Strategy for Prioritization of Investments, Funding and Modernization of Ukraine's Road Sector

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Prepared by The World Bank Group

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EXECUTIVE SUMMARY

Road transport has long played an important role in Ukraine's domestic and international transport sectors. Between 2012 and 2016, the share of international trade by value handled by road transport increased from 30 to 37%. This increase coincided with a shift in international trading patterns, away from the Russian Federation and towards the European Union.

Despite the road sector's importance, Ukraine spends only around four-fifths of 1% of GDP on its 47,000 km main road network[1]. Recognizing this deficiency, the Ukrainian government recently adopted legislation for the creation of a new Road Fund (RF) which came into effect in January 2018. The RF will deliver significantly more funds to the road sector, sufficient to maintain assets if efficiently used, but not to finance capital expenditure of major road upgrading and new roads projects.

It is crucial that additional sources of funding be explored, including from private sector involvement. Equally, project implementation capacity must be bolstered so that the continued financial support from international financial institutions (IFIs) can be utilised in a timely and effective manner. At the current rate it would take 14 years to invest all the resources currently committed to Ukrainian transport projects through IFI loans.

Following the first draft of the roads assessment prepared by the World Bank in December 2016 on the maintenance and repair needs, which estimated that USD 500 million (about UAH 15 billion) per year was needed to avoid further deterioration of the International, National and Regional roads, an exceptional budget allocation was made and materialized in terms of road expenditure in 2017.

Ukravtodor tends to view its funding shortage as the root cause of problems with the road system. While budget funds for maintenance are certainly constrained, there is an obligation to ensure that all resources are well spent. Whatever money is available needs to be used more efficiently and objectively, with decisions based on up-to-date data about the road network and its condition and utilization, and objective analyses of the priorities. Decision-making and project implementation need to be sufficiently transparent so that the public can see that the best value for money is being achieved with whatever limited funding is available.

This report draws on analytical work conducted by the World Bank Group (WBG) to prioritize investments in maintenance projects, assess the potential for private sector participation in capital investments, and propose wider sectoral reforms. It proposes a systematic approach and an action plan containing both network and policy sector priorities. Without reform, the condition of Ukraine's roads will continue the deterioration that saw the share of roads in poor condition increase from 5 to 17% between 2011 and 2016.

Sector Priority #1 – Revamp the data collection and road management system (RMS)

Better road sector planning needs accurate data on traffic and road conditions. Immediate actions should include:

- restore the Automatic Traffic Counters;
- implement of a GIS-based RMS;
- perform a full-fledged condition survey on main roads (M, H, P);
- perform simplified (app-based) conditions survey on Territorial roads;

[1] Excluding local roads

- mainstream the use of the RMS as a tool for investment decisions.

Sector Priority #2 – Improve road safety

Several initiatives have been adopted by Ukraine to improve road safety including the recently approved State Road Safety Program. Key sector priorities include:

- analyse and prioritize the best uses of that share of the RF that will be dedicated to road safety;
- mainstream road safety improvement as a core mandate of all stakeholders involved in the road sector;
- fully implement the State Road Safety Program.

Sector Priority #3 – Improve vehicle load control

Road investments will not be sustainable if overloaded trucks continue to be allowed to cause premature road deterioration. Key priorities are:

- acquire 'weigh-in-motion' equipment and implement periodic anti-overloading campaigns;
- increase the penalties for overloaded trucks and repeated violators;
- improve transparency through automatic data collection and publication to reduce the occurrence of bribery.

Sector Priority #4 – Improve project preparation

Improving project preparation is essential to mobilize funds for implementation in a timely and effective way. Key priorities are:

- use robust analytical tools such as computerized road transport models built on robust data to pinpoint where investment is needed and the economic performance of that investment;
- establish a prioritized pipeline for preparation, based on technical criteria rather than political aspiration;
- use available resources (ongoing projects and large TAs) to support preparation of a pipeline of projects and increase project readiness;
- work towards the implementation of a multimodal multi-donor project preparation facility.

Sector Priority #5 – Promote competition in the maintenance industry

Better and more cost-effective maintenance needs to rely on an efficient market in road maintenance and management services. Key priorities are:

- Ukravtodor to continue the reform of the DAKs, aiming at converting them into full commercial entities which will genuinely compete for maintenance contracts;
- assess the lessons learned during the first performance-based contracting (PBC) experience and design the new roll-out of PBC on main International roads;
- establish a review and monitoring framework for maintenance costs so that bids for work can be objectively benchmarked.

Network Priority #1 – Ensure routine maintenance.

Routine maintenance should be performed on the entire network. The estimated annual cost is USD 230 million (UAH 6 billion) at an average of USD 10,000 per km.

Network Priority #2 – Repairs on the strategic network

These include about 6,200 km of current repairs and 700 km of capital repairs for a total amount of USD 1.93 billion (UAH 50 billion).

Figure 1: Repairs on the strategic network

Network Priority #3 – Repairs on other international roads

Includes the repairs of 1,773 km of International roads which are not included on the strategic network, representing a total cost of USD 424 million (UAH 11 billion).

Network Priority #4 – Repairs on other national roads

Includes the repairs of 2,554 km of National roads which are not included on the strategic network, representing a total cost of USD 731 million (UAH 19 billion).

Network Priority #5 – Repairs on other regional roads

Includes the repairs of 8,926 km of Regional roads which are not included on the strategic network, representing a total cost of USD 2.6 billion (UAH 67 billion).

Network Priority #6 – Prepare capacity improvement projects

The key road section priorities for preparation and assessment of private financing are:

- M-09 Lviv–Ternopil (FS ongoing)
- M-12 Ternopil - Stryi
- M-06 Rivne-Lviv
- M-06 Lviv–Stryi

However, the government should also consider targeting a more radical and innovative program of 'brownfield' road PPPs (that is, creating much higher quality roads on existing alignments rather than in new 'greenfield' locations) covering a much larger network (1,000 km+). This should be matched by a more corresponding range of innovative funding sources including direct user charging, e-tolling, e-vignettes, leveraging additional funds for the RF, etc. Public support for such a program would need to be promoted through the clear articulation of the financial and physical challenges facing the sector, the imperative of adopting new approaches, and the economic and social community benefits that will ensue. A central PPP unit under the Cabinet of Ministers could be established with the mandate and capacity to design and roll out this comprehensive program (among others), including all the necessary analysis and due diligence to ensure transparency and value for money for Ukrainian citizens.

Finally, while road safety is not the focus of this report, nearly all its recommendations will, in one way or another, contribute to safer roads and fewer road deaths and injuries among Ukraine's citizens. The Ministry of Infrastructure and Ukravtodor have declared road safety to be one of their key priorities. Ukraine's traffic fatality rate is more than double the EU average – and the second-worst among 'Eastern Partnership' (EaP) countries. Annual losses due to traffic accidents are estimated to be equivalent to 3.4% of the country's GDP. Five percent of the proposed RF is to be allocated to road safety. This will represent a big boost in resources to tackle the problem. To take full advantage, the State Road Safety Program should contain prioritized investments and systemic actions to improve the institutions, regulations, enforcement, vehicles and infrastructure which can all contribute to safer roads.

ACKNOWLEDGMENT

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The report was prepared by a joint World Bank and IFC team led by Antonio Nunez (Senior Transport Specialist), Oleg Kudashov (Senior Investment Officer) and Simon Ellis (Program Leader) and including Rodrigo Archondo-Callao (Senior Transport Specialist), Ioannis Dimitropoulos (Transport Specialist), Yevhen Bulakh (Transport Specialist), Paul Amos (Senior Transport Consultant), Galyna Beschastna (Transport Consultant), Tetyana Kuchma (GIS Consultant), Alberto Brignone (Transport Model Consultant), Jamie Lee-Brown (Transport Consultant) and consultants from Egis. The report benefited from the comments of Peer Reviewers: Baher El-Hifnawi (Lead Transport Economist), Gregoire Gauthier (Senior Transport Specialist) and Aymen Ali (Senior Transport Specialist). The team is grateful for the guidance provided by Juan Gaviria (Practice Manager), Fiona Colin (Lead Transport Specialist) and Ludmilla Butenko (Program Leader).

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EXCHANGE RATE

Currency units (as of May 2018)

UAH 1 = USD 0.0384

USD 1 = UAH 26

ACRONYMS AND ABBREVIATIONS

AADT	Annual Average Daily Traffic
ATC	Automatic traffic counters
ASE	Automated speed enforcement
BF	Brown field
CBA	Cost benefit analysis
DBT	Design build transfer
EaP	Eastern Partnership
EIB	European Investment Bank
EBRD	European Bank for Reconstruction and Development
EIRR	Economic Internal Rate of Return
EU	European Union
FIDIC	Federation Internationale des Ingenieurs-Conseil
FS	Feasibility study
GDP	Gross domestic product
GF	Green field
GIF	Global infrastructure facility
GoU	Government of Ukraine
HDM-4	Highway Design and Maintenance Standards Model 4
IFC	International Finance Corporation
IFI	International financial institution
IRI	International Roughness Index
KS	Kyivstar
LNB	Lviv Northern Bypass
MoI	Ministry of Infrastructure
NPV	Net present value
O&M	Operation & maintenance
OD	Origin-destination
OPRC	Output performance and results-based contract
PBC	Performance-based contracting
PPP	Public private partnership
PRA	Project readiness assessment
PVC	Present value of capital
RAMS	Road asset management system
RUC	Road user cost
RF	Road fund
SOE	State Owned Enterprises
TEN-T	Trans-European Network for Transport
TRACECA	International Transport Corridor Europe-Caucus-Asia
UAD	Ukravtodor (Ukrainian Roads Agency)
UAH	Ukrainian Hryvnia
USD	US Dollars
UN	United Nations
UNECE	United Nations Economic Commission for Europe
VAT	Value added tax
VOC	Vehicle operating costs
WB	World Bank
WBG	World Bank Group

1: BACKGROUND AND CONTEXT

1.1: Background

The current financial and institutional arrangements in the road sector in Ukraine have not delivered results. The shortage of maintenance funding, combined with a large share of overweight trucks, has resulted in premature deterioration of the network. From 2011 to 2016, the share of roads in poor condition (International Roughness Index (IRI) > 6) increased from 5 to 17%.

Ultimately, the overall condition of the road network can only be improved with sufficient resources. Current resources are grossly inadequate. Of the UAH 20 billion allocated to the road sector in 2014, which would have been insufficient to cover even the maintenance needs, UAH 17 billion went to service existing loans with just UAH 3 billion allocated to maintenance and operating costs. The situation has improved in recent years, with debt servicing levels declining, budgets increasing, and the government adopting legislation for the creation of a new Road Fund (RF), to be effective in 2018. However, even at these levels of funding, the overall deterioration of the network is inevitable. Even the recently rehabilitated major highways are at risk of falling into disrepair. The exceptional allocation of UAH 22.6 billion in 2017 following the World Bank's preliminary assessment helped in addressing the situation but needs to be followed by a sustainable maintenance strategy.

There are several key sector challenges facing Ukraine which include the lack of a road development strategy, inadequate investment and maintenance funds for the network, and an inability to carry out the much-needed reform agenda for the various road sector State Owned Enterprises (SOEs). Maximizing the effectiveness of the new RF instrument will also be a key challenge.

Clarity on priority expenditures and performance targets will be key to the effectiveness of the new RF. The urgent need for a new road development strategy identifying the sector priorities for investment is reinforced by the changing traffic patterns within Ukraine following the conflict in the East.

In this context, the Prime Minister of Ukraine requested the World Bank (WB) to support the preparation of a road prioritization and financing study to help re-establish the roads sector as a key driver of economic growth.

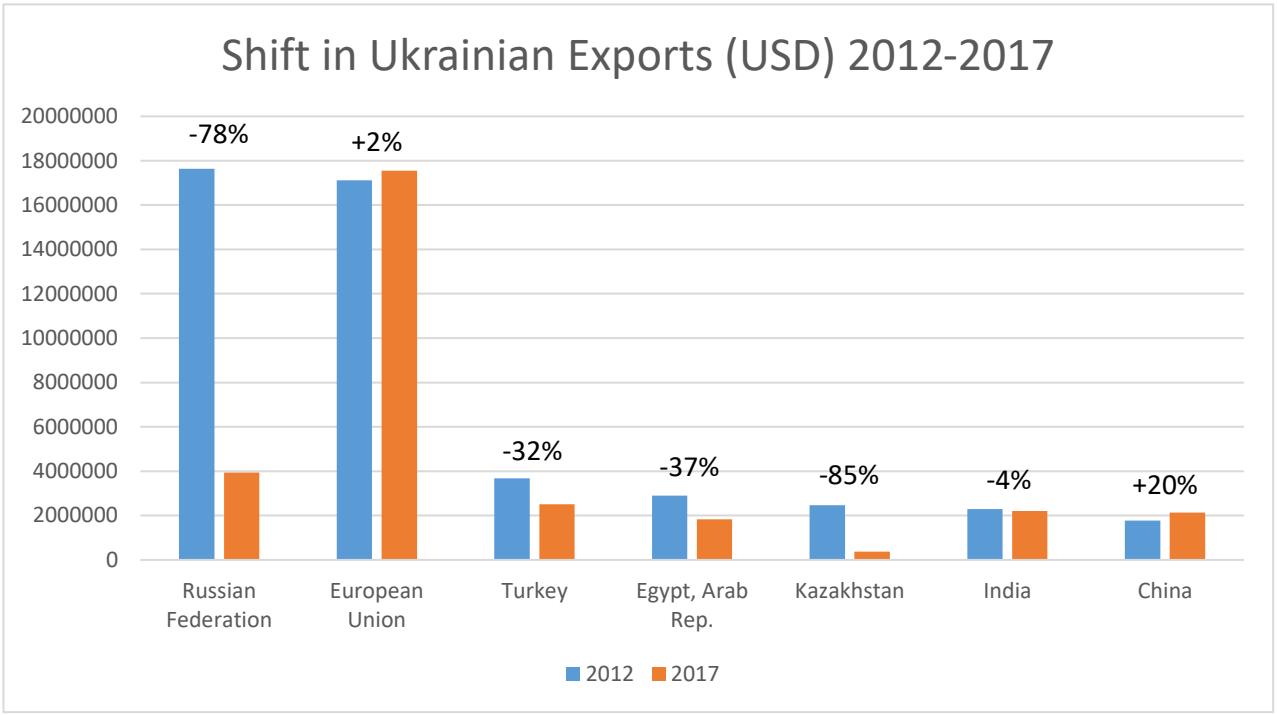
This road prioritization and financing study provides advice on the 2018-2022 priorities for maintenance and identifies longer term investment and other priorities in the sector. This study also intends to fill the planning gap in the road sector for the next three years, the expected timeline for the completion of an EU-funded comprehensive multi-modal transport master plan.

1.2: International trade flows

Ukraine's foreign trade in 2017 represents only about 60% of its 2012 value. Over this period, Russia's share of Ukrainian exports and imports fell by 65% and 55% respectively.

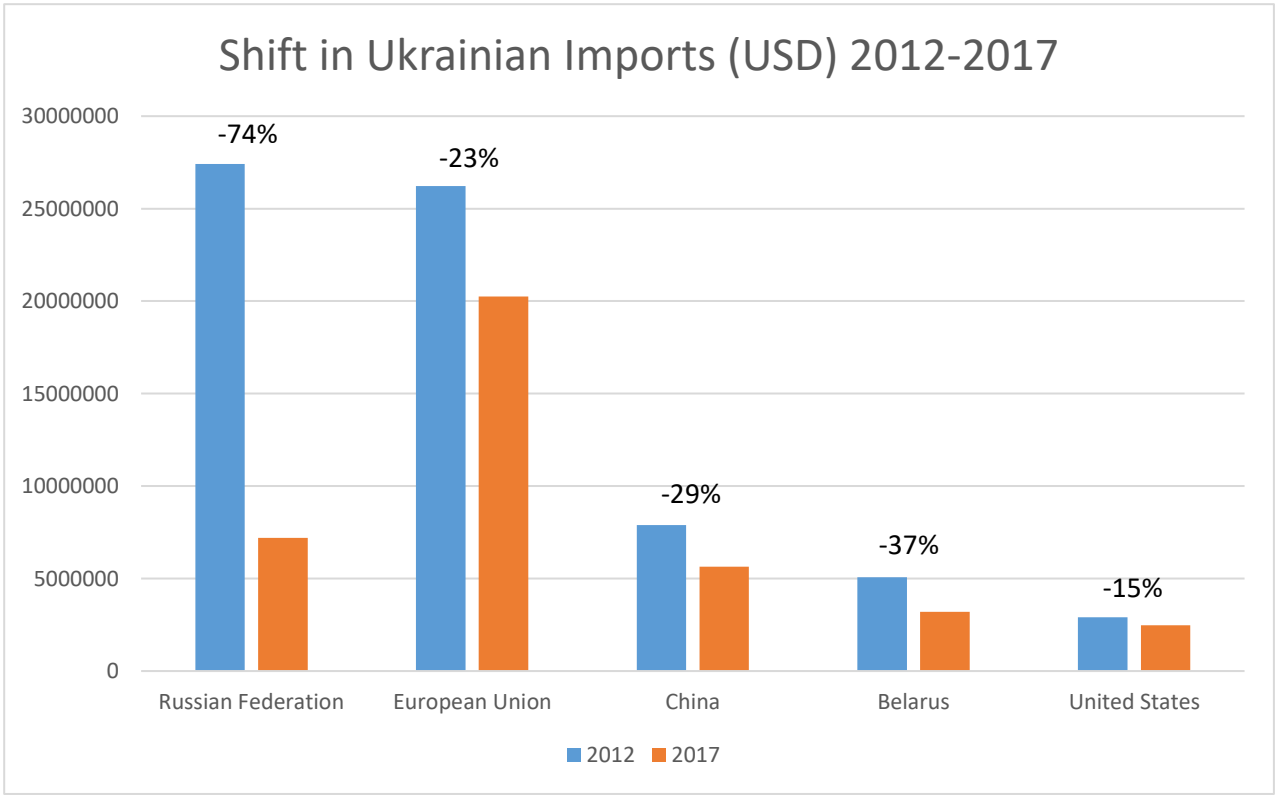
Figure 2: Ukraine's main export and import partners, USD thousand, 2012-17

a. Top Export Partners by Value



Source: UN COMTRADE database

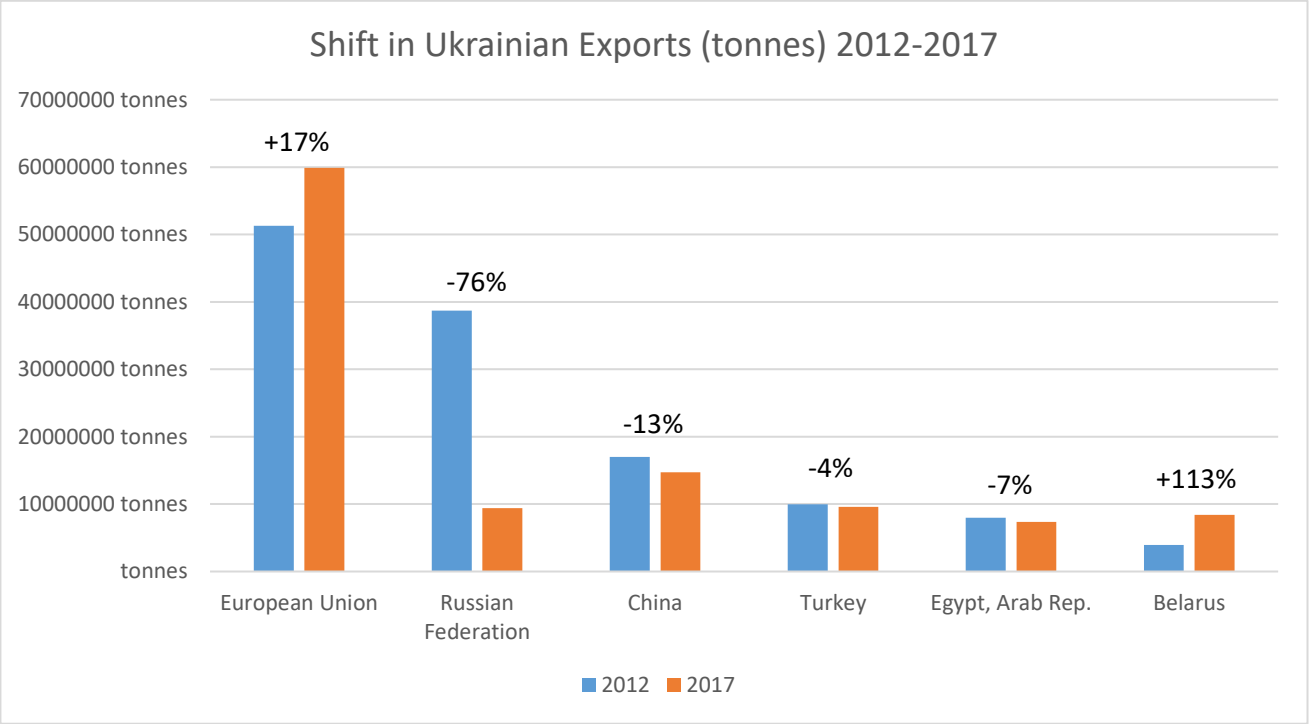
b. Top Import Partners by Value



Source: UN COMTRADE database

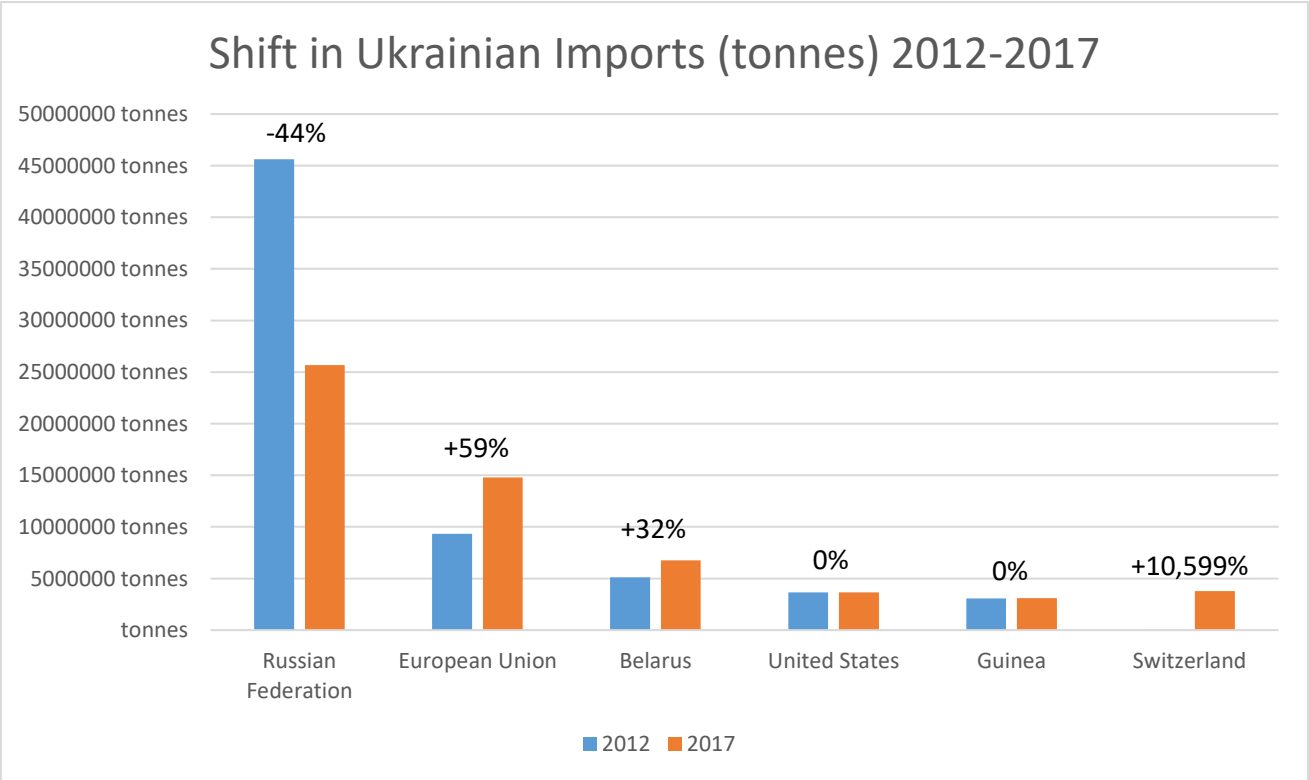
Figure 3: Ukraine's main export and import partners, tonnes, 2012-17

a. Top Export Partners by Volume



Source: UN COMTRADE database

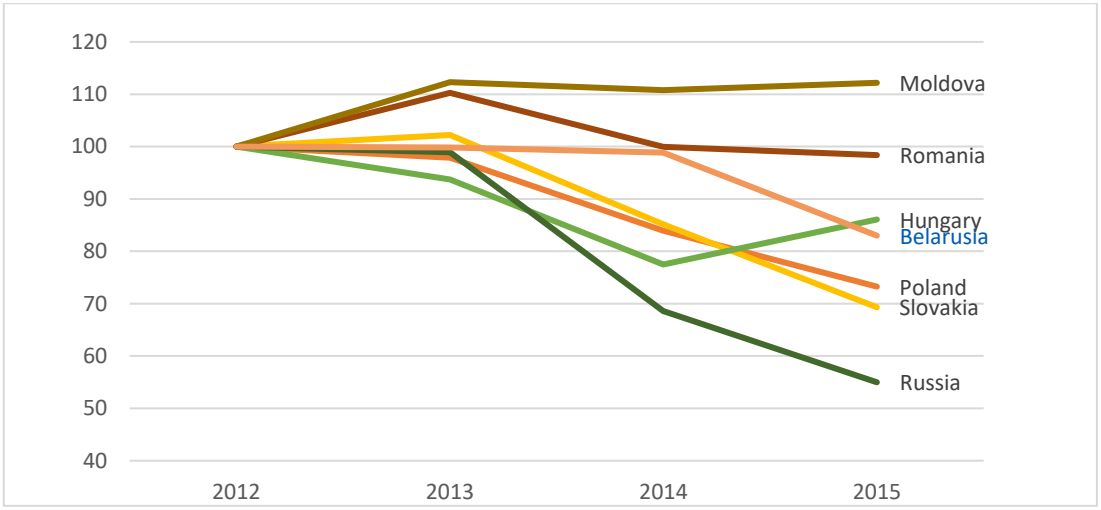
b. Top Import Partners by Volume



Source: UN COMTRADE database

As a result of a 52% decrease in overall trade between 2012 and 2016, there has been a decline in the number of trucks crossing Ukraine's borders.

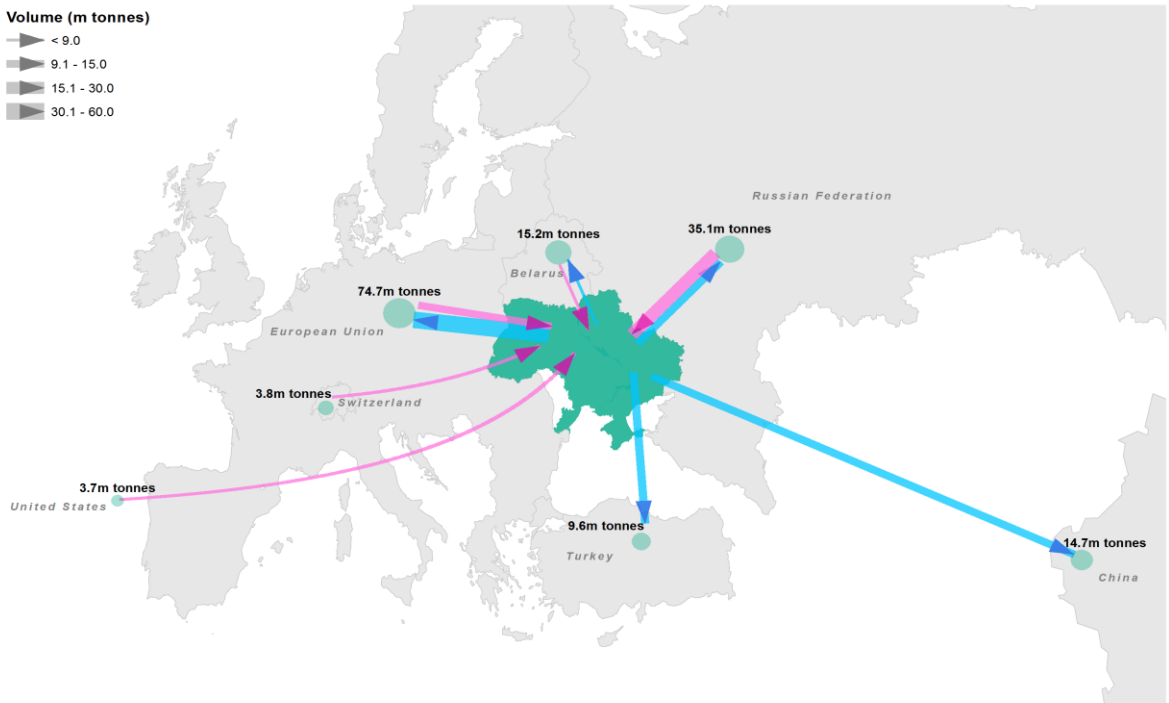
Figure 4: Trucks crossing borders with Ukraine (2012=100)



Source: Ukrainian State Statistics Service, ukrstat.gov.ua

Currently, the EU represents about 33% of all Ukrainian trade in tonnage terms, with a total of about 75 million tonnes transported in 2017.

Figure 5: Ukraine trade in Volume (2017)[2]



Source: UN COMTRADE database

[2] Top 5 export flows and top 5 import flows

These fluctuations in trade represent a shift in freight exchange away from Russia in Ukraine's east, towards an increase with Ukraine's neighbors to the north (Belarus) and west (EU 28), all of which have viable land routes to Ukraine.

