Direct damages to the infrastructure of Mykolaiv as a result of the war

December 2022

The purpose of the project

Ukraine is creating a list of all damaged objects of real estate belonging to citizens, businesses, state and municipal bodies in the affected settlements, which is unique in terms of evidence base and detail. The damaged.in.ua project conducts independent verification of damage from satellite data, which will contribute to improving the quality of data collected by local authorities in these extremely difficult conditions, and also evaluates aggregated data according to a defined methodology.

This data will be used as:

1   Independent top-level assessment - how much money is needed for primary needs and general reconstruction

2   A high-quality evidence base with independent confirmations that allows to start the compensation process faster

3   Intelligent accelerated formation of quality recovery plans

Satellite data limitations

- Despite using the best commercially available images with a resolution of 50 cm/pixel, it is not possible to visually identify all damaged objects
- Some relatively weakly or point-damaged objects, objects with probably incorrectly entered coordinates during inspection, as well as frontal destruction require further examination from drones
- Within different categories of objects, it is possible to independently confirm visually from 30% to 90% of destruction (on average, we've independently identified 43% of damaged structures in the city database)
- Remaining objects are recognized as polygons (a total of 87,209 structures) and can be combined with the city data upon further entry into the RPZM
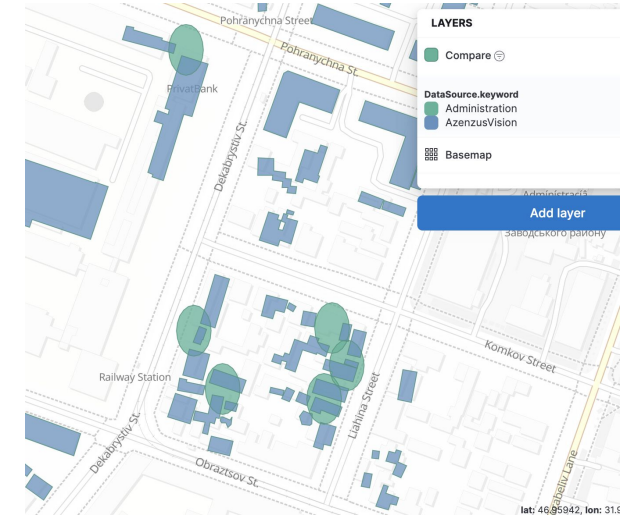
How did we process visual data?

Combining Maxar photos to get an image of the city, removing clouds

(c) Maxar 2022
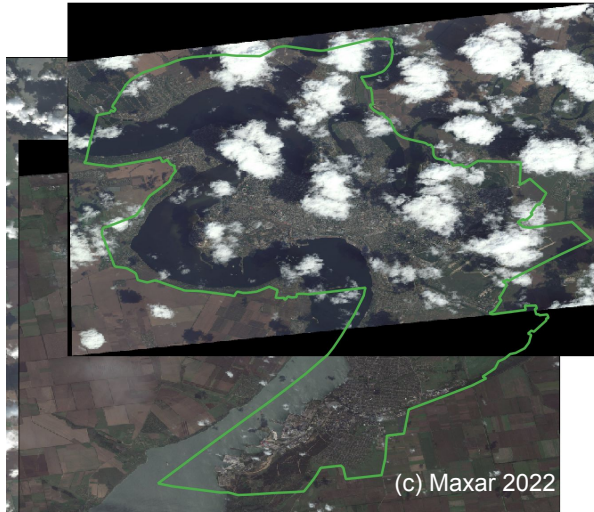
AI analysis identified 92,000 structures
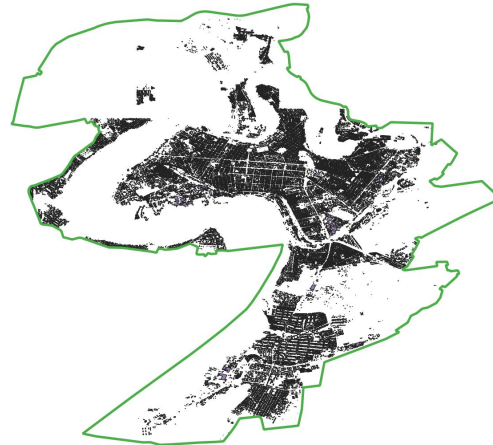
Combining with the data of the city authorities and relevant ministries

MAXAR

The project team got access to use high-quality satellite photos for non-commercial purposes
A number of photos as of the beginning of October were used to obtain the full picture

NEURO MARKET

A Ukrainian company offering AI-based solutions has developed a proprietary object and damage detection model

AZENZUS

A cloud-based SaaS solution for visual inspections to facilitate and speed up facility and equipment maintenance. The platform has a built-in interface for AI/Computer Vision from other developers

The process of visual data analysis

1. **Initial damage classification with AI**

2. **Initial review by humans / annotators**

3. **Control comparative analysis**

   a. Comparison with damage found by AI

   b. Comparison with data received from the city authorities

   c. Comparison with information from media / public sources

   d. Comparison with photos on Google Maps (pre-war photos, 2020)

