relevance of addressing the identified problem using modern methodological approaches and innovative tools widely applied in the study of tourism services.

Purpose of the Study

The purpose of the article is to substantiate the mechanisms for overcoming spatial differentiation of tourist traffic under contemporary conditions and to explore the patterns of development of tourist services in the regions of Ukraine.

Presentation of the Main Research Material

Under current conditions, when the need to transform the economic structure of Ukraine has become particularly urgent, the tourism sector is gaining increasing significance as an instrument of stable financial and economic growth of the national economy through both direct and indirect stimulation aimed at expanding service provision and creating additional value.

Active tourist flows act as a catalyst for the sustainable development of the entire tourism industry and are directly linked to the effectiveness and scale of the tourism services market, which in its development passes through four stages (initial, accumulative, consolidation, and modernization). Therefore, it is necessary to examine the impact of tourist flows on the development of the tourism market in Ukraine.

It should be noted that the management of the tourism services market at each stage is determined by the interaction of general national and local market influences, which must be taken into account given the constant emergence of trends whose realization lies largely outside the competence of the market actors themselves. The duration of each stage is not defined and depends largely on the type of tourism in the region, external and internal factors, the intensity of tourist flows over a certain period, and the possibilities and risks that constantly arise due to tourist movement in the tourism services market.

Tourist Flow at Various Stages of the Tourism Services Market Development

Stage of Tourism Services Market Formation

Initial Stage

A low-intensity tourist flow, dominated by domestic and outbound tourism.

Accumulative Stage

Significant growth of inbound tourism; domestic tourism begins to dominate over outbound tourism.

Consolidation Stage

Active development of mass international tourism; inbound tourism exceeds both outbound and domestic tourism.

Modernization Stage

Decrease in outbound tourism; reorientation of domestic tourism toward inbound tourism.

The stages of development of the tourism services market, both for individual regions and for Ukraine as a whole, are defined by general factors that significantly influence tourist flows. In this context, the tourism, economic, and social development of every region of Ukraine deserves particular attention, as it constitutes an objective condition for the sustainable development of the tourism market.

Uneven tourism distribution among regions is caused by the following factors:

- significant differences in the quantity and accessibility of natural resources;
- climatic characteristics;
- cultural and historical heritage;

- **uneven distribution of infrastructure**, including transportation, communications, and recreational facilities;
- **asymmetry in the distribution of recreational resources** across regions.

In connection with the issues raised regarding the development of tourist mobility with consideration of differentiation aspects, the spatial aspects of tourism development are becoming increasingly relevant. Therefore, it is necessary to define the scientific and theoretical meaning of the concept of *spatial differentiation* and to provide a general definition for more effective practical research.

The development of tourist flows under conditions of spatial differentiation is often characterized by the presence of the following interdependent trends:

- the significant influence of resource-related factors specific to individual market participants;
- the distribution of the active influence of factors and resources according to their functional location.

It should be noted that, in a broader sense, *spatial-differentiation factors* influencing tourist flows should be understood as a combination of external environmental factors inherent to a particular setting – territorial, informational, resource-based, and institutional.

It is important to emphasize that for successful practical research it is necessary to generalize and systematize individual categories of *spatial differentiation* as general economic as well as tourism-specific concepts.

Parfinenko Yu.I. argues that spatial differentiation reflects **economic development disparities** arising from uneven redistribution of economic resources, income, and expenditures, manifested through different levels of socio-economic and ecological development.

Eykova V. A. also notes that spatial differentiation may reflect a state in which a certain set of resources of the natural-economic and socio-economic system is concentrated within a given territory at a specific moment in time.

From another perspective, Shkromada V. I. emphasizes that spatial differentiation primarily represents a set of characteristics of regional development influenced by basic factors, as well as dynamic trends shaped by current conditions that determine structural changes in production-economic, financial-economic, and socio-economic directions.

Equally noteworthy is the category of *spatial differentiation*, as defined by Soroko I. V., who considers it a manifestation of the uneven distribution of knowledge and innovation activities, originating from the non-linear process of self-organization of innovation relations within complex systems. In this context, innovation becomes both a product and a process integrated into the formation of innovation activity and the rise of innovation levels.

Tarasenko A. I. views the concept of *spatial differentiation* in the global tourism industry as an objective manifestation of the formation of tourism development centers and zones through uneven distribution of tourist demand, capital, and innovation in the tourism complex. Zinenko A. A., in her works, also concludes that spatial differentiation is a proportional dependence between economic benefits derived from tourist flows and the levels of tourist mobility.

Of particular value are the studies of Krugman P., who identified two types of territorial organization of economic space: a more developed center (core) and closely Thus, it can be concluded that spatial differentiation in the tourism sector is driven by significant disparities in the development of the market for tourism services, which stem from pronounced differences in the distribution of natural resources, climatic characteristics, cultural and historical conditions of cities and regions, uneven placement of transport, communication, and recreational infrastructure, as well as the asymmetric distribution of recreational resources among regions.

Ukraine's tourism potential, if effectively implemented and utilized, can ensure the fulfillment of economic, social, humanitarian, and other essential functions of the state. It may raise the standard of living, increase the share of tourism revenues in state and local budgets, expand employment opportunities within the tourism industry and related sectors, and stimulate the development of domestic tourism resources.

Dynamics of Domestic and International Tourism in Ukraine, 2000–2019

Table 1 shows that during 2018–2019, Ukraine experienced a notable increase in the overall tourism performance compared to previous years in the statistical sample. It should also be noted that until 2009 the largest share (50–60%) of tourist flows in Ukraine consisted of domestic tourism. This trend was largely the result of limited household budgets and the growing desire of Ukrainian citizens to explore tourism and recreational sites within their own country. These years also recorded the highest share of inbound international tourism, i.e., foreign visitors traveling to Ukraine for tourism purposes.

Since 2010, however, there has been a steady decline in outbound tourism and a significant reduction in other types of tourism flows. The reasons for these trends include:

- **temporary restrictions on tourism** in the Autonomous Republic of Crimea, Sevastopol, and the temporarily occupied territories of Donetsk and Luhansk oblasts;
- **insufficient development** of tourism and recreational zones in many regions of Ukraine and the lack of services that meet European standards;
- **growing interest** among Ukrainians in discovering new tourism routes;
- **increase in savings** and financial resources among households that can be allocated to vacations abroad.

To conduct a more detailed study and analyze the preconditions and distribution of spatial differentiation in tourism flows across Ukraine, it is essential first to review statistical data on regional tourism performance for 2019 (see Table 2).

Improving the Efficiency of Regional Tourism Markets

Enhancing the efficiency of tourism market actors in Ukrainian regions will allow identification of the processes driving spatial differentiation. To achieve this, it is necessary to develop a universal and effective mechanism that considers the specific features of each region and strengthens the tourism infrastructure of border regions. These areas possess a rich historical and cultural legacy capable of increasing tourist flows from peripheral territories while preserving the indicators characteristic of the "Center".

The organization of tourism activities must be guided by the need to consider the spatial structure of regional differentiation in Ukraine, which influences the functioning of tourism entities at both the regional and national levels. Proper understanding of these structures creates the basis for strategic tourism development. The regulatory and legal framework governing the tourism market in Ukraine plays a key role in shaping mechanisms for tourism service provision, enhancing quality standards, ensuring safety, and improving certification practices.

Achieving the objectives of the mechanism is ensured through the implementation of target priorities and development management tasks, namely:

1. **Rational and efficient use of natural heritage, territories, and resorts** will make it possible to introduce advanced experience in sustainable tourism sector development, ensure financial and technological support, enable the development of innovative projects and best practices for tourism market growth in the regions, as well as preserve ecosystems and cultural heritage.
2. **Improving legal and institutional support** for market formation will ensure the rule-of-law framework and effective mechanisms of state policy for stimulating and supporting tourism enterprises across the regions of Ukraine.
3. **Building a high-quality tourism and related infrastructure**, taking into account spatial imbalance in development and differentiation of economic space.
4. **Increasing employment through the tourism sector**, which carries important socio-economic value for the state as a whole, and becomes particularly significant for depressed regions of Ukraine.
5. **Integrating tourism services into the global tourism market** through alignment with contemporary trends of international tourism (transnationalization, globalization, clustering, etc.).
6. **Achieving national interests through integration into the global tourism market**, ensured through

effective state regulatory mechanisms that promote tourism entrepreneurship in the regions of Ukraine.

Functioning of an effective regional tourism activity mechanism in Ukraine is based on the following principles:

1. **Systematic approach** – tourism activities represent a multi-component, holistic, open, dynamic system with interdependent elements interacting across microeconomic and macroeconomic levels;
2. **Competitiveness** – ensuring that tourism services meet relevant basic quality indicators and maintain competitiveness in domestic and international markets;
3. **Adaptability** – the ability to adjust the developed mechanism to appropriate conditions, where tourism companies must remain highly flexible in responding to internal and external changes;
4. **Dynamism** – continuous development of tourism and recreational activities in the regions to successfully overcome existing spatial differentiation challenges;
5. **Sustainability** – implies consistent enhancement of tourism potential in the regions to increase competitiveness in the long term;
6. **Goal orientation** – directing tourism activities in the regions toward achieving overarching objectives and smoothing spatial disparities;
7. **Optimality** – ensuring that decisions in planning, development, and implementation of tourism products best align with selected strategic priorities and development directions;
8. **Scientific justification** – increasing tourist flows in the regions is impossible without integrating innovations and modern technologies based on scientific research and development;
9. **Informational support** – ensuring complete and multi-criteria information about tourism activities in the regions.

Vectors of implementing the tourism market development mechanism are closely related to the key functions of state regulation and aim to achieve the following:

1. **Institutional and legal vector** – establishing a universal institutional and legislative foundation for market development that aligns with global and European standards to ensure its effective functioning.
2. **Socio-economic vector** – fulfilling the state's social function by increasing employment in tourism and related services, which raises income levels and tax revenues across different regions.
3. **Integration vector** – strengthening international cooperation in tourism to enhance interaction and the quality of life across various spheres.

The most important aspect of the developed mechanism for effective management of tourism activities in the regions of Ukraine is the selection of strategic priorities and directions aimed at smoothing spatial differentiation in the field of tourism services in the regions of Ukraine, namely:

1. **Implementation of authentic market development management**, based on consideration of specific tourism opportunities of regional markets. Such management is possible through incorporating the infrastructural asymmetry of regional tourism markets and spatial differentiation of the distribution of forming market factors. Effective authentic management will increase the pace of financial and socio-economic growth and reduce inequality and poverty among the population of the regions of Ukraine through the use of regional tourism competitive advantages.
2. **Formation and development of innovative sectors in the tourism services market**, including the introduction of modern types of tourism (rural, green, industrial); restoration of neglected tourism heritage (castles, fortresses, palaces); implementation of national programs to increase public interest in the culture and history of Ukraine, as well as the history and modernity of individual regions; improving tourism image at both the national and international levels.
3. **Adaptation of traditional tourism sectors under conditions of deeper European integration**, which requires the gradual harmonization of domestic

and international tourism services markets with European service standards.

It should also be emphasized that an important component of the developed mechanism is the system of monitoring and control over the stages of implementing strategic directions under conditions of sustainable development of regional tourism markets in Ukraine, which establishes two-way communication with other subsystems of the mechanism and ensures the practical performance of all its theoretical and methodological principles.

Conclusions and prospects for further research

Based on the conducted study of the problems of spatial differentiation of the tourism services market in Ukraine, the following theoretical and practical results were obtained:

1. **The relevance and theoretical substantiation of tourism flows at different stages of tourism market development have been determined.**
2. **The definition and systematization of the category "spatial differentiation" as it relates to tourism**, meaning the uneven development of the tourism market of services, which is caused by significant differences in the distribution of natural resources, climatic features of regions, cultural-historical preconditions of settlement across territories, uneven distribution of transport, communication, and recreational infrastructure.
3. **An analysis of tourism flows in Ukraine was conducted for the period 2000–2019**, both in general and by individual regions. It was found that the problem of uneven distribution of tourism resources in the regions of Ukraine is significant. The "Centers" of tourism in Ukraine account for only 20% of the total number of existing regions. The remaining 80% constitute the periphery.
4. **Based on the analysis of significant spatial differentiation in the regions of Ukraine**, a mechanism for effective management of tourism activities was developed, which, if successfully implemented in practice, will help smooth the unevenness of tourism development and improve quantitative and qualitative tourism indicators of the regions of Ukraine.

The practical significance of the obtained results lies in the fact that they can be used as a theoretical and methodological basis for further research on issues of reducing spatial differentiation of the tourism services market in Ukraine.

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TESTING OF REGENERATED SAE 15W-40 DIESEL OIL UNDER OPERATIONAL CONDITIONS

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Abstract

This article presents information on the global consumption of mineral diesel oils and their environmental impact. Additionally, it provides the results of tests conducted on regenerated SAE 15/40 diesel oil under operational conditions. By analyzing the results, it was established that after the operation of regenerated SAE 15/40 and fresh SAE 15/40 oils in engines at a distance of 3000 km, regenerated SAE 15/40 oil was several points better than fresh SAE 15/40 oil in terms of kinematic viscosity, viscosity index, freezing point, and color index on the colorimeter, and still meets the standard requirements, and also has a useful and reliable service life.

Keywords: *diesel oil, ecology, mineral oils, bentonite, technology, additive, oxidation, regeneration, viscosity index*

Introduction

Currently, there are three popular methods for waste disposal. The first is the processing of waste by collecting it separately. This method is widely used in developed countries – the USA, Western Europe, Japan. Another way to dispose of waste is to burn it at waste incineration plants. This method poses a serious threat to the environment. When waste is burned this way, hazardous and toxic substances enter the environment. The equipment required to build a modern waste incineration plant with minimal environmental damage is also very expensive. Two hundred and fifty tons of high-quality lime, activated charcoal, and modifiers are used in just one month to remove toxins from combustion products. As a result, the cost of waste disposal at such a plant also increases. For residents to be able to pay such a price for garbage collection and removal, city authorities will have to subsidize municipal services involved in garbage collection and removal. Separate recycling of waste is currently the most promising. Currently, waste utilization is carried out by burning it at waste incineration plants (Fatkullin D. D., 2019). What are used lubricants? Used lubricants are any oils obtained from petroleum or synthetic oils that have been used and contaminated with physical or chemical impurities as a result of their use. In other words, used oil is any lubricant obtained from oil or synthetic oil. During oil use, impurities such as metal

particles, sludge, water, or chemicals can eventually mix with the lubricant, rendering it unusable (Danilov A. M., 1996).

During the operation of oils in machines and technologies, oxidation products, contamination products, and other impurities accumulate in them, which sharply reduces the quality of oils. Oil containing pollutants cannot meet the requirements for them, and it is necessary to replace it with new oil early. Used oils are collected and processed to preserve valuable economically useful raw materials. During the year, about 30 million people live in the territory of the Republic of Uzbekistan. tons of used oils were collected, 6 million tons. tons, that is, 20% (Fatkullin D. D., 2019; Danilov A. M., 1996). The necessity of utilizing MSW (used lubricants) currently raises no doubts, as their burial and destruction (mainly by burning) create even greater environmental problems per hour than the MSW itself, and with significant costs, do not allow for the reuse of valuable secondary raw materials, which is already unprofitable from an economic point of view. At the same time, it is very important that the utilization processes themselves do not pose a significant threat to the biosphere (Fatkullin D. D., 2019, 2–5).

As already noted, the most rational direction in solving modern environmental problems is the practical implementation of the concept of pollution prevention, since the colossal costs of eliminating the resulting pollution and the impossibility of foreseeing and eliminating all its consequences entirely fully justify the development of new, safer technologies and the creation of fundamentally new equipment ((Fatkullin D. D., 2019; Potashnikov Yu.M., 2004). As in the main industries, in the field of secondary raw materials processing, more and more specialists are expressing their support for abandoning traditional methods of combating pollution by installing cleaning equipment at the end of the technological chain. The task of solving environmental problems in the production process, based on fundamentally new technological solutions, is put forward (Yevdokimov A.Yu., 2005). The ideal embodiment of this idea is the creation of industrial enterprises with minimal emissions. Since the occurrence of waste in industrial production cannot be avoided, as it is impossible to avoid thermodynamically determined losses of matter and energy and completely process raw materials into desired products, the creation of enterprises of this type provides for a system of technological processes that ensure the integrated use of raw materials and energy, when the by-products and waste of one process are raw materials or reagents of another. Complex processing of raw materials includes capturing, separating, and processing all waste into finished products or relatively environmentally safe substances suitable for safe burial (Fatkullin D. D., 2019; Gayevik D. T., 2000).

Comprehensive use of raw materials – the most complete, economically and environmentally justified use of all useful components contained in raw materials, as well as in production waste; at the same time, the maximum output of products at each stage of processing is assumed, which increases production efficiency and reduces waste generation (Fatkullin D. D., 2019; Khamidov B. N., Khuzhakulov A. F., Abdunazarov A. A., 2020). Based on the foregoing, the currently existing term “waste-free or environmentally harmless (pure) technology” should hardly be considered successful. Any technology is inherently and objectively opposed to the biosphere and therefore cannot but pose a threat to it (to a greater or lesser extent). The term “low-waste technology” seems most acceptable – such a method of producing products where the harmful impact on the environment does not exceed the level permitted by sanitary and hygienic standards, while for technical, economic, organizational, or other reasons, part of the raw materials and materials passes into unused waste and is sent for long-term storage or burial (Fatkullin D. D., 2019; Khuzhakulov A. F., Khamidov B. N., 2020).

Materials and methods

The most important condition for organizing low-waste production is the presence of a system for neutralizing unused waste, primarily toxic waste. At the same time, the impact of waste on the environment should not exceed the maximum permissible concentrations (Fatkullin D. D., 2019; Khuzhakulov A. F., Khamidov B. N., 2020).

The following ways to create low-waste technologies have been identified:

1) complex processing of raw materials;

2) development of fundamentally new processes and schemes for obtaining known types of products;

3) designing drainless and closed water consumption systems;

4) industrial waste recovery;

5) development and creation of territorial-industrial complexes with a closed structure of material flows of raw materials and waste.