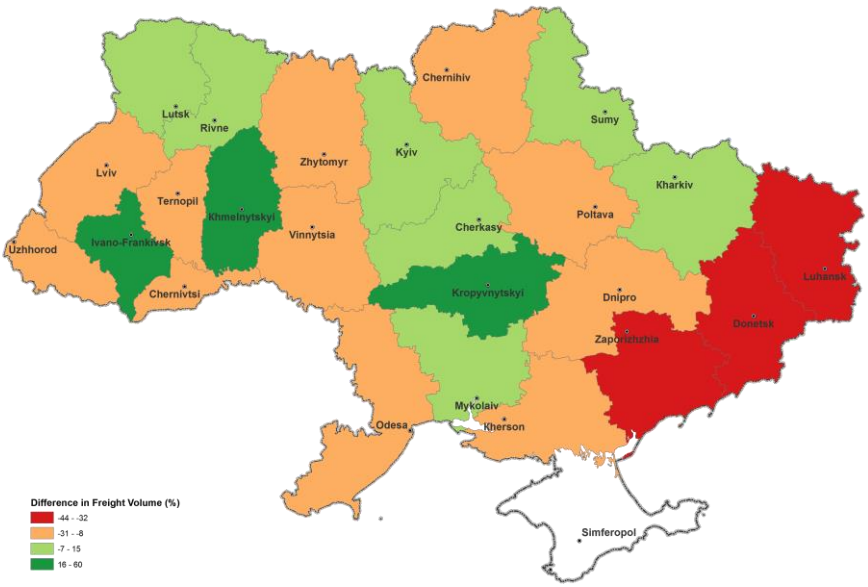
These changes in freight movement will have been accompanied by a shift in pressure on Ukrainian roads and border-crossing points. This substitution of Russian goods with those from elsewhere has also had an impact upon the concentration of Ukrainian trade volumes. In 2012, Ukraine's top 4 trade flows—trade in petroleum gases, pebbles/gravel and coal with Russia, and iron ore with China—accounted for 28% of total trade by volume. While the same commodity classes (with the addition of maize and aluminum ore) still accounted for 28% of total trade in 2017, trade in these goods was spread between 11 different partners (5 of these being members of the EU 28). With trade flows becoming more diffuse across a number of different partners, there is the potential for total trade-generated pressure on Ukraine's roads to be more scattered across the network.

This re-orientation is reflected in both the sector and network priorities listed in Chapter 7 of this report. It is not only important that maintenance- and capacity improvement-related activities take place on the roads affected by trade volume shifts, but that emphasis be put upon improved data collection so that the full impact of external trade shifts on Ukraine's road network can be properly understood.

1.3: National flows and mobility

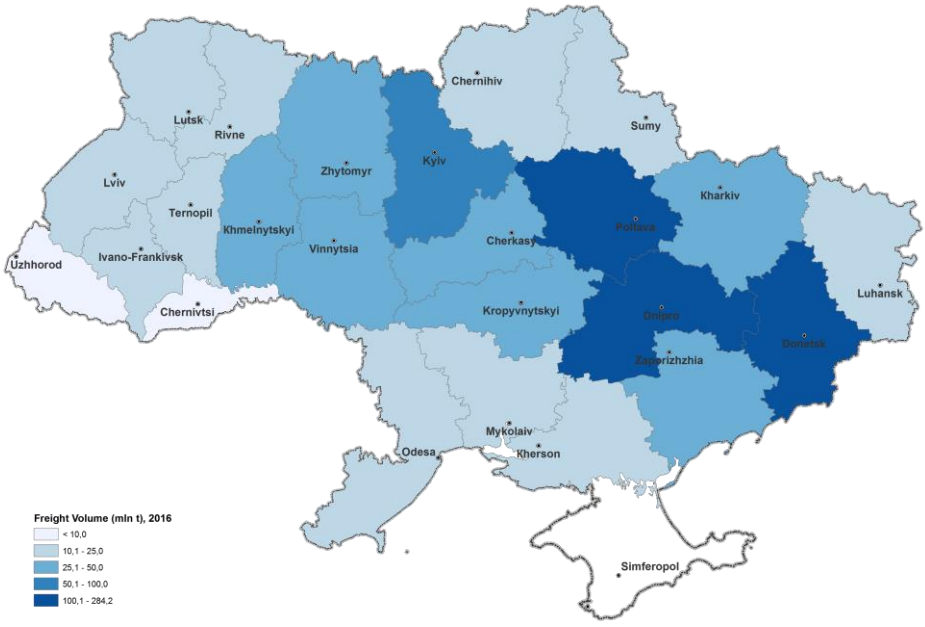
Although the cargo transported domestically decreased by 14% during the 2012-2016 period, the regional distribution varied considerably. While the Donetsk and Luhansk oblasts lost more than 30%, Ivano-Frankivsk oblast saw its volumes increase by 60%, remaining however modest in total. Dnipropetrovsk, generator of about 30% of domestic freight, lost 17% of its volume.

Figure 6: Change in generation of freight by Oblast (2012-2016, percent)



Source: Ukrainian State Statistics Service, ukrstat.gov.ua

Figure 7: Freight Generation by Oblast (2016, million tonnes)



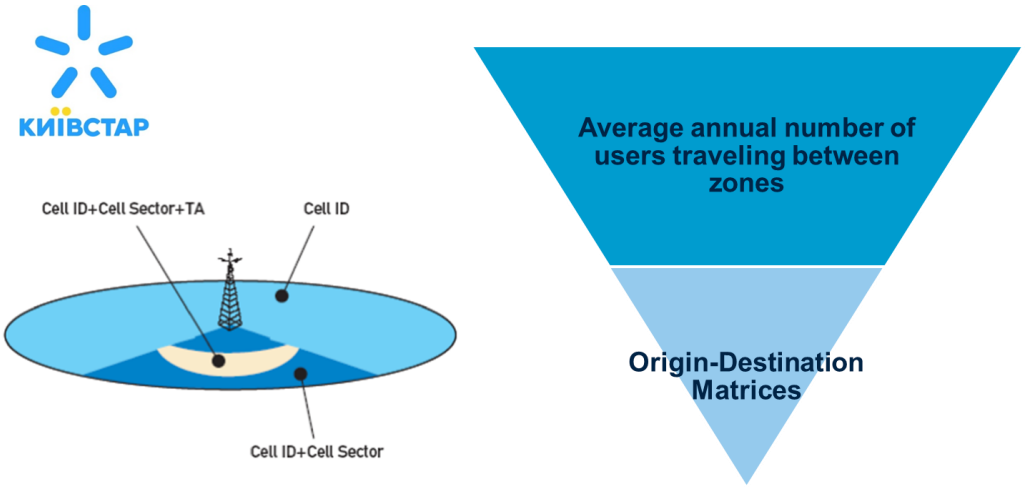
Source: Ukrainian State Statistics Service, ukrstat.gov.ua

The impact for the road sector at national level was a decrease of about 20% in tonnes but only 10% in tonne-km during 2012-2016. In terms of modal split however, particularly due to declining rail and pipeline traffic, the share of freight moving by road has increased 70% (in tonnes) for domestic flows in 2016.

Ideally, origin-destination (OD) data for passenger and trade flows should be collected through OD surveys carried out in many different parts of the network using a significative sample size. Such data is not available in Ukraine. To fill this gap, the WB team sought collaboration from Kyivstar (www.kyivstar.ua/), one of the largest mobile operators in Ukraine, which kindly provided data on the OD flows of mobile phone users. Kyivstar specialists built OD matrices of their subscribers' movements, travelling between zones, by tracking signals of their cell phones, registered by Kyivstar base stations in different locations.

The data on the movements of cell phones has many shortcomings. It does not provide information on vehicle types, number of passengers per vehicle and depends on the number of cell phones per traveler, if any. For these reasons the data is used here as a proxy for movements in general, and in the transport model discussed later, as a source for a prior matrix which is adjusted later. Kyivstar corrected the sample to take account of their competitors' customers and split both by cell sector (as in the figure below) according to their marketing information.

Figure 8: Use of Big Data for OD matrix creation



The map below shows the main 'desire lines' derived from the analysis; the desire lines are straight lines from the center of the origin zone to the center of the destination zones. The map represents only the desire lines characterizing more than 5,000 cell phone movements (trips) per day. While some of the movements relate to freight, most of the desire lines correspond to passenger movements.

Figure 9: Movements of cell phones in Ukraine

Source: World Bank team using data provided by Kyivstar

As one would expect, the main desire lines radiate from the main cities, with a strong density in the western part of the country. Most of the intensive OD pairs have a relatively short distance (about 100 km) except for Kyiv-Odessa with more than 8,000 movements per day. For comparison, the M-05 linking Kyiv to Odessa carries on average 17,000 vehicles per day, but only a proportion of these will travel the entire distance.

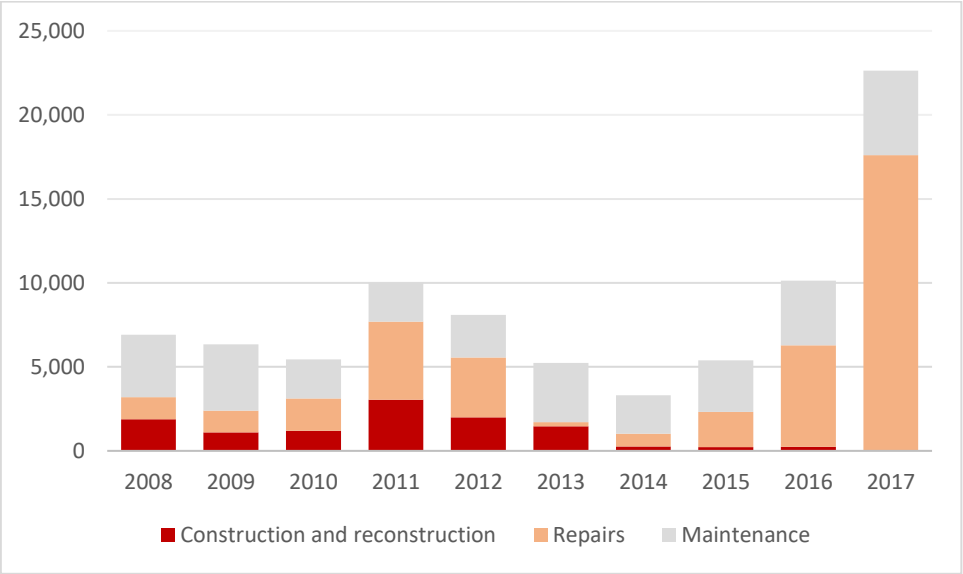
1.4: Road management and expenditure

Ukraine has spent UAH 6.7 billion/year on average during the period 2008-2016 for road construction, reconstruction, repair and maintenance. Out of this, UAH 5.5 billion per year has been dedicated to repair and maintenance, or only about UAH 120,000 (about USD 4,000) per km of road.[3] These expenditures are low by international standards for a network of this size but is consistent with the low level of Ukraine's transport infrastructure investment which, in 2017, was about four-fifths of 1% of GDP.

In 2017, following the first draft of the assessment prepared by the WB in December 2016 on the maintenance and repair needs, which estimated that USD 500 million (about UAH 15 billion) per year was needed to avoid further deterioration of the International, National and Regional roads, an exceptional budget allocation was made and used for road expenditure.

[3] Comprising 47,000 km of International, National, Regional and Territorial roads.

Figure 10: Ukraine road expenditure, 2008-2017 (million UAH)



Source: World Bank team using data provided by Ukravtodor

While there is undoubtedly a shortage of funds for maintenance, a central question is whether the system is efficient enough to ensure that any available resource is well spent. Internally, the underlying cause of almost all problems faced by Ukravtodor is perceived to be a shortage of funding. Supposedly, if more money was available, all of the activities that are currently not possible could be done, solving all of the problems with the road network.

This simplistic argument overlooks the inefficiencies that are widely perceived by the public to have been evident in the past when more money was available. Whatever money is available needs to be used more efficiently, with decisions based on up-to-date data about the road network allied with objective analysis. Decision-making and project implementation need to be sufficiently transparent so that the public can see that the best value for money is being achieved with whatever funding is available. The lack of a reliable pavement management system hinders the planning process. While such a system was adopted in the past, its use has been discontinued. Today, no reliable and up-to-date information on the conditions of the roads is available. Despite more than 200 automatic traffic counters installed in the country, the latest traffic information available dates back to 2008. Many of these counters are damaged or have no power source and are currently not being used, apparently due to lack of finance. Where automatic traffic counters are operable, they often cannot transmit data for lack of funded SIM cards.

Also, there is currently little evidence of effective competition for contracts either for work commissioned from institutes by Ukravtodor or for contracts procured by oblast road service organizations. It appears that government procurement rules are generally being complied with, but the outcome of procurement processes somehow seems to produce little real competition or diversity of suppliers. In many cases, this situation is hardly surprising. Particular institutes have specific skills, experience and equipment that make them the obvious choices for certain specialist contracts. Also, fully equipped and optimally located existing linear road maintenance units could be expected to make it difficult for a new contractor to offer the same service at a lower price.

The procurement law is complied with by various means. For instance, it is understood that if a procurement process fails twice because there is only one bidder, direct negotiations can take place with that bidder. If a proper environment for competitive procurement does not exist, a major

rethink is needed. There is little point in following procedures that are not going to produce the results that are needed. A lack of proper competition, almost inevitably, results in higher costs; and inappropriate procedures lead to delays and extra costs, for instance through repeating failed bidding processes.

In the short term, a way must be found for getting the work done. For instance, if there is only one institute suitable to carry out a contract, find ways to acknowledge this officially and proceed straight to direct procurement but with safeguards to ensure negotiation for best value for money.

In the longer term, the whole contracting environment needs to be restructured to make competition work. For instance, it might be possible to group several linear road maintenance units into a more viable area contract. Larger area contracts over periods of several years might attract more commercially-minded bidders. Centrally procured road data collection for the whole country, perhaps in a small number of lots each covering several oblasts, might enable different institutes to bid competitively.

1.5: Current prioritization framework

The GoU approves 5-year strategies indicating the main road sector development directions. While the previous strategy (2013-2018) identified specific roads, the recently approved strategy for 2018-2022 takes a high-level perspective and does not go into such granular detail.

To prepare and implement the strategy, Ukravtodor coordinates with its regional offices to identify the needs for repairs and reconstruction and combines this information with its wider views on the need to improve certain corridors. The result is a very long list of roads for repair, reconstruction and capacity improvement, without clear prioritization.

The 2013-2018 strategy did not come close to achieving its objectives. While under-funding is asserted, by the new strategy 2018-2022, as the sole reason for the failure of its predecessor, the necessary sector reforms have not been implemented to address systematic issues related to road sector governance.

The new strategy specifies (in its Annex 3) the number of km of construction, reconstruction, repair and maintenance. In total, the plan covers about 6,700 km of roads.

Table 1: Works included in the UAD program, 2018-2022

Name of task	Name of the indicator of the task execution	Unit	Indicator Value					
			Total	including over the years				
				2018	2019	2020	2021	2022
1. New construction of public roads of state importance	the length of the built public roads of state importance	km	325.46	24.29	42.88	44.4	12.32	201.57
2. Reconstruction of public roads of state importance	The length of the reconstructed public roads of state importance	km	431.15	20.56	81.26	106.16	105.24	117.93
3. Capital repairs of public roads of state importance	The length of repaired roads of general use of state importance	km	4347.7	77.94	306.43	1400.55	1198.62	1364.16
4. Current average repair of public roads of state importance	The length of repaired roads of general use of state importance	km	1588.41	950.23	638.19			
5. Provision of a guarantee period of operation of built, reconstructed and capital repairs of public roads of state importance not less than 10 years	length of built, reconstructed and capital repairs of public roads of state importance (1+2+3)	km	5104.32	122.79	430.57	1551.11	1316.19	1683.66

Source: Government of Ukraine

Box 1: Summary of the State Road Program

State target economic program for the development of public roads of state importance for 2018-2022
Approved by the Cabinet of Ministers on March 21, 2018

OBJECTIVES

The purpose of the Program is to restore and develop public roads of state importance for their integration into the European transport system and increase the level of traffic safety, speed, comfort and cost-effectiveness of transportation.

KEY PROGRAM IMPLEMENTATION ASPECTS

- completion of unfinished construction projects with high readiness and socioeconomic efficiency indicators;
- implementation of projects under the scheme "design and construction" ("Design and Build");
- introduction of long-term contracts (for five or seven years) on the maintenance
- intensification of cooperation with international financial organizations to optimize previously borrowed funds for the development of highways;
- introduction of an independent quality control system
- phased transition to the organization of the implementation of road construction works involving the consultant engineer based on the internationally recognized standard forms of contracts, including contracts "FIDIC"
- intensification of innovative and scientific and technical activities
- introduction of a geographic information system for the management of highways
- ecological safety
- unimpeded access of persons with disabilities and other less-mobile groups to road infrastructure
- introduction of traffic safety audit as a systematic, detailed, technical, independent process
- the introduction of automatic dimensional and weight control

KEY EXPECTED RESULTS

- Improvement of the transport and operational condition of public highway roads of state importance on the main routes; new construction and reconstruction of highways in accordance with modern European standards with appropriate road infrastructure;
- collection of additional funds from road transit transportation and development of automobile tourism;
- wider use of export and logistics potential of Ukraine;
- reduction of the cost of transportation of goods and passengers and increase of profits on road transport in connection with improvement of conditions of operation of motor transport;
- saving capital investments in road transport due to increased productivity of road transport due to increased average speed on repaired sections of the road;
- reduction of traffic accidents losses due to unsatisfactory condition of highways;
- the economic effect of reducing the negative impact on the environment;
- stable demand on the domestic market for production of mining and processing industry, metallurgy and other industries;
- increase of the revenue part of budgets of all levels due to the repayment of funds in the form of taxes and obligatory payments;
- strengthening of quality control and financing of roads by users;
- reducing the level of subjective interference in the financing of road development;
- creation of conditions for the development of public roads of state importance in accordance with the requirements of European and world standards;
- physical access of telecommunication operators to transport infrastructure
- the warranty period for the operation of new construction, reconstruction and overhaul of public roads of state importance for at least 10 years.

RESOURCES NEEDED

The estimated amount to fund the program is UAH 298 billion, including UAH 178 billion from the state RF, UAH 6 billion from general budget and UAH 114 billion on loans including UAH 68 billion from IFIs.

1.6: Towards a systematic approach

The approach adopted by the WB team herein separately identifies short-term network expenditure priorities (maintenance and rehabilitation of existing roads) and longer-term investment priorities (network capacity expansion through new roads and road upgrading), for which two different methodologies have been applied:

- **The short to medium-term priorities** have been based on analysis using the WB-originated HDM-4 road maintenance and investment model, described in Section 3.[4]
- **The medium to long-term priorities** have used a more broadly-based and strategically-oriented transport model, described in Section 4.

In addition, the International Finance Corporation (IFC) financed a technical consulting study to consider, inter alia: the necessary annual level of roads expenditure compared with the current budgetary provision; the likely stream of income from the national RF established in January 2018 and possible additional revenue sources; a proposed methodology for identifying and screening projects that might be implemented through public private partnership (PPP) structures; and the necessary conditions to promote private sector involvement in the roads sector.

The recommendations in this report incorporate the full range of work undertaken by the WBG.

[4] The HDM-4 model has been used by the WBG in project appraisals throughout the world, and by and for many highway authorities including in Australia, United Kingdom Malawi, China, India, Kazakhstan and Cameroon.

2: MAIN ROADS NETWORK

2.1: Network classification

Ukraine has around 23,573 km of main roads.[5] This network is sub-divided by Ukravtodor, using a long-standing functional classification, into three classes: (i) International roads (M roads) with total length of around 8,653 km; (ii) National roads (H roads) comprising 4,830 km; and (iii) Regional roads (P roads) comprising 10,089km (Figure 11). This functional classification of roads in Ukraine dates from soviet times: this report later uses the concept of 'strategic corridors' that reflect current functional/policy significance to assist in investment prioritization.

The network included in this analysis includes 20,760 km of roads since no data was available for the remaining 2,813 km which are mainly located in Oblasts in conflict zones.

Figure 11: Ukraine main road network by International, National and Regional road class.

Source: World Bank team using data provided by Ukravtodor

Of the total main roads network, about 88% consists of single-carriageway road and 12% of multi-carriageway road, predominantly of four-lanes total.

[5] Resolution N0 712 (Sept 2015) http://zakon3.rada.gov.ua/laws/show/712-2015-%D0%BF.
There are also about 25,000 km of Territorial (T) roads under responsibility of Ukravtodor.

2.2: Network condition

A high proportion of the main roads network (87%) is in sustainable condition, not yet requiring capital rehabilitation (with roughness ratings of very good, good or fair condition). But a high proportion (41%) is rated for roughness as only 'fair', indicating the need for current repairs. In terms of cracking, just over half the main road network (54%) displays cracks of between 15% and 50% of road surface, which reinforces the case for current repairs. In the absence of adequate current maintenance, the main roads will deteriorate faster and bring forward the time when capital rehabilitation is necessary.

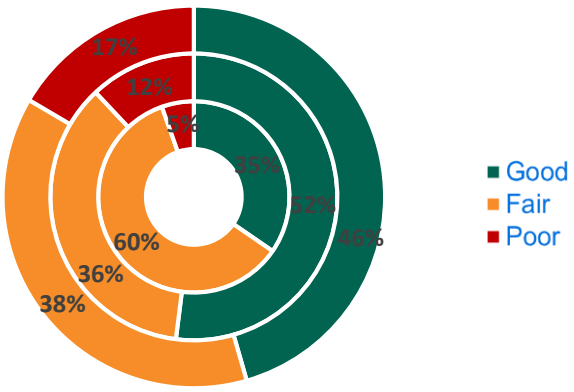
As might be expected, the International roads are in better condition than the National or Regional roads as expressed by roughness or cracking. Figure 12 indicates the distribution of roughness ratings across the main roads network. The highest rating (shown in red) indicates the roughest road sections.

Figure 12: Geographic distribution of roughness ratings across the main road network.

Source: World Bank team using data provided by Ukravtodor

Because of the underinvestment in maintenance, the proportion of roads in poor condition (IRI >6) has been increasing over time. Figure 13 shows that in 5 years, the share of roads in poor condition increased more than three times.

Figure 13: Road conditions in 2011, 2013 and 2016



Source: World Bank team using data provided by Ukravtodor

2.3: Traffic levels

The traffic density on the main road network is not high. The average traffic density is about 5,200 vehicles/day and only 15% of the International, National and Regional roads carry more than 10,000 vehicles/day. However, just over half (51%) of the traffic is carried on the International (M-class) roads which have an average 8,600 vehicles/day. About 23% of traffic is on national (N-class roads) carrying an average of 6,700 vehicles/day. The 26% of traffic on Regional (R-class roads) represents only about 3,100 vehicles/day. Figure 14 shows the intensity of traffic flows over different links in the main roads network.

Ukrainian roads carry an average 30% of heavy vehicles (trucks): this share is 32% on International roads, 30% on National roads and 28% on Regional roads. Only on a few roads is heavy traffic more than 50%: these are M-17, M-20, M-29 and P-03.

Figure 14: Intensity of traffic flows across the main roads network in 2016.

Source: World Bank team using data provided by Ukravtodor

2.4: Strategic network

Section 2.1 noted that the current official functional classification of Ukraine's roads does not necessarily reflect all critical parameters of importance. For purposes of project prioritization, the study sought to identify a 'strategic network'. This was defined to include (a) Corridors of International Importance, and (b) National Connectivity Links. These two sub-networks are described and amalgamated below.

2.4.1: Corridors of international importance

One useful dimension of road significance is whether it is part of an internationally recognized cross-border road network, such as the European (E-roads) network[6], the EU's TEN-T network[7] or the TRACECA[8] Corridors. It also includes the corridors classified by UAD as of international importance. Figure 15 indicates Ukraine's eight main international road corridors.

[6] The international E-road network is a numbering system for roads in Europe developed by the United Nations Economic Commission for Europe (UNECE).

[7] The Trans-European Transport Networks for Transport (TEN-T) covers all l EU Member States, the Western Balkans and the Eastern Partnership (Ukraine, Moldova, Belarus, Georgia, Armenia and Azerbaijan).

[8] The International Transport Corridor Europe-Caucasus-Asia (TRACECA) is a series of linked multi-modal transport corridors between countries which aims to develop economic and trade relations and transportation links between countries and regions.

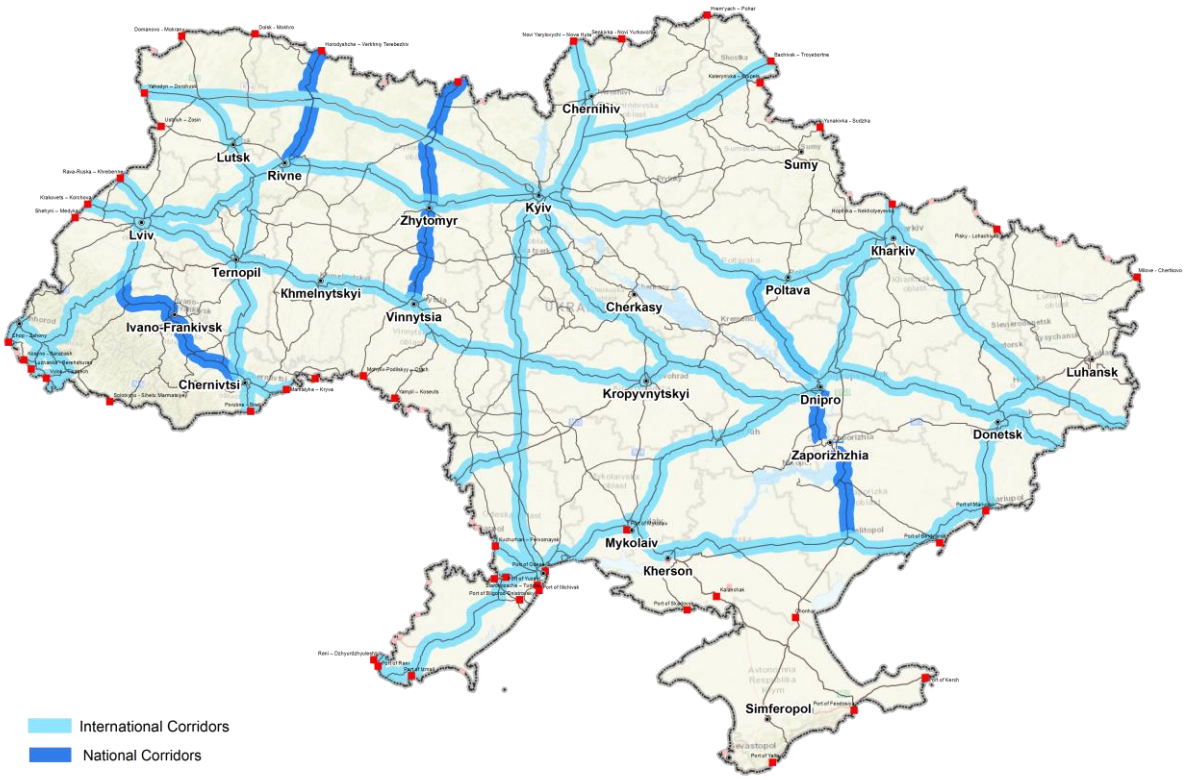
Figure 15: Road Corridors of International Importance

Source: World Bank team

2.4.2: National Connectivity Links

A strategic network must include not only roads of international importance but also the most intensely used domestic routes. These are referred to the 'national connectivity' links because they contribute disproportionately to the connectedness of different parts of the country. The national connectivity links were identified by developing a matrix of current travel origins and destinations synthesized from analysis of aggregate people movements in the country, based on data held by telecommunications company Kyivstar. Figure 16 combines the main national connectivity links with corridors of international importance to identify a strategic road network for analysis purposes.

Figure 16: National connectivity links

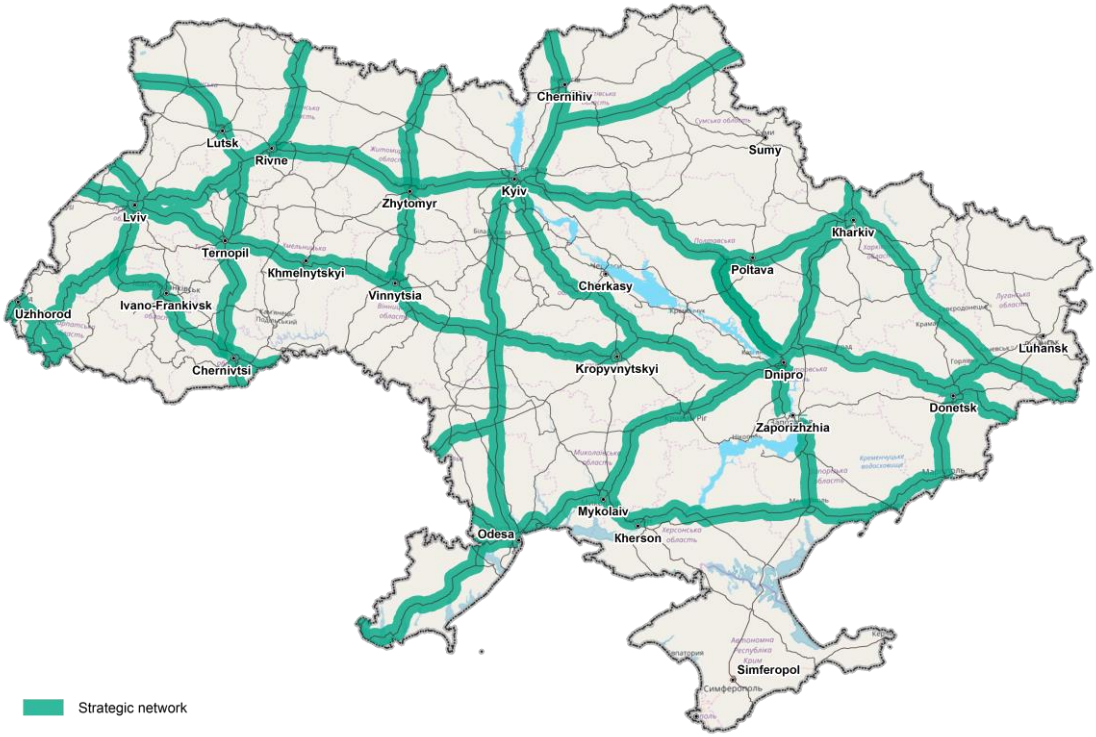


Source: World Bank team

2.4.3: Strategic network

Combining the networks of international and national importance and removing those sections which are TEN-T comprehensive only (not overlapping with other corridors) provides a useful concept of the strategic network for Ukraine.