4. **Elaboration of the type of buildings definition**

   a. Specifying the building type on Google Maps / Bing / OSM

   b. Specifying the building floors on Google Street View / OSM

5. **Final control and publication of data**

After the identification of the objects, the degree of damage is analyzed:
- 1247 damaged objects manually identified
- 486 objects via AI

Integration with city data (2,088 objects with GPS coordinates, another 919 without them) and other sources:
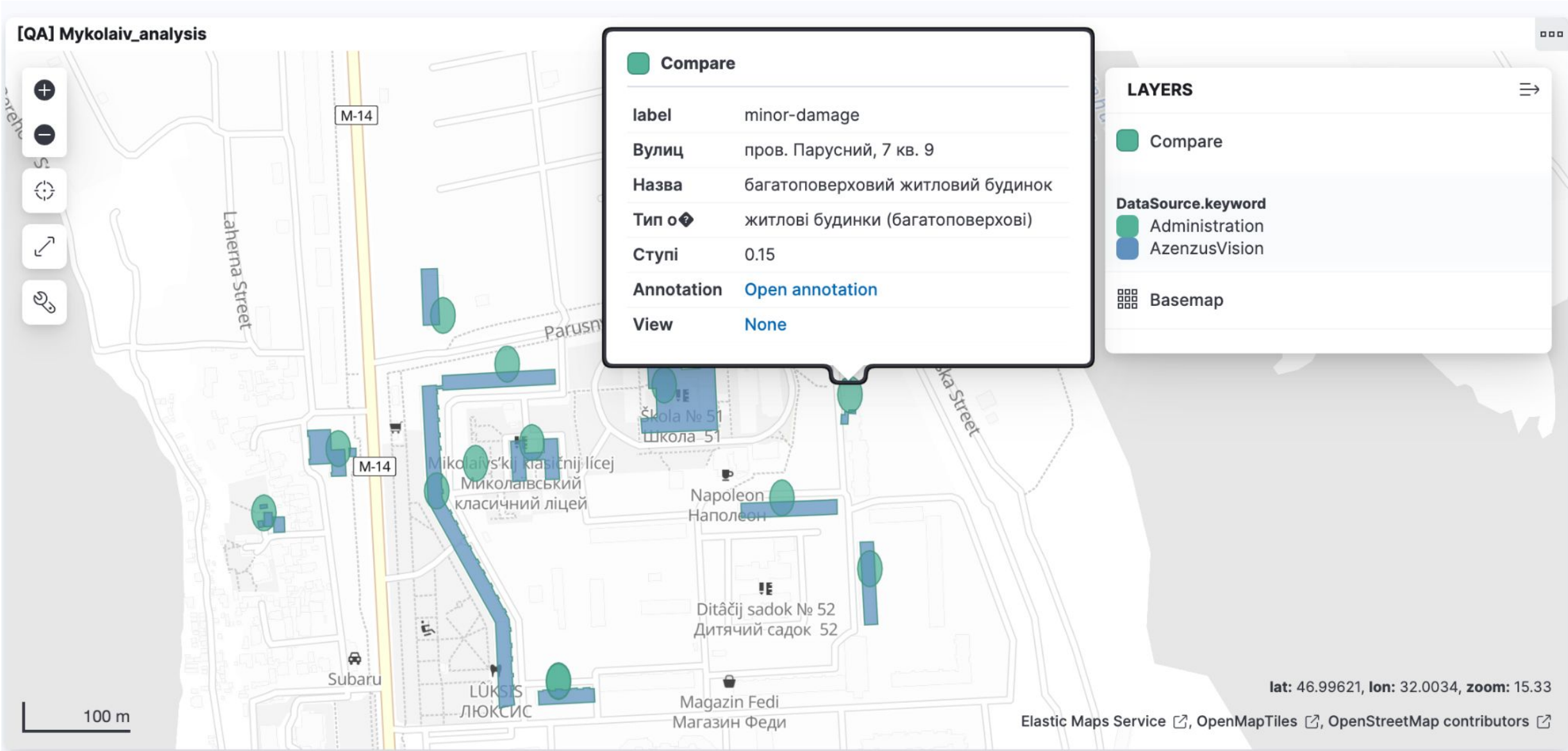- independent confirmation of major destruction
- searching for errors in the data
- search for non-obvious cases

Key characteristics of buildings are taken from public mapping services

If necessary, large/important objects were checked manually

Control comparative analysis

Specifying the type of buildings

(c) Maxar 2022

Final control and publication of data

The final GIS data, which will be transferred to the municipal GIS system in the form of geo-Json

Total damage evaluation to Mykolaiv's infrastructure

Assessment made by damaged.in.ua:

€852m

Including damages that can be independently verified using satellite images:

€220m

The rest are damages mainly to housing, utilities and businesses, which require further verification

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General principles of methodology

