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CHEMISTRY

SYNTHESIS OF ADAMANTYL-CONTAINING QUINOLINE DERIVATIVES WITH ANTICANCER POTENTIAL

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Abstract

A new series of adamantyl-containing quinoline derivatives with potential anticancer activity was synthesized. The structures of all synthesized derivatives were confirmed using 1H-NMR, 13C-NMR, IR spectroscopy, and mass spectrometry. Most compounds demonstrated good activity against the MCF-7 and HeLa cancer cell lines.

Keywords: Quinoline, adamantyl, anticancer activity, rimantadine, midantane, aminomethyladamantane, p-adamantylaniline.

Introdaction

The epidermal growth factor receptor (EGFR) family of receptor tyrosine kinases consists of four members: EGFR/HER1/ErbB1, HER2/ErbB2, HER3/ErbB3 and HER4/ErbB4[1]. These receptors play a fundamental role in physiological cell growth, and 20% of breast cancers show high levels of HER2 protein expression or amplification of the HER2 gene, and all express at least one HER2 receptor to some extent [2,3]. Recurrent HER2 mutations have been found in breast cancer, non-small cell lung cancer, colorectal cancer and gastric cancer [4–7].

EGFR-mediated signaling pathways are critical for various biological processes, cancer progression and development, such as adhesion, cell proliferation, differentiation, migration and survival [8–10]. It has been found in many types of cancer such as ovarian cancer, breast cancer, colon cancer and others [11]. Tumors harbor (anchor) activating mutations in EGFR in patients with non-small cell lung cancer (NSCLC) [12]. Gefitinib (I) and erlotinib (II) (Figure 1) were the first drugs available for the treatment of NSCLC. Unfortunately, a secondary mutation threonine-methionine-790 (T790M) in the catalytic domain of EGFR is responsible for 50% of cases of clinically acquired drug resistance in patients with NSCLC [13–15]. Side effects are the main problems with higher doses of these compounds [16]. Given these challenges, fourth-generation EGFR tyrosine kinase inhibitors (TKIs) have been developed, representing a key step forward in extending patient survival [17]. Recent FDA approvals have highlighted the importance of several EGFR inhibitors, such as lapatinib (III) [18] and icotinib (IV), [19] as promising agents in the fight against cancer (Figure 1). In light of these advances, it is critical to innovate and develop new EGFR inhibitors with enhanced anticancer efficacy and minimal toxicity. EGFR inhibitors such as neratinib and bosutinib have shown that the quinoline moiety plays an important role in antitumor activity, especially the 4-aminoquinoline moiety.

Quinoline derivatives are key components of numerous bioactive compounds exhibiting a diverse spectrum of pharmacological properties such as antifungal, antibacterial, anti-inflammatory, antimalarial, and anticancer activities [20–25]. For example, neratinib (V) demonstrated significant inhibition of HER2 kinase with an inhibitory concentration (IC50) of 59 nM and EGFR with an IC50 of 92 nM in cell-free assays [26]. Furthermore, pelitinib (VI) exhibits potent anticancer activity through irreversible inhibition of EGFR [27]. Furthermore, bosutinib (VII) serves as an orally active dual Src/Abl kinase inhibitor, demonstrating enhanced inhibitory activity against Bcr-Abl in chronic myelogenous leukemia cell lines [28]. Based on the structural motifs of bosutinib and neratinib, novel hybrid compounds were developed. Compounds were synthesized that combine the quinoline moiety, a characteristic feature of these agents, with adamantyl-containing substituents, which are known to enhance the pharmacological effect or even impart new beneficial properties.

As shown in Figure 1, neratinib, pelitinib, and bosutinib share a common quinoline structure and are recognized as potent anticancer agent.

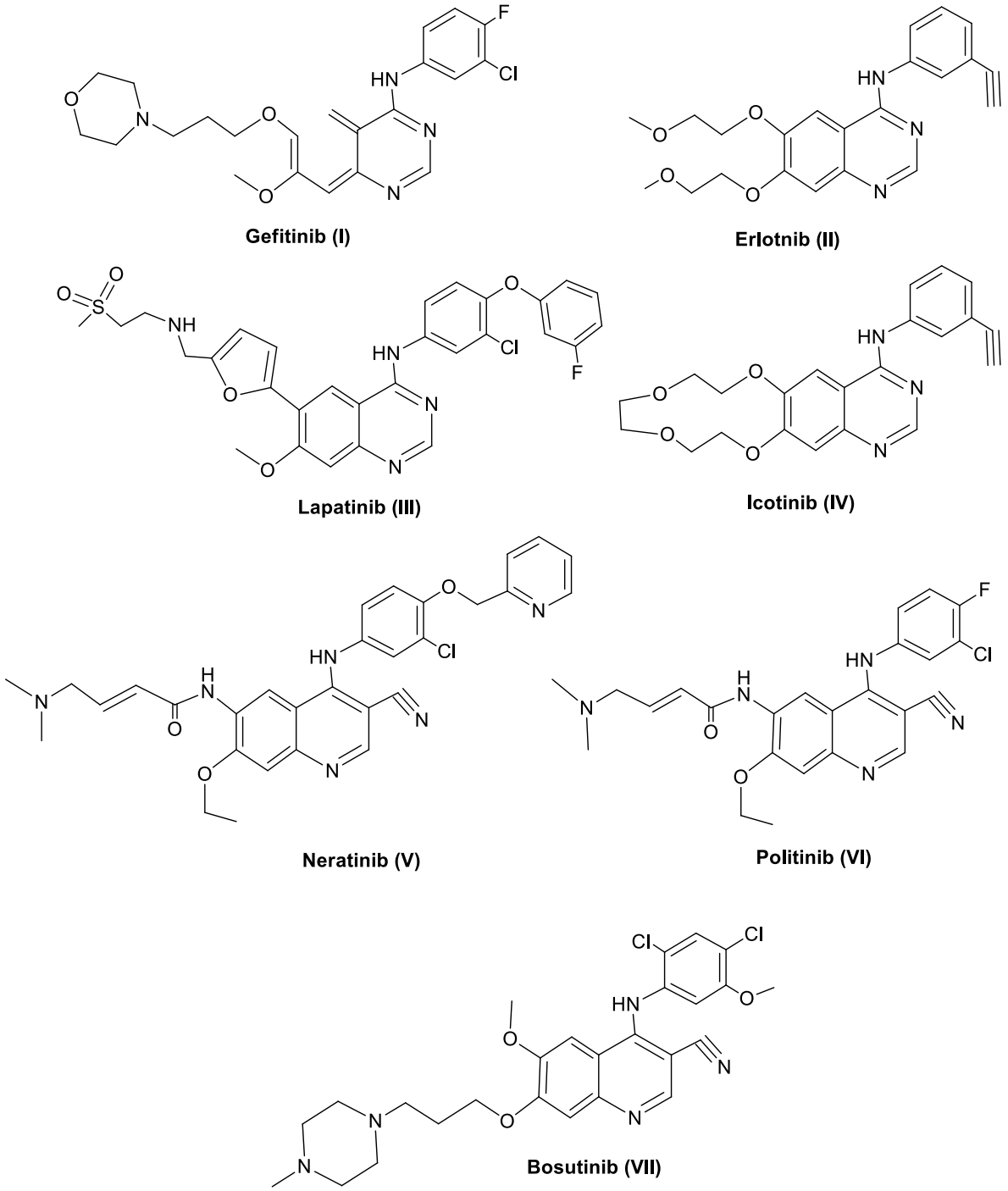


Figure 1. Neratinib, pelitinib, and bosutinib share a common quinoline structure and are recognized as potent anticancer agent.

Experimental

Materials.

Adamantyl-containing reagents: midantan, rimantadine, 1-aminomethyladamantane, p-(1-adamantyl)aniline were provided by Aldrich.

General Methods.

Reactions were studied by applying the reaction mixture to pre-coated Merck 60F254 plates and observing under ultraviolet light (UV 254 nm). Compounds were purified by column chromatography.

Melting points (MP) were determined using open capillaries and are uncorrected.

NMR spectroscopy was performed on a Bruker Avance 400 instrument (100 and 400 MHz for ^{13}C and ^{1}H, respectively). ^{13}C and ^{1}H NMR spectra in solution were obtained either in dimethyl sulfoxide (DMSO-*d6*) or in $CDCl_3$ with tetramethylsilane as an internal standard. Chemical shifts were recorded in parts per million (ppm). Mass spectra were obtained with a Shimadzu MS spectrophotometer. FTIR spectra were obtained with a Shimadzu FTIR spectrophotometer.

Reagent abbreviations used: LiOH (lithium hydroxide), HOBt (1-hydroxy-1,2,3-benzotriazole), EDC HCl (1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride), TEA (triethylamine), $MgSO_4$.

Synthetic procedure.

General experimental procedure for the synthesis of N-(7-chloroquinolin-4-yl)-amino)-4-methylbenzoates ***(2)****:* A reaction mixture containing 4,7-dichloro-

quinoline (1 eq.) and methyl 3-amino-4-methylbenzoate (or) ethyl 3-aminobenzoate (1 eq.) in ethanol was refluxed at 80 °C for 6–8 h, then the solvent was removed in vacuo. The resulting crude residue was diluted with water and then extracted with ethyl acetate. The extracted layer was dried over Na_2SO_4, filtered, and concentrated. The crude residue was purified by flash chromatography on silica gel (hexane/ethyl acetate) to afford compounds (2a–2b).

General experimental procedure for the synthesis of N-(7-chloroquinolin-4-yl)-amino-3-(4-methylbenzoic acid) ***(3).*** The reaction mixture containing compound (2) (1 g, 3.06 mmol) and lithium hydroxide monohydrate (1.3 g, 30.6 mmol) dissolved in THF/H_2O (1:2, 12 mL) was stirred overnight at room temperature and then concentrated in vacuo. The crude residue was acidified with 1 N HCl (pH 2) and extracted with ethyl acetate. The organic layer was washed with brine and dried over Na_2SO_4. The resulting solution was filtered, concentrated, and washed with pentane to afford pure compound (3) as a solid. The yield was 80-85%.

General experimental procedure for the synthesis of N-(7-chloroquinolin-4-yl)-amino-3-(4-methylbenzamides) ***(4a-4d):*** A reaction mixture containing the appropriate carboxylic acid (3) (500 mg, 1.59 mmol) in anhydrous DMF (5 mL) at room temperature was added anhydrous HOBt (215 mg, 1.59 mmol) and EDC HCl (304 mg, 1.59 mmol) in anhydrous medium. After stirring for 10 min, the appropriate adamantyl-containing amine (203 mg, 1.59 mmol) was added along with TEA (0.33 mL, 2.38 mmol), and the reaction mixture was stirred at room temperature for 12-16 h. Water was added to the reaction mixture, and the mixture was extracted with EtOAc. The organic layers were separated, washed with brine, dried over anhydrous Na2SO4, filtered, and concentrated under reduced pressure. The residue was purified by flash chromatography (hexane/ethyl acetate) to afford compounds (4a-4d) in 85-76% yields.

N-(7-chloroquinolin-4-yl)-amino)-4-methylbenzoates ***(2):*** Yield: 90%. Pale yellow crystals. M.p. 223–225 °C. ^{1}H-NMR (400 MHz, DMSO-d6, δ): 11.05 (s, 1H), 8.83 (d, J = 1.8, Hz, 1H), 8.50 (d, J = 6.8 Hz, 1H), 8.13 (s, 1H), 8.01–7.98 (m, 1H), 7.94 (d, J = 1.6, Hz, 1H), 7.92 (d, J = 2.0 Hz, 1H), 7.66 (d, J = 8.0 Hz, 1H), 6.30 (d, J = 6.8 Hz, 1H), 3.87 (s, 3H), 2.29 (s, 3H). ^{13}C-NMR (100 MHz, DMSO-d6, δ): 165.3, 155.4, 143.5, 141.3, 138.9, 138.3, 135.8, 132.1, 129.1, 129.0, 128.3, 127.3, 126.3, 119.2, 115.6, 100.1,52.2, 17.5. IR (KBr, cm^{-1}): 3105, 3008, 1716, 1604, 1537, 1294, 1207, 844, 756; MS *(m/z)*: $[M+H]^+$ = 327.

N-(7-chloroquinolin-4-yl)-amino-3-(4-methylbenzoic acid) ***(3):*** Yield: 85%. Pale yellow crystals. M.p. 285–287 °C. ^{1}H NMR (400 MHz, DMSO-d6, δ): 8.94 (s, 1H), 8.50 (d, J = 8.8 Hz, 1H), 8.34 (d, J = 5.2 Hz, 1H), 7.86 (d, J = 2.0 Hz, 1H), 7.78 (s, 1H), 7.76 (s,1H), 7.54 (dd, J1 = 2.0 Hz, J2 = 2.4 Hz, 1H), 7.30 (d, J = 7.6 Hz, 1H), 6.07 (d, J = 5.6 Hz, 1H), 2.16 (s, 3H). ^{13}C NMR (100 MHz, DMSO-*d6*, δ) 168.8, 151.8, 149.5, 149.34, 138.3, 136.8, 136.0, 133.7, 130.1, 128.2, 127.5, 127.4, 124.5, 124.4, 117.5, 100.7, 17.4; IR (KBr, cm^{-1}): 3437, 3354, 3251, 1521, 1406, 1369, 1327, 775; MS (*m/z*): [M + H]+= 313.

N-(7-chloroquinolin-4-yl)-amino-3-methoxybenzoate ***(2a):*** *Yield: 80%. Yellow crystals.* M.p. 196–198 °C; ^{1}H NMR (400 MHz, DMSO-*d6*, δ): d 9.82 (s, 1H), 8.54 (s, 1H), 8.30 (d, J = 8.8 Hz, 1H), 7.96 (s, 1H), 7.64 (d, J =8.0 Hz, 1H), 7.47 (s, 1H), 7.19 (s, 1H), 7.09 (s, 1H), 3.86 (s, 3H), 3.83 (s, 3H), 3.77 (s, 3H); ^{13}C-NMR (100 MHz, DMSO-*d6*, δ): 167.5, 153.9, 152.5, 149.4, 147.5, 144.9, 137.3, 134.7,127.9, 126.38, 123.7, 119.07, 113.3, 106.1, 103.3, 56.3, 56.2, 52.6; IR (KBr, cm^{-1}): 3439, 3010, 2968, 1739, 1612, 1529, 1435, 1363, 1271, 1209, 989, 781; MS (*m/z*): $[M+H]^+$ =373.

N-(7-chloroquinolin-4-yl)-amino-3-(4-methyl-methoxybenzoate) ***(2b):*** Yield: 80%. Yellow crystals. M.p. 85–87 °C. ^{1}H NMR (400 MHz, DMSO-*d6*, δ): 8.84

(s, 1H), 8.45 (d, J ¼ 7.6 Hz, 1H), 8.40 (s, 1H), 8.00 (s, 1H), 7.97 (s, 1H), 7.89 (s, 1H), 7.58 (s, 1H), 6.89 (d, J = 7.6 Hz, 1H), 6.67 (s, 2H), 6.15 (s, 1H). ^{13}C NMR(100 MHz, DMSO-*d6*, δ): 151.9, 151.7, 149.1, 148.8, 135.6, 133.6, 127.3, 124.9, 124.5, 124.4, 122.4, 118.0,113.7, 101.2; IR (KBr, cm^{-1}): 3458, 3352, 3020,2968, 2945, 1635, 1571, 1444, 1367, 1205, 906, 877, 812, 754; MS (*m/z*): $[M+H]^+$ = 315.

N-(7-chloroquinolin-4-yl)-amino-3-(4-methylbenz(1-adamantyl)amide ***(4a):*** Yield: 85%. White powder. M.p. 221–223 °C. ^{1}H NMR (400 MHz, DMSO-*d6*, δ): 11.87 (s, 1H), 8.32 (d, J = 4.4 Hz, 1H), 8.21 (d, J = 8.8 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 7.2 Hz, 1H), 7.44 (d, J = 8.8 Hz, 1H), 7.34 (d, J = 8.8 Hz, 1H), 6.57 (d, J = 4.8 Hz, 1H), 6.06 (d, J = 7.2 Hz, 1H), 1.92 (s, 3H), 1.48-1.95 (m, 15H). ^{13}C NMR (100 MHz, DMSO-*d6*, δ): 164.57, 151.9, 149.3, 149.05, 139.1, 138.0, 138.0, 133.8, 133.4, 131.3, 128.4, 127.7, 127.2, 126.4, 125.8, 124.8, 124.2, 121.9, 117.5, 101.2, 17.6. IR (KBr, cm^{-1}): 3296, 2976, 1653, 1564, 1519, 1487, 1323, 812, 744. MS (*m/z*): $[M+H]^+$ = 463.

N-(7-chloroquinolin-4-yl)-amino-3-(4-methylbenz(1-adamantylmethyl)amide) ***(4b):*** Yield: 81%. White powder. M.p. 240–242°. ^{1}H NMR (400 MHz, DMSO-*d6*, δ): 11.87 (s, 1H), 8.32 (d, J = 4.4 Hz, 1H), 8.21 (d, J = 8.8 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 7.2 Hz, 1H), 7.44 (d, J = 8.8 Hz, 1H), 7.34 (d, J = 8.8 Hz, 1H), 6.57 (d, J = 4.8 Hz, 1H), 6.06 (d, J = 7.2 Hz, 1H), 2.5 (s, 2H), 1.92 (s, 3H), 1.45-1.87 (m, 15H). ^{13}C NMR (100 MHz, DMSO-*d6*, δ): 164.57, 151.9, 149.3, 149.05, 139.1, 138.0, 138.0, 133.8, 133.4, 131.3, 128.4, 127.7, 127.2, 126.4, 125.8, 124.8, 124.2, 121.9, 117.5, 101.2, 17.6. IR (KBr, cm^{-1}): 3296, 2976, 1653, 1564, 1519, 1487, 1323, 812, 744. MS (*m/z*): $[M+H]^+$ = 477.

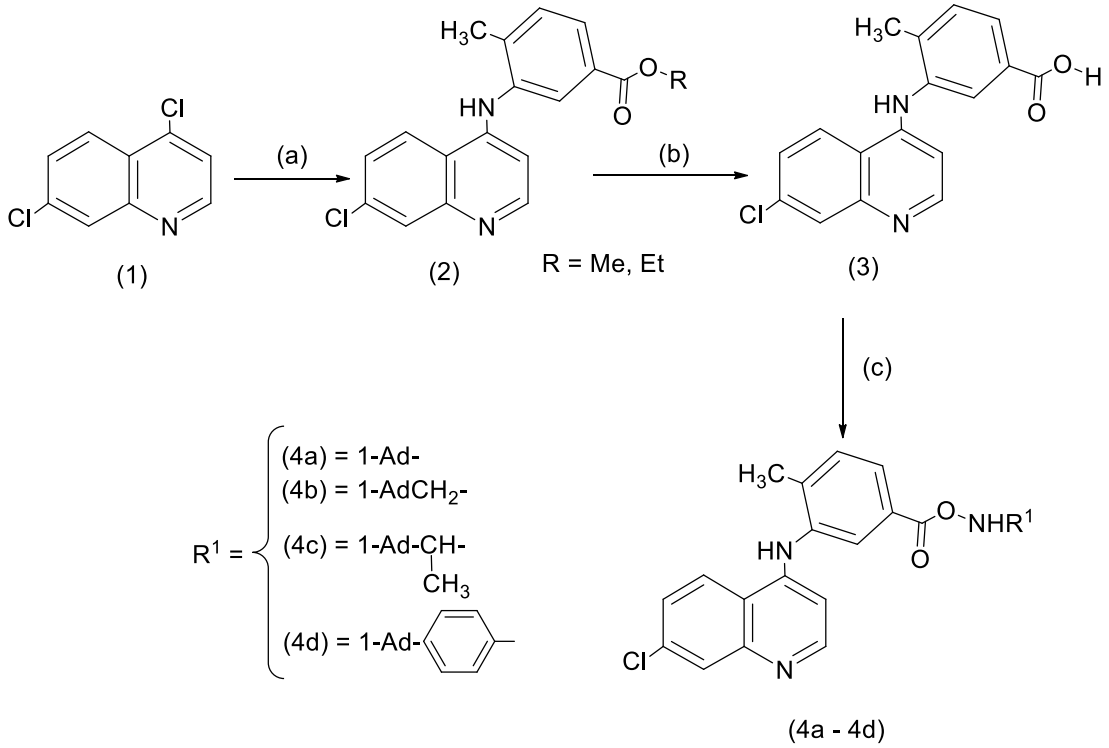
N-(7-chloroquinolin-4-yl)-amino)-3-(4-methyl-benz(1-adamantyl-1-ethyl)amide ***(4c).*** Yield: 76%. White powder. M.p. 219–221 °C. ^{1}H NMR (400 MHz, DMSO-*d6*, δ): 11.87 (s, 1H), 8.32 (d, J = 4.4 Hz, 1H), 8.21 (d, J = 8.8 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 7.2 Hz, 1H), 7.44 (d, J = 8.8 Hz, 1H), 7.34 (d, J = 8.8 Hz, 1H), 6.57 (d, J = 4.8 Hz, 1H), 6.06 (d, J = 7.2 Hz, 1H), 3.8 (m, 1H), 2.5 (s, 2H), 1.92 (s, 3H), 1.45-1.87 (m, 15H), 1.34 (d, 3H). ^{13}C NMR (100 MHz, DMSO-*d6*, δ): 164.57, 151.9, 149.3, 149.05, 139.1, 138.0, 138.0, 133.8, 133.4, 131.3, 128.4, 127.7, 127.2, 126.4, 125.8, 124.8, 124.2, 121.9, 117.5, 101.2, 17.6.

IR (KBr, cm^{-1}): 3296, 2976, 1653, 1564, 1519, 1487, 1323, 812, 744. MS (*m/z*): $[M+H]^+$= 491.

N-(7-chloroquinolin-4-yl)-amino)-4-methylbenz(1-adamantyl-4-phenyl)amide ***(4d).*** Yield: 83%. White powder. M.p. 183–185 °C. ^{1}H NMR (400 MHz, DMSO-*d6*, δ): 11.87 (s, 1H), 8.32 (d, J = 4.4 Hz, 1H), 8.21 (d, J = 8.8 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 7.2 Hz, 1H), 7.44 (d, J = 8.8 Hz, 1H), 7.34 (d, J = 8.8 Hz, 1H), 6.84 (d, J = 6.0 Hz, 2H), 6.57 (d, J = 4.8 Hz, 1H), 6.43 (d, J = 6.0 Hz, 2H), 6.06 (d, J = 7.2 Hz, 1H), 1.92 (s, 3H), 1.48-1.95 (m, 15H). ^{13}C NMR (100 MHz, DMSO-*d6,* δ): 164.57, 151.9, 149.3, 149.05, 139.1, 138.0, 138.0, 133.8, 133.4, 131.3, 128.4, 127.7, 127.2, 126.4, 125.8, 124.8, 124.2, 121.9, 117.5, 101.2, 17.6. IR (KBr, cm^{-1}): 3296, 2976, 1653, 1564, 1519, 1487, 1323, 812, 744. MS (*m/z*): $[M + H]^+$ = 539.

Results and discussion

Scheme 1 outlines the synthetic routes used to prepare the desired analogs. The synthetic route begins with the initiation of the synthesis process, in which 4,7-dichloroquinoline **(1)** reacts with both methyl 3-amino-4-methylbenzoate and ethyl 3-aminobenzoate. This reaction, carried out under reflux in ethanol, leads to the formation of the desired compounds **(2).** The resulting compounds **(2),** which inherently contain ester functional groups, are subsequently converted to the corresponding acid **(3)** via a reaction using LiOH in a tetrahydrofuran (THF)-water mixture, giving yields of 80-85%. In the final step of the synthetic work, compound **(3)** undergoes coupling reactions with various adamantyl-containing amines. This process, facilitated by the sequential addition of EDC HCl, HOBT, TEA, and DMF, yields the desired products **(4a–4d)** in impressive yields, ranging from 76% to 85% [29–32]. A comprehensive characterization of all synthesized compounds included thorough analysis using a variety of analytical techniques, including ^{1}H NMR, ^{13}C NMR, mass spectrometry (MS), and Fourier transform infrared spectroscopy (FTIR), which enabled the elucidation of their structures.



Scheme 1. Reagents and conditions: (a) various amines, ethanol, reflux at 80 °C for 6-8 h; (b) LiOH and H2O, THF/H2O, overnight, 80-85%; and (c) various adamantyl-containing amines, HOBt, EDC, HCl, TEA, DMF, room temperature, 15-17 h, 76-85%.

Conclusions

1.Adantyl-containing quinoline derivatives with potential anticancer activity have been synthesized.

2. Synthesis methods have been optimized.

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ECONOMY

ОЦЕНКА РИСКОВ, СВЯЗАННЫХ С ИЗМЕНЕНИЕМ КЛИМАТА, В ДОЛГОСРОЧНОЙ СТРАТЕГИИ РАЗВИТИЯ КОРПОРАЦИЙ

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ASSESSMENT OF CLIMATE CHANGE-RELATED RISKS IN THE LONG-TERM DEVELOPMENT STRATEGY OF CORPORATIONS

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Аннотация

В статье предложен методический подход к количественной оценке климатических рисков в системе долгосрочного стратегического планирования корпораций. Авторы обосновывают необходимость перехода от формальной декарбонизации к финансовому стресс-тестированию физических и переходных рисков. Разработан пошаговый алгоритм интеграции климатических факторов в инвестиционные решения, бюджетирование и ESG-отчетность. Особое внимание уделено специфике энергетического сектора и уязвимости инфраструктуры в условиях Центральной Азии.

Abstract

The paper proposes a methodological approach to quantitative climate risk assessment within the framework of long-term corporate strategic planning. The authors argue for a transition from declarative decarbonization to financial stress testing of physical and transition risks. A step-by-step algorithm is developed for integrating climate factors into investment decisions, budgeting, and ESG reporting. Special attention is paid to the specifics of the energy sector and infrastructure vulnerability in Central Asian conditions.

Ключевые слова: климатические риски, корпорации, стратегия развития, ESG, стресс-тестирование, декарбонизация, устойчивость, энергетический сектор.

Keywords: climate risks, corporations, development strategy, ESG, stress testing, decarbonization, resilience, energy sector.

Введение

Климатические аномалии 2025-2026 годов – от аномальной жары в Южной Европе до разрушительных паводков в Центральной Азии – со всей очевидностью продемонстрировали ограниченность традиционных моделей риск-менеджмента. Эти модели, как правило, ориентированы на краткосрочные финансовые и операционные колебания. Однако для крупных корпораций изменение климата превращается в стратегический вызов: оно затрагивает стоимость активов, надежность цепочек поставок, доступ к заемному капиталу, страховые тарифы и, в конечном счете, инвестиционную привлекательность бизнеса [9, 11].

Мы исходим из того, что финансовые рынки уже сегодня дифференцируют компании по качеству их климатической стратегии. Это не гипотетический сценарий, а реальность: кредитные рейтинговые агентства включают климатические факторы в оценку долговой нагрузки, а крупные институциональные инвесторы требуют раскрытия информации в соответствии со стандартами TCFD и IFRS S2 [7, 10]. Компании, не имеющие внятных планов адаптации, сталкиваются с удорожанием кредитования и риском недооценки со стороны рынка [4, 6].

Главная проблема, на наш взгляд, заключается в следующем. Многие корпорации декларируют цели по декарбонизации, однако не интегрируют климатическую адаптацию в операционную, инве-

стиционную и финансовую деятельность. Климатическая повестка остается в границах ESG-отчетности, тогда как ее потенциал для защиты стоимости бизнеса используется неполно.

Цель настоящей работы – усовершенствовать методический подход к количественной оценке климатических рисков и их интеграции в долгосрочную стратегию развития крупных корпораций. Для достижения этой цели мы последовательно рассматриваем виды климатических рисков, предлагаем алгоритм климатического риск-менеджмента и формируем матрицу стратегического реагирования с апробацией на примере энергетической отрасли.

Обзор литературы

В современной научной литературе климатические риски рассматриваются как комплексная управленческая категория, объединяющая природно-климатические, финансовые, регуляторные и инвестиционные аспекты. В докладах МГЭИК (IPCC) риск раскрывается через триаду: климатическая опасность, подверженность активов и уязвимость социально-экономических систем. Для корпоративного управления это означает, что риск формируется не только самим природным явлением, но и тем, где расположены активы, насколько устойчива инфраструктура и как выстроены процессы реагирования [9].

Материалы Всемирной метеорологической организации фиксируют усиление экстремальных погодных явлений: рост температуры, учащение засух, наводнений и других проявлений климатической нестабильности [11]. Эти выводы подтверждаются эмпирическими данными: с 1993 по 2022 год более 9400 экстремальных событий привели к прямому экономическому ущербу в размере почти 4,2 трлн долларов США (с поправкой на инфляцию). Для бизнеса это означает, что физические риски становятся фактором прямых потерь: повреждение основных средств, рост затрат на ремонт, перебои в поставках и увеличение страховых расходов.

В исследованиях Bruegel и других аналитических центров подчеркивается, что климатические катастрофы повышают не только частные, но и бюджетные издержки. Важный вывод для бизнеса: превентивные инвестиции в устойчивость инфраструктуры почти всегда оказываются дешевле, чем затраты на ликвидацию последствий после наступления климатического события [9].

Отдельный блок литературы посвящен раскрытию климатической информации. Рекомендации TCFD предлагают рассматривать риски через четыре измерения: корпоративное управление, стратегию, риск-менеджмент, показатели и цели [10]. Стандарт IFRS S2 развивает этот подход, требуя от компаний раскрытия информации о рисках и возможностях, существенных для пользователей финансовой отчетности [7].

Эмпирические исследования последних лет подтверждают значимость климатических факторов для финансовых показателей компаний. В работе Xu и соавторов установлено, что реализовавшиеся экстремальные климатические события оказывают значимое влияние на имплицитную стоимость собственного капитала компаний на международном уровне [12]. Liu и соавторы показали, что климатический риск на уровне дочерних структур может приводить к обвалам цен на акции всей группы компаний [8]. Кроме того, Demir и соавторы выявили, что инвесторы положительно реагируют на качественные раскрытия по всем четырем столпам TCFD, тогда как простое декларирование поддержки стандартов не приводит к росту рыночной капитализации [5]. Гупта на данных британских нефинансовых компаний продемонстрировал, что внедрение обязательного раскрытия по TCFD хотя и требует первоначальных инвестиций, но в итоге улучшает финансовые показатели (рентабельность активов и капитала) [1].

Вместе с тем, как показывают публикации последних лет, многие компании ограничиваются формальным включением климатической тематики в отчеты. Они испытывают трудности при внедрении климатических факторов в систему стратегического планирования, инвестиционного анализа и операционного управления [6]. Особенно это заметно в капиталоемких отраслях, где физические активы имеют длительный срок службы, а инвестиционные решения принимаются на горизонте 10-30 лет.

Таким образом, мы приходим к выводу: существующие исследования достаточно полно раскрывают классификацию климатических рисков и требования к раскрытию информации. Однако недостаточно разработан практический алгоритм, позволяющий перевести климатические сценарии в финансовые показатели и связать их с инвестиционной программой, бюджетированием, модернизацией активов и долгосрочной стратегией корпорации.

Постановка проблемы исследования

Ключевая проблема, на наш взгляд, носит управленческий, а не технический характер. В корпоративной практике климатическая повестка по-прежнему воспринимается как элемент внешней отчетности, а не как часть системы управления стоимостью бизнеса. Компании могут заявлять о целях по декарбонизации, однако редко оценивают, как изменение климата повлияет на конкретные производственные площадки, логистику, энергопотребление, страховые платежи и устойчивость поставщиков.

Эмпирические исследования подтверждают этот разрыв. Анализ компаний S&P 500 показал, что простое объявление о поддержке стандартов TCFD не приводит к росту акций в краткосрочной перспективе. Однако инвесторы положительно реагируют на качественные, детализированные раскрытия по всем четырем столпам TCFD [5]. Это означает, что рынок ценит конкретную стратегию и измеримые результаты, а не пустые заявления.