Figure 17: Strategic Network



Source: World Bank team

3: SHORT TO MEDIUM-TERM INVESTMENT PRIORITIES

3.1: Approach

This study evaluated the current repair and capital repair needs of the International, National and Regional Roads of Ukraine, which are managed by the Ukraine State Roads Agency (Ukravtodor). This evaluation used the Highway Development and Management Model (HDM-4)[9] developed by the WB and other international organizations over the last three decades.

This evaluation was based on the data collected by Ukravtodor during the period October 2016 to April 2017. The data included the network inventory, condition and traffic, and unit costs of road works and vehicle operation. The HDM-4 model was used to evaluate a matrix of 109 representative Ukrainian road condition categories based on the number of lanes, roughness, area of cracks, and traffic volume. Each road class was evaluated with HDM-4 with the objective of identifying the optimal treatment (current repair or capital repair), timing of the treatment, and cost of the treatment per road category and the corresponding economic indicators. The resulting reduction of road user costs (vehicle operating costs[10] and travel time costs) was estimated over the evaluation period by comparing the 'with-treatment' case with a 'without-treatment' (base) case. The cost of each maintenance treatment (or project) is brought together with these road user cost reductions (the user benefits) to measure what is known as the Net Present Value (NPV) of the project.[11]

The current repair works were subdivided into 5 representative repair treatments of the surface layer, defined by the resulting repaired surface layer thickness. The capital repair works were subdivided into 5 representative pavement reconstruction options representing different resulting pavement structures, defined by a pavement Structural Number (an index that is indicative of the total strength of the pavement) as defined by AASHTO[12]. See Annex 1 for more details.

The first stage of the evaluation was to identify a road maintenance works program for 2018 to 2022 in the absence of budget constraints (the unconstrained scenario), and then set maintenance priorities under budget constraints (constrained scenarios).

3.2: Unconstrained scenario

The International, National and Regional Roads of Ukraine (main roads) total around 23,573 km. The HDM-4 evaluation shows that, for the main roads network of around 20,760 km for which road condition and traffic data is available (88% of all main roads managed by Ukravtodor), the financial requirements to fully eliminate the backlog of current repair and capital repair needs amounts to USD 5.7 billion (UAH 148.2 billion) that is an average USD 1.14 billion (UAH 30 billion) per year from 2018 to 2022. This would bring the proportion of the network in good condition from the current 46% to 96% by 2022.

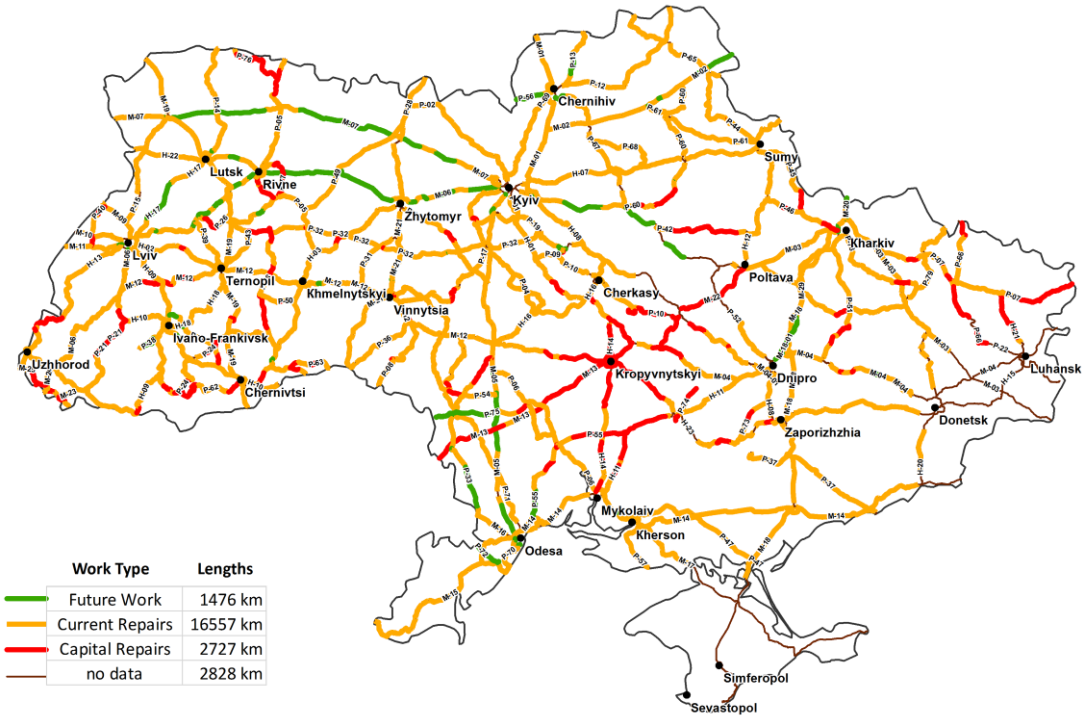
Thereafter, the current repair and capital repair needs over the period from 2023 to 2033 would reduce to about USD 393 million/year (UAH 10.2 billion/year). In addition, recurrent maintenance road works (routine maintenance and winter maintenance) are needed, which were estimated to

[9] http://www.hdmglobal.com/
[10] Vehicle operating costs include fuel, maintenance, tyres, lubricants and depreciation.
[11] Net Present Value is the aggregate present value of a future stream of costs and benefits of a project discounted at a rate of 8% annually.
[12] American Association of State Highway and Transportation Officials

amount to USD 97 million/year (UAH 2.22 billion/year) for the main roads managed by Ukravtodor. Figure 18 shows where the current and capital repairs would be required to achieve this impact.

However, the full elimination of the road preservation works backlog by 2022 (that is, to complete all the works shown on Figure 18) represents an unrealistic or 'unconstrained' expectation. In practice, it is important to consider the financial limitations and implementation capacity constraints of Ukravtodor and the road sector of Ukraine generally. To do this it is necessary to prioritize the sections to be maintained, allowing for budget constraints.

Figure 18: Locations of 'budget-unconstrained' scenario maintenance priorities



Source: World Bank team

Table 2 below presents the distribution of the required expenditures in the first five years per road work class (current repair or capital repair) for the Unconstrained scenario. In this case, capital repair expenditures (USD 1.7 billion) correspond to 30% of the total expenditures (USD 5.7 billion[13]). Road works are needed on 19,284 km of roads.

[13] The Unconstrained scenario typically does not yield a uniform distribution of expenditures per year because that is not criteria for the selection of the recommended road work per road class, which is based only on economic considerations.

Table 2: Road Works Requirements Unconstrained Budget

Unconstrained Scenario	Preservation Capital Expenditures (m US$)		
Year	Current	Capital	Total
2018	1,404	734	2,138
2019	582	0	582
2020	853	892	1,746
2021	516	48	563
2022	635	0	635
Total	3,991	1,673	5,664
Percent	70.5%	29.5%	100.0%
	Preservation Capital Works (km)		
Year	Current	Capital	Total
2018	5,217	1,196	6,413
2019	2,184	0	2,184
2020	3,424	1,455	4,879
2021	2,431	76	2,507
2022	3,301	0	3,301
Total	16,557	2,727	19,284
Percent	85.9%	14.1%	100.0%

Source: World Bank team

Table 3 presents the distribution of the required road works for the Unconstrained scenario for each Oblast.

Table 3: Current and Capital Repairs Works Unconstrained Scenario per Oblast

	Road Works over Next 5 Years						Economic Priority	
Oblast	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
Cherkasy	224	47	271	830	76	906	830	3.1
Chernihiv	237	0	237	1,135	0	1,135	553	2.3
Chernivtsi	80	47	127	327	76	403	288	2.3
Dnipropetrovsk	226	65	291	877	106	982	757	2.6
Donetsk	103	0	103	332	0	332	978	9.5
Ivano-Frankivsk	145	111	256	595	181	776	1,331	5.2
Kharkiv	305	78	383	1,172	127	1,299	1,713	4.5
Kherson	169	0	169	675	0	675	422	2.5
Khmelnytskiy	179	85	264	683	139	822	550	2.1
Kirovohrad	40	373	413	159	608	767	479	1.2
Kyiv	334	6	341	1,321	10	1,331	1,540	4.5
Luhansk	43	154	198	174	251	425	157	0.8
Lviv	142	26	168	900	42	942	981	5.8
Mykolaiv	121	183	303	533	298	830	428	1.4
Odesa	240	60	300	1,046	98	1,144	1,013	3.4
Poltava	76	160	236	282	261	543	827	3.5
Rivno	77	117	194	383	191	574	431	2.2
Sumy	195	9	203	842	14	856	442	2.2
Ternopil	162	19	181	649	32	681	367	2.0
Vinnytsa	278	33	312	1,032	53	1,085	875	2.8
Volyn	137	0	137	623	0	623	461	3.4
Zakarpattia	140	89	229	547	146	693	711	3.1
Zaporizhya	173	0	173	713	0	713	545	3.2
Zhytomyr	166	11	176	726	17	744	469	2.7
Grand Total	3,991	1,673	5,664	16,557	2,727	19,284	17,147	3.0

Source: World Bank team

3.3: Constrained budget scenario

Different budget constraint scenarios were evaluated. For each budget level, the road sections that compose the network were sorted by economic priority. Economic priority was attained by maximizing the NPV of the Road User Benefits per the Present Value of Road Work Costs (PVC)[14] to help plan a rationally prioritized program of road works under budget constraints.

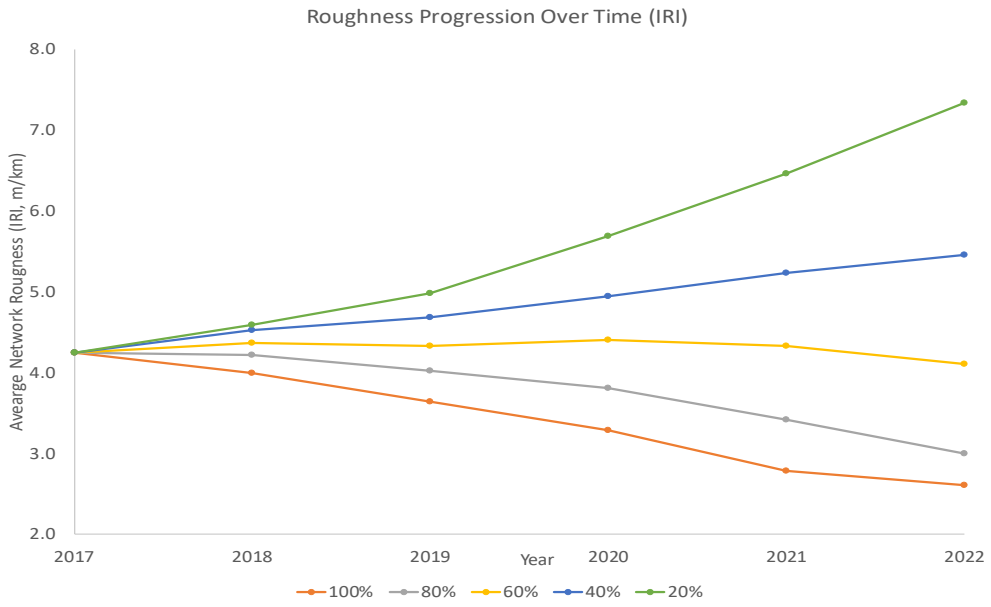
A range of budget scenarios were evaluated using HDM-4. As a result, it is suggested that a scenario based on a budget of at least 50 to 60% of the unconstrained level should be targeted because this level of funding is necessary to prevent the existing network from further deterioration. The 60% scenario would deliver a target of 67% of main roads in very good or good condition by 2022; this is

[14] The ratio of NPV to Present value of capital costs (NPV/PVC) is a measure of capital efficiency that is well-suited to a situation on which capital resources are constrained.

better than the current 46% and would marginally improve the average network roughness. Therefore, this scenario represents approximately maintaining the current network condition over the next five years and so prevent the maintenance backlog growing.

This program would entail capital repairs on 1,200 km of roads and current repairs on 14,130 km of roads. This would cost around USD 3.6 billion (UAH 93.6 billion) or USD 718 million/year (UAH 18.7 billion/year) for current repairs and capital rehabilitation works. However, it is important to acknowledge that this 'no further deterioration' scenario would not tackle the substantial maintenance backlog.

Figure 19: Progression of roughness under different budget assumptions



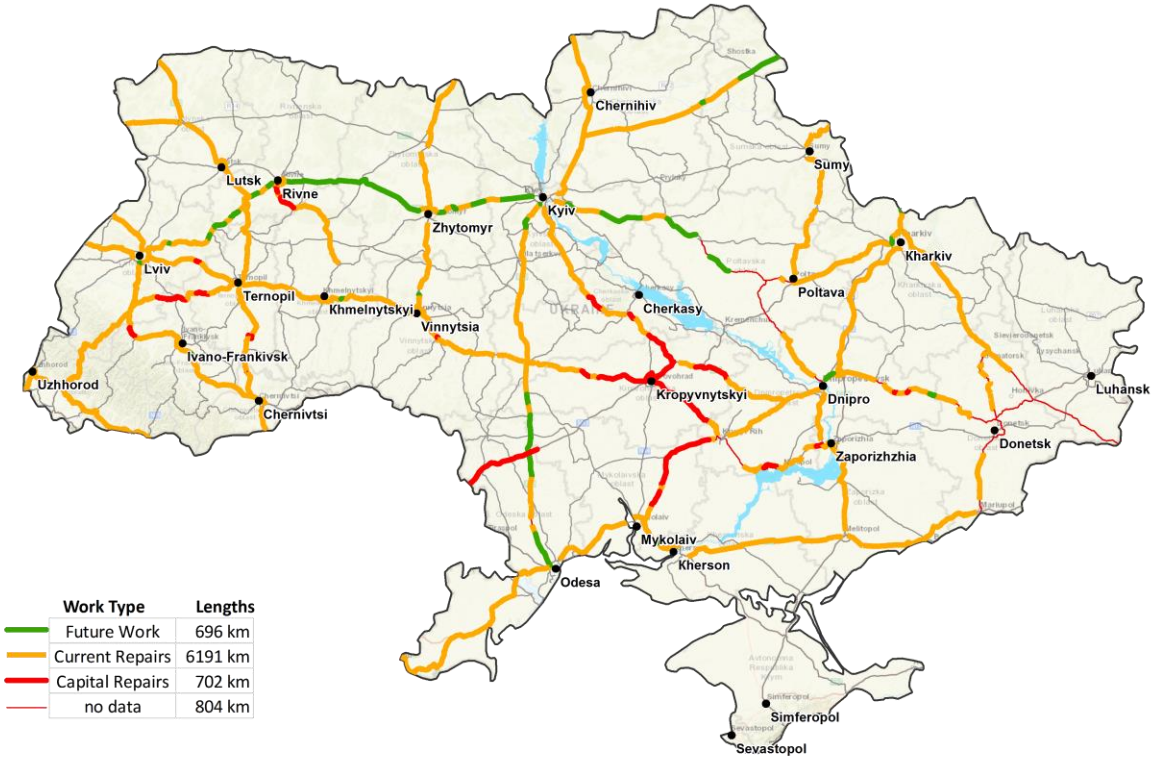
Source: World Bank team

While this budget represents much more than what has been allocated for the transport sector in the past, it could be accommodated within the RF (which will be discussed on chapter 5). The clear implication is that more will need to be spent on the maintenance of Ukraine's main roads just to preserve their current unsatisfactory condition. The detailed Excel spreadsheets, which provide results broken down by road-class, year and oblast have been provided to Ukravtodor.

3.4: Priorities on the strategic network

The HDM-4 assessment described in Sections 3.2 and 3.3 above evaluated the entire main roads network and the used of budget distributed across the road network. An alternative approach to prioritization would be to focus the budget on strategic corridors. The strategic network defined in section 2.4 comprised 7,500 km of roads. The financial needs on the strategic network would be of USD 1.93 billion (UAH 50.2 billion), roughly one-third of the financial needs to cover the entire network. Figure 20 indicates the location of maintenance works prioritized to these corridors using the HDM-4 methodology.

Figure 20: Road maintenance priorities along strategic network



Source: World Bank team

4: MEDIUM TO LONG TERM INVESTMENT PRIORITIES

4.1: Approach

The scope of analysis in Section 3 is about short- to medium-term priorities: that is about maintenance and rehabilitation expenditures to try to prevent further deterioration in the condition of existing roads. Section 4 addresses the issue of capital investment in expanding and upgrading the road network: seeking to identify those investments in the road network that should be prioritized given the budget constraints that will exist for the foreseeable future, even with an expanding RF.

A Ukraine-specific transport model was developed by the WB to support the prioritization of medium- to long-term road investments. The four main components of the model are:

1. A computer model of the current network containing all the main links in the network

The starting point of the model was the network preparation. The WB team developed a very detailed road network for Ukraine in GIS ESRI format, including all the relevant attributes needed for the development of the model. Details on distance, free flow speed, IRI (then used to derive capacity), number of lanes and others, were specified for the whole network. In addition to data describing the geometric and functional characteristics of the network, it includes several details related the Annual Average Daily Traffic (AADT) on a vast number of links.

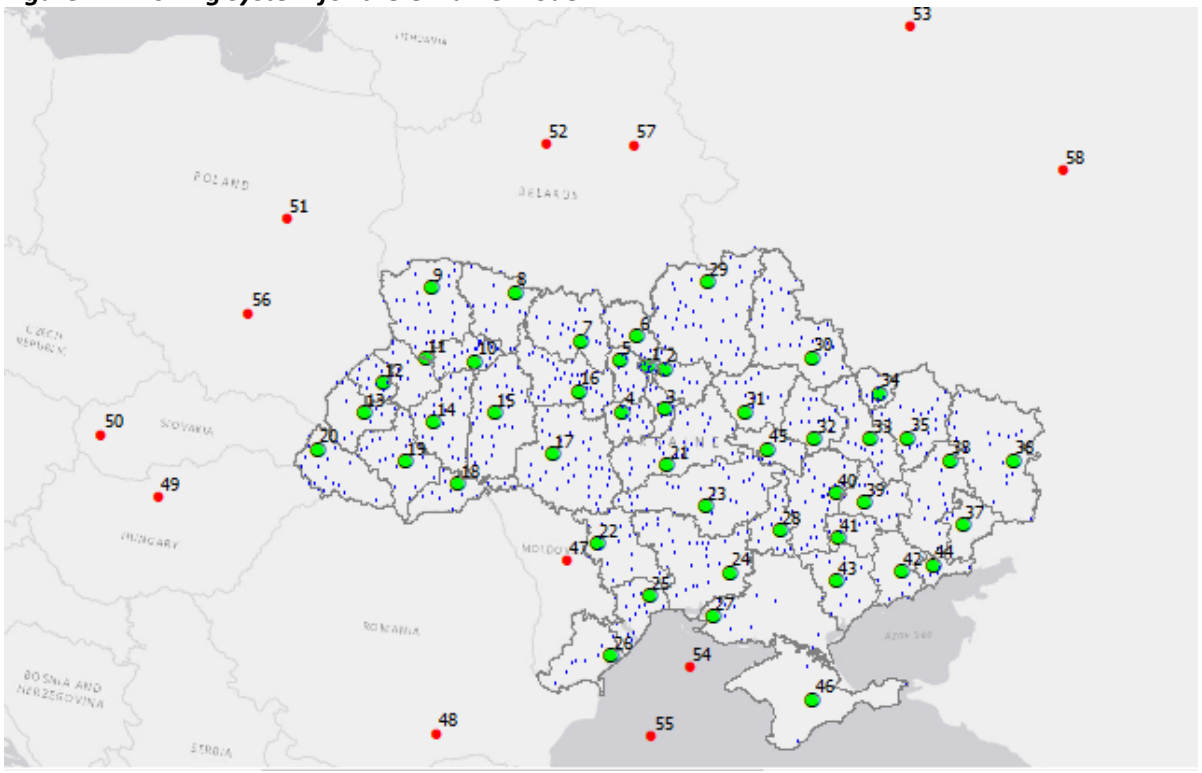
The network includes details and information pertaining to future projects, so to make possible the analysis and evaluation of impacts of either building new infrastructure or improving the quality of the existing network.

2.A matrix of current travel origins and destinations

An OD matrix was synthesized from an analysis of aggregate people movements in the country based on data held by telecommunications company Kyivstar and adjusted to reflect the available traffic counts on key sections.

The zoning system of the Ukraine model is comprised of 58 zones, 46 of them internal (shown in green, these represent either an oblast, a part of an oblast or a main city) and 12 of them external (shown in red).

Figure 21: Zoning system for the Ukraine model



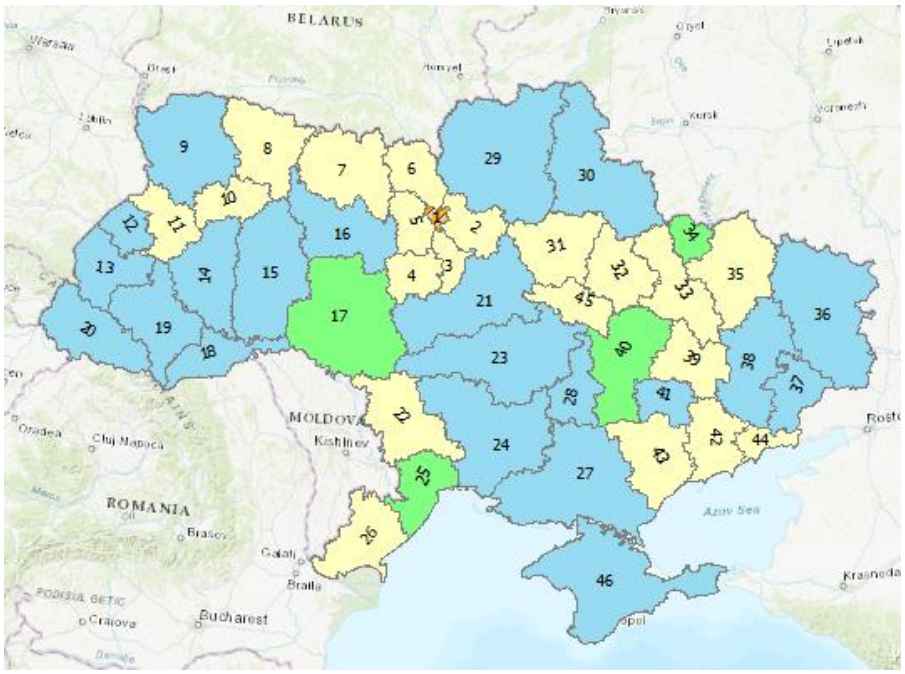
3. A forecast of how travel demands would grow in the future

The zones where split into four groups according to the expected traffic growth

- Kyiv 4% p.a.
- High growth 3% p.a., in green
- Medium growth 2% p.a., in blue
- Low growth 1% p.a., in yellow

The list of growth by zone is provided in Annex 2.

Figure 22: Growth rates by zone



4. An 'assignment model'

The assignment model matches origin to destination flows with the most likely routes of travel, validated by reference to actual recorded traffic flows on sections, considering specific cost functions expressed in monetary costs and different by modes:

$$GenCost_{Car} = VOC_{Car} * Distance + VOT_{Car} * \frac{Time}{60} + Toll$$

$$GenCost_{Bus} = VOC_{Bus} * Distance + VOT_{Bus} * \frac{Time}{60} + Toll$$

$$GenCost_{Truck} = VOC_{Truck} * Distance + VOT_{Truck} * \frac{Time}{60} + Toll$$

Where

- VOC_{Car} represents Vehicle Operating Cost for cars;
- VOT_{Car} represents Value of Time for cars;
- VOC_{Bus} represents Vehicle Operating Cost for buses;
- VOT_{Bus} represents Value of Time for buses;
- VOC_{Truck} represents Vehicle Operating Cost for trucks;
- VOT_{Truck} represents Value of Time for trucks;

A congestion function adjusts the travel time according to the following equation:

$$t = t_0 \times \left(1 + \alpha * \left(\frac{V}{C}\right)^{\beta}\right)$$

Where:

- t is the time with congestion
- t_0 is the time without congestion (at free-flow speed)
- V is the volume on the link
- C is the capacity of the link

The fundamental parameters of the equation used in the model are:

- α: 0.5
- β: 4

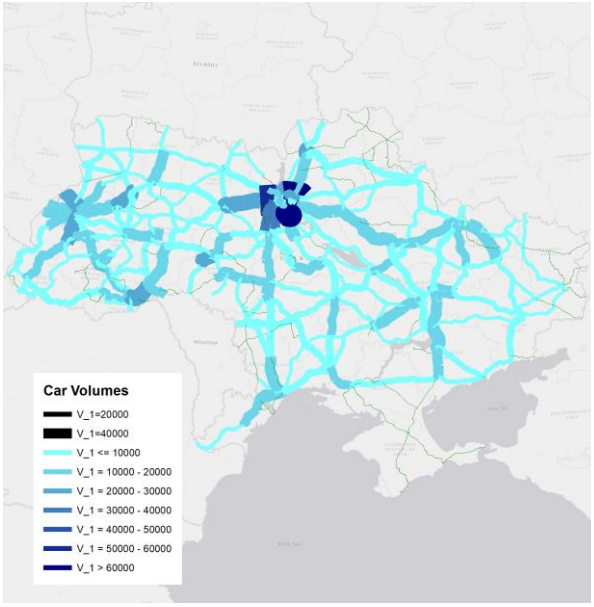
The four main outputs provided by the analysis are:

1. A forecast of future traffic levels

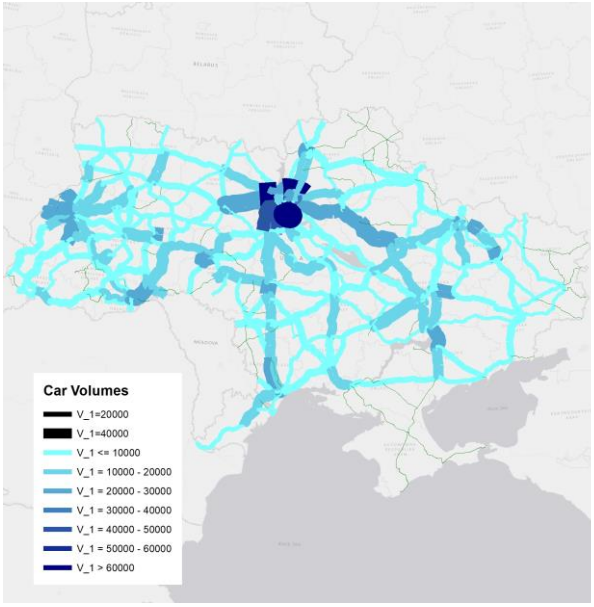
The model assigns the future demand on the network providing the forecast traffic for each link.

Figure 23: Network assignment for 2025 and 2030

Year 2025



Year 2030

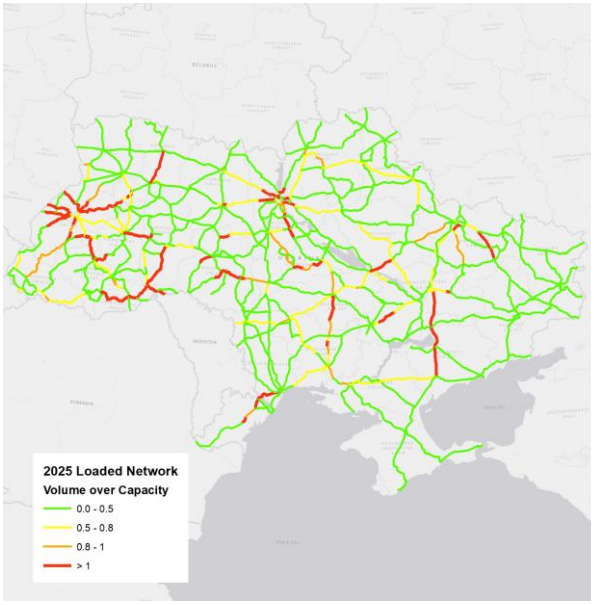


2.Estimates of the impact of future traffic flows on various parts of the network

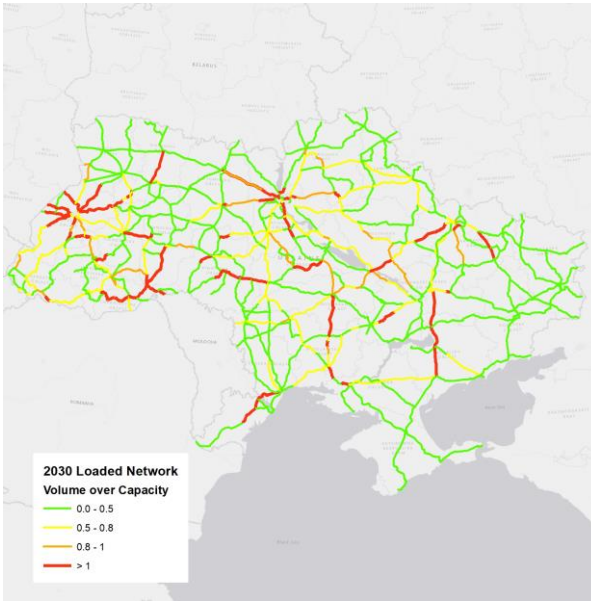
The network assessment provides information of where capacity constraints exist or are likely to arise in the future as traffic increases.

