A database of damaged bridges in Ukraine and preliminary reconstruction cost assessment

Joseph Lambden, MSc Project and Infrastructure Engineering

Sotirios Argyroudis, Reader in Infrastructure Engineering

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1 Introduction

The full-scale war in Ukraine amounted so far to $411 bn according to the World Bank[1] as of October 2023. Damage to critical infrastructure such as highways, railways, hospitals, port and energy assets, contribute significantly this loss. As of March 2023, 345 bridges have been damaged or destroyed since the start of the conflict with this number increasing every week[2]. Bridges play a vital role providing access routes for supplies, troops, and civilians over obstacles. Their destruction causes large direct and indirect financial losses spanning from replacement and reconstruction costs to increased congestion and travel time. Restoration of damaged infrastructure is imperative for peacebuilding due to the reliance of functioning infrastructure to society. Yet, post-conflict infrastructure resilience require a new framework that includes different scales of resilience, considering different levels of knowledge, including standoff observations and data-driven assessments to facilitate prioritisation during reconstruction[3] . In this context, this report aims to collect and map damage data for bridges from the ongoing conflict in Ukraine. This data is then used to assess the reconstruction cost and prioritise bridge reconstruction. A detailed GIS database has been developed based on information collected by social media and news crowdsourcing, available reports, satellite images and other open data sources. The methodology is outlined in Figure 1. This report demonstrates the pivotal role of civil engineers in the reconstruction of critical infrastructure both during and after conflicts.

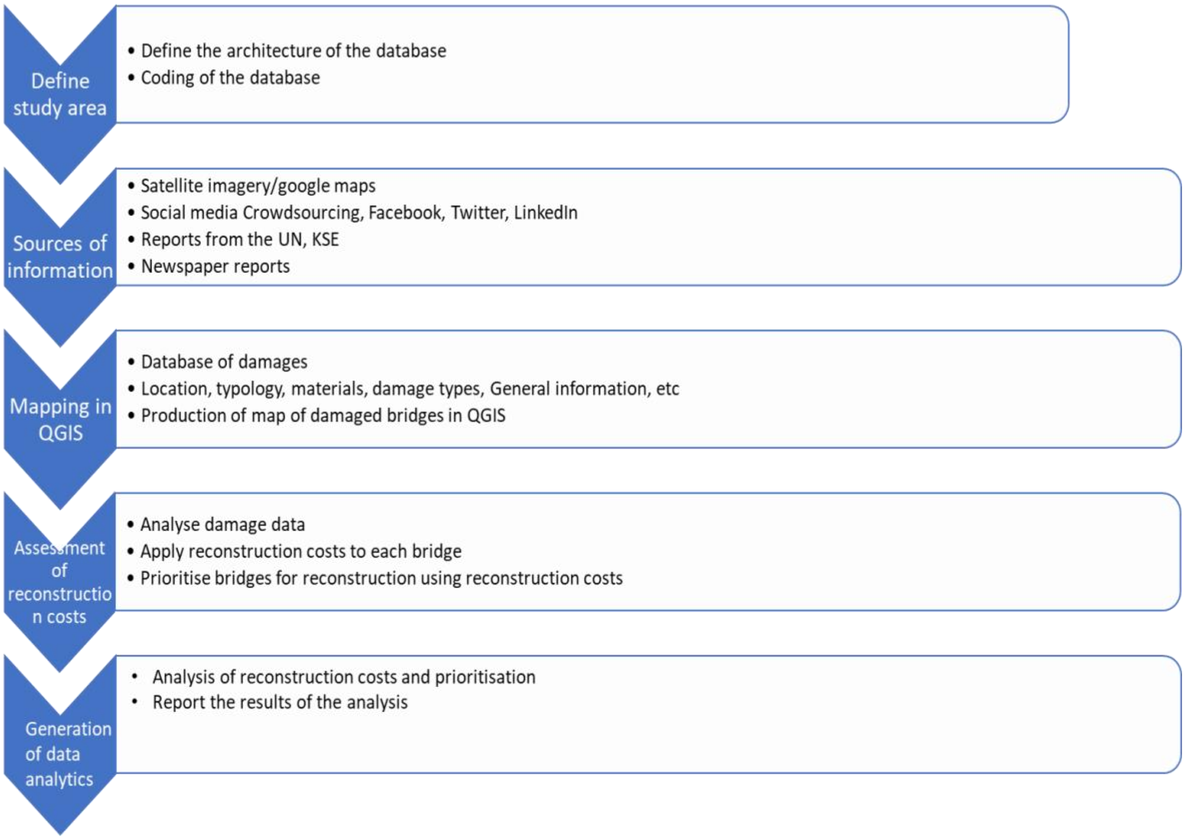


Figure 1. Flowchart of the methodology of this study.