Кроме того, мы обращаем внимание на эффект цепочки поставок. В работе Liu и соавторов доказано, что климатический шок у дочерней компании

или ключевого поставщика может вызвать обвал цен на акции всей группы, даже если головной офис находится в безопасном регионе [8]. Xu и соавторы на данных по 38 странам показали, что фирмы из стран с наиболее высоким уровнем климатического ущерба сталкиваются со стоимостью капитала в среднем на 30 базисных пунктов выше, чем компании из стран с минимальным ущербом [12].

Отметим также специфику Кыргызстана. По оценкам Секретаря Совета безопасности Кыргызской Республики, среднегодовой ущерб от климатических изменений в стране составляет $30-50 млн, а при сохранении текущих тенденций может достичь $1 млрд [2]. Эмпирические исследования, проведенные в Кыргызстане в 2023-2024 годах, показывают, что более 80% сельских респондентов отмечают снижение урожайности за последние 10 лет, а дефицит поливной воды зафиксирован у 74% опрошенных домохозяйств [3]. Эти данные иллюстрируют, что физические климатические риски уже сегодня наносят ощутимый урон экономической деятельности в регионе.

Мы полагаем, что необходим методический подход, который объединяет климатические сценарии, картирование активов, финансовое стресс-тестирование и стратегические решения. Именно на решение этой задачи направлена предлагаемая ниже модель.

Методический подход к оценке климатических рисков

Предлагаемый нами подход базируется на последовательном сочетании сценарного анализа, геопространственного картирования активов, финансового стресс-тестирования и последующей интеграции результатов в стратегические документы корпорации. Его практическая ценность, как мы видим, состоит в том, что он позволяет связать климатические угрозы с конкретными управленческими решениями: инвестициями, модернизацией, диверсификацией и раскрытием информации перед инвесторами.

Ниже представлен пошаговый алгоритм, который мы рекомендуем для внедрения в корпоративную практику.

Первый этап – формирование организационного контура. Наш опыт показывает, что без закрепления ответственности на высшем уровне управления системная оценка рисков невозможна. Поэтому мы рекомендуем назначить ответственного члена совета директоров или создать профильный комитет. Кроме того, целесообразно сформировать кросс-функциональную рабочую группу из риск-менеджеров, стратегов, финансистов, инженеров и специалистов по логистике. Итогом этого этапа должно стать закрепление климатических KPI за топ-менеджментом.

Второй этап – определение временных горизонтов и климатических сценариев. Здесь мы исходим из того, что климатические риски реализуются медленнее обычных рыночных циклов. Стандартного горизонта планирования в 3-5 лет недостаточно. Для долгосрочной стратегии мы выделяем три горизонта: краткосрочный – до 2030 г., среднесрочный – до 2040 г., долгосрочный – до 2050-2060 гг. При этом мы рекомендуем использовать не менее двух контрастных сценариев:

- условно «зеленый» (SSP1-2.6) с ограниченным потеплением и высокими переходными рисками;
- критический (SSP5-8.5) с высокими физическими рисками и слабым регулированием.

Третий этап – идентификация уязвимостей и картирование активов. На данном этапе проводится геопространственный анализ производственных площадок, складов, транспортных узлов и критических поставщиков. Мы предлагаем использовать ГИС-технологии, климатические карты, данные о паводковых зонах, засушливости, температурных экстремумах и состоянии инфраструктуры. Результатом становится тепловая карта климатических уязвимостей компании.

Особо подчеркнем: для Центральной Азии таяние вечной мерзлоты и дефицит воды для охлаждения ТЭС – это не отдаленная перспектива, а уже фиксируемая реальность. Прогнозы CAWa (2025) указывают на возможное снижение стока рек Нарын и Чу на 15-20 % к 2040 году, что критично для гидрозависимых энергосистем.

Четвертый этап – количественная оценка и финансовое стресс-тестирование. Физические и переходные угрозы мы интерпретируем в финансовых показателях: рост операционных затрат, обесценение активов, снижение выручки, увеличение страховых платежей, рост капитальных расходов и возможные штрафы. На этом этапе рассчитываются потенциальные убытки, включая показатель Value at Risk (VaR), который позволяет оценить максимально возможные потери от климатических факторов на выбранном горизонте.

Пятый этап – интеграция результатов в бизнес-стратегию и инвестиционный план. Выявленные риски должны влиять на распределение капитала. Например, компания может перенести будущие мощности из зон повышенного риска, инвестировать в оборотное водоснабжение и энергоэффективность, модернизировать здания и оборудование, пересмотреть портфель углеродоемких активов или развивать низкоуглеродные направления.

Шестой этап – мониторинг, отчетность и раскрытие информации. Для укрепления доверия инвесторов и регуляторов мы рекомендуем регулярно раскрывать данные о климатических рисках, обновлять сценарные модели и пересматривать стресс-тесты. Как показывают эмпирические исследования, компании, внедрившие системное раскрытие по стандартам TCFD, в итоге улучшили свои финансовые показатели (рентабельность активов и капитала), хотя изначально это потребовало инвестиций [1].

Результаты исследования

Для практического внедрения климатического риск-менеджмента в стратегические документы мы предлагаем матрицу стратегического реагирования. Она связывает выявленную угрозу, климатиче-

ский сценарий, финансовые последствия и управленческое решение. Это позволяет перейти от общей экологической повестки к конкретным инвестиционным и организационным действиям.

Таблица 1

Пример матрицы стратегического реагирования на климатические риски

Выявленный риск	Сценарий	Финансовое последствие	Стратегическое решение
Аномальная жара / засуха	SSP5-8.5 (физический риск)	Остановка охлаждающих систем, дефицит воды для производства, рост операционных затрат	Инвестиции в оборотное водоснабжение, модернизация систем охлаждения, перенос площадок
Введение трансграничного углеродного регулирования	SSP1-2.6 (переходный риск)	Рост экспортных пошлин, снижение маржинальности на ключевом рынке, риск потери контрактов	Модернизация оборудования, переход на возобновляемые источники энергии, декарбонизация производственного процесса
Физический шок у ключевого поставщика	SSP5-8.5 (физический риск)	Риск обвала цен на акции компании из-за нестабильности поставок [8]	Картирование цепочек поставок, диверсификация поставщиков, страховые резервы
Рост стоимости капитала из-за климатической уязвимост	SSP2-4.5 (средний)	Увеличение стоимости заемного капитала на 30-50 б.п. [12]	Раскрытие информации по стандартам TCFD/IFRS S2, повышение ESG-рейтинга

Источник: составлено авторами.

В качестве эмпирической апробации мы применили предложенную логику к энергетическому сектору. Эта отрасль одновременно подвержена как физическим климатическим шокам, так и переходным регуляторным ограничениям. В энергетике климатические факторы влияют на надежность инфраструктуры, устойчивость генерации, стоимость топлива, структуру спроса и инвестиционные приоритеты.

Таблица 2

Матрица климатических шоков в энергетике

Тип риска	Конкретная угроза для ТЭК	Финансовые последствия	Стратегический ответ компании
Физический хронический	Таяние вечной мерзлоты в местах добычи и прокладки трубопроводов	Деформация опор ЛЭП, аварии на трубопроводах, рост OPEX на ремонт	Термостабилизация грунтов, мониторинг свайных оснований, изменение маршрутов
Физический острый	Аномальная жара и засуха, дефицит охлаждающей воды	Снижение мощности или принудительная остановка ТЭС/АЭС	Переход на воздушное охлаждение, модернизация водозаборов
Переходный регуляторный	Введение жесткой платы за углеродный след и квоты	Падение маржинальности угольной генерации, штрафы, рост стоимости капитала	Консервация неэффективных угольных блоков, инвестиции в ВИЭ и накопители энергии
Переходный рыночный	Снижение зимних пиков потребления вследствие мягких зим	Падение выручки от продажи тепловой и электрической энергии	Диверсификация бизнеса, развитие услуг энергоэффективности и зарядной инфраструктуры

Источник: составлено авторами.

Обсуждение результатов

Проведенный анализ позволяет сделать вывод, что климатические риски должны рассматриваться как фактор, напрямую влияющий на стоимость бизнеса. Если корпорация не оценивает уязвимость активов и цепочек поставок, она принимает инвестиционные решения на основе неполной информации. Это повышает вероятность будущих убытков, обесценения активов и потери конкурентных преимуществ.

Особое значение, на наш взгляд, имеет различие между расходами на превентивную адаптацию и затратами на ликвидацию последствий. Превентивные инвестиции в климатическую устойчивость экономически выгоднее, поскольку они позволяют заранее снизить операционные риски, сократить простои, уменьшить страховые потери и сохранить способность компании выполнять долгосрочные обязательства перед клиентами и инвесторами [9, 11].

Эмпирические исследования подтверждают этот тезис. Гупта на данных британских компаний показал, что внедрение обязательного раскрытия по TCFD, хотя и требует первоначальных организаци-

онных и финансовых затрат, в долгосрочной перспективе улучшает показатели рентабельности активов и капитала [1]. Demir и соавторы установили, что инвесторы готовы платить премию за компании с качественным раскрытием климатической информации [5]. Это означает, что инвестиции в климатическую адаптацию и прозрачность окупаются через снижение стоимости капитала и повышение рыночной оценки.

Вместе с тем мы осознаем ряд ограничений предлагаемого подхода. Во-первых, долгосрочное прогнозирование на горизонте 10-30 лет связано с высокой неопределенностью. Во-вторых, доступность точных метеорологических и геопространственных данных остается неодинаковой для разных стран и регионов. В-третьих, у многих компаний отсутствует внутренняя компетенция для перевода климатических сценариев в финансовые показатели. Поэтому мы рекомендуем применять методику гибко, с регулярным обновлением данных и постепенным повышением качества моделей.

Практическая значимость нашего подхода состоит в том, что он позволяет менеджменту перейти от формального раскрытия ESG-информации к управленческим решениям. Климатический риск-менеджмент должен быть встроен в процессы бюджетирования, инвестиционного анализа, управления активами, выбора поставщиков и оценки эффективности топ-менеджмента.

Заключение

Проведенное исследование позволяет нам сделать следующие выводы. Интеграция климатических факторов в долгосрочную стратегию корпораций – это не просто элемент экологической ответственности. Это условие сохранения финансовой устойчивости, рыночной стоимости и инвестиционной привлекательности бизнеса.

Предложенный алгоритм климатического риск-менеджмента включает шесть этапов: формирование организационного контура, выбор сценариев и горизонтов планирования, картирование активов, финансовое стресс-тестирование, интеграцию результатов в инвестиционную программу, а также регулярный мониторинг и раскрытие информации.

Для менеджмента корпораций мы рекомендуем:

1. Внедрять сквозной климатический контроль на уровне совета директоров;
2. Закреплять климатические KPI за топ-менеджментом;
3. Проводить стресс-тестирование ключевых активов не реже одного раза в два года;
4. Учитывать результаты оценки при распределении капитала.

Такой подход позволит не только снизить потери от физических и переходных рисков, но и укрепить доверие инвесторов, кредиторов и других заинтересованных сторон.

Перспективным направлением дальнейших исследований мы считаем разработку отраслевых моделей оценки климатических рисков, учитывающих специфику энергетики, промышленности, транспорта, сельского хозяйства и финансового сектора. Особое внимание следует уделить повышению точности исходных данных, адаптации международных стандартов раскрытия информации к национальным условиям Кыргызстана и других стран Центральной Азии, а также разработке методик оценки экономического эффекта от инвестиций в климатическую устойчивость.

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GEOGRAPHY

THE RUSSO-UKRAINIAN WAR THROUGH THE PRISM OF GEOECONOMICS: CONCEPTUALIZATION AND SYSTEMATIZATION OF THE ISSUE

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Abstract

Conflicts in the twenty-first century demonstrate that interstate confrontation is no longer limited to military operations; economic coercion mechanisms often exert an influence on conflict outcomes comparable to, or even greater than, direct military actions. In this context, the Russia–Ukraine war represents one of the most comprehensive and large-scale examples of modern geoeconomic warfare, where military operations have been accompanied by extensive use of financial sanctions, energy restrictions, trade barriers, technological controls, and various forms of pressure implemented through international financial systems.

The aim of this study is to examine the new strategies of contemporary geoeconomic warfare through the case of the Russia–Ukraine war. Particular attention is devoted to the economic instruments employed to achieve geopolitical objectives and to their impact on both the states directly involved in the conflict and the broader global economic system.

The theoretical framework of the study is based on the concepts of geoeconomics, economic statecraft, complex interdependence, and weaponized interdependence. The research employs a mixed-methods approach that integrates both qualitative and quantitative methodologies. The empirical analysis relies on data obtained from major international organizations, including the International Monetary Fund (IMF), the World Bank, the International Energy Agency (IEA), the World Trade Organization (WTO), the United Nations Conference on Trade and Development (UNCTAD), Eurostat, the National Bank of Ukraine, and the Federal State Statistics Service of the Russian Federation. Comparative, dynamic and statistical methods are applied throughout the study.

The findings indicate that the Russia–Ukraine war is not merely a military confrontation but also a geoeconomic conflict. The empirical analysis demonstrates that Western sanctions imposed on Russia have significantly affected the financial and technological sectors, although the Russian economy has partially adapted by redirecting economic activities and trade flows toward Asian markets. At the same time, the European Union has substantially reduced its dependence on Russian energy resources, thereby reshaping the energy balance of power in Europe. The study further reveals that the war has significantly altered international trade flows, strengthened the trend toward economic regionalization, and accelerated the fragmentation of the global economy.

One of the key contributions of this research is the development of an integrated model of geoeconomic warfare that combines financial, energy, trade, and technological dimensions within a unified analytical framework. This model provides a comprehensive tool for evaluating the effectiveness of geoeconomic pressure mechanisms and their influence on economic and geopolitical processes.

The study concludes that in the twenty-first century a significant portion of international power is shifting toward the economic sphere. The experience of the Russia–Ukraine war demonstrates that financial sanctions, energy policies, technological controls, and the management of international trade have become essential instruments of strategic influence in the hands of modern states. Consequently, geoeconomic warfare is emerging as one of the defining features of contemporary international relations, exerting a substantial impact on both national development trajectories and the transformation of the global economic order.

Keywords: Geoeconomic wars, sanctions, Russia-Ukraine war, energy, technological restrictions.

1. Introduction.

The twenty-first century has witnessed profound transformations in the nature of international competition. While military power remains an important component of state influence, economic instruments have increasingly become central mechanisms for achieving geopolitical objectives. The growing importance of economic instruments has become particularly evident in the context of the Russia–Ukraine war. Recent studies suggest that financial sanctions, trade restrictions, and technological controls increasingly serve as strategic instruments of interstate competition, often complementing or substituting traditional military means (Blackwill & Harris, 2016; Drezner, 2021; Farrell & Newman, 2019). Mastanduno (1998) further argues that economic instruments are often more flexible and politically acceptable than military interventions.

Globalization, financial integration, technological interdependence, and the expansion of international trade networks have created new opportunities for states to exercise power through economic means. Consequently, geoeconomics has emerged as one of the most influential approaches for understanding contemporary international relations.

The growing importance of geoeconomic instruments has become particularly evident in the context of the Russia–Ukraine war. Since the outbreak of the conflict in 2022, economic sanctions, energy restrictions,

trade controls, financial isolation measures, and technological embargoes have been deployed on an unprecedented scale. These developments have transformed the conflict into a multidimensional confrontation extending far beyond the battlefield.

The Russia–Ukraine war demonstrates that economic instruments can significantly influence both military capabilities and political decision-making processes. Furthermore, the conflict has accelerated structural changes within the global economy, including the regionalization of trade, the diversification of energy markets, the fragmentation of financial systems, and the emergence of alternative economic partnerships.

From the perspective of human geography and geoeconomics, the conflict provides a unique opportunity to examine how economic networks, spatial interdependencies, and strategic resources shape contemporary geopolitical competition. Therefore, analyzing the Russia–Ukraine war through the lens of geoeconomic warfare contributes not only to theoretical debates but also to a better understanding of current transformations in the international system.

Research Problem. Although numerous studies have examined the military, political, and diplomatic dimensions of the Russia–Ukraine war, less attention has been devoted to the comprehensive analysis of geoeconomic instruments and their effectiveness. Existing research often focuses on individual dimensions such as sanctions or energy security, while overlooking the broader interaction between financial, trade, technological, and energy mechanisms.

The central research problem of this study is to determine how geoeconomic instruments function within modern interstate conflicts and to evaluate their effectiveness through the case of the Russia–Ukraine war.

Research Aim. The primary aim of this research is to analyze the new strategy of geoeconomic warfare in the context of the Russia–Ukraine war and to assess the effectiveness of financial, energy, trade, and technological instruments in achieving geopolitical objectives.

Research Objectives. To achieve the research aim, the study pursues the following objectives:

1. To examine the theoretical foundations of geoeconomics and geoeconomic warfare.
2. To identify the principal geoeconomic instruments employed during the Russia–Ukraine war.
3. To assess the impact of financial sanctions on the Russian economy.
4. To analyze the role of energy resources as instruments of geopolitical influence.
5. To evaluate changes in trade patterns and economic partnerships.
6. To evaluate changes in trade patterns and economic partnerships.

Research Hypotheses. H1: Economic instruments have become as influential as military power in contemporary international conflicts; **H2:** The intensity of economic sanctions negatively affects economic growth and development; **H3:** Reducing energy dependence decreases the effectiveness of geoeconomic pressure; **H4:** The Russia–Ukraine war has accelerated the fragmentation and regionalization of the global economy.

Scientific Novelty. The scientific novelty of this research lies in the development of an integrated analytical model of geoeconomic warfare that combines financial, energy, trade, and technological dimensions within a unified framework. Unlike previous studies that focus on individual instruments, this research evaluates the interaction among multiple geoeconomic mechanisms and their cumulative impact on national economies and the global economic system.

Moreover, the study contributes to the field of human geography by incorporating a spatial perspective into the analysis of geoeconomic warfare, emphasizing the importance of economic networks, transportation corridors, energy infrastructure, and regional interdependencies.

2. Theoretical Framework

2.1. The Evolution of the Concept of Geoeconomics. The concept of geoeconomics has become one of the most influential analytical frameworks for understanding contemporary international relations. The increasing interdependence of national economies, the globalization of trade and finance, and the growing importance of technological innovation have transformed the ways in which states pursue power and influence. In this context, economic instruments have emerged as strategic tools capable of achieving objectives that were traditionally pursued through military means. The modern concept of geoeconomics is most commonly associated with Edward Luttwak (1990), who argued that the logic of conflict had increasingly shifted from military confrontation to economic competition. According to Luttwak, geoeconomics represents "the logic of conflict in the grammar of commerce," emphasizing that states increasingly employ economic instruments to achieve strategic and geopolitical objectives. Luttwak's argument emerged in the aftermath of the Cold War, when the decline of ideological confrontation and the expansion of global markets created new forms of interstate competition. Rather than relying exclusively on military capabilities, states began to use trade policies, investment strategies, technological innovation, and financial influence as instruments of national power. Subsequent scholars expanded the concept beyond trade and economic competition. According to Wigell (2016), geoeconomics should be understood as a strategic framework through which states pursue geopolitical objectives using economic means. Similarly, Scholvin and Wigell (2018) argue that geoeconomic competition increasingly shapes regional power dynamics. Contemporary geoeconomic strategies frequently involve financial coercion, investment policies, trade regulation, and infrastructure development (Blackwill & Harris, 2016; Roberts et al., 2019). Robert Blackwill and Jennifer Harris (2016) define geoeconomics as the use of economic instruments to promote and defend national interests and to produce beneficial geopolitical outcomes. Their work emphasizes that economic statecraft has become one of the primary dimensions of strategic competition in the twenty-first century. Today, geoeconomics encompasses a broad range of instruments, including:

- Economic sanctions;
- Trade restrictions;

- Financial controls;
- Energy policies;
- Technological regulations;
- Infrastructure investments;
- Supply-chain management;
- Currency and monetary policies.

As a result, geoeconomics has evolved into a multidisciplinary field that integrates insights from international relations, political economy, economic geography, and strategic studies.

2.2. Economic Statecraft Theory. One of the most important theoretical foundations of geoeconomics is the concept of Economic Statecraft. David Baldwin (1985) defines economic statecraft as the use of economic means to influence the behavior of other actors in the international system. According to Baldwin, economic resources can serve both coercive and persuasive functions. Economic statecraft generally operates through two categories of instruments:

Positive Instruments. Positive instruments seek to encourage cooperation through incentives, including:

- Foreign aid;
- Development assistance;
- Preferential trade agreements;
- Investment programs;
- Economic partnerships.

Negative Instruments. Negative instruments seek to alter behavior through pressure and coercion, including:

- Economic sanctions;
- Trade embargoes;
- Financial restrictions;
- Export controls;
- Asset freezes.

The Russia–Ukraine war provides a contemporary example of economic statecraft on an unprecedented scale. Western states have employed extensive sanctions and financial restrictions against Russia, while simultaneously providing economic assistance and financial support to Ukraine. Economic statecraft theory suggests that the effectiveness of such measures depends on several factors, including the target state's economic vulnerability, international coordination, and the availability of alternative economic partners.

2.3. Complex Interdependence Theory. A crucial theoretical perspective for understanding contemporary geoeconomic warfare is the theory of complex interdependence developed by Robert Keohane and Joseph Nye (1977). The theory challenges traditional realist assumptions that military power is the dominant form of international influence. Instead, it argues that globalization has created multiple channels of interaction among states, making economic relations increasingly important. According to Keohane and Nye, complex interdependence is characterized by:

- Multiple channels of interaction between societies;
- The absence of a clear hierarchy among international issues;
- The reduced utility of military force in certain policy areas.

Under conditions of interdependence, economic relationships become sources of both cooperation and vulnerability. States that depend heavily on external markets, technologies, or energy supplies may become susceptible to economic pressure.

The Russia–Ukraine conflict illustrates how interdependence can generate strategic vulnerabilities. Europe's dependence on Russian energy and Russia's dependence on Western financial systems both created opportunities for geoeconomic coercion.

2.4. Weaponized Interdependence. Building upon the concept of interdependence, Henry Farrell and Abraham Newman (2019) developed the theory of Weaponized Interdependence.

According to this framework, globalization has produced highly centralized international networks in areas such as:

- Finance;
- Technology;
- Telecommunications;
- Logistics;
- Data infrastructure.

States occupying central positions within these networks can leverage their structural advantages to influence or constrain other actors. Farrell and Newman identify two primary mechanisms:

Panopticon Effect. This mechanism allows states to monitor and collect information through their control of key network nodes.

Chokepoint Effect. This mechanism enables states to restrict access to critical networks and infrastructure, thereby exerting pressure on target actors.

The exclusion of selected Russian financial institutions from SWIFT represents a prominent example of the chokepoint effect. Similarly, export controls on advanced technologies demonstrate how network centrality can be transformed into geopolitical influence.

The theory of weaponized interdependence is particularly relevant for understanding the geoeconomic dimensions of the Russia–Ukraine war.

2.5. Sanctions Theory. Economic sanctions constitute one of the most widely used instruments of geoeconomic warfare. According to Gary Clyde Hufbauer et al. (2007), sanctions are deliberate restrictions imposed by one or more states to influence the policies or behavior of another state.

Financial sanctions represent one of the most powerful instruments of contemporary geoeconomic warfare. According to Baldwin (1985), economic coercion can alter the behavior of target states through the manipulation of incentives and constraints. Hufbauer et al. (2007) argue that sanctions are most effective when implemented multilaterally and maintained over a prolonged period. More recently, Drezner (2021) has emphasized that sanctions increasingly function as instruments of strategic competition in an interconnected global economy

Sanctions may take various forms:

- Financial sanctions;
- Trade sanctions;
- Technological sanctions;

- Diplomatic restrictions;
- Investment prohibitions.

Scholarly debates regarding sanctions generally fall into two categories. Optimistic Perspective

Supporters argue that sanctions can successfully alter behavior when:

- International cooperation is strong;
- The target state is economically vulnerable;
- The measures are comprehensive and sustained.

Skeptical Perspective Critics contend that sanctions often:

- Fail to achieve political objectives;
- Encourage economic nationalism;
- Promote alternative economic alliances;
- Generate unintended consequences.

The Russia–Ukraine war offers an important opportunity to evaluate these competing perspectives. While sanctions have imposed significant economic costs on Russia, they have also encouraged diversification toward alternative markets and financial arrangements.

2.6. Energy Geoeconomics. Energy has emerged as one of the most important dimensions of geoeconomic competition in the twenty-first century (Yergin, 2020). The strategic significance of energy resources is closely linked to national security and international power relations. According to the International Energy Agency (2024), disruptions in energy supply chains can generate significant economic and geopolitical consequences. The Russia–Ukraine war has demonstrated how energy dependence may be transformed into a mechanism of both cooperation and coercion (Eurostat, 2024). Control over energy resources, transportation routes, and infrastructure provides states with substantial geopolitical leverage. Energy geoeconomics encompasses:

- Oil and gas production;
- Energy transportation corridors;
- Pipeline networks;
- LNG infrastructure;
- Renewable energy technologies.

For decades, Russia utilized its position as a major energy exporter to strengthen its geopolitical influence in Europe. Conversely, European dependence on Russian energy created strategic vulnerabilities. The Russia–Ukraine war transformed this relationship. The European Union pursued diversification strategies, expanded LNG imports, and accelerated investments in renewable energy. These developments illustrate how energy interdependence can simultaneously serve as a source of cooperation and coercion.

2.7. The Integrated Model of Geoeconomic Warfare. Based on the theoretical approaches discussed above, this study develops an integrated model of geoeconomic warfare. The model conceptualizes geoeconomic warfare as a multidimensional process involving four interconnected components: Financial Dimension Includes:

- Financial sanctions;
- Asset freezes;
- Banking restrictions;
- Payment-system controls.

Energy Dimension Includes:

- Resource exports;
- Energy dependence;
- Infrastructure control;
- Market diversification.

Trade Dimension Includes:

- Export controls;
- Import restrictions;
- Supply-chain restructuring;
- Trade reorientation.
- Technological Dimension
- Includes:
- Technology embargoes;
- Semiconductor restrictions;
- Digital infrastructure controls;
- Innovation constraints.

Thus, these dimensions interact to influence the overall effectiveness of geoeconomic pressure.

The integrated model assumes that the effectiveness of geoeconomic warfare depends not on a single instrument but on the combined impact of multiple economic mechanisms. Consequently, the Russia–Ukraine war serves as an ideal case for examining how financial, energy, trade, and technological instruments interact within a broader geoeconomic strategy.

The theoretical framework demonstrates that geoeconomics has evolved into a central component of contemporary international relations. Drawing upon theories of economic statecraft, complex interdependence, weaponized interdependence, sanctions, and energy geoeconomics, the chapter establishes the conceptual foundation for analyzing the Russia–Ukraine war as a multidimensional geoeconomic conflict.

The integrated model proposed in this study provides the analytical basis for the empirical chapters that follow. By examining financial, energy, trade, and technological dimensions simultaneously, the research seeks to provide a comprehensive understanding of the new strategies of geoeconomic warfare in the twenty-first century.

3. Research Methodology

3.1. Methodological Foundations of the Study. This research adopts an interdisciplinary methodological approach that integrates perspectives from geoeconomics, human geography, international political economy, economic geography, and strategic studies. The study is based on the assumption that contemporary international conflicts can no longer be adequately explained solely through military or political variables. Instead, economic, financial, technological, and energy-related factors have become increasingly important determinants of state behavior and international power relations.

The methodological framework of this study is grounded in the **pragmatic research paradigm**, which allows for the combination of qualitative and quantitative methods within a single analytical framework (Creswell & Creswell, 2018). The pragmatic approach is particularly suitable for examining complex contemporary phenomena such as geoeconomic warfare, where both statistical evidence and theoretical interpretation are necessary for comprehensive analysis.

The study is further informed by several theoretical perspectives discussed in the previous chapter, including: Geoeconomic Theory (Luttwak, 1990); Economic Statecraft Theory (Baldwin, 1985); Complex Interdependence Theory (Keohane & Nye, 1977); Weaponized Interdependence Theory (Farrell & Newman, 2019). These theoretical approaches provide the conceptual basis for understanding how economic instruments function as mechanisms of geopolitical influence and strategic competition.

3.2. Research Design. The research employs a **case study design**, focusing on the Russia–Ukraine war as a representative example of contemporary geoeconomic warfare. According to Yin (2018), case study research is particularly appropriate when investigating complex phenomena within their real-world context. The Russia–Ukraine war constitutes a unique and highly relevant case because it involves the simultaneous application of multiple geoeconomic instruments, including:

- Financial sanctions;
- Energy restrictions;
- Trade controls;
- Technological embargoes;
- International financial isolation.

The conflict also provides an opportunity to evaluate the effectiveness of these instruments and to examine their broader implications for the international economic system.

The study combines descriptive, explanatory, and analytical elements. Descriptive analysis is used to identify major geoeconomic instruments, explanatory analysis seeks to understand causal relationships, and analytical methods are applied to assess economic outcomes.

3.3. Research Objectives and Questions. The primary objective of this research is to examine the new strategy of geoeconomic warfare through the case of the Russia–Ukraine war. To achieve this objective, the study addresses the following research questions:

RQ1. How has the concept of geoeconomic warfare evolved in contemporary international relations?

RQ2. What geoeconomic instruments have been employed during the Russia–Ukraine war?

RQ3. How effective have financial sanctions been in influencing Russia's economic performance?

RQ4. What role has energy dependence played in shaping geoeconomic interactions between Russia and the European Union?

RQ5. How has the conflict affected international trade patterns and global economic networks?

RQ6. What are the long-term implications of the Russia–Ukraine war for the global economic system?

3.4. Research Hypotheses Based on the theoretical framework and existing literature, the following hypotheses are formulated: **H1-** Economic instruments have become as influential as military power in contemporary interstate conflicts; **H2 -** The increasing intensity of sanctions negatively affects economic growth and development; **H3 -** Reducing energy dependence decreases the effectiveness of geoeconomic pressure; **H4 -** The Russia-Ukraine war has accelerated the fragmentation and regionalization of the global economy. These hypotheses are tested through empirical analysis presented in subsequent chapters.

3.5. Variables and Analytical Framework

The study employs an integrated analytical framework consisting of dependent, independent, and intervening variables. **Dependent Variable Effectiveness of Geoeconomic Pressure (Y)**

The effectiveness of geoeconomic pressure is measured through:

- GDP growth rates;
- Export and import performance;
- Foreign direct investment flows;
- Inflation dynamics;
- Financial stability indicators.

Independent Variables

Sanctions Intensity Indicators include:

- Number of sanctions imposed;
- Financial restrictions;
- Trade limitations;
- Asset freezes.

Energy Dependence Indicators include:

- Dependence on imported energy resources;
- Energy export revenues;
- Energy diversification levels.

International Trade Indicators include:

- Export volumes;
- Import volumes;
- Trade turnover;
- Trade partner diversification.

Technological Restrictions Indicators include:

- Export controls on advanced technologies;
- Semiconductor restrictions;
- Technology transfer limitations.

Intervening Variables The study recognizes several intervening factors that may influence outcomes:

- International economic support;
- Global energy prices;
- Exchange rate fluctuations;
- Domestic economic policies;
- Alternative trade partnerships.

These variables help explain variations in the effectiveness of geoeconomic instruments.

3.6. Data Sources and Data Collection. The empirical analysis is based on secondary data collected from international organizations, governmental institutions, and official statistical databases. **Macroeconomic Data**

- International Monetary Fund
- World Bank
- Organisation for Economic Co-operation and Development

Energy Data

- International Energy Agency
- Eurostat

Trade Data

- World Trade Organization
- United Nations Conference on Trade and Development

Ukrainian Sources

- National Bank of Ukraine
- State Statistics Service of Ukraine

Russian Sources

- Federal State Statistics Service
- Central Bank of Russia

The analysis covers the period from 2021 to 2025, allowing for the comparison of pre-war and wartime economic dynamics.