The project focuses on the assessment of **damages (according to the World Bank methodology): losses of physical infrastructure** of Ukraine due to the war (destruction of residential buildings, utilities, roads, railways, educational and medical institutions, etc.); and estimation of the **financial value of these losses.**

The methodology includes the following approaches to calculations:

1. **Large facilities** (airports, large industrial plants, ships, aircraft, etc.) are assessed individually using financial statements or other available data. The value of fixed assets as of the beginning of 2021 is taken for the identified **enterprises**. Depreciation and incomplete investments and inventories are not included.
2. **Medium-sized facilities** that can be counted (schools, hospitals, shops, cultural facilities, etc.) are valued at the average unit cost (estimated from financial statements, Prozorro tenders, etc.).
3. **Mass facilities** (real estate, vehicles, small business assets) and networks (road and rail, electricity and gas distribution, telecommunications) are estimated by indirect methods, combination of relevant regional statistics and the share of losses for individual oblasts or cities.
4. For **facilities about which public information on damage is insufficient** (infrastructure, bridges, railway stations, schools), the data of relevant authorities (Ministry of Infrastructure, Ministry of Education and Science, etc.) are taken into account; at the same time an alternative assessment of losses by indirect methods is conducted. Different damage factors are used for such facilities.
   - For residential buildings: (a) if the damage is less than 40%, a factor of 0 to 40 is used, (b) if the damage is more than 40%, the building is considered completely destroyed and the restoration value is determined by the value of the analogue object, what corresponds to the methodology of the WB;
   - Additional destruction factors may be used for other objects.
5. The value of lost assets is calculated at the cost of recovery, not at market value. For example, if a small old house built in a village in the 1970s is demolished, its market value may be zero, but it could be a shelter for a family of four. Therefore, to restore such a facility it will be needed to spend money on the reconstruction of this house, taking into account current prices for materials. If utilities are damaged, even at their lowest market value, the cost of rebuilding such networks (excluding the "Build Back Better" principle) will mean the need to spend on materials at current prices.
6. In the absence of information, at this stage, **the assessment includes only losses from destruction/ ruining of buildings, not taking into account the cost of equipment** (including hospitals, research institutions, damaged vehicles, etc.). These estimates will be gradually added in the next stages of valuations.
7. **Approach to valuation**:
   - **For housing**: renewable, as of the end of 2021.
   - **For industrial assets**: inflation-adjusted initial cost, in prices at the end of 2021.
   - Prices as of December 2021 are used to estimate losses, which does not take into account existing and further expected price increases; reduced availability of materials due to the destruction of industrial facilities and supply chains; increase in labor costs during reconstruction, etc.

Housing

Russia caused the greatest war damage to the Mykolaiv city by destroying the apartment and individual residential houses.

Based on all available data, we estimated the total amount of damages due to destruction to private and apartment buildings at over €386m. At the same time, the effective area of the damaged residential buildings reached 358.5 thousand m2.

Of these, satellite images show severely damaged objects valued at over €111m.* The total area of damaged and destroyed residential buildings exceeds 148 thousand m2. Satellite images recorded substantial damage to 60 apartment buildings and 617 private houses.

The rest of the damage is frontal damage to the facades, or individual debris that requires a drone survey.

*In addition, more than 600 barns, garages and summer houses were destroyed with damage estimated at around €1.3m

Housing evaluation methodology (1)

To make estimates, we determine the replacement cost of housing at the last date before the war - ie the cost of construction of 1 square meter of destroyed housing, taking into account the dismantling of destroyed structures, the cost of construction of 1 square meter of housing, and the coefficient of repair to the stage of readiness.

Data sources:
- International organizations and companies (satellite images of affected settlements),
- Ukrainian ministries and state agencies,
- Ministry of Regional Development (construction cost),
- State Statistics Service (housing stock by regions, population by settlements),
- Commercial construction companies and specialized trading platforms (cost of repairs, cost of dismantling),
- Commercial companies specialized in satellite and aerial photography (pictures of affected settlements),
- Local governments (level of damage in settlements),
- Other public sources (media, public organizations, locals, other witnesses - damage level in settlements).
- Assessment

$$Damage = Damage_{housing} + Damage_{util} + Damage_{landscape}, \text{ where}$$

$Damage_{housing}$ is the damage to residential real estate

$Damage_{util}$ is the damage to utilities (water supply and drainage, heat supply, waste management)

$Damage_{landscape}$ is the damage to landscaping (recreational and funeral services)

$$Damage_{housing} = Area_{housing} * (Cost_{cons} + Cost_{repair} + Cost_{dism}), \text{ where}$$

$Area_{housing}$ is the area of destroyed housing

$Cost_{cons}$ is the specific cost of construction (restoration) of destroyed residential buildings

$Cost_{repair}$ is the specific cost of cosmetic repairs in newly built homes

$Cost_{dism}$ is the specific cost of dismantling the remains of destroyed houses

Housing evaluation methodology (2)

Cost

The price of renovation of residential buildings (Cost $_{cons}$) is the average cost of construction of 1 sq m of housing in the region, according to the Ministry of Regional Development in January 2022.

