

UDC 711.4

Torekhan Sabrina

11th-grade student

Scientific supervisor: Nurbakova Gulia Serikmukhametovna

Physics teacher

Pifagor High School

(Almaty, Kazakhstan)

WHERE ALMATY WALKS ITS OWN WAY: INFORMAL SHORTCUTS IN OPENSTREETMAP AND THE DETOURS THEY AVOID

Abstract: Desire paths are the worn tracks people make when the planned walking network does not follow the route they want to take. They have been mapped at city scale in the United States, but, to our knowledge, not in Central Asia. Using the open OpenStreetMap database for Almaty (snapshot of 28 September 2026), we tested a simple least-effort prediction: informal shortcuts should appear where the walking network forces a long detour between two points. We first planned to compare city parks, but the map is too sparse for that: only 7 of 127 mapped parks contain any way tagged with an unpaved surface. The test was therefore run city-wide. Of 576 unpaved pedestrian ways, 78 are short enough to be shortcuts (600 m or less), touch the mapped walking network (footways and walkable streets) at both ends, and have a route between their ends. Walking between the two ends of these shortcuts along the network takes a median of 2.16 times the straight-line distance, compared with 1.38 for randomly chosen pairs of network points at the same distance within 1 km of each shortcut (Mann-Whitney $z = 4.65$ to 5.31 across 20 random baseline draws; matched sign test 56 of 78 above their own baseline, $p < 0.001$). The median shortcut saves 108 m of walking, and 76 of 78 save distance. The result holds when the length cut-off is changed to 300 m or 1,000 m and when neighbouring shortcuts are grouped. It is consistent with least-effort theory, but it rests on the shortcuts volunteers have mapped, and the most important finding about the data is that most of Almaty's informal paths are not yet on the map.

Keywords: desire paths; pedestrian behaviour; OpenStreetMap; route directness; walkability; Almaty

Introduction. A desire path is a track worn into grass or earth by people who repeatedly take a route that the designed network does not provide. Such paths are cheap-to-observe evidence of where a public space disagrees with the way people use it. In Detroit, Foster and Newell mapped 5,680 informal footpaths from aerial imagery, with a combined length of about 157 miles, and linked them to vacant land and to trips toward everyday destinations such as schools and bus lines [1]. A study of a closed desire path found that it was used about four times more several months after closure than immediately after, suggesting that closing a shortcut does not remove the demand for it [2]. Agent-based models have also been developed to predict where desire paths will form in small neighbourhoods [3].

The common explanation is least effort: pedestrians minimise walking distance, and repeated shortcutting across open ground wears a visible track. Transport research measures how indirect a network is with circuitry, the ratio of the network distance between two points to the straight-line distance [4, 5]. If least effort is right, informal paths should appear where circuitry is high, that is, where the designed network makes walkers go a long way around.

This study tests that prediction in Almaty using data that already exist online: do the ends of Almaty's mapped informal shortcuts sit where the walking network makes people detour more than it usually does? It also measures how well OpenStreetMap covers informal paths in the city, which matters for any later work on this subject. OpenStreetMap is known to be close to complete for roads in many countries [6], but its coverage of small informal paths has not been assessed for Almaty.

Materials and Methods. Data. All pedestrian ways (OpenStreetMap tags highway = footway, path or pedestrian), all walkable streets (residential, living street, service, unclassified, tertiary, secondary and primary roads, their links, steps, tracks and corridors) and all mapped parks (leisure = park, including multipolygon relations) inside the Almaty administrative boundary were downloaded through the public Overpass API [7]. All three downloads have the data timestamp 2026-09-28T01:41Z. OpenStreetMap data are openly licensed under the ODbL [8].

Informal ways and the walking network. A way was classified as informal if its surface was tagged as ground, dirt, compacted, unpaved, grass, earth, mud or sand, or if it carried informal = yes. The walking network was defined as all footways, pedestrian ways and walkable streets that are not informal and are not marked as closed to pedestrians or private, plus paths with a recorded surface. Streets are included because in Almaty most sidewalks are not drawn as separate ways but are part of the street itself. Paths without any surface tag (764 ways) were left out of both groups, because they cannot be classified as either designed or informal. The resulting network has 97% of its points in one connected piece.