3.7. Methods of Data Analysis. To ensure a comprehensive assessment of geoeconomic warfare, several complementary analytical methods are employed.

Comparative Analysis. Comparative analysis is used to examine differences and similarities between:

- Russia's economic performance;
- Ukraine's economic performance;
- European Union energy policies.

This method helps identify the differential impacts of geoeconomic instruments on various actors.

Time-Series Analysis. Time-series analysis is applied to evaluate changes in key indicators over time, including:

- GDP growth rates;
- Trade volumes;
- Energy dependence levels;
- Inflation rates.

The method facilitates the identification of trends associated with the implementation of geoeconomic measures.

Statistical Analysis. Descriptive statistical techniques are used to summarize and interpret economic data. These include:

- Means;
- Growth rates;
- Percentage changes;
- Index calculations.

The objective is to quantify the economic consequences of sanctions, energy disruptions, and trade adjustments.

3.8. Reliability and Validity. To ensure the reliability and validity of the research findings, several methodological safeguards are employed.

Reliability. Reliability is strengthened through the use of official datasets from internationally recognized institutions. Multiple data sources are compared to minimize measurement errors and inconsistencies.

Internal Validity. Internal validity is enhanced through the integration of theoretical and empirical analysis, allowing causal relationships to be evaluated systematically.

External Validity. Although the Russia–Ukraine war represents a unique case, many of the findings may be applicable to other contemporary geoeconomic conflicts and sanctions regimes.

3.9. Research Limitations. Several limitations should be acknowledged. First, the Russia–Ukraine war remains an ongoing conflict, meaning that some long-term economic consequences have not yet fully materialized. Second, access to certain Russian statistical indicators has become more restricted since 2022, potentially affecting data availability and transparency. Third, differences among international datasets may lead to variations in reported economic indicators. Fourth, sanctions often produce delayed effects, making it difficult to assess their full impact within a limited time horizon. Despite these limitations, the combination of multiple data sources and analytical methods provides a robust basis for evaluating the effectiveness of geoeconomic instruments.

3.10. Methodological Contribution of the Study. The methodological contribution of this research lies in the development of an integrated framework for analyzing geoeconomic warfare.

Unlike conventional studies that focus on a single dimension of economic pressure, this research simultaneously examines:

- Financial sanctions;
- Energy dependence;
- Trade transformation;
- Technological restrictions.

Furthermore, the study incorporates a geographical perspective by emphasizing the role of spatial networks, transportation corridors, energy infrastructure, and regional economic interdependencies.

The resulting framework offers a comprehensive methodological model for future research on geoeconomic conflicts and economic statecraft.

This chapter has outlined the methodological foundations of the study, including the research design, objectives, hypotheses, variables, data sources, and analytical methods. By adopting a mixed-methods approach and integrating multiple theoretical perspectives, the study provides a robust framework for examining the geoeconomic dimensions of the Russia–Ukraine war.

The next chapter develops the conceptual model of geoeconomic warfare and identifies the principal mechanisms through which financial, energy, trade, and technological instruments influence economic and geopolitical outcomes.

4. Conceptual Model of Geoeconomic Warfare and Contemporary Strategies

4.1. Introduction. The Russia–Ukraine war provides a particularly important case for understanding these developments. Unlike traditional conflicts, this war involves the simultaneous application of military force and multiple forms of economic coercion. Consequently, it offers a unique opportunity to examine the structure, mechanisms, and effectiveness of modern geoeconomic warfare.

This chapter develops the conceptual model that guides the empirical analysis of the study. It identifies the principal dimensions of geoeconomic warfare and explains how they interact to influence economic and geopolitical outcomes.

4.2. Conceptualizing Geoeconomic Warfare. Geoeconomic warfare may be defined as the strategic use of economic instruments by states to achieve political, geopolitical, or security objectives. Unlike conventional military warfare, geoeconomic warfare relies on economic resources and networks as mechanisms of influence and coercion. Modern geoeconomic warfare involves the deliberate manipulation of:

- Financial systems;
- Trade relations;
- Energy markets;
- Technological networks;
- Investment flows;

- Transportation corridors;
- Supply chains.

The primary objective is not necessarily the physical destruction of an opponent but rather the weakening of its economic capacity, strategic autonomy, and long-term development potential.

According to Blackwill and Harris (2016), geoeconomic instruments have become increasingly attractive because they allow states to impose costs on adversaries while avoiding the risks associated with direct military confrontation.

The Russia–Ukraine war demonstrates that economic measures can operate simultaneously with military operations, creating a multidimensional form of conflict in which economic resilience becomes a crucial determinant of national security.

4.3. Evolution of Geoeconomic Warfare. The nature of geoeconomic competition has evolved significantly over time. First Stage: Mercantilist Competition. During the seventeenth and eighteenth centuries, economic rivalry focused primarily on:

- Trade monopolies;
- Colonial expansion;
- Control of strategic resources.

States sought to maximize wealth through protectionist policies and imperial expansion. Second Stage: Industrial Geopolitics. The nineteenth and early twentieth centuries witnessed the emergence of industrial competition centered on:

- Industrial production;
- Transportation infrastructure;
- Access to raw materials;
- Strategic manufacturing capabilities.

Economic power became closely linked to industrial capacity and technological development.

Third Stage: Globalization and Economic Interdependence. Following the Cold War, globalization transformed international economic relations. Key characteristics included:

- Expansion of international trade;
- Growth of multinational corporations;
- Financial integration;
- Global supply chains.

Economic interdependence increased both opportunities for cooperation and vulnerabilities to coercion. Fourth Stage: Digital Geoeconomics. The contemporary era is increasingly characterized by digital and technological competition. Strategic assets now include:

- Semiconductor production;
- Artificial intelligence;
- Cyber infrastructure;
- Data networks;
- Digital platforms.

As a result, geoeconomic warfare increasingly targets technological capabilities rather than merely traditional economic sectors.

4.4. The Integrated Model of Geoeconomic Warfare. This study proposes an integrated model of geoeconomic warfare consisting of four interconnected dimensions:

Financial Dimension. Includes:

- Financial sanctions;
- Asset freezes;
- Banking restrictions;
- Payment-system controls;
- Currency-related measures.

Energy Dimension. Includes:

- Energy exports;
- Energy dependence;
- Pipeline infrastructure;
- LNG transportation networks;
- Energy diversification strategies.

Trade Dimension. Includes:

- Export controls;
- Import restrictions;
- Trade embargoes;
- Supply-chain restructuring;
- Market reorientation.

Technological Dimension.Includes:

- Technology sanctions;
- Semiconductor restrictions;
- Software export controls;
- Digital infrastructure limitations.

These dimensions interact through several intermediate mechanisms:

- Financial isolation;
- Investment reduction;
- Supply-chain disruptions;
- Technological degradation;
- Increased transaction costs.

The cumulative effect of these mechanisms determines the overall effectiveness of geoeconomic pressure.

4.5. The Causal Mechanism of Geoeconomic Warfare. The analytical model developed in this research assumes that geoeconomic warfare operates through a sequence of causal relationships.

Stage 1: Implementation of Geoeconomic Instruments. States introduce:

- Sanctions;
- Trade restrictions;
- Energy controls;
- Technological limitations.

Stage 2: Economic Transmission Mechanisms. These measures affect:

- Financial markets;
- Production systems;
- Investment activity;
- Trade networks;
- Technological development.

Stage 3: Economic Outcomes. The resulting effects include:

- Reduced economic growth;
- Higher inflation;
- Lower investment levels;
- Increased production costs;
- Structural economic adjustments.

Stage 4: Geopolitical Outcomes. Economic consequences ultimately influence:

- Strategic decision-making;
- Foreign policy behavior;
- Alliance formation;

- International power balances.

This framework enables the systematic examination of how economic instruments generate political and geopolitical effects.

4.6. The Four Pillars of Contemporary Geoeconomic Warfare. The empirical evidence from recent international conflicts suggests that modern geoeconomic warfare rests upon four fundamental pillars.

A. **Financial Warfare**. Financial warfare focuses on controlling access to international financial systems. Its primary instruments include:

- Banking sanctions;
- Capital market restrictions;
- Asset freezes;
- Exclusion from payment systems.

Financial warfare has become increasingly effective due to the centralization of global financial networks. The freezing of Russian sovereign assets and restrictions on financial transactions illustrate this dimension of geoeconomic warfare.

Energy Warfare. Energy remains one of the most important strategic resources in the international system. Energy warfare involves:

- Manipulation of energy supplies;
- Control of transportation routes;
- Export restrictions;
- Energy market diversification.

The Russia–Ukraine war demonstrated how energy dependence can be transformed into a source of geopolitical vulnerability. At the same time, European diversification efforts revealed how such vulnerabilities can be reduced through strategic adaptation.

B. **Trade Warfare**. Trade warfare seeks to alter economic behavior by restricting access to markets and supply chains. Common instruments include:

- Tariffs;
- Import bans;
- Export controls;
- Trade embargoes.

Trade restrictions can significantly affect industrial production, technological development, and economic growth. The reorientation of Russian trade toward Asian markets illustrates the adaptive responses that often emerge in response to trade pressure.

C. **Technological Warfare**. Technological warfare has become one of the most dynamic dimensions of geoeconomic competition. Key areas include:

- Semiconductors;
- Artificial intelligence;
- Telecommunications;
- Cybersecurity;
- Advanced manufacturing.

Unlike many financial measures, technological restrictions often generate long-term effects by limiting innovation and productivity growth. Consequently, technological competition increasingly represents a central component of contemporary geoeconomic strategies.

4.7. Spatial Dimensions of Geoeconomic Warfare. From the perspective of human geography, geoeconomic warfare possesses a significant spatial dimension. The effectiveness of economic instruments depends heavily on:

- Geographic location;
- Transportation infrastructure;
- Access to seaports;
- Energy corridors;
- Regional connectivity.

Geographic factors shape both vulnerabilities and opportunities within geoeconomic competition.

In the case of Russia, strategic importance has increasingly shifted toward:

- Asian trade corridors;
- Arctic transportation routes;
- Eurasian logistics networks.
- For Ukraine, access to:
- Black Sea ports;
- European transportation systems;
- International logistics corridors has become crucial for maintaining economic resilience.

The spatial distribution of economic networks therefore plays a decisive role in determining the effectiveness of geoeconomic strategies.

4.8. Geoeconomic Warfare in the Russia–Ukraine Conflict. The Russia–Ukraine war represents one of the most comprehensive examples of geoeconomic warfare in modern history. The conflict involves all major dimensions of geoeconomic pressure:

- Financial Measures;
- Sovereign asset freezes;
- Banking sanctions;
- Restrictions on international payments.

Energy Measures:

- Reductions in energy exports;
- Diversification of European energy supplies;
- Restructuring of global energy markets.

Trade Measures:

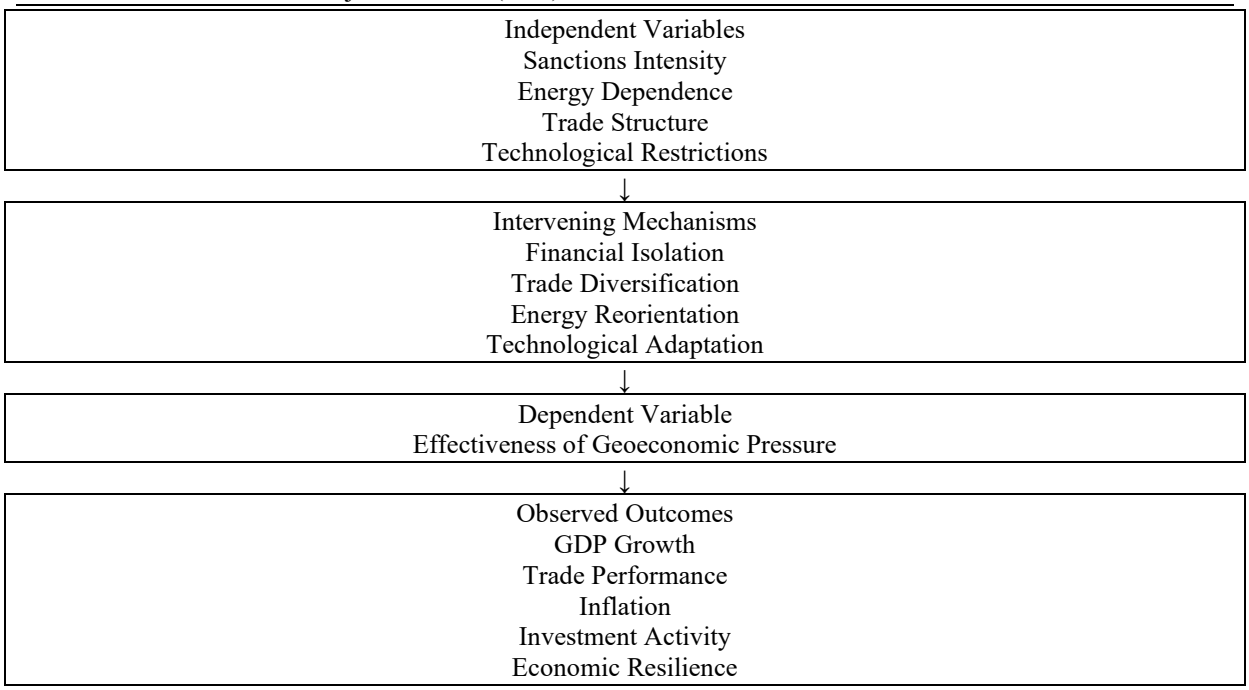
- Export controls;
- Import restrictions;
- Trade reorientation.

Technological Measures:

- Semiconductor restrictions;
- Software controls;
- Technology embargoes.

The simultaneous application of these instruments makes the conflict an ideal case for examining the effectiveness of geoeconomic warfare.

4.9. Proposed Analytical Framework for Empirical Assessment. Based on the conceptual model developed in this chapter, the empirical analysis in subsequent chapters will evaluate the relationships between:



This framework provides the basis for testing the research hypotheses and evaluating the effectiveness of contemporary geoeconomic strategies.

This chapter has developed a comprehensive conceptual framework for understanding contemporary geoeconomic warfare. The analysis demonstrates that modern interstate competition increasingly relies on economic instruments operating through financial, energy, trade, and technological channels. The integrated model proposed in this study highlights the multidimensional nature of geoeconomic warfare and provides a systematic framework for examining its effects. The Russia–Ukraine war serves as a particularly valuable case because it illustrates how multiple geoeconomic instruments can be employed simultaneously within a broader strategic confrontation.

The next chapter examines these instruments in detail, focusing on the specific financial, energy, trade, and technological mechanisms employed during the Russia–Ukraine war and their implications for both regional and global economic systems.

5. Geoeconomic Instruments and Strategies in the Russia–Ukraine War

5.1. Introduction. The Russia–Ukraine war has become one of the most significant geopolitical and geoeconomic events of the twenty-first century. Although the conflict began as a military confrontation, it rapidly evolved into a multidimensional struggle involving economic, financial, technological, and energy instruments. Consequently, the war provides a unique opportunity to examine how geoeconomic strategies are employed in contemporary international relations.

Unlike traditional military conflicts, the Russia–Ukraine war is characterized by the extensive use of economic coercion and strategic interdependence. Western states, led by the European Union, United States, United Kingdom, Canada, and their allies, have imposed a wide range of sanctions and restrictions on Russia. At the same time, Russia has sought to counter these measures through economic adaptation, trade diversification, and the reorientation of strategic partnerships toward non-Western markets.

This chapter examines the principal geoeconomic instruments used during the conflict and evaluates their strategic significance.

5.2. Financial Sanctions as Instruments of Geoeconomic Warfare. Financial sanctions represent one of the most powerful instruments of contemporary geoeconomic warfare. Because the global financial system is highly interconnected, restrictions on financial transactions can significantly affect economic performance and strategic decision-making.

Following the escalation of the conflict in 2022, Western governments introduced unprecedented financial measures against Russia. These measures included:

- Freezing of sovereign assets;
- Restrictions on banking operations;
- Exclusion of selected financial institutions from international payment systems;
- Limitations on access to foreign capital markets;
- Constraints on international investment activities.

The primary objective of these sanctions was to reduce Russia's ability to finance military operations and to increase the economic costs of the conflict.

One of the most significant measures was the freezing of a substantial share of Russia's foreign exchange reserves held abroad. This action demonstrated how financial infrastructure can be transformed into an instrument of geopolitical influence.

However, the Russian government implemented several countermeasures, including:

- Increased use of alternative payment systems;
- Expansion of domestic financial infrastructure;
- Greater reliance on national currencies in international transactions;

- Strengthening financial cooperation with Asian partners.

As a result, while financial sanctions imposed considerable economic costs, they did not lead to the immediate collapse of the Russian economy.

5.3. Energy Geoeconomics and Strategic Dependence. Energy has historically occupied a central position in relations between Russia and Europe. Prior to the war, Russia was one of the largest suppliers of natural gas, oil, and coal to European markets.

This relationship created a situation of mutual dependence:

- Europe depended on Russian energy supplies;
- Russia depended on European energy revenues.

The outbreak of war fundamentally altered this relationship. European governments adopted comprehensive strategies aimed at reducing energy dependence on Russia. These strategies included:

- Diversification of supply sources;
- Expansion of LNG imports;
- Increased energy efficiency measures;
- Accelerated development of renewable energy;
- Construction of new energy infrastructure.

At the same time, Russia sought to redirect energy exports toward Asian markets, particularly China and India. The conflict demonstrated several important characteristics of energy geoeconomics. First, energy dependence can serve as a source of geopolitical leverage.

Second, excessive dependence creates vulnerabilities for both suppliers and consumers.

Third, diversification strategies can significantly reduce the effectiveness of energy-based coercion.

The European experience illustrates how energy security has become an essential component of national and regional security policy.

5.4. Trade Restrictions and the Transformation of Global Trade Networks. Trade restrictions constitute another important dimension of geoeconomic warfare. Since 2022, numerous countries have introduced restrictions affecting:

- Imports from Russia;
- Exports to Russia;
- Strategic goods;
- Advanced technologies;
- Transportation services.

The objective of these measures has been to limit Russia's access to critical products and international markets. However, the implementation of trade restrictions has also produced significant adjustments in global trade geography. Several notable developments can be observed:

Reorientation Toward Asia. Russia increased trade with China, India, Turkey and Kazakhstan

Emergence of Alternative Trade Corridors. New transport routes have gained importance, including: Eurasian rail corridors, Caspian Sea transport routes, and North-South transport corridors.

Regionalization of Trade. The conflict has accelerated the trend toward regional economic blocs and geographically concentrated trade networks. These developments suggest that trade restrictions often generate adaptation and restructuring rather than complete economic isolation.

5.5. Technological Warfare and Innovation Competition. Technology has emerged as one of the most strategically important dimensions of contemporary geoeconomic competition. Modern economies depend heavily on access to:

- Semiconductors;
- Advanced machinery;
- Software systems;
- Telecommunications equipment;
- Artificial intelligence technologies.

Recognizing the strategic significance of technology, Western countries introduced extensive export controls targeting high-tech sectors. Restrictions focused particularly on:

- Semiconductor technologies;
- Microelectronics;
- Aerospace equipment;
- Advanced manufacturing systems;
- Dual-use technologies.

The objective was to reduce Russia's technological capabilities and constrain long-term economic modernization. Technological sanctions differ from traditional trade sanctions because their effects often emerge gradually over time.

Short-term impacts may appear limited, but long-term consequences can include:

- Lower productivity growth;
- Reduced innovation capacity;
- Industrial modernization challenges;
- Increased technological dependence.

Therefore, technological warfare has become one of the most significant forms of geoeconomic competition in the twenty-first century.

5.6. Information, Digital Infrastructure, and Cyber Geoeconomics. The Russia–Ukraine war has also highlighted the growing importance of digital infrastructure in geoeconomic competition.

Digital systems now constitute critical components of national economic security, including: Telecommunications networks, Financial technologies, Cloud computing systems, Data centers Digital systems are currently critical components of national economic security, including telecommunications networks, financial technologies, cloud computing systems, data centers, and digital platforms. Control over digital infrastructure provides opportunities for both economic influence and strategic pressure. The conflict has demonstrated how cyber capabilities and digital technologies can affect: Financial operations, Government services, Commercial activities and Communication networks.

Consequently, digital infrastructure has become an increasingly important arena of geoeconomic competition. The growing integration of technology and economics suggests that future geoeconomic conflicts will likely involve even greater emphasis on digital and cyber dimensions.

5.7. Economic Adaptation Strategies. An important aspect of geoeconomic warfare concerns the

ability of targeted states to adapt to external pressure. The Russian case illustrates several adaptation mechanisms:

Market Diversification - Expansion of trade relations with non-Western partners.

Import Substitution - Development of domestic production capabilities to replace imported goods.

Financial Adjustment - Creation of alternative payment systems and financial arrangements.

Energy Reorientation - Redirection of exports toward alternative markets.

Institutional Adaptation - Modification of regulatory frameworks to address new economic conditions.

These responses demonstrate that geoeconomic pressure does not operate in a static environment. Targeted states actively seek strategies to mitigate economic costs and reduce vulnerabilities.

Therefore, the effectiveness of geoeconomic warfare depends not only on the strength of coercive measures but also on the adaptive capacity of the target state.

5.8. Ukraine's Economic Resilience and International Support. While much attention has focused on sanctions against Russia, Ukraine's economic resilience constitutes another critical dimension of the conflict. Ukraine has faced severe challenges, including:

1. Infrastructure destruction;
2. Population displacement;
3. Industrial disruption;
4. Export constraints.

Despite these difficulties, international support has played a crucial role in sustaining economic activity. Assistance has included: Financial aid; Budget support; Humanitarian assistance; Reconstruction programs; Military assistance with economic implications.

The Ukrainian case illustrates how external economic support can function as a geoeconomic instrument designed to strengthen resilience and sustain national capacity during conflict.

5.9. Geoeconomic Consequences for the Global Economy. The Russia–Ukraine war has produced consequences extending far beyond the immediate participants. Several global trends have accelerated:

- Fragmentation of Economic Networks - Economic relations increasingly reflect geopolitical considerations.
- Regionalization- Regional trade and investment networks have gained importance.
- Energy Market Transformation - Global energy flows have undergone substantial restructuring.
- Strategic Supply Chains - States increasingly prioritize supply-chain security over efficiency.
- Technological Decoupling - Competition over advanced technologies has intensified.

These developments indicate that the conflict has become a catalyst for broader transformations within the global economic system.

5.10. Evaluation of Geoeconomic Effectiveness. The evidence presented in this chapter suggests that geoeconomic instruments have become indispensable components of contemporary international competition. However, their effectiveness varies considerably. Financial sanctions have increased economic costs but have not produced complete economic isolation. Energy strategies have reduced dependence but required substantial investments and policy adjustments. Trade restrictions have altered commercial patterns but have also stimulated adaptation. Technological controls appear to possess the greatest long-term strategic significance due to their influence on innovation and productivity.

Overall, the Russia–Ukraine war demonstrates that geoeconomic warfare is most effective when multiple instruments operate simultaneously within a coordinated strategic framework.

This chapter examined the principal geoeconomic instruments employed during the Russia–Ukraine war, including financial sanctions, energy policies, trade restrictions, technological controls, and digital infrastructure measures. The analysis demonstrated that contemporary geoeconomic warfare is multidimensional and relies on the interaction of several interconnected mechanisms.

The findings indicate that while geoeconomic pressure can generate significant economic costs, its effectiveness is shaped by the adaptive capacity of targeted states and the broader structure of international economic networks. These insights provide the foundation for the empirical analysis presented in the next chapter, which evaluates the measurable economic consequences of geoeconomic warfare using statistical and comparative evidence.

6. Empirical Analysis of Geoeconomic Warfare: The Russia–Ukraine War Case.

6.1. Introduction. The previous chapters examined the theoretical foundations of geoeconomics, the methodological framework of the study, and the principal geoeconomic instruments employed during the Russia–Ukraine war. This chapter presents the empirical analysis of the conflict and evaluates the effectiveness of geoeconomic measures through selected macroeconomic, energy, trade, and technological indicators.

The empirical analysis is based on data obtained from the International Monetary Fund (IMF), World Bank, International Energy Agency (IEA), Eurostat, World Trade Organization (WTO), UNCTAD, the National Bank of Ukraine, Rosstat, and the Central Bank of Russia. The period under consideration covers 2021–2025, enabling a comparison between the pre-war and wartime periods.

The chapter seeks to test the hypotheses formulated in Chapter 3 and to assess how financial sanctions, energy policies, trade restrictions, and technological controls have affected the economic performance of Russia and Ukraine as well as broader global economic processes.

6.2. Economic Growth Dynamics in Russia and Ukraine One of the most important indicators for evaluating the effectiveness of geoeconomic pressure is Gross Domestic Product (GDP) growth. (Figure 6.1).

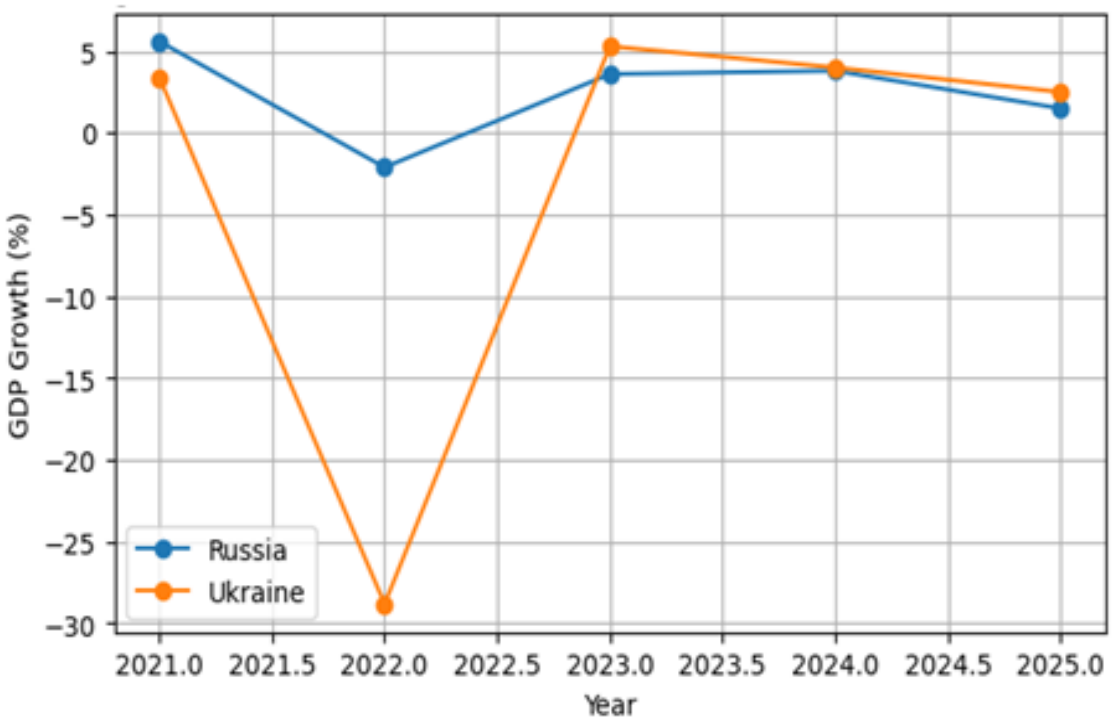


Figure 6.1. GDP Growth Rates in Russia and Ukraine (2021–2025, %).
Source: Constructed by the author (based on data from IMF World Economic Outlook (2025); World Bank (2025)
Note: Estimated values.

Figure 6.1 illustrates the dynamics of GDP growth in Russia and Ukraine during the period 2021–2025. The selected timeframe enables comparison between the pre-war economic situation and the economic consequences that emerged after the escalation of the Russia–Ukraine conflict in February 2022.

Pre-War Economic Conditions (2021). In 2021, both countries recorded positive economic growth. Russia's GDP increased by 5.6%, while Ukraine achieved growth of 3.4%. The relatively strong performance of Russia was primarily associated with:

- High global energy prices;
- Recovery from the COVID-19 pandemic;
- Increased export revenues;
- Stable fiscal performance.

Ukraine also experienced economic recovery after the pandemic period, supported by:

- Expanding exports;
- Growth in domestic consumption;
- Improved investment activity.

These indicators demonstrate that both economies entered 2022 from a position of moderate economic stability.

Immediate Economic Shock (2022). The most significant feature of the graph is the dramatic divergence observed in 2022.

Ukraine's GDP declined by approximately 28.8%, representing one of the largest economic contractions recorded globally in recent decades. The sharp decline of Ukraine's GDP in 2022 is consistent with findings reported by the World Bank (2024) and the IMF (2024), which identify infrastructure destruction, population displacement, and disruptions to export activities as major drivers of economic contraction. Similar conclusions are presented by the National Bank of Ukraine (2024), emphasizing the role of wartime uncertainty and investment decline. Several factors contributed to this decline:

Infrastructure Destruction Military operations caused extensive damage to:

- Industrial facilities;
- Energy infrastructure;
- Transportation networks;
- Housing and public services.
- Population Displacement

Millions of Ukrainians were displaced internally or migrated abroad, reducing labor supply and consumer demand.

Export Disruptions - Ukraine's export-oriented economy was severely affected by interruptions in:

- Black Sea shipping routes;
- Agricultural exports;
- Industrial production chains.

According to the World Bank (2025), these disruptions significantly reduced economic output across most sectors.

Russia also experienced economic decline in 2022; however, the contraction was considerably smaller (-2.1%).

This finding is particularly important because it demonstrates that the unprecedented sanctions imposed by Western countries did not generate immediate economic collapse.

Several factors explain Russia's relative resilience:

Energy Revenues - Despite sanctions, high global oil and gas prices generated substantial export income.

Fiscal Support - Government spending increased significantly, supporting economic activity.

Financial Stabilization Measures. The Russian authorities implemented:

- Capital controls;
- Exchange-rate management policies;
- Financial market interventions.

Trade Reorientation. Exports increasingly shifted toward Asian markets, particularly China and India. Consequently, the Russian economy experienced recession but avoided systemic economic crisis.

Recovery Phase (2023)

The graph indicates economic recovery in both countries during 2023. Russia recorded GDP growth of 3.6%. Several factors contributed to this rebound:

- Expansion of military-industrial production;
- Increased government expenditure;
- Adaptation to sanctions;
- Growth of trade with Asian partners.

At the same time, Ukraine achieved GDP growth of 5.3%. The Ukrainian recovery was supported by:

- International financial assistance;
- Reconstruction activities;
- Partial restoration of exports;
- Improved macroeconomic stability.

Although positive growth returned, Ukraine's economy remained substantially below its pre-war production level.

Stabilization Period (2024). In 2024, both economies continued to expand. Russia recorded growth of 3.8%, while Ukraine achieved approximately 4.0%. This phase demonstrates the growing importance of economic adaptation mechanisms. For Russia, growth was increasingly linked to:

- mport substitution;
- Domestic industrial production;
- Energy exports to non-European markets.

For Ukraine, growth depended heavily on:

- Foreign aid;
- International reconstruction programs;
- European economic integration.

The data indicate that economic adjustment processes had begun to offset some of the immediate wartime shocks.

Moderation of Growth (2025). The estimated values for 2025 suggest slower growth in both countries. Russia's projected growth declines to approximately 1.5%. Possible explanations include:

- Continuing technological restrictions;
- Labor shortages;
- Declining productivity growth;
- Structural constraints caused by sanctions.

Ukraine's projected growth rate of 2.5% reflects:

- Ongoing security risks;
- Reconstruction challenges;
- Fiscal pressures.

Nevertheless, positive growth indicates continued economic resilience.

Comparative Interpretation. Several broader conclusions emerge from Figure 6.1.First - The economic consequences of military conflict were substantially more severe for Ukraine than for Russia in the short term. Second - Economic sanctions imposed significant costs on Russia but did not produce immediate economic collapse. Third - Economic adaptation played a crucial role in shaping outcomes. Both countries adjusted through different mechanisms:

Russia through trade diversification and state intervention;

Ukraine through international assistance and reconstruction. Fourth The findings demonstrate that geoeconomic warfare generates complex and uneven outcomes.

