DOI: https://doi.org/10.32782/2308-1988/2025-57-21
UDC 330.55:355.48

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WARTIME RISKS AND REGIONAL ECONOMIC RESILIENCE IN UKRAINE: AIR RAIDS, INFRASTRUCTURE ATTACKS AND BUSINESS RELOCATION

ВОЄННІ РИЗИКИ ТА РЕГІОНАЛЬНА ЕКОНОМІЧНА СТІЙКІСТЬ УКРАЇНИ: ПОВІТРЯНІ ТРИВОГИ, АТАКИ НА ІНФРАСТРУКТУРУ ТА РЕЛОКАЦІЯ БІЗНЕСУ

Summary. The article examines how wartime risks related to air raid alerts and infrastructure attacks affect regional economic stability in Ukraine. Based on data for August 2024 – August 2025, it integrates business relocation flows, shopping mall downtime, alert dynamics and strikes on energy, residential, medical and educational infrastructure. Regional comparison reveals strong spatial asymmetry: some frontline regions lose up to 50% of mall operating time, while western regions record less than 1%. Despite high security threats, Kharkiv, Dnipropetrovsk and Zaporizhzhia remain key relocation destinations, proving that business movement does not follow a simple "east-to-west" model. The findings enhance quantitative understanding of wartime regional inequality and can support policies on business relocation, resilience monitoring and economic recovery.

Keywords: air raids, business relocations, business downtime, economic analytics, economy during the war, Ukraine.

Анотація. У статті проаналізовано вплив воєнних ризиків, пов'язаних із інтенсивністю, тривалістю та добовою структурою повітряних тривог, а також атаками на об'єкти інфраструктури, на регіональну економічну стійкість України. На основі даних за серпень 2024 – серпень 2025 років інтегровано інформацію про міжрегіональні релокації бізнесу (Opendatabot), простій торговельних центрів (УРТЦ), динаміку повітряних тривог та вибухів, а також удари по енергетичній, житловій, медичній та освітній інфраструктурі (ACLED). Застосовано описову статистику, порівняльний міжрегіональний аналіз та елементи просторової візуалізації даних, що дозволило виділити відмінності областей за середньою кількістю та тривалістю тривог на добу, часткою нічних сповіщень, операційними простоями в робочий час і характером пошкоджень інфраструктури. Сформовано типові поєднання показників безпеки та економічної активності, які дозволяють виділити регіони з різними профілями ризику для бізнесу та населення. Показано, що висока безпекова загроза

не завжди означає нижчий притік бізнесу і переміщення бізнесу не зводиться до простої схеми «зі Сходу на Захід»: низка прифронтових та високоризикових регіонів, зокрема Харківщина, Дніпропетровщина та Запоріжжя, є водночас центрами релокацій та зонами підвищеної небезпеки. Виявлено значну асиметрію у втраті робочого часу торговельних центрів: в окремих прифронтових областях магазини втрачають до 50% свого операційного часу, тоді як у західних регіонах час простою падає нижче 1%. Окремо проаналізовано відмінності у транспортній стійкості регіонів та потенційний вплив нічних тривог на продуктивність праці та повсякденну мобільність населення. Додатково встановлено, що удари по житловій, енергетичній, медичній та освітній інфраструктурі часто накладаються на території активної релокації бізнесу, що формує асиметричні профілі ризику для інвесторів та місцевих громад. Отримані результати поглиблюють кількісне розуміння просторової нерівності воєнних ризиків у різних регіонах України та її зв'язку з економічною активністю. Запропонований підхід може бути використаний для формування програм підтримки бізнесу, моніторингу регіональної стійкості, оновлення економічної карти України в умовах війни та планування післявоєнного відновлення на основі реальних даних, а не лише формальних адміністративних критеріїв.

Ключові слова: повітряні тривоги, релокації бізнесу, простій бізнесу, економічна аналітика, економіка під час війни, Україна.

Problem statement. Russia's full-scale invasion has radically reshaped the spatial configuration of Ukraine's economy. Business relocation from frontline and high-risk regions to relatively safer territories, repeated air raid alerts and systematic attacks on critical infrastructure simultaneously affect production, employment, consumer behaviour and local budgets. These factors deepen pre-existing regional disparities that, as previous research shows, stem from historical development paths and uneven implementation of regional policy [4].