Which shortcuts can be tested. Network lines were divided into points every 10 m, so that the end of a shortcut can be attached to the nearest point of a line and not only to a junction. An informal way was tested if it is at most 600 m long (longer ways are trails rather than shortcuts), if each end lies within 25 m of the network, if its two ends attach to network points at least 10 m apart, and if a network route between them exists within 3 km.

Detour measure. For each tested shortcut, the shortest route along the network between its two attachment points was computed with Dijkstra's algorithm, and divided by the straight-line distance between the same two points. This ratio is the circuitry of the network between the ends of the shortcut: 1.0 means the network is perfectly direct, higher values mean a longer detour. Walking distance saved is the network route, plus the short connections from each end to the network, minus the length of the shortcut itself.

Comparison. For each shortcut, 10 pairs of network points were drawn at random from the area within 1 km of the shortcut, with the two points of a pair at the same straight-line distance as the shortcut's ends (within 15%). Their circuitry was computed in the same way, from network point to network point, so that shortcuts and comparison pairs are measured identically. Circuitry of shortcut ends was compared with the comparison pairs using a two-sided Mann-Whitney test, repeated for 20 different random draws of comparison pairs. Because each shortcut has its own comparison pairs, a matched sign test was also used: for each shortcut, whether its circuitry is above or below the median of its own 10 comparison pairs.

How the design changed. The first plan, written in September 2026, was to compare desire paths inside parks, starting with Roshcha Bauma, and to test the angle of path corners and nearby attractors such as entrances. When the data were downloaded, too few parks contained any mapped informal path to support that plan (Results). A first city-wide version of the test used footways only and was then corrected to include walkable streets, because without streets the

network was broken into thousands of disconnected pieces. The results reported here are from the corrected network.

Results. Coverage of the map. The city layer contains 21,434 pedestrian ways: 19,889 footways, 1,337 paths and 208 pedestrian streets. A surface is recorded for only 4,581 of them. Of the 127 mapped parks, 73 contain any pedestrian way, 1,650 ways in total, and 1,228 of these have no surface recorded. Only 12 parks contain any way tagged as a path, and only 7 contain any way tagged with an unpaved surface; 48 of those 74 unpaved ways are in Roshcha Bauma. A park-by-park comparison was therefore not possible with the current map.

Which shortcuts could be tested. Of 576 informal ways in the city, 196 are longer than 600 m, 278 have at least one end more than 25 m from the walking network, 10 have both ends attaching to practically the same point, and 14 have no network route between their ends within 3 km. The remaining 78 shortcuts were tested. Their median length is 88 m.

The detours they avoid. Walking between the ends of these shortcuts along the network takes a median of 225 m. The median circuitry is 2.16 (interquartile range 1.31 to 3.95), compared with 1.38 (1.07 to 2.22) for the 780 comparison pairs of the first draw (Figure 1). Across 20 random draws of comparison pairs, the Mann-Whitney z ranges from 4.65 to 5.31, all $p < 0.001$. In the matched test, 56 of the 78 shortcuts have a higher circuitry than the median of their own comparison pairs and 22 a lower one (sign test $p < 0.001$). Of the shortcuts, 68% sit where the network route is at least 1.5 times the straight line, compared with 40% of comparison pairs.

Distance saved. Seventy-six of the 78 shortcuts are shorter than the network alternative (Figure 2). The median saving is 108 m (interquartile range 29 to 316 m). Three shortcuts save more than one kilometre; each connects two points that the mapped network joins only by a long way around, which may reflect a real gap in the network or a missing link on the map.

Sensitivity. With a length cut-off of 300 m, 71 shortcuts are tested and the median circuitry is 2.18 against 1.36 for comparison pairs (z from 4.48 to 5.01 across draws); with 1,000 m, 80 shortcuts, 2.16 against 1.34 (z from 4.78 to 4.91). Some shortcuts lie next to each other and may describe one crossing. Keeping only one shortcut in each group within 100 m leaves 61, with a median circuitry of 2.18 and $z = 4.52$.

Discussion. The ends of Almaty's mapped informal shortcuts are located where the walking network is unusually indirect, and almost every shortcut makes the walk shorter. This is what least-effort theory predicts, and it agrees with the Detroit study, where informal paths were linked to places the planned network does not serve [1]: people cut their own paths where the designed route asks them to walk too far. The difference is not small. At the ends of a typical shortcut, the network route is more than twice the straight line, while for comparable points nearby it is about one and a third.