The cost of repairs in the destroyed residential areas (Cost) is calculated as:

$$\text{Cost}_{repair} = \text{Cost}_{cons} * \% \text{ of the cost of repair}$$

% of the cost of repair Is an expert assessment of the cost of repair from the cost of 1 sq.m. housing

The cost of dismantling the destroyed residential buildings (Cost $_{demol}$) is calculated as

$$\text{Cost}_{dism} = \text{Area}_{housing} * \% \text{ Remaining building} * \text{Price}_{dism}$$

The price of dismantling is determined on the basis of data from the aggregator platform, which shows the average cost of dismantling 1 square meter of buildings based on the analysis of ads of 885 performers (data on 22 Mar 2022) - https://omastere.com.ua/price/demontazh_zdanij/

Social sphere

As a result of the war and enemy shelling, objects of the social infrastructure of the Mykolaiv city also suffered.

According to the data of satellite images, it is possible to identify the destruction at least:

2 social institutions

- Institution for the elderly
- Social center

€143 ths.

the amount of damages caused due to damage to identified objects

According to the city authorities, a total of 4 objects were damaged, and the damage to the social sphere can be estimated at €1.4m:

- Mykolaiv geriatric boarding house
- City geriatric house of mercy named after St. Nicholas
- Communal Institution "Mykolaiv Center for Social and Psychological Rehabilitation of Children"
- City complex rehabilitation center for children with disabilities

Education

Based on all available data sources, damage was caused to 98 educational facilities, which damaged.in.ua estimated at €45.3m Among them:

- Mykolaiv Lyceum No. 60
- Mykolaiv Vocational Lyceum of Construction and Services
- Mykolaiv secondary school of grades I-III No. 48
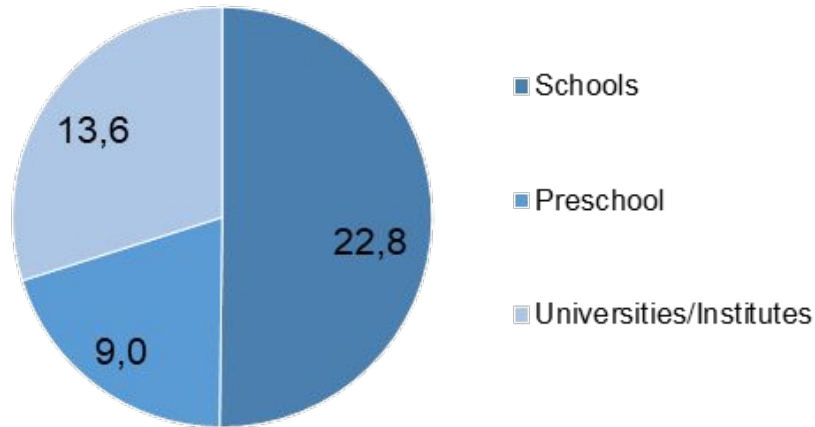
Some of the above-mentioned facilities worth €26m can be identified from visual sources (the rest are not visible or have frontal hits):

- Damaged — 18 objects
- Destroyed — 2 objects

Pie chart:
- 13,6
- 22,8
- 9,0
- Schools
- Preschool
- Universities/Institutes

Education evaluation methodology

Sources of information:

- the number of destroyed state educational institutions provided by the Ministry of Education and Science (MES) by categories (see the section "Categories" below) with the division into destroyed and damaged institutions;
- micro-data from open sources on the destruction caused by private educational institutions.

Frequency of data update:

MES data is updated weekly, and microdata is processed as it comes from open sources.

Categories:

The following categories are distinguished for state educational institutions (classification of the ministry):

- Preschool institutions (kindergartens);
- Secondary education institutions (schools);
- Out-of-school education institutions;
- Institutions of vocational education (vocational schools and technical schools);
- Institutions of professional higher education (schools);
- Institutions of higher education (institutes, universities, academies);
- Special education institutions.

Calculation methods

The amount of losses is calculated as the product of the number of objects at the average cost. The average value of an object for each category is defined as the arithmetic mean of the value of similar procurements for the construction of such objects, obtained from open sources, in particular Prozorro.

Key assumptions on which we base our calculations

We assume that the cost of a partially damaged educational institution is equivalent to 20% of the cost of building such an institution from scratch.