Economic pressure alone rarely determines final results. Instead, outcomes depend on:

1. Economic resilience;
2. Institutional capacity;
3. International support;
4. Access to alternative markets;
5. Government policy responses.

Figure 6.1 provides empirical support for several theoretical arguments developed earlier in the article. The results support the arguments of Luttwak (1990), Blackwill and Harris (2016), and Farrell and Newman (2019), who emphasize the growing importance of economic instruments in contemporary strategic competition. At the same time, the graph demonstrates that the effectiveness of geoeconomic warfare is conditioned by adaptive capacity and structural economic characteristics rather than by sanctions intensity alone. Therefore, Figure 6.1 constitutes one of the key empirical foundations for confirming Hypotheses H1 and H2 of this study.

6.3 Energy Dependence and Geoeconomic Transformation Energy represented one of the most important dimensions of geoeconomic warfare during the conflict.(Table 6.1).

Table 6.1.

European Union Dependence on Russian Natural Gas, 2021–2025 (%)

Year	Share of Russian Gas Imports
2021	40
2022	24
2023	15
2024	10
2025	8

Source: Constructed by the author (based on data from Eurostat (2025); International Energy Agency (2025)

Analysis. The data reveal a substantial reduction in European dependence on Russian natural gas. Between 2021 and 2025, the share of Russian gas imports decreased from 40% to 8%. Several factors contributed to this transformation:

- Expansion of LNG imports;
- Increased imports from Norway and other suppliers;
- Renewable energy investments;
- Energy efficiency measures.

The results support Hypothesis H3 by demonstrating that reduced dependence significantly weakens the effectiveness of energy-based coercion. Furthermore, the findings illustrate how energy security has become an integral component of geoeconomic strategy.

6.4. Transformation of Russian Trade Geography Trade restructuring represents one of the most significant economic consequences of the conflict. (Table 6.2).

Table 6.2

Russia's Trade Structure by Major Partners (%)

Partner	2021	2024
European Union	36	14
China	18	33
India	2	12
Türkiye	4	8
Others	40	33

Source: Constructed by the author (based on data from WTO (2025); UNCTAD (2025); Rosstat (2025).

Analysis. The data indicate a significant geographical reorientation of Russian trade.

The European Union's share declined substantially, while China and India increased their importance as trade partners. The increase in China's share from 18% to 33% demonstrates the growing importance of Eurasian economic cooperation. Similarly, India's growing share reflects the redirection of Russian energy exports toward alternative markets. The findings suggest that sanctions altered trade patterns rather than completely eliminating international economic relationships.

6.5. Sectoral Impact of Sanctions on the Russian Economy. Different sectors of the Russian economy experienced varying levels of exposure to sanctions. (Table 6.3).

Table 6.3

Estimated Impact of Sanctions by Sector (2024)

Sector	Impact Level
Finance	High
Technology	High
Manufacturing	Medium
Energy	Medium
Agriculture	Low

Source: Constructed by the author (based on data from OECD (2025); World Bank (2025); IMF (2025).

Analysis. The strongest effects are observed in financial and technological sectors. Financial restrictions increased transaction costs and reduced access to international capital markets. Technology-related restrictions affected access to advanced equipment, semiconductors, and innovation networks. Agriculture experienced comparatively limited impacts due to domestic production capacity and continued access to alternative export markets. The findings indicate that technological sanctions may generate the most significant long-term consequences because they directly affect productivity and innovation.

6.6. Global Economic Implications of the Conflict. The Russia–Ukraine war has generated broader consequences for the international economic system.(Table 6.4).

Table 6.4.

Major Global Economic Transformations Associated with the Conflict

Area	Main Transformation
Energy Markets	Diversification of suppliers
Trade Networks	Regionalization
Financial Systems	Fragmentation
Technology	Strategic competition
Supply Chains	Security-oriented restructuring

Source: World Economic Forum (2025); WTO (2025); OECD (2025).

Analysis. The evidence suggests that the conflict has accelerated several long-term structural trends. Economic networks increasingly reflect geopolitical considerations rather than purely economic efficiency. Governments are placing greater emphasis on resilience, strategic autonomy, and supply-chain security.

These developments support Hypothesis H4, which predicted increased fragmentation of the global economy.

7. Conclusions

7.1. General Conclusions. The purpose of this study was to examine the new strategies of geoeconomic warfare through the case of the Russia–Ukraine war and to evaluate the effectiveness of economic instruments in achieving geopolitical objectives. The research combined theoretical analysis with empirical investigation in order to understand how financial sanctions, energy policies, trade restrictions, and technological controls influence contemporary interstate conflicts. The findings of this study support the arguments of Luttwak (1990), Blackwill and Harris (2016), and Farrell and Newman (2019), who suggest that economic networks increasingly function as arenas of geopolitical competition. The Russia–Ukraine war demonstrates that geoeconomic instruments have become fundamental components of contemporary power politics.

The findings demonstrate that the Russia–Ukraine war represents not only a military confrontation but also one of the most comprehensive examples of geoeconomic warfare in modern history. The conflict has revealed the growing importance of economic instruments as mechanisms of power and influence within the international system. Consequently, geoeconomics has become an increasingly important analytical framework for understanding contemporary international relations.

The study confirms that economic competition and economic coercion have become central components of global strategic rivalry. In many cases, economic instruments are capable of producing effects comparable to those generated by traditional military power.

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Conclusions According to Research Objectives

Objective 1: To Examine the Theoretical Foundations of Geoeconomics.The research demonstrated that geoeconomics has evolved into a distinct field of study integrating international relations, economic geography, political economy, and strategic studies. Theoretical analysis confirmed that contemporary power increasingly depends on the ability of states to control:

- Financial systems;
- Trade networks;
- Energy resources;
- Technological infrastructures;
- Global supply chains.

The concepts of economic statecraft, complex interdependence, and weaponized interdependence provide valuable tools for understanding modern geoeconomic competition.

Objective 2: To Identify Geoeconomic Instruments Used in the Russia–Ukraine War. The study identified four principal categories of geoeconomic instruments:

1. Financial sanctions;
2. Energy-related measures;
3. Trade restrictions;
4. Technological controls.

These instruments were applied simultaneously and formed an integrated strategy of economic pressure. The findings suggest that contemporary geoeconomic warfare is multidimensional and relies on the interaction of several complementary mechanisms.

Objective 3: To Evaluate the Economic Impact of Sanctions. The empirical analysis showed that sanctions significantly affected several sectors of the Russian economy. The strongest effects were observed in:

- Finance;
- Technology;
- International investment.

However, sanctions did not generate immediate economic collapse.

Instead, the Russian economy responded through:

- Trade diversification;
- Alternative financial arrangements;
- Increased cooperation with Asian partners;
- Domestic adaptation policies.

Therefore, sanctions proved effective in increasing economic costs but less effective in producing rapid political change.

Objective 4: To Assess the Role of Energy in Geoeconomic Competition. The study confirmed that energy remains one of the most important instruments of geoeconomic influence.

Prior to the conflict, Europe's dependence on Russian energy resources created significant strategic vulnerabilities. However, the empirical analysis demonstrated that diversification strategies substantially reduced this dependence between 2021 and 2025.

Consequently, the effectiveness of energy-based coercion declined over time.

The findings indicate that energy security has become a fundamental component of national security and geoeconomic strategy.

Objective 5: To Analyze Trade Transformation During the Conflict. The research revealed significant changes in the geography of international trade. Russia's trade relations shifted from European markets toward Asian partners, particularly China and India. These developments indicate that sanctions frequently lead to trade reorientation rather than complete economic isolation. The findings also demonstrate the increasing importance of regional trade networks within the global economy.

Objective 6: To Evaluate the Global Consequences of the Conflict. The study found that the Russia–Ukraine war accelerated several structural transformations within the international economic system. Major developments include:

- Economic regionalization;
- Fragmentation of financial networks;
- Energy market restructuring;
- Supply-chain diversification;

- Intensified technological competition.

These changes suggest that the global economy is becoming increasingly shaped by geopolitical considerations.

General Conclusions.

The purpose of this study was to examine the new strategies of geoeconomic warfare through the case of the Russia–Ukraine war and to evaluate the effectiveness of economic instruments in achieving geopolitical objectives. The research combined theoretical analysis with empirical investigation in order to understand how financial sanctions, energy policies, trade restrictions, and technological controls influence contemporary interstate conflicts. The findings demonstrate that the Russia–Ukraine war represents not only a military confrontation but also one of the most comprehensive examples of geoeconomic warfare in modern history. The conflict has revealed the growing importance of economic instruments as mechanisms of power and influence within the international system. Consequently, geoeconomics has become an increasingly important analytical framework for understanding contemporary international relations.

The study confirms that economic competition and economic coercion have become central components of global strategic rivalry. In many cases, economic instruments are capable of producing effects comparable to those generated by traditional military power.

The findings of this study support the arguments of Luttwak (1990), Blackwill and Harris (2016), and Farrell and Newman (2019), who suggest that economic networks increasingly function as arenas of geopolitical competition. The Russia–Ukraine war demonstrates that geoeconomic instruments have become fundamental components of contemporary power politics.

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- Energy market restructuring;
- Supply-chain diversification;
- Intensified technological competition.

These changes suggest that the global economy is becoming increasingly shaped by geopolitical considerations.

Evaluation of Research Hypotheses

Hypothesis H1. Economic instruments have become as influential as military power in contemporary interstate conflicts. **Confirmed.** The Russia–Ukraine

war demonstrates that sanctions, trade restrictions, technological controls, and energy policies significantly influence political and economic outcomes.

Hypothesis H2. Increasing sanctions intensity negatively affects economic growth and development**. Partially Confirmed.** Sanctions imposed substantial economic costs on Russia but did not produce economic collapse due to adaptation mechanisms and alternative economic partnerships.

Hypothesis H3. Reducing energy dependence decreases the effectiveness of geoeconomic pressure. **Confirmed.** The European Union's diversification policies substantially reduced energy-related vulnerabilities and weakened Russia's energy leverage.

Hypothesis H4. The Russia–Ukraine war accelerated the fragmentation of the global economy. **Confirmed.** The conflict strengthened regionalization, strategic decoupling, and the emergence of competing economic blocs.

Scientific Contribution of the Research. The principal scientific contribution of this study is the development of an integrated analytical model of geoeconomic warfare.

Unlike conventional approaches that focus on individual dimensions of economic pressure, the proposed framework combines:

- Financial factors;
- Energy factors;
- Trade factors;
- Technological factors.

This integrated approach provides a more comprehensive understanding of how geoeconomic instruments interact and influence geopolitical outcomes. The study also contributes to the field of human geography by emphasizing the importance of spatial networks, transportation corridors, energy infrastructures, and regional interdependencies in contemporary geoeconomic competition.

Practical Implications. The findings have several practical implications for policymakers.

First, economic resilience has become a crucial element of national security. Second, excessive dependence on a single supplier, market, or technology source creates strategic vulnerabilities.

Third, diversification of trade, energy supplies, and technological partnerships enhances national resilience against geoeconomic pressure. Fourth, sanctions are most effective when implemented as part of a broader, coordinated strategy involving multiple economic instruments. Finally, governments must increasingly consider geoeconomic risks when developing economic and foreign policy strategies.

Recommendations for Future Research. Future research could expand the analytical framework developed in this study by:

- Examining additional case studies of geoeconomic warfare;
- Conducting econometric analyses of sanctions effectiveness;
- Investigating the role of digital platforms and artificial intelligence in geoeconomic competition;
- Analyzing the long-term consequences of technological decoupling;
- Exploring the geoeconomic implications of emerging transportation corridors and supply-chain transformations.

Such research would contribute to a deeper understanding of the evolving relationship between economics, geography, and international power.

Final Conclusion. The Russia–Ukraine war demonstrates that the nature of international conflict is undergoing profound transformation. Economic instruments have become essential components of strategic competition and increasingly complement or substitute traditional military power.

Financial sanctions, energy policies, trade restrictions, and technological controls now constitute critical mechanisms through which states pursue geopolitical objectives. At the same time, the effectiveness of these instruments depends on the resilience, adaptability, and international integration of targeted economies.

The study concludes that geoeconomic warfare has become one of the defining features of the contemporary international system. As globalization evolves and geopolitical competition intensifies, the ability to understand and manage geoeconomic processes will become increasingly important for states, international organizations, and scholars alike.

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MATHEMATICS

МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ОПТИМАЛЬНОЇ ДІЯЛЬНОСТІ ТУРИСТИЧНОЇ ОРГАНІЗАЦІЇ В УМОВАХ СТАЛОГО РОЗВИТКУ

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MATHEMATICAL MODELING OF OPTIMAL ACTIVITIES OF A TOURIST ORGANIZATION IN THE CONDITIONS OF SUSTAINABLE DEVELOPMENT

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Анотація

У статті розглянуто структуру та описано методику побудови математичної моделі розвитку туристичного бізнесу, досліджено методи багатопараметричної оптимізації діяльності туристичної організації та сформовані її математичні моделі з різними цільовими функціями. Запропоновано застосування графових моделей побудови оптимальних туристичних маршрутів в певному регіоні.

Abstract

The article examines the structure and describes the methodology for building a mathematical model of tourism business development, investigates the methods for multiparameter optimization activities and forms its mathematical models with various objective functions. The application of graph models for building optimal tourist routes in a certain region is proposed.

Ключові слова: багатопараметрична оптимізація, маршрут графа, матричне числення, алгоритм Беллмана-Форда.

Keywords: multiparameter optimization, graph route, matrix calculus, Bellman-Ford algorithm.

Актуальність дослідження. Індустрія туризму, оздоровлення та гостинності являється важливим напрямом розвитку економіки країни. На даний час ця сфера постійно змінюється під дією геополітичних явищ та неперервної інтеграції економічних, екологічних та соціальних процесів [1]. Наукові аспекти реалізації сталого розвитку туризму, досягнення на практиці, заходи, що стимулюють сталий розвиток туризму в Україні розглянуті у працях багатьох науковців. Лебедєв І. [2] досліджував досвід Європейського Союзу й завдання для України щодо сталого розвитку туризму. Низку сучасних, науково-методичних і теоретичних підходів щодо встановлення концептуальних засад сталого розвитку туристичної діяльності розглянуті Ісаєнко В., Ніколаєвим К., Бабіковою К. та ін.

Стрімкий інформаційний розвиток суспільства, особливо останніми роками, сприяє інноваційно-технологічному оновленню всіх напрямів суспільно-економічної діяльності, у тому числі і сфери обслуговування та туризму, як її складової ланки. Основними критеріями таких змін слугують зручність та доступність актуальної інформації, швидкий доступ до неї, поінформованість клієнтів, знання їх вподобань, зацікавлень та можливостей. Для того, щоб заклад туризму відповідав даним критеріям необхідно постійно збирати та оновлювати інформацію про споживачів послуг, а особливо про цікаві та актуальні напрями і об'єкти туризму в регіоні, тобто обробляти великі обсяги даних. Для виконання цих завдань необхідно застосовувати сучасні засоби математичного моделювання, які дозволяють виконати теоретичні дослідження та розробити практичні підходи до ефективного управління діяльністю туристичної організації певного регіону та визначення оптимальних туристичних маршрутів різних напрямів [4, 5].

Метою даної роботи є методика розробки актуальних математичних моделей для оптимізації діяльності туристичної організації в умовах сталого розвитку. Предметом дослідження являються математичні методи оптимізації розвитку підприємства туризму.

Виклад основного матеріалу. Фактори, які впливають на розвиток туризму, базуються на загальних критеріях сталого розвитку даного регіону та існуючих проблемах туристичного бізнесу у ньому. У проведеному дослідженні було розглянуто наступні фактори, визначені експертами туристично-рекреаційної галузі (коефіцієнт конкордації Кендалла при 4 експертах дорівнює 0,967): обсяг приватних інвестицій в туристичну інфраструктуру; рівень розвитку зимового туризму для розв'язання проблеми сезонності туристичних потоків; туристичний імідж регіону; ефективність функціонування туристичних об'єктів, їх рентабельність; стан і рівень охорони оточуючого середовища, збереження природного комплексу регіону.

Рівні економічного, екологічного, соціально-культурного та визначеного ними рівня туристичного розвитку становлять чотири взаємопов'язані блоки структури моделі, які будемо розглядати в якості неявних змінних, значення яких неможливо чітко визначити чи виміряти. При цьому змінна рівня туристичного розвитку є цільовою змінною математичної моделі. Для ідентифікації неявних змінних та можливості їх оцінювання використаємо явні змінні, в якості яких візьмемо вказані фактори розвитку та їх індикатори, значення яких можливо визначити в результаті спостережень, опитувань, експертного оцінювання і т.д.

У запропонованій математичній моделі ідентифікаторами відповідних неявних змінних були взяті: для неявної цільової змінної рівня туристичного розвитку (Y) – показник повторних відвідувань (T1), фонд заробітної платні у туризмі (T2), загальний імідж регіону у туризмі (T3), податкові надходження від туристичного бізнесу (T4); для неявної змінної що визначає рівень соціально-культурного розвитку регіону (X1) – ступінь збереження історичних пам'яток (S1), державні витрати на соціальні виплати для населення (S2), рівень безробіття (S3); для неявної змінної стану екології в регіоні (X2) – державні витрати на охорону оточуючого середовища (P1), середній об'єм споживання води (P2); рівень якості повітря (P3); державні витрати на охорону суспільної безпеки (P4); а для латентної змінної рівня економічного розвитку (X3) – державні витрати на економічний розвиток (E1), середній чек одного туриста (E2), частка робочих місць в туристичному бізнесі (E3), середня вартість житла (E4). На рис. 1 наведено структуру вхідної моделі розвитку туристичного бізнесу, її основні блоки та індикатори, що їх описують.

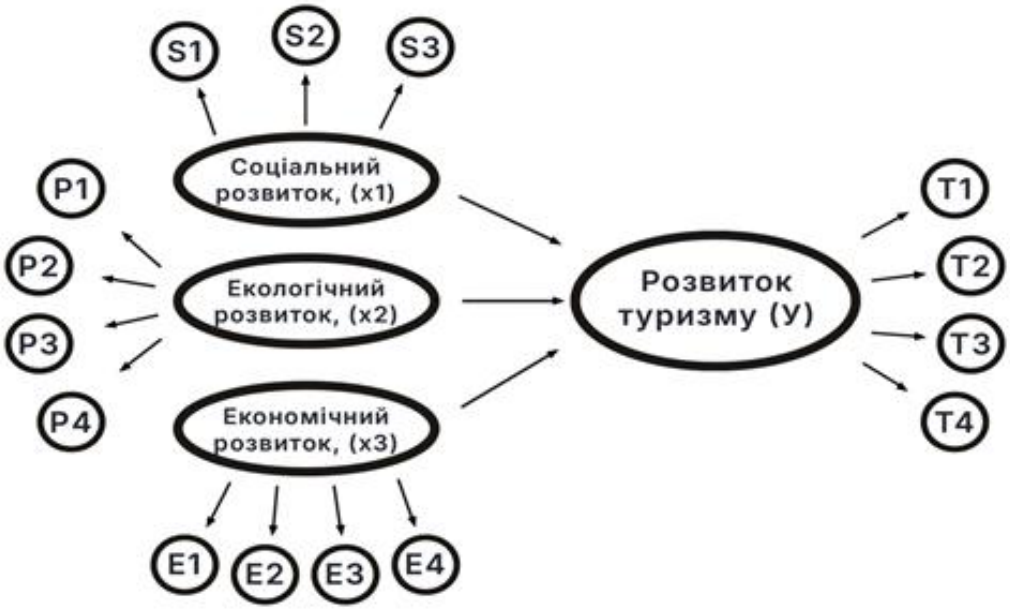

Рисунок 1 – Структура моделі розвитку туристичного бізнесу

Внутрішню модель взаємозв'язку латентних змінних можна представити у вигляді рівняння:

$$Y = \alpha_0 + \alpha_1 X1 + \alpha_2 X2 + \alpha_3 X3 + y_{errow},$$

де $\alpha_0, \alpha_1, \alpha_2, \alpha_3$– коефіцієнти, що характеризують силу зв'язку змінних, y_{errow} – залишковий член.

Зовнішню модель, що описує взаємозв'язок неявних та явних змінних можна описати системою рівнянь:

$$\begin{cases} T1 = \lambda_{0t1} + \lambda_{1t1}Y + t1_{error}, \\ T2 = \lambda_{0t2} + \lambda_{1t2}Y + t2_{error}, \\ \dots \\ S1 = \lambda_{0s1} + \lambda_{1s1}X1 + s1_{error}, \\ S2 = \lambda_{0s2} + \lambda_{1s2}X1 + s2_{error}, \\ \dots \\ P1 = \lambda_{0p1} + \lambda_{1p1}X2 + p1_{error}, \\ P2 = \lambda_{0p2} + \lambda_{1p2}X2 + p2_{error}, \\ \dots \\ E1 = \lambda_{0e1} + \lambda_{1e1}X3 + e1_{error}, \\ E2 = \lambda_{0e2} + \lambda_{1e2}X3 + e2_{error}, \\ \dots \end{cases}$$

де λ_{1t1}, λ_{1t2}, $\dots\lambda_{1e3}$, λ_{1e4}– вагові коефіцієнти, λ_{0t1}, λ_{0t2}, $\dots,\lambda_{0e3}$, λ_{0e4}– вільні члени, $t1_{error}$, $t2_{error},\dots,e2_{error}$– залишкові члени.

Для моделювання структурних параметрів застосуємо метод частинних найменших квадратів (PLS), за яким для оцінки неявних змінних розглядається система рівнянь:

$$\begin{cases} \hat{Y} = \varpi_{T1}T1 + \varpi_{T2}T2 + \varpi_{T3}T3 + \varpi_{T4}T4, \\ \hat{X}1 = \varpi_{S1}S1 + \varpi_{S2}S2 + \varpi_{S3}S3, \\ \hat{X}2 = \varpi_{P1}P1 + \varpi_{P2}P2 + \varpi_{P3}P3 + \varpi_{P4}P4, \\ \hat{X}3 = \varpi_{E1}E1 + \varpi_{E2}E2 + \varpi_{E3}E3 + \varpi_{E4}E4, \end{cases}$$

де $\varpi_{T1},\varpi_{T2},\dots,\varpi_{E4}$– зовнішні вагові коефіцієнти.

Для оптимізації моделі, аналізу складних взаємозв'язків та кількісної оцінки якісних характеристик – параметрів моделі згідно методики PLS-PM виконуються наступні кроки:

1. Оцінювання зовнішньої моделі, що містить наступні дії:

1) Виконується перевірка, чи правильно підібрані індикатори для кожної латентної змінної.

2) Визначається, яким чином кількісні індикатори утворюють або відображають латентні змінні.

3) Визначаються типи зв'язків між змінними: зв'язки є рефлективними, якщо індикатори являються наслідком латентної змінної і нормативними, якщо індикатори є причиною латентної змінної, тобто формують і визначають її.

2. Оцінювання внутрішньої моделі

На цьому етапі визначається сила та напрямок зв'язків між латентними змінними через шляхові коефіцієнти за допомогою кореляційного аналізу і матричних формул для визначення вагових коефіцієнтів внутрішньої та зовнішньої моделей.

Будується матриця, елементами якої є нулі та одиниці, 1 означає, що даний рядок впливає на відповідний стовпчик

$$X1 \geq (0;\ 0;\ 0;\ 0);$$
$$X2 \geq (0;\ 0;\ 0;\ 0);$$
$$X3 \geq (0;\ 0;\ 0;\ 0);$$
$$Y \leq (1;\ 1;\ 1;\ 1).$$

Далі визначаються прямі, непрямі та загальні результати впливу однієї змінної на іншу, обчисливши коефіцієнт детермінації R^2 для цільової змінної Y.

Обробку вибірок даних великих об'ємів можна виконувати засобами програмного забезпечення *R* (пакет *plarm*) чи *SmartPLS* (алгоритм *PLS-SEM*) чи засобами *ET Excel*, якщо вибірка невеликого об'єму.

3. Аналіз результатів обчислень та їх використання для оптимізації моделі.

Побудована модель дозвляє оцінити, який блок і відповідна йому неявна змінна має найбільший прямий вплив на розвиток туризму досліджуваного регіону. Результати використання описаної методики дозволяють також визначити, які явні змінні – індикатори блоків мають найбільш тісний зв'язок з формованою за ними неявною змінною, що дозволить зменшити кількість змінних при виконанні багатопараметричної оптимізації діяльності туристичного підприємства.

Значення коефіцієнтів кореляцій за кожним блоком наведені на рисунках 2 – 5.

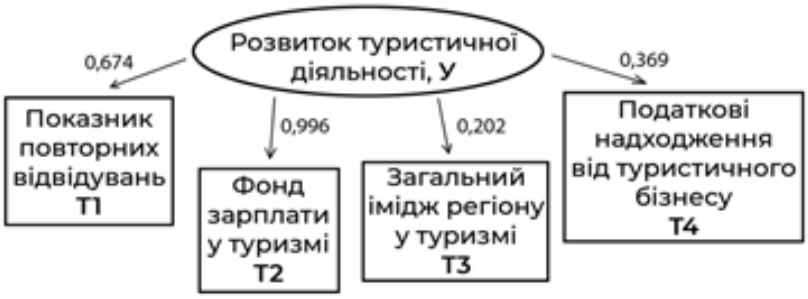

Рисунок 2 – Коефіцієнти кореляції між рівнем розвитку туристичної діяльності та його індикаторами

Рисунок 3 – Коефіцієнти кореляції між рівнем соціально-культурного розвитку регіону та його індикаторами

За отриманими результатами можемо прослідкувати, що найбільш тісний зв'язок розвитку туристичної діяльності з величиною заробітної плати в галузі (0,996) та показником повторних відвідувань туристичних об'єктів у регіоні (0,674). Рівень соціально-культурного розвитку найбільш тісно пов'язаний з величиною державних витрат на соціальні виплати населенню (0,993) та ступенем збереження історичних пам'яток регіону (0,881).

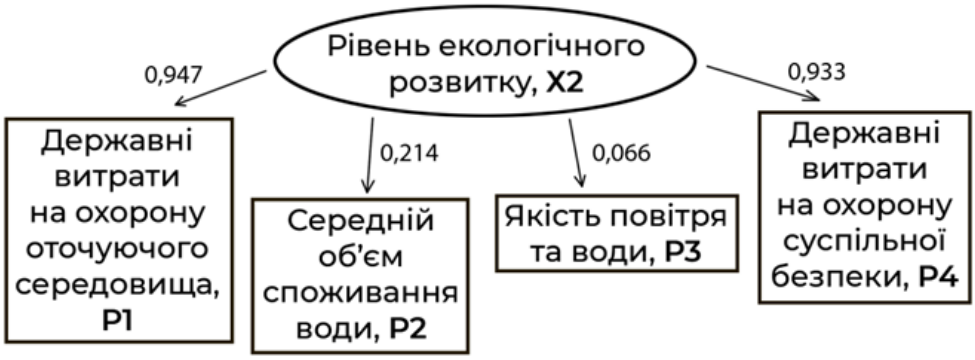

Рисунок 4 – Коефіцієнти кореляції між рівнем екологічного стану регіону та його індикаторами

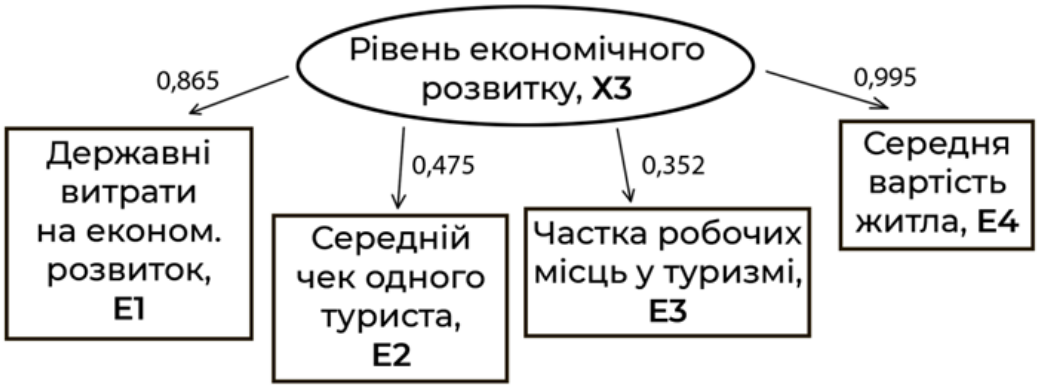

Рисунок 5 – Коефіцієнти кореляції між рівнем економічного розвитку регіону та його індикаторами

Рівень екологічного розвитку найбільш корелює з величинами державних витрат на охорону оточуючого середовища (0,947) та на охорону суспільної безпеки (0,933). А рівень економічного розвитку має найтісніший зв'язок з середньою вартістю житла (0,995) та державними витратами на економічний розвиток регіону (0,865). Саме перелічені

індикатори найтісніше пов'язані з розвитком блоків.

Для подальшої багато параметричної оптимізації актуальними являються метод цільового програмування, метод аналізу ієрархій, засоби теорії обмежень системи, засоби побудови графових моделей і мережевого планування та інші [5]. У дослідження було застосовано метод побудови графових моделей. Представлення досліджуваної системи у вигляді графу певного типу і опису його властивостей та характеристик дає можливість наочного зображення структури задачі і схеми її розв'язання. При застосуванні графових моделей для зазначеного виду задач ефективним є алгоритм Беллмана-Форда, який застосовуються при необхідності визначення найкоротших маршрутів від однієї вершини графа, яка є вхідною, до інших вершин в зваженому орієнтованому графі. За допомогою алгоритма Беллмана-Форда можна також побудувати графові моделі розробки оптимальних туристичних маршрутів актуальних напрямів в регіоні, задавши цільову функцію та визначивши відповідні обмеження для її змінних.

Цільові функції математичної моделі можна представити у вигляді:

$$F_1(X) = \sum_i \sum_j \sum_k \left(B_{jk} - V_{ijk}\right) \cdot x_{ijk} \rightarrow \max,$$

$$F_2(X) = \sum_i \sum_j \sum_k \left(\frac{S_{ij} \cdot r_{tr}}{v_{\max} \cdot q_{ij}} \right) \cdot x_{ijk} \rightarrow \min,$$

$$F_3(X) = \sum_j \left(1 - \frac{N_j}{CCO_j} \right) \rightarrow \max,$$

де $F_1(X)$ – функція прибутковості, $F_2(X)$ – функція часових витрат у дорозі, $F_3(X)$ – функція екологічності;

B_{jk} – дохід (грн.) від туриста маршруту k у пункті j;

V_{ijk} – витрати (грн.) туристичного підприємства на туриста маршруту k на ділянці з пункту i до пункту j;

$$x_{ijk} = \begin{cases} 1, \text{ якщо турист маршруту } k \text{ прямує з точки і до } j, \\ 0, \text{ якщо не прямує.} \end{cases}$$

S_{ij} – довжина шляху з пункту і до пункту j,

r_{tr} – показник трафіку дороги з пункту i до пункту j,

v_{max} – максимально допустима швидкість руху з пункту i до пункту j,

N_j – кількість туристів у пункті j,

CCO_j – екологічна місткість пункту j.

Так як не можливо одночасно досягти максимуму прибутку і мінімуму витрат часу та ресурсів, математичну модель за принципом оптимальності Парето можна представити у вигляді лінійної згортки факторів, яка визначатиме цільову функцію:

$$F(X) = \alpha_1 F_1(X) - \alpha_2 F_2(X) + \alpha_3 F_3(X),$$

де α_i, $i = 1,2,3$ - вагові коефіцієнти, $\sum_{i=1}^{3} \alpha_i = 1$, а $F_1(X)$, $F_2(X)$, $\rightleftarrows$ $F_3(X)$ - нормовані значення відповідних цільових функцій, які обчислюються за формулами нормування:

$$F_{1norm} = \frac{F_1 - F_{1min}}{F1min_{1max}}; \quad F_{2norm} = \frac{F_2 - F_{2min}}{F2min_{2max}}; \quad F_{3norm} = \frac{F_3 - F_{3min}}{F3min_{3max}}$$

Певний туристичний маршрут представляється у вигляді зваженого орієнтованого графа $G(V,E)$, множиною вершин $V(G)$ якого є туристичні локації, а множиною ребер $E(G)$ – шляхи руху між ними. В якості ваг ребер графа можна обирати відстані між вершинами – пунктами маршруту і розв'язувати задачу мінімізації шляху або вагами можуть бути значення цільової функції при попередньому нормуванні значень її критеріїв. В залежності від мети та задач туристичної поїздки її маршрут можна представити у вигляді ланцюгового, зірчастого або циклічного графа. Далі реалізується описаний вище алгоритм Беллмана-Форда і за його результатами визначається оптимальний туристичний маршрут, а потім складається мережевий план даного маршруту та обчислюються його фінансові показники.