At the same time, the impact of these shocks is not uniform across the country. Regions experience a multilayered system of risks to very different degrees. Frequent air raid alerts disrupt transport, retail and everyday work routines, causing uneven losses of working time and reducing the predictability of local economic activity. In several regions, especially those near the frontline, the accumulation of such interruptions has become a structural constraint for both businesses and households.

Another important aspect is the growing mismatch between objective security conditions and actual business relocation flows. While it might be suggested that firms gradually concentrate in safer territories, empirical data point to more complex relocation patterns shaped by market size, logistics, institutional support and pre-war economic ties. As a result, regional resilience depends not only on the intensity of military threats, but also on how local economies adapt to continuous disruptions. This creates the need for an integrated assessment of wartime risks and their spatial effects.

Analysis of recent research and publications. Regional inequality, wartime business relocation and enterprise support in Ukraine have attracted significant attention in recent literature.

Lavreniuk V. et al. [6] show that regional and local authorities became key actors in forming a new economic map of Ukraine after the invasion. Their support programmes for relocating firms – from simplified procedures to infrastructure and advisory support – helped stabilise host regions, generating jobs and investment despite wartime shocks. Olechnicka A. and Kniazevych A. [8] similarly argue that successful relocation of high-tech companies depends on regulatory clarity, fast local support and cooperation between public and private institutions. At the same time, in Ukraine these factors interact with substantial technical, logistical and psychological constraints, such as disruptions in electricity supply and communications, lack of access to shelters, mobilisation of the population and constant threat of attacks. In a country without active hostilities, in contrast, the main challenges are mostly regulatory and cultural.

Mulska O., Baranyak I. and Demkiv I. [7] document how western regions, particularly the Carpathian region, became the safest territories during the war for firms from different sectors. The significant concentration of businesses in these territories confirms the growing economic role of Zakarpattia, Chernivtsi, Lviv and Ivano-Frankivsk.

Broader regional development patterns are analysed by Huk K. and Zeynalov A. [4], who show that pre-war disparities are rooted in historical trajectories and policy imbalances, alongside factors such as natural resources, demographic structure, production and social infrastructure and the level of urbanisation. Their classification of regions by GRP per capita is a useful baseline for assessing how wartime risks interact with existing inequality.

Kosheliuk O. and Blahovirna N. [5] emphasise the psychological and informational dimension of air raid alerts: frequent alarms, information overload and hybrid operations undermine trust, affect mobility and productivity and may influence relocation decisions. Yakymova L. [12] summarises key reasons for business relocation, such as threats to safety, destruction of production facilities due to hostilities, temporary occupation, proximity to frontline territories and related risks of physical danger, logistics disruptions and loss of access to raw materials and markets. AIN.Business and Suziria Group [2] complement this evidence with survey data on factors considered by firms when choosing a host region, including security, infrastructure, housing costs and local support programmes.

To summarise, the existing literature reveals multiple dimensions of war-induced business relocation, the role of local authorities and support instruments, as well as pre-war regional disparities and the psychological and social consequences of air raid alerts. However, there is still a lack of quantitative studies that integrate the dynamics of air raid alerts, infrastructure attacks and business downtime with actual interregional relocation flows in Ukraine for the period 2024–2025. This article addresses that gap using regional data on business relocations, air raid alerts, mall downtime and infrastructure attacks.

The aim of this article is to quantify how spatial differences in wartime risks – the intensity, duration and temporal structure of air raid alerts and infrastructure attacks – are associated with interregional business relocation flows, shopping mall downtime and conditions for urban economic activity and labour mobility across Ukrainian regions in August 2024–August 2025. This makes it possible to assess how wartime risks reinforce or modify emerging and pre-existing patterns of regional economic inequality and resilience.