The more important finding, however, is about the map itself. Informal paths are one of the clearest signs of how a city is really used, yet in Almaty they are almost absent from the open map. Only 7 of 127 mapped parks show any unpaved way, and three quarters of pedestrian ways in parks have no surface recorded at all. The shortcuts that could be tested are only the ones that volunteers happened to draw and tag. Any analysis of desire paths in Almaty, by researchers or by the city, will need more complete mapping or another source, such as open satellite imagery.

Limitations. The tested sample (78 shortcuts) is not a random sample of Almaty's desire paths: it contains only paths that volunteers mapped and tagged, and it may over-represent the most visible ones. Whether a way is informal is decided by its surface tag, not by direct

observation. The walking network treats every street as walkable, although some wide roads are hard to cross, and it may still have missing links, which is one explanation for the few very large savings. The data show where shortcuts exist, not how many people use them. The analysis tests only one predictor, the detour; other factors that may matter, such as the angle of a corner or the pull of an entrance or bus stop, were not tested. The findings describe association and do not prove why each path was made.

Conclusion. In Almaty's open map, informal pedestrian shortcuts appear where the walking network makes people detour most: the network route between their ends is a median 2.16 times the straight line, against 1.38 for comparable nearby points, and the typical shortcut saves about 110 m. The result holds across random draws, length cut-offs and grouping of neighbouring shortcuts. The same data show that most of the city's desire paths are not yet mapped, which is the first obstacle for any study, or any planning decision, that wants to use them.

Data availability. All data are publicly available from OpenStreetMap through the Overpass API; the queries and the analysis code are available from the author on request.

Conflict of interest. The author declares no conflict of interest.

References:

1. Foster A., Newell J.P. Detroit's lines of desire: Footpaths and vacant land in the Motor City // *Landscape and Urban Planning*. 2019. Vol. 189. P. 260-273. DOI: 10.1016/j.landurbplan.2019.04.009.
2. Saxena N., Rashidi T.H., Babana J., Cheung C. Pedestrian Characteristics That Favor Desire Lines Despite Closure // *Journal of Urban Planning and Development*. 2020. Vol. 146, No. 2. DOI: 10.1061/(ASCE)UP.1943-5444.0000577.
3. Bossowski J., Szandala T., Mazurkiewicz J. Predicting Desire Paths: Agent-Based Simulation for Neighbourhood Route Planning // *Computers, Environment and Urban Systems*. 2025. URL: <https://www.sciencedirect.com/science/article/pii/S0198971525000043> (accessed: 28.09.2026).
4. Randall T.A., Baetz B.W. Evaluating pedestrian connectivity for suburban sustainability // *Journal of Urban Planning and Development*. 2001. Vol. 127, No. 1. P. 1-15.
5. Levinson D., El-Geneidy A. The minimum circuitry frontier and the journey to work // *Regional Science and Urban Economics*. 2009. Vol. 39, No. 6. P. 732-738.
6. Barrington-Leigh C., Millard-Ball A. The world's user-generated road map is more than 80% complete // *PLoS ONE*. 2017. Vol. 12, No. 8. Art. e0180698. DOI: 10.1371/journal.pone.0180698.
7. Overpass API. URL: <https://overpass-api.de> (accessed: 28.09.2026).
8. OpenStreetMap contributors. OpenStreetMap data, Open Database License (ODbL). URL: <https://www.openstreetmap.org/copyright> (accessed: 28.09.2026).