Висновки. Завдяки результатам опису моделі можна визначити оптимальні сценарії розвитку туристичного бізнесу – розробити оптимальні регіональні маршрути для різних туристичних напрямів, а також ефективно розподіляти бюджетні кошти, можливі інвестиції та гранти. За допомогою розроблених підходів було сформовано послідовність оптимізаційних заходів для багатокритеріального розвиту туристичної організації та розроблені графові моделі та програми 4 регіональних туристичних маршрути У Дніпропетровській області, а також визначено оптимальний варіант руху за локаціями маршрутів для мінімізації часу та витрат за принципом оптимальності Парето.

Отримані результати можуть бути застосовані для організації діяльності туристичного підприємства та при розв'язанні інших прикладних задач багатопараметричної оптимізації.

Метою подальших досліджень є розробка у вигляді графових моделей туристичних програм та їх маршрутів для міжсезоння та подальший аналіз крихких місць системи для їх згладжування.

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NORMAL AND PATHOLOGICAL PHYSIOLOGY

THE LOWEST STEP, THE GREATEST IMPACT: DIETARY THERAPY IN EXTREME OBESITY – A CASE REPORT

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Abstract

Introduction: Obesity is a chronic multifactorial disease associated with substantial metabolic, cardiovascular, respiratory, and hepatic complications. Management of extreme obesity is particularly challenging in patients with complex comorbidities, requiring individualized therapeutic strategies. In such cases, lifestyle and dietary interventions may remain the only feasible therapeutic approach.

Case report: We report the case of a 41-year-old man admitted with rapid weight gain of approximately 100 kg over six months, accompanied by progressive exertional dyspnea. Evaluation revealed extreme obesity (BMI 69.4 kg/m²), liver cirrhosis of mixed etiology, chronic heart failure with preserved ejection fraction, obesity hypoventilation–related hypoxemia, and metabolic syndrome in the absence of overt glycemic disorder. Given the complex cardiovascular and respiratory comorbidities and increased perioperative risk, a conservative management strategy was initially preferred, while bariatric surgery was deferred. A structured, individualized dietary intervention based on caloric restriction and intermittent fasting (16:8) was initiated under dietetic supervision. Over six months, the patient achieved a weight reduction of 52 kg (24.2% of baseline body weight), accompanied by significant reductions in BMI and waist circumference. Clinical improvement, including reduced exertional dyspnea, was observed alongside favorable metabolic changes despite the absence of baseline glucose intolerance. Owing to the excellent response to dietary approach, escalation to anti-obesity pharmacotherapy was not considered necessary during follow-up.

Conclusion: This case highlights the potential role of structured dietary intervention as an effective first-line therapeutic strategy in selected patients with extreme obesity and complex comorbidities. Individualized nutritional therapy may achieve substantial weight loss and postpone or reduce the need for further intervention.

Keywords: Extreme obesity; dietary intervention; caloric restriction; intermittent fasting; case report.

Introduction

Obesity is a chronic multifactorial disease characterized by excessive adipose tissue accumulation that adversely affects health and is associated with increased morbidity and mortality worldwide. Its prevalence has risen dramatically over recent decades, making it a major global public health concern affecting both developed and developing countries. [1,2] Obesity is strongly linked to metabolic, cardiovascular, respiratory, and hepatic complications, including type 2 diabetes mellitus, congestive heart failure, obstructive sleep apnea, and nonalcoholic fatty liver disease. [2,3]

Current recommendations support a stepwise therapeutic approach, beginning with lifestyle and dietary modification as the foundation of obesity management, followed by pharmacological therapy and bariatric surgery in selected cases. [3,4] However, management of extreme obesity remains particularly challenging, especially in patients with advanced comorbidities that require careful risk assessment, multidisciplinary management, and individualized treatment planning. [4,5] In this context, individualized nutritional strategies remain an essential component of therapy and may achieve clinically meaningful outcomes either as first-line treatment or as a bridge to future pharmacological or surgical intervention.

Case report

Patient information: A 41-year-old man was admitted to the Endocrinology clinic with a history of rapid weight gain of approximately 100 kg over six months, accompanied by progressive exertional dyspnea. He had previously been evaluated by a dietitian but reported poor adherence to the prescribed dietary regimen. His medical history included liver cirrhosis of mixed etiology (alcohol-related and hepatitis C virus [HCV]-associated), portal hypertension, chronic heart failure with preserved ejection fraction [HFpEF] and atrial fibrillation. The patient had received etiologic treatment for HCV infection; however, follow-up of virological status had been incomplete. Chronic pharmacological therapy included irbesartan, esomeprazole, spironolactone, torasemide, carvedilol, silymarin, rivaroxaban and acetylsalicylic acid.

Clinical findings: On physical examination, the patient appeared severely obese, with a body mass index (BMI) of 69.4 kg/m² (height 176 cm, weight 215 kg), waist circumference of 190 cm, and a waist-to-

height ratio of 0.93. Cardiopulmonary examination revealed normal vesicular breath sounds bilaterally, without wheezes or crackles, and distant heart sounds with an irregular rhythm (heart rate 120 bpm), consistent with known atrial fibrillation. Blood pressure was 140/90 mmHg under ongoing antihypertensive therapy. No clinical signs of acute heart failure decompensation were observed. Dyspnea occurred on exertion.

Diagnostic assessment: Reduced high-density lipoprotein (HDL) cholesterol levels were observed, while glycated hemoglobin (HbA1c) and fasting plasma glucose showed no evidence of diabetes mellitus. Blood gas analysis demonstrated hypoxemia consistent with obesity hypoventilation syndrome. Additional laboratory and instrumental findings are summarized in Table 1.

	Value on admission	Reference range
Cholesterol (mmol/L)	3.68	2.70-5.20
HDL cholesterol (mmol/L)	0.56	1.0-1.6
LDL cholesterol (mmol/L)	2.34	0-2.6
Triglycerides (mmol/L)	1.7	0-1.7
HbA1C (%)	4.96	
ASAT (U/L)	24	0-34
ALAT (U/L)	11	10-49
Uric acid (mcmol/l)	605.0	220-547
Glucose (mmol/l)	5.5	4.1-5.9
pH	7.342	7.36-7.44
pCO2 (kPa)	6.45	4.66-5.99
pO2 (kPa)	7.14	10.66-13.33
sO2 (%)	85.7	92.0-98.5

Based on NCEP ATP III criteria, the patient fulfilled the diagnostic criteria for metabolic syndrome, including decreased HDL cholesterol, increased waist circumference, and hypertension.

Therapeutic intervention: Following multidisciplinary evaluation involving an endocrinologist, cardiologist, pulmonologist, and a dietitian, a conservative, individualized treatment strategy was initiated. Treatment with GLP-1 receptor agonists was discussed but was not initiated because of financial constraints and the decision to first evaluate the response to intensive lifestyle intervention. Bariatric surgery was deferred because of the elevated perioperative risk associated with the patient's complex comorbidity profile.

The intervention consisted of a structured nutritional program based on caloric restriction (initial daily caloric intake of 2,200 kcal) combined with intermittent fasting (16:8 regimen), implemented under continuous dietetic supervision. The dietary plan was individualized according to the patient's comorbidities and emphasized a gradual caloric deficit, adequate protein intake, and restriction of simple carbohydrates and sodium to support weight reduction.

Following cardiology consultation, medical therapy was optimized with the addition of an SGLT2 inhibitor and febuxostat. Treatment with diuretics, beta-blockade, angiotensin receptor blockade, and anticoagulation, was continued. The patient underwent regular clinical follow-up with monitoring of anthropometric parameters, functional status, and metabolic profile throughout the intervention period.

Follow-up and outcomes: After three months, the patient achieved a significant weight reduction of 30 kg, with body weight decreasing to 185 kg and BMI to 58.3 kg/m².

Given the substantial clinical and anthropometric response, no escalation of anti-obesity treatment was considered necessary at that stage. The nutritional plan was subsequently adjusted by reducing the daily caloric intake to 1,800 kcal to further support weight reduction while maintaining metabolic stability.

Continued adherence to the dietary regimen resulted in further improvement. At six months, body weight had decreased to 163 kg and BMI to 51.4 kg/m². Waist circumference was reduced to 155 cm, corresponding to a total decrease of 35 cm.

Overall, the patient achieved a clinically significant weight loss of 52 kg (24.18% of initial body weight) over six months. This was accompanied by marked improvement in functional status, including reduced exertional dyspnea, without episodes of acute cardiopulmonary decompensation during follow-up.

Discussion:

This case illustrates an extreme phenotype of morbid obesity (BMI 69.4 kg/m²) complicated by liver cirrhosis and chronic heart failure with preserved ejection fraction. Notably, despite a body weight of 215 kg and a history of poor dietary adherence, the patient did not exhibit overt glycemic abnormalities, with normal fasting plasma glucose and no prior diagnosis of type 2 diabetes mellitus. This finding is relatively uncommon in extreme obesity, where insulin resistance and dysglycemia are typically prevalent.

Another notable feature was asymptomatic hyperuricemia without clinical gout. Hyperuricemia is increasingly recognized as a contributor to renal microvascular injury, particularly in the presence of obesity and hypertension, both present in this patient, thereby increasing the risk of obesity-related nephropathy. [6]

Interestingly, lipid profile assessment did not reveal significant dyslipidemia, which is atypical in extreme obesity and may reflect altered hepatic lipid metabolism in the context of chronic liver disease. Nonalcoholic fatty liver disease (NAFLD), now more precisely termed metabolic dysfunction-associated steatotic liver disease (MASLD), represents a major obesity-related hepatic manifestation and is strongly linked to overnutrition and insulin resistance. Globally, MASLD affects approximately one-quarter of adults, with up to 25% progressing to steatohepatitis and fibrosis. [7] Nutrition remains a cornerstone in both prevention and treatment, with sustained weight loss being the most effective intervention for histological improvement. Evidence indicates that a ≥10% body weight reduction can lead to regression of fibrosis and resolution of steatohepatitis in a substantial proportion of patients, while even modest reductions (≥5%) confer metabolic benefit. [8]

In the present case, pharmacological anti-obesity therapy was not initiated at presentation. Metformin was avoided because of chronic hypoxemia and the associated risk of lactic acidosis. [9] Bariatric surgery, although the most effective long-term intervention for extreme obesity, was deferred because of the elevated perioperative risk associated with the patient's complex cardiovascular and respiratory comorbidities. [5]

Current evidence supports glucagon-like peptide-1 receptor agonists (GLP-1 RAs) as effective pharmacologic agents for obesity management, with mean weight loss of 15–17% for semaglutide and up to 22.5% for tirzepatide in clinical trials. [10,11] These agents also provide cardiovascular benefit, with reductions in major adverse cardiovascular events of approximately 20% in high-risk populations. [10,12] Emerging therapies, including dual and triple incretin agonists, may further enhance weight loss outcomes and approach the efficacy of bariatric surgery. In many healthcare systems, however, the high-cost of anti-obesity pharmacotherapy remains an important barrier to access.

Bariatric surgery remains the most effective intervention for sustained weight loss, typically resulting in 25–35% total body weight reduction and significant improvement in obesity-related comorbidities. It is generally reserved for patients with severe obesity (BMI ≥40 kg/m² or ≥35 kg/m² with comorbidities) who fail conservative therapy. [5] Nevertheless, 20–30% of patients may experience suboptimal response or weight regain, for which adjunctive pharmacotherapy may be considered. [5,13] Given the substantial weight loss achieved and persistent perioperative risk, surgical intervention was not pursued during the follow-up period.

The marked improvement in exercise tolerance observed during follow-up may further facilitate long-term adherence to lifestyle interventions and support continued weight reduction.

This case highlights the potential role of structured dietary intervention as an effective first-line therapeutic strategy in selected patients with extreme obesity and complex comorbidities. The substantial weight reduction achieved demonstrates that carefully-supervised nutritional therapy may produce clinically meaningful outcomes and, in some cases, delay or reduce the need for pharmacological or surgical escalation.

Conclusion:

The presented case demonstrates that, even in extreme obesity complicated by advanced cardiovascular, respiratory and hepatic comorbidities, clinically meaningful weight reduction can be achieved through a structured, individualized nutritional approach. In this patient, bariatric surgery was deferred because of the elevated perioperative risk, while pharmacological anti-obesity therapy was initially withheld in favor of the intensive lifestyle intervention. Sustained dietary treatment resulted in substantial reductions in body weight, BMI, and central adiposity, underscoring the central role of lifestyle modification as the foundation of obesity management. The absence of overt diabetes despite severe obesity further highlights the heterogeneity of metabolic risk profiles. Multidisciplinary, patient-centered care remains essential to optimize outcomes, and successful lifestyle intervention may delay or reduce the need for pharmacological or surgical treatment in carefully selected patients.

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ИЗМЕНЕНИЕ ПОЛОВЫХ ГОРМОНОВ ПРИ РАННЕЙ БЕРЕМЕННОСТИ И ГЕНИТАЛЬНЫХ ИНФЕКЦИЯХ ПОД ВЛИЯНИЕМ КОНТРИКАЛА И КЛЕКСАНА

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CHANGES IN SEX HORMONES DURING EARLY PREGNANCY AND GENITAL INFECTIONS UNDER THE INFLUENCE OF CONTRICAL AND CLEXANE

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Аннотация

В работе изучалось влияние комплекса контрикал и гепарин на изменение половых гормонов у женщин на ранних сроках беременности при наличии генитальных инфекций и присутствии чрезмерной иммунной реакции. Сделано заключение, что у женщин на ранних сроках беременности имеющих генитальные инфекции и обладающие чрезмерной про воспалительной иммунной реакцией, имеют возможность, к дисбалансу половых гормонов и неблагоприятному течению беременности, а также к развитию выкидышей. Применение только антибиотиков или только комплекса контрикал и клексан не способствует снижению чрезмерной про воспалительной иммунной реакции и уменьшению восстановления дисбаланса половых гормонов, а также не способствует благоприятному течению в ранние сроки беременности. В тоже время совместное применение антибиотиков с комплексом контрикал и клексан способствует снижению чрезмерной про воспалительной иммунной реакции, восстановлению дисбаланса половых гормонов, также способствует благоприятному течению ранних сроков беременности.

Abstract

This study examined the effect of a combination of Contrical and heparin on changes in sex hormones in women with genital infections and an excessive immune response in early pregnancy. It was concluded that women with genital infections and an excessive proinflammatory immune response in early pregnancy are at risk for sex hormone imbalance, an unfavorable pregnancy outcome, and miscarriage. The use of antibiotics alone or the combination of Contrical and Clexane alone does not reduce the excessive proinflammatory immune response, reduce

the restoration of sex hormone imbalance, or promote a favorable pregnancy outcome in early pregnancy. However, the combined use of antibiotics with Contrical and Clexane reduces the excessive proinflammatory immune response, restores sex hormone imbalance, and promotes a favorable pregnancy outcome in early pregnancy.

Ключевые слова: половые гормоны, ранние сроки беременности, генитальные инфекции.

Keywords: sex hormones, early pregnancy, genital infections.

Введение. Имеющиеся данные показывают, что гепарин является мощным противовоспалительным агентом благодаря его способности взаимодействовать с двумя ключевыми цитокинами в развитии цитокинового шторма, IFNγ и IL-6, тем самым подавляя их биологическую активность. Это наблюдение подтверждает возможность благоприятного влияния гепарина на состояния, характеризующиеся сверхэкспрессией определенных цитокинов. Кроме того показано, что эффективность гепарина (имеется в виду низкомолекулярный гепарин) обусловлена его антицитокиновой активности в дополнение к предотвращению свертывания крови [7].

Гепарин обладает способностью снижать воспаление. и, в целом, считается, что гепарин действует несколькими путями, включая взаимодействие с цитокинами и как ингибитор гепараназы, для достижения снижения рекрутирования лейкоцитов [8].

Потенциал, основанный на прогнозе способности гепарина ингибировать бактериальную инфекцию и уменьшать воспаление, также исследовался [10], но заметного улучшения при низких дозах (50 000 МЕ) не было показано.

Было показано, что гепарин и его производные эффективны в предотвращении инфицирования клеток вирусом гриппа, штаммом H5N1 [11], и оказывают воздействие на ZIKV-индуцированную гибель клеток, независимое от адгезии и инвазии [3]. В этом случае гепарин обладает лишь умеренной способностью защищать от инфекции по аналогии с вирусом денге, который также принадлежит к семейству флавивирусов и взаимодействует с гепарином через гликопротеины оболочки [6]. Скорее, гепарин может защищать инфицированные клетки от цитотоксических эффектов и гибели клеток посредством активации сигнальных путей выживания клеток. Способность гепарина защищать клетки от запрограммированной гибели их уже наблюдалась в клетках человека (неинфицированных) [4], и это может открыть новые интересные возможности для применения производных гликозаминогликанов, в частности гепарансульфата (HS) и гепарина как таковых.

Противовоспалительные свойства контрикала (апротинина) известны уже более 10 лет, однако молекулярные механизмы, с помощью которых это достигается, остаются неуловимыми. На основе экспериментальных моделей воспаления были предложены ингибирование контактной активации тромбоцитов и нейтрофилов, косвенные эффекты за счет ингибирования калликреина и блокада экстравазации лейкоцитов [1, 9]. Клинически апротинин также уменьшает накопление нейтрофилов и секрецию IL-8. Однако специфические рецепторные механизмы были обнаружены на тромбоцитах только путем воздействия на протеазо-активируемый рецептор 1 (PAR1) in vitro и in vivo [2, 5]. Поскольку тот же рецептор присутствует на эндотелиальных клетках и опосредует провоспалительные сигнальные пути, обусловленные тромбином, в исследованиях изучалось, воздействует ли апротинин на эндотелиальный PAR1 in vitro.

Цель исследования: изучить влияние комплекса контрикал и гепарин на изменение половых гормонов у женщин на ранних сроках беременности при наличии генитальных инфекций и присутствии чрезмерной иммунной реакции.

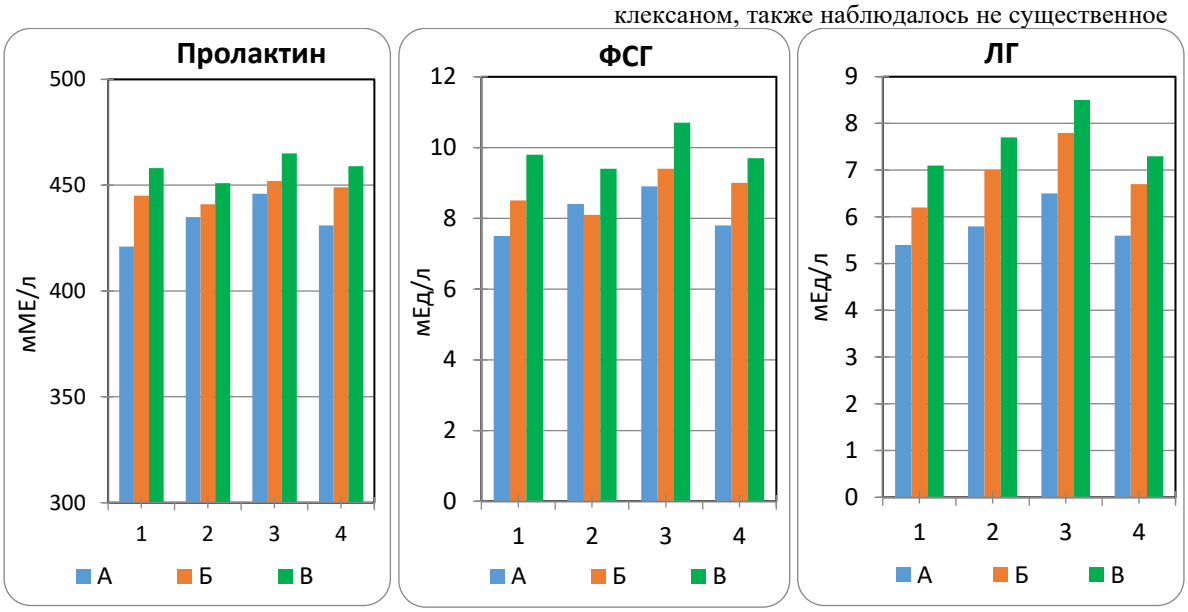
Материал и методы. В работе были обследованы 79 женщин, которые имели выкидыши сроком до 12 недель беременности и генитальные инфекции. А также обладали чрезмерной про воспалительной иммунной реакцией проведены исследования и представлены сравнительные данные: 27 женщин (1 группа) без прегравидарного лечения, 16 женщин (2 группа), получавших прегравидарно антибиотики кларитромицин и доксициклин по 1 таблетке 2 раза в день в течение 15 дней, 19 женщин (3 группа), прегравидарно получавших ингибитор протеаз контрикал в дозе 10 тыс. ЕД, который вводился внутривенно в шприце при соотношении 1:2 со стандартным растворителем 1 раз в день и низкомолекулярный гепарин клексан в дозе 20 мг 1 раз в день в течение 15 дней под контролем протромбинового индекса, 17 женщин (4 группа), которые прегравидарно получали ингибитор протеаз контрикал в дозе 10 тыс. ЕД, в/в и низкомолекулярный гепарин клексан в дозе 20 мг 1 раз в день в течение 15 дней под контролем протромбинового индекса, а также антибиотики кларитромицин и доксициклин по 1 таблетке 2 раза в день в течение 15 дней.

В крови у женщин до беременности, до 6 и до 12 недель беременности определяли методом ИФА показатели: провоспалительных - интерлейкин-1β (ИЛ-1) и фактор некроза опухолей-α (ФНО- α), и противовоспалительных - интерлейкин -10 (ИЛ-10) с применением тест-систем ЗАО «Вектор-Бест» Россия, также трансформирующего фактора роста-β1 (TGF-β1) с использованием тест-систем «DRG» Германия. Помимо этого определяли ингибиторы протеаз α-1-анти-трипсин и α-2-макроглобулин с использованием тест-систем «Sentinel» Италия.

Результаты и их обсуждение. Из проведенных исследований пролактина было установлено (Рис.), что у женщин 1 группы имеющих выкидыши до 12 недель беременности и наличие генитальных инфекций, а также присутствие чрезмерной про воспалительной иммунной реакции. При этом не получавшие лечение, этот показатель в крови, находился на не существенно более высоком уровне на 6 неделе и еще выше на 12 неделе беременности по сравнению с результатами до беременности. Аналогичная направленность отмечалась сроком до 12

недель беременности, также до беременности имевших генитальные инфекции, но обладали чрезмерной про воспалительной иммунной реакцией и которые получали прегравидарно лечение антибиотиками. При этом показатели пролактина 2 группы существенно не отличались от результатов 1группы. Похожая динамика изменений пролактина отмечалась и у женщин 3 группы, у которых до беременности имели генитальные инфекции, но по изменению иммунологических показателей и ингибиторов протеаз крови, имели чрезмерную про воспалительную иммунную реакцию и потенциальную возможность выкидышей до 12 недель беременности. Эти женщины в период прегравидарной подготовки получали лечение с применением ингибитора протеаз контрикала и низкомолекулярного гепарина клексана. Тем не менее показатели пролактина 3 группы существенно не отличались от результатов 1. 2, групп. В тоже время у женщин 4 группы имеющих нарушения подобные в 1, 2, и 3 группах, но получавших лечение в период прегравидарной подготовки с применением антибиотиков совместно с ингибитором протеаз контрикалом и низкомолекулярным гепарином клексаном. Отмечалась также аналогичная направленность изменений пролактина, как и в 1, 2, и 3 группах, которая проявлялась в незначительном повышении на 6 неделе и еще большем на 12 неделе беременности по отношению к показателям до беременности. При этом показатели пролактина 4 группы существенно не отличались от результатов 1. 2, и 3 групп (Рис.).

При исследовании ФСГ в крови у женщин 1 группы имеющих выкидыши до 12 недель беременности и имеющих генитальные инфекции, а также обладающих чрезмерной про воспалительной иммунной реакции. При этом прегравидарно не получавшие лечение, этот показатель в крови, также как и пролактин был не значительно выше на 6 неделе и еще больше на 12 прегравидарно антибиотики кларитромицин и доксициклин наблюдалась аналогичная направленность изменения как у пролактина (Рис.). При этом у женщин как 1 группы, так и у женщин 2 группы показатель ФСГ был не существенно выше на 6 и 12 неделе беременности по сравнению с показателями до беременности, а существенной разницы между показателями 2 и 1 группы не было выявлено. У женщин 3 группы получавших прегравидарно лечение контрикалом и клексаном, также наблюдалось не существенное



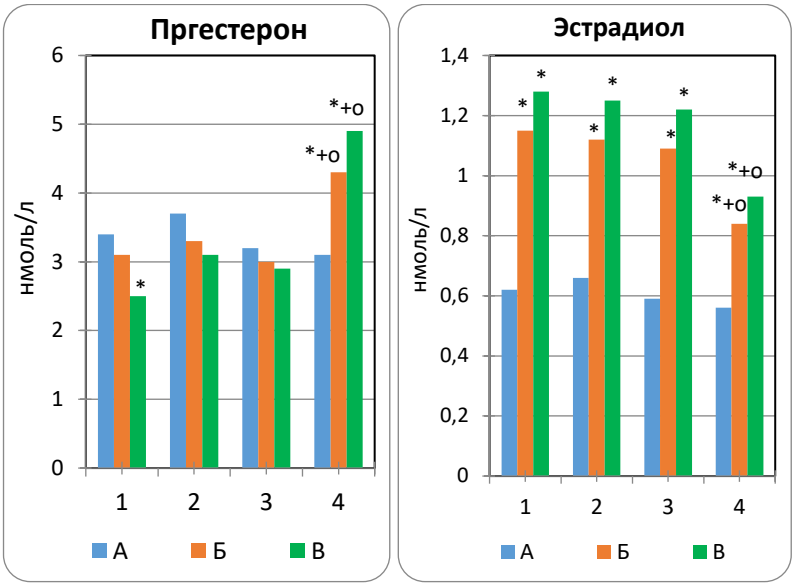


Рисунок. Изменение показателей половых гормонов в крови женщин обследованных групп.
Примечание: А - до беременности; Б – на 6 неделе беременности; В – на 12 неделе беременности. 1-женщины без прегравидарного лечения; 2 – женщины, получавшие прегравидарно антибиотики; 3 – женщины, получавшие прегравидарно (комплекс) контрикал+клексан; 4– женщины, получавшие прегравидарно антибиотики+контрикал+клексан.
**- достоверно отличающиеся величины к показателям до беременности.*
^{o} - достоверно отличающиеся величины к показателям 1 группы.
$^{+}$ - достоверно отличающиеся величины к показателям 2 группы.

повышение показателя ФСГ на 6 и 12 неделе беременности по отношению результатов до беременности. В тоже время показатели ФСГ у неделе беременности по отношению к показателям до беременности. В тоже время при исследовании ФСГ у женщин 2 группы получавших женщин 3 группы существенно не отличались от результатов 1 и 2 групп. У женщин 4 группы получавших прегравидарно лечение антибиотиками совместно с контрикалом и клексаном. Динамика изменения показателей ФСГ была аналогична как в 1, 2, и 3 группах с незначительным увеличением этого показателя на 6 и 12 неделе беременности и отсутствием существенных отличий показателей 4 группы по отношению к результатам 1, 2, и 3 групп (Рис.).

При сравнительном изучении результатов ЛГ была выявлена аналогичная направленность изменений показателей, как пролактина, так и ФСГ (Рис.).

По результатам изучения прогестерона в крови было установлено значительное проявление изменения по сравнению с пролактином, ФСГ и ЛГ. Так у женщин 1 группы, которые имели выкидыши сроком до 12 недель беременности и генитальные инфекции, а также обладали чрезмерной про воспалительной иммунной реакцией не получавших лечение. Отмечалось снижение прогестерона не достоверное на 6 и достоверное на 12 неделе беременности по отношению результатам до беременности. При этом у женщин 2 группы, имевшие выкидыши сроком до 12 недель беременности и до беременности, имевшие генитальные инфекции, также обладавшие чрезмерной про воспалительной иммунной реакцией, но получавшие лечение с применением антибиотиков. Наблюдалось не достоверное снижение прогестерона на 6 неделе и еще более выраженное уменьшение на 12 неделе беременности по сравнению с показателями до беременности. Также, показатели прогестерона у женщин 2 группы на 6 не достоверно и на 12 неделе были не существенно выше аналогичных результатов, чем у женщин 1 группы. В тоже время у женщин 3 группы, у которых аналогичные нарушения как у женщин 1 и 2 группы, но в период прегравидарной подготовки получавшие ингибитор протеаз контрикал и низкомолекулярный гепарин клексан. У данной группы женщин показатели прогестерона на 6 неделе беременности были не существенно меньше и еще ниже на 12 неделе беременности, по отношению результатов до беременности, а также существенно не отличались от показателей 1 и 2 группы (Рис.). Исследование прогестерона у женщин 4 группы получавших прегравидарно лечение антибиотиками совместно с контрикалом и клексаном показало более выраженные изменения этого показателя. При этом наблюдалось значительное и достоверное увеличение прогестерона на 6 неделе беременности и ещё боле выраженное и достоверное увеличение его на 12 неделе беременности. В тоже время показатели как на 6 неделе, так и на 12 неделе беременности были достоверно выше подобных результатов 1. 2, и 3 группы (Рис.).

Полученные данные изучения эстрадиола показали что, у женщин 1 группы имеющих выкидыши до 12 недель беременности, также имеющих генитальные инфекции, а также обладающих чрезмерной провоспалительной иммунной реакции и не получавшие лечение. Было выявлено значительное и достоверное увеличение этого показателя на 6 неделе и еще большее, и достоверное повышение его на 12 неделе беременности. У женщин 2 группы получавшие прегравидарно лечение антибиотиками,

также отмечалось значительное и достоверное увеличение эстрадиола на 6 неделе и еще большее, и достоверное повышение его на 12 неделе беременности. При этом показатели эстрадиола на 6 и на 12 неделе беременности у женщин 2 группы получавших лечение существенно не отличались от результатов 1 группы не получавших лечение. У женщин 3 группы получавшие лечение контрикалом и клексаном, также как у женщин 1 и 2 групп отмечалось значительное и достоверное увеличение эстрадиола на 6 неделе и еще большее, и достоверное повышение его на 12 неделе беременности. При этом показатели эстрадиола на 6 и на 12 неделе беременности у женщин 3 группы получавшие лечение существенно не отличались от результатов 1 и 2 группы. Исследование эстрадиола у женщин 4 группы получавших прегравидарно лечение антибиотиками совместно с контрикалом и клексаном показало более выраженные изменения этого показателя. При этом наблюдалось значительное и достоверное увеличение эстрадиола на 6 неделе беременности и ещё боле выраженное и достоверное увеличение его на 12 неделе беременности. В тоже время показатели как на 6 неделе, так и на 12 неделе беременности были достоверно выше подобных результатов 1, 2, и 3 группы (Рис.).

Таким образом, применение только антибиотиков или только комплекса контрикал и клексан у женщин, имевших выкидыши сроком до 12 недель беременности, также имеющих генитальные инфекции и обладающих чрезмерной про воспалительной иммунной реакцией, не содействует восстановлению дисбаланса половых гормонов, а также не способствует благоприятному течению беременности в ранние сроки. Однако совместное применение антибиотиков с комплексом контрикал и клексан способствует восстановлению дисбаланса половых гормонов, а также способствует благоприятному течению беременности в ранние сроки.