Summary of the main research material. The empirical analysis is based on several open data sources at the regional level. Business relocation flows were provided by Opendatabot [9] and aggregated by records of changes in the registered address of companies between August 2024 and August 2025. Data on the number and duration of air raid alerts and explosion records per region were obtained from the official alert system ALERTS.IN.UA [3] and aggregated by month. Information on downtime of shopping and entertainment centres (malls) is based on estimates by the Ukrainian Council of Shopping Centres [10], while data on infrastructure attacks (energy, residential, educational and healthcare facilities) is collected from ACLED records [1]. Using descriptive statistics and cross-regional comparisons, the study calculates indicators of alert dynamics (average daily number and duration of alerts, average duration of a single alert, share of night-time and mall-hours alerts) and relates them to business relocation flows, mall downtime and patterns of infrastructure damage.

Scale and geography of business relocations. According to data provided by Opendatabot [9], 24,836 interregional business relocations were recorded between August 2024 and August 2025. The capital remains the main hub of these movements: Kyiv is simultaneously the leading origin and destination of relocated enterprises.

The most popular relocation routes between August 2024–August 2025 were:

- Kyiv – Kyiv region – 779 companies.
- Kyiv – Dnipropetrovsk region – 597 companies.
- Kyiv region – Kyiv – 583 companies.
- Dnipropetrovsk region – Kyiv – 510 companies.
- Kyiv – Kharkiv region – 490 companies.

The dynamics (Fig. 1) show that many destination regions are precisely those territories where active hostilities are taking place (or took place) or that are temporarily occupied by the Russian Federation: Dnipropetrovsk, Zaporizhzhia, Kyiv, Odesa and Kharkiv regions, as well as the city of Kyiv.

According to own calculations for the selected period (Fig. 1), Kharkiv region became the leader in terms of net inflow of businesses: the number of arriving firms exceeded those leaving by 523. It is followed by Zaporizhzhia (+340), Lviv (+213), Kyiv region (+155) and Zhytomyr region (+106). In contrast, Kyiv recorded the largest net outflow (-975 firms), followed by Donetsk (-167), Dnipropetrovsk (-107), Cherkasy (-81) and Poltava (-76) regions.

Sectorally, in January–August 2025 wholesale trade dominates among relocated companies (31.5%), followed by construction (6%) and real estate and agriculture (5.1% each), according to Opendatabot (2025) [9].

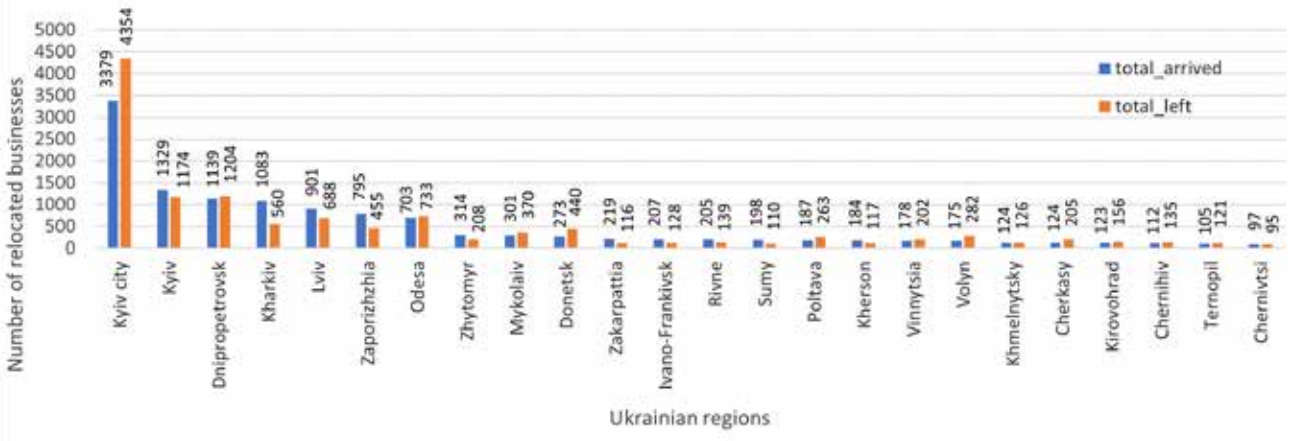

Figure 1 – Total number of businesses that arrived (total_arrived) and left (total_left) in Ukrainian regions (August 2024–August2025)

Source: own calculations based on [9]

These figures show that business relocation is not a simple one-way movement "from East to West". Instead, it reveals a complex trade-off between security risks, market size, infrastructure, and labour resources, creating new patterns of regional economic inequality in wartime conditions. To better understand how security-related disruptions translate into economic losses, the next part focuses on the impact of air raid alerts on urban economies and retail activity.