Summarizing all this, it should be noted that mineral resource recycling, like any technogenic system, cannot be a solution to environmental problems, as it requires the expenditure of energy and substances, the production and use of which, in turn, leads to environmental pollution and degradation. The energy expended in this process cannot be reused; by disposing of some waste, we obtain others, sometimes even more dangerous ones, and create new environmental problems. The way out, we repeat, is found only in the spiritual sphere (Fatkullin D. D., 2019, 4–12). Environmentally safe use of MSM involves their processing to obtain commodity products of various purposes (fuel, oils, plastic lubricants, preservation materials, etc.). Analysis of the current state of the issue indicates that it is practically unresolved both in theory and practice. Only some processes of processing and direction and use are exceptions. However, there is undoubtedly a trend towards low-waste utilization of MSM worldwide, driven by the increasing number of environmental problems (Fatkullin D. D., 2019; Khuzhakulov A. F., Khamidov B. N., 2020).

In modern technical literature, when considering the issue of restoring the quality of MSW, various terms are used – purification, regeneration, secondary processing. Therefore, it is important to clearly distinguish the purpose and areas of application of these processes. By "cleaning," we mean the continuous or periodic cleaning of the operating lubricant in the operating equipment, carried out using settling tanks, filters, centrifuges, and adsorbers. Such purification does not always lead to the production of a product corresponding in quality to the level of fresh lubricant. Often, this is not required due to operating conditions. Such measures contribute not only to the rational disposal of MSW but also to extending the service life of lubricants. Cleaning operating oils without draining them from the equipment is only possible if there are circulating lubrication systems for a number of motor, industrial, and turbine oils and for practically all transformer oils (Fatkullin D. D., 2019, 7–12). In the case of processing mixtures of various used petroleum oils (ONMs) collected centrally from industrial enterprises, the term "secondary processing" is used. From such raw materials, it is possible to obtain base oils of various compositions and purposes. Secondary processing is only possible at large specialized enterprises and involves the use of a complex of processes – vacuum distillation, extraction, hydrotreating, and some other physical and chemical methods (Fatkullin D. D., 2019; Fuchs I. G., 2002). The main place in solving the problem is occupied by the ONMs. The industry of purification and regeneration of used synthetic oils also begins to develop. A significant number of experimental studies on the utilization of used plastic lubricants are known, however, their practical application is difficult due to a number of factors. The most important problem is the disposal of used environmentally safe lubricants based on synthetic oils and natural fats (Fatkullin D. D., 2019, 6–12).

Western European countries hold a leading position in the processing of used oil, where highly developed processing industries have been established, and a number of technological processes continue to be improved. To a certain extent, the development of processing technologies is mainly aimed at neutralizing the environmentally hazardous components of used petroleum oils (Fatkullin D. D., 2019, 2–5). Oil oils occupy a leading position in the production of lubricants. Oil oil production continues to increase, which, in turn, leads to an increase in the volume of used oils. In all industrially developed and developing countries, large-scale collection, purification, utilization, and processing of used oils are carried out, their resources account for about 50% of the consumption of new oils, and used petroleum oils account for about 30% of all petroleum waste (Danilov A. M., 1996).

Results and discussion

SAE 15/40 grade mineral diesel oil is used in internal combustion engines operating on diesel fuel used in production enterprises, particularly in mining and metallurgical industry enterprises producing ferrous and non-ferrous metals, and is replaced in engines at distances of 3000 km. The results of studies to determine the physicochemical properties and composition of the spent samples of SAE 15/40 grade mineral diesel oil, treated with NaOH and regenerated with "Navbahor" bentonite, are presented in Table 1.

Table 1. *Physicochemical properties of the used samples of SAE 15/40 mineral diesel oil, treated with NaOH and regenerated with Navbakhor bentonite*

Name indicators	Indicator value			
	Oil SAE 15/40	Sample No. 1 used oil SAE 15W-40	Sample No. 2 oil SAE 15/40 treated with NaOH	Sample No. 3 oil SAE 15/40 regenerated with Navbakhor bentonite
1. Density 20 °C, kg/m^3, GOST 3900	887	865	868	887
2. Kinematic viscosity at 100 °C, mm^2 /s GOST 31391	14,1	13.45	13.87	14.1
3. Viscosity index, GOST 25371	120	114	117	120
4. Water quantity, % GOST 2477	absent	0.1	0,03	absent
5. Flash point in an open crucible, °C, GOST 4333	220	212.9	206.9	221
6. Content of water-soluble acids and alkalis, GOST 6307	absent	absent	Water-soluble alkalis are present	absent
7. Mechanical impurities, % GOST 6370	absent	0.2	absent	absent
8. Freezing temperature, °C GOST 20287	–27	–18	–21	–27
9. Sulfate ash content, % GOST 1461	0.8	0.9	0.8	0.8
10. Alkaline number, mg KOH/g, not less than	6.0	6.1	6.8	6.0

The main operational properties of SAE 15/40 grade diesel oil regenerated with Navbakhor bentonite were studied under laboratory conditions at JSC "Neftgaztadqiqot." At the same time, its kinematic viscosity at 100 °C is 14.1 mm^2/s, freezing point is –27 °C, alkaline number is 7.0 mg KOH/g, density at 20 °C is 887 kg/m^3, viscosity index is 120, ignition temperature in an open crucible is 221 °C, sulfate ash content is 0.8%, results meeting the established requirements were obtained. 20 liters of regenerated SAE 15/40 diesel oil was tested from June 25, 2025, to July 25, 2025, on trucks belonging to the "Drilling Operations Department" OJSC. MAN CLA 37.280 trucks equipped with a German 4-speed D0836 LFL13 turbocharged diesel engine, manufactured by

the Uzbek-German joint venture "JV–MAN AUTO," were selected for testing.

The testing process was conducted under moderate difficulty conditions. The selected MAN CLA 37.280 truck engines were fueled with regenerated Navbakhor bentonite and SAE 15/40 brand fresh oil and operated under the same conditions. After traveling 3000 km, samples of used motor oils were taken and their physical and chemical properties were studied in the 17th testing laboratory of the Fergana Oil Refinery. The research results are presented in Table 2.

Table 2. *Results of tests of used and fresh SAE 15/40 diesel oils under operating conditions*

No.	Name of indicators	Norm according to Ts 05767930–240:2014	Regenerated SAE 15/40, 0 km	Regenerated SAE 15/40, 3000 km	Fresh SAE 15/40, 0 km	Fresh SAE 15/40, 3000 km	Fresh SAE 15/40, 4000 km	Fresh SAE 15/40, 4500 km
1.	Kinematic viscosity, at temperature, 100 °C, mm^2/s	13.5–14.5	13.9	14.5	14	15.2	14.9	15.5
2.	Viscosity index	no more than 85	126	121	92	82	117	104
3.	Flash point in an open crucible, °C	no more than 220	220	221	227	231	227	2 22
4.	Alkaline number, mg KOH/g	no more than 6.0	6.8	6.5	7.15	6.8	6.2	5.8
5.	Freezing temperature, °C	no more than –15	–21	–19	–19	–15	–17	–14
6.	Color on the colorimeter, with dilution of 15:85, units. CNT	no more than 4,0	1.0	2	3	4.5	2	3
7.	Density, at 20 °C, kg/m^3	no more than 910	883	889	888	893	893	897
8.	Sulfate ash content, %	no more than 1.15	0.8	1.05	0.9	1.2	1.1	1.4

Conclusion

Analyzing the results of this table, it was established that after the operation of regenerated SAE 15/40 and fresh SAE 15/40 oils in engines at a distance of 3000 km, regenerated SAE 15/40 oil was several points better than fresh SAE 15/40 oil in terms of kinematic viscosity, viscosity index, freezing point, and color index on the colorimeter, and still meets the standard requirements, and also has a useful and reliable operating life. It has been proven that the operational quality indicators of the obtained oil sample meet the requirements for modern diesel oils and meet operational requirements.

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STRUCTURAL OPTIMIZATION AND MODIFICATION OF ELECTRONIC MODULES. (Integration of traditional and innovative materials and composites in the comprehensive structural optimization and modification of electronic modules)

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Abstract

In modern electronic engineering, particularly in mass-produced systems, the accurate formulation of initial technical requirements is essential to ensure the long-term adaptability of products throughout their production and operational lifecycle without altering their fundamental design principles, circuit architectures, or material compositions. A key challenge lies in anticipating future technological development pathways that enable the introduction of innovative properties and performance enhancements while preserving the core characteristics established at the design stage. This paper examines non-contact liquid monitoring devices for pipeline applications, with particular emphasis on the shielding system of the electromagnetic resonance sensor as the critical functional subsystem. To identify effective pathways for optimizing the technical performance of such devices, the study highlights the use of computer-based simulation of technical parameters, applying the methodology developed in the research and publications of **Alina Marakshyna**. This approach focuses on modeling the integration of advanced structural materials and circuit solutions into serially manufactured products, especially in components responsible for measurement-zone shielding and the mitigation of electronic noise, thereby ensuring measurement accuracy and system reliability.

Keywords: *Impedance–resonance sensors, Non-contact pipeline monitoring, Shielding system optimization, Electronic system design requirements, Computer-based performance simulation, Liquid condition diagnostics*

Integration of traditional and innovative materials and composites in the comprehensive structural optimization and modification of electronic modules

In modern electronic engineering, particularly in mass-produced systems, the correct definition of initial technical requirements is critically important. These requirements must enable innovative modification of a product during manufacturing and operation without altering the fundamental principles of its design, circuit architecture, or the established combination of materials and components.

One of the most challenging tasks is to anticipate the principal trends and pathways for the further development and improvement of the underlying technology in such a way that the product acquires new innovative properties and performance characteristics while preserving the positive qualities and parameters embedded at the design stage.

For analytical purposes, the author proposes to examine a class of devices intended for non-contact monitoring of the condition and parameters of liquids in pipelines, highlighting the most critical subsystem – the shielding system of the working zone of the impedance-resonance sensor, which represents the core and functional foundation of such instruments.

For a more detailed examination of all aspects related to the optimization of technical characteristics of devices incorporating impedance-resonance sensor blocks and their associated shielding assemblies, the author considers computer-based simulation of performance parameters to be the most effective approach under current conditions. This simulation is carried out using the methodology proposed in the advanced developments, books, and publications of **Alina Marakshyna.**

Alina Marakshyna's fundamental approach to simulation is primarily focused on modeling the pathways and consequences of integrating new structural materials and circuit solutions into serially manufactured products. This is particularly relevant for subsystems responsible for shielding the measurement zone and preventing distortion of measurement results caused by electronic noise.

The three-dimensional model illustrates such a shielding assembly, based on a combination of advanced composite materials and innovative electrolytic coatings, which together determine the efficiency and quality level of the shielding system.

Figure 1.

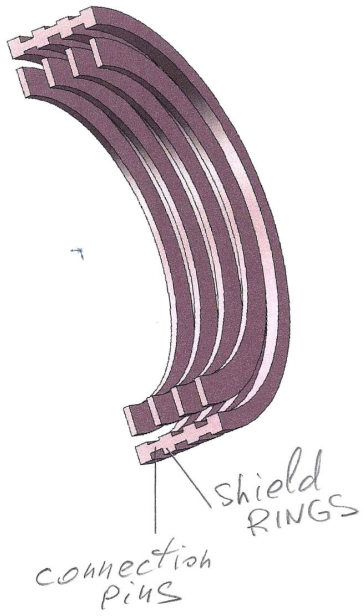
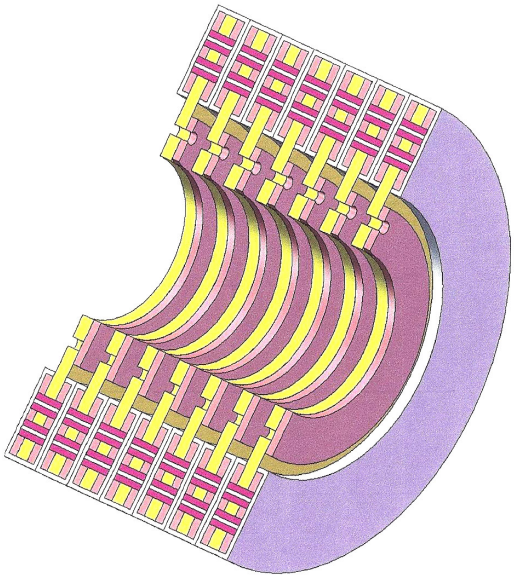


Figure 2.



To enable the subsequent application of general system-level recommendations in real-world developments, the main variants of initial technical requirements for products of this type are proposed. These requirements are formulated based on the results of computer modeling and software simulation of all impedance–resonance phenomena occurring within the working zone of the module, which is protected from electronic noise by a shielding system. All simulations were carried out in an integrated and harmonized manner, in accordance with the methodologies, modeling techniques, and simulation programs developed and published by Alina Marakshina.

As an initial step, **Marakshyna Alina** considers it essential in her research to generalize and specify the technical requirements related to the measurement process itself and to the technological principles underlying impedance–resonance metrology.

When implementing the technological principles of impedance–resonance metrology, the following conditions must be ensured:

- relatively low specific cost of the measurement process;
- high reliability of the measurement process;
- simplicity of the measurement procedure, enabling operation by personnel with limited qualifications or allowing the technology to be used in domestic environments for monitoring or assessing drinking water quality;
- compact dimensions of monitoring equipment;
- capability of integration into existing technological schemes and equipment complexes;
- high throughput;
- capability for continuous 24-hour operation;
- high process efficiency and high repeatability of results;
- feasibility of simple and reliable automation of the process;
- possibility of using disposable technologies and materials;
- capability for remote monitoring and remote use of monitoring results;
- capability to perform comparative quality assessment of processes and of liquids or water based on a minimal set of technological parameters.

As an illustrative example, let us consider a device for monitoring water quality.

1. The product is based on the application **Water Quality RST Sensor**. The product represents a section of pipeline on the outer surface of which a resonance sensor is installed, with union nuts mounted at both ends to enable connection to the pipeline.
2. A cable from the sensor is intended for connection to a monitoring and analytical unit or to a centralized control and management system for the entire pipeline infrastructure.
3. The product size range covers pipelines from **1/8 inch to 4 inches** made of various structural materials and equipped with **ring-type sensors**, and pipelines **4 inches and larger**, equipped with **sector-type sensors**.
4. **Key technical requirements for the product:**

4.1. High measurement accuracy

The device must be sensitive to changes in the chemical composition of water equivalent to concentrations as low as **0.000001 mg per liter**.

4.2. Simplicity of design

The device design must employ only standard or serially manufactured components and materials. The product should consist entirely of standard pipeline fittings, ensuring high reliability, ease of maintenance, low manufacturing costs, and the possibility of production without the use of specialized technological equipment.

4.3. Reliability and service life.

The reliability of the device shall be defined by a mean time to first failure of not less than **10,000 hours**, and the device shall maintain operational capability for at least **10 years**.

4.4. Complete absence of contact with the measured liquid.

The sensitivity of the device must not decrease when a dielectric spacer with a thickness of up to **2.5 millimeters** is present between the sensitive element and the liquid.

4.5. Integration capability.

The device must be capable of integration into any existing technological scheme, including capital equipment, boilers, steam equipment, water supply networks, agricultural irrigation systems, and industrial water supply systems.

4.6. Low energy consumption.

Total electrical power consumption of the device shall not exceed **50 watts per hour**.

4.7. Capability to monitor aggressive and toxic liquids.

The device must be manufactured from materials and components that allow its use for monitoring aggressive and toxic liquids.

4.8. Capability to monitor ultra-pure liquids.

The materials used in the device must not contaminate the monitored liquids and must not degrade under exposure to such liquids.

4.9. Capability for integration into automated control systems

The sensor signals must be compatible with commercially available processors and control system components used in industrial and agricultural equipment.

4.10. Capability for autonomous operation

The device must include all necessary components to operate autonomously, without being connected to the networks or control systems of the primary technological equipment.

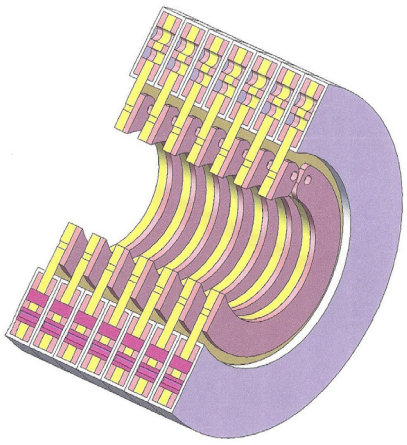
The device must also be capable of functioning as a **level sensor**. In this configuration, the device must not differ structurally from the water quality monitoring device, and all required components and fittings for such installation must be provided.

This requirement deserves particular attention, as it represents a clear example of a combinatorial approach to forming the future technical characteristics of an innovatively modified product and related products with similar performance attributes.

This forecasting principle makes it possible, with minimal additional costs, to develop several parallel products across all stages of design and development, based on a unified and equivalent component base.

The implementation of this system-level predictive analysis principle, proposed by **Marakshyna Alina**, enables any innovative development to yield multiple practical outcomes for several products that share similar properties and performance characteristics.

Figure 4.



It is also critically important, for the systemic coordination of all stages and phases of development with respect to their initial requirements, to clearly identify and define the minimum necessary maturity level of the device project and its underlying technology at the outset of systematic development.

In accordance with the recommendations of **Marakshyna Alina**, the following prerequisites must be fulfilled:

- the fundamental structural and technological principles of the product must be developed;
- a basic universal prototype of the device must be manufactured;
- a cycle of preliminary testing of the device must be conducted;
- the universal prototype must be refined based on the results of preliminary testing;
- materials for a patent application must be prepared;
- a patent and licensing protection strategy for the technology must be developed.

To bring the device (product) to the stage of mass production and the active marketing phase, the following activities must be carried out:

- development of initial technical requirements for the product, taking into account feedback and recommendations from potential customers;
- preparation of the technical assignment for the project;
- development of a technical proposal, including design, fabrication, and testing of product models;
- development of a technical design, including design, fabrication, and testing of product prototypes;
- development of a working design, including design, fabrication, and testing of pilot samples;
- verification and evaluation of the products for compliance with applicable standards;
- certification of the products by a standards institute;
- production of an initial pilot batch;
- pilot industrial operation of the initial batch;
- development of a marketing strategy;
- preparation of a production and commercialization program for the market adaptation period, development of a warranty service system, identification

of a strategic partner, and execution of the first phase of active marketing.