В целом женщины, имеющие генитальные инфекции и обладающие чрезмерной про воспалительной иммунной реакцией, имеют возможность, к дисбалансу половых гормонов и неблагоприятному течению беременности в ранние сроки и развитие выкидышей. Применение только антибиотиков или только комплекса контрикал и клексан не способствует снижению чрезмерной про воспалительной иммунной реакции и уменьшению восстановления дисбаланса половых гормонов, а также не способствует благоприятному течению в ранние сроки беременности. В тоже время совместное применение антибиотиков с комплексом контрикал и клексан способствует снижению чрезмерной про воспалительной иммунной реакции, восстановлению дисбаланса половых гормонов, также способствует благоприятному течению ранних сроков беременности.

Выводы. Женщины на ранних сроках беременности имеющие генитальные инфекции и обладающие чрезмерной про воспалительной иммунной реакцией, имеют возможность, к дисбалансу половых гормонов и неблагоприятному течению беременности, а также к развитию выкидышей. Применение только антибиотиков или только комплекса контрикал и клексан не способствует снижению чрезмерной про воспалительной иммунной реакции и уменьшению восстановления дисбаланса половых гормонов, а также не способствует благоприятному течению в ранние сроки беременности. В тоже время совместное применение антибиотиков с комплексом контрикал и клексан способствует снижению чрезмерной про воспалительной иммунной реакции, восстановлению дисбаланса половых гормонов, также способствует благоприятному течению ранних сроков беременности.

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PEDAGOGY

EXAMINATION OF THE OUTCOMES OF MUSIC TEACHER CANDIDATES REGARDING THE COMMUNITY SERVICE PRACTICES COURSE

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Abstract

This study aims to examine the processes carried out by pre-service music teachers within the scope of the Community Service Practices course and the multidimensional effects of these processes based on participant views. The course process was addressed within the framework of planning, implementation, reflection, and evaluation stages, and its effects on the affective, behavioral, social, and cognitive development of pre-service teachers were investigated. The study was conducted using a phenomenological design, one of the qualitative research approaches, with 25 pre-service music teachers who took the Community Service Practices course in the spring semester of the 2023-2024 academic year. Participants were selected through easily accessible sampling, one of the purposive sampling methods. Data were collected through a semi-structured interview form administered at the end of a 12-week implementation process. The findings indicate that community service practices were conducted systematically, collaboratively, and under instructor guidance, contributing to the academic, social, affective, and behavioral development of pre-service teachers while enhancing their social awareness. In conclusion, the Community Service Practices course supported pre-service teachers in transferring theoretical knowledge into practice and made significant contributions to their development of social sensitivity, sense of responsibility, and professional awareness.

Keywords: Community Service Practices, Music Teacher Candidates, Social Responsibility, Teacher Education, Professional Development.

1. Introduction

Society is not merely a collection of individuals living within a specific geographical area; rather, it is conceptualized as a dynamic social system in which individuals continuously interact through shared values, norms, social relationships, cultural exchanges, and a collective sense of identity [1]. Within the framework of contemporary understandings of society, mutual interdependence among individuals, social solidarity, and a shared sense of responsibility are regarded as fundamental components that sustain social cohesion and collective well-being.

Similarly, Eriksen [2] argues that society cannot be adequately defined solely by shared language, religion, or geographical boundaries. Rather, the network of political, economic, cultural, religious, and social relationships that connects individuals plays a decisive role in the formation and maintenance of society. According to Eriksen [2], society constitutes a continuous system of interaction that fosters a shared sense of belonging among individuals and integrates them into a larger collective entity. In the context of globalization, the concept of society has increasingly evolved from a fixed and bounded structure into a more flexible, multicultural, and dynamic social formation characterized by fluid boundaries and diverse forms of social interaction.

From the perspective of contemporary higher education institutions, society is no longer viewed merely as a target population to which services are delivered; rather, it is regarded as a network of stakeholders with whom universities engage in reciprocal interactions through their educational and research activities. This perspective necessitates that universities assume responsibility not only for education and research but also for generating societal impact and contributing to social development [3].

The sustainable development of society is closely associated with individuals' acquisition of social responsibility awareness and their active participation in addressing societal challenges. In this regard, community service practices implemented in higher education provide students with opportunities to connect their academic knowledge with real-world problems while fostering the development of social responsibility, empathy, communication skills, and democratic citizenship competencies [4].

The concept of society holds particular significance within teacher education programs. Teachers are widely recognized as key agents in the transmission of cultural values, the strengthening of social solidarity, and the promotion of social transformation processes [5].

Consequently, enabling prospective teachers to understand the structure, needs, and challenges of society, develop a sense of social responsibility, and acquire the ability to generate solutions for societal benefit is considered an essential component of professional competence. Within this framework, society is understood not merely as a collection of individuals living together but as a dynamic social system in which people collaborate toward common goals, assume mutual responsibilities, share cultural values, and work collectively toward sustainable development.

Faculties of education are institutions that aim not only to conduct research and provide education but also

to serve society. Such service should extend from local communities to national and international contexts. The effectiveness of these institutions depends largely on the principles they adopt and the methods they employ. Sensitivity to social issues, collaboration, volunteerism, critical thinking, and creativity are considered fundamental principles in community engagement. Furthermore, faculties of education are expected to contribute to reducing social inequalities and addressing the needs of disadvantaged groups [Anonymous, 2006, as cited in 6].

Social responsibility is a concept that guides individuals' behaviors and decision-making processes. Individuals who act with a sense of social responsibility take into account the consequences of their actions for society and the environment. Moreover, they demonstrate sensitivity not only toward society and the environment but also toward their families, friends, and others for whom they bear responsibility [7]. The development of social responsibility awareness encourages both individuals and institutions to contribute to the communities in which they operate and to fulfill their societal obligations [8].

The Community Service Practices course seeks to cultivate social awareness, civic consciousness, and a sense of responsibility among teacher candidates. Through participation in social responsibility projects, prospective teachers contribute to society while simultaneously enhancing their professional effectiveness. By developing solutions to real societal problems through teamwork and collaborative action, teacher candidates may also transmit these values and responsibilities to their future students. Consequently, future generations can become more actively engaged in addressing social challenges, highlighting the important role of faculties of education in fostering social responsibility and civic awareness [9].

Community service organizations and initiatives may not provide the same level of benefit to every student; however, they offer valuable opportunities to cultivate socially engaged individuals and to establish long-term connections between students and specific social causes or civil society organizations [10]. Similarly, Community Service Practices courses have been shown to prepare students for voluntary engagement within community service organizations and equip them with competencies related to community-based care and service provision [11].

According to Noyan and Kesten [12], the primary objective of Community Service Practices is "to foster students' sensitivity toward events occurring in society and to encourage them to develop projects that generate solutions to contemporary social problems."

Universities are not merely institutions responsible for education and research; they are also higher education institutions with a mission to contribute to social development. In Türkiye, Article 12 of the Higher Education Law No. 2547 emphasizes universities' responsibilities to provide education and training responsive to societal needs, conduct scientific research, offer consultancy and dissemination activities, educate qualified human resources, produce and transfer scientific knowledge to society, contribute to economic, social, and cultural development, support industrial and agricultural advancement, propose solutions to environmental issues, and conduct research addressing societal challenges. Accordingly, a fundamental function of universities is to contribute to the economic, social, and cultural development of their regions and countries while enhancing societal well-being through social and cultural activities, environmental initiatives, and community engagement [13]. During their educational preparation, prospective teachers are expected not only to acquire pedagogical knowledge and general cultural competencies but also to develop qualities that enable them to contribute to the economic, social, and cultural development of society [14].

The Community Service Practices course generally consists of four stages: needs assessment, planning, implementation, and evaluation. Initially, community needs are identified, and decisions are made regarding the types of activities to be conducted and the target populations to be served. Subsequently, weekly schedules are prepared, objectives are established, and learning processes are planned. Programs are then implemented in accordance with the characteristics and needs of the target group. Finally, evaluations are conducted to determine the extent to which program objectives have been achieved, and participants' perspectives are collected [15].

Designed to foster social responsibility among prospective teachers, the Community Service Practices course encourages teacher candidates to analyze social problems related to their respective disciplines and to develop project-based, solution-oriented interventions [16].

Taylor et al, [17] noted that community-based service-learning activities may pursue either transformative learning outcomes or more practice-oriented objectives. Their review of the literature suggests that service-learning supports reflective and collaborative learning, strengthens the connection between theory and practice, enhances multicultural competencies, and increases sensitivity toward civic engagement and social justice. Furthermore, these experiences contribute to professional identity development, foster students' understanding of themselves in relation to others, and enhance self-confidence regarding disciplinary knowledge and practice.

Although numerous studies have examined Community Service Practices courses in both national and international contexts, the majority have treated teacher candidates as a homogeneous group and have primarily focused on disciplines such as elementary education, social studies education, science education, and early childhood education. In contrast, studies that comprehensively examine pre-service music teachers' experiences in Community Service Practices courses across planning, implementation, and evaluation processes, as well as their affective, behavioral, social, and cognitive outcomes, remain limited. Moreover, much of the existing literature relies on quantitative methodologies, providing insufficient insight into participants' lived experiences, personal transformations, and meaning-making processes throughout the course. Therefore, there is a need for qualitative research that explores pre-

service music teachers' process-oriented experiences and multidimensional learning outcomes within Community Service Practices courses.

Addressing this gap in the literature, the present study aims to provide a comprehensive examination of pre-service music teachers' experiences in the Community Service Practices course, with particular attention to their development of social responsibility awareness, professional growth, social interaction, and academic gains.

In line with the purpose of the study, the main research question was formulated as follows:

"How do pre-service music teachers describe their experiences and perceived gains regarding the Community Service Practices course?"

Based on this overarching research question, the following sub-research questions were developed:

- What are the planning stages of the Community Service Practices course process?
- What are the implementation stages of the Community Service Practices course process?
- What are the evaluation stages of the Community Service Practices course process?
- What are the affective outcomes associated with participation in the Community Service Practices course?
- What are the behavioral outcomes associated with participation in the Community Service Practices course?
- What are the social outcomes associated with participation in the Community Service Practices course?
- What are the cognitive outcomes associated with participation in the Community Service Practices course?

This study is considered significant in that it contributes to understanding how participation in the Community Service Practices course supports pre-service music teachers in developing a sense of social responsibility, gaining professional experience, and enhancing social skills such as communication, cooperation, solidarity, and interpersonal relationships.

2. Method

2.1. Research Design

In this study, content analysis, a qualitative data analysis method, was employed. Qualitative research is a systematic approach that aims to gain an in-depth understanding of individuals' experiences, perceptions, thoughts, and social realities within their natural contexts. Rather than reducing phenomena to numerical data, qualitative research seeks to interpret and explain the meanings constructed by participants and the social processes underlying these meanings [18].

One of the most widely used data analysis techniques in qualitative research is content analysis. Content analysis refers to the systematic and objective examination of written, verbal, visual, or digital data in order to identify, classify, and interpret recurring concepts, categories, themes, and patterns [19]. This method enables researchers to transform large volumes of qualitative data into a meaningful structure and to reveal relationships embedded within the data.

Content analysis involves several interconnected stages, including the careful examination of raw data, coding meaningful units of information, grouping similar expressions into categories, and generating higher-order themes [20]. Through this process, researchers are able to systematically interpret participants' experiences and perspectives and to explain the fundamental characteristics of the phenomenon under investigation.

The implementation of content analysis generally consists of four main stages. First, researchers become familiar with the data through repeated and detailed readings. Second, meaningful statements and units of analysis are identified and coded. Third, similar codes are grouped into categories based on conceptual similarities. Finally, these categories are synthesized into broader themes and interpreted in relation to the research questions [21].

The use of content analysis in qualitative research facilitates the systematic organization of complex and multidimensional data, enables the identification of both shared and divergent participant experiences, and contributes to the clear and coherent presentation of research findings [22]. To enhance the trustworthiness and rigor of the analysis, it is recommended that coding procedures be explicitly described, themes be directly linked to the research questions, and researchers' interpretations be supported by representative excerpts from the data [23].

In conclusion, content analysis represents a systematic, flexible, and rigorous analytical approach that plays a significant role in the interpretation and meaning-making of qualitative data. It has been widely employed in educational research, social sciences, and music education studies to provide a comprehensive understanding of participants' experiences, perceptions, and viewpoints.

Accordingly, the present study examined Community Service Practices within a qualitative research framework. Since the study aimed to explore pre-service teachers' perceptions, feelings, thoughts, and experiences regarding Community Service Practices, content analysis was considered the most appropriate method for analyzing and interpreting the collected data.

2.2. Study Group

The study was conducted during the spring semester of the 2023–2024 academic year with 25 pre-service music teachers enrolled in the Community Service Practices course in the fourth year of the Music Education Department who voluntarily agreed to participate in the research. The participant group consisted of 14 female and 11 male pre-service teachers.

2.3. Data Collection Process and Data Collection Instruments

The data collection process in this study was conducted in two stages. In the first stage, participants were asked to keep reflective journals to facilitate the systematic monitoring of their experiences throughout the Community Service Practices course, to document the experiences they encountered during the implementation process, and to support the internalization of these experiences. However, these journals were not used as the primary data collection instrument of the study.

The primary purpose of the reflective journals was to encourage participants to document their experiences, encountered situations, and personal observations at the end of each implementation day. By doing so, the journals were intended to support participants in reflecting on the process, engaging in self-evaluation, and developing greater awareness of community service practices. Accordingly, the journals were not employed for the purpose of generating research data; rather, they served as a pedagogical tool designed to support participants' learning processes and foster reflective self-assessment.

The research data were collected upon the completion of the implementation process. For this purpose, a semi-structured interview form was administered to elicit participants' views regarding both the Community Service Practices course and the learning outcomes they perceived from their participation in the course. Therefore, the semi-structured interview form constituted the primary data collection instrument of the study. Only the data obtained through this instrument were included in the analysis process.

The activities conducted within the scope of the Community Service Practices course were implemented over a 12-week period. The activities were collaboratively planned and carried out under the guidance of the course instructor. Throughout the implementation process, weekly meetings were held with the participation of both the instructor and the students to discuss the execution and evaluation of the activities. At the end of each implementation day, participants recorded their experiences, observations, and personal reflections related to that day's activities in their reflective journals.

To guide participants throughout the reflective journaling process, a reflective journal guideline was developed. The guideline was structured around two main dimensions.

The first dimension focused on reflective evaluations of the Community Service Practices course process. Within this dimension, participants were asked to reflect on the various stages and experiences associated with the implementation of the course.

- Planning phase: This phase included reflections on conducting a needs assessment of the target population prior to implementation, identifying logistical requirements, managing communication processes with stakeholders, and developing an implementation schedule.
- Implementation phase: Participants reflected on the execution of the planned activities, the development of solutions to challenges encountered during the process, and the implementation of participant-centered practices.
- Reflection phase: This phase involved comparing the outcomes achieved with the initial objectives, relating practical experiences to theoretical knowledge, and critically evaluating individual learning gains and personal development.
- Evaluation phase: Participants engaged in self-evaluation regarding the effectiveness of the activities, the number of individuals reached, process management, resource utilization, and time management. They were also encouraged to formulate recommendations for the improvement of similar initiatives in future implementations.

The second dimension consisted of reflective evaluations concerning the impact of the Community Service Practices course on participants. Within this dimension, participants were encouraged to reflect on the personal, social, and educational outcomes they perceived as a result of their involvement in the course.

- Affective impact: Reflections focused on participants' levels of empathy, social sensitivity, sense of community belonging, and awareness of disadvantaged groups.
- Behavioral impact: Participants evaluated the development of professional competencies, including crisis management, effective communication, time management, and collaboration skills.
- Social impact: Reflections addressed community solidarity, interactions among individuals and institutions, the strengthening of social capital, and changes in levels of social awareness.
- Academic [cognitive] impact: Participants evaluated the extent to which they were able to transfer theoretical knowledge to real-life problems, as well as the gains they achieved in critical thinking, analytical reasoning, and synthesis skills.

The activities conducted within the scope of the study were planned in accordance with the Community Service Practices Project Guidelines of Erzincan Binali Yıldırım University, and all necessary institutional permissions were obtained prior to implementation. In collaboration with the participants, four community service projects were carried out: Hand in Hand with the Environment, Clothing Support for Children, Visiting Older Adults, and Assistance for Individuals with Disabilities.

At the conclusion of the implementation process, a semi-structured interview form was administered to explore participants' views regarding the Community Service Practices course. Prior to data collection, participants were informed about the content and purpose of the interview form and were asked to provide written responses to the following questions:

1. What are your views regarding the planning process of the activities conducted within the Community Service Practices course?
2. What are your views regarding the implementation process of the activities?
3. What are your views regarding the evaluation process of the activities?
4. What are your views regarding the affective impacts of the activities?
5. What are your views regarding the behavioral impacts of the activities?
6. What are your views regarding the social impacts of the activities?
7. What are your views regarding the academic [cognitive] impacts of the activities?

The data obtained from the semi-structured interview forms completed by the participants were subjected to analysis. First, the data were organized and systematically reviewed. Subsequently, they were categorized into themes and codes and presented in tabular

form. To enhance the credibility and richness of the findings, direct quotations from participants' responses were included. Participants were identified using the code "P" [Participant] to ensure anonymity and confidentiality.

During the development of the interview form, the opinion of an academic expert in the field of educational sciences was sought to ensure the appropriateness and clarity of the questions. To enhance the trustworthiness of the study, expert review, participant confirmation, and the inclusion of direct quotations were employed. In addition, the data collection and analysis procedures were described in detail to ensure methodological transparency. Furthermore, the semi-structured interview form was completed in written form by the participants in an effort to minimize potential data loss and ensure the accuracy of the collected data.

2.4. Data Analysis

Content analysis was employed to analyze the data. Participants' responses to the interview questions were systematically examined by the researchers, and initial codes were generated. Codes with similar characteristics were subsequently grouped together to form broader themes. To enhance the dependability of the study, the data collection and data analysis procedures were described in detail, and the resulting codes and themes were presented in tabular form in the findings section. To enrich the presentation and interpretation of the findings, direct quotations from participants' written responses in the semi-structured interview forms were included. In these quotations, participants were identified using the code "P" [Participant] to ensure anonymity. Finally, the findings were discussed in relation to relevant studies in the literature, and the results were interpreted within the context of previous research.

2.5. Research Ethics

This study was conducted in accordance with established research and publication ethics principles. Ethical approval was obtained from the Human Research Ethics Committee in Educational Sciences at Erzincan Binali Yıldırım University [Decision No. 06/27, dated March 29, 2024]. Participation in the study was entirely voluntary, and all participants were informed about the purpose and procedures of the research prior to data collection. Participants' personal information was kept confidential, and anonymity was ensured throughout the research process. Furthermore, all citations and references were presented in accordance with accepted academic and scientific standards.

3. Findings

In this section of the study, participants' experiences and evaluations regarding the "Community Service Practices Course Process" and the "Effects of Community Service Practices" are presented. The data obtained were addressed in line with the identified themes and were systematically analyzed and interpreted.

3.1. Findings Regarding the Community Service Practices Course Process

Table 1.

Findings on The Planning Process of Community Service Practices

Theme	Codes	f	%	Participants
Cooperation with the Supervising Teacher	Teacher Guidance, Mutual Exchange of Views, and Teacher Leadership	12	48%	P2, P3, P4, P5, P7, P10, P13, P18, P19, P20, P22, P23
Coordination with Associations and Institutions	Erzincan Volunteer Youth Association, Communication with Association Members, Official Permissions, and Collaboration	13	52%	P1, P12, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P25
Group Work and Joint Decision-Making	Holding Meetings, Exchanging Ideas, Class-Wide Decision-Making, and Joint Project Selection	10	40%	P2, P3, P7, P8, P9, P13, P14, P20, P21, P23
Alignment of Activities with Objectives	Community Benefit, Needs Analysis, Serving Society, Environmental Cleanliness, and Social Responsibility	14	56%	P1, P6, P8, P9, P11, P15, P16, P17, P19, P20, P21, P22, P24, P25
Time and Venue Planning	Determining Date, Time, and Venue; Checking Suitability; and Adjusting Participant Numbers	15	60%	P3, P6, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P25
Individual Preparation and Responsibility	Personal Research, Task Allocation, and Improvement of Deficiencies	4	16%	P6, P8, P9, P11
Project Design and Implementation Process	Appropriate Project Selection, Idea Generation, and Feasibility Analysis	9	36%	P7, P8, P10, P13, P14, P15, P16, P17, P24

Table 1 examines students' views regarding the planning process of the activities carried out within the scope of community service practices. The findings indicate that the activities were planned under the guidance of the instructor and in collaboration with relevant institutions and organizations, encompassing stages such as needs identification, goal setting, time–space planning, and task distribution.

Furthermore, based on students' views, it was determined that the planning process of the activities conducted within the scope of community service practices was carried out systematically and collaboratively under the guidance of the supervising instructor.

The following section presents students' views regarding the findings:

P1- The planning process was decided together with school-related activities. Afterwards, decisions were made regarding what we would do and how we would proceed. For other social activities, we also acted in collaboration with the Association, and implementation was carried out through participation in the activities.

P2- During the planning process of the activity, we collectively discussed the projects we would carry out in the classroom. We shared our ideas and opinions with our supervising instructor and classmates who conducted the community service course, and based on these discussions, we completed the planning process.

P3- The activities were first planned during the course through mutual exchange of ideas with our instructor. Then, under the guidance of our instructor, we were informed about where, when, and how the activity would take place. Activities were carried out either with our instructor, individually, or in groups.

P4- During the activity planning process, we prepared in coordinated collaboration with the course instructor. We exchanged information about the process and discussed in detail what needed to be done. We participated in the activities carried out under the leadership of our teacher.

P5- First, the instructor asked us several questions about the Community Service Practices course, such as our opinions about the course. Then, the instructor explained how the course would be carried out and asked us to participate in various activities. After that, we directly participated in the activities and became actively involved in the implementation process.

P6- In our activity, I attended classes at a school that did not have a music teacher. In the planning process, I first learned about the aspects I was lacking in this field from necessary sources. Then, starting from the basics of the subject, we began the process by introducing the diaphragm, followed by how to use it and how to breathe correctly.

P7- We started the planning process in our first lesson. After receiving information in line with the course objectives, everyone began preparing assistance projects within the scope of the Community Service Practices Course. Suitable projects were then implemented.

P8- We presented some ideas that had not been implemented before and that we thought would benefit the community. Based on these ideas, we selected the ones that were easy to implement and cost-free or low-cost. We gradually put the selected ideas into practice over time.

P9- The planning process of the activity was quite productive. First, the group collectively determined who needed what. Then, the children in need were identified together.

P10- I believe that the regular and planned progress of the activity planning process provided us with many benefits in carrying out the activity.

P11- First, we contacted the relevant institutions and planned how we would reach the addresses and families identified by these units, as well as what kind of approaches we would take and what needs we would address when we reached them.

P12- During the planning process of the activities, we communicated with an association member we had previously agreed with, arranged the day, time, and date, and completed the planning accordingly.

P13- In the planning process, everyone first came together. We held two to three meetings to discuss how the activities could be made more efficient. We talked about and discussed everyone's availability, and under the leadership of our instructor, we carried out the activity planning processes.

P14- Within the scope of the "Hand in Hand with Children" activity, families in need were identified, and information about the number of children was obtained. Communication was established with the Erzincan Volunteer Youth Association, and the location and time of the activity were determined.

P15- After deciding what the project would be, the day and time were set, and necessary permissions were obtained. We received the required support from the Erzincan Volunteer Youth Association. We completed the planning process of our project. We evaluated projects in line with the objectives of community service practices, selected the feasible ones, and among them chose the "Hand in Hand with the Environment" project. In this process, we listed the necessary materials and equipment, determined the day and time, and finalized our planning.

P16- After determining the number of participants and obtaining the necessary permissions, we completed our planning in coordination with the Erzincan Volunteer Youth Association. During the activity planning process, the project topic and its benefit to society were taken into consideration. Issues such as participation numbers, materials to be used, and coordination with the relevant institution were arranged. The program was carried out in accordance with the planning process.

P17- A decision was made regarding the nature of the activity, and permissions were obtained from relevant institutions and organizations. The number of participants, location, and time were determined, and the activity was carried out together with the Erzincan Volunteer Youth Association. When planning an activity, what would be done, the project topic, and its benefit to society were primarily considered. Among the proposed projects, issues such as the number of participants, materials to be used, and coordination with the relevant institution were arranged. Decisions were made regarding for whom, according to what criteria, and where the activity would take place, as well as its suitability for its purpose and expected outcomes.

P18- During the class hour, decisions were made regarding the scope, day, and time of the activity. We contacted the Erzincan Volunteer Youth Association

and relevant organizations, and then carried out our activity.

P19- First, we evaluated what we could do within the scope of community service. With the participation of an instructor from the Guidance and Psychological Counseling [PDR] field in our class, we received information about how to communicate with people in community service contexts and what issues to pay attention to, which was very productive. Afterwards, we made our plans. We carried out a project to clean a park in Erzincan and raise awareness. In later lessons, we also conducted a nursing home visit and additional environmental cleaning projects.

P20- While planning our activity, we took our immediate surroundings into consideration. Based on this idea, we collectively decided to carry out an environmental cleaning activity in the most frequently used recreational area of our city. After our instructor completed all the necessary procedures, we carried out our activity on the assigned day in accordance with our plan.

P21- While planning the activity, we first considered what we could do within the scope of community service. In this regard, to the best of our ability, we selected Atatürk Park, which suffers from environmental pollution in our city. Then we determined the date and time and carried out our activity.

P22- Within the scope of the "Hand in Hand with the Environment" project, during the class hour, we determined together with our instructor when and at what time the park cleaning would take place. Then, by identifying the individuals responsible for the content of the activity, the day's activity was completed in a planned and organized manner.

P23- During the planning process of the activity, the number of participants was determined during the class. Then we arranged where and when we would meet. The units hosting the activity were informed, and the necessary tools and materials were provided. The planning process was very successful.

P24- During the planning process of the activity, we first determined the environmental theme. We discussed what we could do regarding this topic and what our options were. Afterwards, we decided that Atatürk Park, which we had chosen as our topic, would be the site for the activity.

P25- We found answers to the question, "What can we do while planning the activity?" We contacted the authorities and determined the day and time of the activity. A suitable location for the activity was selected.

Table 2.

Findings Regarding The Implementation Process of The Activity

Theme	Codes	f	%	Participants
Planned and Coordinated Implementation	Implementation at the scheduled date/time, smooth progress of activities, task allocation, and teamwork	18	72%	P1, P3, P4, P5, P7, P8, P12, P13, P14, P15, P16, P17, P18, P20, P21, P22, P23, P24
Contribution to Community Welfare and Social Sensitivity	Assistance to individuals in need, social benefit, sensitivity, and awareness of community service	17	68%	P2, P4, P5, P6, P9, P11, P14, P15, P16, P17, P18, P19, P20, P21, P23, P24, P25
Student Participation and Voluntariness	Voluntary participation, students' active involvement, and willing and devoted engagement	11	44%	P2, P4, P5, P7, P13, P14, P15, P16, P18, P21, P24
Advisor/Mentor Teacher Contribution	Academic guidance, teacher direction, and monitoring of the process	10	40%	P3, P5, P13, P15, P17, P18, P22, P24, P25, P19
Collaboration and Solidarity	Group work, collective action, cohesion, and mutual support	9	36%	P5, P14, P16, P18, P20, P21, P22, P23, P24
Awareness and Personal Development	Acquisition of responsibility, social awareness, empathy, and value development	8	32%	P2, P5, P6, P17, P19, P20, P21, P25
Challenges Encountered During the Implementation Process	Communication problems, lack of coordination, and unforeseen situations	2	8%	P10, P15

Table 2 examines students' views on the implementation process of the activities carried out within the scope of community service practices. The findings indicate that the activities were conducted at the planned time and place, under the guidance of the instructor, and in collaboration with relevant institutions. In addition, the findings derived from student opinions demonstrate that active participation, collaborative work, and instructor guidance were prominent in the implementation process of community service activities.

Student views regarding the findings are presented below:

P1- The implementation process began with fundamental information about the instrument; the instrument was defined and introduced, and the process continued by building upon this foundation step by step.

P2- During the implementation process of the activity, I conducted "art" education classes with students at an Imam Hatip High School. Through this experience, which took place within the scope of the community service course, I both provided a beneficial education to students and gained experience in this

context. At the same time, I contributed to different projects [for example, assisting individuals in need to access a wheelchair activity] and participated in a breakfast event with an elderly man. These experiences made me feel good and instilled a sense of social responsibility.

P3- The implementation process progressed under the meticulous supervision of our instructor. With the guidance of external individuals and groups, various activities and practices were carried out in the field of community service.

P4- The implementation process took place on the day and within the timeframe we had previously planned, and in every activity we participated in, the benefit to society was prioritized. It had positive social impacts on our future teaching profession, in which we will be pioneers.

P5- First, we formed a group under the name of community service, consisting of students and Levent Hodja. Later, a man who was a member of the Erzincan Genç Gönüllüler Foundation joined the group, and during that period we voluntarily participated in various activities. Afterwards, we visited elderly people in their homes, bought holiday clothes for children, and so on. The process continued in this way.

P6- My views on the implementation process are that many talented individuals can reach a much better position by receiving education.

P7- The first project I attended during the implementation process was a music lesson at an Imam Hatip High School. I regularly went every week and gave guitar lessons. It was a very beneficial practice in terms of students' learning and development.

P8- After being informed by those organizing the activities, a meeting day and place were determined, and ideas were exchanged on how the activities would be implemented before taking action.

P9- After identifying the children in need, we went to the contracted stores, determined a specific budget, first bought clothes for the children, and then purchased shoes and delivered them to their families.

P10- I believe that some communication problems during the implementation of the activity negatively affected the activity.

P11- In line with the planning, together with the designated groups and necessary materials, we tried to help the determined families as much as we could on the scheduled days within a framework of respect and compassion.

P12- On the date and time we had determined, we contacted the relevant association member and worked in the field for community service.

P13- During the implementation process, the days of the activities we would attend were determined. I participated in a six-week activity. Each of us carried out the implementation process individually under the supervision of our instructor.

P14- On the designated day and time, we gathered in front of the store where the children would be clothed together with our instructor. We started the activity with the members of the Gönüllü Gençler Association. Each of us took care of one child. While selecting clothes with the child, we also chatted and had a pleasant time with them.

P15- When the project day and time arrived, we entered the store where the project would take place. We wore our vests to work together with the Gönüllü Gençler Association. We carefully dressed each child and completed our project with dedication and determination. During the implementation process, after going to the project area and collecting the tools and materials, we started cleaning the environment. In fact, the park was cleaner than we had expected. I believe the municipality had already been carrying out the necessary work. We completed the cleaning of the park in a proper manner.

P16- We met with our association at the planned time and address. It was discussed and implemented that we needed to communicate sensitively and carefully with the children. During the implementation process of the "Hand in Hand with the Environment" project, we gathered at the agreed time. The necessary materials and preparations were provided. We dispersed to different areas and carried out our project smoothly.

P17- At the activity implementation time, we gathered, and beforehand we were informed by the association president about what we should pay attention to [such as not showing the children's faces and avoiding personally hurtful comments]. Then, we accompanied each child one by one, without interfering with their choices, helping them select the clothes they wanted while having brief conversations. During the implementation process of the activity, various people came together, the necessary materials were obtained, and after a short planning and preliminary meeting, the activity began.

P18- We gathered on the planned day and time. First, we were given Gönüllü Gençler logos and vests, and then we were told what we needed to do. In proportion to our numbers, we each had specific responsibilities, and we completed the activity accordingly.

P19- The activities had a positive emotional impact. We gained and raised awareness. Our feelings of socialization and solidarity developed. As a part of society, doing beneficial work for the community felt good. I believe that first I myself, and then society, gained awareness of responsibility toward the environment and the community.