Air raid alerts directly affect shopping and entertainment centres (malls) and retail trade. Once an alert is announced in the city, malls must stop operations and evacuate visitors and staff immediately to shelters. In addition to the duration of the alert itself, businesses need time to restart operations, which further increases downtime. As a result, effective operating hours fall, reducing turnover and tax revenues and complicating inventory management and planning. Sectoral experts estimate that in high-risk regions operational stops can lead to losses of up to 50% of business activity (D. Sichkar, 2025) [15], although precise national-level estimates are hard to obtain due to strong regional heterogeneity in alert dynamics.

Frequent alerts also influence consumer and investor behaviour. Higher perceived uncertainty discourages households from visiting malls and reduces firms' willingness to invest in high-risk regions. For businesses this means both lower footfall and higher costs of equipping shelters, organising evacuation procedures and supporting staff. A practical illustration is provided by the managing partner of Retail.Pro, Artem Retyn [16]. In discussions with representatives of McDonald's, it was revealed that the suspension of operations in Sumy, Kharkiv and Zaporizhzhia was driven by an economic calculation: the number of alerts is multiplied by the average recovery time after each alert, and if the resulting loss of operating hours exceeds an acceptable threshold, the company temporarily closes its restaurants in that city. Using this logic, the chain continues to operate in Chernihiv and Odesa, where the frequency of alerts is lower.

According to the Ukrainian Council of Shopping Centres (UCSC) [10], since the beginning of the full-scale invasion the accumulated downtime of malls due to air raid alerts has reached the equivalent of 116.1 working days on average across the country; in August 2025 alone it amounted to 1.7 working days. Compared with July 2025, this value decreased; from a peak of 12.7% of working time lost in January 2025, the indicator steadily declined to 8.1% in May and 8.0% in June.

Our calculations (Fig. 2) for August 2024– August 2025 show pronounced spatial asymmetry. The highest average mall downtime is observed in Sumy (57.5%), Donetsk (55.7%) and Kharkiv (27.7%) regions, while western regions (Zakarpattia, Chernivtsi, Ivano-Frankivsk, Lviv, Ternopil and Volyn) record values below 1%. This gap widens regional differences in the possibility to operate without interruptions, with direct implications for local consumption and investment attractiveness.

Public transport operations during air raids are also an important channel through which alerts affect labour mobility and access to workplaces. In many cities trams and trolleybuses continue running (with some exceptions), whereas in Kyiv the metro significantly restricts surface operations during alerts, partly turning stations into shelters. This extends commuting time and shifts demand towards taxis, increasing households' transport expenditures [11]. Financial reports of municipal operators indicate rising losses: the net revenue of Kyivpastrans in 2024 was 32% lower than in 2019, while losses of Kyiv Metro increased from -635.5 million UAH in 2019 to –2.59 billion UAH in the first half of 2025, with similar though smaller negative trends in Kharkiv, Dnipro and Kryvyi Rih [13, 14].