[1] https://rusi.org/explore-our-research/publications/commentary/can-open-data-form-basis-transparent-recovery-process-ukraine
[2] https://tsn.ua/en/ato/at-least-345-bridges-are-destroyed-in-ukraine-how-many-have-already-been-repaired-and-which-ones-are-being-repaired-first-2293123.html
[3] Mitoulis, S. A., Argyroudis, S., Panteli, M., Fuggini, C., Valkaniotis, S., Hynes, W., Linkov, I. (2023). Conflict-resilience framework for critical infrastructure peacebuilding. Sustainable Cities and Society, 91, 104405.

2 Mapping of damaged bridges

Figure 2 shows a QGIS map with 22 damaged bridges included in this database (highlighted in red). The distribution of bridges in the portfolio shows that many bridges damaged to the south and east of Ukraine where the main Russian attack has steamed from with a few bridges damaged on highways or railways entering the capital Kyiv. Many bridges are damaged in proximity around the towns of Severodonetsk and Slovyansk in the west of Ukraine. Bridges damaged in a small area cause huge problems given bridges are the primary way of moving people and resources over bodies of water. Also, having several damaged in a small area causes connectivity disruption, while diversion distances are too large and make most journeys unsuitable, hence, cutting accessibility between villages, towns and critical facilities. This map doesn't include all the damaged bridges in the area.