P20- During the implementation process of our activity, we all prepared willingly and sensitively. During the implementation, we divided the work and completed the cleaning of a large area in small groups.

P21- Together, in a spirit of solidarity, we cleaned Atatürk Park, and while implementing this activity, being in unity, togetherness, and cooperation made us all very happy. We did not even notice how time passed.

P22- On the designated day, we gathered with the friends who would participate in the activity at the time set by our instructor. Within the framework of the "Hand in Hand with the Environment" project planned in the course, the activity proceeded without any problems.

P23- During the implementation process, we met at the location we had determined. After receiving the

materials, we started cleaning the environment and finished our work in a short time. During this process, we worked together and paid attention to working in harmony. After fulfilling our duties, we conducted a collective evaluation and concluded the implementation. It was a well-executed and successful practice.

P24- Regarding the implementation process of the activity: With the necessary equipment on the day and time we had determined and with the guidance of our instructor, we easily completed the activity together with our friends.

P25- Thanks to our academic instructor who guided us during the implementation process, we obtained what was necessary for our project. He instilled in us a sense of sensitivity for a better environment.

Table 3.

Findings Regarding The Evaluation of The Activity

Theme	Codes	f	%	Participants
Societal Benefits and Social Contributions	Contributing to the community, environmental sensitivity, awareness of community service, social awareness, and social responsibility	20	80%	P2, P3, P4, P6, P7, P8, P9, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P23, P24
Personal and Professional Development	Contribution to teacher candidacy, gaining experience, sense of responsibility, communication skills, and professional awareness	16	64%	P1, P2, P4, P5, P7, P10, P13, P14, P15, P17, P18, P19, P22, P23, P24, P25
Critical Reflection in the Evaluation Process	Identification of shortcomings, determination of areas for development, feedback, and reflection on how improvements could be made	6	24%	P6, P8, P16, P17, P23, P25
Spiritual Dimension and Emotional Impact of the Activities	Inner peace, empathy, emotional fulfillment, touching hearts, and imparting values	8	32%	P2, P5, P11, P14, P15, P17, P19, P21
Sensitivity to Nature and the Environment	Environmental awareness, appreciation for the environment, responsibility toward nature, and ecological consciousness	6	24%	P17, P20, P21, P23, P24, P25
Alignment of the Activity with Planned Objectives	Alignment with course content, implementation in line with objectives, and execution in a planned and effective manner	4	16%	P18, P22, P23, P25

Table 3 presents the evaluations of students regarding the activities conducted within the scope of Community Service Practices. The findings indicate that the activities contributed to providing social benefits, raising awareness, and supporting the students' social, professional, and affective development. Furthermore, based on the participants' evaluations, it was determined that the community service activities were positively assessed in terms of both the effectiveness of the implementation process and the individual and societal gains achieved.

Below are the students' statements regarding the findings:

P1- The activities brought participants together and provided a social environment. Knowledge was transferred and shared, enabling social interaction.

P2- The activities and projects allowed us, as prospective teachers, to engage more socially in the field and to help individuals in need. Additionally, providing music education in a school without any prior music lessons was both beneficial for the students and an enriching experience for me within the scope of the Community Service course.

P3- The activities provided benefits within the field of Community Service.

P4- The activities I participated in consistently prioritized societal benefit. They fostered social solidarity and cooperation, as well as a sense of responsibility, which are integral aspects of the teaching profession and are expected to continue throughout one's career.

P5- I evaluate the activity as follows: such activities help us become more involved with real-life situations and provide guidance on how to navigate the course process.

P6- I consider that the primary value of the activities lies in their contribution to society and the arts. Although we had some shortcomings, we assisted as much as possible.

P7- During the last activity, I noticed that even at a basic level, students learned something. Moreover, in other activities I participated in, such as providing clothes and shoes to children, the experience brought them great joy.

P8- At the end of each activity, we evaluated how the activities could provide more benefit or how any shortcomings could be improved. Through this reflective process, we aimed to achieve maximum efficiency.

P9- I consider it a highly productive activity, as assistance was delivered efficiently and collaboratively with the community.

P10- Because the activities were structured to provide multiple experiences, I believe I gained substantial practical experience.

P11- As implied by its name, the Community Service Practices course emphasizes contributing to others, touching people's hearts, and, most importantly, responding to their needs, which is a fundamental human duty.

P12- There are many individuals in society in need of assistance. More associations and activities like this should be organized to reach a broader population.

P13- During the evaluation process, I observed that the students' actions created both auditory and visual behavioral changes in the participants.

P14- The activity was very beneficial for the children, and also for us. Their needs were met, and they had the opportunity to interact with us, engage in conversation, and share their interests. As prospective teachers, we had the opportunity to develop our communication skills with children.

P15- Our project supporting orphaned children was highly meaningful spiritually. I believe we conducted the necessary work with dedication and perseverance. We received adequate support from institutions and organizations and believe we contributed positively to society, inspiring future generations.

P16- The activity could have been even more effective if it had not been limited by time and scope and included additional activities. Our project served as a model for society and provided a learning experience. While performing cleaning activities, we were able to communicate with the community and received informational support.

P17- The activity was spiritually enriching and raised awareness. It helped participants understand what may seem insignificant to us but holds meaning for others. A brief evaluation at the end could measure the activity's efficiency, message delivery, and target achievement. Participants realized the benefits of helping others. The aim was not only to collect waste but also to promote environmental consciousness.

P18- The activity conducted under the Community Service course was beneficial both socially and academically and was implemented in accordance with the course plan.

P19- The activities provided significant learning outcomes. They contributed to my social relationships and helped me become a more environmentally and socially conscious individual. I realized that unity and cooperation can lead to a better society, and even a small awareness can positively impact people. I gained many valuable outcomes from these activities and am pleased to have taken this course.

P20- During the activity, I observed that both our perspectives and those of the public in the recreational area toward the environment changed. The process fostered awareness throughout the activity.

P21- By conducting this activity, we expressed gratitude to nature, which provides us with numerous blessings. Every action we took for the environment will return to us manifold. I wish such activities were increased and accessible to all.

P22- The Community Service course and the project were conducted in alignment with the course content.

P23- After implementing the activity, we checked for any issues, tasks we missed, or actions required. We determined that the implementation was highly successful and contributed positively to society and the environment. The planning and implementation phases did not require extraordinary effort but were completed successfully.

P24- The chosen activity fostered environmental awareness for both us and those participating, positively influencing our attitudes toward the environment.

P25- The activity demonstrated what it means to be a conscientious citizen and highlighted the importance of leaving a clean environment and sustainable life for future generations.

3.2. Regarding the Impacts of Community Service Practices

Table 4.

Findings Related to The Emotional İmpact of The Activity

Theme	Codes	f	%	Participants
Empathy, Compassion, and Tolerance	Empathy, compassion, benevolence, tolerance, moral sensitivity, and understanding others' emotions	15	60%	P2, P3, P5, P8, P9, P12, P14, P15, P16, P17, P18, P20, P22, P23, P25
Social Sharing and Interaction	Participating in activities together, social interaction, emotional sharing, and bonding	11	44%	P1, P4, P5, P7, P14, P15, P17, P19, P21, P22, P23
Awareness and Social Responsibility	Gaining awareness, environmental consciousness, social responsibility, and becoming a socially conscious individual	16	64%	P3, P6, P8, P9, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25
Preparation for the Teaching Profession	Essential emotional competencies in teaching, self-confidence, responsibility, guidance skills, communication, and awareness of service to society	10	40%	P2, P4, P7, P10, P13, P14, P17, P19, P23, P25
Inner Satisfaction and Happiness	Spiritual peace, happiness, pride, selflessness, and the intrinsic satisfaction derived from contributing	12	48%	P2, P5, P6, P11, P12, P15, P16, P18, P20, P21, P23, P24

Table 4 presents the findings regarding students' perceptions of the emotional impact of the activities carried out within the scope of Community Service Practices. The findings indicate that the activities fostered empathy, a sense of responsibility, social sensitiv-

ity, and positive emotional outcomes among the students. Furthermore, the data obtained from student perspectives suggest that community service activities enhanced students' emotional awareness, strengthened their sense of empathy and compassion, and contributed to the development of their professional identity.

Below are the students' statements regarding the findings:

P1- In the activities we participated in, there was, of course, emotional sharing. Since the activities were conducted collectively, we achieved social interaction and mutual sharing.

P2- I can say that the emotional dimension of the activity positively affected me; while carrying out these projects, I acted with a sense of responsibility and felt good about myself.

P3- In the activity I participated in, gifts were distributed to orphaned children across the province. The fact that these children did not have fathers, making them quieter and more withdrawn compared to other children with fathers, was very moving for me.

P4- Activities drawn from real-life situations affected me emotionally in a significant way. I established closer relationships with society and believe that I gained very valuable experiences and developed my emotional side before starting my professional life.

P5- The emotional impact of the activity, frankly, contributed to me in all areas. Emotionally, visiting elderly people's homes and sharing in their concerns was a meaningful contribution.

P6- Emotionally, sharing what we know made me feel happy and peaceful.

P7- I believe that emotionally, the activities provided confidence and continuity both for the children and for myself. It particularly improved my communication skills.

P8- Because the activities aimed to reach people from all segments of society, they prompted us to self-reflect and develop empathy.

P9- I believe I developed emotionally. Through these activities, I had the opportunity to closely observe social problems, which I consider to have moral and ethical benefits.

P10- Participating in one or two activities that allowed me to develop emotionally provided insights on how I should behave in my future teaching life.

P11- I think that the smiling faces of every group and family we were able to help represent the most important feedback from our service.

P12- Emotionally, the activities instilled empathy, compassion, and kindness in me. Being able to touch the lives of people in need of help or affection made me happy.

P13- Emotionally, the activities contributed to preparing us for the teaching profession by developing qualities such as self-confidence, a sense of social responsibility, and other characteristics essential for a teacher.

P14- The activities created meaningful emotional awareness. Seeing the children happy made us happy as well. It strengthened our love for children and instilled values of tolerance and mutual aid.

P15- Extremely strong feelings of tolerance and helpfulness emerged. Being with the children, listening to their dreams, and talking to them had a spiritual impact on us as well. By the end of the project, I felt emotionally and physically at peace. I realized once again how valuable and important our environment is, and how even a discarded cigarette butt can harm the environment, emphasizing the need to raise awareness among people.

P16- I learned to approach young children with love and compassion. I acquired the skill to value and fulfill their requests. The activity demonstrated how every piece of litter negatively affects us. Cleaning our environment gave me awareness, empathy, and a sense of happiness.

P17- The activity taught that there are many children like the ones participating, and even a brief contact with their lives is valuable. It fostered mutual respect, moral awareness, and collaboration. The general objective was always to create awareness, encourage bonding, and guide participants toward the right values through a correct and structured activity. While conducting the activity, feelings such as respect, tolerance, unity, and usefulness should be evoked for both parties.

P18- Being useful to people and serving the community while observing the children's happiness strengthened our awareness and sense of helping others. We realized that this spirit of mutual aid is not limited to the course but can be practiced outside as well.

P19- The activity stimulated feelings of unity, togetherness, solidarity, socialization, mutual aid, setting examples, awareness, sensitivity, and responsibility.

P20- The emotional impact of the activity on me was primarily a sense of compassion toward the environment and humans. During the activity, I felt a burden lift due to my contributions, and I realized I need to be more careful and responsible, not only for myself but for others as well.

P21- The activity created strong personal motivation in me. I have become a more environmentally conscious individual. I am grateful for this experience.

P22- In this project, we experienced the importance of cooperation, increasing societal sensitivity through unity, and strengthening our awareness of keeping the environment clean.

P23- This activity allowed us to experience a wide range of emotions. As prospective teachers, serving our community and environment gave us pride and honor akin to serving our country. Participating in such an activity both during and after the implementation made me very happy. I also understood once again how important tolerance and helpfulness are.

P24- The activity fostered a perception that we should show more sensitivity and carefulness toward the environment.

P25- The "Hand in Hand with the Environment" activity was a community service project that addressed environmental cleanliness, impacting both us and the animals living in natural environments. We all gave due attention to cleaning, learned the lesson, and realized the need to act more cautiously in the future.

Table 5.

Findings on The Impact of The Activity on Skills

Theme	Codes	f	%	Participants
Social and Communication Skills	Effective Communication, Group Work, Social Interaction, Child Communication, and Community Integration	14	56%	P1,P2, P4, P5, P7, P8, P12, P13, P14, P18, P19, P22, P23, P24, P25
Acquisition of Responsibility and Discipline	Sense of Responsibility, Disciplined Work, Task Awareness, and Participation in Planning and Implementation Processes	11	44%	P2, P4, P6, P7, P10, P12, P13, P18, P19, P22, P24
Environmental Awareness and Sensitivity	Environmental Cleanliness, Proper Waste Disposal, Alerting Polluters, and Raising Environmental Awareness	13	52%	P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25
Technical and Applied Skill Development	Stage Preparation, Use of Sound Systems, Program Flow, Physical Activities [Garden Cleaning, Planting, etc.], Leadership, and Role-Taking	8	32%	P3, P5, P6, P12, P13, P18, P22, P24
Empathy and Tolerant Behavior	Developing Empathy, Acting Considerately, Helping Others, Approaching Children as Individuals, and Fostering Positive Social Behaviors	10	40%	P4, P8, P11, P14, P15, P16, P17, P18, P19, P25
Self-Confidence and Leadership Skills	Development of Self-Confidence, Decision-Making, Leadership, and Initiative-Taking	6	24%	P7, P10, P12, P13, P14, P20

Table 5 examines students' perspectives on the behavioral [skills-related] effects of activities carried out within the scope of community service applications. The findings indicate that these activities contribute to the development of students' behavioral competencies, such as communication, collaboration, taking responsibility, problem-solving, and social awareness. Furthermore, the data derived from student feedback reveal that community service activities support the enhancement of skills including environmental sensitivity, effective communication, leadership, empathy, and active participation.

Below are selected student perspectives regarding these findings:

P1- Through my participation in the activities, I experienced a significant improvement in my social skills and became more effective in communicating with others.

P2- The activity was a behavioral example within community service applications, fostering skills such as reaching a common ground in society and working actively [including an illustrative activity related to supportive shopping].

P3- During the activity, I performed certain operations in the sound system room. In this respect, I gained some experience. Additionally, I acquired experience in gift presentation, selecting children, and locating them. I also gained experience in stage arrangement and program flow.

P4- Behaviorally, I believe the activity had positive effects such as helping others, inclining towards kindness, and acting with professional experience in one's career.

P5- The activities I participated in added significantly to my skills. They taught me how to behave appropriately when entering a community. For example, one day we participated in cleaning the gardens of elderly people: we cleaned, planted, and trimmed, gaining many practical skills in the process.

P6- During voice training with students, I experienced that the diaphragm developed and that the best teacher is the student.

P7- These activities improved my communication skills, discipline, and ability to progress patiently. They also positively affected my daily communication.

P8- The activities provided skills in communicating with people, responding to needs, and interacting with individuals from all social backgrounds. Communication and sociality levels were positively influenced.

P9- Previously indifferent to certain issues, I now approach them more carefully and strive to find solutions to societal problems.

P10- It contributed to the development of my self-confidence.

P11- Humanity, the essential emotion that is disappearing in people, should be inherent in creation. Being able to help another person respectfully is fundamental.

P12- The activities fostered leadership and role-taking skills, enhanced my sense of responsibility, and enabled me to integrate more effectively into society.

P13- I can describe the behavioral effects as the emergence and development of previously unnoticed skills.

P14- The activities fostered skills in interacting with children, promoting friendliness and tolerance. We tried to understand children with empathy and gained the ability to understand their behaviors.

P15- I realized the importance of recognizing each child's value for our society and future and frequently helping children in need. Behaviorally, when encountering individuals harming or littering the environment, I learned to warn them calmly and kindly to raise environmental awareness. Another effect was making an effort to clean places we saw as dirty.

P16- I became aware of the importance of being tolerant, loving, and respectful toward people in our

environment. I learned that waste should be disposed of properly rather than left in nature.

P17- During the activity, I respected children's choices, helped them feel valued as individuals, avoided harmful attitudes or behaviors, recognized that children in our environment require similar care, and realized the importance of continuing such practices. Through the activity, awareness increased, leading to efforts to prevent repeated improper actions, clean even the smallest litter, and understand the damage caused to the environment.

P18- Through collaborative activities involving assistance, task division, and solidarity, we acquired many behavioral skills, including how to interact with children and manage tasks in group settings.

P19- My social relationships improved, my ability to work in groups increased, my communication with people strengthened, and I developed environmentally conscious behaviors.

P20- The behavioral effect of the activity reinforced my pre-existing environmental awareness. It enabled me to communicate effectively with those indifferent in my immediate and broader environment and raise awareness about the damage they caused.

P21- The activity influenced our behaviors. I now warn people who litter more frequently and am conscious of our responsibilities toward the environment.

P22- As mentioned, the project fostered cooperation, solidarity, and collaborative assistance, promoting a disciplined approach to leaving a beneficial environment for society.

P23- This activity contributed significantly to behavioral development. Specifically, as teacher candidates, we realized that after performing the activity, we would be more careful not to pollute the area. I will be more attentive and meticulous because every piece of litter represents effort to remove it.

P24- Behaviorally, it encouraged us to be more active. I completed the activity using practical knowledge and observation.

P25- In addition to behavioral skills, we realized that we should alert and educate those who harm the environment unconsciously or knowingly and raise their awareness.

Table 6.

Findings Regarding The Social Impact of The Activity

Theme	Codes	f	%	Participants
Socialization and Meeting New People	Meeting New People, Expanding Social Circles, Learning About Different Cultures, Participating in Joint Activities, and Community Integration	15	60%	P2, P3, P5, P8, P9, P10, P11, P13, P14, P15, P17, P18, P20, P23, P24
Development of Communication Skills	Self-Expression, Effective Communication, Empathy, Active Listening, and Communication with Children and the Elderly	13	52%	P4, P5, P6, P7, P8, P13, P14, P16, P17, P19, P20, P23, P24
Social Awareness and Sensitivity	Sensitivity to Society, Problem-Solving, Conscious Approach to Social Issues, Altruism, and Social Responsibility	12	48%	P1, P2, P8, P12, P15, P16, P17, P18, P19, P21, P22, P25
Collaboration and Teamwork	Group Cohesion, Collaborative Work, Coordination, and Team Spirit	10	40%	P2, P5, P13, P20, P23, P24, P25
Self-Confidence and Increased Participation	Assertiveness, Initiative, Social Courage, and Active Participation in Society	6	24%	P2, P4, P7, P10, P13, P19

Table 6 examines students' perspectives on the social effects of activities conducted within the scope of community service applications. The findings indicate that these activities contributed to the development of students' socialization, communication, collaboration, and social adaptation skills. Furthermore, data obtained from student feedback reveal that community service activities enhanced students' interactions with society, improved their ability to communicate with diverse social and cultural groups, and fostered social sensitivity.

Below are selected student perspectives regarding these findings:

P1- This course enabled us to encounter social events and situations directly, providing us with awareness of both sensitivity and appropriate responses to these situations.

P2- Participating in activities with a common goal and in a joint project was beneficial for building self-confidence and socialization.

P3- Through the activity I participated in, I had the opportunity to meet new people. Thanks to these connections, I became aware of more activities and had the chance to participate in them.

P4- The activity had positive social effects, allowing me to establish relationships with society, express myself, and develop effective communication. I believe I can now express myself more comfortably socially in my professional life.

P5- In the activities I attended, there were students from another school. We performed various readings together, working with a spirit of collaboration, and later visited their families.

P6- It strengthened communication with students, enabled me to express myself, and resolved my problems in conveying information.

P7- Socially, it had limited impact, but it promoted initiative and assertiveness.

P8- The activities conducted during the course encouraged us to become more social and proactive. They provided the opportunity to meet people from different cultures, economic backgrounds, and age groups, broadening our social environment.

P9- Socially, the activities allowed me to meet new people and integrate into society.

P10- The activities contributed to the social development of both the community and those providing the service, positively influencing interpersonal communication.

P11- During this period, we had the opportunity to meet new people, visit new places, and, most importantly, experience new lives.

P12- We were able to engage with the community and find solutions to their problems. It taught us to have a voice in society.

P13- Socially, the activities enhanced communication skills, which are essential in the teaching profession, strengthening my social competence.

P14- We socialized with children, improved communication with them, and became aware of their interests and needs.

P15- The activities promoted social awareness of helpfulness and tolerance. They fostered compassion in people's hearts and positively influenced our perspective toward children. The collaboration within the project encouraged social unity, generating human connections, friendship, and a spirit of altruism.

P16- I learned how to communicate with children and what to pay attention to. People in the field noticed our increased sensitivity. The project taught me to politely warn those who litter and to communicate effectively with others.

P17- It was significant in getting to know different people, understanding children's worlds, guiding them, and setting an example. It facilitated socialization among participants and enabled us to gain various emotional and social perspectives.

P18- Activities aimed at creating happier individuals in society made both children and us more sensitive and aware.

P19- It helped me approach society more tolerantly. I gained insight into how to communicate and contribute to elderly people, children, and individuals with special needs.

P20- From planning to implementation, I realized the value of cooperation. I understood how enjoyable and rewarding working as a community can be.

P21- While performing the activity, even the way people around us looked at us was meaningful. Perhaps they wanted to join us at that moment.

P22- The cleaning required and requested by the social environment can be maintained regularly. I believe we were able to raise awareness regarding environmental cleanliness.

P23- The social impact of the activity included fostering a sense of unity, helping, and working harmoniously. Experiencing cooperation and contributing to society alongside friends was very rewarding.

P24- The social effect of the activity: By working in a team with our friends and instructor, I became more active in collaboration, coordination, and communication.

P25- The "Hand in Hand with the Environment" project aimed to leave a clean and livable space, providing a positive contribution to participants' social awareness.

Table 7.

Findings Regarding The Academic Effects of The Activity

Theme	Codes	f	%	Participants
Professional Development and Teaching	Contribution to the Teaching Profession, Development of Teaching Skills, and Understanding Teacher Responsibilities	14	56%	P1, P3, P4, P5, P6, P7, P10, P11, P13, P14, P19, P21, P23, P25
Learning by Doing and Experiencing	Field-Based Learning, Experiencing, Applying Theoretical Knowledge, Learning by Doing, and Observation	13	52%	P2, P4, P6, P7, P8, P13, P17, P18, P20, P21, P23, P24, P25
Planning and Implementation Skills	Preparing Activity Plans, Writing Reports, Managing Projects, and Acquiring Process Management Skills	7	28%	P8, P13, P18, P20, P22, P24, P25
Acquisition of Academic Knowledge and Awareness	Social Awareness, Environmental Consciousness, Recycling, Human-Nature Relations, and Public Education and Awareness	10	40%	P12, P15, P16, P17, P19, P20, P21, P22, P23, P25
Cognitive Development	Inquiry, Analysis, Problem-Solving, Developing Alternative Methods, and Establishing Cause-and-Effect Relationships	6	24%	P2, P7, P8, P9, P17, P23

Table 7 examines students' perspectives on the academic [cognitive] effects of activities conducted within the scope of community service applications. The findings indicate that these activities enhanced students' professional knowledge and awareness, reinforced theoretical knowledge through practical application, and contributed to their academic development. Furthermore, data obtained from student feedback reveal that community service activities enabled students to apply theoretical knowledge in real-world settings, increasing the retention of learning and supporting their professional cognitive development. Additionally, according to participant statements, activities conducted within the scope of community service contributed to teacher candidates' acquisition of professional awareness, the development of problem-solving and planning skills, and the strengthening of their academic perspectives.

Below are selected student perspectives regarding these findings:

P1- It provided awareness related to our future professional life.

P2- Academically, the courses I took added to my experience. Additionally, through other activities, I learned what to do and how to do it by doing and experiencing it. In this context, I can say it was beneficial.

P3- Academically, I believe the Community Service Applications course has been further reinforced and shaped. As a teacher candidate, I think it will contribute to my future professional life.

P4- Academically, I am very pleased that our university offers a course that allows us to do something beneficial for society. Participating in various activities positively affected my academic status. I gained experience before entering the profession, which had a positive impact.

P5- I want to become a teacher, for example. In this context, the activities I participated in contributed greatly. They helped me think about how I will be integrated with society when I become a teacher.

P6- I believe it developed my ability to provide voice training, improved my professional formation, and advanced my communication skills.

P7- I think it was one of the experiences I will encounter in my professional life. I developed new methods I could use and tried more effective communication techniques.

P8- Academically, it had a positive impact. It enabled us to answer questions such as how a plan is prepared, how it is implemented, what results are obtained, and how the outcomes benefit our professional and daily life.

P9- Through the activities, I gained the ability to work collaboratively and produce practical solutions in school life.

P10- One of the most significant academic gains for me is the understanding that a teacher who benefits society is always important in life.

P11- Within all these Community Service Applications and in my future teaching career, serving my students, their families, my environment, and all people in a manner befitting my profession will be my most sacred duty.

P12- Academically, it allowed me to know society more closely and understand the educational level of the community.

P13- Academically, the activities provided special opportunities to apply the knowledge we learned at the university and allowed us to gain more experience.

P14- As teacher candidates, we gained contributions to our profession by socializing and communicating with children.

P15- Within projects helping and serving orphaned children, sufficient competence and awareness were achieved. Cognitively, awareness of environmental cleanliness was developed. In addition to community service awareness, attributes such as environmental awareness, awareness of cleanliness, and a sense of social unity and solidarity were cultivated.

P16- I learned the importance of communication, the importance of empathy, and how to behave toward people around us. Academically, I learned about recycling waste and its impacts on humans and nature. I understood that society must be informed and that we should also contribute actively.

P17- Academically, such activities provide interaction and knowledge acquisition both for the participants and the recipients. In future academic life, encountering similar situations will bring significant experience. In contrast to theoretical knowledge, participating in such field applications allows immediate and different learning outcomes. Each stage of the activity provides new experiences.

P18- We learned how to prepare reports on planning and programming of activities and reinforced it through implementation.

P19- I gained better knowledge about society and the environment. As a teacher candidate, I will progress in my academic life with increased awareness of society and the environment, and I believe it will have a positive impact on my profession.

P20- Previously, we only knew theoretically about the effects of harmful substances on the environment. I observed these impacts directly and realized that certain materials cannot be naturally decomposed quickly and remain as waste and pollution.

P21- As a future teacher, such projects provide incredible cognitive contributions. They motivate us to educate our students as conscious individuals, fostering sensitivity toward people and the environment.

P22- By cleaning our environment, we raised social awareness and learned valuable information regarding which types of waste remain in nature for how long, fostering awareness to leave a clean environment for future generations.

P23- Every individual has a responsibility to contribute to society. As teacher candidates participating in this activity, I became more aware of this duty and the necessary practices in future teaching life, gaining stronger societal and community consciousness through this application.

P24- Academically, I learned how to create an activity or plan for the course, how to progress step by step, and observed the process to consolidate my learning.

P25- For every teacher candidate in the Faculty of Education, this project is a civic duty provided by every academic staff member to prepare them to serve students or participate in cleanliness-themed projects in schools where they will work in the future.

4. Discussion, Conclusion and Recommendations

In this section of the study, the findings obtained within the scope of the "Community Service Applications Course Process" and "Effects of Community Service Applications" were examined from a holistic perspective and evaluated as conclusions. Based on the participants' experiences and assessments, the results were summarized according to thematic categories, and general inferences regarding the course's implementation process as well as its individual, professional, and societal impacts were presented.

4.1. Regarding the Community Service Applications course process;

The findings indicate that the majority of participants carried out the planning of activities under the guidance of the instructor, in collaboration with institutions/associations, and with a focus on societal benefit.

Time and location planning were among the most frequently emphasized elements (60%), indicating that a planned and organized process was conducted. Approximately 56% of participants evaluated the activity in terms of providing societal benefits, which is a positive indicator regarding the course's alignment with its objectives. Emphasis on group work and collective decision-making was also high (40%), suggesting a democratic planning process. However, individual responsibility and personal preparation (16%) were relatively less emphasized, indicating an area in which students may still develop.

Overall, the activity planning process was largely organized, collaborative, and oriented toward societal benefit. Nevertheless, supporting individual responsibility and leadership skills more extensively could make the process more balanced and student-centered. These findings demonstrate that the course is effective in fostering planning, organizational, and social sensitivity skills necessary for the teaching profession. Ekşi and Cinoğlu [24] emphasized that for community service activities to be successfully implemented, stakeholders must be engaged, and unplanned approaches disrupt institutional functioning; therefore, activities should be pre-planned and scheduled at the end of the preceding semester. Similarly, Yılmaz [25] reported that participants generally experienced challenges in planning the course and collaborating with the institutions where the activities would take place.

Uğurlu and Kıral [26] reported that teacher candidates encountered various challenges during the Community Service Applications (THU) course, including bureaucratic procedures, technical malfunctions, division of labor, insufficient time and space, limited advisor support, and budget constraints. However, they noted that efforts to overcome these obstacles contributed to the development of their perseverance and resilience. Similarly, Kocadere and Seferoğlu [27] found that students participating voluntarily in projects within the scope of the THU course developed a sense of community service, aiming to sustain this awareness in their own lives and to foster it within their surroundings.

Regarding the Implementation Process of the Activity, the majority of participants (72%) reported that the activities were carried out as planned, in an organized and coordinated manner, indicating that the practical dimension of the course was successfully conducted. Emphasis on social awareness and societal benefit was expressed by 68% of participants, demonstrating that students developed not only technical skills but also ethical and social responsibility. Approximately 44% of participants stated that they participated voluntarily and willingly in the activities, thereby forming an emotional connection to the process. Advisor support strengthened the process for 40% of participants, highlighting the importance of teacher guidance in ensuring the success of the activities. Additionally, 32% emphasized awareness development, reflecting that the course effectively fostered community consciousness and empathy-key objectives of the Community Service Applications course. However, a small proportion (8%) reported challenges such as communication problems, indicating the need for further development of communication and coordination skills in future implementations.

The implementation process was largely effective, well-planned, volunteer-based, and grounded in ethical values. Participants' voluntary engagement, advisor guidance, awareness of societal benefit, and the acquisition of social consciousness demonstrate that the course successfully achieved its academic and humanistic objectives. Nonetheless, communication challenges identified during the process suggest that practice-based courses would benefit from a stronger communication infrastructure.

Regarding Activity Evaluation, the theme of societal benefit emerged as the most dominant, reported by 80% of participants, who highlighted the activities' important role in serving the community and the environment. Approximately 64% of participants reported gaining personal and professional development, particularly acquiring experience relevant to the teaching profession, illustrating the contribution of the Community Service Applications course to applied education. Spiritual satisfaction and emotional impact were noted by 32% of participants, indicating that empathy skills improved and internal fulfillment was achieved through voluntary work. Some participants (24%) critically evaluated the activities, reflecting on deficiencies and considering ways to enhance their effectiveness, demonstrating that participants were not only implementers but also reflective and analytical individuals. Additionally, 24% highlighted environmental awareness and a sense of responsibility toward nature, showing that environmentally oriented projects achieved their intended objectives. Finally, a smaller proportion (16%) reported that the activities were conducted in alignment with the course content and objectives.

The evaluation process indicates that the Community Service Applications course successfully achieves its fundamental goals, including providing societal benefits, contributing to professional development, fostering affective gains, and developing critical thinking skills. Participants' critical perspectives also offer important opportunities for continuous program improvement. Emphasis on environmental awareness aligns with contemporary educational policies and contributes to sustainability objectives.

Overall, the study demonstrates that the course had multidimensional and positive effects on participants. Adopting a societal benefit- and collaboration-oriented approach throughout the planning, implementation, and evaluation phases contributed to participants' personal and professional growth, while supporting the development of affective skills such as empathy, responsibility, and social sensitivity. Moreover, applied experiences reinforced cognitive gains, enhanced critical thinking abilities, and increased environmental awareness. This holistic development indicates that the Community Service Applications course provides a meaningful and lasting contribution to educational processes.