Figure 24: Volume-capacity ratios for 2025 and 2030

Year 2025



Year 2030



3.An estimation of savings in travel time and vehicle operating costs

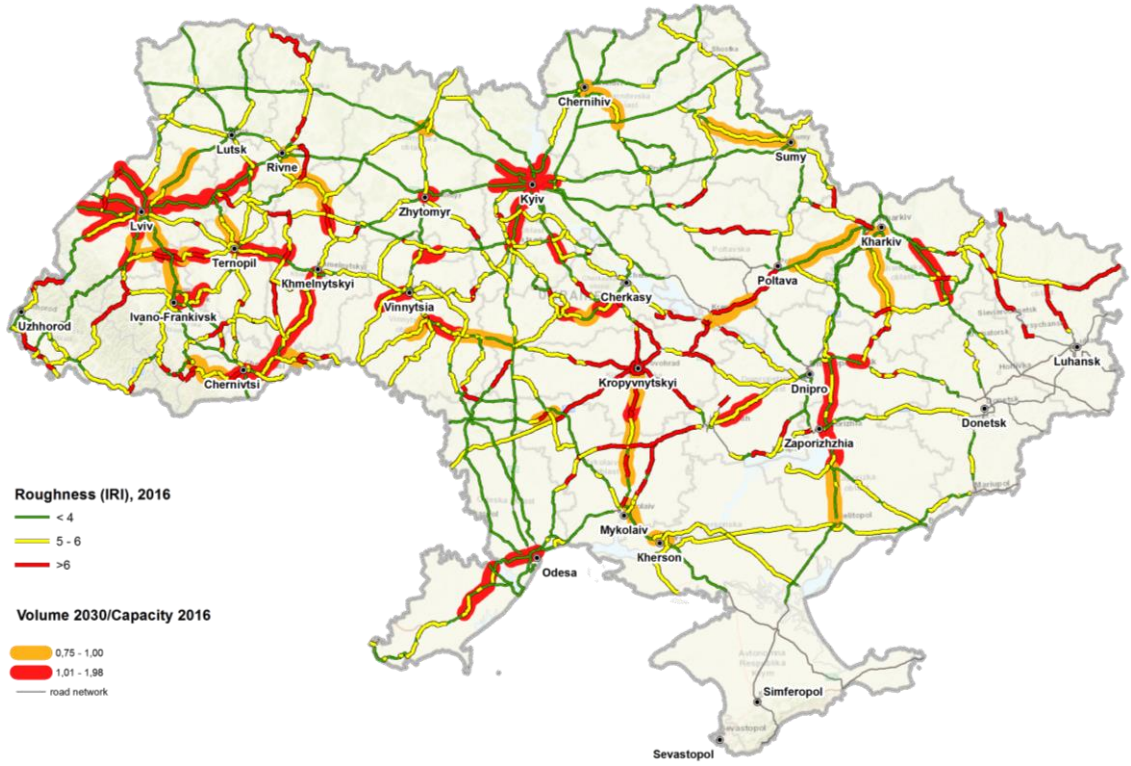
The inclusion of a project is represented in the model as either a new link of changing the characteristics of an existing link, such as its capacity, roughness and free-flow speed.

The model computes the time and the vehicle operating costs savings by comparing the with and the without project situation. These savings can then be used as an input to (a) an economic evaluation of each improvement and (b) prioritization based on relative economic performance.

4.2: Capacity improvement needed

Figure 25 below provides a good indication for the need of rehabilitation/capacity improvement by combining the information on the condition of the roads and the estimated congestion level in 2030 taking into account the expected traffic and the current capacity of the roads. In addition, the assessment shows that the network is sufficiently mature not to require wholly new construction projects (new links between cities or economic poles).

Figure 25: Need for capacity improvement



The main critical sections appear to be:

- M-06 from Rivne to Lviv (USD 613 million) and Lviv to Stryi (USD 276 million), which would constitute a continuation of the recently upgraded section from Kyiv to Rivne;
- M-15, to the south of Odessa as part of the Odessa-Reni road, is currently being rehabilitated using State funds (USD 1.81 billion);
- M-09 (USD 388 million*), M-10 (USD 225 million), M-11 (USD 480 million*), all linking Lviv to the Polish border. The traffic data used here are those provided by Ukravtodor, on the M-10, counts indicate much lower levels. The Government of Ukraine intends to provide a concession for M-10. The WB is currently assessing the feasibility of green/brown field and alternative options;
- M-01, M-03, M-05, M-06 and M-07, the 'star' around Kyiv will reach substantial levels of traffic. Works are being implemented on M-01, M-05, and M-07 with support from EIB. Also, a greenfield concession project for a parallel road on the part of M-05 from Kyiv to Bila Tserkva is currently advocated by Ukravtodor officials and will be tested and analyzed in the Section 5 of this report;
- M-03 from Kharkiv to Chutove (USD 223 million) would be the continuation of the WB project on M-03;
- N-03 Khmelnytskyi to Chernivtsi (USD 1.12 billion*) which links to Romania;
- M-12 Ternopil - Stryi section (USD 930 million*), which has a strategic importance in redirection of the south-western traffic flows from Lviv that is already overloaded. Currently all the traffic from Romanian, Hungarian and Slovenian borders mainly goes through Lviv, which has a negative impact on the largest and most populated city in western Ukraine. In addition, Stryi is an important railway node with intermodality facilities that impact road traffic.

- H-14 Kropyvnytskyi (Kirovograd)-Mykolaiv section (USD 1.09 billion*) is critical for the movement of agricultural products, which is a key industry of this region (e.g. in 2016 share of agricultural in Gross Regional Product of Kirovohrad oblast was 34.3%, while in 2012 - 21.9%), and most of the agricultural products are exported through the port of Mykolaiv. Currently, due to the limited railway capacities, agricultural producers have redirected their cargo flows to road transport. The sustainability of a road investment will depend on the capacity of the railways to attract this demand back.

*cost estimate unavailable; a figure of USD 6 million per km was assumed for this project

Investment costs include road safety design and audits, in accordance to international best practices, which, as discussed in Chapter 6, should become standard practice for any road investment.

5: FINANCING FRAMEWORK

5.1: Road fund

The Law establishing the Road Fund[15] became effective in January 2018.[16] The RF income will come from a range of existing excise and import duties on road vehicles and fuel, and prospective future sources as defined in Articles 4 and 5 of the Law. The RF may be used for financing several expenditure heads: construction, reconstruction, repair and maintenance and other supporting costs of public roads of national importance; subvention to local budgets for construction, reconstruction, repair and maintenance of public roads of local importance and communal roads in settlements; debt payments on government loans or against government guarantees for the development and maintenance of public roads; and actions to ensure traffic safety under government programs. RF income will be transferred to the specialized accounts of the Treasury used for financing of public roads based on approved budgetary programs.

The overall operational responsibility for managing RF expenditures rests with Ukravtodor (for roads of national importance), State Oblast Administrations (for local roads), and the Ministry of Infrastructure (for road safety programs). These agencies remain subject to the normal national budgeting process, but the allocation of the Fund's resources is prescribed: 60% to national roads; 35% to local roads; 5% to road safety programs.

An assessment carried out by IFC[17] forecast that revenues from existing income sources to be allocated to the Special Budget Fund (and thence to the RF), would grow from UAH 30.17 billion (USD 1.23 billion) in 2018 to UAH 87.9 billion (USD 3.58 billion) in 2022. This increase would be partly due to inflation but mainly due to the Government's commitment to increase by stages the proportion of specified revenues allocated to roads from about 25% on implementation to 100% in 2022. This projection is similar to, though marginally more optimistic than, the MoF's own projection. The results of the RF forecast analysis are presented in Table 4 below.

It is important to recognize that the RF is a re-allocation of available resources and will represent a large share of public investments. At 100% allocation (to be reached in 2020) the RF would represent about 3% or the GDP (2017) and about 15% of the total public expenditure in 2016. There are serious concerns whether resourcing of the RF will fully materialize as planned.

Out of the total RF revenues, only 60% will be allocated to Ukravtodor (35% will be allocated to local roads and 5% to road safety).

Although the RF is likely to deliver more funds for the road sector, and an amount that will increase over time, the Fund will still leave a significant financing gap in the sector, even if fully materialized. In a best-case scenario, and assuming routine and periodic maintenance and rehabilitation is adequately financed[18], the existing revenue sources used to generate RF income will be just sufficient in the long term to cover the RF's non-capital expenditure. In other words, new capital construction would need to be funded either by RF income generated from permitted (but not currently used) sources, or from external financing sources.

[15] Law no 1762 of November 2016.
[16] The Road Fund will consist of revenues from a range of existing taxes and charges on road vehicles and road users, and prospective future sources, as defined in Articles 4 and 5 of the Law.
[17] Implemented by Egis International
[18] And that fund management, debt charges and road safety are prior charges on the Fund.

Table 4: Projection of Road Fund Revenues 2018-22 (UAH billion)

	TOTAL	2018	2019	2020	2021	2022
Import duty revenues	**27.89**	**5.31**	**5.44**	**5.57**	**5.71**	**5.86**
Excise revenues (domestic):	**49.94**	**8.94**	**9.48**	**10.04**	**10.58**	**10.90**
Fuel excise	**49.63**	8.89	9.42	9.98	10.51	10.83
Excise on vehicles	**0.30**	0.05	0.05	0.06	0.07	0.07
Excise revenues (imported):	**294.41**	**46.06**	**52.27**	**59.02**	**65.97**	**71.09**
Fuel excise	**273.76**	42.91	48.66	54.90	61.32	65.97
Excise on vehicles	**20.66**	3.15	3.62	4.12	4.65	5.12
Weight Control	**0.10**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
Total Road Fund revenues (billion UAH)	**325.39**	**30.17**	**50.41**	**74.65**	**82.29**	**87.87**

5.2: Other public sources of funding

The RF legislation permits income from several other potential new sources. Some potential sources, such as income from specific new motorways or concession fees, are associated with individual new projects and inherently limited in comparison with overall national road funding needs. The only approach which has the potential to substantially boost and sustain the total available RF would be a road user charging scheme. which could, in principle, relate either to:

- use of specific roads (e.g. new motorways) or wider classes of roads;
- for specific classes of users such as commercial vehicles, or for wider road user groups.

Naturally, the wider scope the greater the income potential. Road user charges could in principle be levied through toll-booths, physical or electronic vignettes or e-tolling systems. Toll-booths are only considered realistic for specific road sections such as on new motorways. Several countries successfully operate paper-based vignette systems, which provide authority to use roads for a given time-period and are effective in raising revenue, including income capture from international users, though they are not directly related to road distance used. E-tolling involves substantial investment in in-vehicle and external identification/sensing technology, but once in place can generate continuing and substantial income directly related to road use. E-tolling is already used in some countries for collection of tolls of new motorways, bridges and tunnels, though not yet applied more widely across national road networks.

GoU has initiated and should persevere with investigations into road user charging, which could in due course generate substantial net increases in the RF while also helping manage road infrastructure utilization more efficiently. One possible pathway could be to start with a simpler vignette system and in the longer-term migrate to a more sophisticated e-tolling system.

5.3: IFI financing

In the 5-years to 2017, International Financial Institutions (principally the EIB, EBRD and the WB) lent the equivalent of around UAH 47 billion (USD 1.8 billion) into Ukraine's transport sector, principally for roads and railways sectors.

While it is reasonable to expect a continuation of IFI support, there is a problem of investment delivery. The current ratio of disbursements to outstanding IFI lending commitment is 7.2%. In other

words, at the current rate it would take 14 years to invest all the resources currently committed through IFI loans. IFI project preparation and management requirements tend to be more stringent than those of projects financed by domestic sources but many countries do meet these requirements and implement IFI projects at much faster rates.

For IFI financing to effectively support the improvement of the road network, greater attention must be given to the quality of project preparation and the efficiency of project delivery.

5.4: Potential for private sector financing

With public sector indebtedness (including sovereign guarantees) being equivalent to 78% of Ukrainian GDP at the end of 2016, there is a need to explore the feasibility, advantages and disadvantages of private sector involvement in the financing of road sector investments.

A holistic approach to financing projects and funding maintenance work will be key to creating a sustainable environment in Ukraine's road sector. Medium- to long-term funding stability will require a structured approach towards identifying and securing sources of revenue which go beyond the current state-dominated model and involves private sector capital and expertise.

This will entail the proper assessment of user charges such as electronic and conventional tolling options, in combination with strategies to leverage resources from the RF and derive revenue from enforcement activities. Though a crucial component of Ukraine's strategy for the future, such an assessment is beyond the scope of this report. In accordance with Ukravtodor's request, the following addresses only conventional PPP arrangements for a number of priority road sections.

The IFC investigated the scope for attracting private finance to specific road investments in Ukraine. It identified a seven-stage process of identifying and screening possible PPP projects and three main criteria for selection: profitability for private investors and operators; affordability for the GoU; and the public interest – in other words, overall socio-economic returns.

The current potential for fully-privately financed toll-road concessions is limited by several factors: many of Ukraine's main routes are not heavily trafficked by comparison with busy tolled motorways internationally; average income levels limit the value of time savings to users and the affordability (and hence the realistic level) of tolls; traffic growth projections are modest; and there is a legal requirement that tolls can only be levied where there is an alternative 'free' route available (less than twice as long). In addition, there is a firm opinion in Government that the improvement of an existing road is insufficient to qualify the road as a candidate for a toll concession and that road users would recognize only newly constructed roads as worth paying for through tolls.

In collaboration with Ukravtodor, ten projects were shortlisted of which five were judged to have PPP potential. Two of the five were appraised with brownfield and greenfield options; the remainder were appraised only in brownfield form.

Only three were found to be economically justified, in the sense that EIRR exceeded the threshold of 8% pa. One more was marginal:

- M-09 Lviv–Ternopil (EIRR 17.7%pa)
- M-06 Lviv–Stryi (EIRR 11.7%pa).
- M-05 Kyiv–BilaTserkva Brownfield (EIRR 8.9%pa).
- M-10 Lviv–Krakovets Greenfield (EIRR 7.4%pa).

These and two additional candidates (M-06 Lviv–Brody–Dubno–Rivne, and the Lviv Northern Bypass) were appraised as possible PPP projects. M-06 Lviv–Brody–Dubno–Rivne was included despite a low EIRR because of its strategic significance, lying on the route between Kyiv and Lviv, with international connections to all of Ukraine's western neighbors, and the Lviv Northern Bypass was later included at Ukravtodor's request.

The projects are of three kinds:

- Brownfield – that is, when it is possible to rehabilitate and/or upgrade an existing road to Category 1B standard. This may entail widening, easing of curves or construction of bypasses; but essentially the alignment is unchanged.
- Greenfield 1B – new construction on a new alignment to Category 1B standard.
- Greenfield 1A – new construction on a new alignment to Category 1A (Motorway) standard. Design specifications are more demanding, to allow vehicles to travel at a consistent speed up to 130km/h. Capital costs are 3%–4% higher than for Category 1B.

All projects were appraised as brownfield projects, and three as greenfield projects too. Those three are among the five projects that were considered to have potential for a public-private partnership (PPP). For those projects a financial analysis was undertaken on the following basis:

- A private investor incurs all capital, maintenance and operating costs for the duration of a 30-year concession period.
- Funding comes from a prudent combination of equity and loans, which may include borrowing from an international financial institution (IFI) such as IFC. The financial analysis assumes debt:equity ratios in the range 70:30 to 80:20, and a real interest rate of 6%pa on loans. This is equivalent to a nominal rate of about 7%pa in hard currency terms, and 10.25%pa in UAH terms.
- Toll rates are set by a government agency, with future adjustment for inflation (projected at 5%pa), and all toll revenue accrues to the concessionaire.
- A default tariff was applied. This ranged from USD 0.04 (cars) to USD 0.18 (articulated trucks) per vehicle-km, with a weighted average of USD 0.07 per vehicle-km. HDM-4 results did not reveal road user cost (RUC) savings that would justify higher tolls. Indeed, in the case of M-05 Kyiv–Bila Tserkva the default tariff was factored by 0.5 because of low predicted RUC savings (attributable to the road's present good condition and high travel speeds).
- Other revenues such as rental from commercial use of the right-of-way and roadside advertising have not been estimated. They may also accrue to the concessionaire, subject to negotiation.
- Subsidies from government may also be negotiated to enhance commercial viability. In the analysis it was assumed that these would take the form of annual operating subsidies, declining to zero over an initial period of about 15 years. The amount of subsidy each year was set to ensure a minimum debt coverage ratio of 1.3.
- Commercial viability is defined as a real return on equity (ROE) of approximately 15%pa after allowing for debt servicing expenses, tax, asset depreciation and subsidies. This is based on IFC's recent experience with similar projects.
- As well as paying subsidies where necessary, it is envisaged that the Government would also share risks with concessionaires, for example the risk that traffic projections prove over-optimistic.

- Other assumptions are included in Annex 3.

On this basis, all greenfield PPP projects were found to need substantial public subsidies – exceeding 70% of capital cost – to produce the target 15%pa real return on equity. In contrast, all but one of the brownfield options were found to be profitable without subsidy.

Table 5: PPP assessment

Project road and improvement option		Traffic* vehicles per day	Length km	Condition IRI Av | Max	Capex $M	Financial (PPP)	
						Project IRR	Subsidy $M**
M-06 Lviv – Stryi		22,700	59.5	1.4 | 1.8	276	13.0%	Nil
M-10 Lviv – Krakovets (consultant's traffic count)	Greenfield 1A	8,100	68.0	1.9 | 2.3	290	1.4%	378
	Greenfield 1B				281		
	Brownfield 1B				225	5.0%	161
Lviv Northern Bypass	Min capex	10,500	25.5	New	180	–3.4%	132
	Max capex				270	–6.8%	228
M-05 Kyiv – Bila Tserkva	Greenfield 1A	25,500	50.2	3.0 | 4.3	536	5.2%	378
	Greenfield 1B				516		
	Brownfield 1B				142	12.5%	Nil
M-06 Lviv – Brody – Dubno – Rivne		15,200	194.6	1.4 | 1.9	613	11.3%	Nil
M-09 Lviv – Ternopil		9,100	118.4	4.7 | 6.4	293	12.2%	Nil

* Distance-weighted average traffic in 2017.

** Undiscounted total of annual operating subsidies required to maintain a minimum debt service coverage ratio of 1.3.

5.4.1: Sector-wide key elements for private participation in infrastructure financing

Greenfield versus Brownfield

Ukravtodor, and to a certain extent the GoU, appear to share a binary view of how the private sector can deliver road projects, as either toll funded (with government support) green-field highways with free alternatives or traditionally procured O&M of existing highways. Given the relatively low traffic volumes in Ukraine, it is important that the GoU consider intermediate options to upgrade existing highways, potentially blending tolls with other road user charges such as vignettes, to provide the desired level of service to users, at an acceptable user charge, supported by a network wide approach to sustainable financing.

The need to finalize the proposed new Concession Law

A PPP law was passed earlier this year specifically for roads but there is a broader and more comprehensive PPP law being proposed by the Ministry of Economy and already registered in Parliament; this new law is receiving advisory input from WB, IFC and EBRD and has passed its first reading by the Transport Committee.

The new proposed law is a critical step to allowing a larger-scale, more pragmatic approach to upgrading the level of service of the Ukrainian strategic road network without the need to rely solely on greenfield investments. It appears some significant challenges remain. There is pressure from the parliament to specify the permitted model to a far greater degree than would be typical in laws

elsewhere. As a result, the law may not allow the necessary flexibility in the future for Ukraine to explore the range of concession models that may bring best economic value and value for money to the sector.

5.4.2: Network priorities for private participation in infrastructure financing

The preliminary PPP assessment indicates the following directions for further investigations:

M-06 Lviv–Stryi (59.5 km)

The brownfield option is clearly worth pursuing. This section has also been identified as priority for medium to long term capacity improvement.

M-09 Lviv–Ternopil (118.4 km)

The brownfield option may be worth pursuing, subject to an OD survey to verify or amend the predicted extent of traffic diversion. This project needs to be compared with the improvement of M-12 Ternopil- Stryi and the above-mentioned M-06 Lviv–Stryi.

M-05 Kyiv–Bila Tserkva (50.2 km)

The brownfield option appears to be feasible without subsidy. There is a need to verify the willingness to pay and the impact of diverted traffic. This section has also been identified as priority for medium to long term capacity improvement.

M-10 Lviv–Krakovets (68 km)

The greenfield option would require subsidies higher than the estimated capital cost. An additional option is currently being analysed. This will include the Lviv Northern Bypass in the concession in the hope that the financial metrics would be improved.

Responding to Ukraine Ministry of Infrastructure's request for Global Infrastructure Facility (GIF) transaction preparation support, GIF is currently implementing a Project Readiness Assessment, with a due diligence style gateway audit of the proposed transaction to assess its state of readiness vis-à-vis procurement through private sector financing. This PRA looks at expected viability (multi-aspect), and where a potentially viable PPP project is confirmed (either the currently proposed project or other specification), provides an action plan to move the project forward through the project preparation cycle.

5.4.3: Towards a PPP program

Instead of focusing on specific sections for greenfield, the government should target a program of brownfield road PPPs covering a large network (1,000 km+), considering different financial arrangements including traditional user charging, e-tolling, e-vignettes, leveraging additional funds from the RF resources, etc. IFC and WB are currently developing an internal Road Sector Program which could be a good model for Ukraine to follow.

A central PPP unit should be set-up under the Cabinet of Ministers with the capacity and mandate to design and roll out such program (among others), including all the necessary analysis and due diligence to ensure transparency and value for money for Ukrainian citizens. IFC and WB (through PPIAF) are supporting the Government with this initiative.

6: INSTITUTIONAL FRAMEWORK AND GOVERNANCE

6.1: Need for better governance

Although these issues go much beyond the scope of this work, it is important to highlight the need for better governance of the sector, to ensure that the available resources are well spent.

Ukravtodor has a reputation long troubled by allegations of corruption. Anecdotes of unfair business practices are rife; and it is estimated that, for some road construction projects, losses from unscrupulous financial management reach up to 50% of the original budget[19].

Several activities, promoted mainly by the donor community and civil society, have been promoting more transparency to help rduce corruption and improve governance. In particular, the Construction Sector Transparency initiative (CoST) aims at achieving international transparency standards by ensuring basic project information is disclosed to the public.

The CosT found for example that out of 120 tenders, 38% had only two bidders, and 5 contractors received 51% of their total contract value. The study found that for actual and perceived corruption to diminish, public oversight of Ukravtodor's operations and spending must be improved. CoSt advocates a multi-stakeholder group to hold the Agency to account. This group must be properly empowered to influence the way in which the Agency is run; and must be set up in such a way that its influence – and the Agency's commitment to openness – is not undermined by political reshuffles.

6.2: Need for better and systematic planning

Sound maintenance management and methods sustains the utility and economic effectiveness of road assets. These involve both better targeting of maintenance resources and more efficient delivery of maintenance work. Heavy maintenance investments should ideally be prioritized within an integrated road asset management system. Manuals specifying a systematic approach to maintenance for the whole life-cycle of road infrastructure are essential, covering the range of routine and periodic/heavy maintenance activities: inspections, preventive/routine maintenance, periodic/heavy maintenance, winter service, and repairs. Such an asset management system must be supported by the appropriate asset inventories, activity logs and other reporting, IT systems and other equipment, and relevant management and technical procedures.

Ukraine has a large number of automatic traffic counters (ATC) which are not operational due to lack of maintenance. Ukravtodor's manual traffic counts are implemented with very limited resources and for very short periods of time, challenging their reliability. There is an urgent need to revamp and expand the ATC system and use manual traffic counts only on exceptional basis to validate or refine information. Traffic data must be centralized and available to the public on real time.

Road condition data needs to be collected in a systematic way using adequate equipment on the main network. New cheaper technologies allow for rapid assessment to cover the territorial and local roads.

To store and process the data, a GIS-based Road Asset Management System (RAMS) must be implemented and maintained with the proper technical expertise to make the best use of it. The availability of public data on traffic and road conditions will also enable the private sector to develop apps and solutions for different stakeholders and final road users.

[19] Improving transparency in Ukrainian roads procurement. Adam Smith International.

Ukravtodor management should create both the technical conditions to implement the RAMS but also the demand for its results, to drive the prioritization of investments. In addition, with the decentralization of the local roads to the Oblast, a similar approach to asset management and prioritization will need to be developed at each Oblast.

6.3: Need for more rigorous project preparation

The analysis shows that during the foreseeable future, the RF will not be able to accommodate large capital investments in rehabilitation and capacity improvement. While there might be some scope for private sector participation, it is likely that the main source of funding for such investments will continue to be the IFIs.

To enable more investments in the road sector, good project preparation is essential, following international standards. Currently, only one feasibility study is available on the road sector (M-03 Kharkiv-Valky) and another one covering several sections from Lviv to Mykolaiv is under preparation.

In addition, robust project preparation is key to implementing projects in a cost-efficient and timely manner and can minimize wastage resulting from unforeseen circumstances. There is a need for additional attention and resources be given to high-quality project preparation and implementation in Ukraine's road sector. This should include objective feasibility studies detailing risks and contingencies, technical constraints, project alternatives, and the cost estimate associated with a potential project's lifecycle.

The lack of good quality project preparation goes beyond the road sector. A project preparation facility for Ukraine (or including all EaP countries) should be considered.

6.4: Need for better road maintenance

Until 2017, Ukravtodor was responsible for all interurban roads. From January 2018 decentralization is progressing. The top hierarchical categories of roads ('roads of national importance') remain with Ukravtodor, while the remaining 120,000 km (or two-thirds of the total) are being transferred to the responsibility of local authorities. Ukravtodor will focus on the almost 50,000 km of international, national, regional and territorial roads.

Ukravtodor relies for maintenance almost entirely on a state-owned group of companies, known as DAK – Roads of Ukraine (or simply DAK). This group of enterprises is organized at a regional level: each oblast or county has its own oblavtodor, meaning local maintenance provider. Ukravtodor and oblavtodors both stem from the older state-run, centralized organization. Nominally, competition for maintenance contracts is open, but in practice the oblavtodors are awarded practically all routine maintenance contracts, which they execute from their own maintenance bases[20].

After an aborted liquidation process (envisaged earlier but abandoned in 2017), the DAK group is to undergo financial and operational restructuring. GoU has taken the strategic decision to improve the performance of the DAK group and keep state enterprises involved in routine maintenance. The authorities argue that this approach is a practical necessity, and that no other entity is as 'ready' as the DAK group, especially to take on the winter maintenance activities.

[20] There are two types of maintenance base – one type focusing on roads of national importance, another type on the local network – and each Oblavtodor has several of each.

Experience of using private contractors for routine maintenance has been rare and almost entirely with IFI support. These projects are pilots for performance-based contracting (PBC) and are handled directly by Ukravtodor. By focusing now on the state-importance roads, Ukravtodor can use PBC principles for defining quality standards for the desired condition of its entire network. This will mark a shift from the traditional input-based approach and, if well-designed, could lead to significant efficiency gains. Performance agreements can be introduced within 'traditional' contracts, but with encouragement of private-sector participation, competitively procured private maintenance-only contracts would be readily attainable, just as they exist in many other countries in Europe and elsewhere. Both on national- and local-importance roads, reformed DAK companies could compete against private firms.

The prospective RF will provide maintenance resources but cannot ensure effective and efficient use of those resources. But the Fund does provide an opportunity for Ukravtodor and local authorities to re-focus on maintenance management through road asset management systems or, at minimum, rational annual and multiyear plans for routine and heavy maintenance.

The Reform Support Team is engaged by the MoI in several areas related to road maintenance. Continued cooperation between MoI and Ukravtodor, as well as local authorities, will be beneficial in spreading good practices and introducing benchmarking. All road managers will be in a position to: (a) target use of the new RF more effectively and (b) develop a more competitive road maintenance industry to deliver the works more efficiently.

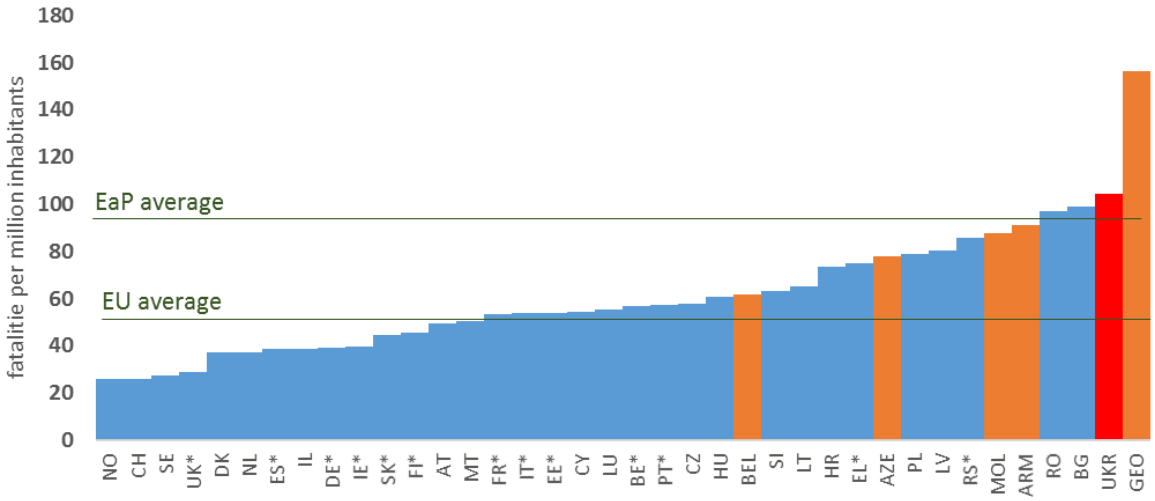
6.5: Need for safer roads

Ukraine lags in road safety performance compared with its European peers. In 2016 the highest recorded number of traffic fatalities in a single European country (excluding Russia) was recorded in Ukraine: 4,687 people were killed. This fatality rate of just over 104 road accident fatalities/million inhabitants is more than double the EU average – and the second-worst among 'Eastern Partnership' (EaP) countries, after Georgia (Figure 26).

The WB has identified the key road safety concerns as traffic speed, pedestrian safety and dangerous intersections.[21] The interurban network exhibits a proliferation of unsafe features such as U-turns and level pedestrian crossings. The poor surface condition of a large part of the country's network is also detrimental to road safety.

