ORMS TODAY

September 21, 2022 in Reconstructing Ukraine

Operations Research for the Recovery and Reconstruction of Ukraine

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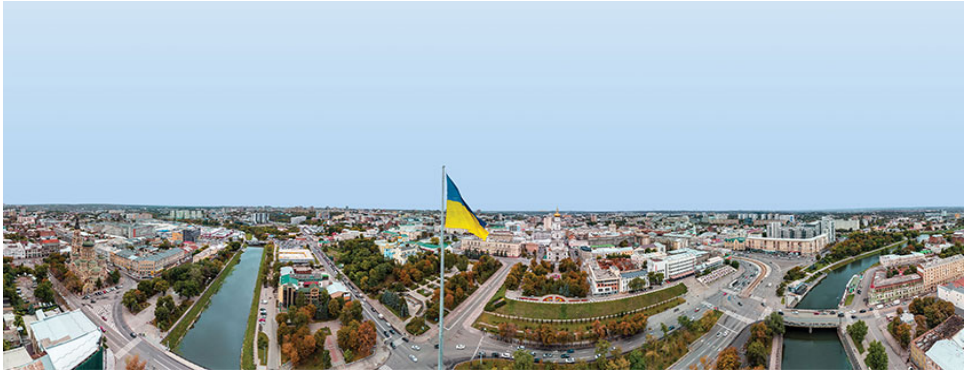
https://doi.org/10.1287/orms.2022.05.01



On February 24, 2022, Russia invaded the sovereign nation of Ukraine, disrupting lives, trade and the economy. Since the start of this unprovoked war, Ukraine's losses have been countless, with thousands of civilians perishing, others injured; dozens of cities severely damaged; hundreds of infrastructure facilities from hospitals to educational institutions compromised, if not outrightly destroyed; and numerous enterprises, plus thousands of homes, in ruins. Four months later, the estimated cost of this war on Ukraine's economy due to just the damage and destruction of buildings and infrastructure was more than $95 billion. The total losses of Ukraine's economy due to the war, including both direct and indirect losses, have been estimated at more than $600 billion [1]. Millions of Ukrainians have been displaced, creating the worst refugee crisis since World War II.

According to the Kyiv School of Economics (KSE), as of mid-June 2022, more than 388 enterprises, 18 civilian airports, 779 medical institutions, 1,271 educational institutions, 600 kindergartens, 33 shopping centers, 28 oil depots, 105,200 private

estimated $4.3 billion in damages [3]. Some estimates of the costs of reconstruction now range as high as $1 trillion. The war has rendered devastating consequences on Ukraine, with global repercussions.

In disaster management, there are four phases: mitigation, preparedness, response and recovery, which includes reconstruction. Clearly, war is a disaster, and we are still in the midst of the COVID-19 pandemic. Operations researchers have done great work in both theory and practice in disaster management and humanitarian logistics. Now it is time to channel our resources to assist in the recovery and reconstruction of Ukraine, which must begin even during the war. Our skills and expertise have never been more in demand. In early April 2022, I wrote an op-ed in the *Chicago Sun-Times* emphasizing the need for a Marshall Plan for Ukraine [4], and several of my KSE-affiliated colleagues co-authored "A Blueprint for the Reconstruction of Ukraine" [5]. These can serve as a foundation for guiding principles. Recall that, in the original Marshall Plan, the U.S. distributed more than $150 billion in today's dollars in economic aid after WWII to rebuild the economies of war-torn European countries.

My Connection with Ukraine

I vividly remember the morning of February 24. I was hosting (via Zoom) Denise Sumpf of the U.N. Armenia Country Team as a guest speaker in my Humanitarian Logistics and Healthcare class at the Isenberg School of Management. She had just taken part in the U.N. Security Council Meeting on the unfolding invasion of Ukraine by Russia and was therefore late to the Zoom. Her presentation on her work with the U.N. in Armenia was interspersed with her deep concern about the invasion and its ramifications. Throughout the spring 2022 semester, my classes discussed the war and its impacts from supply chain disruptions and exacerbated food insecurity to logistical challenges and humanitarian relief, plus the Ukrainian refugee crisis.

My connections to Ukraine are strong and deep. I am the daughter of WWII refugees from Ukraine and I was born in Canada. My first language is Ukrainian. For several years, I have had the honor of serving on the board of directors and the International Academic Board of KSE. I serve in this capacity with the Nobel laureate in Economics Roger Myerson and former U.S. ambassador to Ukraine John Herbst. Since March 2022, I have been serving as one of four co-chairs of the Kyiv School of Economics.