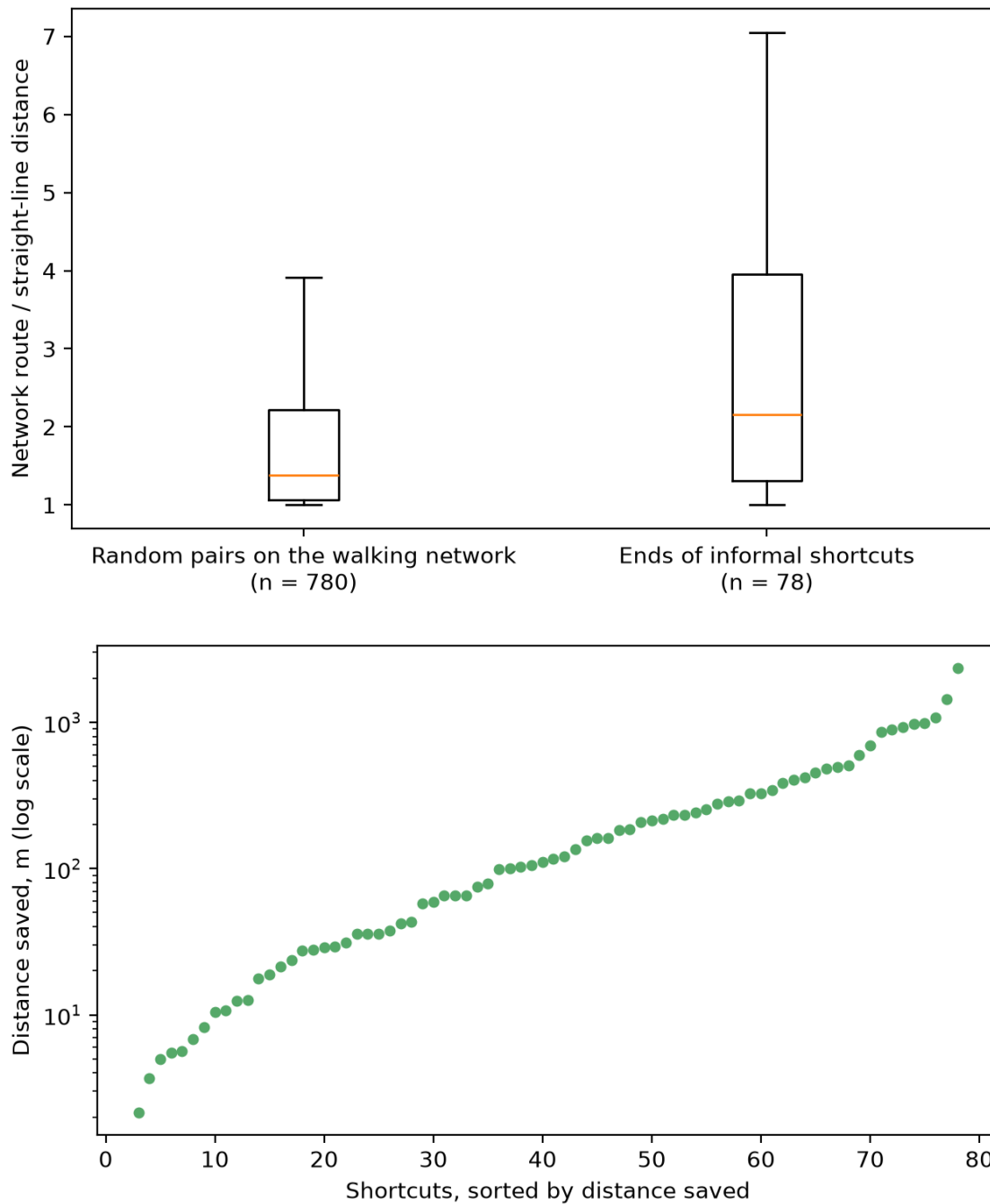


Figure captions:

Figure 1. Circuitry (network route divided by straight-line distance) between the ends of 78 informal shortcuts and for 780 random comparison pairs of network points at matched distances within 1 km. Boxes show the interquartile range; values above the whiskers are not drawn.

Figure 2. Walking distance saved by each informal shortcut, sorted, on a logarithmic scale. Two shortcuts with no saving are not shown.