As readers may note, at all stages the system follows the core principle articulated in the developments and publications of **Marakshyna Alina**, namely the principle of **horizontal and vertical combinatorial integrative development**.

Devices for impedance – resonance monitoring of water quality and other liquids must be fully suitable for effective operation within the following key industrial sectors, which represent the primary consumers of this technology and its subsequent extensions.

Primary Industrial Sectors – Core Consumers of the Technology

- Pharmaceutical industry
- Microbiological industry
- Semiconductor manufacturing
- Microelectronics
- Power engineering, including nuclear power plants
- Industrial air-conditioning systems
- Water treatment and water purification across all industrial sectors, as well as residential, industrial, and public buildings and facilities
- Fine chemical technology
- Cosmetic product manufacturing
- Production of alcoholic and non-alcoholic beverages
- Food industry
- Greenhouse agriculture
- Agricultural irrigation technologies
- Electroplating and electrochemical industries
- Oil extraction and production

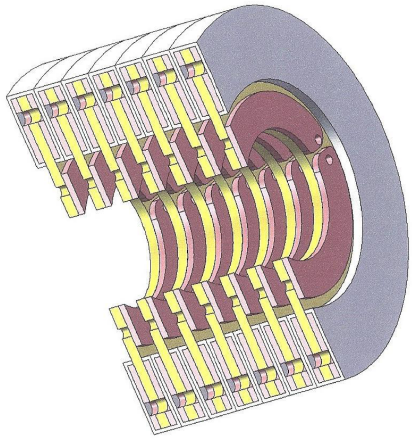
Innovative Combinatorial Mass-Market Products Expected as Project Outcomes

1. **Household indicator for tap water purity.**
2. **Industrial indicator for tap water purity.**
3. **Pipeline sensor for non-contact monitoring of liquid conductivity**, manufactured on the basis of industrial polyvinyl chloride (PVC) pipeline components; operating diameters: 1/16, 1/8, 1/4, 3/8, 1/2, 3/4, 1, 1–1/4 inches, and further in 1/4-inch increments up to 4 inches; intended for integration into automated process control systems.
4. **Pipeline sensor for non-contact monitoring of liquid conductivity**, manufactured on the basis of industrial polypropylene pipeline components; operating diameters as specified in item 3; intended for integration into automated process control systems.
5. **Autonomous pipeline sensor for monitoring liquid conductivity**, manufactured on the basis of industrial polyvinyl chloride (PVC) pipeline components; operating diameters as specified in item 3.
6. **Autonomous pipeline sensor for monitoring liquid conductivity**, manufactured on the basis of industrial polypropylene pipeline components; operating diameters as specified in item 3.
7. **Pipeline sensor systems**, analogous to items 3–6, manufactured on the basis of industrial polycarbonate pipeline components.
8. **Pipeline sensor systems**, analogous to items 3–6, manufactured on the basis of industrial pipeline components made of Teflon, composite polymer materials, thermosetting plastics, polymers with various fillers, and heat-resistant materials.
9. **Sensor systems integrated into automated control complexes** for non-contact monitoring of liquid quality in pipelines with diameters greater than 4 inches; pipelines manufactured from polyvinyl chloride (PVC), polypropylene, heat-resistant polymers, and thermosetting plastics.
10. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids supplied to agricultural irrigation systems.
11. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids in irrigated agriculture complexes.
12. **Sensor systems**, in accordance with items 3–9, intended for monitoring the condition of liquids in greenhouse agricultural complexes.
13. **Non-contact level sensor systems with horizontal mounting configuration;**

14. **Non-contact level sensor systems with vertical mounting configuration;**
15. **Integrated systems combining level sensors and quality monitoring sensors.**

As follows from the presented material, in accordance with the methodology proposed and developed by **Marakshyna Alina** in her publications, focusing and concentrating attention on the most critical product element from the standpoint of technology and its core development principles makes it possible – through deeper elaboration – to achieve both horizontal and vertical integration of tasks and principles that are aligned in terms of technological and structural identification. This approach enables attainment of the ideal final result, even in the case of parallel development streams.

Figure 3.



The author of this article initially considers shielding issues to be the most critical for impedance–resonance sensor systems and measurement and control instrumentation.

Problems related to uncontrolled and unmanageable so-called electronic noise represent a real obstacle to the further development of non-contact measurement and monitoring technologies and devices. The accuracy of determining the parameters of the resonance signal is a decisive factor in the systemic assessment of the accuracy of actual measurement results. This accuracy is a direct function of the reliability and sophistication of the sensor shielding system.

At the same time, shielding based on traditional principles does not provide the required level of accuracy and necessitates additional, workaround technical solutions that are far removed from the most advanced and innovative concepts in this field.

Applying the same methods and approaches to innovative project organization, product development, and optimization as formulated by **Marakshyna Alina**, the author of this publication arrived at a sufficiently optimal framework of stages and phases for the development of a household device for monitoring drinking water quality.

Stages and phases of development of a household drinking water quality monitoring device

Initial technical requirements

- Initial technical requirements for the materials of the device;
- Initial technical requirements for anti-corrosion and decorative coatings permitted for use in the device design;
- Initial technical requirements for elements involved in installing the device into a residential water supply system;
- Initial technical requirements for the ideology and concept of drinking water quality monitoring;
- Initial technical requirements for the system of identification and interpretation of monitoring results and sensor readings.

Technical proposal

- Calculation and explanatory report for the technical proposal stage;
- Block diagrams and schematic diagrams of project components at the technical proposal stage;
- Models, mock-ups, and physical prototypes of the device;
- Project presentation prepared for the technical proposal stage.
- Technical assignment
- Formation of the project developer company;
- Development and preparation of all foundational corporate documentation;
- Formation of working groups to execute the project;
- Development and approval of the technical assignment for design and engineering.

Development and approval of the technical specification for the product; develop-

ment of the technical characteristics of the new product; development of the technical specification for manufacturing pilot prototypes of the product. Development of the technical specification for all stages of testing of the new product.

Development of the technical specification for the industrial design of the new product, including packaging, storage, transportation, and the structure and format of operational documentation.

Development of the technical specification for pilot and pre-production documentation.

Development of the technical specification for the patent and licensing protection strategy of the new product and the underlying technology.

Conceptual (Preliminary) Design

- Calculation and explanatory report for the conceptual design of the device;
- Schematics, diagrams, and general arrangement drawings;
- Mock-ups, models, and prototypes at the conceptual design stage;
- Presentation materials for the conceptual design stage.

Technical Design

- Calculation and explanatory report for the technical design of the device;
- Schematics, diagrams, and general arrangement drawings of device subassemblies;
- Models of components and fragments of the device, including versions intended for installation;
- Presentation materials for the technical design stage;
- Materials for invention and patent applications.

Working (Detailed) Design

- Calculation and explanatory report for the working design of the device and all its components;
- A complete set of technical documentation for the device and its installation variants;
- Models, prototypes, and experimental samples;
- Presentation materials for the working design stage;
- Materials for invention and patent applications.

Development of a business plan. Development of an implementation program and search for strategic partners for pilot-industrial operation. Manufacturing of an initial pilot batch of devices for pilot-industrial operation.

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MODULAR SYSTEMS FOR REGENERATION AND RECIRCULATION OF PROCESS FLUIDS. (Principles of formation of modular structures of systems for regeneration and recirculation of process fluids, including water and aqueous solutions)

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Abstract

Modularity, unification, and multifunctional interchangeability are key principles in the development of smart technologies for wastewater treatment and regeneration, particularly in advanced leather production. Inventive activity, as the highest form of technical creativity, requires substantial intellectual effort, creative initiative, and time investment that far exceed the development of purely technical or technological components.

In modern conditions, inventive processes are inseparable from unification and partial standardization, which, while increasing apparent obviousness, enable the innovative use of standard components in new configurations with non-obvious technical characteristics. Furthermore, in a globalized market environment, successful commercialization of inventions depends on adapting innovations to diverse technological cultures and consumer conditions, making cooperation with specialists in innovation commercialization essential.

Recent practice demonstrates that the most commercially successful technical solutions are not those aimed at existing demand, but those that create new, previously unknown market needs. This underscores the importance of forward-looking inventive strategies that integrate technical originality with modular design, market adaptability, and commercialization-oriented thinking.

Keywords: *Principles of forming modular structures; Integrative and complex solutions; Technical level of technology and engineering; Technical creativity; Inventive activity; Newly emerged circumstances; Innovative compositions in demand by society; Adaptation to the principles of standardization and unification; Stage of idea generation; Recirculation infrastructure; Commercial value of the invention; Jet metallization technologies; Integrative inventions; Balanced formation of a technical solution*

Dynamic Adaptation of Technical Requirements in Integrative Technologies under TRIZ and ARIZ Principles

Since in such, as a rule, integrative and complex solutions, the technical level of technology and technology is constantly growing and technical requirements and technical conditions are constantly changing and improving, following the laws, postulates and principles of TRIZ and ARIZ requires constant comparison of existing provisions with newly emerging circumstances.

And even after realizing the need for systemic modification and optimization of the ideological, computational and technical-technological base of such multi-stage cooperation between idea generators – technical and innovative interpreters of global and partly even abstract ideas into really solvable and implementable technical solutions, after realizing the need for deep cooperation with specialists in the commercialization of new technological ideas and solutions, there remain specific, but in principle absolutely strategic questions that can only be solved by the inventor himself, who understands and knows the features of his invention better than anyone else.

The author of this publication believes that, precisely to help inventors in the process of identifying and deepening their understanding of the possibilities and features of their inventions, the adaptation of TRIZ and ARIZ to the principles of standardization and unification and other modern conditions can provide all the necessary analytical tools.

The developments and methods proposed by Viktor Kniaz play a huge role in this process;

The opening of new markets, internal and external, and the development of economic organization from the craft shop and factory to concerns like U. S. Steel, illustrate the same process of economic mutation – if one may use the biological term – which continually revolutionizes... the economic structure *from within,* destroying the old structure and creating a new one.

This process of "creative destruction" is the very essence of capitalism. Every capitalist concern has to exist within its framework...

The behavior of a particular enterprise should be assessed only against the background of the overall process, in the context of the situation it has generated. It is necessary to clarify its role in the constant flow of "creative destruction"; it is impossible to understand it outside this flow...

In the future series of articles offered to readers, the author set the goal of linking future work on the commercialization of any invention with the initial stages of work on its creation, especially at the stages of idea generation.

An inventor, starting the process of forming basic ideas and principles for creating his future invention, even without knowing the principles of TRIZ and ARIZ, whether he wants it or not, uses them, even intuitively.

At the same time, TRIZ and ARIZ in their historical and classical versions do not help the inventor to determine the expected commercial value of his future invention.

Unlike the unique, repeatedly tested in practice techniques and principles, laws of development of technical systems, which are basic for TRIZ and ARIZ, the techniques of commercialization and analysis of potential possibilities of inventions – as commercial products do not have a systematic theoretical basis.

As an example, it is important to cite the original version of the development complex of the well-known initiator of innovative optimization of infrastructure processes of irrigation technologies, Viktor Kniaz, aimed at the innovative formation of the recirculation infrastructure of the water treatment system, primarily in greenhouse farms, but not only.

Let us consider a part of this multifunctional technological process – Electrochemical regeneration of aqueous solutions containing heavy metals.

The project is based on the following information arrays and experience from previous developments:

- inventions related to high-speed metallization technology;
- inventions relating to jet metallization technology;
- inventions concerning methods for controlling high-speed electrochemical processing processes;

– patents for inventions on electrochemical correction of acidity or alkalinity of water or aqueous solutions;
– patents for inventions on electrochemical disinfection of water and aqueous solutions and on antibacterial treatment of water and aqueous solutions;
– patents for inventions on electrocoagulation in water and in aqueous solutions, including heterocoagulation;
– patents for inventions on the control and synchronization of energy supply processes for electrochemical processes in water and aqueous solutions;

Experimental developments on the use of carbon-graphite non-woven materials in technologies for extracting heavy metals from water and aqueous solutions;

Experimental developments in the use of composites based on coal and graphite, including carbon-carbon composites, including those obtained by methods of sequential thermal pyrolysis of carbon on a fabric base, such as viscose;

Pilot-industrial development of equipment for water purification from radioactive isotopes, including the use of combined technologies that combine electrochemical extraction with sorption in biological materials in the form of specially modified seaweed (OZOLA);

The technology proposed to solve this problem is comprehensive and includes:

– preliminary treatment of water or aqueous solutions using the turbo-flotation method with the help of aerodynamic activators (this is a patentable technical solution for which there is a prototype of an activating head, tested and showing more than satisfactory results in purifying water from industrial oils and organic matter of all types);

– electrochemical treatment of water or aqueous solutions, carried out in the flow of purified (regenerated) liquid and representing the electrochemical deposition of heavy metals contained in it on the active working surface of the cathode (electrode connected to a negative electric potential); this type of treatment is the basis for the proposed technological complex and has a high potential for patentability, including a pioneering invention on composite permeable contacts for electrodes of an electrochemical reactor;

– a method of pulsed power supply for the process of electrochemical deposition of heavy metals, taking into account that the electrodes and contacts for them are permeable to liquid; made of non-metallic materials; have a three-dimensional active, developed working surface and are not an element of the design of an electrochemical reactor for multiple use.

Such a comprehensive approach to solving modern technological problems is characteristic of the works of Viktor Kniaz and, as numerous examples of his projects show, with such an approach there is a significant gain in all component aspects and parts of projects, in which, based on the system proposed by Viktor Kniaz, the necessary level of unification of components, while maintaining the originality and fundamental novelty of complex solutions, in addition to a purely economic effect, also provides the necessary level of novelty to ensure full patentability at all levels.

Recently, many publications have appeared that provide recommendations for commercialization, and on their basis, a decision was made to use one of them, in order to, firstly, give inventors operational information that they can, if desired, adapt to the technical characteristics and advantages of their invention, and, what is especially important, secondly, to show one of the possible versions and principles of practical actions, showing how to change and adjust the technical characteristics and parameters of a future innovative development depending on market requirements.

Taking into account the conditions and all sorts of limitations formed by the peculiarities of the innovation process in the globalization mode of the world economy, it can be assumed that it is the systemic unification of elements of innovative products at the component level that can help gradually form a library of components, units and basic parts from which inventors can form the technological embodiment of their ideas.

It seems to me that taking into account possible market requirements will allow, at the stage of generating an innovative idea, to form such a technical characteristic of a new product that will contribute to a more confident and economically advantageous implementation of the innovation, but also in the

event that the assessment of the commercial significance of the generated idea is low, to abandon this idea and turn your attention to something else or, through modulation and unification, return the idea to an economically advantageous channel.

In my articles devoted to TRIZ and ARIZ, I had to repeatedly note that the majority of inventions being created at the present time are integrative, since any modern effective technical solution includes digital control systems, composite materials, nano-coatings and various integrative combinations, such as a program, system, method and apparatus.

For such complex, combined and integrated systems, principles of system analysis of their commercial value have yet to be formulated and publication of information on methods, techniques and working schemes of commercialization will help inventors working today in the field of innovative projects.

At the same time, many examples have emerged of how the structure and system of a modern large enterprise levels out innovative projects and concentrates on what appear to be the most effective innovative ideas at the time of decision-making, often leaving behind equally effective solutions, the inventors and authors of which receive (and often undeservedly) serious psychological trauma.

A systemic approach to the comprehensive, balanced formation of such an innovative technical solution or a group of local unified innovative ideas linked by a single innovative integrative idea is very important.

The system's approach is a reflection and development of the dialectical principles of "universal interconnection" and "development" and, in fact, is one of the principles of the dialectical method of cognition.

The methodology of the systems approach involves representing any object as a system and its comprehensive consideration.

2. A system is a complex of elements, regularly organized in space and time, interconnected with each other and forming a certain integral unity. The system is characterized by the composition of elements, structure and performs a certain function.

3. Elements are relatively indivisible parts of a whole; objects that together form a system. An element is considered indivisible within the limits of preserving a certain given quality of the system.

4. Structure is a regular, stable connection between the elements of a system, reflecting the form, the method of arrangement of elements and the nature of the interaction of their aspects and properties.

The structure makes the system a certain qualitatively defined whole, distinct from the sum of the qualities of its constituent elements (since it assumes the interaction of elements with each other in different ways, only by certain aspects, properties, and not as a whole.)

5. Function – external manifestation of the properties of an object (element) in a given system of relations; a certain way of interaction of an object with the environment, the "ability" of an object. Systems have many functions.

6. Subsystems (subsystems) are parts of the system that represent some arbitrarily or naturally selected groups of elements. The selection of subsystems is carried out according to a functional feature.

One element can sometimes coincide with a certain subsystem or be included in several different subsystems at once.

In this case, the connection between elements within subsystems and within the system differs from the nature of the connection between the subsystems themselves. Elements and subsystems are united by the concept of system components.

7. Supersystem (metasystem) – a system of a higher order in relation to a given one, and into which the given system is integrated and functions "as" a subsystem.

8. A technical system (TS) is an artificially created material unity of elements that are regularly organized in space and time and are in mutual connection, the purpose of which is to satisfy a certain social need. TS elements can be both artificial and natural.

Any TS is part of two systems of relations. On the one hand, it is an object of the material world, subject to the laws of nature (primarily the laws of physics as the most general), on the other hand, the TS acts as an element of social relations, since technology is only a means for achieving social goals.

If the TS is characterized by the spatial arrangement of elements, then the TS is

a device or substance. If the TS is characterized by the organization of elements in time, then we are dealing with a method.

The concept of TS allows us to formulate the main feature of a technical solution (TS): TS indicates a specific TS, the functioning of which allows us to achieve the set goal, i.e. it indicates the relationship of the TS to a certain goal.

From the standpoint of systems engineering, the TS can be represented as:

INPUT – PROCESSOR – OUTPUT.

The processor provides the conversion of input into output and at the same time is a component (constant) of the input.

INPUT and OUTPUT – reflect the interaction of the system with the environment. From a physical point of view, the TS has space, time, mass, energy and information at the output and input.

From a socio-technical point of view, at the input we have the "needs" of the TS – the costs of society for its creation, and at the output – the "capabilities" of the TS, the main part of which are the functions of this system.

Acting in the form of action, the functions of the TS in unity determine the composition and structure of the system's activity, show what the TS can do: move in space, carry out heating, resist the action of the wind.