The Education Sector

As an academic, the education sector is near and dear to me. During the war, many educational institutions in Ukraine, including universities, have been physically damaged; some shifted to online education, whereas others in safer parts of the country continue their instruction, often at a reduced level because many faculty and students joined the territorial defense forces in Ukraine or have become volunteers. Because the majority of institutions of higher education in Ukraine are government funded, many faculty suffered a decrease in salaries as well as a decrease in funding for their scholarly research.

Some academic institutions, such as the private Kyiv School of Economics, innovated and, in addition to advising the government of Ukraine, started various speaker series featuring global thought leaders, including economists [6]. KSE has been incredibly agile and adaptable in wartime. Although classes were suspended immediately after the invasion, KSE began online classes within a month. Its faculty and administrators have taken part in many virtual panels and webinars to inform and educate the public. Some of the virtual events that I took part in were interrupted by air raid sirens, and we watched as the speakers ran to bomb shelters. Oftentimes, after a short pause, the event continued from the shelter. In addition, several of the KSE faculty and top administrators have been heavily engaged with the media and produced multiple white papers and studies on the impact of the war. Their dedication to education and the dissemination of timely information and studies are laudatory.

Investment in education will be essential in Ukraine – education is the bedrock of democracy and fundamental to Ukraine's recovery and reconstruction. I envision partnerships between universities in North America and Europe with academic institutions in Ukraine. For example, my own institution, University of Massachusetts Amherst, has created a partnership with KSE for Virtual Scholars and student exchange programs [7]. In addition to the physical infrastructure of educational institutions that will need to be restored, faculty must also be supported in their teaching and research, and the same for students. I foresee many such collaborations, with accompanying novel research studies being a positive outcome in the recovery and reconstruction of Ukraine. It is important that brain drain be curtailed and that investments in quality education

and the accompanying methodologies, plus applications, will be essential to education in this period of recovery and reconstruction and beyond. The COVID-19 pandemic revealed the criticality of supply chains and their efficient and effective management and functionality. This war has further supported the recognition of the importance of supply chains, including military-based as well as agricultural ones; the essential role of logistics and transportation in the wartime economy; relevance of energy security and independence; the criticality of telecommunications and other infrastructure networks; and the importance of labor, along with the need for powerful risk management and investments tools. Technology, so essential in wartime, will also play a critical role in peacetime. The associated education, including on cybersecurity and information systems, will be in high demand. The high-tech sector in Ukraine has actually managed to thrive in wartime [8].

The Agricultural Sector and Food Supply Chains

Ukraine is known as the breadbasket of Europe, if not the world, and the food grown there has, in recent years, fed up to 400 million people annually [9]. Ukraine is famous for its rich black soil and exports of wheat, barley, corn and sunflower oil. Its blue and yellow flag symbolizes the blue sky and the fields of wheat. According to the U.N., the farming sector constituted about a quarter of Ukraine's GDP last year.

Before the war, Ukraine exported approximately 5 million metric tons of grain each month, with about 90% from its ports on the Black Sea, including Odesa. MENA countries (Middle Eastern and North African) rely on grain exports from Ukraine. Developing countries – including Egypt, Lebanon and Yemen, where hunger is always of concern – as well as developed countries (even several European ones) depend on food products grown in Ukraine. China imports corn and sunflower oil from Ukraine, and India imports agricultural products from Ukraine. Many do not know that the World Food Programme typically purchased 50% of its grain from Ukraine [10]. According to the U.N. Food and Agriculture Organization, world food commodity prices reached their highest levels ever in March 2022 as the war on Ukraine spread shocks through markets [11].

During the war, many of the major ports in the Black Sea have been damaged, others blockaded, and parts of the Black Sea mined. Agricultural fields have been mined and some even set on fire by the invading Russian forces. Agricultural machinery has been damaged, and the price of fertilizer – which is now difficult to get – has risen. As of June, about (and this number may be an overestimate) 1-1.5 million tons of grain are being exported monthly. The "new" routes, as opposed to maritime ones, are inefficient and involve the use of trucks, rails and barges. The volume of vehicles needed for transport adds to congestion and slows the export of critical agricultural trades. Additionally, the workers associated with these tasks, including truckers, are already overwhelmed with demands in the transport of products and supplies during wartime. Ukraine's current cereal stocks are estimated at about 20-25 million tons, which need to be shipped to demand markets and to make room in storage facilities for upcoming harvests.

missiles on Odesa, the major port for grain shipments [13]. On August 1, it was reported that the first ship since the war on Ukraine, laden with 26,000 tons of corn, set sail from the port of Odesa and was headed for Lebanon [14].