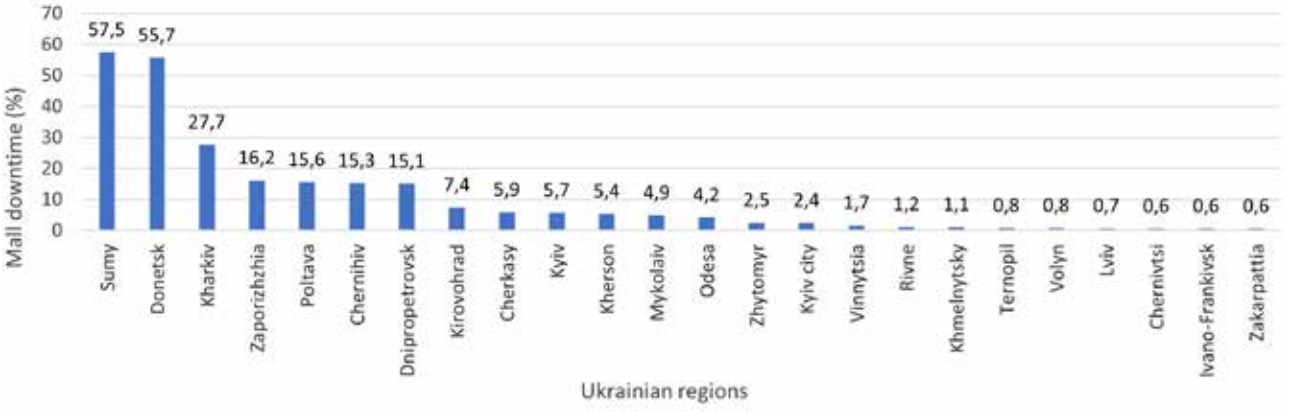

Figure 2 – Average mall downtime in Ukrainian regions (%) (August 2024–August 2025)

Source: own calculations based on [10]

Air raid alerts also shape behavioural patterns at the workplace. Employers must interrupt work and move staff to shelters, and cannot require employees to work under conditions that pose an obvious threat to life. Survey data reported by Suspilne Novyny [17] suggest that approximately 64% of respondents move to a safe place during alerts, while others tend to ignore alarms or wait nearby. Such differences in behaviour and in the enforcement of safety protocols may generate social tensions and reduce productivity by disrupting work schedules and undermining motivation.

Given these behavioural and operational impacts, a closer examination of the alert dynamics themselves provides further insight into regional disparities. First, it is essential to examine the overall number and duration of air alerts (Fig. 3). As expected, the highest values are observed in the eastern regions bordering Russia or located near the frontline. Kharkiv Oblast recorded the most alerts (2116), followed by Zaporizhzhia (1876), Donetsk (1833), Sumy (1731), and Dnipropetrovsk (1520). These regions also experienced the largest cumulative duration of alerts (Fig. 3): Sumy Oblast – over 5750 hours; Donetsk – 5269 hours; Kharkiv – 4098.3 hours.

Meanwhile, the western regions present an opposite trend (Fig. 3), with the lowest frequency and duration of alerts: Zakarpattia Oblast – only 120 alerts (117.6 hours); Lviv – 147 (153.3 hours); Volyn – 148 (177 hours); Ivano-Frankivsk – 149 (166.5 hours).

Although all regions bordering Russia show the highest intensity of alerts, the impact of the Belarusian border proved to be more ambiguous. A notable exception is Chernihiv, which borders both Russia and Belarus and ranks among the leaders: over 1100 alerts with a total duration of 2816 hours.

Next, we analyse the average values for each region (Fig. 4). Based on the average number of alerts per day (the proportion of monthly alerts divided by the number of days in that month), four groups can be distinguished:

• Very high intensity (5) – frontline and border regions: Kharkiv, Zaporizhzhia, Donetsk, Sumy, Dnipropetrovsk.

• High (3–4) – central regions: Poltava, Chernihiv, Kirovohrad, Mykolaiv, Kherson.

• Moderate (1–2) – Kyiv and central regions: Cherkasy, Kyiv, Odesa, Zhytomyr, Vinnytsia, Khmelnytskyi, Rivne.

• Almost absent – western regions: Ternopil, Chernivtsi, Ivano-Frankivsk, Volyn, Lviv, Zakarpattia.

When considering the average duration of alerts per day (the proportion of the total number of hours in a month to the number of days in that month) (Fig. 4), the "heaviest" regions are: Sumy (14.5 h); Donetsk (13.3 h); Kharkiv (10.3 h).

This indicator is crucial for businesses: even if the total number of alerts is not extreme, prolonged downtime creates much stronger economic pressure – reducing working hours and making it difficult to plan operations. Poltava and Chernihiv Oblasts also fall into the high-risk category.

Another key metric is the average duration of a single alert (total monthly alert hours divided by the number of alerts) (Fig. 4). Again, the leading regions are border areas: Sumy (3.6 h); Donetsk (2.9 h); Chernihiv (2.4 h).

This indicates that each individual alert lasts longer, making rapid restoration of business operations after an alert difficult. High values are also estimated in Kyiv (2.5 h), Zhytomyr (2.4 h), Poltava (2.1 h), and Kharkiv (1.9 h).