4.2. Regarding the Effects of Community Service Applications;

The theme of awareness and social responsibility was the most frequently mentioned in relation to the emotional effects of the activities, with 64% of participants highlighting it. Participants reported becoming more sensitive to the environment, society, and people. Sixty percent indicated that their empathy and compassion had developed, becoming more attuned to others' emotions and experiencing moral engagement. Internal satisfaction and happiness were noted by 48% of participants, demonstrating that voluntary work provided spiritual fulfillment and personal peace. Forty-four percent emphasized that the activities fostered social interaction and sharing, creating emotional bonds through collaborative work. Additionally, 40% highlighted that the activities served as preparation for the teaching profession, enhancing emotional resilience and guidance skills prior to entering the field.

These findings indicate that the Community Service Applications course fosters critical affective gains in individuals, including social responsibility, empathy, internal satisfaction, and social connectedness. It also contributes significantly to developing emotional resilience in a professional preparation context, reinforcing the educational and multidimensional value of community service projects.

In terms of behavioral effects, social and communication skills emerged as the most prominent theme (f=14, 56%). Activities facilitated participants' development of effective communication with diverse individuals, collaboration within groups, and interaction with broader social environments. Environmental awareness and sensitivity were also emphasized by 52% of participants, who reported greater consciousness in protecting the environment and increased awareness in both personal behaviors and attitudes toward others. Forty-four percent of participants indicated improvements in responsibility and disciplined behavior, which is particularly relevant for professional preparation. Technical skills (32%) were prominent in applied activities, such as stage setup, sound system operation, and physical environment arrangements.

Empathy and considerate behavior development were reported by 40% of participants, particularly during activities involving children or older adults. Additionally, 24% highlighted positive effects on self-confidence and leadership, reporting increased courage and initiative-taking. These results suggest that Community Service Applications effectively enhance participants' social, environmental, technical, and personal leadership skills. The diversity of behavioral gains confirms that such applications significantly prepare individuals for professional and societal engagement [28-31].

Regarding social impacts, socialization and meeting new people was the most prominent theme (60%, f=15). Participants expanded their social networks by interacting with individuals from diverse age groups, cultures, and social backgrounds, forming lasting relationships. Communication skill development was emphasized by 52% of participants, particularly in interactions with children, older adults, and individuals with special needs, highlighting the instructional value of empathy and social sensitivity. Social awareness and responsibility were reported by 48%, demonstrating the course's role in fostering conscious citizens capable of addressing societal issues. Cooperation and teamwork (40%) showed positive effects on group harmony and collaborative functioning. Although self-confidence and societal participation were less frequently reported (24%), some participants noted increased social courage and assertiveness.

Community Service Applications thus provide a significant learning experience, strengthening social skills, societal awareness, and social networks. The course enhances interaction with diverse social groups, contributing to both individual and collective social development [13, 32].

In the cognitive domain, professional development and teaching skills were the most prominent theme (56%). Participants emphasized that the experience would support their future professional roles. Experiential learning was noted by 52%, as students applied theoretical knowledge in practical settings, reinforcing long-term learning. Academic knowledge and awareness were highlighted by 40%, particularly regarding environmental, societal, and recycling-related topics. Planning and implementation skills appeared in 28%, indicating improvements in project preparation, planning, and reporting abilities. Cognitive development (24%) reflected gains in problem-solving, analysis, and the development of alternative approaches.

Overall, the study demonstrates that Community Service Applications have multidimensional positive effects. Emotionally, participants gained social responsibility, empathy, and internal satisfaction. Behaviorally, they developed social communication, environmental awareness, responsibility, and leadership skills. Socially, participants expanded their networks, interacted with diverse societal groups, and enhanced their social consciousness. Academically and cognitively, professional development, experiential learning, problem-solving, and planning skills were strengthened, equipping participants with both theoretical knowledge and practical experience for the teaching profession. This holistic development underscores the substantial and lasting educational contributions of the Community Service Applications course [33-36]. The findings indicated that pre-service teachers engaged with various social issues, developed community-oriented projects, gained greater self-awareness, employed different strategies to overcome challenges, and generally perceived the Community Service Practices process as a beneficial and positive learning experience [37].

To further enhance the effectiveness of the course, it is recommended to strengthen individual responsibility and leadership skills during the planning phase, enabling students to take greater initiative and prepare more independently, thereby promoting a balanced, student-centered process. In the implementation phase, a robust communication infrastructure should be established to improve coordination and interaction skills. Increased guidance from mentor teachers may enhance participants' engagement and success. During the evaluation phase, supporting critical thinking and expanding the integration of environmental awareness within the curriculum are essential for sustainability. Additionally, deepening empathy and social responsibility

content, diversifying group work and applied projects, promoting interaction with diverse age and cultural groups, and reinforcing experiential learning methods will collectively enhance cognitive and academic gains. Encouraging student initiative alongside mentor guidance will create a holistic learning environment, ensuring that Community Service Applications continue to develop professionals who are both technically competent and socially conscious.

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"STUDY OF DENTAL DISEASES AND SALIVA CRYSTALLIZATION TYPES IN WOMEN WITH NORMAL AND DYSFUNCTIONAL THYROID GLAND"

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Abstract

Multiple internal and external factors affect dental tissues, including endocrine diseases. Any disruption in neuroendocrine regulation can interfere with the formation of oral tissues. Hypothyroidism is a condition in which the thyroid gland does not produce enough thyroid hormones. Typically, women aged 45–55 are affected. Hypothyroidism causes chemical imbalances in the body. If the thyroid hormone is insufficient in the blood, metabolism slows down. Common signs of hypothyroidism include fatigue, weight gain, and feelings of depression. Although symptoms may be subtle in early stages, it is a widespread condition that affects all age groups and races, more frequently women.

Thyroid dysfunction also impacts the rate of salivary secretion. Normal salivary flow is crucial for maintaining oral health. Saliva has buffering capacity, enabling it to neutralize acids and bases through its bicarbonate, phosphate, and protein systems. Buffering capacity may change due to various factors, including endocrine disorders.

To determine the relationship between thyroid dysfunction and dental status, we examined 70 women. Dental conditions were assessed as follows: oral hygiene status was evaluated using the Hygiene Index (HI) according to the Fedorov–Volodkina method, while the extent of inflammatory changes in the periodontal tissues was assessed using the Papillary–Marginal–Alveolar (PMA) Index according to the Parma modification (Parma, 1960).

For microbes, an essential aspect of saliva is its quantity. Thyroid dysfunction often leads to hyposalivation, reducing saliva's buffering capacity. It is known that when hyposalivation occurs, especially with xerostomia (absence of saliva), oral mucosal disease can develop within 3–6 months, followed by multiple carious lesions.

Reduced salivary secretion contributes to caries development and increases viscosity, impairing oral self-cleaning mechanisms. Saliva's mineralizing function is based on mechanisms that prevent the loss of enamel components and support their re-incorporation. It has been shown that when saliva droplets dry on glass slides, they leave deposits with different microscopic structures depending on the individual (7,43,151–152). In addition to its well-known roles, saliva also connects with endocrine organs—a function not yet thoroughly studied. Data on the interaction between salivary and thyroid glands are scarce. These considerations highlight the need to study saliva microcrystallization (SMC) and salivary mineralization potential (SMP) in adolescents with high caries intensity and thyroid dysfunction.

Keywords: Hypothyroidism, Crystallization, Dental Caries, Hyposalivation.

Introduction

The thyroid gland is one of the most important endocrine organs in the human body. It produces the thyroid hormones thyroxine (T4) and triiodothyronine (T3), both of which are synthesized from the amino acid tyrosine. The primary function of the thyroid gland is to supply the body with thyroid hormones. The essential substrates required for hormone synthesis are the trace element iodine and the amino acid tyrosine.

The effects of thyroid hormones are diverse and far-reaching. They maintain basal metabolic activity in the majority of cells by regulating metabolic processes, cellular proliferation, and apoptosis. Normal levels of thyroid hormones are essential for the proper functioning of all organ systems. In cases of thyroid dysfunction, pathological changes are typically multisystemic in nature. Hypofunction of the thyroid gland leads to severe pathological alterations affecting both individual organ systems and the organism as a whole.

Thyroid dysfunction, specifically hypothyroidism, leads to disruption in neuroendocrine regulation and affects the biochemical balance of oral tissues. Recent data show that patients with hypothyroidism often experience changes in salivary biochemical properties, such as reduced salivary secretion, decreased buffering capacity, and low concentrations of calcium and phosphate. These factors increase the risk of dental caries development (Borzuei et al., 2023; Alshehri et al., 2023).

It has been established that individuals with autoimmune thyroid disorders—especially women—have a significantly higher prevalence of caries and other oral diseases (Silva et al., 2024). In such cases, oral dryness

(xerostomia) is often observed, which further elevates the risk of dental diseases (Park et al., 2023).

Materials and Methods

We studied 70 women aged 45–55 years. They were divided into two groups. The main group consisted of 43 women with thyroid dysfunction, specifically hypothyroidism, with a high caries index (0.52±0.6). The control group included 27 practically healthy patients with low caries index (0.02±0.01).

Saliva microcrystallization was assessed using the following method: Each patient's oral fluid was collected from the floor of the mouth with a sterile pipette (0.2–0.3 ml), in the morning while fasting. Three drops were placed on pre-cleaned glass slides. The samples were dried at room temperature, protected from dust and movement. Dried droplets were analyzed under an MBR-1 microscope using reflected light at 8×0.20 magnification.

Crystallization quality was assessed based on the observable area of the dried drops and expressed as mean scores, based on the types of crystal structures found. Three types of microcrystallization were identified and linked to caries intensity:

- **Type I** – well-formed, elongated, prismatic crystals occupying the entire drop area. Associated with compensated caries.
- **Type II** – smaller, dendritic crystals in the center with irregular prismatic structures at the periphery. Associated with subcompensated caries.
- **Type III** – irregular crystals of isometric distribution throughout the drop. Associated with decompensated caries.

To determine the relationship between thyroid dysfunction and dental status, we examined 70 women. Dental conditions were assessed as follows: oral hygiene status was evaluated using the Hygiene Index (HI) according to the Fedorov–Volodkina method, while the extent of inflammatory changes in the periodontal tissues was assessed using the Papillary–Marginal–Alveolar (PMA) Index according to the Parma modification (Parma, 1960).

In accordance with research goals, we examined the prevalence and intensity of dental caries in adolescents and the oral hygiene status under thyroid dysfunction.

According to the method of Fedorov and Volodkina (Fedorov Yu.A., Volodkina V.V.), oral hygiene status was determined as follows: the vestibular surfaces of teeth 43, 42, 41, 31, 32, and 33 were stained using the Schiller–Pisarev solution, Lugol's solution, or other staining agents. The stained area of the tooth crown was assessed using a five-point scoring system:

- 1 – absence of staining;
- 2 – staining of one-quarter of the tooth crown;
- 3 – staining of one-half of the tooth crown;
- 4 – staining of three-quarters of the tooth crown;
- 5 – staining of more than three-quarters of the tooth crown.

The Hygiene Index (HI) was calculated using the following formula:

HI=Σ6HI = \frac{\Sigma}{6}HI=6Σ

where Σ represents the sum of the scores for all six examined teeth, and 6 represents the number of examined teeth.

Based on the HI values, the level of oral hygiene was interpreted as follows:

- 1.1–1.5 points – good oral hygiene;
- 1.6–2.0 points – satisfactory oral hygiene;
- 2.1–2.5 points – unsatisfactory oral hygiene;
- 2.6–3.4 points – poor oral hygiene;
- 3.5–5.0 points – very poor oral hygiene.

The Fedorov–Volodkina Hygiene Index cannot exceed 5 points or be lower than 1 point.

For determination of the PMA index, the vestibular surface of the gingiva was stained using the Schiller–Pisarev solution, after which the gingival condition was assessed for each tooth in the regions of the interdental papilla, free (marginal) gingiva, and attached (alveolar) gingiva. Inflamed areas exhibited a dark brown coloration.

The following codes were used to evaluate the severity of gingival inflammation:

- 0 – absence of inflammation;
- 1 – inflammation of the interdental papilla;
- 2 – inflammation of the interdental papilla and marginal gingiva;
- 3 – inflammation of the interdental papilla, marginal gingiva, and alveolar gingiva.

The PMA index was calculated using the following formula:

PMA=Sum of codes×100%Number of examined gingival unitsPMA = \frac{\text{Sum of codes} \times 100\%}{\text{Number of examined gingival units}}PMA=Number of examined gingival unitsSum of codes×100%

Results

The data showed the impact of hypothyroidism on the examined pathology, particularly on dental tissues. Type III microcrystallization was predominant in hypothyroid patients and was associated with low salivary mineralization potential, which promotes the growth of pathogenic flora and increases both the prevalence and intensity of caries.

Table 1.

Prevalence and intensity of dental caries in the studied population

Study Group	Number of Subjects	Caries Prevalence (%)	Caries Intensity
Main group (hypothyroidism)	**43**	45% ± 0.492	3.73 ± 4.648
Control group	**27**	**-**	1.5 ± 0.57
P < 0.05			

In the control group, Types I and mixed I/II microcrystallization were most common (45.0% and 35.5%, respectively). In the main group, Type III was found in 50.0% of cases and Type II in 36.7%.

Table 2.

Types of saliva microcrystallization and mineralization potential in healthy and hypothyroid women

Group	Microcrystallization Types (%)	SMP Score (mean ± SD)
Control	I: 45.0%, I/II: 35.5%, II: 28.7%	2.8 ± 0.03*
Main (hypothyroid)	III: 50.0%, II: 30.3%, I/II: 9.0%, I+II: 2.33%	1.90 ± 0.04*

We evaluated the structural changes in crystallization patterns in oral fluid. Patients without thyroid pathology had a mineralization potential of 2.8±0.03. In hypothyroid women, this value was significantly lower at 1.90±0.04—approximately two times less.

Table 3.

Changes in Periodontal Tissues in Examined Healthy women with Thyroid Dysfunction

Changes in Periodontal Tissues	Practically Healthy women	Women with Thyroid Dysfunction
Catarrhal gingivitis	3%	15%
Ulcerative gingivitis	1%	6%
Mild periodontitis (Grade I)	2.5%	8.5%

According to the obtained results, the frequency of unsatisfactory and poor oral hygiene indicators was high, whereas the proportion of very poor oral hygiene indicators was considerably lower (14.9%). The lowest frequency was observed for good oral hygiene status.

Table 4

Oral Hygiene Index Distribution

Oral Hygiene Index	Absolute Number	Percentage (%)
1.1–1.5 points (good oral hygiene)	11	13%
1.6–2.0 points (satisfactory oral hygiene)	15	21%
2.1–2.5 points (unsatisfactory oral hygiene)	23	27%
2.6–3.4 points (poor oral hygiene)	12	23%
3.5–5.0 points (very poor oral hygiene)	9	16%
Total	70	100%

Conclusion

Saliva can be considered a biological fluid whose unique composition and properties contribute to the homeostasis of mineral components in the oral cavity. Based on literature data and our clinical research findings, we conclude that for women aged 45–55, it is advisable to account for changes in saliva properties and composition caused by somatic pathology when planning preventive and therapeutic dental interventions.

Summary:

- Women with thyroid dysfunction tend to have higher caries intensity and lower salivary mineralization potential compared to those with low caries intensity.
- Therefore, it is advisable to evaluate saliva crystallization and consider salivary changes during somatic pathologies when planning dental interventions for such patients.

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CLINICAL AND ESTHETIC REHABILITATION WITH ZIRCONIA CROWNS FOLLOWING ENDODONTIC THERAPY

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Abstract

The rehabilitation of endodontically treated teeth in the esthetic zone represents a significant clinical challenge, requiring the restoration of function, structural integrity, periodontal health, and natural appearance [1,4]. Advances in restorative dentistry and CAD/CAM technology have expanded the use of zirconia crowns due to their excellent mechanical properties, biocompatibility, and favorable esthetic characteristics [8–10]. This case report describes the multidisciplinary management of a patient presenting with compromised maxillary anterior esthetics, spacing between anterior teeth, irregular tooth morphology, and dissatisfaction with smile appearance. Comprehensive clinical and radiographic examinations were performed to establish a definitive diagnosis and treatment plan [3,7]. The treatment protocol included professional oral prophylaxis, endodontic therapy of the affected maxillary teeth, and definitive prosthodontic rehabilitation using zirconia crowns [1,2,4]. Following treatment, substantial improvements were observed in smile esthetics, tooth proportions, dental symmetry, and functional occlusion. Clinical evaluation demonstrated satisfactory marginal adaptation of the restorations, healthy periodontal tissues, and stable occlusal relationships [2]. Radiographic assessment confirmed successful endodontic outcomes and the absence of periapical pathology [4]. The patient reported a high level of satisfaction with the final esthetic and functional results, accompanied by improved self-confidence and overall quality of life, findings that are consistent with previous reports on esthetic dental rehabilitation [5,6]. The successful outcome of this case highlights the importance of interdisciplinary treatment planning and demonstrates that zirconia crowns can provide a predictable and effective restorative solution for endodontically treated anterior teeth [8–10]. The integration of endodontic therapy, periodontal management, and prosthodontic rehabilitation contributed to the achievement of long-term biological stability, functional efficiency, and esthetic excellence.

Keywords: Zirconia crowns, esthetic rehabilitation, endodontic therapy, prosthodontics, full-coverage restorations, case report.

Introduction

The growing demand for esthetic dental treatment has increased the importance of multidisciplinary approaches that combine periodontal, endodontic, and prosthodontic therapies to achieve optimal clinical outcomes [1,2]. Modern esthetic rehabilitation aims not only to improve dental appearance but also to restore oral function, preserve biological health, and enhance patient quality of life [5,6].

Endodontically treated teeth frequently require comprehensive restorative management because structural loss associated with caries, trauma, or previous restorations may compromise their long-term prognosis [4]. Full-coverage crowns are commonly recommended to protect the remaining tooth structure and improve fracture resistance [1,4].

Among contemporary restorative materials, zirconia has gained widespread acceptance due to its high flexural strength, excellent biocompatibility, low plaque accumulation, and favorable esthetic properties [8–10]. Recent advancements in zirconia manufacturing and CAD/CAM technologies have further improved translucency and color matching, making zirconia suitable for esthetic rehabilitation in the anterior region [9].

This case report presents the successful rehabilitation of a patient with compromised maxillary anterior esthetics through professional prophylaxis, endodontic treatment, and zirconia crown restorations.

Case Presentation

A patient presented to the Dental Clinic *"GRANADA"* with the chief complaint of dissatisfaction with dental appearance and smile esthetics. Clinical examination revealed spacing between the maxillary anterior teeth, irregular tooth morphology, and crowding of the mandibular incisors. The patient reported decreased confidence while smiling and requested comprehensive esthetic rehabilitation.

Periodontal assessment revealed satisfactory oral hygiene potential, while radiographic analysis identified maxillary teeth requiring endodontic treatment before definitive restoration.

Based on the clinical findings, a multidisciplinary treatment plan was developed to restore esthetics, function, and biological stability.

Initial Clinical Findings

A patient presented to the Department of Dentistry with the chief complaint of dissatisfaction with anterior esthetics and smile appearance. Extraoral examination revealed no significant facial asymmetry; however, the patient exhibited reduced smile confidence due to visible irregularities in the anterior dentition.

Intraoral examination demonstrated spacing between the maxillary anterior teeth, altered tooth propor-

tions, and compromised esthetics in the anterior maxillary region. Additionally, crowding of the mandibular incisors was observed. Periodontal assessment revealed generally satisfactory oral hygiene status with no advanced periodontal disease, although localized plaque accumulation was present in the anterior region.

Pulp vitality testing and radiographic examination identified several maxillary teeth requiring endodontic intervention prior to definitive prosthetic rehabilitation. Periapical radiographs showed no severe periapical pathology but confirmed the need for root canal treatment due to compromised pulpal status. Diagnostic evaluation was performed in accordance with established clinical protocols for comprehensive oral examination and treatment planning [3,7].

Figure 1. Intraoral frontal view before treatment (patient presented with misaligned dentition).

Diagnosis

Based on clinical and radiographic findings, the following diagnoses were established:

- Esthetic disharmony of the maxillary anterior segment
- Spacing in the maxillary anterior region
- Malalignment of mandibular anterior teeth
- Teeth requiring endodontic therapy prior to restorative rehabilitation
- Functional and esthetic deficiency of anterior occlusion

A multidisciplinary treatment approach involving endodontic, periodontal, and prosthodontic disciplines was indicated to achieve optimal outcomes [1,2].

Treatment Plan

A staged treatment protocol was developed:

- Professional oral prophylaxis and oral hygiene reinforcement
- Endodontic therapy of indicated maxillary teeth
- Fixed prosthodontic rehabilitation using monolithic zirconia crowns
- Final occlusal adjustment and polishing

Zirconia was selected due to its high flexural strength, fracture resistance, biocompatibility, and improved optical properties compared with earlier ceramic systems [8–10].

Clinical Procedures

Phase I: Professional Oral Prophylaxis

Initial therapy included supragingival and subgingival scaling, polishing, and removal of extrinsic stains. Oral hygiene instructions were provided to improve plaque control and optimize periodontal conditions prior to definitive treatment. Maintenance of periodontal health is a critical factor influencing the long-term success of fixed prosthodontic restorations [2].

Phase II: Endodontic Treatment

Root canal treatment was performed on the indicated maxillary teeth following standard endodontic protocols. Cleaning, shaping, irrigation, and obturation were completed to achieve complete disinfection of the root canal system. Postoperative radiographs confirmed adequate obturation length and density without procedural errors.

Successful endodontic therapy is essential for preserving compromised teeth and providing a stable foundation for prosthodontic rehabilitation [4].

Phase III: Prosthodontic Rehabilitation

Following completion of endodontic treatment, the maxillary anterior teeth were prepared for full-coverage restorations. Tooth preparation followed ferrule and biological width principles to ensure long-term stability and fracture resistance [1].

Impressions were taken and monolithic zirconia crowns were fabricated using CAD/CAM technology. Try-in evaluation assessed marginal adaptation, proximal contacts, occlusal relationships, and esthetic integration. Final cementation was performed using a resin-based luting system.

Figure 2. Post-treatment frontal intraoral photograph showing zirconia crown rehabilitation of the maxillary dentition.

Zirconia was chosen due to its well-documented clinical performance and improved esthetic potential in modern restorative dentistry [8–10].

Clinical Outcomes

Post-treatment evaluation demonstrated significant improvement in both esthetics and function. The maxillary anterior spacing was successfully corrected, and tooth proportions were restored to achieve harmonious smile design. The final restorations exhibited favorable color matching, contour, and symmetry within the dental arch.

Periodontal tissues surrounding the restorations remained healthy, with no signs of inflammation, bleeding on probing, or pocket formation. Proper marginal adaptation of zirconia crowns contributed to plaque resistance and periodontal stability, consistent with previous findings in prosthodontic literature [2].

Occlusal analysis revealed stable intercuspation without premature contacts or functional interferences. The patient reported improved mastication efficiency and absence of discomfort during function. Restoration of occlusal harmony is a key determinant of long-term prosthodontic success [1,5].

Radiographic follow-up confirmed satisfactory root canal obturation and absence of periapical pathology, indicating successful biological integration of endodontic treatment [4].

Discussion

The present case highlights the importance of interdisciplinary management in the rehabilitation of esthetic and functionally compromised dentition. Esthetic rehabilitation is not limited to visual improvement but must also ensure biological health and functional stability [1,2].

Endodontically treated teeth present increased biomechanical vulnerability, necessitating full-coverage restorations to reduce fracture risk and improve longevity [4]. Zirconia has become a material of choice due to its high strength, chemical stability, and continuously improving optical properties [8–10].

Fradeani emphasized that esthetic rehabilitation requires systematic analysis of facial and dental proportions to achieve natural and harmonious results [5]. Similarly, Magne and Belser highlighted the importance of biomimetic principles in restorative dentistry to preserve tooth structure and mimic natural biomechanics [6].

Clinical studies have demonstrated high survival rates of zirconia restorations, supporting their reliability in both anterior and posterior regions [8,9]. Raigrodski further confirmed the long-term clinical success of all-ceramic systems when proper case selection and technique sensitivity are respected [10].

In this case, the combination of endodontic therapy, periodontal preparation, and prosthodontic rehabilitation resulted in successful restoration of esthetics, function, and patient satisfaction.

Conclusion

This case report demonstrates that multidisciplinary treatment involving endodontic therapy and zirconia crown rehabilitation can successfully restore compromised maxillary anterior teeth. The use of monolithic zirconia provided predictable esthetic and functional outcomes, while maintaining periodontal health and structural stability. Careful diagnosis, treatment planning, and adherence to evidence-based protocols are essential for achieving long-term success in esthetic rehabilitation [1,2,4,8–10].

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PHILOLOGY

APPLYING ARTIFICIAL INTELLIGENCE TO IMPROVE SYNONYM ACCURACY

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Abstract

The modern communication landscape demands precision and nuance. Current methods of synonym selection, often relying on simple lexical databases, frequently fail to capture the subtle contextual differences between words, leading to potential misinterpretations and diminished impact. This paper explores the potential of artificial intelligence (AI) to revolutionize synonym selection, arguing that advanced natural language processing (NLP) models can significantly improve the accuracy and effectiveness of communication by providing contextually appropriate synonyms. We delve into the limitations of traditional synonym finding methods, highlighting the need for nuanced understanding of semantic relationships and contextual factors. The paper examines the role of deep learning models, specifically transformer architectures, in capturing complex semantic relationships, and analyzes their potential to generate more effective synonym replacements. Furthermore, we discuss the ethical considerations surrounding AI-powered synonym selection, including the potential for bias and the need for transparency in model outputs. Ultimately, this paper argues that integrating AI into synonym selection processes can lead to more effective and nuanced communication, ultimately fostering clearer, more impactful interactions in various domains, from literature and journalism to legal and medical contexts. Further research is necessary to explore the practical applications and refine the models for optimal performance in diverse contexts.

The future of communication is poised to be transformed by the seamless integration of artificial intelligence, particularly in enhancing the effectiveness of synonym selection. As AI models become increasingly sophisticated, they will enable more nuanced and context-aware language use, allowing individuals and organizations to communicate with greater precision and emotional resonance. This evolution will facilitate real-time adaptation of vocabulary to suit diverse audiences, cultural contexts, and specific purposes, ultimately fostering clearer understanding and reducing misinterpretations. For example, AI-powered communication tools could automatically adjust word choices to match the formality level required, ensuring messages are appropriately tailored without manual effort, thereby streamlining professional and personal interactions alike.

Looking ahead, advancements in natural language understanding will also empower AI systems to grasp subtle connotations, idiomatic expressions, and cultural sensitivities, further refining synonym effectiveness. This will open new avenues for personalized communication, where AI can generate content that resonates more deeply with individual preferences and backgrounds. Additionally, as AI continues to evolve, it may assist in bridging language barriers by offering accurate, contextually relevant synonyms across different languages and dialects. Overall, the integration of AI into communication strategies promises a future where language becomes more adaptable, inclusive, and impactful, paving the way for more meaningful global dialogue.

Keywords: synonym choice, artificial intelligence, accurate word selection, context-based variants, idiomatic, meaning.

Harnessing AI to Enhance Nuance and Context in Synonym Selection

In the realm of natural language processing (NLP), the accurate selection of synonyms remains a significant challenge due to the subtle nuances and contextual dependencies inherent in human language. Traditional thesauruses and rule-based systems often fall short in capturing these complexities, leading to imprecise communication and potential misunderstandings. However, recent advances in artificial intelligence (AI), particularly deep learning models, have begun to revolutionize how machines understand and generate language, offering promising solutions to this problem. [7] One of the key breakthroughs has been the development of contextual word embeddings, such as Word2Vec and more recently, transformer-based models like BERT [8]. Unlike traditional methods that assign static meanings to words, these models generate dynamic representations that encapsulate a word's meaning based on its surrounding context. This allows AI systems to distinguish between different senses of a word and select synonyms that align precisely with the intended nuance. For example, in the sentence "She sat on the river bank,"BERT recognizes "bank" as a landform beside a river, suggesting synonyms like "riverbank" or "shore." Conversely, in "He deposited money in the bank," it understands "bank" as a financial institution, recommending synonyms like "financial institution" or "credit union" [4].

Furthermore, AI models are increasingly capable of understanding subtle differences in tone, formality,

and connotation, which are crucial for effective communication. For instance, in a formal context, replacing "help" with "assist" or "aid" maintains professionalism, whereas in casual speech, "help out" might be more appropriate. Fine-tuning pre-trained models on domain-specific datasets enhances their ability to recommend contextually suitable synonyms in specialized fields such as medicine, law, or technology. [2] For example, in medical texts, AI might suggest "myocardial infarction" instead of "heart attack," providing precise terminology that aligns with professional standards.

Despite these advancements, challenges remain. AI models require vast amounts of training data and computational resources, and they can sometimes produce biased or inappropriate suggestions if not carefully managed . [1] For example, biased training data might lead to gender stereotypes in synonym suggestions, such as associating "nurse" predominantly with women. Ongoing research aims to mitigate these issues through improved training techniques and ethical guidelines. Overall, harnessing AI for synonym selection holds immense potential to refine communication, making it more nuanced, context-aware, and aligned with human intent.

Examples:

1. "The manager requested an urgent meeting."

AI might suggest "urgent" synonyms such as "immediate" or "pressing," depending on the context, whereas "crucial" might be less appropriate here.

2. "The artist's work was innovative."

Depending on tone, synonyms like "creative," "original," or "groundbreaking" can be suggested, with AI selecting the most fitting based on context.

Artificial Intelligence in Explaining Idiomatic Expressions: A Study of Synonym Suggestion

Idiomatic expressions are phrases whose meanings cannot be deduced solely from the literal definitions of their words. They are ubiquitous in language and play a crucial role in conveying nuanced and context-dependent meanings. However, the complexity of idioms poses significant challenges to NLP systems, which often struggle to provide clear and concise explanations of these expressions. In recent years, AI has emerged as a promising tool for addressing this challenge.

The potential of AI is in suggesting synonyms as a means of explaining idiomatic expressions is quite satisfactory. For example, in the idiom "She is feeling blue today." AI recognizes the idiomatic meaning of "blue" as feeling sad, suggesting synonyms like "downcast" or "melancholy," rather than color-related options. [6] The model is able to suggest a range of synonyms for each idiom, including:

- "Break the ice": thaw, ease, relax
- "Spill the beans": reveal, disclose, confess
- "Bend over backwards": accommodate, compromise, oblige

These synonyms provided a clear and concise explanation of the idiomatic expression, allowing users to better understand the intended meaning.

The use of AI to suggest synonyms as a means of explaining idiomatic expressions has several benefits, including:

- Improved understanding: By suggesting synonyms, AI can provide users with a clear and concise explanation of idiomatic expressions, improving their understanding of the intended meaning.
- Increased accessibility: AI can provide explanations of idiomatic expressions in a range of languages, making language learning and communication more accessible.
- Enhanced creativity: By suggesting a range of synonyms, AI can encourage users to think creatively about language and explore new meanings.

While the use of AI to suggest synonyms as a means of explaining idiomatic expressions has several benefits, there are also several limitations and potential drawbacks:

- Limited contextual understanding: AI may struggle to understand the context in which an idiom is being used, potentially leading to inaccurate or misleading explanations.
- Overreliance on technology: The use of AI to suggest synonyms may lead to an overreliance on technology, potentially undermining users' ability to think creatively about language.
- Cultural and linguistic limitations: AI may struggle to understand cultural and linguistic nuances, potentially leading to explanations that are insensitive or inaccurate.

In conclusion, AI is rapidly transforming how we approach language and communication. By personalizing and refining language selection, AI tools have the potential to significantly improve the effectiveness of communication across diverse contexts and potential in suggesting synonyms as a means of explaining idiomatic expressions. As AI technology continues to evolve, its role in enhancing human communication will undoubtedly become even more sophisticated and pervasive, leading to clearer, more impactful, and more accessible interactions. While there are several benefits to this approach, there are also several limitations and potential drawbacks. Further research is needed to fully explore the potential of AI in this area and to address the challenges and limitations of this approach.

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