Contributions. Regarding the impact of this on global hunger and food prices, I was interviewed for a *Bulletin of Atomic Scientists* article titled "Global hunger crisis looms as war in Ukraine sends food prices soaring," by Susan D'Agostino [15]. In addition, INFORMS hosted professor Tim Lowe of the University of Iowa and myself for a recent webinar on "How Supply Chain Disruptions are Impacting our Food Supply and Creating Food Insecurity." I began the webinar by speaking about Ukraine and the major disruptions to agriculture because of the Russian aggression [16]. I thank Jeff Cohen and Ashley Smith of INFORMS for making this webinar possible, to which folks from Capitol Hill were invited among other guests. I was thrilled to receive emails of thanks afterward from as far as the U.K. and Mexico. I also spoke to FeedStuffs for a very informative segment, "Russia-Ukraine war and global food security: What's at stake?" [17].

O.R. and operations researchers have been wonderful contributors to the formulation, analysis and solution of numerous agricultural and related supply chain problems (cf. [18, 19, 20, 21, 22] and the references therein) with resilience also playing an increasingly prominent role [23, 24]. Ukraine's farming sector will need expertise as to where to rebuild and reinvest and how to rebuild wisely and with sustainability in mind. I expect that there will also be a need for enhanced trade policies and the quantification of their impacts, topics that my group has been researching for quite a while [25, 26]. Furthermore, because of the casualties of the war, investing in labor will also be pivotal [27].

Recovering and Rebuilding Infrastructure

Infrastructure comes in different forms, including physical (transportation, energy, telecommunications, etc.) as well as social (housing, schools, hospitals, etc.). As noted, the damage to infrastructure in Ukraine – including homes, businesses and educational institutions as well as medical facilities, along with roads, bridges and other forms of critical infrastructure – has been significant during this war, and one can expect that, if it continues for a prolonged period, the costs will significantly escalate. Building back better, in accordance with appropriate studies as to what and where to build, will be imperative. The displaced population, both within Ukraine and other countries, will need to be considered. According to the Blueprint [5], serious investments and work are expected to be required to restore/expand ports, railroad tracks, highways and bridges, with the replenishment of railroad cars, trucks, buses, etc. It will be very important to identify complementarities between restoring (and modernizing) infrastructure and reviving particular sectors. Of course, work will be needed to remove mines on property as well as to mitigate the environmental damages caused by the war.

Also noted in the Blueprint [5], a key component of reconstruction is to enable Ukrainian refugees and displaced persons to return to their prewar residences. To make this happen, besides guaranteeing safety and security, it will be imperative to rebuild housing, schools, hospitals, etc.

Furthermore, the recovery and reconstruction should be done with a view of energy security, which has been a major issue in this war, as well as putting Ukraine on a trajectory toward carbon neutrality. There are opportunities for technological leaps in the reconstruction of buildings and other infrastructure in addition to modernization. It is expected that the funding for recovery and reconstruction will come from multiple sources [28]. However, Ukraine must play a primary role in reconstruction decisions.

Clearly, a major component of the infrastructure that will need rebuilding includes transportation and energy networks. Research conducted by our discipline can be brought to bear on how to optimize the design of new networks and the repair of existing ones [29]. This will create opportunities for impactful results on behalf of Ukraine and the world. With ongoing challenges to our planet, from increasing geopolitical risks to climate change and the number of disasters rising as well as the number of people affected by them (cf. [30] and the references therein), analytical tools will be key in decision support.

The security of Ukraine, its families, workers and officials must be guaranteed for the reconstruction to be considered successful and sustainable. Security will also necessitate the requisite funding and support. The same goes for public health and healthcare in Ukraine.

Concluding Thoughts

This has been a challenging article to write because I needed to distill a combination of research and practice with the war against Ukraine still ongoing. I thank Kara Tucker, editor of *OR/MS Today*, for the invitation. The war situation is fluid and dynamic and, when this article is published, I hope that there will be peace and victory for Ukraine, whose courageous defenders are fighting not only for their country but also for the free world. Speaking out, writing, working toward peace and supporting institutions that are assisting in Ukraine all have validity and can elicit positive change. Ukrainians who have endured incomprehensible pain and suffering and continue to stand for their sovereign nation with its rich history and culture are heroes – from the farmers who continue to sow and reap to the educators who continue to teach and mentor, and even manage, somehow, to conduct research; the healthcare providers treating those with wounds and trauma; and, of course, all the humanitarian workers, who are risking their lives to provide aid. Operations researchers, with their expertise, will be essential to the recovery and reconstruction of Ukraine and envisioning a bright future for the country and its people, once again, under freedom and democracy.

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