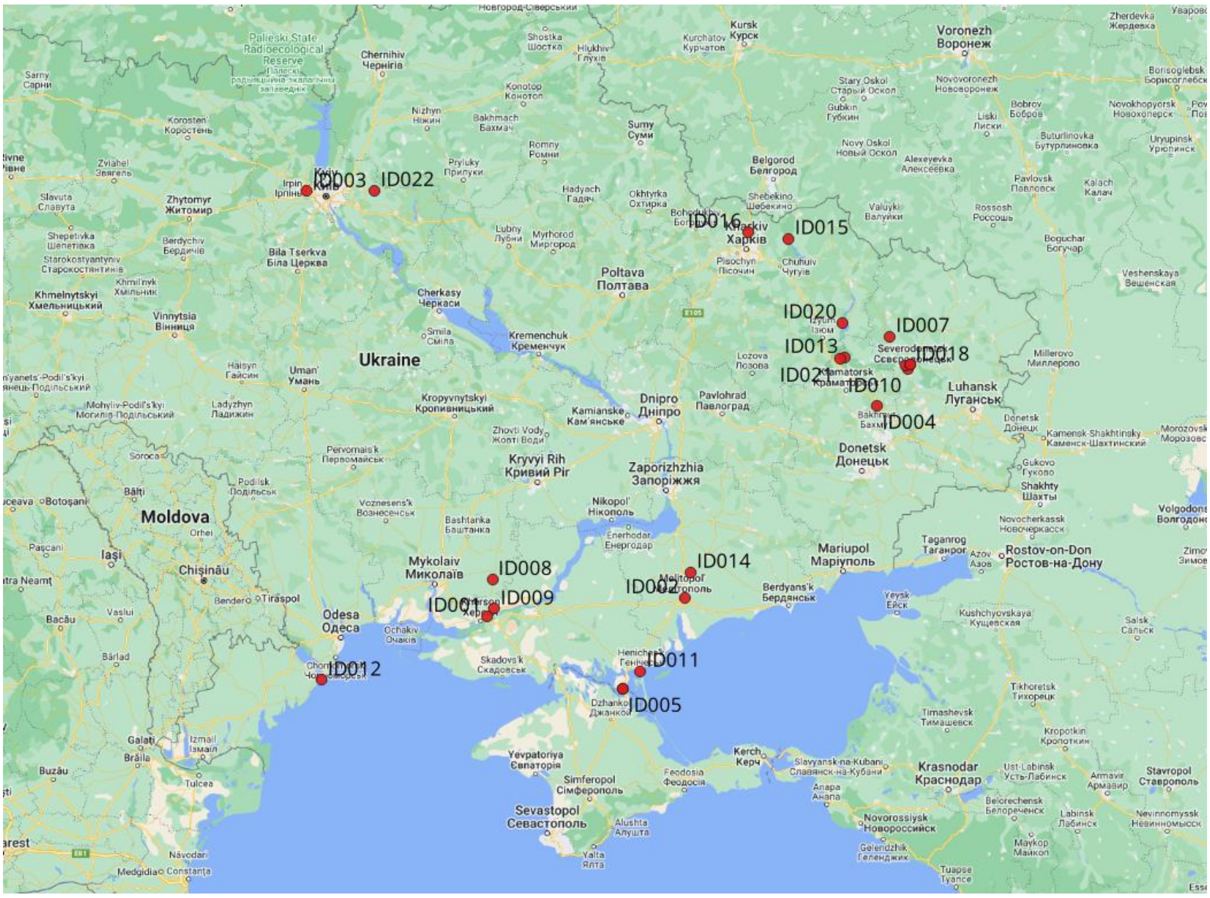


Figure 2. QGIS map of damaged bridges listed in the portfolio.

2.1 Database fields and coding

The bridge database includes a range of fields, some of them have been coded for making it easier to process and analyse the data. The database includes the following fields:

Bridge ID, Bridge Name, Region, Lat coordinate, Long coordinate, Material, Typology, Type of pier, Type of pier to deck connections, Bridge function, Crossing over (type of obstacle), Length of bridge (m), Width of bridge (m), Number of piers, Length of spans (m), Number of spans damaged, Length of bridge damaged, % of bridge damaged, Damage level, Damage spans over (type of obstacle), Length of diversion (km), Photos of damaged bridges (provided in the Annex).

Tables 1a, 1b, 1c, 1d, and 1e show the coding for the coded fields of the database.

Table 1a. Coding for the predominant material.

Materials	Coding
Concrete	C
Steel Reinforced concrete	RC
Fibre reinforced concrete	FRC
Steel	ST
Masonry	MA

Table 1b. Coding for the type of piers used.

Type of pier	Coding
Single column with cylindrical section	SCC
Single column with rectangular hollow section	SCR
Multi-column bent	MCB
Wall-type	WT
No piers	NP

Table 1c. Coding for the type of pier to deck connection.

Type of pier to deck connections	Coding
Monolithic	M
Through bearings	TB
Combination of monolithic and bearing connections	MTB

Table 1d. Coding for the function of the bridge.

Bridge function	Coding
Highway	HW
Railway	RW

Table 1e. Coding for what the bridge is crossing over.

Bridge crossing over	Coding
Road	RD
Railway	RW
Water channel	WC
Valley	V

Figure 3 shows the data gathered in QGIS for each of the bridges in the portfolio. This data can support reconstruction by enabling the planning of resources. The data is stored in a data table in the attribute table section of QGIS. This database can be continually updated as more data is obtained or more bridges get damaged.

Bridge ID	Bridge name	Region	X cooridnate	Y coordinate	Material	Typology	Type of pier
ID001	Antonivsky bridge	Kherson Oblast	46.6702° N	32.7201° E	RC	Box girder bridge	MCB
ID002	Molochna river crossing	Zaporizhzhia Oblast	46.8421°N	35.4076°E	C	Multi span continous Bea	MCB
ID003	Irpin river bridge	Kyiv Oblast	50.4913°N	30.2592°E	RC	Simply supported multi sp	SCR
ID004	Bakhmut rail bridge	Donetsk Oblast	48.6011°N	38.0059°E	ST	Truss bridge	NP
ID005	Chongar bridge	Kherson Oblast	45.9878°N	34.5530°E	RC	Continous span girder bri	MCB
ID006	Second Chongar bridge	Kherson Oblast	45.9873°N	34.5525°E	RC	Multi span continous Bea	SCR
ID007	Krasna river bridge	Luhansk Oblast	49.2162°N	38.1857°E	FRC and ST	Simply supported girder b	MCB
ID008	Snihurivka canal bridge	Mykolaiv Oblast	47.0176°N	32.7884°E	C	Simply supoorted beam b	MCB
ID009	Darivka Bridge	Kherson Oblast	46.7434°N	32.8113°E	RC	Simply supported multi sp	MCB
ID010	Pavlograd Bridge	Luhansk Oblast	48.9245°N	38.4370°E	C and ST	Box girder bridge	MCB
ID011	Henichesk Bridge	Kherson Oblast	46.1602°N	34.7955°E	RC	Simply supported multi sp	SCC
ID012	Zakota bridge	Odessa Oblast	46.0767°N	30.4702°E	ST	Truss bridge	SCR
ID013	Siverskyi Donets river brid	Donetsk Oblast	49.0306°N	37.5695°E	C	Simply supported multi sp	SCC
ID014	Starobohdanivka railway	Zaporizhzhia Oblast	47.0787°N	35.4863°E	ST	Truss Bridge	
ID015	Staryi Saltiv dam bridge	Kharkiv Oblast	50.0771°N	36.8116°E	RC	Simply supported multi sp	MCB
ID016	Rus'ka Lozova bridge	Kharkiv Oblast	50.1395°N	36.2614°E	RC	Simply supported single s	NP
ID017	Siverskyi Donests railway	Luhansk Oblast	48.9612°N	38.3981°E	ST	Truss Bridge	SCC
ID018	Borova highway bridge	Luhansk Oblast	48.9674°N	38.4616°E	C	Simply supported multi sp	SCC
ID019	Borova railway bridge	Luhansk Oblast	48.9670°N	38.4607°E	C	Simply supported multi sp	MCB
ID020	Horokhovatka Bridge	Kharkiv Oblast	49.3431°N	37.5484°E	ST	Truss bridge	SCC
ID021	Bohorodychne bridge	Donetsk Oblast	49.0224°N	37.5132°E	RC	Simply supported multi sp	MCB
ID022	Rusaniv Bridge	Kyiv Oblast	50.4947°N	31.1810°E	C	Single span beam bridge	NP

