

характерних для військового середовища. Вивчення зміни ідентичності ветеранів є особливо важливим для розуміння соціальної реінтеграції, адже після завершення участі в бойових діях вони вже не є тими, ким були до входження у військове середовище, оскільки набувають нової ідентичності, сформованої через спільно пережитий досвід, наприклад участь у бойових діях.

Підсумовуючи, соціальна реінтеграція ветеранів є системним процесом, вивчення якого включає послідовний аналіз досвіду ветеранів з соціальної інтеграції, дезінтеграції, а також власне соціальної реінтеграції. Такий підхід дозволяє оцінити процес соціальної реінтеграції як системний та послідовний, вивчення якого неможливе без оцінки попереднього досвіду ветеранів до початку інтеграції у військове середовище, інтеграції у військове середовище, дезінтеграції з військового середовища, а також реінтеграції у цивільні середовища, з яких ветеран був дезінтегрований через початок служби у війську. На кожному з цих етапів важливо також розуміти досвід переходів між середовищами, процес асиміляції до військової та цивільної культури, трансформацію ідентичності ветерана, а також зміну його статусу, позицій та ролей у наслідок переходів. Отже, системність та рівневість процесу соціальної реінтеграції вказує на те, що даний процес є реляційним процесом, а отже вивчення соціальної реінтеграції ветеранів та її успішності не відбувається відокремлено від індивідуальних дій, взаємодії з близьким оточенням, взаємодії з вторинними групами, функціонування ветеранів у просторі а також взаємодії з інститутами та системами.

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AGENT-BASED SIMULATING OF UKRAINIAN UNIVERSITIES ADAPTATION TO A FULL-SCALE RUSSIAN INVASION АГЕНТНА СИМУЛЯЦІЯ АДАПТАЦІЇ УКРАЇНСЬКИХ УНІВЕРСИТЕТІВ ДО ПОВНОМАШТАБНОГО ВТОРГНЕННЯ

Background: Russia’s full-scale invasion of Ukraine has severely disrupted the country’s higher education system, damaging infrastructure, displacing staff and students, and forcing institutions to rapidly adapt. Despite these challenges, Ukrainian universities have demonstrated resilience by relocating, switching to online education, and modifying academic procedures.

Purpose: To explore how Ukrainian universities, students, and faculty adapt to war-induced disruptions using an agent-based model that captures individual behaviors, institutional strategies, and systemic patterns under crisis conditions.

Methods: The study employed agent-based modeling (ABM) to simulate the behavior of students, teachers, and universities in a wartime context. The model was calibrated using official statistics and empirical studies from 2022–2024. Scenario analysis was used to assess the effects of ongoing war and policy changes, such as the removal of military deferment for students.

Results: The model reproduced major empirical trends, including drops in enrollment and staff numbers and patterns of stress-related dropout. Scenario analysis revealed that the war accounted for a 10% reduction in student numbers, while eliminating military deferment would cause an additional 6% decline. University performance declined under war intensity and recovered more slowly when relocation or online transitions occurred.

Conclusion: The results demonstrate that agent-based modeling is a valuable tool for analyzing crisis adaptation in higher education. Both external shocks (e.g., war) and internal policy changes (e.g., deferment rules) significantly affect system stability. Universities' survival depends on flexible adaptation strategies informed by simulation-based insights.

Keywords: agent-based modeling, Ukraine, war, organizational adaptation, simulation, higher education.

Russia's full-scale invasion of Ukraine has severely disrupted the country's higher education system. By early 2023, 167 institutions had been damaged and 24 destroyed (Zayachuk, 2024). Students and staff faced large-scale displacement: 20% of academic personnel at Zaporizhzhia Polytechnic were internally displaced or emigrated, while 5% of students suspended studies due to occupation and insecurity (Greshta et al., 2023). Despite this, Ukrainian universities, students, and faculty have shown remarkable resilience.

The war has created unstable conditions requiring constant adaptation to shifting dangers and policies. To simulate these dynamics among diverse actors in a system that never stabilizes, we use agent-based modeling (ABM). ABM captures complexity and continuous change, making it suitable for testing government policies—such as relocations or online education mandates—before implementation.

ABM, a generative social science method, models macro-level outcomes emerging from individual interactions (Epstein & Axtell, 1996). Agents are autonomous, governed by simple decision rules, and operate within environments shaped by local or network-based interactions (Epstein, 2008). ABMs emphasize dynamics over static outcomes, helping to reveal patterns traditional methods may miss.