Calculation formula

$$Damages_{tot} = \sum_{i=1}^{8} quantity\ of\ demolished\ * \ cost_i + 0,2 \ \times \sum_{i=1}^{8} quantity\ of\ damaged\ * cost_i$$

Healthcare

Based on the satellite images, it was possible to identify **3 destroyed medical facilities**, with the respective damages estimated at **€196.3 ths.**

According to the calculations of damaged.in.ua experts, based on data from the Ministry of Health, Mykolaiv's losses from the destruction of medical facilities amount to €26.3m. According to the ministry, **there are 50 such facilities**, among them:

- 24 hospitals
- 23 facilities, which include medical offices, laboratories, medical warehouses, dormitories, forensic medical expertise offices
- 3 polyclinics

Damages to healthcare units, €m

5,6

35,3

- Policlinics
- Hospitals
- Other
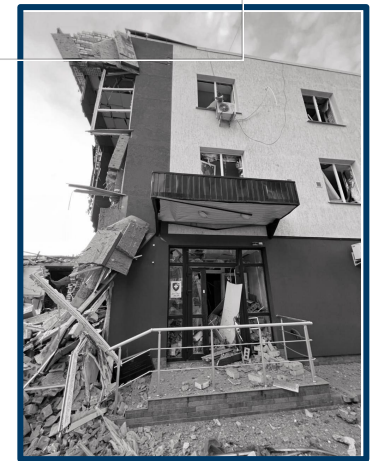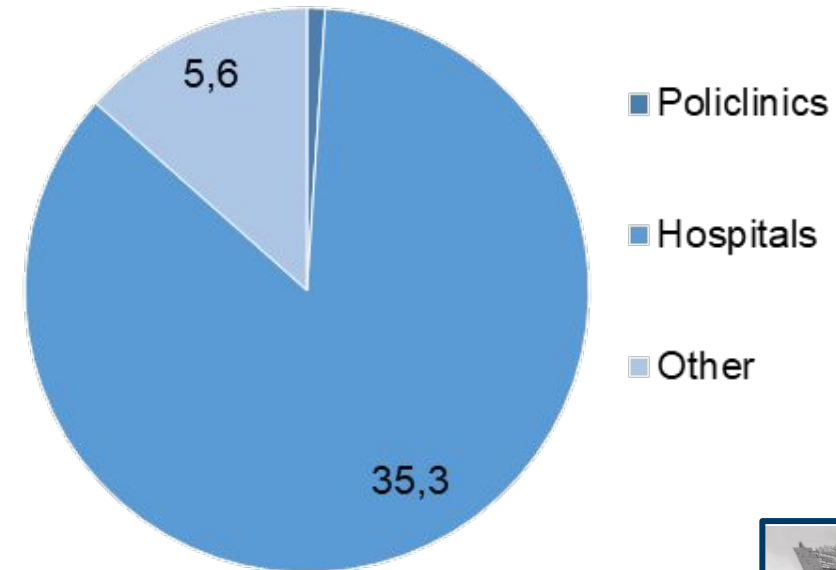
Healthcare evaluation methodology

Sources of information:

- database of damaged objects, maintained by the Ministry of healthcare of Ukraine
- data on average cost of square meter and average cost of one bed (including construction and equipment)
- microdata on damages

The estimation is updated weekly upon provision of the MOH database of damages by the following methodology:

1. For objects for which there is information on the area, damages from complete destruction are determined by the formula:

$$Damage_{heathcare} = Area_{healthcare\ facility} * Price\ m2, where$$

$Area_{healthcare\ facility}$ - area of healthcare facility according to the object's passport,

Price per square meter - average price per m2 area according to letter No. 7/15.1/3301-22 of April 12, 2022

2. For facilities for which there is information on the number of beds, damages from complete destruction are determined by the formula:

$$Damage_{heathcare} = Number\ of\ beds_{healthcare\ facility} * Price\ of\ a\ bed, where$$

The number of beds - the number of beds in the hospital according to the object's passport,

The price of a bed - the average cost of a bed according to letter No. 7/15.1/3301-22 of April 12, 2022

Damages from destruction caused to private medical institutions are calculated separately.

1. The average object value is calculated for each category based on the estimated value of separate objects based on their area or number of beds. This average value is extrapolated for other objects in the category, where area/number of beds is unavailable, and adjusted for the degree of damages (total / significant, but operating / data not available (e.g. occupied territories) / minor).
2. Where extrapolation is not possible (small population, specific objects), the microdata on public procurement or financial reporting of respective entities is used to obtain cost-based or asset-based estimate.

Culture, tourism, sports

Mykolaiv City Palace of Culture "Korabelny"

The satellite images show the damage to **10 cultural objects** in Mykolaiv, of which:

- 6 objects of cultural importance
- 4 are related to sports.

The amount of damage to these objects is **€1.4m.**

In total, **there are 55 such damaged or destroyed objects** (not all are visible on satellite imagery), which increases the amount of damages, respectively, to **€10.9m**

"Mykolaiv" football club stadium

Administrative buildings

Satellite images allow to see almost all destroyed and damaged administrative buildings, their **area is 9.7 thousand m2**. **Damages** from these visually identified destructions are estimated at **€10.6m.**

At the same time, based on all available data sources, the total area of d of administrative buildings reaches **10.8 thousand m2**, and thus the **damages amount to €11.9m.**