The remaining "capabilities" characterize how actions are performed: reliably, easily repairable, etc. For each function in the TS, a corresponding subsystem can be identified.

9. Useful functions (UF) are functions corresponding to the purpose of the system, characterizing the most important components of useful outputs. In real TS, not all output is useful.

The usefulness of one or another part of the TS output can be determined only from a social standpoint. Those "abilities" of the TS that correspond to its purpose, i.e., social needs at the level of the supersystem, are useful.

Other abilities may be useless or harmful, and harmful is considered to be something that actively interferes with the implementation of useful "abilities", for example, by destroying elements of the vehicle, etc.

10. Main useful function. For the set of useful functions performed by a TS, it is always possible to find a more general useful function that directly reflects the purpose of the TS, the goal of its existence and activity (and coincides with them).

This general function is called the main useful function – MUP of the entire TS, in contrast to the elementary useful functions (hereinafter – simply useful – PF), in total

ensuring the implementation of the GPF. The relationship between the GPF and the PF is the same as between the system and its subsystems. The GPF refers to the system as a whole, and the PF to its subsystems.

11. Positive effect. Any change in the TS that increases the capabilities of this TS to satisfy the needs of supersystems (including society) is an improvement of the system.

The improvement of the TS is manifested in the following changes of the system at the level of external functioning:

– quantitative growth of useful "abilities" of the TS – transformation of unuseful "abilities" into useful ones;

– elimination of harmful "abilities" up to their transformation into useful ones;

– increasing the ratio of useful output to input, i.e. increasing the efficiency of the TS.

14. Dialectical contradiction. The source of development of the TS, as well as any object of the material world, is the law of unity and struggle of opposites – the universal law of development of nature, society, technology.

Opposites are the sides of an object that are in mutually exclusive relationships. In this case, the side of an object or phenomenon is understood to be everything that is somehow inherent in the object or phenomenon, characterizes it and can be known.

Opposites in TS are "input" and "output", useful functions of cost and "ability".

The interaction of opposites, when they simultaneously mutually presuppose and at the same time deny, exclude each other, constitutes a dialectical contradiction.

15. Technical contradiction (TC) is a dialectical contradiction that manifests itself in a technical system in the form of deterioration of one side of the TS at the level of external functioning (from the standpoint of the needs of the supersystem) with improvement of the other side of the TS.

In other words, TP can be defined as a dialectical unity of interdependent positive and undesirable effects in the TS. TP is always

associated with some component of the TS (element, group of elements or interaction of elements), which is usually called the nodal component (NC).

This component of the TS is connected with two sides of the TS at once, and a quantitative change in some parameter (or state) of this component leads to an improvement of one side of the TS and a deterioration of the other.

Therefore, TP should be more precisely defined as a dialectical unity of positive and undesirable effects, interdependent on quantitative or qualitative changes in the nodal component of the TS.

16. An inventive task arises when the TP inherent to the TS is aggravated. In this case, the improvement of some TS "abilities" by means of a quantitative change in some parameters becomes impossible due to a significant deterioration of other "abilities".

Attempts to preserve the TS by means of a compromise between the opposing parties are unsuccessful in this case. The resolution of the TP is possible in the event of the transition of the TS to a new qualitative state – a dialectical leap. This is an invention.

When considered from a more general position, the problem of resolving the contradiction between a social need and the possibility of satisfying it can be reduced to one of two tasks:

a) the search for a material form based on the laws of nature and allowing the performance of a function corresponding to a specific social need – an information task (search for a new system);

b) resolution of an internal dialectical contradiction in a technical system that satisfies a certain social need – a contradictory problem.

These two types of tasks are related to each other and in the practice of technical creativity they flow into each other.

17. Physical contradiction. Technical contradiction in its form appears in the TS at the level of its external functioning. At the level of internal functioning, mutually exclusive relations between the parties of the system are not observed: from a physical point of view, the TS is in a certain state determined by the laws of nature.

But if we set the task of eliminating the TP within the framework of a given TS, affirming the positive and denying the undesirable effects, then mutually exclusive relations will manifest themselves at the level of internal functioning, in the form of incompatible requirements for the parameter (state) of the nodal component of the TS, or more precisely, for the physical state of the MC.

Such contradictions are called physical (PC). PC is manifested when the task of eliminating TP is set, in other words, PC is a form of expression of the problem of eliminating TP within the framework of a given TS. The resolution of PC consists in establishing new forms of organization and movement of matter in the TS, in which both incompatible requirements for the state of the MC are implemented, or, in the words of K. Marx, in establishing such a "form of movement in which this contradiction is simultaneously realized and resolved."

Introduction to the theory of inventive problem solving (TRIZ), modified on the basis of the recently emerged conditions for the development of unified innovative systems and complexes

1. Creative activity is usually defined through the result. As an example, one of the most common definitions can be given: "Creativity is a human activity that creates qualitatively new material and spiritual values."

If we try to formulate a definition of creativity as **a process, we will see that creative activity is a process of finding a solution.**

In essence, all human activity can be divided into two large areas: the area of routine operations and the area of problem solving.

The idea of creativity as a problem-solving process makes the conclusion self-evident: in order to scientifically organize creative activity, it is first necessary to put the problem-solving process on a scientific basis. In other words, TRIZ is needed.

2. There are two types of solutions to problems: strict and non-strict. Strict solutions are based on complete reliability, accurate information and, as a rule, are quite unambiguous. Solutions obtained on the basis of incomplete, inaccurate information, under conditions of uncertainty, are called non-strict.

Accordingly, the methods of obtaining solutions are divided into strict and heuristic methods. When solving problems put forward at the current level of development of society, these methods complement each other.

As science develops, many heuristic methods of solution are formalized and move into the class of strict ones according to the scheme: accumulation and systematization of knowledge – development of "gut feeling", intuition – formalization, development of theory – algorithm.

3. The existing problem-solving apparatus is adapted to search for strict, quantitative solutions. It includes such sciences as systems analysis, the theory of search for solutions, and the theory of decision-making. The main idea of systems analysis is the following statement: "The solution to any problem is the process of creating a new system."

Systems analysis is the basis for: systems engineering (design of large technical systems) and organizational systems engineering (system design of organizations).

Decision theory examines methods for finding optimal ways to achieve goals.

Includes such disciplines as operations research (the use of mathematical, quantitative methods to justify decisions in all areas of targeted human activity), the linear programming method (selecting the optimal solution from a large number of possible ones).

The theory of decision search considers the process of finding a solution under conditions of uncertainty in terms of information.

4. TRIZ is engaged in the search for heuristic solutions. Its main features include the following: a) the theory should provide a significant increase in the probability of obtaining correct solutions; b) the theory should search for solutions at a qualitative level; c) the theory should take into account the characteristics of the object and subject of creativity.

TRIZ meets all the above requirements. In addition, it is based on two main provisions:

1. A new, truly creative solution in technology corresponds to the next stage of development of the object to which the solution relates.

2. The patterns of the development process of a technical object are knowable and can be used to search for new technical solutions.

A factor of peculiarity is something that is inherent only to a given theory, is most characteristic of it and distinguishes this theory from similar areas of knowledge. For TRIZ, the factors of peculiarity are:

– use of identified patterns of construction and development of technical systems;

– the presence of optimal logic for identifying a problem and searching for new technical solutions.

List of references, patent and license materials

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Process and Apparatus for Complex Treatment of Liquids
Published: September 9, 2010.

Appendix 2
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Published: September 9, 2010.

Appendix 3
United States Patent Application No. 20110069579 (A1)
Fluid Mixer with Internal Vortex
Published: March 24, 2011.

Appendix 4
United States Patent Application No. 20100193445 (A1)

Foaming of Liquids
Published: August 5, 2010.

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Foaming of Liquids
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Appendix 6
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Appendix 7
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PREPARATION OF GASEOUS FUEL MIXTURES

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Abstract

The text examines the fundamental limitation of internal combustion engines – their inherently low mechanical efficiency – despite the near-perfect optimization of the fuel combustion process. While the reciprocating-to-rotary motion conversion mechanism remains the primary source of energy losses, numerous proposed technical alternatives have not yet gained sufficient investor interest. Modern internal combustion engines operating on the Otto cycle achieve up to 98% efficiency in extracting the chemical energy of fuel during combustion, largely due to advanced fuel delivery systems and highly optimized combustion chambers designed for constant-pressure combustion. However, the mechanical inefficiencies inherent in traditional motion conversion systems continue to restrict overall engine performance, creating a persistent technical contradiction that remains unresolved despite thousands of recent innovations in this field.

Keywords: *Gaseous fuel mixtures, Stable combustion, Constant flame volume, Internal combustion engines, Efficiency, Technical contradiction, Fuel mixture combustion cycle, Combustion cycle implementation, Conversion of reciprocating motion into rotational motion, Distortion of Otto cycle conditions, Vortex mixing of combustible gas, Vortex mixing of combustible gas in a vortex generator, Geometry of tangential channels*

Subtitle:Inventions in the field of preparation of gaseous fuel mixtures, allowing to obtain stable combustion in a constant volume of the torch;

Introduction:

All specialists in the field of internal combustion engines had to deal with the key problem of these engines – low efficiency; The reasons for this phenomenon are also well known – the imperfection of the mechanism for converting reciprocating motion into rotary motion.

It would seem that since the causes of power losses are in the mechanical motion conversion systems, then replacing such a mechanism with a more efficient one should resolve this technical contradiction.

Over the last year alone, several thousand technical solutions have been announced in this area, but investors are in no hurry to take advantage of them.

Figure 1. *The figure shows a vortex generator that forms a vortex tube in a flow of combustible gas*

What are the reasons?

Let's consider one of these reasons.

The combustion cycle of the fuel mixture in the cylinders of a modern internal combustion engine (Otto cycle) has been brought to complete perfection, its real efficiency on serial internal combustion engines has been brought to 98%, which means that during the implementation of the combustion cycle, 98% of the energy contained in the fuel is extracted.

This result is achieved to a large extent due to the design of the fuel system, which has been developed to almost complete perfection, and the associated system of combustion chambers in the engine cylinders, in which combustion today occurs due to combustion at constant pressure.

As practice has shown, any known changes to the design of the cylinder-piston group of the engine lead to a distortion of the Otto cycle conditions, which ultimately leads to a decrease in mechanical losses and a decrease in the efficiency of extracting energy obtained from the combustion process.

It would seem that the innovative development of this category of technology could be slowed down because of this, but fortunately this is not happening.

Where is the innovative way out of this situation, and does it even exist?

As it turns out, there is such a way out;

It is known that when combustion occurs in a constant volume of flame, energy output increases by 20%.

That is, without changing the design of the injectors and the volume and configuration of the combustion chamber, only by monitoring and regulating the volume of the combustion chamber and the volume of the flame torch in it can the required result be achieved.

Let us consider a model of conditions for obtaining combustion at a constant torch volume for gaseous fuel

Vortex mixing of combustible gas in a vortex generator;

(VORTEX DYNAMIC MIXING OF GASEOUS MEDIUMS IN VORTEX DYNAMIC MIXING AND ACTIVATION DEVICE; ADDITIONAL EXPLANATIONS)

Linear flow velocity (LINEAR VELOCITY OF STREAMS)

The flow of natural gas moves in the central opening of the vortex generators under a certain pressure and with a certain linear velocity

A stream of compressed air is introduced into the natural gas stream from the tangential channels of the vortex generator at a speed at least three times greater than the linear speed of the natural gas stream.

In this case, the pitch of the spiral in the formed vortex tube is equal to the linear velocity of the natural gas flow.

In this case, the linear velocity in the outer boundary layer of the vortex tube is greater than the linear velocity in the inner boundary layer of the vortex tube.

Since all the flows that form the vortex tube move perpendicular to the flows of natural gas, they collide repeatedly and, since the linear velocity of the compressed air flows

exceeds the linear velocity of the natural gas flows.

The indicated collisions, with high kinetic energy of the flows, form a developed turbulent state, which turns into Brownian motion (Brownian movement of the mix components).

Since ideal combustion conditions for natural gas require a mixing ratio of 17.2 to 1, which means there are 17.2 air molecules per molecule of natural gas, meaning there are 17.2 more gas molecules with a higher kinetic energy level entering the mixture

Due to this circumstance, the molecules of natural gas, which are lighter, are surrounded by molecules of air, which are heavier, and which, having a higher level of kinetic energy, are more mobile in the Brownian system. movement of the mix components and surround on all sides of the three-dimensional model of the mixture of natural gas molecules

Pressure V PRESSURE IN THE STREAMS

The natural gas flow moves in the central hole of the vortex generators with a certain pressure.

The level of this pressure determines the pressure of the medium in the central hole of the vortex generators.

Compressed air is supplied to vortex generators under pressure ranging from 2 to 20 bar.

When moving through tangential channels with a small cross-section and parallel walls, the speed of movement of compressed air flows increases sharply and, accordingly, the pressure in the flow drops.

At the outlet of such channels, the pressure in the air flows coincides with the pressure in the natural gas flow.

When moving along tangential channels with a variable cross-section, at the entrance to the central opening of the vortex generators, expansion occurs and the pressure in the integral flow acquires the pressure level in the natural gas flow

Geometry of tangential channels (TANGENTIAL CHANNELS GEOMETRY)

Vortex generators use two types of tangential channels.

Tangential channels with variable cross-section are used when it is necessary to obtain the maximum possible effect – the Joule-Thomson effect (JOULE – THOMSON).

Tangential channels with equal cross-section along the entire length are used when the efficiency of the JOULE – THOMSON, RANQUE – HILSCH effects are not of fundamental importance and it is necessary to obtain a high local (BERNOULLI) Bernoulli effect.

Formation of the local Bernoulli effect (LOCAL BERNOULLI EFFECT CREATION)

The level of the local BERNOULLI effect is determined by the ratio of the cross-sectional area of the pipeline for supplying compressed air to the cross-sectional area of the tangential channel.

For example, with a ratio of the cross-sectional area of the channels as 1 to 15, the linear velocity of the flow in the tangential channel increases by 15 times, and with a decrease in the pressure level, also by 15 times

At the same time, due to the increase in the linear speed of movement, the level of kinetic energy increases proportionally to the increase in the linear speed.

The nature of Brownian motion in gas mixture flows (BROWNIAN MOVEMENT CHARACTER IN GASEOUS MIX STREAM)

From the moment of entering high-speed flows of compressed air into the flow of natural gas moving in the central opening of the vortex generators, the phenomenon of formation of BROWNIAN occurs MOVEMENT CHARACTER in the environment of two miscible gaseous media.

Compressed air flows are accelerated in the tangential channels of vortex generators to a linear velocity at least three times greater than the linear velocity in a natural gas flow.

The flow from each of the tangential channels is directed perpendicular to the direction of movement of the natural gas flow along a tangent to the outer diameter of the central opening of the vortex generators and has a kinetic energy at least three times greater than the kinetic energy of the natural gas flow.

Air molecules with higher kinetic energy push natural gas molecules apart and enter the flow, causing a chain reaction of collisions between air and natural gas molecules.

More mobile air molecules surround the natural gas molecules and, as they move further along the spiral in the vortex tube, create a complex movement in which the molecules of natural gas and air have a common linear nature of movement along the vortex tube and, at the same time, within the framework of this movement, they move in other direc-

tions until they collide with other molecules standing in their path.

In this case, the resulting movement of the mixture in the vortex tube is subject to the laws of physics and the conditions formed by the geometry of the relationships of the elements of the vortex generators.

As a result of the sequential mixing of gas environments, after repeating the process on each of the vortex generators of the system, a uniform flow of a mixture of natural gas with aerodynamically active air is obtained, with precise observance of the proportions between natural gas and air necessary for an ideal combustion process.

The level of kinetic energy of the mixture is increased proportionally to the number of vortex generators according to the following logical model: at the input, the kinetic energy of the natural gas flow is supplemented by the kinetic energy of the air flows and an integral level of kinetic energy is formed, which is the starting level for the next vortex generator, and so on.

Clean and cooled exhaust gas (CLEAN AND COOL EXHAUST GAS)

With complete and optimal combustion, the exhaust gases do not contain incomplete combustion products.

The proposed composition and active aerodynamic structure of the mixture allow, simultaneously with optimal combustion, to obtain a decrease in the temperature of the exhaust gases, which helps to eliminate the formation of toxic substances and compounds in the exhaust gases.

Efficient and economical combustion (EFFECTIVE AND SAVENESS BURNING)

A homogeneous mixture of natural gas and air is sent from the dynamic vortex mixing device to the combustion chamber, having precise proportions between the components and in which, due to the high kinetic energy and constant movements of air molecules around heavier molecules of natural gas, the structure of the volume of the mixture is maintained and renewed, in which the molecules of natural gas are surrounded by molecules of air.

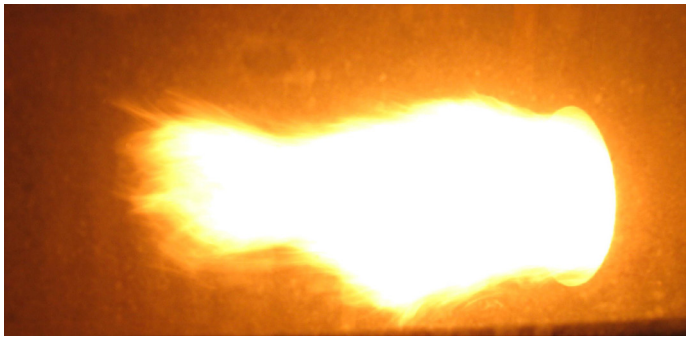
In addition, microscopic water droplets or water vapor molecules are also evenly distributed among the air molecules.

The combustion process of the specified pre-prepared mixture takes place under optimal conditions, with complete combustion of the carbon and hydrogen parts of natural gas, at a high combustion rate, at a high rate of flame front propagation, at a high level of flame stability and the entire combustion process.