[21] World Bank's Road Safety Management Capacity Review and Strategy Development in Ukraine

Figure 26: Road fatality rates in EU and EaP countries 2016



Source: World Bank team compilation

GoU and its authorities are aware of the magnitude of this problem. Annual losses due to traffic accidents are estimated to be in the order of UAH 104-131 billion/year (USD 4-5 billion)[22], equivalent to 3.4% of the country's GDP in 2014[23]. The Ministry of Infrastructure and Ukravtodor have declared road safety to be one of their key priorities. Ukraine has aligned itself with the broader objective of reducing fatalities as adopted at both international (United Nations) and European (EaP) level.

As highlighted in Section 5, 5% of the proposed RF is to be allocated to road safety, representing a big boost in resources to tackle the problem. For 2018, this amount was projected to be UAH 1.5 billion UAH (almost USD 60 million), with another UAH 0.4 billion UAH (USD 15 million) of EU support for blackspot treatment. This initial amount is expected to increase to UAH 2.5-3.0 billion from 2020, as the RF is rolled out.

To realize the benefits of the new dedicated funding sources it is critical that Ukraine prepares a prioritized action plan for road safety, including investments and a series of actions to improve the institutional strengthening, education, regulations, enforcement, vehicles and infrastructure under a system approach perspective to fully implementation of the State Road Safety Program. A dedicated investment prioritization should be prepared to optimize the use of the road safety component of the RF.

Road safety enforcement and emergency response will also be key in attracting private investments, since these costs could potentially become a large part of the operation costs if they need to be provided or supplemented by the private investor.

[22] Presentation by Ukraine's Ministry of Infrastructure at the 10th Eastern Partnership Transport Panel (2016)
[23] World Bank's Road Safety Management Capacity Review and Strategy Development in Ukraine

7: PROPOSED ACTION PLAN

7.1: Sector priorities

Sector Priority #1 – Revamp the data collection and road management system (RMS)

Better road sector planning relies on accurate data on traffic and road conditions. Immediate actions should include:

- restoring the Automatic Traffic Counters;
- implementation of a GIS-based RMS;
- Performing full-fledged conditions survey on main roads (M, N, R);
- Performing simplified (app-based) conditions survey on Territorial roads;
- Mainstream the use of the RMS as a tool for investment decisions.

Sector Priority #2 – Improve road safety

Several activities have been implemented to improve road safety in Ukraine including the recently approved State Road Safety Program, as well as number of specific actions, often with IFIs and EC support, to implement reforms and targeted investments. Key sector priorities include:

- prioritize the use of the share of the RF dedicated to road safety;
- mainstream road safety improvement as a core mandate across stakeholders involved in the road sector;
- fully implement the State Road Safety Program.

Sector Priority #3 – Improve vehicle load control

Road investments will not be sustainable if overloaded trucks cause premature road deterioration.

- acquire weight-in-motion equipment and implement periodic campaigns;
- increase the fines for overloaded trucks;
- improve transparency through automatic data collection and publication to reduce the occurrence of bribery.

Sector Priority #4 – Improve project preparation

Improving project preparation is essential to mobilize funds for implementation and also to support timely implementation and avoid delays due to poor project preparation. These include:

- use robust analytical tools such as computerized transport models build with reliable data to identify the needs for capacity improvements;
- established a prioritized pipeline for project preparation, based on technical criteria rather than political agendas;
- use available resources (ongoing projects and large TAs) to support project preparation;
- work towards the implementation of a multimodal multi-donor project preparation facility.

Sector Priority #5 – Promote competition in the maintenance industry

Better and more cost-effective maintenance needs to rely on an efficient market for maintenance. This requires:

- Ukravtodor to continue the reform of the DAKs, aiming at converting them into full commercial entities which will genuinely compete for maintenance contracts;
- assess the lessons learned of the first performance-based contracting (PBC) experience and design the new roll-out of PBC on main International roads;
- establish a review and monitoring framework for maintenance costs.

7.2: Network priorities

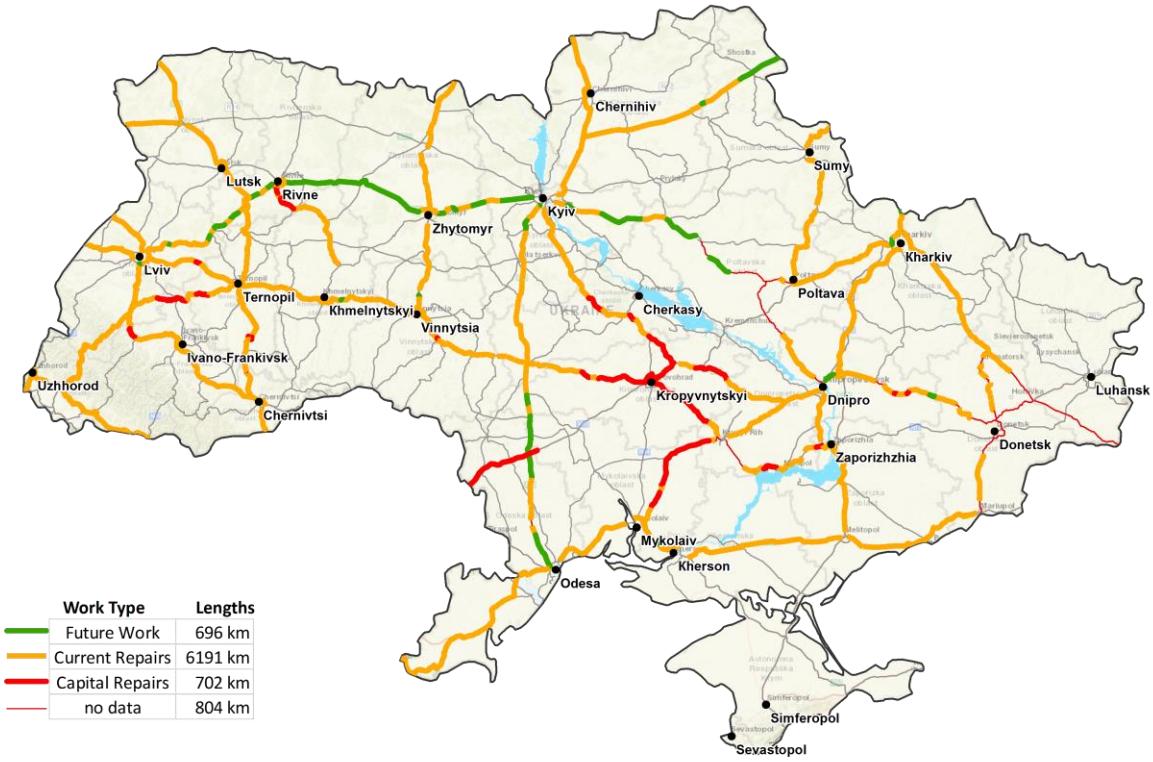
Network Priority #1 – Ensure routine maintenance[24]

Routine maintenance should be performed on the entire network. The estimated annual cost is USD 230 million (UAH 6 billion) at an average of USD 10,000[25] per km.

Network Priority #2 – Repairs on the strategic network

These include about 6,200 km of current repairs and 700 km of capital repairs for a total amount of USD 1.93 billion (UAH 50 billion).

Figure 27: Repairs on the strategic network



Source: World Bank team

[24] The routine maintenance here refers to what Ukravtodor classifies as operational maintenance, which includes routine maintenance, winter maintenance and emergency repairs.
[25] See annex 5 for details.

Network Priority #3 – Repairs on other international roads

Includes the repair of 1,773 km of International roads which are not included on the strategic network, representing a total cost of USD 424 million (UAH 11 billion).

Figure 28: Repairs on other international roads

Source: World Bank team

Network Priority #4 – Repairs on other national roads

Includes the repair of 2,554 km of National roads which are not included on the strategic network, representing a total cost of USD 731 million (UAH 19 billion).

Figure 29: Repairs on other national roads

Source: World Bank team

Network Priority #5 – Repairs on other regional roads

Includes the repair of 8,926 km of Regional roads which are not included on the strategic network, representing a total cost of USD 2.6 billion (UAH 67 billion).

Figure 30: Repairs on other regional roads

Source: World Bank team

Network Priority #6 – Prepare capacity improvement projects

Combining the expected capacity constraint with the potential for private sector involvement, the key priorities for preparation and assessment of alternatives sources of finance are:

- M-09 Lviv–Ternopil (FS ongoing)
- M-12 Ternopil - Stryi
- M-06 Rivne-Lviv
- M-06 Lviv–Stryi

7.3: Investment plan

Assuming the RF will evolve and grow in line with policy intentions, its revenues should be able to cover priorities 1 to 4 and partially priority 5 during the period 2018-2022.

Table 6: Network investment plan

	2018	*2019*	*2020*	*2021*	*2022*
Total Road Fund revenues (A)	30.2	50.4	74.7	82.3	87.9
Available for Ukravtodor (0.6*A)	18.1	30.2	44.8	49.4	52.7
Territorial Roads[26]*	3.7	3.9	4.1	4.4	4.7
Debt Servicing	4.5	3.7	3.8	3.7	3.5
Priority #1 – Ensure routine maintenance (M, H, P roads)*	6.0	6.4	6.7	7.1	7.6
Priority #2 – Repairs on the strategic network	3.9	16.2	29.8		
Priority #3 – Repairs on other international roads			0.3	10.7	
Priority #4 – Repairs on other national roads				19.0	
Priority #5 – Repairs on other regional roads				4.4	37.0

*Considers a 6% annual inflation rate

[26] Estimated at USD 5,000 per km in 2018.

ANNEX 1: HDM-4 ANALYSIS

Road Network

The total length of the Ukrainian main roads is around 23,573 km.[27] This network is sub-divided by functional classification[28] into three classes: (i) International roads or Magistral roads (M roads) that total around 8,653 km; (ii) National roads (H roads) that total around 4,830 km; and (iii) Regional roads (P roads) that total 10,089km. The WB has undertaken an assessment of the required expenditure levels for the current repair[29] and capital repair[30] of that network for the roads in which the required data is available. The Highway Development and Management (HDM-4) model was used to evaluate the performance of the network under several current repair and capital repair standards and under different budget constraints scenarios. The table below presents the main roads length distribution by network type.

Table 7: Available Network Data

Network	Network Length (km)	Available Data (km)	Available Data (%)
International	8,653	7,287	84%
National	4,830	4,165	86%
Regional	10,090	9,308	92%
Total	23,573	20,760	88%

Source: Ukravtodor and World Bank team

The HDM-4 evaluation was done for the main roads for which current data is available for road inventory, condition and traffic, representing 20,760 km or 88% of the main roads network. The network was subdivided into 1,855 homogeneous road sections, with an average length of 15 km, a function of the Oblast location, road type, road class, number of lanes, traffic and condition. The figure below presents the distribution of the network evaluated with HDM-4 by number of lanes, traffic and condition, expressed as roughness[31] and percentage of all cracks. Annex 1.1 presents the distribution of the network by Oblast.

[27] Resolution Number 712, 16 September 2015 http://zakon3.rada.gov.ua/laws/show/712-2015-%D0%BF

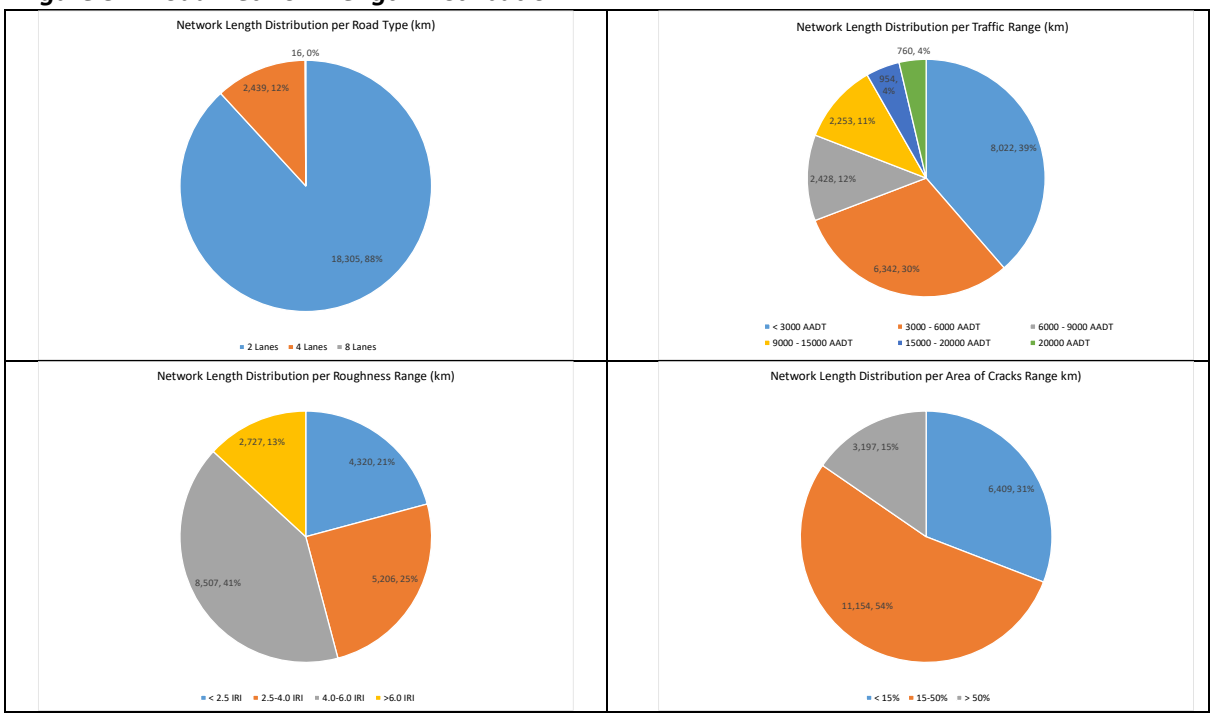
[28] The functional classification of roads in Ukraine dates to soviet times and needs to be updated to reflect current conditions.

[29] Current repair is defined as road works that treat the surface layer, such as overlays or mill and replace works.

[30] Capital repair is defined as road works that treat all the pavement structure, including the surface layer, the base and the sub-base.

[31] Roughness represents the longitudinal deformation of the road affecting the ride comfort and the road user costs. It is measured by the International Roughness Index (IRI in m/km).

Figure 31: Road Network Length Distribution



Source: World Bank team using data provided by Ukravtodor

The percentage of the main roads in sustainable condition, requiring only recurrent and current repair (very good, good or fair condition as defined by roughness) is high at 87%, but a high percentage of the network (41%) is in fair condition requiring current repairs. The percentage of the main roads with a crack rate of between 15% and 50% is 54%, which corroborates the notion that a high percentage of the network requires current repairs. The network carries high traffic with the percentage of roads that carry more than 3,000 vehicles per day being 61% and more than 9,000 vehicles per day being 20%.

The main roads carry around 44,581 million vehicle-km per year, of which 51% utilize the International (M) roads (22,950 million vehicle-km per year) and 23% (10,183 million vehicle-km) utilize the National roads. The average traffic of the International roads is around 8,628 vehicles per day, while the average traffic of the National roads is around 6,698 vehicles per day indicating that the National roads also carry high traffic (see table below). As expected, the International roads are in better condition than the National or Regional roads as expressed by roughness or cracking.

Table 8: HDM-4 Road Network Traffic and Condition

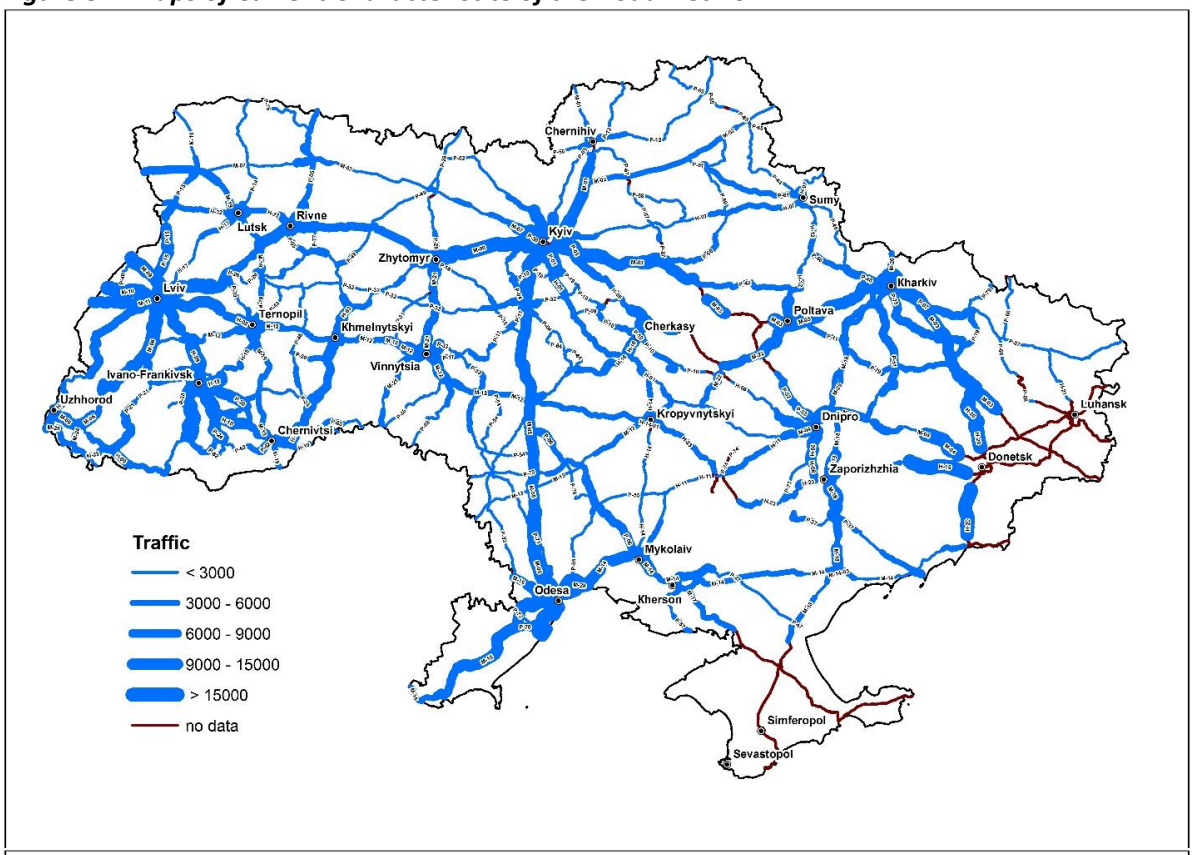
Network	Length (km)	Vehicle Utilization (m veh-km)	Average Traffic (AADT)	Average Roughness (IRI)	Average Cracks (%)
International	7,287	22,950	8,628	3.4	22
National	4,165	10,183	6,698	4.6	32
Regional	9,308	11,448	3,370	4.7	32
Total	20,760	44,581	5,883	4.2	28

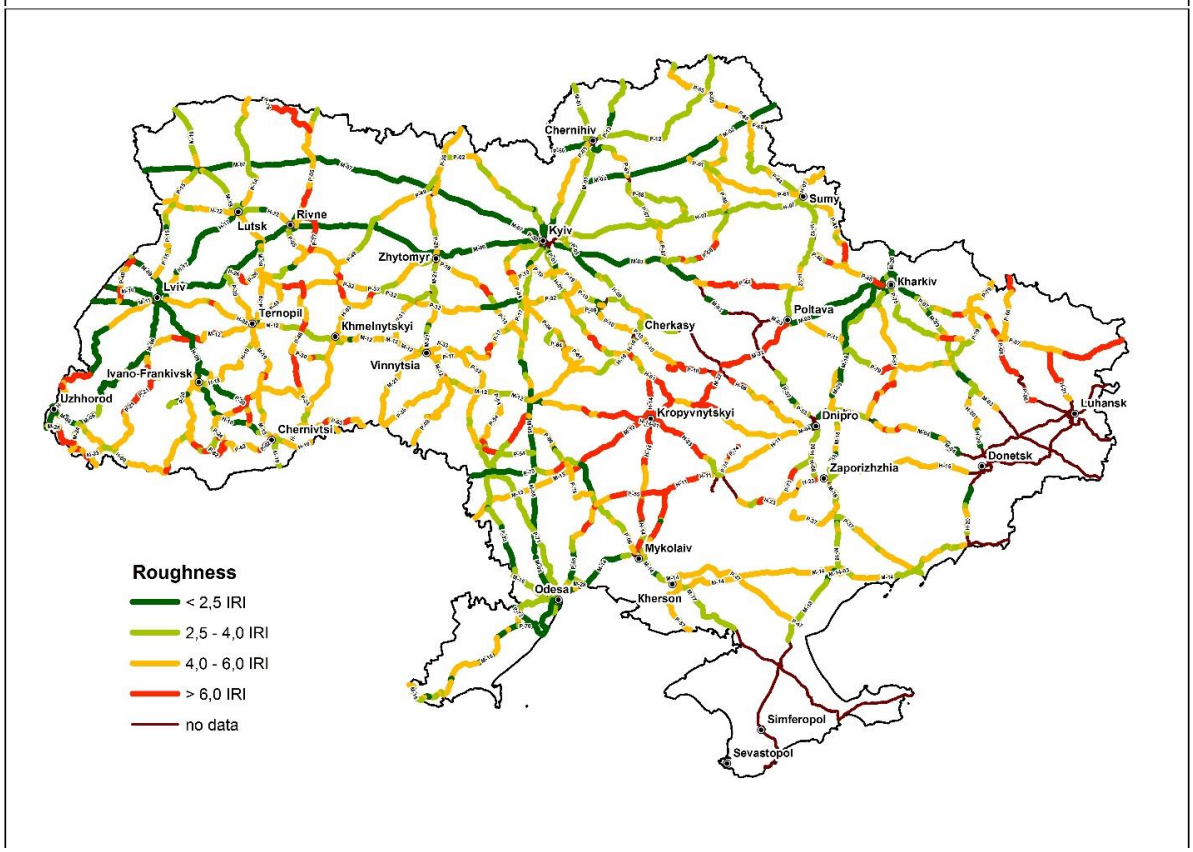
Source: World Bank team

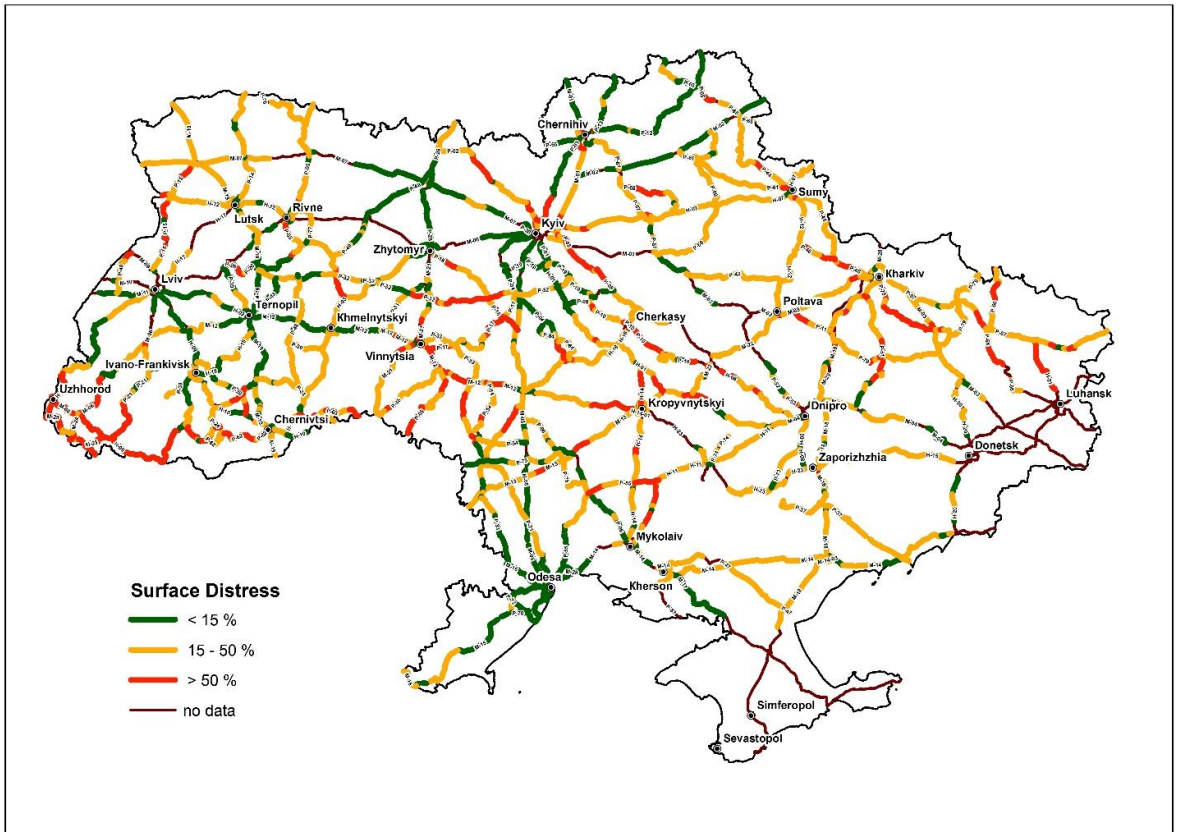
The HDM-4 model evaluated a matrix of representative road categories based on the number of lanes, roughness, area of cracks, and traffic. In total 109 road categories were identified. Annex 1.2 present the network length distribution for the representative road categories. Each road class was evaluated with HDM-4 with the objective of identifying the optimal treatment (current repair or capital repair), timing of the treatment and cost of the treatment per road category and the corresponding economic indicators.

The figures below shows maps of the main roads network traffic, roughness and surface distress.

Figure 32: Maps of Current Characteristics of the Road Network







Source: World Bank team using data provided by Ukravtodor

Road Works and Road Works Unit Costs

The table below presents the unit costs of the alternative road works evaluated. The costs are in financial terms and in economic terms, net of taxes. These costs were based on the unit cost data provided by Ukravtodor given on Annex 1.3 and international experience. The current repair works were subdivided into 5 representative repairs of the surface layer, defined by the resulting repaired surface layer thickness. The capital repair works subdivided into 5 representative pavement reconstruction options representing different resulting pavement structures, defined by a pavement Structural Number (an index that is indicative of the total strength of the pavement) as defined by AASHTO[32].

[32] American Association of State Highway and Transportation Officials

Road Works Evaluated with HDM-4

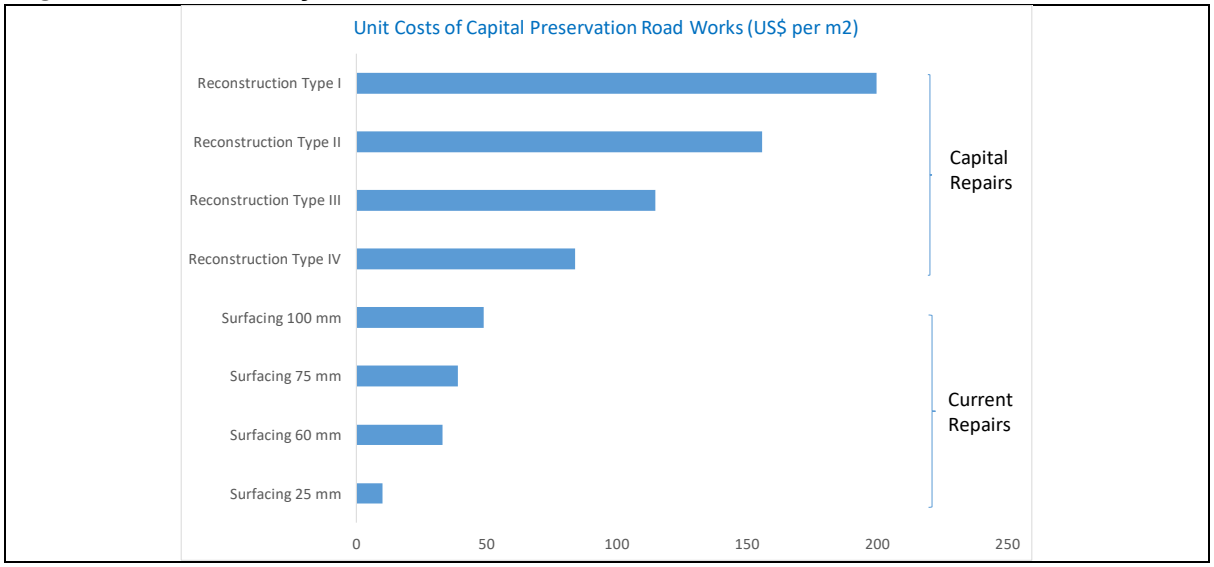
Road Work Code	Road Work Description	Repair Type	Financial Cost* (US/km)	Financial Cost (US/m2)	Economic Cost (US/m2)	Financial Cost* (UAH/km)	Financial Cost (UAH/m2)	Economic Cost (UAH/m2)	Sruc_ tural Number
W01	Surfacing 25 mm	Current	73,000	10.00	8.30	1,898,000	260	216	
W02	Surfacing 60 mm	Current	240,900	33.00	27.39	6,263,400	858	712	
W03	Surfacing 75 mm	Current	284,700	39.00	32.37	7,402,200	1,014	842	
W04	Surfacing 100 mm	Current	357,700	49.00	40.67	9,300,200	1,274	1,057	
W05	Surfacing 150 mm	Current	569,400	78.00	64.74	14,804,400	2,028	1,683	
W06	Reconstruction V	Capital	321,200	44.00	36.52	8,351,200	1,144	950	2.7
W07	Reconstruction IV	Capital	613,200	84.00	69.72	15,943,200	2,184	1,813	3.6
W08	Reconstruction III	Capital	839,500	115.00	95.45	21,827,000	2,990	2,482	4.6
W09	Reconstruction II	Capital	1,138,800	156.00	129.48	29,608,800	4,056	3,366	6.2
W10	Reconstruction I	Capital	1,460,000	200.00	166.00	37,960,000	5,200	4,316	7.0

* Assuming a width of 7.3 meters

Source: World Bank team based on Ukrainian data

The figure below presents a graphical representation of the adopted unit costs of road works.