Type of pier to deck c	Bridge function	Crossing over	Length of bridge (m)	Width of bridge (m)	Number of spans	Number of piers/colu	Length of spans (m)	Number of spans dam
TB	HW	WC	1370	25	30	31	45.5	2
	HW	WC	142	14.6	7	6	20.3	2
M	HW	WC	133	22.1	5	4	26.6	2
TB	RW	WC	41.3	4.49	1	0	41.3	1
TB	HW	WC	178	14.4	8	7	22.3	1
TB	HW	WC	156	8.34	9	8	17.4	1
TB	HW	WC	100	12.7	10	9	10	2
TB	HW	WC	43.8	10.4	3	2	14.6	3
M	HW	WC and V	278	14.7	8	7	34.8	4
TB	HW	WC & V & RW	286	10.5	12	11	23.8	2
TB	HW	WC	156	12.3	8	7	19.5	1
TB	RW and HW	WC	370	20.9	6	5	61.6	1
TB	HW	WC	205	5.52	9	8	22.7	5
	RW	WC	171	6.32	5	4	34.2	5
TB	HW	WC	157	6.81	9	8	17.4	2
NP	HW	WC	50.2	13.1	1	0	50.2	1
TB	RW	WC	200	11.6	3	2	66.6	2
M	HW	WC	116	8.03	8	7	14.5	3
Tb	RW	WC	128	6.84	9	8	14.2	2
TB	HW	WC	204	7.6	7	6	29.1	2
TB	HW	WC	240	11.6	8	7	30	4
NP	HW	WC	23.6	11.6	1	0	23.6	1

Length of bridge dam	% of bridge damaged	Damage level	Damage spans over	Length of Diversion (k
91	6.66	L4	WC	126
40.6	28.6	L3	WC	29
53.2	40	L4	WC	9
41.3	100	L4	WC	RW
22.3	12.5	L3	WC	182
17.4	11.1	L3	WC	182
20	20	L4	WC	48
43.8	100	L4	WC	29
139	50	L4	WC and V	64
47.6	16.6	L4	V	6
19.5	12.5	L3	WC	7
61.6	16.6	L3	WC	127
114	55.4	L4	WC	54
171	100	L4	WC	RW
34.8	22.2	L4	WC	62
50.2	100	L4	WC	2
133	66.6	L4	WC	RW
43.5	37.5	L4	WC	3
28.4	22.2	L4	WC	RW
58.2	28.6	L4	WC	74
120	50	L4	WC	50
23.6	100	L4	WC	10

Figure 3. Database of bridges.

3 Assessment of restoration costs

Based on the database a preliminary cost assessment is performed, assuming a reconstruction cost of €3,000 per m^2 (Table 1). Figure 3 shows the restoration cost of each damaged bridge as a percentage of the bridge value, i.e. re-construction cost of the entire bridge.

Table 1 Reconstruction costs for the bridges in the database.