They are especially valuable in understanding complex social processes, generating hypotheses, bounding outcomes, and testing policy in contexts with limited data or experimental access. However, ABMs face challenges: balancing simplicity and realism, validating with empirical data, modeling decision uncertainty, and scaling computationally (Collins et al., 2024; Lee et al., 2015; Gilbert et al., 2018).

The scientific problem this research addresses is how to model and understand the dynamic, interdependent behaviors of higher education institutions, students, and staff under conditions of armed conflict and policy uncertainty. The purpose of this research is to simulate and analyze how Ukrainian universities, students, and academic staff adapt to wartime disruptions and policy changes using an agent-based model calibrated with real-world data. Using real data to calibrate the model, we aim to explore future trends and test potential scenarios.

Model Description

Our model simulates Ukraine's higher education system following the full-scale Russian invasion of February 24, 2022, using NetLogo 6.4.0. It incorporates real parameters: 314 universities, an average of 3,090 students per university, and a student-to-teacher ratio of 7.23.

Agents include students, teachers, and universities. Students have demographic, academic, and psychological attributes. They apply to universities, may drop out under stress (with special thresholds for military-age males), study abroad, return as stress decreases, and graduate. Teachers have

professional and psychological traits; they seek employment, may resign under stress, face layoffs during downsizing, and experience skill decay. Universities vary by location, quality, capacity, infrastructure damage, and operational mode. They assess local risk, manage faculty stress, relocate under threat, merge when damaged, switch to online teaching, expel students, fire staff, or shut down.

The environment represents Ukraine with a shifting frontline, city network (20–24 cities, minimum spacing), and regional war intensity tied to frontline distance. Big cities are marked red, home cities cyan. Universities are pentagons sized by student count: blue (normal), red (damaged), violet (merged), turquoise (relocated). Students are green (idle), yellow (abroad), or hidden (enrolled); expelled or dropped-out students appear near former institutions. Teachers are orange (unemployed) or hidden (employed).

The simulation starts in September 2022, progressing one day per tick. War intensity fluctuates with a sine wave. The academic calendar includes September/February admissions, June/December graduations, expulsions after exams (February/June), and quarterly dropout checks. Academic progress updates monthly (Bachelor's: 4 years; Master's: 2; PhD: 4). The model is calibrated with empirical data from 2022–2024.

Adaptation Strategies

All agents operate under environmental impact where war intensity, proximity to the frontline, and damage to their university facilities significantly impact stress levels and overall functioning. Some environmental events like air raids trigger immediate adaptation reactions such as forced online transitions and stress spikes. Other environmental demands like bureaucratic and regulatory changes generate secondary adaptation via higher stress levels. Students adapt to war conditions through **mobility decisions** (going abroad or returning) based on stress thresholds and safety considerations. Military-age males exhibit extra university persistence due to **conscription avoidance motivation**. Students' academic performance deteriorates when stress exceeds certain thresholds, with recovery occurring at variable rates depending on environmental conditions. Teachers respond to high stress by potentially **quitting their positions**. Their teaching effectiveness diminishes under sustained stress, with skill deterioration occurring when stress exceeds 60%.

Universities adapt to safety threats through **relocation** and **switching to online** education mode. When facing physical damage, they implement **rebuilding** efforts or **relocation** strategies. Enrollment challenges trigger **faculty layoffs**, institutional **closures**, or **mergers** with other universities. Poor student performance leads to **expulsion** policies, while faculty overcapacity results in **faculty layoffs**.

Calibration with Real-World Data

Our model's parameters were calibrated using Ukrainian higher education studies during the full-scale Russian invasion and statistical information provided by the State Statistics Bureau.

On the university level, calibrated parameters include the student-teacher ratio of 7.23 (SSSU, 2024) and program distribution of 71% bachelor's, 25% master's, and 4% doctoral programs (Eurydice, 2023). The monthly infrastructure recovery rate after a missile attack or war-induced damage was set to 33% (Porkuian et al., 2023). Transition to an online mode of study is triggering at 40% of the local risk with a quality impact of -15%. University relocation has a 20% impact on quality (Zayachuk, 2024; Galynska & Bilous, 2022).