Figure 33: Unit Costs of Road Works



Source: World Bank team estimate

The table below presents the road works evaluated for each road class per road condition, defined by roughness ranges. For roads in very good condition (<2.5 IRI), reseals or thin overlays were evaluated occurring after the initial three years of the evaluation period. For road is good and fair condition (2.5 to 6.0 IRI) alternative current repair works were evaluated. For roads in poor condition (> 6.0 IRI), alternative capital repair works were evaluated. The current repair and capital repair works were schedule to occur on either year 1, 2, 3, 4 or 5 of the evaluation period. This structure of the evaluation allows for HDM-4 to determine what should be the proper road work and the proper timing of that road work for each road class based on economic considerations.

Table 9 Road Works Evaluated with HDM-4 per Road Roughness

Roughness Ranges (IRI)			Road					
ID Code	From	To	Work	Alternative Years				
A	0	2.5	W01	Year 4	Year 5	Year 6		
			W02	Year 4	Year 5	Year 6		
B	2.5	4.0	W01	Year 1	Year 2	Year 3	Year 4	Year 5
			W02	Year 1	Year 2	Year 3	Year 4	Year 5
			W03	Year 1	Year 2			
			W04	Year 1	Year 2			
C	4.0	6.0	W02	Year 1	Year 2	Year 3	Year 4	Year 5
			W03	Year 1	Year 2	Year 3	Year 4	Year 5
			W04	Year 1	Year 2	Year 3	Year 4	Year 5
D	6.0	30.0	W07	Year 1	Year 2	Year 3	Year 4	Year 5
			W08	Year 2	Year 2	Year 3	Year 4	Year 5
			W09				Year 4	Year 5
			W10				Year 4	Year 5

Source: World Bank team

Road User Costs

The HDM-4 model estimates the reduction of road user costs (vehicle operating costs and travel time costs), over the evaluation period, with the project-alternatives in comparison to a without-project alternative (base alternative). Road user costs are a function of the vehicle fleet characteristics, the geometry of the road and the condition of the road, expressed as roughness. The table below presents the estimated unit cost of road works function of roughness for current Ukrainian conditions, which were estimated based on the current Ukrainian vehicle fleet characteristics given on Annex 1.4. A roughness of 2.0 IRI represents a paved road in very good condition, while a roughness of 16 IRI represents a road in extremely poor condition.

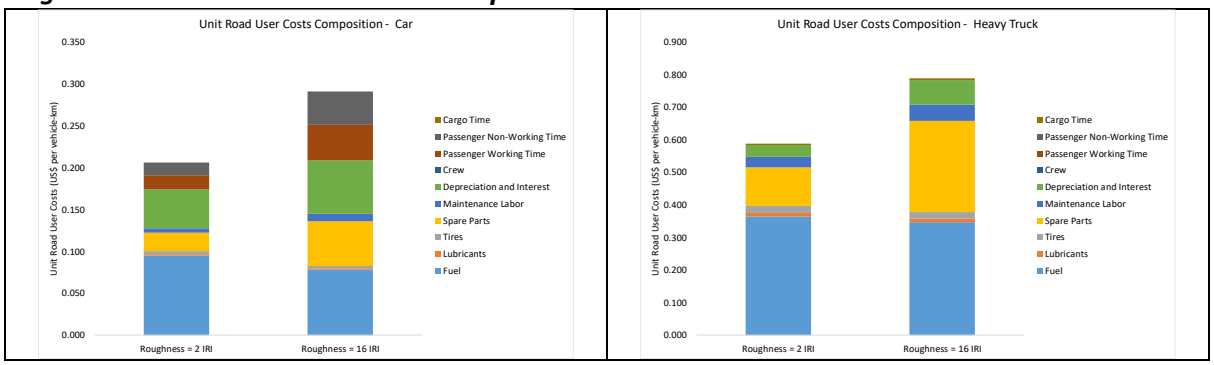
Table 10: Unit Road User Costs (US$/vehicle-km)

Roughness (IRI)	Car	Mini Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Artic Truck
2	0.206	0.374	0.743	0.249	0.341	0.609	0.912
4	0.210	0.378	0.764	0.253	0.352	0.639	0.953
6	0.212	0.386	0.802	0.257	0.362	0.668	0.962
8	0.216	0.402	0.873	0.261	0.366	0.671	0.976
10	0.230	0.433	0.983	0.272	0.377	0.700	1.040
12	0.250	0.474	1.111	0.289	0.399	0.751	1.131
14	0.272	0.520	1.234	0.311	0.426	0.806	1.199
16	0.291	0.553	1.256	0.327	0.447	0.838	1.249

Source: HDM-4 EGIS Study

Road user costs are composed of different elements, such as fuel consumption, depreciation of the vehicle and travel costs. The figure below shows the different road user costs components.

Figure 34: Unit Road User Costs Components



Source: HDM-4 EGIS Study

Unconstrained Budget Evaluation

The HDM-4 assessment was based on several assumptions: (i) a 4% annual traffic growth rate for all vehicles during the evaluation period based on the estimated GDP growth rate for Ukraine by the IMF from 2017 to 2021 of 3.4% per year and an elasticity of 1.2; (ii) an 8% discount rate based on WB practice for road projects in European countries; and (iii) a 20-year evaluation period based on common practice. The project-alternatives were compared to a without-project alternative defined as doing recurrent maintenance until the road reaches poor condition (10 IRI), when the road is then reconstructed. The project alternatives include over the evaluation period the road works, plus future periodic maintenance works defined as doing a current repair (W02) when the road reaches fair condition (4 IRI). HDM-4 identified the project-alternative that minimizes the present value of total transport costs (road user costs plus road agency costs) over the evaluation period for each road category, which represents the Unconstrained scenario.

The table below presents the distribution of the required expenditures in the first five years per road work class (current repair or capital repair) for the Unconstrained scenario. In this case, capital repair expenditures (US$1,673 million) correspond to 30% of the total expenditures (US$5,664 million[33]). Road works are needed on 19,284 km.

[33] The Unconstrained scenario typically does not yield a uniform distribution of expenditures per year because that is not criteria for the selection of the recommended road work per road class, which is based only on economic considerations.

Table 11: Road Works Requirements Unconstrained Budget

Unconstrained Scenario	Preservation Capital Expenditures (m US$)			
	Year	Current	Capital	Total
	2018	1,404	734	2,138
	2019	582	0	582
	2020	853	892	1,746
	2021	516	48	563
	2022	635	0	635
	Total	3,991	1,673	5,664
	Percent	70.5%	29.5%	100.0%
	Preservation Capital Works (km)			
	Year	Current	Capital	Total
	2018	5,217	1,196	6,413
	2019	2,184	0	2,184
	2020	3,424	1,455	4,879
	2021	2,431	76	2,507
	2022	3,301	0	3,301
	Total	16,557	2,727	19,284
	Percent	85.9%	14.1%	100.0%

Source: World Bank team

The table below presents the distribution of the required road works for the Unconstrained scenario per Oblast.

Table 12: Current and Capital Repairs Works Unconstrained Scenario per

	Road Works over Next 5 Years						Economic Priority	
Oblast	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
Cherkasy	224	47	271	830	76	906	830	3.1
Chernihiv	237	0	237	1,135	0	1,135	553	2.3
Chernivtsi	80	47	127	327	76	403	288	2.3
Dnipropetrovsk	226	65	291	877	106	982	757	2.6
Donetsk	103	0	103	332	0	332	978	9.5
Ivano-Frankivsk	145	111	256	595	181	776	1,331	5.2
Kharkiv	305	78	383	1,172	127	1,299	1,713	4.5
Kherson	169	0	169	675	0	675	422	2.5
Khmelnytskiy	179	85	264	683	139	822	550	2.1
Kirovohrad	40	373	413	159	608	767	479	1.2
Kyiv	334	6	341	1,321	10	1,331	1,540	4.5
Luhansk	43	154	198	174	251	425	157	0.8
Lviv	142	26	168	900	42	942	981	5.8
Mykolaiv	121	183	303	533	298	830	428	1.4
Odesa	240	60	300	1,046	98	1,144	1,013	3.4
Poltava	76	160	236	282	261	543	827	3.5
Rivno	77	117	194	383	191	574	431	2.2
Sumy	195	9	203	842	14	856	442	2.2
Ternopil	162	19	181	649	32	681	367	2.0
Vinnytsa	278	33	312	1,032	53	1,085	875	2.8
Volyn	137	0	137	623	0	623	461	3.4
Zakarpattia	140	89	229	547	146	693	711	3.1
Zaporizhya	173	0	173	713	0	713	545	3.2
Zhytomyr	166	11	176	726	17	744	469	2.7
Grand Total	3,991	1,673	5,664	16,557	2,727	19,284	17,147	3.0

Source: World Bank team

The table below presents the distribution of the required road works for the Unconstrained scenario per road type.

Table 13: Current and Capital Repairs Works Unconstrained Scenario per Road Type

	Road Works over Next 5 Years						Economic Priority	
Road Type	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
Multi Lane	555	1	557	1,730	1	1,731	3,338	6.0
Two Lane	3,435	1,672	5,107	14,827	2,726	17,552	13,809	2.7
Grand Total	3,991	1,673	5,664	16,557	2,727	19,284	17,147	3.0

Source: World Bank team

The table below presents the distribution of the required road works for the Unconstrained scenario per road class.

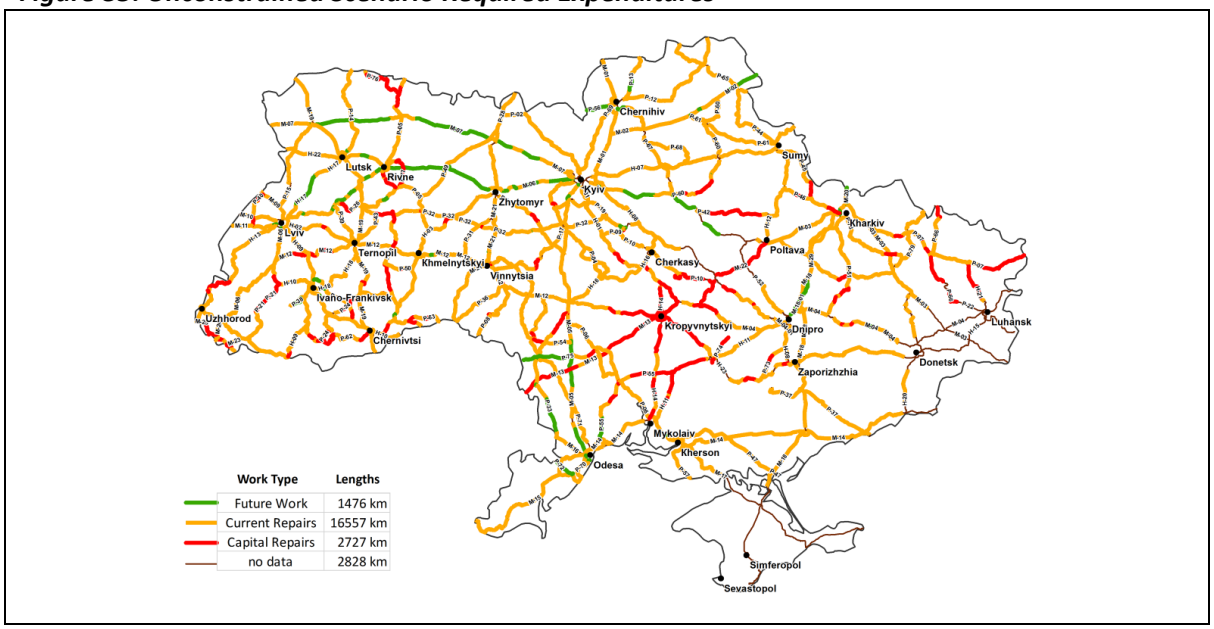
Table 14: Current and Capital Repairs Works Unconstrained Scenario per Road

	Road Works over Next 5 Years						Economic Priority	
Road Class	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
I	636	12	648	2,192	19	2,211	3,547	5.5
II	1,788	448	2,235	7,740	730	8,470	8,347	3.7
III	1,299	1,043	2,342	5,493	1,701	7,194	4,578	2.0
IV	268	170	438	1,132	278	1,410	675	1.5
Grand Total	3,991	1,673	5,664	16,557	2,727	19,284	17,147	3.0

Source: World Bank team

The figure below shows a map with the location of the required expenditures for the Unconstrained scenario.

Figure 35: Unconstrained Scenario Required Expenditures



Annex 1.5 presents a table with the solution matrix for the Unconstrained scenario, showing the required road work and the required timing of the road work that minimized the total transport cost per road category.

Network Budget Constraints Evaluation

The Unconstrained scenario is not feasible to implement due to budget constraints and limited implementation capacity of Ukravtodor and the private road sector of Ukraine. Therefore, different network budget constrain scenarios were evaluated with HDM-4. The six budget scenarios were evaluated with HDM-4 as summarized on below.

- Scenario 1 - Unconstrained. This scenario selects the current repair and capital repair road work per road class that minimizes the present value of road agency costs plus road user costs over the evaluation period. This represent the totally unconstrained budged scenario, which maximizes the economic benefits but presents the recommended road works not evenly distributed over the years with a high concentration of road works in years 1, thus not being a practical program to implement.

- Scenario 2 – 100%. This scenario expends around the same amount as the Unconstrained scenario during the first five years, but evenly distributes the road works over the first five years, thus is more practical to implement if the required budget is available.

- Scenario 3 – 80%. This scenario reduces the current repair and capital repair expenditures over the first five years to 80% of the 100% scenario.

- Scenario 4 – 60%. This scenario reduces the current repair and capital repair expenditures over the first five years to 60% of the 100% scenario.

- Scenario 5 – 40%. This scenario reduces the current repair and capital repair expenditures over the first five years to 40% of the 100% scenario.

- Scenario 6 – 20%. This scenario reduces the current repair and capital repair expenditures over the first five years to 20% of the 100% scenario.

The table below presents the resulting annual total current repair and capital repair expenditures over the next five years, the network NPV, the estimated average network roughness over the next five years and the estimated percentage of the network in good condition in 2022.

Table 15: Comparison of Budget Scenarios

Budget Scenario	Years 1 to 5 Expenditures (m US$)	Annual Expenditures (m US$/yr)	NPV (m US$)	Average Network Roughness (IRI)						Good Condition
				2017	2018	2019	2020	2021	2022	2022 (%)
Unconstrained	5,664	1,133	17,146	4.2	3.5	3.5	2.7	2.7	2.5	96%
100%	5,578	1,116	16,985	4.2	4.0	3.6	3.3	2.8	2.6	95%
80%	4,784	957	16,518	4.2	4.2	4.0	3.8	3.4	3.0	78%
60%	3,591	718	15,549	4.2	4.4	4.3	4.4	4.3	4.1	67%
40%	2,393	479	13,723	4.2	4.5	4.7	4.9	5.2	5.5	43%
20%	1,194	239	10,488	4.2	4.6	5.0	5.7	6.5	7.3	28%

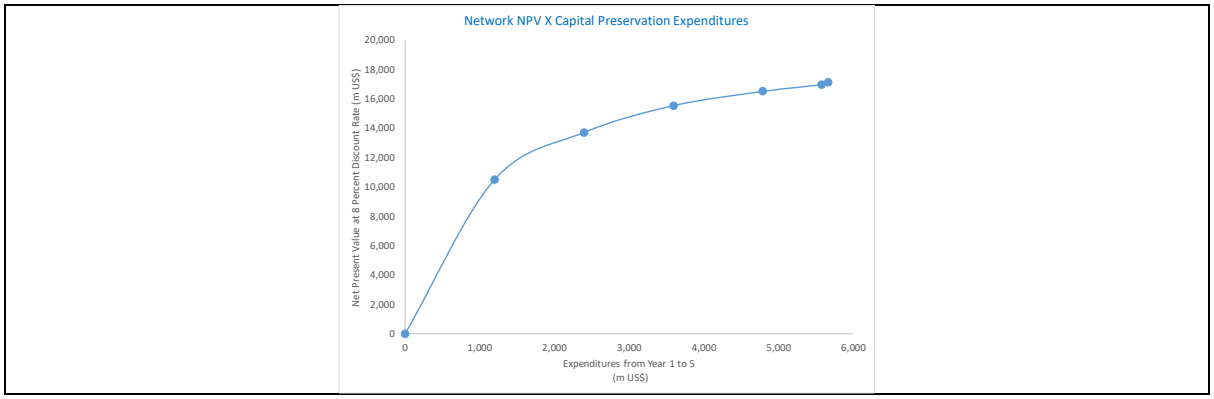
Source: World Bank team

The unconstrained scenario achieves a target of 96% of main roads in very good or good condition by 2022 from the current 46%. In this case, it is estimated that the current repair and capital repair backlog would be addressed within five years at a cost of US$1,133 million per year from 2018 to 2022.

The 60% scenario achieves a target of 67% of main roads in very good or good condition by 2022 from the current 46% and maintains the average network roughness from the current 4.2 IRI to 4.1 IRI. Therefore, this scenario represents the case of keeping approximately the current network condition over time. In this case, it is estimated that the current repair and capital repair backlog would be addressed within five years at a cost of US$718 million per year from 2018 to 2022.

The figure below presents the reduction of the net economic benefits (total network NPV) of the different budget scenarios compared to unconstrained budget scenario. The NPV is the reduction of total transport costs (road user costs + road agency costs) of the project-alternative in relation to the without-project alternative, expressed in present value terms at a given discount rate. The higher the NPV the higher is the benefits of a project. A negative NPV indicates that a project is not economically justified.

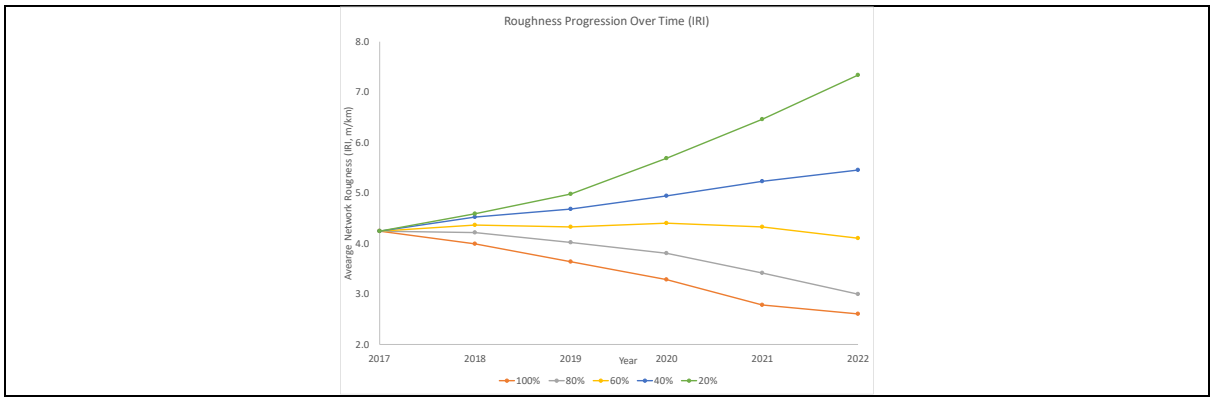
Figure 36: Network NPV (m US$)



Source: World Bank team

The figure below presents the estimated average network roughness over the next five years for the different budget scenarios, showing that the 60% scenario (718 M US$ per year) roughly keeps the network at the same condition as today. The unconstrained scenario will reduce the average network roughness to 2.5 IRI, m/km.

Figure 37: Average Network Roughness (IRI)



Source: World Bank team

The required road preservation expenditures computed with HDM-4 don't include recurrent maintenance expenditures (routine and winter maintenance). Considering a unit cost of US$4,117 per km per year (107,034 UAH per km per year) estimated by Ukravtodor for recurrent maintenace activities and a total main roads network of 23,573 km managed by Ukravtodor, the annual financial requirements for recurrent maintenace of the main roads network total US$97 million per year.

The table below presents the distribution of the required expenditures in the first five years per road work class (current repair or capital repair) 100% and 60% scenarios. For the 100% scenario, capital repair expenditures (USD 1.67 billion) correspond to 30% of the total expenditures (USD 5.57 billion per year). Under budget constraints (60% budget scenario), the capital repair expenditures reduce to (USD 735 million) that is 21% of the total expenditures (USD 3.5 billion), which indicates that under budget constraints the focus should be in current repair expenditures that yield higher economic benefits than capital expenditures.

Table 16: Road Works Requirements 100 and 60% Scenarios

100% Scenario	Preservation Capital Expenditures (m US$)			
	Year	Current	Capital	Total
	2018	1,150	50	1,200
	2019	520	668	1,187
	2020	897	292	1,189
	2021	537	663	1,200
	2022	802	0	802
	Total	3,905	1,673	5,578
	Percent	70.0%	30.0%	100.0%
	Preservation Capital Works (km)			
	Year	Current	Capital	Total
	2018	4,286	81	4,367
	2019	2,030	1,089	3,119
	2020	3,661	477	4,138
	2021	2,175	1,080	3,255
	2022	4,405	0	4,405
	Total	16,557	2,727	19,284
	Percent	85.9%	14.1%	100.0%
60% Scenario (keep current condition)	Preservation Capital Expenditures (m US$)			
	Year	Current	Capital	Total
	2018	684	36	720
	2019	720	0	720
	2020	601	112	713
	2021	719	0	720
	2022	132	587	719
	Total	2,856	735	3,591
	Percent	79.5%	20.5%	100.0%
	Preservation Capital Works (km)			
	Year	Current	Capital	Total
	2018	4,986	58	5,044
	2019	2,884	0	2,884
	2020	2,432	182	2,614
	2021	2,909	0	2,909
	2022	918	957	1,875
	Total	14,130	1,197	15,327
	Percent	92.2%	7.8%	100.0%

Source: World Bank team

Annex 1.6 presents the distribution of the required expenditures in the first five years per road work class (current repair or capital repair) for the 60% scenario per Oblast, road type and road class, presenting the expenditures needed, the road works length needed and the corresponding indicators.

Annex 1.1: Distribution of the network by oblast

The tables below present the distribution of the network by Oblast.

Table 17: Road Network Length Evaluated with HDM-4

Oblast	2010 Population (million)	Area (km2)	HDM-4 Evaluation Length (km)
Cherkasy	1,238,593	20,900	929
Chernihiv	1,040,492	31,865	1,205
Chervivstsi	909,081	8,097	403
Dnipropetrovsk	3,244,341	31,914	1,076
Donetsk	4,255,450	26,517	332
Ivano-Frankivsk	1,381,014	13,900	807
Kharkiv	2,711,475	31,415	1,311
Kherson	1,059,481	28,461	684
Khmelnytskiy	1,291,187	20,645	825
Kirovohrad	969,662	24,588	767
Kyiv	4,641,926	28,970	1,443
Luhansk	2,200,807	26,684	425
Lviv	2,531,265	21,833	1,004
Mykolaiv	1,155,174	24,598	837
Odesa	2,386,441	33,310	1,499
Poltava	1,433,804	28,748	612
Rivno	1,161,537	20,047	757
Sumy	1,108,651	23,834	907
Ternopil	1,063,264	13,823	691
Vinnytsa	1,597,683	26,513	1,086
Volyn	1,042,218	20,144	730
Zakarpattia	1,258,507	12,777	693
Zaporizhya	1,747,639	27,180	713
Zhytomyr	1,244,219	29,832	1,021
Total	42,673,911	576,595	20,760

Source: World Bank team

Table 18 Road Network Length Evaluated with HDM-4 by Category (km)

Oblast	Category I	Category II	Category III	Category IV	Total
Cherkasy	152	436	269	72	929
Chernihiv	136	144	691	234	1,205
Chervivstsi	15	189	172	27	403
Dnipropetrovsk	279	624	138	34	1,076
Donetsk	159	173			332
Ivano-Frankivsk	34	365	233	175	807
Kharkiv	182	482	646		1,311
Kherson	44	398	242		684
Khmelnytskiy	37	352	425	12	825
Kirovohrad		243	487	37	767
Kyiv	447	616	277	103	1,443
Luhansk	6	66	353		425

Lviv	46	703	233	21	1,004
Mykolaiv	41	446	232	119	837
Odesa	218	510	413	358	1,499
Poltava	79	213	294	26	612
Rivno	133	313	243	68	757
Sumy	5	353	480	69	907
Ternopil	27	381	282		691
Vinnytsa	105	319	657	5	1,086
Volyn	66	387	174	103	730
Zakarpattia	19	254	412	8	693
Zaporizhya	58	619	36		713
Zhytomyr	745	107	167	3	1,021
Total	3,032	8,695	7,558	1,475	20,760
Percent	15%	42%	36%	7%	100%

Source: World Bank team

Table 19: Road Network Length Evaluated with HDM-4 by Lanes (km)

Oblast	Two Lane	Four Lane	Eight Lane	Total
Cherkasy	777	152		929
Chernihiv	1,081	124		1,205
Chervivstsi	388	15		403
Dnipropetrovsk	796	279		1,076
Donetsk	182	150		332
Ivano-Frankivsk	773	34		807
Kharkiv	1,096	214		1,311
Kherson	640	44		684
Khmelnytskiy	788	37		825
Kirovohrad	767			767
Kyiv	1,106	321	16	1,443
Luhansk	420	6		425
Lviv	959	45		1,004
Mykolaiv	797	41		837
Odesa	1,267	232		1,499
Poltava	493	120		612
Rivno	626	132		757
Sumy	902	5		907
Ternopil	663	27		691
Vinnytsa	952	134		1,086
Volyn	665	65		730
Zakarpattia	674	19		693
Zaporizhya	660	53		713
Zhytomyr	830	191		1,021
Total	18,305	2,439	16	20,760
Percent	88%	12%	0%	100%

Source: World Bank team

Table 20: HDM-4 Road Network Traffic and Condition

Oblast	Length (km)	Vehicle Utilization (m veh-km)	Average Traffic (AADT)	Average Roughness (IRI)	Average Cracks (%)
Cherkasy	929	1,777	5,238	4.2	33
Chernihiv	1,205	1,120	2,546	3.4	21
Chervivstsi	403	634	4,308	5.0	35
Dnipropetrovsk	1,076	1,947	4,960	4.4	24
Donetsk	332	2,099	17,293	3.5	21
Ivano-Frankivsk	807	3,230	10,958	4.7	23
Kharkiv	1,311	3,555	7,432	3.9	39
Kherson	684	1,121	4,492	4.1	23
Khmelnytskiy	825	1,192	3,958	5.1	25
Kirovohrad	767	1,010	3,607	8.5	51
Kyiv	1,443	4,974	9,441	3.3	27
Luhansk	425	251	1,617	6.6	52
Lviv	1,004	4,353	11,876	2.9	15
Mykolaiv	837	1,219	3,990	5.6	30
Odesa	1,499	4,154	7,594	2.9	14
Poltava	612	1,872	8,375	5.2	30
Rivno	757	1,300	4,702	4.2	25
Sumy	907	1,052	3,178	3.8	31
Ternopil	691	1,055	4,183	4.8	14
Vinnytsa	1,086	1,631	4,113	5.0	41
Volyn	730	1,021	3,834	3.2	24
Zakarpattia	693	1,308	5,173	4.7	65
Zaporizhya	713	1,233	4,737	4.0	21
Zhytomyr	1,021	1,472	3,950	3.3	17
Total	20,760	44,581	5,883	4.2	28

Source: World Bank team

Annex 1.2: Distribution of the main number of lanes, condition and traffic

The table below presents the network length distribution by number of lanes, condition and traffic.