The specified mixture during combustion allows eliminating losses of natural gas due to inefficient combustion in zones of non-uniform mixing, since these zones do not exist in the specified mixture;

Figure 2. Standard Flame Torch

Figure 3. *Modified flame torch based on a vortex tube*



Explanations and illustrations (ILLUSTRATIONS)

The explanation is illustrated by the fact that the aerodynamic design of the vortex generator is multifunctional, and in addition to mixing, it has the goal of cooling the flows of mixed gases and lowering the temperature of the mixture;

The vortex generator uses and applies a scheme of sequential local formation of the BERNOULLI, JOULE – THOMSON, RANQUE – HILSCH effects for use in dynamic mixing and sequential step-by-step cooling in flows of mixed components of gaseous media and the resulting mixture of gaseous media;

The aerodynamic scheme of sequential local formation of the BERNOULLI, JOULE – THOMSON, RANQUE – HILSCH effects allows for enhanced formation of the BERNOULLI effect to increase the linear velocity of the compressed air flow, which ensures uniform homogeneous mixing of the mixture components, while maintaining the Brownian movement of the mix components

Let us give another typical example of the formation of conditions for the implementation of the combustion process in a constant volume, which is:

– Increasing the specific power of an internal combustion engine in relation to the amount of fuel consumed, using fuel mist – a fuel composite obtained by dynamically mixing hydrocarbon liquid fuel with a compressed gaseous oxidizer ...

a) If gasoline is used as fuel for the internal combustion engine:

A homogeneous mixture of gasoline with compressed air, in which the compressed air (at a pressure of at least 5 atmospheres), in the form of bubbles no more than 50 microns in diameter, is uniformly distributed throughout the volume of gasoline, in such a way that, due to the forces of surface tension, the gasoline forms a shell around the air bubbles

The volume of compressed air in the resulting mixture is more than 200 times greater than the volume of gasoline and its quantity is sufficient for optimal combustion.

The mixture has compressibility properties.

When injected into the engine cylinder, the proportions and ratios in the volume of the mixture do not change, due to the fact that the diameter of the bubbles with shells does not exceed 20–40 microns, due to the minimal size and compressibility, the mixture does not change its properties and geometric proportions during injection;

After injection into the cylinder, the pressure in which at the moment of injection is practically equal to atmospheric pressure, an adiabatic expansion of air occurs inside the bubbles, proportional to the difference in pressure inside the bubbles and in the cylinder.

The expanding air breaks the bubble shells into small fragments no larger than 3–5 microns and evenly envelops these fragments, while maintaining the volumetric proportions between gasoline and air sufficient for optimal combustion.

The entire process of converting the mixture – fuel composite into fuel mist, in which gasoline particles of 3–5 microns in size are uniformly mixed with a volume of air sufficient for optimal combustion, takes no more than 0.001 seconds.

Thus, ignition can be carried out immediately after the injection is completed and, due to the fact that time is not required for mixing gasoline with air, injection and subsequent ignition of the fuel mist are carried out at a time when the engine's motion conversion system is not in one of the dead points, in which at least 60% of engine power is lost.

Conservatively, the use of fuel mist with the properties described above can reduce power losses by 45–50%, and accordingly increase the specific power obtained per 1 gallon of gasoline.

b) If diesel fuel is used as fuel for a diesel engine:

A homogeneous mixture of diesel fuel with compressed air, in which compressed air (at a pressure of at least 5 atmospheres), in the form of bubbles no more than 50 microns in diameter, is uniformly distributed throughout the volume of diesel fuel, so that, due to the forces of surface tension and high viscosity, the diesel fuel forms a shell around the air bubbles

The volume of compressed air in the resulting mixture is more than 200 times greater than the volume of diesel fuel and its quantity is sufficient for optimal combustion.

The mixture has compressibility properties.

The mixture – fuel composite – is fed into the high-pressure pump, from where it is in-

jected into the diesel engine cylinder in an even more compressed form.

When injected into the cylinder of a diesel engine, the proportions and ratios in the volume of the mixture do not change, due to the fact that the diameter of the bubbles with shells during formation does not exceed 20–40 microns, and in a high-pressure pump, with strong compression, the size of the bubbles with shells is further reduced to 15–20 microns;

Due to its minimal dimensions and compressibility, the mixture does not change its properties and geometric proportions during injection;

After injection into the cylinder of a diesel engine, the pressure in which at the moment of injection is significantly less than in the bubbles, an adiabatic expansion of air occurs inside the bubbles, proportional to the difference in pressure inside the bubbles and in the cylinder of the diesel engine.

The expanding air breaks the bubble shells into small fragments no larger than 2–4 microns and evenly envelops these fragments, while maintaining volumetric proportions between diesel fuel and air sufficient for optimal combustion.

The entire process of converting the mixture – fuel composite into fuel mist, in which diesel fuel particles of 2–4 microns in size are uniformly mixed with a volume of air sufficient for optimal combustion, takes no more than 0.001 seconds.

Thus, compression in the cylinder and ignition can be carried out immediately after the injection is completed and due to the fact that time is not required for mixing diesel fuel with air, injection and subsequent compression and ignition of the fuel mist are carried out at a time when the motion conversion system in the diesel engine is not in one of the dead points, in which at least 50% of the diesel engine power is lost.

Conservatively, the use of fuel mist with the properties described above can reduce power losses by 40–45%, and accordingly increase the specific power obtained per 1 gallon of diesel fuel.

c) If natural gas is used as fuel for the internal combustion engine:

Before injection into the engine cylinder, natural gas and compressed air form a vortex tube in a vortex dynamic mixing device;

In this vortex tube, the natural gas flow is homogeneously mixed with cooled compressed air in a volumetric ratio of 9.7 to 1, and after mixing, the mixture – a fuel gas composite – is completely ready for combustion and does not require additional air.

The mixture, after leaving the hermetically sealed space, retains the state and proportions obtained during its formation in the vortex tube for more than 3 seconds.

Since the mixture is completely ready for ignition at the moment of injection, injection and ignition are performed at the moment when the engine's motion conversion mechanism is not in one of the dead points, and thus eliminate or reduce engine power losses to overcome dead points, which in a conventional engine can reach 60% or more.

This fact allows to reduce power losses for overcoming dead points by 45–55% and to increase the specific power developed by the engine per 1 cubic foot of natural gas in the same proportion.

But there are also known design solutions in which the authors assume that combustion in the cylinders will occur in accordance with the Otto cycle.

A quick analysis of the mechanics of such a solution leaves no doubt that it is very difficult or even impossible to build such an engine.

It is felt that the author of these inventions does not have such deep experience in creating crankless engines as multidisciplinary specialists in the field of smart technologies have;

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STABILITY AND SAFETY OF ENERGY-GENERATING EQUIPMENT OPERATION WITHIN SMART HOME INFRASTRUCTURE. (Issues of ensuring the stability and safety of energy-generating equipment operation within the infrastructure of a smart home (and smart garage space), including through various innovative aspects of cybersecurity)

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Cite: *Petrovych V. (2026). Stability and safety of energy-generating equipment operation within smart home infrastructure. European Journal of Technical and Natural Sciences 2025, No 1*. https://doi.org/10.29013/EJTNS-26-1-79-84

Abstract

The paper examines the autonomous operation of energy-generating equipment and the potential for effective operational management and online monitoring using embedded processors and controllers. It is demonstrated that, when properly formulated and economically justified, tasks related to computer modeling of equipment operating cycles can be performed using internal computational resources without the need for external systems. The study highlights modern engineering approaches to optimizing electricity generation processes, including the use of advanced fuel mixtures based on diesel fuel and methanol, with a growing trend toward increasing the methanol content up to 95–100%. Particular attention is given to the contribution of innovative publications by Dmytro Pastukh as an important source of engineering knowledge. The paper substantiates the necessity of rapid reconfiguration of control and management systems and the deployment of specialized software when fuel type and composition are changed. Special emphasis is placed on protective methods and devices that ensure reliable protection of control equipment without complicating operational schemes or requiring modifications to the base system design. The results support the feasibility of implementing mobile, simplified, and fully autonomous systems capable of ensuring stable equipment operation without the use of additional data carriers in industrial environments.

Keywords: *Smart home infrastructure, Smart garage infrastructure, Smart home ecosystem, Smart garage ecosystem, Stability and safety of energy-generating equipment, Innovative aspects of cybersecurity, Autonomous equipment operation, Additional data carriers, Computer modeling of energy-generating equipment operating cycle parameters, Operational scheme of energy-generating equipment, Circuit, kinematic, and schematic elements of energy-generating equipment*

Issues of ensuring the stability and safety of energy-generating equipment, including through various innovative aspects of cybersecurity.

Energy-generating equipment, during operation, is largely autonomous. Therefore, issues of operational management and online monitoring can be addressed within the capacities of its internal processors and controllers. In many cases, the tasks of computer modeling the parameters of such equipment's operating cycle, when formulated correctly and efficiently, can also be solved using the above-mentioned resources.

As a rule, modern electric power companies possess significant engineering resources to optimize electricity production processes, including the use of advanced fuel mixtures based on diesel fuel and methanol, with a tendency to increase the methanol proportion in the fuel mixture up to 95–100%.

Changing the type and composition of fuel requires the rapid reconfiguration of all control and management systems, along with the deployment of specialized software that takes into account all nuances and modifications in operating parameters, as well as in the calibration and adjustment of management and monitoring systems.

In industrial environments, protection methods and devices are required that, without complicating the schemes familiar to maintenance personnel, can nevertheless ensure reliable and comprehensive protection of control and management equipment. At the same time, such solutions must preserve nearly all schematic, kinematic, and fundamental design elements of the system while introducing new components that do not require modifications to the base equipment during adaptation.Industrial practice and experience have demonstrated the demand for mobile and highly simplified systems capable of ensuring autonomous equipment operation without involving additional data carriers in the operational schemes.

During the search and analysis of existing protection systems, specialists of a typical Electric Power Company conclude that the most economical and effective solution should be a system of information carrier protection, one that does not require substantial modifications to the structures and circuit solutions of power-generating equipment. Many electric power companies in their regions are pioneers in the use of methanol as an alternative fuel for power-generating gas turbines. The fundamental issues of such applications have been thoroughly addressed and professionally recommended in the publications of the well-known expert Dmytro Pastukh, based on his highly positive and successful professional experience.

Turbines of this capacity (20–25 MW) typically use Diesel Fuel No. 2 as their primary fuel. One of the original objectives pursued by the team of developers behind the new innovative technology was the utilization of so-called evaporation energy, which is the highest in methanol compared to other types of liquid fuels used in practice. To implement this and other innovative objectives, various modifications and optimizations of the turbine fuel system were explored. In addition to the complete replacement of diesel fuel with methanol, innovative options for dynamic mixing of methanol with small proportions of conventional diesel fuel were also developed.

Such dynamic mixing helped to mitigate the impact of certain methanol properties on the combustion process – primarily those associated with methanol's relatively low flame temperature. Considering the fact that today hundreds and even thousands of turbines with long operating histories are still in service, using heavy diesel fuels such as fuel oil, as well as natural gas, coal dust, and other types of fuels and fuel mixtures, it becomes logical to focus the analysis on the differences in systems for adapting devices for dynamic mixing of methanol with these fuels. This includes analyzing the mixing devices themselves, particularly in the light of the innovative publications of Dmytro Pastukh. Experimental trials and qualification testing confirmed the feasibility of key technical solutions in such devices, which demonstrated certain variations depending on the type of fuel and the number of components being mixed.

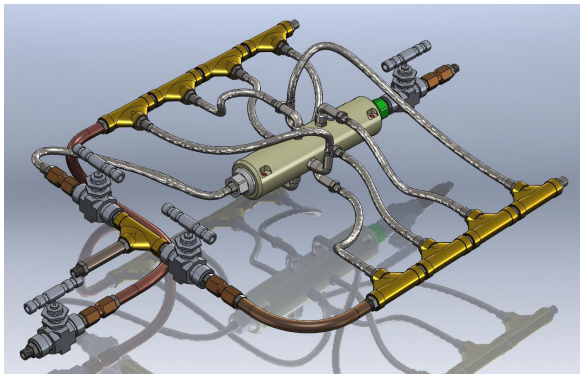
At the same time, despite the high level of unification and standardization of fuel preparation systems and fuel mixtures, the overall infrastructure and ecosystem of thermodynamic equipment remain highly dependent on the mobility and effectiveness of manage-

ment, monitoring, and calibration systems – including the ability to promptly adapt all incoming and outgoing signals in real time.

The expertise of practitioners in this area is of paramount importance, especially as presented in the professional publications of experts of such high caliber as Dmytro Pastukh. His books and articles provide well-founded justifications for adopting innovative organizational decisions in combination with the specific features and technical characteristics of existing power-generating equipment.

Moreover, the publications of Dmytro Pastukh offer essential starting information for organizing brainstorming sessions aimed at developing comprehensive technical solutions, the implementation of which allows reaching the level of the *ideal final result* in the modernization of existing power-generating equipment.

Figure 1.



The first image presents a three-dimensional model of a device designed for dynamic mixing of diesel fuel with methanol directly within the fuel line of thermodynamic equipment.

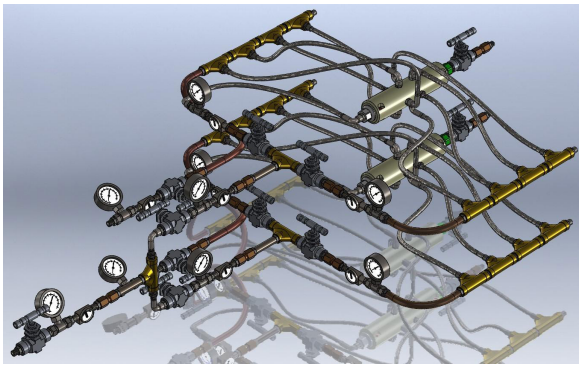
The device is extremely simple, and even in this configuration it can have at least two modes of application: as a static mixer (the device has no moving parts) and as a static online unit for homogenizing fuel or fuel mixtures directly in the fuel line.

Due to the particular uniqueness and complexity of power-generating equipment, the integration of even such a compact and simple device requires adequate adjustments to its operational characteristics. This, in turn, necessitates modifications to the processor software and onboard computers.

From the standpoint of mechanical and hydraulic installation, such replacement is absolutely standard and causes no complications. However, from the perspective of cybersecurity, the temporary pause required for program adjustment or replacement constitutes precisely the window and channel through which computer viruses may infiltrate the management and control system of thermodynamic equipment.

Given the inherent inertia of such systems, it can be assumed that detecting such infiltration would only be possible after a certain period of time, during which the most critical components of the equipment may be disabled.

Figure 2.



Moreover, if a dual mixing system is integrated with the equipment, the corresponding risk is practically doubled. In addition, if the system also includes recirculation of excess fuel, then under the influence of a hostile program, several times more units and mechanisms may be affected, further increasing the risks of modernization.

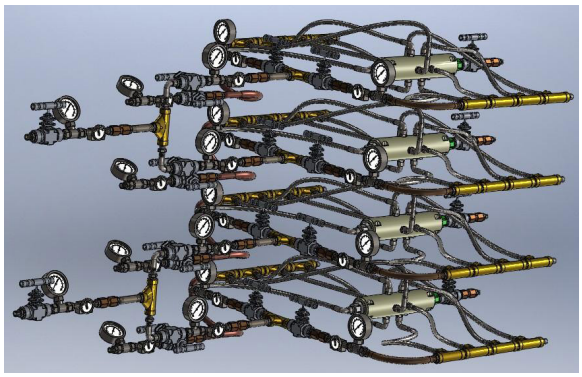
In real operating conditions, there is often a need for significantly greater volumetric or mass fuel consumption. This is due to the fact that the calorific value of methanol, compared to diesel fuel, is about two times lower, which, during modernization, requires an increase in fuel consumption by more than twofold.

This further complicates the modernization process and necessitates the inclusion of twice as many devices in the system, each with the full set of required control and management elements.

Such a system demands even greater power and capacity from processors and programmable controllers, which confirms the validity of the previous conclusions.

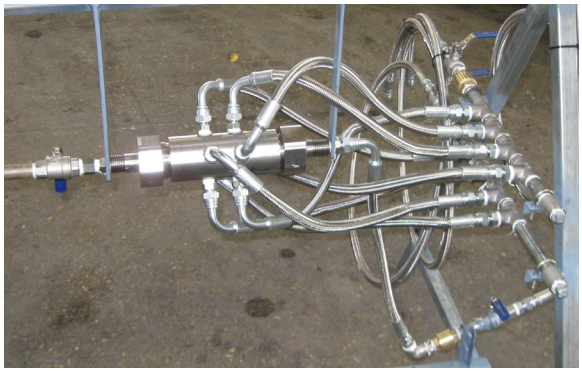
The next image shows such a quadruple system, comprising four independent and, if necessary, autonomous devices.

Figure 3.



Recently, powerful and high-performance systems have also emerged, which, in principle, can replace multi-element systems while delivering the same or even more efficient thermodynamic performance.

Figure 4.



The next image shows such a system with a capacity of 1,000 liters per hour. In this system, despite having only three external inlets and one outlet, the specifics of management, monitoring, and hydrodynamic coordination require no less extensive control and management operations, as well as equivalent potentials from management, monitoring, and modeling systems of the thermodynamic equipment's operating cycle. Thus, the importance of high-quality and guaranteed protection of operational software uploads into control-management and control-analytical tools remains at the highest level, regardless of the type and configuration of the device used for mixing fuel blends. If we consider the initial technical requirements for such systems, the following can be highlighted:

- data carriers must have original systemic protection;
- data carriers must include a system and methodology of identification equivalent to the information reading systems used in processor and on-board computer technology;
- the identification code must be applied to the data carrier in such a way that it does not alter the standard form and dimensions of the carrier's docking elements;
- the identification code must contain only one control-measurement parameter;
- the identification of this parameter must be performed in a non-contact manner.

The above represent some of the characteristic requirements; however, comprehensive compliance with these requirements is not currently ensured by existing mobile data carriers, which typically possess only some of the specified properties.

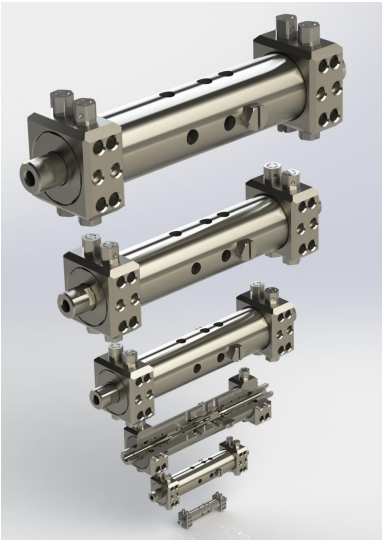
In this context, it is important to note that, after reviewing the highly relevant publications of **Corresponding Member of the Ukrainian Academy of Sciences, Dmytro Pastukh**, on this subject, our working group deemed it essential to test an information carrier coding system in accordance with his innovative proposals and recommendations outlined in his works.