Utilities: water and heat supply

Since April 12, the second most populous regional center of southern Ukraine has been living without a centralized supply of drinking water due to a water pipeline, that stretches for more than 70 km from the Dnipro river, being cut off by the Russians. Pyrotechnicians are working on demining the area, and the quality of water for the residents of Mykolaiv remains technical.
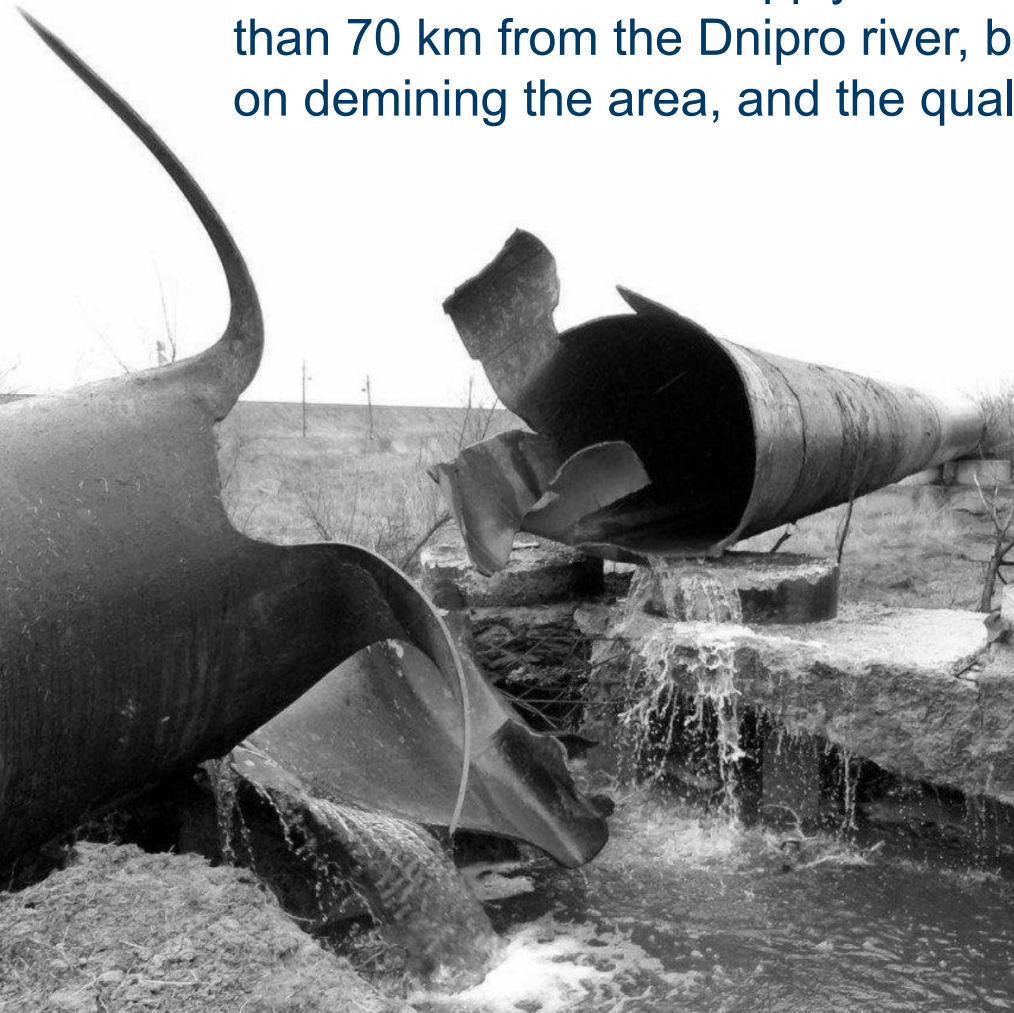
The estimate of damages* from destruction to water supply systems according to the damaged.in.ua project is €41m.

The city's heating networks were also damaged during the war.
Thus, according to city data, at least 26 boiler houses and 5 central heating stations were damaged or destroyed, the damage from these destructions equals €13.9m.

*The assessment was carried out by KSE using indirect methods based on open data sources

Business and infrastructure

During the 10 months of hostilities, the city's industrial facilities were also significantly damaged. Among the identified damaged enterprises:
- SE NVKG "Zorya"-"Mashproekt"
- LLC "Mykolaiv shipbuilding plant"
- LLC "MKHP"
- NICOTEX LLC

According to the damaged.in.ua project estimates, **damages** from shelling of businesses amounted to €299m. In addition, the port infrastructure of Mykolaiv suffered significant destructions (to be assessed separately).

The area of destroyed and damaged industrial and agricultural buildings visible from the satellite is **72.8 thousand m2**. **Damages** from these destructions are estimated at €68.8m, excluding the cost of equipment.

In addition, based on city data, two bridges/overpasses were damaged - we estimate these infrastructural objects to be worth over **€0.6m**.