МАЗМҰНЫ – СОДЕРЖАНИЕ – CONTENT

ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ ЖӘНЕ ҚҰҚЫҚ ҒЫЛЫМДАРЫ - СОЦИАЛЬНО-ЭКОНОМИЧЕСКИЕ И ЮРИДИЧЕСКИЕ НАУКИ - SOCIO-ECONOMIC AND LEGAL SCIENCES

Төлегенов Тимур Сейфуллаулы

**ДИНАМИКА ТУРИСТСКИХ ПОТОКОВ И ЭФФЕКТИВНОСТЬ ИНФРАСТРУКТУРЫ
ТУРКЕСТАНА: ОТ ЭКСТЕНСИВНОГО РОСТА К СМАРТ-УПРАВЛЕНИЮ 10**

Alexander Gorevoy

**WHICH INEQUALITY STATISTICS SURVIVE AN ADMINISTRATIVE BOUNDARY CHANGE?
EVIDENCE FROM KAZAKHSTAN, 2010–2023 14**

Rakhimov Djalil

**DOES THE SHIFT TO CASHLESS PAYMENTS GO TOGETHER WITH FASTER GROWTH IN
HOUSEHOLD CREDIT? EVIDENCE FROM THE REGIONS OF KAZAKHSTAN, 2023-2025 26**

Kazhgerey Asan

**HOW MANY FOOD BASKETS DOES AN AVERAGE WAGE BUY? WAGES AND FOOD PRICES IN
THE 20 REGIONS OF KAZAKHSTAN, 2024-2026 37**

Tagimova Alua

**WHO WAS LEFT BEHIND? EDUCATION AND FINANCIAL INCLUSION IN KAZAKHSTAN AND
THREE CENTRAL ASIAN NEIGHBOURS, 2021-2024 44**

Wei Wei, Mynzhanova Gulzhakan, Niyetalina Gaukhar

**DIGITAL–PHYSICAL INTEGRATION AND ECONOMIC PERFORMANCE IN INDUSTRIAL
INTEGRATED ENERGY SYSTEMS: A SCENARIO-BASED ANALYSIS OF SMART GRID
CONTROL, BATTERY ENERGY STORAGE, AND DIGITAL TWINS 51**

Xu Fumin, Wei Wei, Ruziyeva Elvira, Moldabekova A.

**FROM CULTURAL RESOURCES TO GLOBAL CONSUMER VALUE: THE BRIDGE–IMC MODEL
AND THE INTERNATIONALIZATION OF BLACK MYTH: WUKONG UNDER THE BELT AND
ROAD INITIATIVE 64**

Ibraimkhan Alikhan

**WHICH CRIMES CAN A 14-YEAR-OLD BE TRIED FOR? THE LIST IN ARTICLE 15 OF
KAZAKHSTAN'S CRIMINAL CODE COMPARED WITH 30 OTHER JURISDICTIONS 80**

Yerboluly Madi

**DID IMPORTED CARS REALLY GET CHEAPER? CHINESE CARS AND THE AVERAGE
CUSTOMS VALUE OF PASSENGER CARS IMPORTED INTO KAZAKHSTAN, 2015-2025 91**

Салимбаев Ербол Аманжолович

**АНАЛИЗ ИНВЕСТИЦИОННОЙ АКТИВНОСТИ КАК ИНДИКАТОР ИЗМЕНЕНИЙ
ПОТЕНЦИАЛЬНОГО СПРОСА НА КОНСАЛТИНГОВЫЕ УСЛУГИ 99**

Rambergenov Ramil

**REGIONAL NEW-FIRM FORMATION IN UZBEKISTAN AFTER THE 2017 REFORMS:
PERSISTENCE IN SCALE, CONVERGENCE IN INTENSITY, AND RECOMPOSITION TOWARD
TRADE 107**

Abdesh Dinara

**FROM A WOMEN'S LEAD TO A MEN'S LEAD: THE GENDER GAP IN DIGITAL PAYMENTS IN
KAZAKHSTAN AND THREE CENTRAL ASIAN NEIGHBOURS, 2021-2024 116**

Amangeldi Aidana

**DID SMALL BUSINESS IN KAZAKHSTAN REALLY SHRINK IN 2026? THE NEW TAX CODE,
REGIONAL TAX RATES AND THE FALL IN THE NUMBER OF INDIVIDUAL ENTREPRENEURS 124**

Cheng Che	
BUILD, BUY, OR PARTNER? ENTRY MODE SELECTION AND RISK GOVERNANCE FOR WIND POWER INVESTMENT IN KAZAKHSTAN	133
Wang Liang	
FROM CAPACITY EXPANSION TO SYSTEM VALUE: COORDINATED DEVELOPMENT OF RENEWABLE ENERGY, GRID FLEXIBILITY AND ENERGY STORAGE IN KAZAKHSTAN	146
Chen Jun	
CONSTRUCTION-PERIOD CREDIT RISK MANAGEMENT FOR LARGE INFRASTRUCTURE PROJECT FINANCE IN KAZAKHSTAN	159
Alniyaz Danial	
HOW MUCH FUEL DOES A HYBRID REALLY SAVE? A SAME-MODEL COMPARISON OF HYBRID AND GASOLINE CARS IN US FUEL ECONOMY	173