Table 21: Road Network Length Distribution by Number of Lanes, Condition and Traffic (km)

	Roughness:	A < 2.5 IRI			B 2.5-4.0 IRI			C 4.0-6.0 IRI			D >6.0IRI		
	Cracks:	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
	Traffic (AADT)	< 15%	15-50%	>50%	< 15%	15-50%	>50%	< 15%	15-50%	>50%	< 15%	15-50%	>50%
Two Lane	1 < 3000	552	189	12	681	1223	143	612	2501	542	75	1004	451
	2 3000 - 6000	478	83	60	430	991	169	444	1779	530	26	454	478
	3 6000 - 9000	305	68	65	147	188	144	110	531	239	1	153	28
	4 9000 - 15000	451	173	73	86	210	31	146	237	39	5	52	0
	5 15000 - 20000	200	42	9	52	54	0	45	73	5	0	0	0
	6 > 20000	161	48	0	38	0	0	78	112	0	0	0	0
Four Lane	1 < 3000	0	0	0	0	14	17	0	0	6	0	0	0
	2 3000 - 6000	138	132	0	25	22	22	20	62	0	0	1	0
	3 6000 - 9000	124	33	4	39	80	20	39	96	13	0	0	0
	4 9000 - 15000	297	82	7	15	185	5	24	93	42	0	0	0
	5 15000 - 20000	262	47	11	54	16	5	18	62	0	0	0	0
	6 > 20000	165	34	0	61	15	24	4	0	3	0	0	0
Eight Lane	1 < 3000	0	0	0	0	0	0	0	0	0	0	0	0
	2 3000 - 6000	0	0	0	0	0	0	0	0	0	0	0	0
	3 6000 - 9000	0	0	0	0	0	0	0	0	0	0	0	0
	4 9000 - 15000	0	0	0	0	0	0	0	0	0	0	0	0
	5 15000 - 20000	0	0	0	0	0	0	0	0	0	0	0	0
	6 > 20000	0	16	0	0	0	0	0	0	0	0	0	0

Source: World Bank team

Annex 1.3: Ukrainian unit costs of road works

Усереднені показники вартості дорожніх робіт на автомобільних дорогах загального користування

Показники розраховані виходячи з даних за 2016 рік

Категорія дороги	Вартість будівництва, за 1 км	Вартість капітального ремонту, за 1 км	Вартість поточного ремонту, за 1 км
I	**$ 4 134 000** *78 643 000 грн.*	**$ 1 217 400 – $ 2 435 000** *23 160 000 – 46 320 000 грн.*	**$ 487 000 – $ 913 000** *9 264 000 – 17 370 000 грн.*
II	**$ 2 150 000** *40 894 000 грн.*	**$ 913 000 – $ 1 217 400** *17 370 000 – 23 160 000 грн.*	**$ 183 000 – $ 347 000** *3 474 000 – 6 601 000 грн.*
III	**$ 1 943 000** *36 962 000 грн.*	**$ 548 000 – $ 913 000** *10 422 000 – 17 370 000 грн.*	**$ 122 000 – $ 304 000** *2 316 000 – 5 790 000 грн.*
IV	**$ 1 075 000** *20 447 000 грн.*	**$ 365 000 – $ 548 000** *6 948 000 – 10 422 000 грн.*	**$ 91 000 – $ 243 500** *1 737 000 – 4 632 000 грн.*
V	**$ 262 000** *4 981 000 грн.*	**$ 121 000 – $ 243 000** *2 310 000 – 4 632 000 грн.*	**$ 18 000 – $ 61 000** *347 000 – 1 158 000 грн.*

Source: Ukravtodor

Table 22: Average Costs of Preservation Works

	Category	Capital Repair	Current Repair
2016 Cost Per km (US$/km)	I	1,826,200	289,150
	II	1,065,200	265,000
	III	730,500	213,000
	IV	456,500	167,250
	V	182,000	39,500
2017 Cost Per km (US$/km) + 10%	I	2,008,820	318,065
	II	1,171,720	291,500
	III	803,550	234,300
	IV	502,150	183,975
	V	200,200	43,450
Road Width (m)	I	15.0	15.0
	II	7.5	7.5
	III	7.0	7.0
	IV	6.0	6.0
	V	4.5	4.5
2017 Cost Per m2 (US$/m2)	I	134	21
	II	156	39
	III	115	33
	IV	84	31
	V	44	10

Source: Ukravtodor

Annex 1.4: Vehicle fleet characteristics

Table 23: Vehicle Fleet Economic Unit Costs and Basic Characteristics

	Car	Mini Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Artic Truck
Economic Unit Costs							
New Vehicle Cost (US$/vehicle)	10,790	16,600	41,500	13,280	20,750	41,500	66,400
New Tire Cost (US$/tire)	62.00	100.00	290.00	100.00	166.00	208.00	290.00
Fuel Cost (US$/liter)	0.83	0.83	0.75	0.83	0.75	0.75	0.75
Lubricant Cost (US$/liter)	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Maintenance Labor Cost (US$/hour)	2.02	2.02	2.22	2.02	2.22	2.22	2.22
Crew Cost (US$/hour)	0.00	1.17	1.53	1.49	1.70	1.64	1.80
Overhead (US$/year)	170	225	560	340	450	560	670
Interest Rate (%)	8	8	8	8	8	8	
Working Passenger Time (US$/hour)	1.59	1.06	1.06	0.00	0.00	0.00	0.00
Non-working Pass. Time (US$/hour)	0.80	0.53	0.53	0.00	0.00	0.00	0.00
Cargo Delay (US$/hour)	0.00	0.00	0.00	0.09	0.19	0.25	0.32
Basic Characteristics							
Kilometers Driven per Year (km)	23,000	30,000	70,000	30,000	40,000	86,000	86,000
Hours Driven per Year (hr)	550	750	1,750	750	1,000	2,050	2,050
Service Life (years)	10	8	8	8	12	14	14
Percent Private Use (%)	100	0	0	0	0	0	0
Number of Passengers (#)	3	12	40	0	0	0	0
Work Related Passenger-Trips (%)	35	35	35	0	0	0	0
Gross Vehicle Weight (tons)	1.20	1.50	17.01	1.50	10.30	19.98	31.46
Equivalent Standard Axels (ESA)	0.000	0.010	4.310	0.010	2.070	2.841	3.574

Source: HDM-4 EGIS Study

Annex 1.5: Solution matrix per road category

The table below present the solution matrix per road category for the Unconstrained scenario showing the required road work and the required timing of the road work.

Table 24: Solution Catalog for Unconstrained Budget Scenario

Road Type	Roughness: / Cracks: / Traffic (AADT)	A < 2.5 IRI X < 15%	A < 2.5 IRI Y 15-50%	A < 2.5 IRI Z >50%	B 2.5-4.0 IRI X < 15%	B 2.5-4.0 IRI Y 15-50%	B 2.5-4.0 IRI Z >50%	C 4.0-6.0 IRI X < 15%	C 4.0-6.0 IRI Y 15-50%	C 4.0-6.0 IRI Z >50%	D >6.0IRI X < 15%	D >6.0IRI Y 15-50%	D >6.0IRI Z >50%
Two Lane	1 < 3000	None	None	None	W02 - 5	W02 - 5	W02 - 4	W02 - 4	W02 - 3	W02 - 2	W07 - 4	W07 - 3	W07 - 3
	2 3000 - 6000	W01 - 5	W02 - 4	W02 - 4	W02 - 3	W02 - 2	W02 - 1	W02 - 1	W02 - 1	W02 - 1	W07 - 1	W07 - 1	W07 - 1
	3 6000 - 9000	W01 - 4	W02 - 4	W02 - 4	W02 - 2	W02 - 2	W03 - 1	W02 - 1	W03 - 1	W03 - 1	W07 - 1	W07 - 1	W07 - 1
	4 9000 - 15000	W01 - 5	W02 - 4	W02 - 4	W02 - 1	W04 - 1	W03 - 1	W02 - 1	W03 - 1	W03 - 1	W07 - 1	W07 - 1	W07 - 1
	5 15000 - 20000	W01 - 4	W02 - 4	W02 - 4	W04 - 2	W04 - 1	#N/A	W04 - 1	W04 - 1	W04 - 1	#N/A	#N/A	#N/A
	6 > 20000	W01 - 4	W02 - 4	#N/A	W04 - 1	#N/A	#N/A	W04 - 1	W04 - 1	#N/A	#N/A	#N/A	#N/A
Four Lane	1 < 3000	None	#N/A	#N/A	W01 - 5	W01 - 5	W01 - 5	#N/A	#N/A	W02 - 5	#N/A	#N/A	#N/A
	2 3000 - 6000	None	W01 - 4	#N/A	W01 - 5	W01 - 4	W01 - 2	W02 - 5	W02 - 3	#N/A	#N/A	W07 - 4	#N/A
	3 6000 - 9000	None	W01 - 4	W02 - 4	W01 - 5	W01 - 3	W01 - 2	W02 - 5	W02 - 3	W02 - 1	#N/A	#N/A	#N/A
	4 9000 - 15000	None	W02 - 4	W02 - 4	W01 - 2	W01 - 3	W01 - 2	W02 - 5	W02 - 2	W03 - 2	W07 - 4	#N/A	#N/A
	5 15000 - 20000	W01 - 5	W02 - 4	W02 - 4	W02 - 3	W01 - 3	W03 - 2	W02 - 5	W02 - 2	#N/A	#N/A	#N/A	#N/A
	6 > 20000	None	W02 - 4	#N/A	W02 - 1	W02 - 1	W01 - 1	W03 - 5	#N/A	W04 - 1	#N/A	#N/A	#N/A
Eight Lane	1 < 3000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	2 3000 - 6000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	3 6000 - 9000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	4 9000 - 15000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	5 15000 - 20000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
	6 > 20000	#N/A	W02 - 4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Source: World Bank team

Annex 1.6: Current and capital repair expenditures for 60% scenario

Table 25: Current and Capital Repairs Works for 60% Scenario per Oblast

	Road Works over Next 5 Years						Economic Priority	
Oblast	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
Cherkasy	142	30	172	699	48	747	721	4.2
Chernihiv	119	0	119	981	0	981	521	4.4
Chernivtsi	68	18	87	305	30	335	262	3.0
Dnipropetrovsk	200	17	217	834	27	862	703	3.2
Donetsk	67	0	67	246	0	246	954	14.2
Ivano-Frankivsk	97	78	175	421	127	548	1,255	7.2
Kharkiv	189	67	256	976	109	1,084	1,561	6.1
Kherson	136	0	136	671	0	671	401	2.9
Khmelnytskiy	153	17	170	681	27	708	492	2.9
Kirovohrad	38	238	276	159	388	547	263	1.0
Kyiv	230	0	230	1,105	0	1,105	1,436	6.2
Luhansk	43	0	43	174	0	174	78	1.8
Lviv	87	3	90	378	5	383	950	10.6
Mykolaiv	90	23	113	414	37	451	320	2.8
Odesa	121	0	121	810	0	810	945	7.8
Poltava	56	160	216	253	261	514	754	3.5
Rivno	63	19	82	261	31	292	369	4.5
Sumy	129	0	129	790	0	790	407	3.2
Ternopil	154	10	164	640	16	656	349	2.1
Vinnytsa	253	4	257	1,012	5	1,018	836	3.3
Volyn	72	0	72	500	0	500	403	5.6
Zakarpattia	105	53	157	497	86	582	602	3.8
Zaporizhya	126	0	126	676	0	676	520	4.1
Zhytomyr	117	0	117	648	0	648	447	3.8
Grand Total	2,856	735	3,591	14,130	1,197	15,327	15,550	4.3

Source: World Bank team

Table 26: Current and Capital Repairs Works for 60% Scenario per Road Type

	Road Works over Next 5 Years						Economic Priority	
Road Type	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
Multi Lane	379	1	380	1,174	1	1,175	3,154	8.3
Two Lane	2,478	733	3,211	12,956	1,196	14,152	12,396	3.9
Grand Total	2,856	735	3,591	14,130	1,197	15,327	15,550	4.3

Source: World Bank team

Table 27: Current and Capital Repairs Works for 60% Scenario per Road Class

	Road Works over Next 5 Years						Economic Priority	
Road Class	Current Repairs (M US$)	Capital Repairs (M US$)	Total Repairs (M US$)	Current Repairs (km)	Capital Repairs (km)	Total Repairs (km)	NPV (M US$)	NPV/ Cost (#)
I	447	1	449	1,535	1	1,536	3,347	7.5
II	1,248	249	1,497	6,407	406	6,813	7,769	5.2
III	998	449	1,446	5,099	732	5,831	3,882	2.7
IV	163	36	199	1,089	59	1,148	552	2.8
Grand Total	2,856	735	3,591	14,130	1,197	15,327	15,550	4.3

Source: World Bank team

ANNEX 2: TRANSPORT MODEL ASSUMPTIONS

This report describes the main technical assumptions and methodologies applied for the preparation of the Cube model for Ukraine.

Network preparation

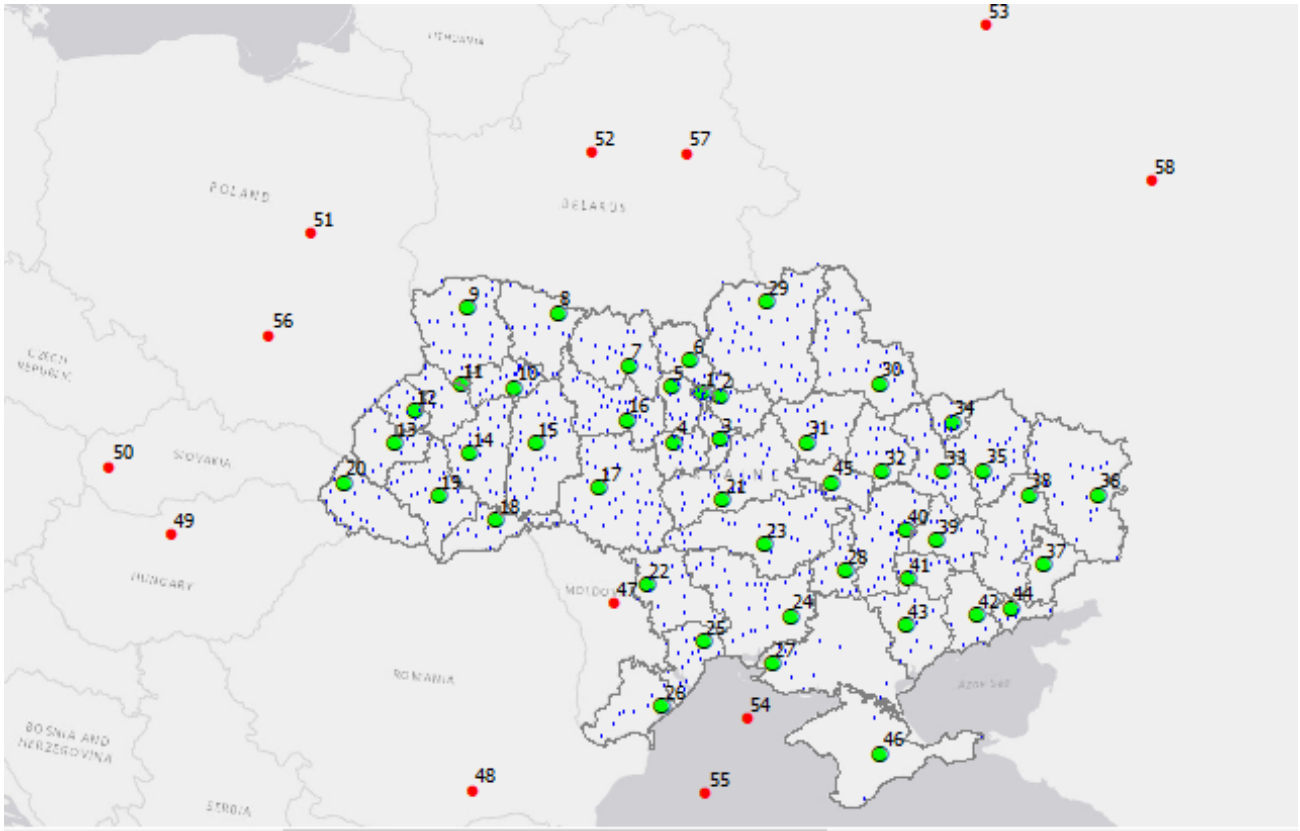
The starting point of the model was the network preparation. The WB team developed a very detailed road network for Ukraine in GIS ESRI format, including all the relevant attributes needed for the development of the model. Details on distance, free flow speed, IRI (then used to derive capacity), number of lanes and others, were specified for the whole network. In addition to data describing the geometric and functional characteristics of the network, it includes several details related to AADT traffic data on a vast number of links.

The network includes details and information pertaining to future projects, so to make possible the analysis and evaluation of impacts of either building new infrastructure or improving the quality of the existing network.

Demand preparation

The zoning system of the Ukraine model is comprised of 58 zones, 46 of them internal (shown in green, these represent the oblasts and main cities) and 12 of them external (shown in red).

Figure 38: Zoning system for the Ukraine model



With reference to the external zones, the model considers:

- Zone 47: Moldova
- Zone 48: Romania
- Zone 49: Hungary
- Zone 50: Slovakia
- Zones 51 and 56: Poland
- Zones 52 and 57: Belarus
- Zones 53 and 58: Russia

An extensive dataset of mobile data, made available by one of the largest mobile operators in Ukraine (Kyivstar - www.kyivstar.ua), came to play a fundamental role in the development of the Ukraine model. This database, properly organized and structured, has been used to prepare the model's basic input demand data. Using this data set, it has been possible to derive the number of journeys using data representing the movement of mobile phones between zones for a period of three months:

- OD matrix for cars: 815,944 daily trips, in persons
- OD matrix for buses: 1,025,161 daily trips, in persons
- OD matrix for trucks: 251,060 daily trips, in persons

To harmonize the trip tables in unique units, "persons" have been converted to vehicles, so to be in a further step converted to PCU (Passenger Car Units). The conversion coefficients used in the model are:

- 2 persons per car
- 25 persons per bus
- 1.2 persons per truck

The totals of the developed OD tables (in vehicles) are summarised below:

- OD matrix for cars: 407,972 daily trips, in vehicles
- OD matrix for buses: 41,006 daily trips, in vehicles
- OD matrix for trucks: 209,216 daily trips, in vehicles

In addition to the above-mentioned trip tables from Kyivstar, "external to external" trips have been added to the car/truck/bus components, using data based on a set of sources available to the WB.

- External to external, OD matrix for cars: 13.425 daily trips, in vehicles
- External to external, OD matrix for buses: 2.024 daily trips, in vehicles
- External to external, OD matrix for trucks: 6.321 daily trips, in vehicles

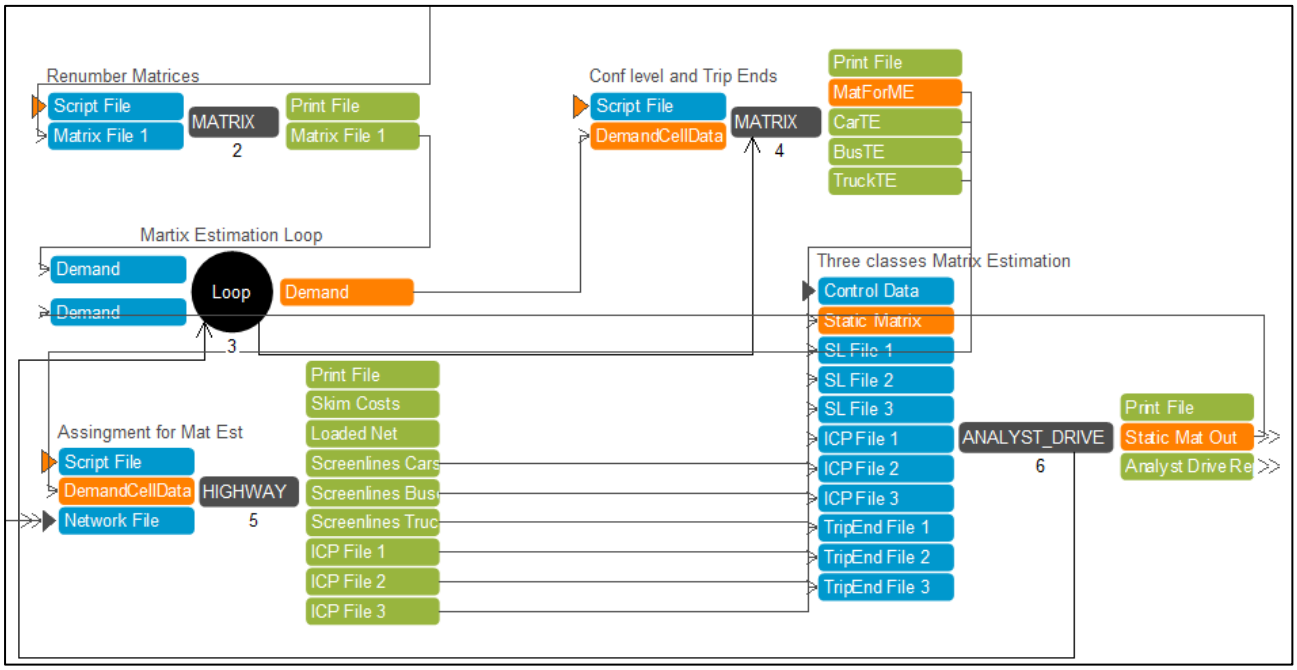
A final manipulation has been implemented to make the trip tables symmetric: this leads to OD tables that will be used as "prior matrices" in the "matrix estimation procedure" that will be described below. The totals are:

- OD matrix for cars: 421,451 daily trips, in vehicles;
- OD matrix for buses: 43,058 daily trips, in vehicles;
- OD matrix for trucks: 215,565 daily trips, in vehicles;

Highway assignment and matrix estimation

This paragraph will describe the approach used in the combined "highway assignment" and "matrix estimation" loop. The image below is a graphical representation of the procedure implemented in the Cube model for Ukraine.

Figure 39: Matrix Estimation Procedure – Cube Ukraine Model



Conceptually, the process consists of:

- Assignment of the initial (prior matrix);
- Comparison with observed data (traffic counts organized in screenlines);
- Estimation of the matrix;
- Assignment of the estimated matrix;
- Comparison with observed data (traffic counts organized in screenlines);
- Loop until observed data and assigned data are within a certain statistical range (per screenline)

Matrix estimation

The matrix estimation process has been implemented by using Cube Analyst. Cube Analyst is a program which estimates an OD trip matrix. The characteristic common to all estimation options offered by Cube Analyst is that they make the best use, in a flexible way, of commonly available data sources to contribute to the estimation process.

A fundamental aspect of the estimation process in Cube is that data are given "levels of confidence" or "reliability" by the user which affect the weight given to different sources of data in the estimation. The estimation process is based on the maximum likelihood technique, coupled with an optimization procedure.

The implemented procedure considers the following input data files:

- Prior trip matrix for the 3 classes: cars, buses, trucks;
- Trip ends for the 3 classes: cars, buses, trucks;
- Screenline data, for the 3 classes;
- Routing information, from the highway assignment program (as described in paragraph 0 and specific per user class (cars, buses, trucks);

All the data (with the exclusion of routing information) are coupled with "confidence levels". Mathematically, confidence levels are both sampling rates and weighting factors. Confidence levels are entered as percentages but, from both points of view, values of greater than 100 are legitimate. The ability of a confidence level to help match an estimated data item (trip end, screenline flow, matrix cell) to its corresponding observed value is influenced by:

1. Data consistency: If data is consistent and free of errors, then the confidence levels will have no influence as they, essentially, help to mediate between different estimates implied by different data items. Conversely, more discrepancies within the data increase the importance of confidence levels.
2. Data quantity: As all data is present in the objective function, the quantity of data is influential, besides the confidence levels. This means that, for example, relatively large confidence levels applied to the prior matrix, which has many data elements, will tend to restrict the scope of a few count sites to influence the estimated matrix to a significant degree.

In the Ukraine model the confidence levels have been set with the following values:

- For OD tables (prior matrices): 25
- For trip end data: 50 for both productions and attractions
- For screenline data: 100

These values basically instruct Cube Analyst to consider:

- high reliability on traffic counts
- average reliability on trip ends
- low reliability on matrix cells

Screenlines are a fundamental input data for the estimation process and are defined as the set of count sites which intercept traffic/passenger flows between sets of zones which share the same general corridors of movement (across which the screenlines are suitably located). The extent of a screenline is determined by the number of alternative (reasonable) paths which are available. The method for defining such screenlines is manual, and based partly on judgement and the availability of count data sites. The routing information, together with user-defined screenlines, is used to define the set of OD pairs whose routes they intercept. The aim is to group count sites into screenlines that balance the objectives to:

1. Maximize the number of OD pairs that have all routes passing through a screenline.
2. Minimize the number of OD pairs per screenline, as this maximizes the information value of the counts for the corresponding matrix cells.

The matrix estimation process implemented for the Ukraine model considers 39 bidirectional screenlines: the images below represent the network and some of the screenlines:

Figure 40: Screenlines on the border of Ukraine

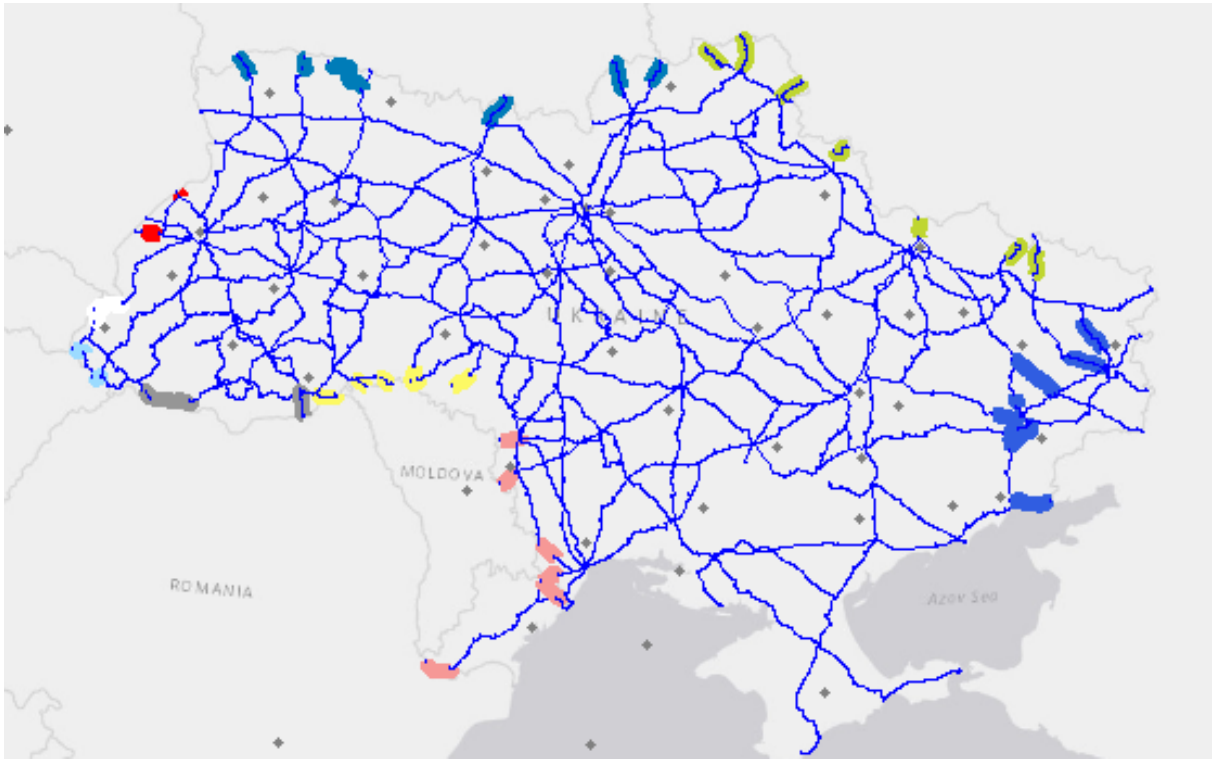
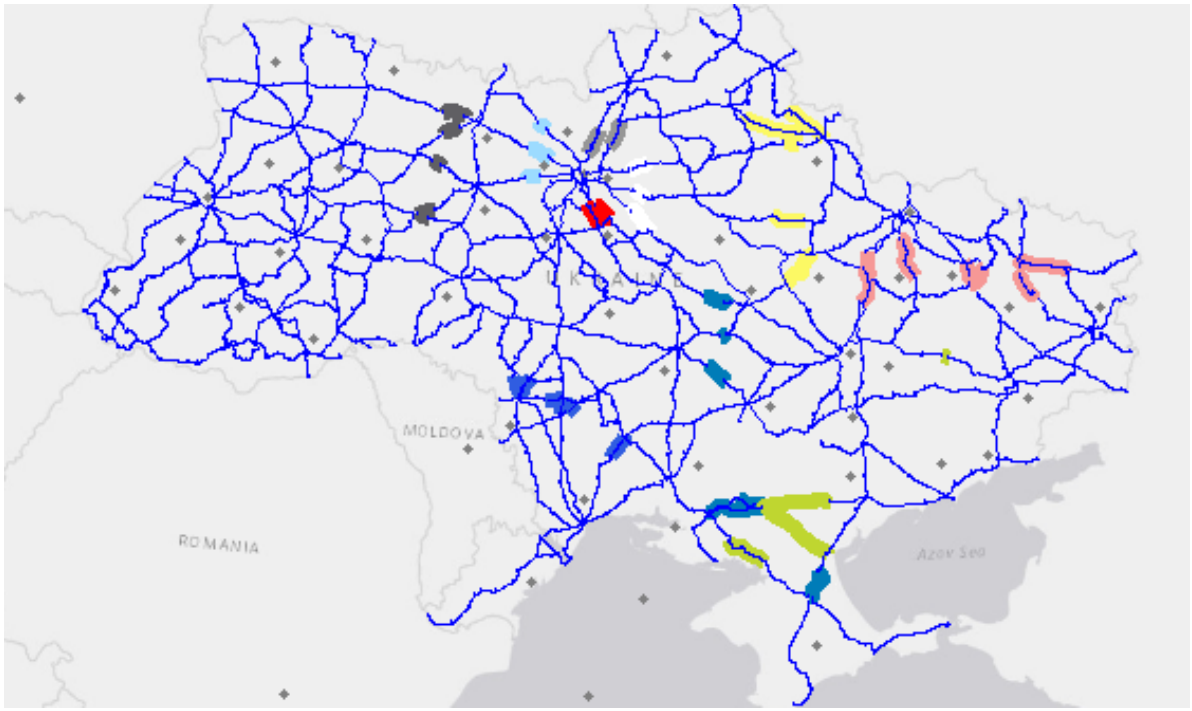


Figure 41: Part of the Screenlines inside of Ukraine



Highway assignment – procedure and main parameters

The highway assignment implemented for the Ukraine model is based on a procedure called "incremental loading", in which the final volumes are the result of adding volumes from subsequent steps, or iterations (13 iterations, in the case of the Ukraine model).