Business and utilities evaluation methodology

Direct method of estimation (for estimation of losses on the enterprises on which there is information):

1. The calculation is performed on microdata (data for individual enterprises);
2. Data collection is carried out using:
   - collection of data on damage / destruction of certain business objects from open sources;
   - use of data submitted by enterprises on the website of the project "Russia will pay" damaged.in.ua
3. In the absence of accurate information on the degree of destruction of the object, it is assumed that the object is destroyed by 100%;
4. The latest publicly available financial statements of companies that have suffered damage are used to evaluate the data;
5. To calculate the cost of losses used so-called "Replacement cost", i.e. the cost of repairing damaged assets, taking into account the need to purchase equipment, repair damaged property under current conditions. For this purpose:
   - the calculations use the initial value of the assets of the company / individual asset (ie, excluding depreciation of assets);
   - the cost of inventories is taken into account in the calculations; unfinished construction / investment;
   - in case of appearance of the company's assets on the balance sheet for a long period of time ago (period 7+ years) value adjustment is used taking into account the dynamics of price growth; Prices are taken to prices at the end of 2021.

Indirect evaluation method:

1. The calculation is based on microdata aggregated at the level of settlements.
2. Aggregation is calculated only for small enterprises (in the sense of the Commercial Code, in particular, the annual revenue should not exceed the equivalent of 10 million euros).
3. The same rows of financial statements are used as in the case of individual calculations of enterprise losses (see previous section).
4. To the sum of the value of assets calculated as described above, the coefficient of destruction in the settlement is applied (in the sense and calculated in the same way as described in the section on the assessment of residential real estate damage).
5. In the case of information about a particular small enterprise, it is further removed from the aggregation.

Utilities evaluation method:

In case of Mykolaiv, damages to water supply were evaluated as 100% of assets of the "Mykolaivvodokanal"
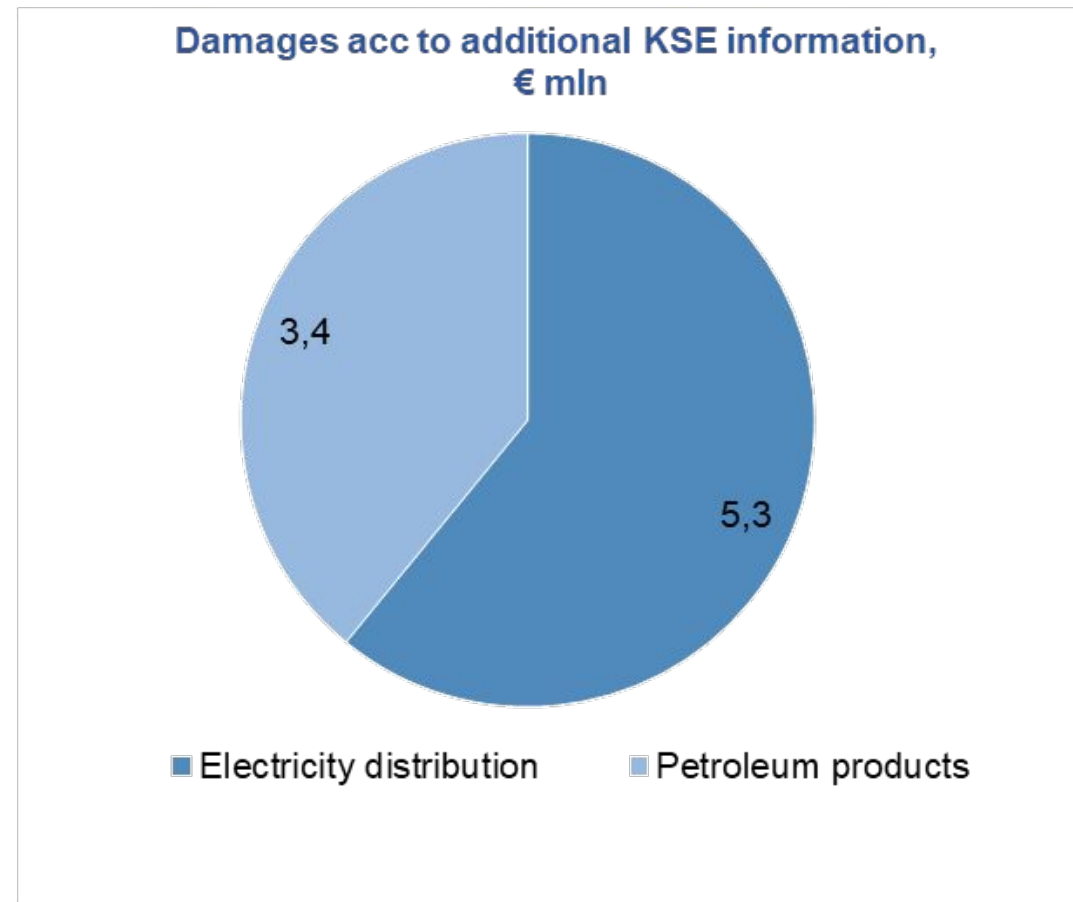
Energy infrastructure of Mykolaiv

The total estimate* of damage to the energy infrastructure in Mykolaiv — €8.7m

Damaged was dealt to:

- electricity distribution (power lines, substations) — €5.3m,
- petroleum products (petrol depot and gas stations) — €3.4m

The further damage assessment may increase depending on the discovered damage to the gas distribution network and other energy infrastructure facilities.