ТЕХНИКАЛЫҚ ҒЫЛЫМДАР - ТЕХНИЧЕСКИЕ НАУКИ - TECHNICAL SCIENCE

Nurmakhan Almira	
ADVANTAGES OF FIBER OPTIC COMMUNICATION OVER TRADITIONAL COPPER CABLES	180
Kozhabai Bereke	
SECURITY CHALLENGES IN IOT-BASED TELECOMMUNICATION NETWORKS	188
Azamatuly Yerassyl	
WHY AI-GENERATED CODE FAILS A BENCHMARK: A FAILURE ANALYSIS OF THREE OPEN LANGUAGE MODELS ON 30 HUMANEVAL+ TASKS	197
Nurzhan Sanzhar	
A FEW SHELLS, A FEW OPERATORS: WHERE LOW EARTH ORBIT IS CROWDED IN AN ALTITUDE-INCLINATION MAP OF 16,620 ACTIVE SATELLITES	206
Askarbek Nurislam	
CAN THE WEATHER TELL WHICH DAYS IN ASTANA WILL BE POLLUTED? CLASSIFYING PM2.5 EXCEEDANCE DAYS WITH MACHINE LEARNING AND CHECKING THE DATA AGAINST A GROUND MONITOR	212
Iliyas Arman	
SHOOTING ON THE MOVE: HOW MUCH AIM A ROBOT LOSES BY IGNORING ITS OWN VELOCITY, AND WHETHER A VIRTUAL-TARGET CORRECTION RECOVERS IT	223
Ануар Әлімжан Бахытжанұлы, Сексенбаева Айша Курманбековна	
СРАВНИТЕЛЬНЫЙ АНАЛИЗ СТАНДАРТОВ И МЕТОДИК ОБУЧЕНИЯ КИБЕРБЕЗОПАСНОСТИ: NICE FRAMEWORK, ECSF И ПРАКТИКО- ОРИЕНТИРОВАННЫЕ ТЕХНОЛОГИИ	229
Mukhamedzhan Yerganat	
GROWTH OF GITHUB DEVELOPER COMMUNITIES IN KAZAKHSTAN, UZBEKISTAN AND KYRGYZSTAN, 2020-2026: EVIDENCE FROM THE GITHUB INNOVATION GRAPH	239

ПӘНДЕР АРАЛЫҚ ҒЫЛЫМДАР – МЕЖДИСЦИПЛИНАРНЫЕ НАУКИ – INTERDISCIPLINARY SCIENCES

Albiyev Asser	
HOW MUCH OF AN ARTICLE COUNT IS HUMAN WORK? DECOMPOSING THE CREATION OF FIVE WIKIPEDIAS, 2010–2025	251
Amangeldy Nurbolat	
HOW MUCH OF KAZAKHSTAN'S URBAN BUILT STOCK PREDATES ITS SEISMIC CODES, AND WHERE DOES THAT STOCK SIT RELATIVE TO HAZARD?	261

Torekhan Sabrina

WHERE ALMATY WALKS ITS OWN WAY: INFORMAL SHORTCUTS IN OPENSTREETMAP AND THE DETOURS THEY AVOID	267
---	------------

ӘЛЕУМЕТТІК ЖӘНЕ ГУМАНИТАРЛЫҚ ҒЫЛЫМДАР - СОЦИАЛЬНО-ГУМАНИТАРНЫЕ НАУКИ - SOCIAL SCIENCES AND HUMANITIES

Мұқатаева Айзат Амантайқызы, Стамбекова Жанат Байғазықызы, Слямханова Гүлім Болатқызы, Қызырбек Аяулым Ерболқызы