As can be seen from these publications, the developments of Dmytro Pastukh in this field collectively ensure compliance with all of the above-mentioned technical requirements, as well as a considerable number of additional independent requirements and their combinations. Moreover, they open up a new and promising technological field – the magnetic-resonance, non-contact method of control and nano-measurements.

As a specialist in the operation of industrial energy-generating equipment, I regard the dissemination of this method among manufacturers and users of specialized computer technologies for power plants as the most effective approach.

Given that equipment for the mixing and preparation of fuel blends has a well-defined and highly effective scaling factor, it can be reasonably assumed that this coding system can be implemented across virtually all areas of the energy sector – not only in turbines but also in diesel generators, boilers, combined heat and power plants, and other thermodynamic equipment.

Figure 5.



The next image presents three-dimensional models of dynamic mixing devices arranged according to dimensional and scaling factors, where the smallest systems can be installed in household machines, while the largest are capable of operating with fuel consumption rates of tens of thousands of liters per hour.

The proposal of Dmytro Pastukh makes it possible to expand the areas of integration of energy innovation projects, which, at the scale of even a single power plant with a capacity of several tens of megawatts, could yield annual savings of hundreds of thousands of US dollars, while simultaneously providing the maximum possible and effective protection of the circuits and control systems of energy equipment.

Moreover, in modern energy systems, such a proposal demonstrates the originality of concept and thinking, as well as the unique extraordinariness of a new innovative technological and software direction. This approach, with relatively low costs, makes it possible to address one of the most critical challenges of contemporary energy – ensuring an adequate level of cybersecurity.

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MANAGING KEY CLIENTS IN AN INTERNATIONAL COMPANY: BALANCING PERSONALIZATION AND STANDARDIZATION OF SERVICE

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Abstract

The article describes how an international company manages its key customers, while striving for a single level of service and taking into account the individual needs and expectations of its large customers. In this article, we will look at how key customer management is carried out as a single system combining various functional areas. The factors that exacerbate the contradiction between personalization and standardization will also be analyzed: the geographical remoteness of teams, the diversity of markets, and the growing demands on service predictability and data management. The article discusses approaches that are successfully applied in international practice: fixing basic service standards, compiling a catalog of available options, determining the procedure for approving exceptions, and implementing a system of indicators reflecting quality, customer value, and cost of services. A stable balance between these factors is achieved through the formalization of decisions and their consolidation in documents and corporate information systems. This allows you to avoid inconsistencies in obligations between different departments and improve the manageability of the service.

Keywords: *key customers, key customer management, international company, personalization of service, standardization of service, quality of service, customer experience, performance indicators, procedure for approving exceptions, data management*

Relevance of the study

The relevance of the study is due to the fact that in most industries it is key customers who bring in a significant portion of revenue and determine the quality standards of interaction at all stages of cooperation: from initial negotiations and conclusion of contracts to service support, change management and joint development of solutions. In international companies, working with key clients is complicated by the multi-level management structure, the distribution of teams, and differences in national markets and business cultures. It is necessary to provide a single level of service, while adapting to local expectations. In such an environment, key customer management goes beyond the sales function and becomes an inter-functional management system that requires consistent processes, clear responsibilities, and measurable quality standards.

At the same time, there is a growing conflict between two approaches to service provision: personalization and standardization. Personalization significantly increases the value of the service in the eyes of customers, helps to strengthen trust and loyalty, allows you to more accurately take into account the specifics of business processes and risks of each client, and helps to build long-term partnerships. However, excessive individualization can lead to increased maintenance costs, complication of quality management, the emergence of so-called "manual" exceptions, increased dependence on individual managers, and increased risk of non-compliance with corporate and legal norms. Standardization, on the other hand, ensures the reproducibility of the service, comparability of indicators between different countries and departments, allows effective management of resources and costs, and meets the requirements of compliance with regulations and internal control. However, excessive rigidity of standards can reduce flexibility, degrade the customer experience, and limit a company's ability to maintain strategically important accounts in a highly competitive environment.

The problem is becoming particularly relevant in the context of digitalization and the growing demands on data management and the quality of customer processes. International companies are increasingly using unified platforms such as CRM and service systems, as well as common communication standards and service level agreements (SLAs). This leads to an increasing role of unified regulations. However, key customers expect an individual approach, predictable service and quick decision-making, especially when it comes to complex supplies, service contracts, project activities and maintenance in different countries. Therefore, the search for a balance between personalization and standardization is becoming an urgent task for scientific and practical specialists. This balance allows you to simultaneously increase value for key customers, control costs and risks, ensure uniform service quality and the sustainability of the operating model at the international level.

The purpose of the study

The purpose of this study is to substantiate a management model that will combine personalization and standardization of key customer service in an international company and develop a practical logic for implementing this model based on basic standards, a catalog of service options, the procedure for approving exceptions and a system of indicators.

Materials and research methods

The research examined scientific and practical materials on key customer management and service in international companies. In addition, open analytical data on customer requirements for the quality of service and the level of consistency in interaction were analyzed.

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The results of the study

Key Account Management (KAM) is considered in the scientific and practical literature as a strategic approach aimed at working with a limited number of the most important clients. The supplier allocates specialized resources and special attention from management to them in order to develop long-term relationships, increase their retention rate and stimulate joint growth. In general, KAM can be described as purposefully establishing and maintaining relationships with "key" customers who make a significant contribution to the company's performance and have high potential for development (Key Account Management | Research Starters | EBSCO Research).

In international companies, the concept of KAM is of particular importance. A key client is often present in several countries and business units, which requires the company to coordinate the interests of global and local management levels. It is necessary to ensure comparability of service approaches and a unified decision-making logic, while maintaining sensitivity to the conditions of a particular market. Scientific papers devoted to the international aspect of KAM emphasize that this concept serves as a tool for servicing large clients "on a global level" and is focused on long-term business relationships. This makes the issues of organizational coordina-

tion and the development of common principles that should be implemented at all levels of management especially important (Key Account Management in an International Context).

The theoretical basis of key customer management in an international company includes the principles of relationship marketing, customer value management, and inter-organizational interaction. The key customer is considered not only as a source of sales, but also as a partner with whom the processes of solution development, integration, quality assurance and risk management are coordinated. Within the framework of an international organization, these relations require formalization, as there is a risk of discrepancies in standards of service, communications and interpretation of obligations between different countries and departments. The ISO 44001:2017 standard is often used as the basis for management, which sets requirements for the identification, development and management of joint business relationships. This approach makes it possible to transfer relations from the field of individual arrangements to a managed system.

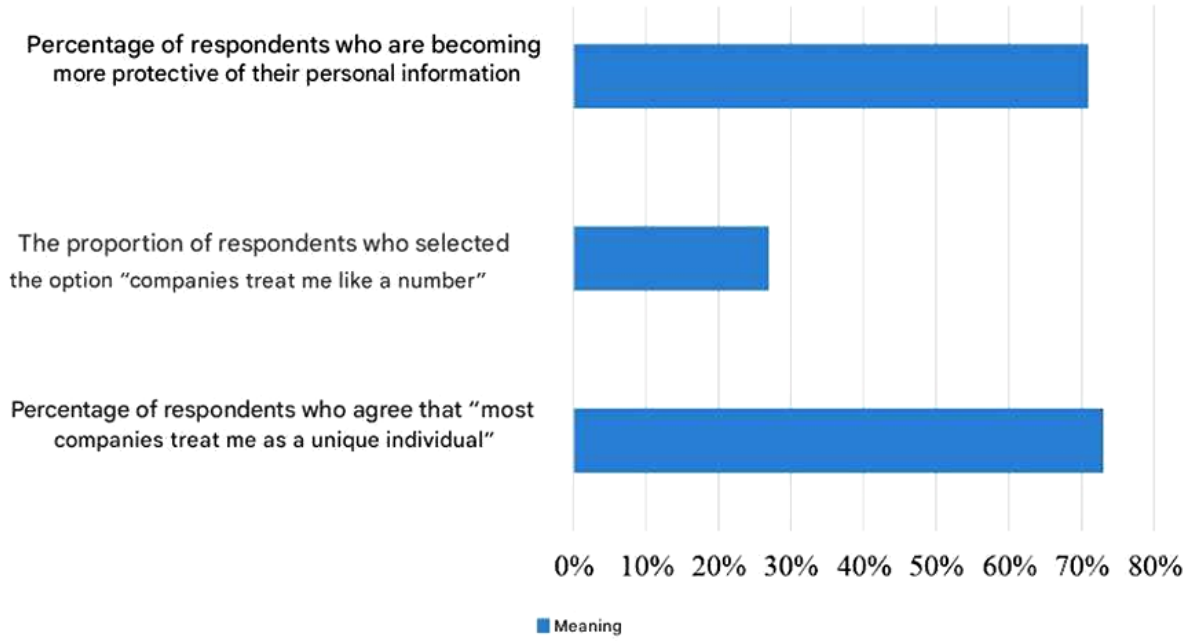
McKinsey's research on global B2B behavior demonstrates customers' growing expectations of service quality and consistency across all channels along the way. If basic expectations are not met, many purchasing companies are willing to consider changing suppliers. One McKinsey survey notes that more than 70% of respondents allow switching to alternative suppliers in such situations (Figure 1). These data are important for the KAM theory, as they confirm the need to combine work through relationships with reproducible standards of service and support availability, especially in an international company.

Figure 1. *Expectations of B2B clients for the interaction experience, in the absence of which they will look for another supplier (Future of B2B sales: The big reframe)*

In addition to B2B expectations, there is a general market trend towards increasing the importance of trust and respect for data in the process of personalized interaction. The Salesforce report "State of the AI Connected Customer" shows how the perception of personalization changes over time (Figure 2).

This means that in an international company, personalization of communication with key customers should be considered not as a "free setup", but as a managed practice. It should be closely linked to the principles of trust, transparency and compliance with data protection requirements, especially if the interaction is carried out through single digital platforms available in different countries.

Figure 2. *Indicators of personalization and attitude to data (State of the Connected Customer)*



In managing key clients in an international company, it is important to find a balance between standardization and personalization. To do this, it is necessary to use tools that ensure the same quality of service, but at the same time can be adapted to the specifics of each client. In practice, this means that the company sets a "mandatory minimum" of service, which should be the same for all countries and departments. These minimums include basic levels of support availability, escalation procedures, principles of customer data management, and uniform reporting requirements. Individual solutions are designed not as separate arrangements, but as predefined options that can be enabled according to clear rules. This approach avoids inconsistencies in customer promises between regions, reduces the dependence of the result on individual employees, and makes the service comparable in quality, cost, and risks (ISO – Quality management: The path to continuous improvement).

One of the key conditions for successful personalization is its formalization. Personalization should fit seamlessly into the standard process through documents, processes, and digital systems. Otherwise, it can turn into a set of exceptions that are difficult to control and scale. In an international company, this is especially important because of the distribution of teams and differences in local practices. The lack of a single language for describing the service leads to confusion in expectations, different interpretations of obligations, and reduced predictability of the service. Therefore, a set of tools occupies a central place in the model of the balance between standardization and personalization. Standardization fixes mandatory elements and rules, while personalization is limited to parameters that can be agreed upon, measured, and tracked in the system (Table).

The above system of tools makes it possible to effectively divide the balance into manageable components. Some of them are standardized and ensure quality stability, comparability of service, and risk control. The other part is personalized and creates direct value for a specific key customer. These aspects can be measured and reconciled. It is important to note that personalization in this model is not arbitrary. It is acceptable only to the extent that it can be documented, reflected in the system, and compared with resources and the expected effect.

The logic of balance in KAM becomes complete only when the tools are complemented by metrics and management control rules. Without uniform metrics, it is impossible to distinguish personalization, which truly adds value and retains key customers,

from costly exclusions, which increase the cost of service, create organizational overload and increase the risk of default. Therefore, for further development of the model, it is necessary to switch to a measurement system: to determine service quality indicators, including compliance with SLA and customer experience parameters, financial indicators for the account and the cost of service, as well as procedures for approving and reviewing individual conditions in the international circuit.

Table 1. *Managed personalization tools in KAM as a mechanism for balancing personalization and standardization*

The tool	Assignment in working with a key client	What is being standardized	What is personalized	Where it is fixed
The Key Client's plan	Account retention and development through a single action plan	Document structure, required sections, frequency of updates	Client's goals and priorities, growth initiatives, risk map	Approved plan, roadmap, CRM entries
Regular reviews	Managing expectations, monitoring progress based on results and service	Report format, basic metrics, preparation procedure	The agenda for the client, the depth of detail on projects	Minutes of the meeting, decisions, deadlines, responsible persons
Catalog of service options	Transparent «menu» of service options and conditions	List of services, descriptions, standard conditions, SLA framework	Package selection, set of additional options	Agreed set of services, connection conditions
SLA/OLA and the escalation matrix	Measurable quality of service and manageable escalations	Metric definitions, calculation rules, escalation levels	Support windows, dedicated channels, account priorities	SLA/OLA, escalation regulations, contacts
RACI (allocation of responsibility)	Role alignment between global and local levels	A single matrix format, a set of key processes	Specific implementers and owners of solutions	Matrix of roles, rules of coordination and substitution
Communication and reporting templates	A single level of quality for client messages	Required blocks, style, and frequency of reports	Accents for the industry and the client's tasks	Templates, communication calendar, report versions
Exclusion rules	Monitoring of non-standard promises and their cost	Criteria, approval procedure, limits	Individual conditions beyond the standard for justification	Application for exclusion, decision, term, effect
Unified CRM/ service system	Transparency of the history of interactions and commitments	Required fields, stages, data quality rules	Client context, account attributes, tags	Account card, tasks, requests, statuses
The client's stakeholder Card	Managing contacts, influence and risks of communications	Map format, and role classification	Specific individuals, expectations, relationship risks	Stakeholder map, interaction plan
Standards for working with customer data	Reducing legal and reputational risks	Rules for access, storage, consent, list of data	Customer preferences by channels and contact format	Consents, restrictions, and customer requirements

A source: author's development

It is advisable to build a practical implementation of the balance of personalization and standardization in an international company according to a consistent scheme, which first defines a single "framework" of the service, then introduces managed customization options, establishes rules for non-standard solutions, and completes the model by measuring results. This logic reduces the risk of disparate promises to the customer, ensures comparability of service quality between countries, and makes the service manageable.

At the beginning of the work, basic service standards are established – mandatory requirements that are minimal and uniform for all departments and markets. These standards define the rules for classifying requests, the order of their escalation, and the requirements for support availability, response time, and storage of client information in corporate systems. It is important that the basic standards are measurable and achievable. They serve as a common language of communication between employees and guarantee the predictability of service for customers.

Then a catalog of service options is developed, which allows you to move from "manual arrangements" to pre-defined solutions focused on individual needs. This catalog highlights basic elements and additional options such as enhanced support, more frequent reporting, dedicated communication channels, and regular collaborative reviews of results. For each option, its content, scope, terms of provision and necessary resources are set in advance. This approach provides flexibility without loss of manageability.

Then the procedure for approving exceptions is established – the rules that regulate any deviations from the basic standards and the catalog. Criteria are defined by which such deviations are considered acceptable, responsible persons are appointed, limits and validity periods are set, and mandatory justification is provided in terms of customer value, costs, and possible risks. This approach helps to protect the company from uncontrolled promises and reduce the likelihood of conflicts between global and local management levels.

The model is rounded off by an indicator system that serves as the basis for evaluating the quality of service, its value to the customer, and its cost. These indicators reflect the fulfillment of standards in terms of time and quality, customer feedback, as well as retention and development of cooperation. In addition, they take into account the workload of the team and the proportion of non-standard solutions. Based on the collected data, the basic standards, the catalog of options and the practice of exceptions are adjusted. This allows you to maintain a balance in different countries and market conditions.

Conclusions

Thus, it is important for international companies to find the optimal balance between personalization and standardization in working with key clients. This balance is achieved not by increasing the number of individual agreements, but by making them effective and measurable. The most effective is a consistent implementation strategy that includes the following steps: definition and consolidation of basic service standards as a mandatory minimum; development of a catalog of service options, which will allow you to control the process of customization; introduction of an exception approval procedure for monitoring non-standard obligations; the formation of a system of indicators that will assess the quality of the service, its value to the customer and the cost.

This model provides greater predictability and comparability of service quality between departments and countries. This reduces the risk of default and promotes the long-term development of key customers, allowing them to control costs and minimize risks.

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AWARDS FROM ACADEMIES AS A STIMULATING FACTOR FOR INNOVATION. (The Role of Public Academies of Sciences in the Targeted Formation of Activating Factors that Stimulate the Accelerated Development of Innovative Smart Technology Projects, Including Those Applying Elements of Artificial Intelligence and Artificial Neural Networks in Control and Monitoring Lines)

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Abstract

In the modern dynamic business environment, where organizations constantly face the challenges of a rapidly changing labor market, issues of employee compensation and motivation become key to successful performance. An effective reward system ceases to be merely a part of human resources policy and transforms into a strategic instrument capable of shaping corporate culture, strengthening engagement, and motivating teams to achieve common goals.

As demonstrated by real innovative practice, awards of public academies of sciences, as well as those of other academies, are important for specialists, since they confirm the high quality and novelty of their innovative projects, open access to grants and partnerships, enhance prestige, attract attention to developments (in the agro-industrial complex, IT, and medicine), and facilitate their implementation and integration into scientific and industrial communities.

The significance of these awards lies in the official recognition of contributions to science and technological development, which motivates researchers and provides an impetus for the further advancement of innovation in the country.

Awards of the Russian Academy of Natural Sciences recognize scientific and pedagogical achievements, stimulating innovation through public recognition of merits, support for new directions in science and education, and the popularization of advanced developments, which is essential for integrating science into practice and enhancing the authority of domestic science. They serve as indicators of quality and innovativeness, motivating researchers to create effective educational and scientific technologies and emphasizing the importance of implementation.