On the level of student and teacher agents, we calibrated stress impacts of 0.4 for students and 0.65 for teachers, with performance declining at 10% and 5% per stress point above 60, respectively (Tsybuliak et al., 2024b; Polyvianaia et al., 2025a). The student dropout threshold was set at 52% based on PHQ-9 scores, while the return-to-study threshold was calibrated at 35%, and the recovery rate at 7.5% monthly (Polyvianaia et al., 2025b; Kurapov et al., 2024). For teachers, the dropout threshold was 60%, with slower recovery at 15% per six months (Tsybuliak et al., 2024a).

Model Validation via Reproducing Real-world Patterns

Due to limited empirical research on the mechanisms linking war, stress, and education, our model validation relies primarily on visualization. This allows us to detect patterns and unexpected behaviors when data is scarce. We ran the model 30 times under medium parameter settings (314 universities, air-raid intensity 3 or 5, regulation intensity 3 of 5), simulating three years (1080 ticks). Results were compared to empirical data (Fig. 1).



Figure 1: War-induced Changes in Ukrainian Higher Education Institutions and Stress Level: Research Data versus Model Output

The model demonstrates **moderate validity**, capturing key trends such as declining university numbers, shifts in enrollment, and reduced academic staff by 2024. It closely replicates student stress distribution patterns across all categories (0–33%, 34–52%, 53–73%, 74–100%).

However, discrepancies remain. The model overestimates the pace and severity of decline, indicating a need to adjust resilience parameters. It misses the temporary rise in 2023 teaching staff and Master's enrollment, suggesting gaps in adaptation mechanisms. It also underestimates high teacher stress (19.8% in the model vs. 40.3% in data), pointing to calibration needs.

Given data constraints and the model's exploratory aim—understanding adaptation in wartime higher education—these results are promising.

To explore the effects of war and conscription policies, we ran three scenarios:

1. **Baseline** (2022–2024): Simulates actual wartime conditions.
2. **No War**: War intensity and air raids set to zero to simulate sudden peace.
3. **No Deferment**: War continues, but student deferments are removed to isolate military service effects.

Each scenario was run 30 times over two years (except Baseline: three years). Results diverged significantly:

- **Enrollment** dropped 46% in the Baseline, 41% in No War (1.02 million students), and 52% in No Deferment (839,000 students).

- **Academic performance** improved slightly in all cases, especially in No Deferment.

- **Stress levels** fell over time across scenarios: about one-third of students had moderate stress in 2022, but by 2023 most remaining students reported low stress.

Results and Discussion

Our model shows that both war conditions and military deferment policies significantly affect Ukraine's higher education system. The war alone accounts for a 10% drop in student numbers, while removing student exemptions from military service would cause an additional 6% decline.

We developed an agent-based model in NetLogo 6.4.0 to simulate how Ukrainian universities, students, and staff adapt to full-scale war. The model, calibrated with real data for 314 institutions, incorporates stress, infrastructure damage, policy changes, and academic cycles. Validation against empirical data confirmed its ability to capture key trends, though it slightly overestimates the pace of change and underestimates staff stress levels.

Scenario analysis highlights the combined impact of conflict and policy decisions on enrollment and institutional stability. These findings underscore the importance of resilience-building strategies and careful policy design during wartime.

Future research will focus on better calibration using additional qualitative and quantitative study. Sensitivity analysis will also help to determine factors and their combinations that can reduce negative effects of the war on the Ukrainian higher education system.

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UNIVERSAL DESIGN OF LEARNING AS A TOOL FOR ENSURING INCLUSIVENESS AND ACCESSIBILITY OF HIGHER EDUCATION УНІВЕРСАЛЬНИЙ ДИЗАЙН НАВЧАННЯ ЯК ІНСТРУМЕНТ ЗАБЕЗПЕЧЕННЯ ІНКЛЮЗИВНОСТІ ТА ДОСТУПНОСТІ ВИЩОЇ ОСВІТИ

Background: Universal Design for Learning at the university is important because it contributes to the creation of an inclusive and accessible educational environment for all students, taking into account their different needs and capabilities. In the context of the war in Ukraine, when many people have been traumatized and displaced, UDL becomes especially relevant to ensure equal access to quality education for the most vulnerable students. The implementation of the UDL helps the university to become more resilient and adaptive to new challenges, providing quality education for all, regardless of their life experience.

Purpose: to analyze the principles of Universal Design for Learning and to study the activity of the Ministry of Education and Science of Ukraine in implementing the principles of UDL in higher education institutions.

Methods: Method of analysis, methods of theoretical exploring and document analysis.

Results: There is a certain disconnect between the progressive principles of UDL and the current level of their reflection in Ukrainian higher education regulations. Although there are provisions in the