A particularly interesting indicator is the cumulative share of night-time alerts (alerts occurring between 22:00–06:00 as a proportion of monthly totals) (Fig. 5). A reverse pattern is observed: regions with the highest overall number of alerts have the lowest proportion of night-time alerts, whereas central and western regions have higher shares.

The highest proportions were found in Khmelnytskyi (67%) and Zhytomyr (60%), while

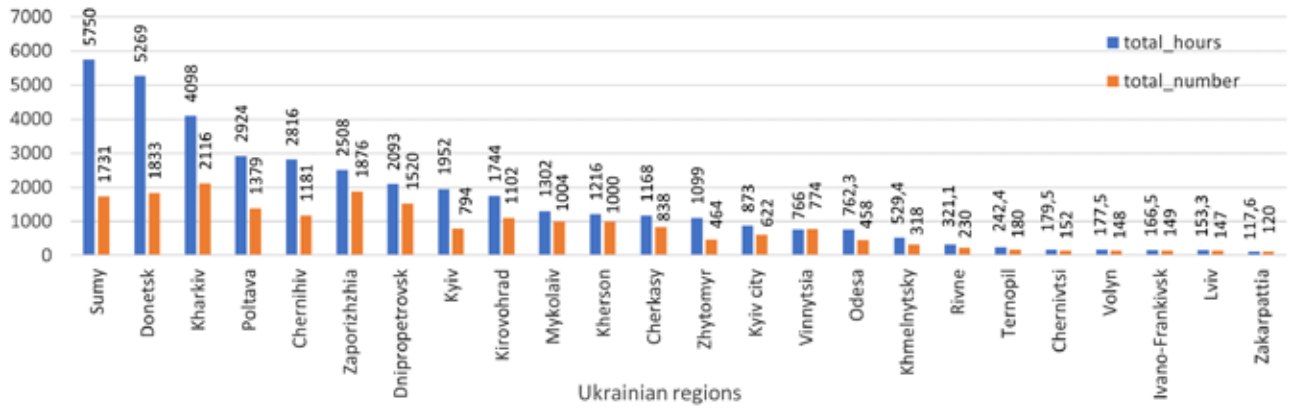

Figure 3 – Total number (total_number) and cumulative duration (total_hours) of air alerts across Ukrainian regions (August 2024–August 2025)

Source: Own calculations based on [3]

regions	avg_hours_pd	avg_number_pd	avg_hours_per_alert
Sumy	14,5	4	3,6
Donetsk	13,3	5	2,9
Kharkiv	10,3	5	1,9
Poltava	7,4	3	2,1
Chernihiv	7,1	3	2,4
Zaporizhzhia	6,3	5	1,3
Dnipropetrovsk	5,3	4	1,4
Kyiv	4,9	2	2,5
Kirovohrad	4,4	3	1,6
Mykolaiv	3,3	3	1,3
Kherson	3,1	3	1,2
Cherkasy	3	2	1,4
Zhytomyr	2,8	1	2,4
Odesa	1,9	2	1
Vinnytsia	1,9	1	1,7
Khmelnytsky	1,3	1	1,7
Rivne	0,8	1	1,4
Ternopil	0,6	0	1,3
Chernivtsi	0,5	0	1,2
Ivano-Frankivsk	0,4	0	1,1
Lviv	0,4	0	1
Volyn	0,4	0	1,2
Zakarpattia	0,3	0	1

Figure 4 – Average daily number of alerts (avg_number_pd), average daily alert duration (avg_hours_pd), and average duration of a single alert (avg_hours_per_alert) across Ukrainian regions (August 2024–August 2025)

Source: own calculations based on [3]

Sumy recorded only 18%, and Kharkiv 22%, Donetsk 23%, Poltava 24%, Dnipropetrovsk 26%, Zaporizhzhia 27%.

This trend is crucial for public safety: night-time alerts pose higher risks, as people are most vulnerable when asleep. Furthermore, sleep disruption impacts next-day productivity, affecting work performance, education, and both physical and mental well-being.

According to another criterion – alerts during standard retail operating hours (10:00–21:00) [10] (Fig. 5) – the highest cumulative share was recorded in Poltava (68%). High values are also present in frontline regions (Kharkiv (65%), Zaporizhzhia (64%), Sumy (64%), Dnipropetrovsk (63%), Chernihiv (61%)) and in Cherkasy (59%).