ЖАСАНДЫ ИНТЕЛЛЕКТ ДӘУІРІНДЕГІ ҒЫЛЫМИ ТАНЫМ: ПОППЕР, КУН ЖӘНЕ ЛАКАТОС ИДЕЯЛАРЫ ТҮРҒЫСЫНАН ТАЛДАУ	272
--	------------

Мұқатаева Айзат Амантайқызы, Сапарханова Мадина Төлегенқызы, Окенова Аружан Муратхановна, Тұрсынғазыева Ақерке Ерболатқызы

ШӘКӘРІМ ФИЛОСОФИЯСЫНДАҒЫ ЕРКІНДІК ЖӘНЕ МОРАЛЬДЫҚ ТАҢДАУ МӘСЕЛЕСІ	282
---	------------

Komekova Saida

DO UNHAPPY REVIEWERS MIX IN MORE RUSSIAN? STAR RATINGS AND KAZAKH-RUSSIAN CODE-SWITCHING IN 175,002 ONLINE REVIEWS	291
---	------------

Zhumagali Yerbol

DOES A BIGGER MODEL CLOSE THE GAP? KAZAKH-LANGUAGE ACCURACY ON KAZAKHSTAN-SPECIFIC VERSUS UNIVERSAL SCHOOL SUBJECTS IN SMALL OPEN-WEIGHT LANGUAGE MODELS	304
---	------------

Abdrakhmanova Madina

DOES A MEDAL BUY ATTENTION? WIKIPEDIA VIEWS OF KAZAKHSTAN'S ATHLETES BEFORE AND AFTER THE PARIS 2024 OLYMPIC	308
---	------------

ПЕДАГОГИКАЛЫҚ ЖӘНЕ ПСИХОЛОГИЯЛЫҚ ҒЫЛЫМДАР – ПЕДАГОГИЧЕСКИЕ И ПСИХОЛОГИЧЕСКИЕ НАУКИ – PEDAGOGICAL AND PSYCHOLOGICAL SCIENCES

Kaldarbek Mergen

FAMILY OR SCHOOL? SOCIOECONOMIC COMPOSITION AND MATHEMATICS ACHIEVEMENT IN KAZAKHSTAN, PISA 2022 AND 2025	316
--	------------

Zhenis Adilzhan

WHICH OLYMPIAD PROBLEMS DO STUDENTS TAKE TO THE BOARD? CHOICES AND DEFENCES IN THE 8TH-GRADE LEAGUE OF KARAGANDY MATHBATTLES 2026	323
--	------------

Базарбаева Айнура Бектуровна

ДЕТСКИЙ ФОЛЬКЛОР И ПОДВИЖНЫЕ ИГРЫ КАК ИНСТРУМЕНТЫ ФОРМИРОВАНИЯ ОСНОВ ПРАВОВОЙ КУЛЬТУРЫ У ДЕТЕЙ СТАРШЕГО ДОШКОЛЬНОГО ВОЗРАСТА	330
---	------------

БИОЛОГИЯ ҒЫЛЫМДАР - БИОЛОГИЧЕСКИЕ НАУКИ - BIOLOGICAL SCIENCES

Bazhenova Diana

GROWTH DYNAMICS OF STERLET (<i>Acipenser ruthenus</i> L.) REARED IN A RECIRCULATING AQUACULTURE SYSTEM	333
---	------------

ТУРИСТИЧЕСКИЕ И СПОРТИВНЫЕ НАУКИ - ТУРИСТІК ЖӘНЕ СПОРТ ҒЫЛЫМДАРЫ - TOURISM AND SPORTS SCIENCES

Төлеп Жазира Маратқызы

ГАСТРОНОМИЯЛЫҚ ФЕСТИВАЛЬДЕРДІҢ ТУРИСТІК ДЕСТИНАЦИЯ ТАРТЫМДЫЛЫҒЫН ҚАЛЫПТАСТЫРУДАҒЫ РӨЛІ МЕН ДАМУ ҮРДІСТЕРІ	340
--	------------

ЕСТЕСТВЕННЫЕ НАУКИ - ЖАРАТЫЛЫСТАНУ ҒЫЛЫМДАРЫ - NATURAL SCIENCES

Нургельдина Асель Ермаковна, Серикбаева Жанерке Алимжановна

ШЕКАРАСЫЗ ФИЗИКА: ӘР ЕЛДЕГІ ФИЗИКАЛЫҚ БІЛІМДІ САЛЫСТЫРУ 347