Keywords: *Public academy of sciences; stimulating factor; stimulating factor for innovation; activating factor; innovative smart technology projects; control and monitoring lines; awards of public academies of sciences for the novelty of innovative projects; popularization*

of advanced developments and their integration into production; motivation of researchers; concrete achievements in the development and implementation of new technologies, creation of world-class engineering solutions; stimulation of innovation through public recognition of merits

Awards of the **Russian Academy of Engineering** recognize outstanding contributions to science and technology, stimulating innovation through the acknowledgment of achievements in the development of new technologies, patenting, the creation of high-tech teams, and workforce training. This enhances the prestige of the profession and contributes to the technological development of the country. The significance of these awards lies in highlighting real engineering successes, motivating further discoveries, and influencing the innovation process through the popularization of advanced developments and their integration into production.

The **International Academy of Engineering** grants awards for outstanding contributions to engineering, the creation of new technologies and patents, as well as for workforce training. These awards stimulate innovative development, raise the prestige of the engineering profession, promote the implementation of advanced solutions, and strengthen international cooperation in science and technology, which is critically important for progress. The awards recognize concrete achievements in the development and implementation of new technologies, the creation of world-class engineering solutions, patenting, and the training of engineers, directly influencing the growth of innovative potential.

The **All-Ukrainian Public Organization "Ukrainian Academy of Sciences"** has united scientists and manufacturers from various sectors of the national economy. As the legal successor of the Ukrainian Academy of Sciences of National Progress, the UAS has its own anthem, flag, and other symbols. The main goals and objectives of the Academy include the study and generalization of scientific knowledge, promoting the fullest possible use of these achievements in the interests of Ukraine's socio-economic development, fostering the development and reproduction of the intellectual potential of society, disseminating scientific and technical achievements, and protecting the common interests of UAS members.

As an example, we cite the system of public stimulation of innovative activity created within the **International United Academy of Sciences (IUAS)** and successfully applied in everyday practice.

As demonstrated by real innovative practice, awards of the International United Academy of Sciences (IUAS), as well as those of other academies, are important for specialists, since they confirm the high quality and novelty of their innovative projects, open access to grants and partnerships, enhance prestige, attract attention to developments (in the agro-industrial complex, IT, and medicine), and facilitate their implementation and integration into scientific and industrial communities.

The significance of these awards lies in the official recognition of contributions to science and technological development, which motivates researchers and provides an impetus for the further advancement of innovation in the country.

Significance of Awards for Specialists:

Recognition and Prestige:

Receiving an award from a recognized academy constitutes a substantial confirmation of expert evaluation of one's work.

Support for Innovation:

Awards are often accompanied by grants, access to laboratories, and funding for the further implementation of projects.

Demonstration of Potential:

They make it possible to present developments to a broad audience, including investors and industrial partners.

Stimulation of Cooperation:

They open opportunities for joint research with other scientists and organizations.

Importance for Innovative Projects:

Identification of Promising Developments:

Academies highlight projects with practical orientation, prototypes, and implementation potential.

Integration into the Ecosystem:

They help projects enter the country's scientific and innovation infrastructure.

Stimulation of Interdisciplinarity:

Projects covering diverse fields – from IT to the agro-industrial sector – are recognized.

Typical Awarded Projects (Examples):

IT and Technologies:

Developments in artificial intelligence, quantum computing, and new materials.

Healthcare:

New diagnostic and treatment methods, pharmaceutical developments.

Agriculture:

Innovations in the agro-industrial complex.

Social Solutions:

Projects aimed at addressing pressing societal challenges.

Who Grants the Awards and How This Occurs:

Organizers:

Scientific and engineering communities, профильные ведомства (specialized government agencies), and technology parks.

Format:

Competitions and festivals of innovative projects with expert evaluation and public defense.

Thus, the awards of the **International United Academy of Sciences (IUAS)** are not merely a mark of honor, but a stimulating instrument for the development of science and technology, helping to bring advanced ideas from laboratories into the real sector of the economy.

What major scientific achievements of the last 10 years can be highlighted?

Let us present the five most significant developments and achievements of the past decade:

- Quantum computer;
- Synthetic DNA;
- The first landing in history on the surface of a comet ...;
- Detection of gravitational waves predicted by Einstein ...;
- Automotive autopilot systems.

The **Russian Academy of Natural Sciences (RANS)** was among the first to stimulate an innovative approach to the development of new promising projects, and its role in this process is recognized as exceptionally important.

Awards of the Russian Academy of Natural Sciences (RANS), such as the Gold Medal "For Innovative Work in the Field of Higher Education" and the Socrates Medal, recognize scientific and pedagogical achievements, stimulating innovation through public recognition of merits, support for new directions in science and education, and the popularization of advanced developments. This is important for integrating science into practice and enhancing the authority of domestic science. These awards serve as indicators of quality and innovativeness, motivating researchers to create effective educational and scientific technologies and emphasizing the importance of implementation.

In order to encourage scientists for scientific works, scientific discoveries, and inventions of major significance for science and practice, the Russian Academy of Natural Sciences awards prizes named after outstanding scientists.

Medals and prizes are awarded on behalf of RANS by the Presidium of RANS on the basis of the results of competitions announced by the Presidium of RANS, in accordance with the procedure established by these Regulations.

Medals are awarded for outstanding scientific works, discoveries, and inventions, or for a body of works of great scientific and practical significance.

In competitions for gold medals, only individual persons may participate personally. For prizes, works or series of works of a single thematic focus, as a rule by individual authors, may be submitted.

In competitions for medals and prizes named after outstanding scientists, both Russian and foreign scientists may participate, in accordance with the status of the medal or prize.

The right to nominate candidates for medals and prizes is granted to:

- Academicians and Corresponding Members of the Russian Academy of Natural Sciences (RANS);
- Research institutions and higher education institutions;
- Scientific and engineering-technical societies;

- Scientific councils;
- Scientific and technical councils of state committees, ministries, and agencies;
- Technical councils of industrial enterprises;
- Design bureaus;
- Teams of authors.

Scientific evaluation of all works submitted to the competition and the recommendation of candidates for the awarding of medals and prizes are carried out by expert commissions organized for each medal and prize.

The bureaus of the departments discuss the works and candidates nominated by the expert commissions for the awarding of gold medals and prizes.

Decisions of the Presidium of RANS on the awarding of medals and prizes are adopted by open voting and are considered approved if more than half of the members of the Presidium present at the meeting vote in favor.

Decisions of the Presidium of RANS on the awarding of medals and prizes, as well as brief abstracts of the works awarded gold medals or prizes, are published in RANS journals.

Medals, as well as diplomas certifying the awarding of medals, are presented to the recipients at sessions or conferences of RANS.

Awards of the **Russian Academy of Engineering (RAE)**, such as the Order of **"ENGINEERING GLORY,"** recognize outstanding contributions to science and technology, stimulating innovation through the acknowledgment of achievements in the development of new technologies, patenting, the creation of high-technology teams, and workforce training. This enhances the prestige of the profession and contributes to the technological development of the country. The significance of these awards lies in highlighting real engineering successes, motivating further discoveries, and influencing the innovation process through the popularization of advanced developments and their integration into production.

Main Awards and Their Significance:

Order of "ENGINEERING GLORY":

Awarded for a significant personal contribution to engineering, the creation of world-class engineering solutions, the successful implementation of new technologies, obtaining patents, освоение новой техники (mastery and deployment of new technologies), and workforce training.

Impact on the Innovation Process:

Stimulation of Developments:

Awards motivate engineers to create breakthrough technologies and to commercialize them.

Recognition and Prestige:

They raise the status of engineering activity, attract talented young people, and strengthen engineering schools.

Demonstration of Achievements:

Laureates become role models, and their projects serve as benchmarks for others, contributing to the dissemination of best practices.

Interstate Cooperation:

Awards are also granted to those who contribute to the development of engineering activities at the international level.

Thus, the awards of the Russian Academy of Engineering play a key role in shaping the innovation environment by recognizing those who advance Russian engineering thought and technology.

The **International Academy of Engineering (IAE)** grants awards for outstanding contributions to engineering, the creation of new technologies and patents, as well as for workforce training. These awards stimulate innovative development, raise the prestige of the engineering profession, promote the implementation of advanced solutions, and strengthen international cooperation in science and technology, which is critically important for progress. Awards such as the Order of **"Engineering Glory"** recognize concrete achievements in the development and implementation of new technologies, the creation of world-class engineering solutions, patenting, and the training of engineers, directly influencing the growth of innovative potential.

For major achievements in science, technology, the organization of production, and the implementation of advanced technologies, awards for the scientific and engineering community have been established in the following nominations:

- Order of **"Engineering Glory";**

- Gold Medal of the **International Academy of Engineering;**
- Badge of **"Engineering Valor".**

Recipients of the Order of "Engineering Glory"

The Order of "Engineering Glory" is awarded to:

- Heads of states and major international associations for leadership in engineering activities and for creating conditions for productive scientific and technological work, ensuring world-class achievements within a state or association;
- Members of the International Academy of Engineering who participate in the creation of a unified engineering space within the framework of the Academy, for a high level of scientific and engineering achievements;
- Representatives of states actively cooperating in the coordination of production and in solving engineering problems at a high scientific and technological level.

Grounds for Awarding the Order of "Engineering Glory"

The Order of "Engineering Glory" is awarded:

- For an outstanding personal contribution to the development of scientific and engineering activities;
- For outstanding achievements in the creation of engineering teams ensuring world-class technology;
- For outstanding results in the development and implementation of new technologies;
- For innovative activity in creating valuable patents and active participation in the deployment of new technologies;
- For major successes in the training and mentoring of scientific and engineering personnel;
- For active cooperation in solving interstate problems that contribute to the development of scientific and engineering activities.

The award is conferred by a resolution of the Presidium of the International Academy of Engineering for the above-listed merits, based on long-term productive scientific, engineering, governmental, and public service, upon the recommendation of the Awards Commission.

Main Awards of the International Academy of Engineering (IAE)

Order of "Engineering Glory" – the principal award for significant merits in engineering, including:

- Personal contributions to scientific and engineering activities;
- Creation of world-class engineering teams;
- Development and implementation of innovative technologies;
- Innovative activity and patents;
- Training of engineering and scientific personnel.

Significance of the IAE Awards

Recognition of Merit:

Officially acknowledges and rewards leading engineers and engineering teams.

Motivation:

Stimulates further research, development, and the implementation of advanced solutions.

Enhancement of the Status of Engineering:

Emphasizes the importance of the engineering profession for society.

Impact on the Development of Innovative Technologies

Stimulation of Innovation:

Awards for patents and new technologies directly encourage innovative activity.

Exchange of Experience:

They contribute to the dissemination of best engineering practices and world standards.

Support for Human Capital:

They recognize achievements in specialist training, ensuring an inflow of new ideas and solutions in the future.

International Cooperation:

They promote the resolution of interstate engineering challenges, uniting efforts for the development of science.

Thus, the awards of the International Academy of Engineering play a key role in shaping a favorable environment for innovative engineering creativity, the implementa-

tion of innovations, and the strengthening of engineering thought within global technological development.

Of particular interest is the **International Academy of Informatization**, established in Kazakhstan;

International Academy of Informatization (IAI)

The International Academy of Informatization (IAI) is an independent, self-governing public association of like-minded individuals in the fields of the study of the nature of information, information technologies, environmental and information-analytical activities, the informatization of society, and the creation of a unified global information community.

The Academy has its representative offices and branches in many regions of Kazakhstan, including the cities of Astana, Karaganda, Shymkent, Ust-Kamenogorsk, Petropavlovsk, Kostanay, Taraz, Aktobe, and Karatau.

Objectives of the Academy

- Formation of the infrastructure of the Republic of Kazakhstan as part of the unified global information space;
- Enhancement of the information culture of the population of the Republic of Kazakhstan and the global community;
- Forecasting the main directions of development of informatization in the Republic of Kazakhstan and the global community;
- Training of specialists and highly qualified scientific personnel; advanced training and retraining of specialists across all sectors of the national economy;
- Publication of industrial, scientific, educational-methodological, and information-analytical literature; issuance of newspapers and journals.

Constitution of the IAI

The Constitution was adopted at the General Assembly of the Academy and entered into force on October 2, 2014.

It includes the Mission, Motto, Value System, and Vision. The Mission reflects the essence of the Academy's activities and its social significance. The Motto concisely emphasizes the key aspects of the IAI's work. The Value System reflects the core features of the Academy's activities and unites the interests and aspirations of its members. The Vision presents how the Academy envisions its future.

The international status of the Academy is defined by the fact that its membership includes not only Kazakhstani scientists, but also representatives from neighboring and distant foreign countries. These are specialists who actively contribute to the development of informatization processes in Kazakhstan and in their respective countries.

At present, the Academy unites more than 1,600 prominent scientists, public figures, and government officials from many areas of science and practice who have made a significant contribution to the development of informatization in the country.

The IAI carries out its Mission through cooperation with public administration bodies, civil society institutions, international organizations, the media, and the social sphere, as well as across economic sectors. It is capable of conducting independent expert evaluations of socio-economic, innovative, and other programs and projects; providing extensive consulting services; and creating and maintaining various information databases.

The Academy annually organizes international scientific and practical conferences, the key theme of which is the monitoring of the current state and assessment of prospects for the development of informatization in Kazakhstan.

The Academy has its own website, which serves as an effective instrument for intellectual and informational communication, exchange of opinions, and dissemination of scientific and practical achievements of the global community.

Throughout its existence, the IAI has implemented a number of international and social projects. The Academy cooperates with various scientific organizations, public associations, ministries, and agencies, maintains international relations with UNESCO and the OSCE, and acts as an implementing partner of UNDP under programs for the introduction of ICT.

Regulations on Awards

These Regulations govern the procedure and processes, in accordance with Clause

2.3 of the Charter of the Public Association "International Academy of Informatization" (hereinafter referred to as the IAI), related to the establishment of awards and the awarding process, and determine the sources of financing for expenses associated with the production of awards and the awarding of IAI members.

These Regulations define the types and status of awards and regulate the procedure for nomination for awards.

Main Principles of Awarding IAI Honors

The main principles governing the awarding of honors by the International Academy of Informatization (IAI) are:

- Encouragement of IAI members who have made a significant contribution to the development of science, enriched science with discoveries and scholarly works, and who recognize the Charter of the IAI;
- Substantiation of awards;
- Transparency;
- Uniformity of requirements and equality of conditions for awarding.

IAI Awards

2.1. IAI awards constitute a form of recognition of merit and encouragement for a significant contribution to the development of national and global science, as well as for a substantial contribution to the development of informatization and the implementation of the IAI Mission.

2.2. The IAI awards include:

2.2.1. Honorary Badge – *"Academician of the IAI"*

2.2.2. Honorary Badge -*"Corresponding Member of the IAI"*

2.2.3. Honorary Badge -*"Adjunct of the IAI"*

2.2.4. Jubilee Medal -*"Gold Medal of the IAI"*

2.2.5. Jubilee Medal -*"Silver Medal of the IAI"*

2.2.6. Gold Order of the IAI

2.3. The Presidium of the IAI is also entitled to establish named prizes and other awards (breast badges and insignia) for outstanding scientific research and discoveries in various fields of science and culture.

Design of IAI Awards

The design of IAI awards, their descriptions, and samples of award certificates, as well as the form of the award nomination sheet and submissions, are approved by the President or the First Vice President of the IAI.

Manufacture, Documentation, Accounting, and Storage of IAI Awards

4.1. The manufacture, accounting, and storage of IAI awards and the certificate forms thereto are ensured by the IAI Directorate.

4.2. The procedure for accounting and storage of IAI awards and certificate forms thereto is established by orders of the IAI Directorate.

4.3. The preparation of award documentation and the accounting of award recipients are carried out by the IAI Directorate.

Eligible Recipients of IAI Awards

5.1. IAI awards are conferred upon members of the Academy who are:

5.1.1. Scientists who have made a substantial contribution to the development of national and global science and have enriched science with discoveries and scholarly works.

5.1.2. Employees of sectoral research institutes and higher education institutions of all profiles.

5.1.3. Specialists in Information and Communication Technologies (ICT) and other industries.

5.1.4. Employees of central and local executive authorities whose functions include matters related to the development of science.

5.2. Awarding different IAI honors for the same merits is not предусмотрено (not envisaged).

Nomination and Awarding Procedure for IAI Honors

6.1. Documents for nomination for IAI honors may be submitted by:

6.1.1. Members of the IAI (Academicians and Corresponding Members);

6.1.2. Heads of sections and regional structures of the IAI; heads of enterprises, organizations, and institutions regardless of

the form of ownership where the nominee is employed;

6.1.3. State authorities whose functions include matters related to the development of science, culture, and industry;

6.1.4. Heads of sectoral research institutes, universities, and colleges.

6.2. For awarding IAI honors, the following documents shall be submitted in the name of the President of the IAI:

- An award nomination sheet in the prescribed format;
- A petition by an organization or an IAI member nominating a candidate for an award, signed by an IAI member or by the head of the organization and affixed with the official seal.

6.3. The awarding of IAI honors is timed to coincide with anniversary dates of IAI members and with state and professional holidays of the Republic of Kazakhstan.

All-Ukrainian Public Organization "Ukrainian Academy of Sciences"

The All-Ukrainian Public Organization "Ukrainian Academy of Sciences" has united scientists and manufacturers from various sectors of the national economy. As the legal successor of the Ukrainian Academy of Sciences of National Progress, the UAS has its own anthem, flag, and other symbols. The main goals and objectives of the Academy are the study and generalization of science, promotion of the fullest possible use of these achievements in the interests of the socio-economic development of Ukraine, support for the development and reproduction of the intellectual potential of society, dissemination of scientific and technical achievements, and protection of the common interests of UAS members.

Through joint efforts of more than 25 research institutes, fundamental and applied research has been conducted, resulting in the development and implementation of the latest technologies, machines, materials, and equipment, including:

- Developments in the field of environmental safety in automotive engineering;
- Development of camouflage coatings to protect military equipment from detection by radar systems and night-vision devices;
- Development of protective anti-corrosion coatings for marine vessels;
- Development of special high-strength cast iron for the production of brake pads, gearboxes, and machine parts operating under load;
- Development of biologically safe monitors for televisions and computers;
- Development of special materials resistant to high temperatures;
- Development of simulators for training flight personnel and cosmonauts;
- Development of new pharmaceutical products and treatment methods in the field of human reproduction;
- Development of systems for the purification of industrial wastewater and drinking water;
- Development of non-traditional energy sources;
- Development of methods for restoring the fertility of Ukraine's chernozem soils;
- Development and implementation of expert systems and computer technologies;
- Development of radio-electronic systems and interactive multimedia systems;
- Research in the history of Ukrainian science and statehood;
- Subsurface tomography for the search for natural mineral deposits, and others.