Another factor directly affecting businesses is the frequency of attacks on cities and their infrastructure. These indicators define security levels, resource stability, and investment attractiveness. The highest proportion of attacks (the share of attacks to total monthly explosions) was recorded in Kherson (85%), followed by Donetsk (47%), Kyiv (42%), and Sumy (36%). Meanwhile, western regions show the lowest rates, making them more suitable for relocation.

Based on own calculations [1], during the observed period almost all regions (except Kirovohrad, Zakarpattia, and Chernivtsi) experienced strikes on energy and residential infrastructure. The most severely affected regions include Zaporizhzhia, Dnipropetrovsk, Cherkasy, Mykolaiv, and Lviv, especially in terms of attacks on energy and educational infrastructure. Chernihiv Oblast recorded the highest number of attacks on residential infrastructure and one of the highest rates of attacks on medical facilities.

Kyiv Oblast suffered mainly from strikes on educational and medical institutions, while the capital city experienced high rates of attacks on residential infrastructure. Kharkiv also recorded high attack levels. This creates an ambiguous situation for businesses: regions that attract relocation are often the same ones most affected by infrastructure damage, producing asymmetric risks that must be considered when making relocation decisions.

Additionally, even the western regions, despite having the lowest number and duration of alerts, show signs of vulnerability: Ternopil, Ivano-Frankivsk, and Lviv Oblasts have also recorded attacks on

region_eng	night_share (%)	mall_share (%)	explosions_share (%)
Cherkasy	30	59	11
Chernihiv	29	61	8
Chernivtsi	49	43	4
Dnipropetrovs	26	63	20
Donetsk	23	58	47
Ivano-Frankiv	47	44	14
Kharkiv	22	65	26
Kherson	36	56	85
Khmelnytsky	67	26	27
Kirovograd	35	57	5
Kyiv	44	47	17
Kyiv city	54	36	42
Lviv	48	44	12
Myloaiv	41	52	10
Odesa	44	48	28
Poltava	24	68	16
Rivne	54	37	7
Sumy	18	64	36
Ternopil	55	37	9
Vinnytsia	58	34	5
Volyn	43	55	18
Zakarpattia	39	52	2
Zaporizhzhia	27	64	11
Zhytomyr	60	31	7

Figure 5 – Cumulative shares (%) of night-time, mall-time, and explosion alerts across Ukrainian regions (August 2024–August 2025)

Source: Own calculations based on [3; 10]

infrastructure, although their overall conditions remain more favourable.

Conclusions. This study shows that wartime risks in Ukraine are spatially heterogeneous and influence regional economic activity through several interconnected channels: business relocation, operational downtime, transport accessibility and infrastructure resilience. The findings reveal four key insights.

First, business relocation flows do not follow a simple "east-to-west" pattern. Some regions with a high level of security threats, in particular Kharkiv, Dnipropetrovsk, Zaporizhzhia, attract more firms than they lose, becoming both relocation hubs and high-risk zones. Kyiv city and Kyiv oblast remain the main nodes of business movements, simultaneously acting as leading origins and destinations of relocated enterprises. This indicates asymmetric risk situations and links to the presence of underlying economic incentives beyond security concerns.

Second, air raid alerts affect regional economies not only through frequency, but also through their temporal structure. Differences in average daily duration, night-time alerts and interruptions during business hours directly influence labour productivity, consumer behaviour and operational planning.

Third, shopping malls and transport systems experience notable regional inequality in wartime disruptions. In certain frontline regions malls lose up to 50% of their operating time, while in western regions downtime is below 1%. This gap directly creates unequal opportunities for local consumption, employment and investment.

Fourth, infrastructure attacks frequently overlap with areas of active business relocation.

This creates asymmetric risks that must be considered when developing regional support instruments, relocation programmes and post-war recovery strategies.

Overall, the results highlight the need for different regional support policies based on empirical indicators of wartime resilience rather than on formal administrative status alone. The integration of real-time data on air raid alerts, infrastructure attacks, mall downtime and business relocations can contribute to monitoring economic vulnerability and updating Ukraine's regional development map during and after the war.

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Стаття надійшла до редакції 24.11.2025