The assessment was carried out by KSE using indirect methods based on open data sources

Damages acc to additional KSE information, € mln

3,4

5,3

■ Electricity distribution   ■ Petroleum products

Energy infrastructure evaluation methodology

General approaches:

Sector is dominated by two types of companies: companies with few large localized assets (like power generation) and companies with distributed assets base and no single core asset (power transmission and distribution). Damages to the first group of companies are estimated on a per-object basis. Damages to the second group of the companies are estimated using the percentage of damaged assets approach estimated on the base of some statistical measures that have area effect such as population density.

Electricity transmission and distribution

The same power line can be damaged and repaired several times over a short period of time. Thus for the power lines where damages are known, evaluated and repaired we use the actual repair costs. For uncontrolled territories and territories where there was no by-item damage assessment we estimate the level of damages by city using a rough estimate of area of damages (share of the city infrastructure that was destroyed as estimated by military experts). We estimate the amount of electricity distribution assets in the city as a share of total number of power lines and transformer stations (split by the voltage level and power line type) owned by the electricity distribution company (operating in the region) and downscale it proportionally to the share of city population in the administrative region total population. We then estimate damages to each type of power lines and transformers and use aggregated figures on average cost of 1 km of lines and 1MVA of capacity of transformers to estimate the total costs of damaged assets and repairs.

Oil&Gas sector:

Petroleum products storage tanks

Russian attacks focused on destroying petroleum products storage tanks to complicate fuel logistics and reduce fuel supply. Newly reconstructed modern tank farms which cost $10-15m according to the market players and smaller, older, regular tank farms with estimated costs of $3-5m per tank farm. Along with the damages to the equipment of tank farms we estimated losses of the fuel products that were stored there when they were attacked.

Damages to fueling stations

The market of fueling stations is very diverse with more than 7000 fueling stations owned by hundreds of players which makes collecting information from market players complicated. To assess damages to fuel retail we visually estimated the share of administrative regions that were under occupation or where active military operation was taking place. We then estimated the number of damaged and destroyed fueling stations by multiplying the total number of fueling stations in the region by the share of the region where military hostilities were taking place. We then split the damaged fueling stations according to the level of damages (light, severe, destroyed) and estimated the average cost per fueling station depending on the type of the station (high-end, mid-end or low end).

About the project

The project "Russia will pay" (damaged.in.ua) is implemented by the KSE Institute together with partner organizations in cooperation with state authorities.

The project focuses on the analysis of direct damage and financial losses caused by the war.
In particular, we work on:

- analysis and evaluation of damages, indirect losses of the economy and assessment of Ukraine's needs for recovery,
- digitization of high-precision images from drones and satellites to assess damage to settlements as a result of the war
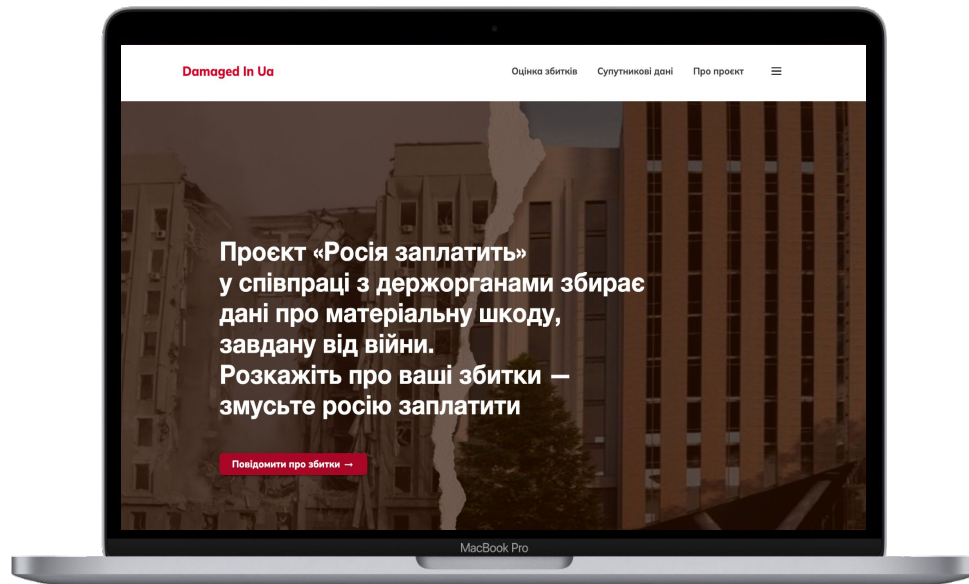
The project is being implemented since February 2022 by the KSE Institute (an analytical center at the Kyiv School of Economics) with the support of the Office of the President of Ukraine, the Ministry of Economy, the Ministry of Reintegration of Temporarily Occupied Territories, the Ministry of Infrastructure, and the Ministry of Community and Territorial Development.

Direct damages to the infrastructure of Mykolaiv as a result of the war

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