Bridge ID	Length of bridge damaged (m)	Width of bridge damaged (m)	Area of bridge damaged (m^2)	Reconstruction costs (€)
ID001	91	25	2275	6,825,000
ID002	40.6	14.6	592.76	1,778,280
ID003	53.2	22.1	1175.72	3,527,160
ID004	41.3	4.49	185.437	556,311
ID005	22.3	14.4	321.12	963,360
ID006	17.4	8.34	145.116	435,348
ID007	20	12.7	254	762,000
ID008	43.8	10.4	455.52	1,366,560
ID009	139	14.7	2043.3	6,129,900
ID010	47.6	10.5	499.8	1,499,400
ID011	19.5	12.3	239.85	719,550
ID012	61.6	20.9	1287.44	3,862,320
ID013	114	5.52	629.28	1,887,840
ID014	171	6.32	1080.72	3,242,160
ID015	34.8	6.81	236.988	710,964
ID016	50.2	13.1	657.62	1,972,860
ID017	133	11.6	1542.8	4,628,400
ID018	43.5	8.03	349.305	1,047,915
ID019	28.4	6.84	194.256	582,768
ID020	58.2	7.6	442.32	1,326,960
ID021	120	11.6	1392	4,176,000
ID022	23.6	11.6	273.76	821,280

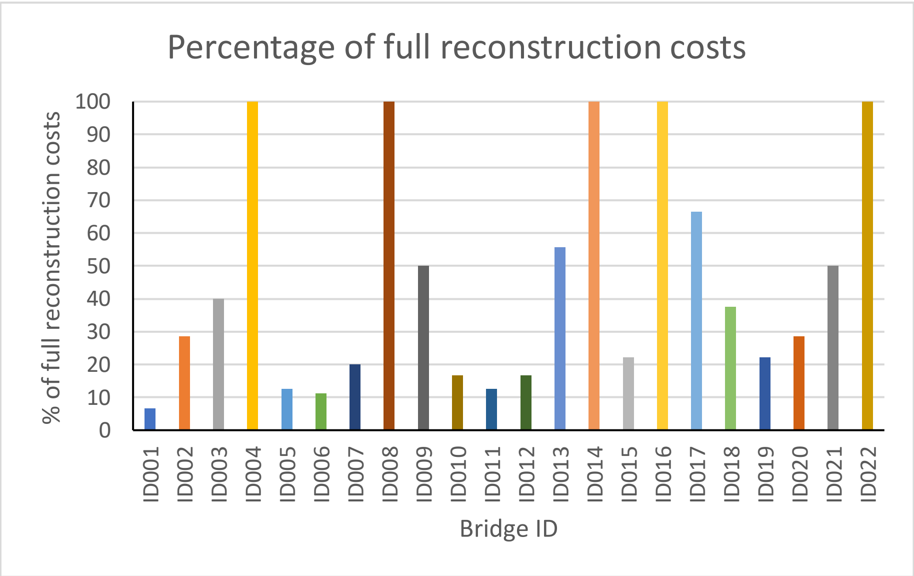


Figure 3. Restoration cost of each bridge as a percentage of the bridge value (construction cost).

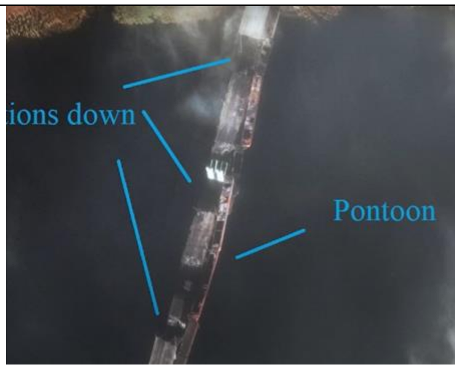
4 Conclusion

In conclusion, the methodology developed to collect and map damage data for a selection of bridges damaged because of the conflict in Ukraine has allowed for an extensive database of a variety of bridges to be collected. By using a variety of methods including social media, newspaper report, and satellite imagery to collect data for conflict induced damage to bridges its subsequently enabled an estimate for the reconstruction costs of each to bridge to be calculated. Along with Mitoulis et al (2023), this report uses a €3000/m2 estimate for the reconstruction costs of each bridge. This value is not unique to costs in Ukraine and does not consider different typologies of bridges so is not a truly accurate representation of reconstruction costs. However, the model still allows for good estimates to be achieved that can be utilised as part of disaster management in the preparedness, response, and recovery sections of Johnson (2000) framework. The reconstruction costs of each bridge found in this report along with corresponding diversion distances and failure modes can each be used to make a post conflict recovery plan prioritising certain bridges to achieve the most effective and efficient post war recovery. This is important given the financial restrictions and lack of resource availability after conflicts.