The Academy comprises 15 regional branches, 3 educational institutions, more than 50 research institutes in Ukraine and worldwide, over 1,000 full members and corresponding members, 20 honorary members, and 50 foreign members.

To become a member of the Ukrainian Academy of Sciences, two recommendations from acting academicians or corresponding members are required. At the document preparation stage, more than 12 registration and rating forms are completed so that the Mandate Commission can objectively assess the significance of the scientist.

In the modern dynamic business environment, where organizations constantly face the challenges of a rapidly changing labor market, issues of employee compensa-

tion and motivation become key to successful performance.

An effective reward system ceases to be merely a component of human resources policy and transforms into a strategic instrument capable of shaping corporate culture, strengthening engagement, and motivating teams to achieve common goals.

Our analysis will focus on the challenges that modern companies face in the area of employee compensation and on how innovative methods can help them reach a new level of efficiency and employee satisfaction.

By opening a discussion on innovative approaches to compensation, we seek to provide readers with a foundational perspective on the topic, to emphasize the importance of this aspect of human resource management, and to draw attention to the key points that will be examined in detail in the following sections of the article.

In today's business world, there are many approaches to employee compensation, each with its own characteristics and advantages. However, in order to effectively analyze existing approaches, it is first necessary to understand their fundamental features and principles of operation.

One of the classical approaches to compensation is a fixed salary, which remains constant regardless of an employee's performance. This approach ensures stability and predictability of income, which may be an important factor for many employees.

The second approach is performance-based compensation. Here, remuneration directly depends on the results of an employee's work, which makes it possible to stimulate them to achieve better results. This approach is often used in sales and other fields where employee performance can be easily measured.

The third approach is competency- and skills-based compensation. In this case, employees are paid according to their level of qualification, experience, and skills, which encourages self-improvement and professional growth.

In addition, there are other approaches, such as flexible forms of compensation (for example, bonuses, incentives, company shares), as well as non-financial motivational mechanisms (for example, opportunities for professional development, recognition, and encouragement by management).

Understanding these different approaches to compensation will help companies choose the most appropriate strategy for their employees and achieve an optimal balance between financial incentives and motivation.

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Section 6. Information technology

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INTEGRATION OF CONTINUOUS TESTING INTO THE DEVELOPMENT LIFECYCLE OF CORPORATE WEB SYSTEMS USING THE EXAMPLE OF DRUPAL

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Abstract

The article describes how to integrate the continuous testing process into the development cycle of corporate web systems using the example of Drupal. It has been proven that moving quality control to earlier stages and regularly performing automated checks with each significant change in code, dependencies, and settings significantly reduces the risk of regressions and increases the predictability of releases. This article focuses on the features of Drupal as an enterprise platform: layered code, dependency management using Composer, and a configuration approach. Changes to settings can cause regressions in the same way as changes to the program code. In this paper, the characteristics of software quality are associated with various types of test checks. A comprehensive model for integrating these checks into the development and delivery process is proposed. The test results are recorded and serve as the basis for making decisions about which changes can be combined and implemented. In addition, the article outlines promising areas of development: strengthening security checks, using observability data, testing infrastructure, and using artificial intelligence tools to support quality control processes.
Keywords: *continuous testing, development lifecycle, enterprise web systems, Drupal, CI/CD, regression testing, Composer, configuration management, test automation, quality assurance.*

Relevance of the study

The relevance of the research is determined by current trends in the development of corporate web systems. Increasingly, these systems are being created and developed in an environment of constant change delivery and continuous integration. In such an environment, there is an increasing need not only to accelerate the release of new versions, but also to ensure consistent quality, security, and reliability of software products at all stages of the software development lifecycle (SDLC).

The traditional testing model, in which quality control is carried out mainly at the final stages of development, has ceased to meet the requirements of corporate projects.

It does not allow timely detection of defects, which reduces the predictability of releases and increases the total cost of errors. In response to these challenges, the concept of continuous testing has emerged, which involves automated quality checks at each stage of the system lifecycle (SDLC). This allows you to detect functional, technical, and business risks when making any changes to the system at an early stage.

The problem is becoming even more urgent due to the increasing complexity of software ecosystems and the increasing dependence of corporate web systems on external components, libraries, and services. In modern conditions, the security of the software supply chain is of particular importance. The integration of quality checks, dependency vulnerabilities, configuration correctness, and standards compliance directly into automated development and deployment pipelines (CI/CD pipelines) becomes a prerequisite for ensuring trust in the software product and its successful operation in the corporate environment.

Choosing the Drupal content management system as an example is also reasonable and relevant. Drupal is widely used to create corporate web platforms, government portals, large information systems, and multi-level digital ecosystems. These systems are characterized by high load, complex modular architecture, and regular updates to the core and extensions. In such circumstances, even minor problems that occur when updating components or changing configurations can lead to serious system failures and financial losses.

Thus, the study on the integration of continuous testing into the development lifecycle of corporate web systems using the example of Drupal is both scientific and practical. It meets the modern requirements of digital transformation, aims to improve the quality of software products and contributes to the creation of reproducible and manageable quality assurance models in modern corporate IT projects.

The purpose of the study

The purpose of this study is to substantiate and describe a model for integrating continuous testing into the development process of corporate web systems using the example of Drupal. This model should provide reproducible quality control, which is especially important when code, dependencies, and configurations change frequently.

Materials and research methods

The research is based on open publications and documentation on continuous integration and delivery practices, as well as various approaches to continuous testing. In addition, we used open sources that describe the architectural and operational features of Drupal, as well as the principles of automated testing within this ecosystem.

The work used methods of analytical review and generalization, comparative analysis of various approaches to quality control, modeling of the continuous process of integrating checks into the software development cycle (SDLC) and systematization of types of test checks according to software product quality criteria.

The results of the study

Continuous testing in the process of developing corporate web systems is an approach that allows you to seamlessly integrate quality control into the process of making changes. The essence of this approach is that checks are carried out regularly and automatically with each significant update of the code, dependencies or configurations. This approach allows you to quickly and objectively receive information about the changes made, identify potential regression risks, and determine whether it is safe to advance the build along the development and deployment chain. Unlike the traditional approach, in which testing is carried out only before release, the continuous model significantly reduces the likelihood of "accumulated" errors and reduces the cost of fixes due to earlier detection of defects (What is Continuous Testing?).

To better understand the role of continuous testing in the corporate development process, it is important to compare the verifiable characteristics of a software product with the types of test checks that are used in practice. In this context, the quality of software is not considered abstractly, but through its specific properties, which can be checked and controlled at various stages of the life cycle. This relationship clearly demonstrates which

aspects of quality can and should be validated through various types of testing when implementing a continuous verification system. (Table 1).

Table 1. Compliance of the quality characteristics of the software product and types of test checks

Quality Characteristics	What is usually checked	Which checks are most often used
Functional suitability	The correct performance of functions in accordance with the established requirements	Functional tests, regression tests, acceptance checks
Productivity and efficiency	Response time, bandwidth, and resource usage	Load testing, profiling, and performance tests
Reliability	Fault tolerance and fast recovery from failures	Fault tolerance tests, recovery checks, incident monitoring
Safety	No known vulnerabilities or insecure settings	Static and dynamic analysis, dependency scanning, configuration checking
Maintainability	The ability to analyze, modify, and test	Static analysis, difficulty level verification, testing, and review
Compatibility	Harmonious coexistence and interaction with other components	Integration and contract (API) tests
Ease of use	Meeting user expectations and ergonomic requirements	User testing, accessibility checks
Portability	The ability to migrate between environments and platforms	Build and deployment checks in target environments, as well as environment tests

A source: author's development

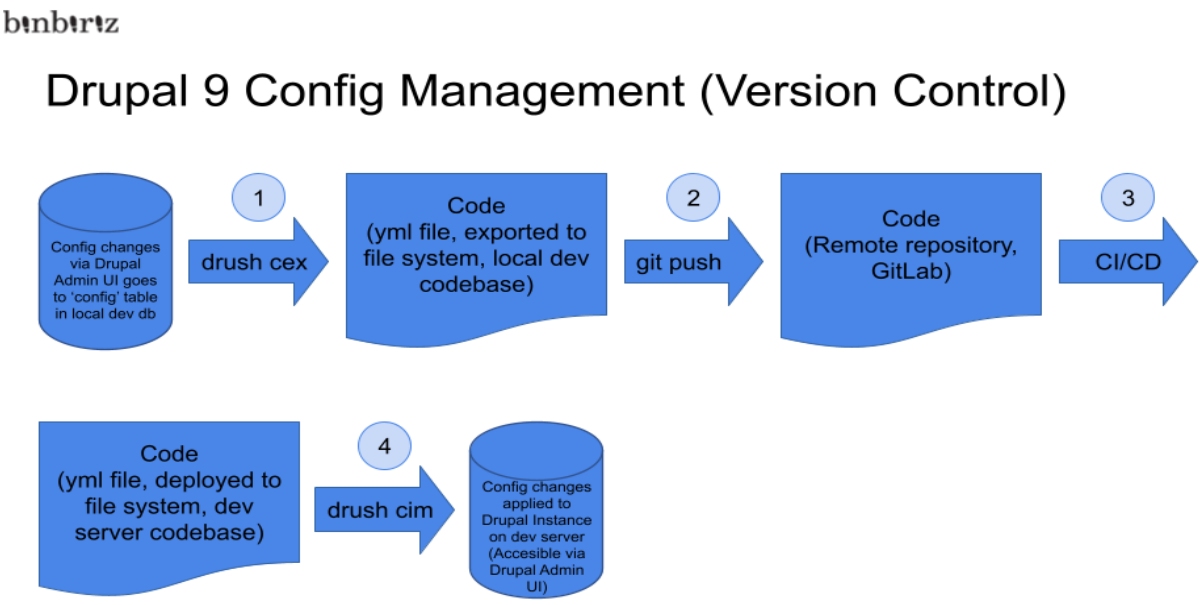
In practice, the effectiveness of continuous testing in corporate development is often assessed by the results of timely delivery and stability of changes. DORA (DevOps Research and Assessment) uses metrics that reflect the speed of change implementation and the stability of deployments. Based on these data, the research identifies performance clusters that allow you to see differences between groups of organizations in the ranges of values of key indicators (Design for a «flow diagram» to workflow configuration page).

Corporate web systems built on Drupal are not just a CMS website, but a full-fledged software platform. Business logic, integrations, and content management processes are implemented through its core, plug-ins, themes, and external libraries. For testing purposes, this means that the quality control object covers several levels: own project code (custom modules); community code; Drupal core; a set of dependencies of the PHP ecosystem, managed through Composer. During the operation of enterprise solutions, updates to the core and modules, changes in dependencies, and configuration discrepancies between environments become important sources of regression. Therefore, testing should include not only functional scenarios, but also build processes, dependency management, and configuration validation (Using Composer to Install Drupal and Manage Dependencies).

One of the key features of Drupal as an enterprise platform is advanced configuration management. Configuration objects that are stored and transferred between environments

through the configuration export and import mechanism (including the configuration synchronization interface) determine a significant part of the system's behavior. In practice, this means that changes in settings such as content types, fields, views, roles and rights, as well as module parameters, can be the same sources of regression as changes in the code. Therefore, the integration of testing should take into account the need to monitor configuration changes and their correctness when importing to test benches. Figure 1 shows an example of visualizing the configuration flow (export/import) as a typical process, which may be associated with risks of environment discrepancies and configuration migration errors.

Figure 1. Example of a Drupal configuration management workflow (export/import configuration) (Drupal Configuration Management Technical Stuff)

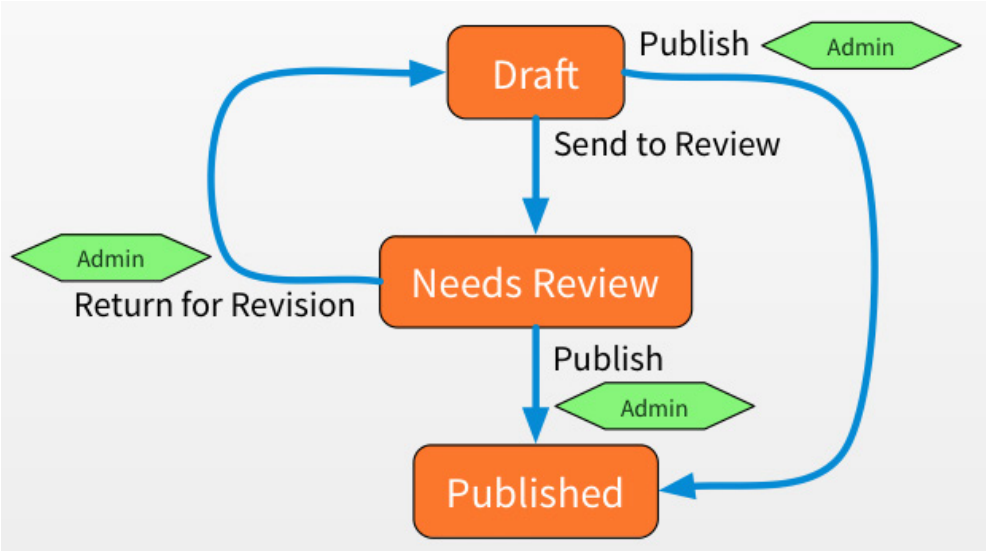


To organize automated testing, Drupal offers various types of PHPUnit-based tests, as well as recommended base classes for writing new ones. This is especially important for enterprise systems, as it allows you to create a multi-level verification model: from fast unit tests that test isolated logic, to functional and browser tests that test the entire system over HTTP, as well as tests with JavaScript behavior. This classification of tests provides a formal basis for selecting the minimum required set of checks for each change, as well as for separating tests by execution time and risk level.

To organize automated testing, Drupal offers various types of PHPUnit-based tests, as well as recommended base classes for writing new ones. This is especially important for enterprise systems, as it allows you to create a multi-level verification model: from fast unit tests that test isolated logic, to functional and browser tests that test the entire system over HTTP, as well as tests with JavaScript behavior. This classification of tests provides a formal basis for selecting the minimum required set of checks for each change, as well as for separating tests by execution time and risk level (Drupal core release schedule).

Finally, the specifics of corporate use of Drupal often include complex processes of working with content: stages of preparation and publication, roles and checks. Therefore, testing should cover not only pages and forms, but also business processes of approval and publication. As an example, below is a diagram illustrating the stages of the publishing process: draft → under review → published. This diagram clearly shows why regression can manifest itself not only in "page crashes", but also in violation of transitions and access rights at different stages of the content lifecycle (Figure 2).

Figure 2. An example of a publishing workflow diagram (content states and transitions) (Design for a «flow diagram» to workflow configuration page)



In the process of integrating continuous testing for Drupal, a key organizational decision is to link checks to each change that goes through the code review process. This allows you to confirm the quality of the changes even before they are combined and deployed. The SDLC (Lifecycle Management System) integration model is built around so-called "control points". These include building and installing dependencies, running automated tests, publishing test results, and deciding whether to allow changes to merge or release. An additional practical basis for this model is provided by the regulations for the release of kernel updates. Drupal patch versions are released monthly and are aimed at secure updates. Therefore, in corporate development, it is logical to accompany regular updates of the core and modules with a regular automated regression run.

Table 2 captures the "end-to-end" model in terms of SDLC: what exactly is embedded in the development flow and what results should be preserved so that the decision to promote the build is verifiable and reproducible.

Table 2. Continuous Testing integration model in SDLC for Drupal (verification flow and artifacts)

A stage in the development and delivery flow	What is controlled	What is saved as a result
Code/Configuration change → Merge request	The ability to build a project and install dependencies in accordance with the established rules (for projects using Composer)	Build log, fixed set of dependencies
Automated checks on the merge request	Running tests when changes are made and/or during the process of sending a merge request	Test reports, pipeline status, run artifacts
Release/update preparation (including kernel patch updates)	A pre-release regression check, given that patches are released regularly	Protocol of the run result, list of changes
Deployment	Using a verified build and confirming successful deployment	Build version, deployment log, result of post-checks

A source: (Release process overview)

Usually, the implementation of a continuous testing system (CI/CD) in Drupal begins with the project being created and maintained as managed using Composer, using official templates. This allows you to update and install dependencies via Composer. To automate tests, Drupal offers a PHPUnit infrastructure and documentation for running tests from the command line, including JavaScript tests. This allows you to create a pipeline in which tests will be automatically run on the CI server with each change. The Drupal ecosystem has documentation on enabling GitLab CI for projects on Drupal.org. And in the Drupal core repository, you can find the GitLab CI configuration (.gitlab-ci.yml), which confirms the practical use of this model.

As a result, the CI/CD continuous testing contour for Drupal boils down to a reproducible assembly of the Composer project, automatic test runs in the pipeline with each change, saving reports/artifacts of runs and applying these results as a formal condition for allowing the change to merge and further deploy.

The development prospects are related to the expansion of continuous testing capabilities beyond functional regression. First, special attention is paid to security. Regular checks of dependencies, configurations, and typical vulnerabilities during development, as well as testing of access rights and data processing scenarios, are becoming increasingly important. Secondly, the role of observability is increasing. Metrics, logs, and traces are used not only during operation, but also as a source of information to identify hidden defects and problems that arise after changes. Thirdly, infrastructure testing is actively developing. Infrastructure as code, reproducibility of environments, and correctness of deployments are checked. Finally, the use of AI for quality support (QA) is a promising area. Artificial intelligence helps to create test cases and data, analyze the causes of crashes, prioritize regressions, and identify unstable tests.

Conclusions

Thus, the integration of continuous testing into the development process of corporate web systems on Drupal becomes a necessary step for the controlled release of updates and reducing the risk of problems. The specifics of Drupal, including dependence on the core and modules, dependency management through Composer, as well as the important role of configurations and content creation processes, require testing not only functional scenarios, but also changes in dependencies and configurations between environments. The end-to-end testing model, based on automating checks with each change and recording the results of these checks as a formal condition for merging and deployment, allows you to make releases more predictable and increase the stability of the system during operation.

Development prospects are associated with increasing the level of security during the development process, the introduction of observability technologies to detect hidden defects, infrastructure testing, and the use of artificial intelligence tools to support quality control processes.

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