Appendix

Photos of damaged bridges included in this database. Each photo is tagged with the bridge ID.

ID001_1



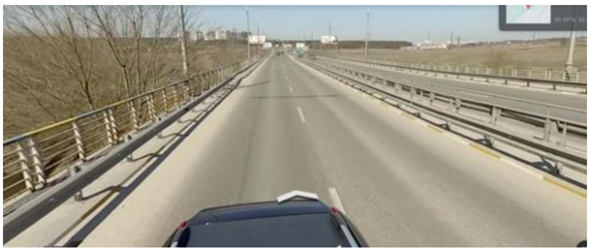
ID001_2

ID001_3

ID002_1

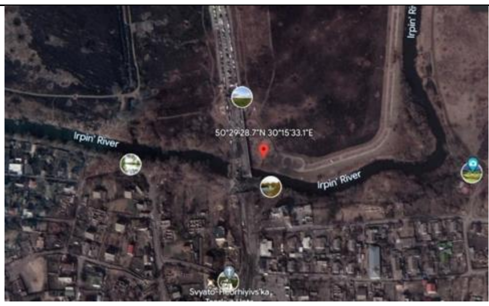
ID002_2

ID002_3

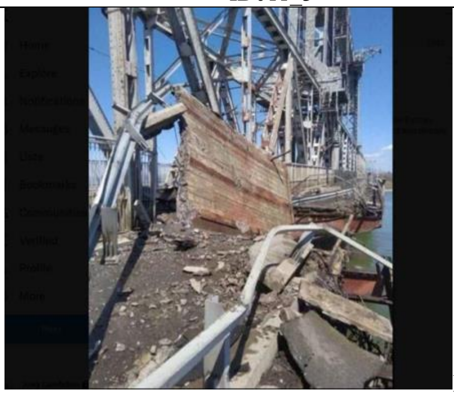


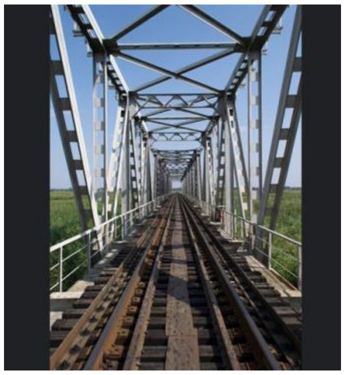
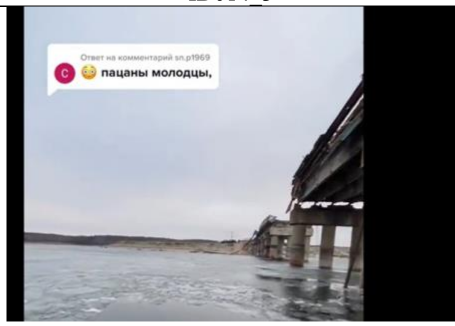
ID003_1

ID003_2

 ID003_3	 ID004_1
 ID004_2	 ID004_3
 ID005_1	 ID005_2
 ID005_3	 ID006_1
 ID006_2	 ID006_3

 ID007_1	 ID007_2
 ID007_3	 ID008_1
 ID008_2	 ID008_3
 ID009_1	 ID009_2
 ID009_3	 ID010_1

 ID010_2	 ID010_3
 ID011_1	 ID011_2
 ID011_3	 ID012_1
 ID012_2	 ID012_3

 ID013_1	 ID013_2
 ID013_3	 ID014_1
 ID014_2	 ID014_3
 ID015_1	 ID015_2
 ID015_3	 ID016_1


ID016_2

ID016_3


ID017_1

ID017_2

ID017_3


ID018_1


ID018_2

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 ID020_2	 ID020_3
 ID021_1	 ID021_2

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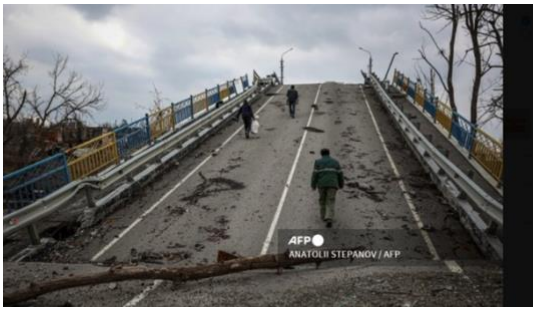
<td>

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