This approach considers that all the iteration volumes are summed to form the final volume. When this process is specified, to user shall specify the fraction of demand that shall be considered at each step. In the Ukraine model, the number of steps and demand portions are:

FRACTIONS=10%; 10%; 10%; 10%; 10%; 10%; 10%; 5%; 5%; 5%; 5%; 5%; 5%

The total volume at the end of each iteration is the accumulated volume for all the iterations to that point. Thus, the V/C ratio used in adjustment of each iteration is based upon a partial assignment. The mathematical function used to represent the impact of V/C over speed on the different links is based on the "BPR[34]" formulation:

$$t = t_0 \times \left(1 + \alpha * \left(\frac{V}{C}\right)^{\beta}\right)$$

The fundamental parameters of the equation used in the model are:

- α: 0.5
- β: 4

In the assignment phase, paths from each origin "I" to each destination "j" are built considering specific cost functions expressed in monetary costs and different by modes:

$$GenCost_{Car} = VOC_{Car} * Distance + VOT_{Car} * \frac{Time}{60} + Toll$$

$$GenCost_{Bus} = VOC_{Bus} * Distance + VOT_{Bus} * \frac{Time}{60} + Toll$$

$$GenCost_{Truck} = VOC_{Truck} * Distance + VOT_{Truck} * \frac{Time}{60} + Toll$$

Where

- VOC_{Car} represents Vehicle Operating Cost for cars;
- VOT_{Car} represents Value of Time for cars;
- VOC_{Bus} represents Vehicle Operating Cost for buses;
- VOT_{Bus} represents Value of Time for buses;
- VOC_{Truck} represents Vehicle Operating Cost for trucks;
- VOT_{Truck} represents Value of Time for trucks;

As mentioned before, the modelled network includes many information and among them the IRI. Vehicle operating costs directly depend by IRI and are expressed in USD/Km. The following table shows the correspondence between VOC and IRI, where a roughness of 2.0 IRI represents a paved road in very good condition, while a roughness of 16 IRI represents a road in extremely poor condition. The values used in the Ukraine model are summarized in the table below (in €/km):

Roughness IRI	VOC_{Car}	VOC_{Bus}	VOC_{Truck}
Less than 4	0.2	0.75	0.6

[34] Bureau of Public Roads

4-6	0.225	0.8	0.65
6-9	0.25	0.9	0.7
Greater than 9	0.275	1	0.9
Not defined	0.3	1.1	0.95

With reference to VOTs, the used values are:

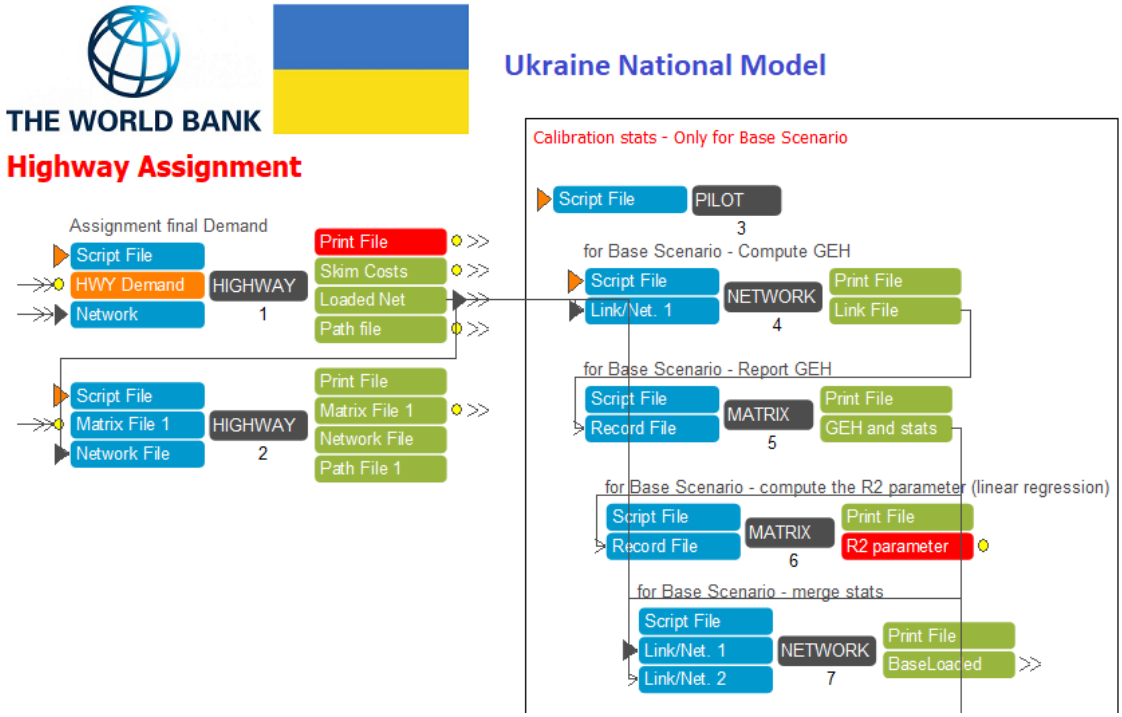
- $\mathrm{VOT}_{\mathrm{Car}}$: 3 €/hour
- $\mathrm{VOT}_{\mathrm{Buses}}$: 8 €/hour
- $\mathrm{VOT}_{\mathrm{Trucks}}$: 9 €/hour

Another relevant element of the highway assignment model consists on the fact that the OD tables, representing cars, buses and trucks in vehicles, needed to be converted into PCU (Person Car Unit). For the Ukraine model, the conversion factors used are:

- Car: 1 PCU
- Buses: 2.5 PCUs
- Trucks: 3 PCUs

The image below shows the application used in the Cube interface for the specific tasks of "highway assignment".

Figure 42 – Highway Assignment Procedure – Cube Ukraine Model



Validation of the matrix estimation model

To measure the fitness of the highway assignment model, a validation process has been performed. Cube Analyst allows to compare the flows per screenline.

<u>For cars:</u>

- 85% of the screenlines have a difference between the observed flows and the estimated flows in the range -5%|+5%
- 88% of the screenlines have a difference between the observed flows and the estimated flows in the range -10%|+10%

For buses:

- 81% of the screenlines have a difference between the observed flows and the estimated flows in the range -5%|+5%
- 90% of the screenlines have a difference between the observed flows and the estimated flows in the range -10%|+10%

For trucks:

- 88% of the screenlines have a difference between the observed flows and the estimated flows in the range -5%|+5%
- 90% of the screenlines have a difference between the observed flows and the estimated flows in the range -10%|+10%

Validation of the highway assignment model

While the matrix estimation model considers screenlines (hence groups of links containing observed traffic data), the highway assignment model can be validated comparing the single links, not grouped. The process consists in an analysis of the assignment obtained using the estimated matrices and comparing observed flows and assigned flows.

The statistical parameter GEH was chosen to validate the model. GEH is currently used in traffic modelling to compare two sets of traffic volume, and is based on the following formula:

$$GEH = \sqrt{\frac{2 * (M - C)^2}{M + C}}$$

Where:

- M (modelled) is the volumes loaded on the link during the assignment
- C (counted) is the observed volumes from traffic counts

GEH hence considers the error in flows between “observed” and “assigned”. This is then compared against the average of the two and leads to a measure where both the relative and absolute error are considered, and all counts can be compared on an equal basis. For this reason, a measure such that is preferred to be using a fixed comparison percentage.

The table below shows the main results on the above mentioned “strategic links”. Most of these links show very good GEH values (with values less than 5), while some show differences between the observed data and the modelled data and will require further investigation (this may require specific data collection to improve the quality of the existing data).

A	B	Count PCU	Loaded PCU	GEH	DELTA	PERC_DELTA
1500	1490	1573.25	1584.29	0.28	11.04	0.70
1490	1500	1573.25	1584.43	0.28	11.18	0.71
1040	1038	14717.25	14731.63	0.12	14.38	0.10
1038	1040	14717.25	14749.33	0.26	32.08	0.22

A	B	Count PCU	Loaded PCU	GEH	DELTA	PERC_DELTA
1011	1008	7638.00	7691.28	0.61	53.28	0.70
1008	1011	7638.00	7671.21	0.38	33.21	0.43
1727	1731	15851.75	12354.92	29.45	-3496.83	-22.06
1731	1727	15851.75	11975.86	32.86	-3875.89	-24.45
1735	1320	17311.75	17314.11	0.02	2.36	0.01
1320	1735	17311.75	17284.69	0.21	-27.06	-0.16
1071	1061	12122.75	11841.81	2.57	-280.94	-2.32
1061	1071	12122.75	11835.35	2.63	-287.40	-2.37
1077	1041	8180.75	7128.61	12.03	-1052.14	-12.86
1041	1077	8180.75	7634.83	6.14	-545.92	-6.67
1203	1189	4999.00	5044.38	0.64	45.38	0.91
1133	1107	6553.25	7793.17	14.64	1239.92	18.92
1189	1203	4999.00	5032.44	0.47	33.44	0.67
1107	1133	6553.25	7277.31	8.71	724.06	11.05
1612	1618	7071.25	7080.36	0.11	9.11	0.13
1618	1612	7071.25	7083.47	0.15	12.22	0.17
1183	1177	9575.75	9537.50	0.39	-38.25	-0.40
1177	1183	9575.75	9535.17	0.42	-40.58	-0.42
1128	1117	7732.25	5896.40	22.24	-1835.85	-23.74
1117	1128	7732.25	5742.01	24.25	-1990.24	-25.74

Despite the variety and uncertainty in the input data, and the lack of some information, the results can be considered as acceptable, especially considering the main corridors where future projects will be implemented.

Growth rates

The growth rates used to forecast the future demand are listed below.

Zone	Zonal Oblast	Class Name	Gross rate
9	Волинська	Medium	2%
12	Львівська	Medium	2%
13	Львівська	Medium	2%
14	Тернопільська	Medium	2%
15	Хмельницька	Medium	2%
16	Житомирська	Medium	2%
18	Чернівецька	Medium	2%
19	Івано-Франківська	Medium	2%
20	Закарпатська	Medium	2%
21	Черкаська	Medium	2%
23	Кіровоградська	Medium	2%
24	Миколаївська	Medium	2%
27	Херсонська	Medium	2%
28	Дніпропетровська	Medium	2%
29	Чернігівська	Medium	2%
30	Сумська	Medium	2%
38	Донецька	Medium	2%
41	Запорізька	Medium	2%
2	Київська	Low	1%

3	Київська	Low	1%
4	Київська	Low	1%
5	Київська	Low	1%
6	Київська	Low	1%
7	Житомирська	Low	1%
8	Рівненська	Low	1%
10	Рівненська	Low	1%
11	Львівська	Low	1%
22	Одеська	Low	1%
26	Одеська	Low	1%
31	Полтавська	Low	1%
32	Полтавська	Low	1%
33	Харківська	Low	1%
35	Харківська	Low	1%
39	Дніпропетровська	Low	1%
42	Запорізька	Low	1%
43	Запорізька	Low	1%
44	Донецька	Low	1%
45	Полтавська	Low	1%
1	м.Київ	KYIV	4%
17	Вінницька	High	3%
25	Одеська	High	3%
34	Харківська	High	3%
36	Луганська	Medium	2%
37	Донецька	Medium	2%
40	Дніпропетровська	High	3%
46	Автономна Республіка Крим	Medium	2%
47	Moldova	High	3%
48	Romania	High	3%
49	Hungary	High	3%
50	Slovakia	High	3%
51	Poland 1	High	3%
52	Belorus 1	Medium	2%
53	Russia 1	Medium	2%
54	Sea 1	High	3%
55	Sea 2	High	3%
56	Poland 2	High	3%
57	Belorus2	Medium	2%
58	Russia 2	Medium	2%

ANNEX 3: KEY ASSUMPTIONS FOR PPP ANALYSIS

Cost estimates were made using the following data sources and assumptions:

- Capital costs (capex) were estimated by Egis using whatever data were available from UAD, Google Earth, unit costs from recent feasibility studies and other local knowledge.
- Factors ranging between 1.1 and 1.7 (weighted average 1.38) were applied to these estimates to take account of site-related uncertainties. The highest factor was applied to a project that would entail extensive realignment and earthworks through mountainous terrain.
- Financial cost estimates were adjusted to arrive at economic (or resource) costs, chiefly by deducting indirect taxes. Economic costs are uniformly 79% of financial costs.
- The salvage value of capital works was assumed to be 25% of the original cost at the end of the appraisal period.
- Periodic maintenance was assumed to take place at 7-year intervals on project roads, with routine maintenance (including winter maintenance) every year.
- A realistic do-minimum maintenance case (the base case) comprising both routine and periodic maintenance was formulated and costed, against which to compare with-project cases. This is considered plausible because Egis's Interim Report established that revenue to the RF should be sufficient to cover long-term network-wide maintenance to a reasonable standard.

Traffic projections were made on the following basis:

- Existing traffic volume on each homogeneous road section was taken from the UAD database, except that in agreement with IFC, the consultant's own traffic count was used for M-10 Lviv–Krakovets.
- The traffic assignment model was used to predict the incidence and extent of traffic diversion attributable to each project.
- Uniform traffic growth of 3%pa was projected.
- Uniform traffic generation was assumed to be equivalent to 20% of normal traffic.
- Introduction of tolling was assumed to result in a 20% reduction of traffic on the tolled road through toll avoidance.

Benefits from road improvement depend largely on the difference between road conditions (geometry, width and surface roughness) that a project brings about. The following data, assumptions and inclusions were used:

- For each homogeneous road section, the UAD database provides its approximate length, network (M, H or P)[35], categorization (1, 2, 3 or 4)[36], the number of lanes (2 or 4), carriageway width and most recently measured roughness (using the International Roughness Index, IRI).
- The HDM-4 model automatically adjusts IRI values over time in response to traffic load and both capital and maintenance interventions.
- The analysis included only benefits in the form of road user cost (RUC) savings, comprising reduced vehicle operating costs (VOC) and time savings. Normal, generated and diverted traffic were all taken into account.

35 Міжнародний (International), National or Regional.

36 Category 1 is subdivided into 1A (Motorway) and 1B, but this is not shown in the database.

- But no objective basis was found for estimating the likely effect of the projects on accident costs or valuing potential exogenous benefits such as reduced emissions and developmental impact – except insofar as generated traffic may be considered evidence of developmental impact.
- Reduced urban congestion was explicitly included only in the economic analysis of the LNB, where the removal of traffic from Lviv City streets represents a major project objective. Those benefits are not amenable to capture by way of tolling.

ANNEX 4: PPP ANALYSIS

Descriptions and more detailed analyses of the projects are presented in tabular form below.

N-11 Dnipro – Kryvyi Rig – Mykolaiv

<table>
<tr><td colspan="4">Project rationale and description
• The N-11 serves important industrial centres and transport hubs and offers the most direct route between Dnipro and Mykolaiv, and more significantly between Kharkiv and Odessa.
• But for most of its length it is Category 2, and in places only Category 3. Its condition is very poor (IRI up to 13.2) largely because of overloaded trucks.
• Consequently an estimated 4,000 vehicles/day avoid the road by taking a circuitous route between Kharkiv and Odessa (M-03, M-22, M-04, M-12, M-13 and M-05) that entails traveling an extra 88km.
• The project would upgrade the whole road to Category 1.</td></tr>
<tr><td>Traffic in 2017
distance-weighted average
6,600 vehicles/day</td><td>Road length
with project
278.5 km</td><td>Road condition
International Roughness Index
Ave 7.2 | Max 13.2</td><td>Capital cost
financial, including VAT
$1,084 million</td></tr>
<tr><td>Economic CBA
in real terms</td><td>EIRR
NPV</td><td>2.5 %pa
–$353 million</td><td>Conclusion
Even with substantial traffic diversion this project is not feasible. Improved maintenance and effective action against overloading would yield much better returns.</td></tr>
</table>

M-06 Stryi – Hungarian Border

Project rationale and description

- The road is an important international link to the Balkan states and southern Europe. It connects to Hungarian highway M-3, whose construction was stopped 20km from the Ukrainian border due to the absence of an agreed cross-border route.
- The road surface is good throughout, but 90% of its length is Category 2 and its alignment (vertical and horizontal) through the Carpathian Mountains makes travel slow and hazardous, especially in winter.
- From WB's traffic analysis it appears that 1,500 vehicles/day would divert from N-13 (just inside the border with Poland and Slovakia) to an upgraded M-06.
- As well as promoting international trade, an improved road would benefit communities south and west of Mukachevo by facilitating economic and cultural ties with the rest of Ukraine.
- The project would upgrade the whole road to Category 1, with straightening of a mountainous section involving large-scale earthworks.

Traffic in 2017 distance-weighted average 9,700 vehicles/day	**Road length** with project 214.5 km	**Road condition** International Roughness Index Ave 2.1 | Max 2.8	**Capital cost** financial, including VAT $1,485 million

Economic CBA in real terms	EIRR NPV	4.5%pa –$392 million	*Conclusion* The cost of upgrading the whole length to Category 1 is prohibitive in economic terms, but selective improvement of mountainous sections may be justified. There are political considerations as well as economic, since the road provides a link to relatively remote communities in border areas. If political benefits are worth at least $392 million, the project becomes worthwhile.

M-06 Lviv – Stryi

Project rationale and description

- This is a well-trafficked road between the principal urban centre of western Ukraine and a city of 60,000 within commuting distance to the south.
- It also lies on the route between two important tourist attractors (Lviv City and the Carpathian Mountains) and a trade route to neighbouring Slovakia, Hungary and Romania.
- The condition of the pavement is very good, but for most of its length the road is Category 2.
- The project would upgrade the whole road to Category 1.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
22,700 vehicles/day	59.5 km	Ave 1.4 | Max 1.8	$276 million

Economic CBA in real terms	EIRR	11.7 %pa	*Conclusion* The project is economically justified, even with a substantial adverse change in assumptions (eg 40% higher capital cost).
	NPV	$122 million	
Financial (PPP) analysis in real terms	Project IRR	13.0%pa	*Conclusion* This road has potential for a toll concession with no need for public subsidy. But since the road is already in good condition, albeit only 2-lanes wide, users may not consider a toll justified. There is a toll-free alternative route (via Territorial Roads T-1416, T-1402 and 1418) that is 36% longer.
	Debt:equity	80:20	
	Subsidy:capex	Nil	
	ROE	24.9%pa	

M-10 Lviv – Krakovets

Project rationale and description

- The M-10 connects Lviv to the Polish border where it joins Polish Road A4 that leads to Krakow, Katowice and Wroclaw, and thence to Berlin and Hamburg.
- It runs parallel to the M-11 which lies up to 17km to the south. The M-09 lies further way to the north, joining Polish Road 17 that goes to Lublin. It is estimated that 10,200 vehicles/day would potentially divert from these roads to an upgraded M-10 or greenfield alternative [a].
- The M-10 is in good condition but only 4km is Category 1. The project would upgrade the whole length to Category 1.
- Previous attempts to attract private investment to a toll concession at this site have failed. The present analysis considered 2 greenfield (GF) options and 1 brownfield (BF) option.
- Another variant of this project is currently being studied. It would include construction and tolling of a 24.4km bypass to the north of Lviv (the Lviv Norther Bypass or LNB) in the hope that it would enhance concession profitability and thereby reduce the need for subsidy; see the next box.

Traffic in 2017 distance-weighted average 8,100 vehicles/day [b]	**Road length** with project 68.0 km	**Road condition** International Roughness Index Ave 1.9 | Max 2.3	**Capital cost** financial, including VAT GF 1A $290 million GF 1B $281 million BF 1B $225 million

Economic CBA in real terms	**Greenfield Category 1A** EIRR 7.4%pa NPV –$19 million **Greenfield Category 1B** EIRR 7.4%pa NPV –$19 million **Brownfield Category 1B** EIRR 5.5%pa NPV –$52 million	*Conclusion* Neither option appears to be economically justified, unless exogenous benefits are worth at least $19 million. Moreover, economic performance depends heavily on traffic diversion from the 2 other roads that connect Lviv to the Polish border. The scale of this diversion must be verified.
Financial (PPP) analysis in real terms	**Greenfield Category 1A** Project IRR 1.4%pa Debt:equity 80:20 Subsidy:capex 1.30 ROE 13.3%pa **Brownfield Category 1B** Project IRR 5.0%pa Debt:equity 80:20 Subsidy:capex 0.72 ROE 14.3%pa	*Conclusion* Commercial viability is possible only with heavy gearing and heavy subsidy. The results would be even worse if the predicted scale of traffic diversion from M-09 and M-11 proves to be over-optimistic.

[a] However, this was estimated by applying percentages that were derived from 2013 OD survey data to 2017 UAD traffic data for M-09 and M-11, which have not been verified.
[b] This is consultants's count west of Ivano Frankove. It is considered more plausible than AUD's average count of 17,900, but comfortably exceeds the average counts of 5,400 by UAD in 2009 and 5,900 by consultants conducting the traffic study for a greenfield Lviv–Krakovets Motorway in 2013.

Lviv Northern Bypass (LNB)

Project rationale and description

- East-west traffic, for example travelling between Kyiv and any origin/destination in Poland or further west, is forced to go through the centre of Lviv City or use the Southern Bypass. The LNB would offer alternative that is about the same distance as the route through Lviv City but much shorter in time.
- As well as saving time for through traffic, the LNB would relieve congestion within the city, benefiting its inhabitants and resident businesses and relieving the local authority of maintenance costs imposed by heavy long-haul vehicles.
- It is conceived as an addition to the proposed Lviv-Krakovets road project (whether brownfield or greenfield), potentially enhancing the viability of a toll concession.
- The LNB would be an entirely new construction, 25.5km in length, traversing difficult terrain that is likely to make it an exceptionally costly project on a per-kilometre basis. Because of the uncertainty two analyses have been made, with financial capital costs of $180M and $270M.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
10,500 vehicles/day [b]	25.5 km	New construction	Min: $180 million Max: $270 million

Economic CBA in real terms	**Minimum capex** EIRR 12.6%pa NPV $61 million **Maximum capex** EIRR 7.9%pa NPV –$2 million	*Conclusion* Even with the highest capital cost estimate, the project is on the borderline of economic feaibility. If benefits to Lviv's inhabitants from reduced pollution and improved road safety were quantified and included, it would certainly exceed the threshold EIRR of 8%pa. Adding the LNB to the M-10 Lviv-Krakovets project would enhance that project's EIRR by between 0.2 and 1.5 percentage points.
Financial (PPP) analysis in real terms	**Minimum capex** Project IRR –3.4%pa Debt:equity 79:21 Subsidy:capex 0.72 ROE 7.6%pa **Maximum capex** Project IRR –6.8%pa Debt:equity 79:21 Subsidy:capex 0.84 ROE 5.5%pa	*Conclusion* Commercial viability is possible only with heavy gearing and heavy subsidy, which may be justified on the grounds of reduced urban congestion and attendant unquantifiable benefits. It is also possible that rather higher tolls could be charged, because of the expected substantial time savings. But even a doubling of the tariff would only bring the real ROE up to 11.1%pa (minimum capex) or 9.2%pa (maximum capex).

M-05 Kyiv – Bila Tserkva

Project rationale and description

- The M-05 connects Lviv to Odessa, through Bila Tserkva which is city of over 200,000 inhabitants with large manufacuring units (automotive tyres and railway brake products). It lies within commuting distance of Kyiv.
- It is a Category 1B road in very good condition, with 4-lane and 6-lane sections and observed traffic speeds up to 130km/h. There is reportedly congestion at peak times and at present growth rates there are expected to be capacity constraints.
- The Government's proposal is for a greenfield project comprising a Category 1A road, parallel to the M-05 and with access only at Kyiv and Bila Tserkva. Its chief purpose would be to reduce costs and travel times for long-haul traffic willing to bear a substantial toll; but commuter traffic may also find it an attractive alternative.
- Two alternatives have also been considered: greenfield (GF) 1B and brownfield (BF) 1B.
- UAD's greenfield concept is for a closed road with access only at Kyiv and Bila Tserkva, while this analysis assumes several intermediate access points.

Traffic in 2017 distance-weighted average 25,500 vehicles/day (Max 41,000)	**Road length** with project 50.2 km	**Road condition** International Roughness Index Ave 3.0 | Max 4.3	**Capital cost** financial, including VAT GF 1A $536 million GF 1B $516 million BF 1B $142 million

Economic CBA in real terms	**Greenfield Category 1A** EIRR 0.2%pa NPV –$289 million **Greenfield Category 1B** EIRR 1.3%pa NPV –$246 million **Brownfield Category 1B** EIRR 8.9%pa NPV $13 million	*Conclusion* The brownfield version is marginally feasible with a social discount rate of 8%pa. There may be exogenous benefits in the form of reduced congestion on Kyiv streets if the project entails some separation between urban traffic and through-traffic; and integral safety measures involving separation of traffic from roadside settlements may reduce accident costs.
Financial (PPP) analysis in real terms	**Greenfield Category 1A** Project IRR 5.2%pa Debt:equity 80:20 Subsidy:capex 0.71 ROE 15.5%pa **Brownfield Category 1B** Project IRR 12.5%pa Debt:equity 75:25 Subsidy:capex Nil ROE 20.8%pa	*Conclusion* The existing Kyiv–BilaTserkva section of M-05 is good now and traffic flows freely at most times. Because greenfield capital costs are 270% higher than brownfield, the financial results are much better for the latter. However, it is doubtful that the default toll (or any toll) would be collectable on an improved M-05. It is also doubtful whether enough short-haul traffic could be attracted to a new (ie greenfield) road. The consultant's financial analysis assumes a distance-weighted average of 33,000 in the first year of operation. Traffic south of Bila Tserkva, towards Odessa, is only 10,000 vehicles/day at present.

M-06 Lviv – Brody – Dubno – Rivne

Project rationale and description

- This is a well-trafficked stretch of the M-06, but although its surface condition is very good only 30% is Category 1.
- There is little correlation between traffic volume and categorization: in some sections 30,000 vehicles/day are traveling on a 2-lane road, with inevitable implications for speed and safety.
- From WB's traffic analysis it appears that 1,100 vehicles/day are currently using R-24 and R-48 to avoid M-06, incurring a distance penalty of 20km.
- The project would bring the whole length to Category 1. This would complement other upgrading works completed and under way on the M-06.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
15,200 vehicles/day	194.6 km	Ave 1.4 | Max 1.9	$613 million

Economic CBA in real terms	EIRR	3.0%pa	*Conclusion* The project is not economically justifiable, even if capital costs were 40% less than estimated.
	NPV	–$264 million	
Financial (PPP) analysis in real terms	Project IRR	11.3%pa	*Conclusion* With the default toll rates, this project could be viable without subsidy. But the low EIRR suggests that the default tolls may be excessive.
	Debt:equity	68:32	
	Subsidy:capex	Nil	
	ROE	17.1%pa	

M-09 Lviv – Ternopil

Project rationale and description

- The condition of this road is reasonable but it is 95% Category 2 and 5% Category 3.
- From WB's traffic analysis it appears that 3,900 vehicles/day are currently using N-09 and M-12 to avoid M-09, incurring a distance penalty of 35km.
- The project would bring the whole road to Category 1 standard, which should attract back the traffic for which it would be the shortest route.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
9,100 vehicles/day	118.4 km	Ave 4.7 | Max 6.4	$293 million

Economic CBA in real terms	EIRR	17.7%pa	*Conclusion* The project is economically justifiable, even if the capital cost were 100% more than estimated.
	NPV	$298 million	
Financial (PPP) analysis in real terms	Project IRR	12.2%pa	*Conclusion* With the default toll rates this project could be viable without subsidy.
	Debt:equity	73:27	
	Subsidy:capex	Nil	
	ROE	20.1%pa	

M-12 Ternopil – Uman

Project rationale and description

- Though lightly trafficked – except in the immediate vicinity of urban centres Ternopil, Khmelnitsyi and Vinnytsia – this long stretch of the M-12 is a substantial link in the Gdansk–Odessa (GO) Highway, which has high strategic priority for Ukravtodor.
- At Uman, its eastern extremity, the road forms a junction with the north-south M-05 that links Kyiv to Odessa. Beyond that junction the M-12 serves Kropyvnytskyi, a city of 234,000, where it becomes the M-04 that continues to Dnipro and Donetsk.
- Only 17% of its length is Category 1 and 12% is Category 3. The project would bring it all to Category 1.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
6,800 vehicles/day	438.0 km	Ave 4.2 | Max 7.0	$1,211 million

Economic CBA in real terms	EIRR	–2.0%pa	*Conclusion*
	NPV	–$678 million	The project is not economically justifiable, even if the capital cost were 50% less than estimated.

M-18 Dnipro – Zaporizhya – Melitopil

Project rationale and description

- This road links significant urban centres, in particular Zaporizhya which is a city of over 750,000 inhabitants with important metallurgical, automotive, chemical and electronics industries.
- Kherson and Odessa lie to the west of Melitopil on M-14. Reportedly some traffic uses M-18/M-14 in preference to the more direct N-11, which would be upgraded under another project proposal.
- The road is in fair condition throughout. 95% is Category 2, the remainder being Category 1. This seems appropriate at present traffic levels, which barely exceed 10,000 vehicles/day except in the immediate vicinity of Zaporizhya.
- The project would bring the whole road to Category 1.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
9,000 vehicles/day (Max 26,100)	207.3 km	Ave 3.6 | Max 4.7	$823 million

Economic CBA in real terms	EIRR	1.5%pa	*Conclusion*
	NPV	–$368 million	This road being in fair condition, with moderate traffic and no expectation of diversion from other routes, the proposed upgrading is not economically justified at present, even if the capital cost were 40% less than estimated.

N-03/R-05 Chernivtsi – Rivne

Project rationale and description

- This stretch of road connects roads that radiate from Lviv and Khytomyr. It directly serves Khmelnytskyi, with a population of 290,000 in 2005, in an area rich in agricultural and mineral resources (especially building materials).
- The R-05 continues north to the Belarusian border (Stolyn). To the south Cherivtsi is only 41km from the Romanian border (Syret) via M-19.
- The condition of the road is fair but less than 10% of its length is Category 1.
- From the WB's traffic analysis it appears that 1,600 vehicle/day that currently use a 20km longer route via R-14 and R-28 and would divert to an improved N-03/R-05.
- The project would upgrade the whole length of the road to Category 1.

Traffic in 2017 distance-weighted average	**Road length** with project	**Road condition** International Roughness Index	**Capital cost** financial, including VAT
7,100 vehicles/day	380.0 km	Ave 4.8 | Max 6.2	$1,056 million

Economic CBA in real terms	EIRR	–0.3%pa	*Conclusion*
	NPV	–$531 million	The project is not economically justifiable, even if the capital cost were 50% less than estimated.

ANNEX 5: ANALYSIS OF MAINTENANCE COSTS

This analysis is based on a number of Excel spreadsheets provided by UAD that show the derivation of operational maintenance costs based on norms.

According to regulations the maintenance budget should be structured as follows:

- Overhaul (rehabilitation without upgrading)
- Current repair (planned preventive repairs, or periodic maintenance)
- Operational maintenance (routine maintenance, winter maintenance, emergency repairs).

The workbooks for estimating routine maintenance costs are for a network that is about 10 000 km less than the officially reported network, perhaps because unsealed roads are excluded:

	Roads of local importance km	Roads of state importance km	Total km
UAD Routine Maintenance Model	112 375	47 037	159 413
UAD reported network (2015)	117 640	52 009	169 649

Operational maintenance costs are calculated on assumed quantities of work for 'Specified' and 'Minimum' maintenance scenarios. Base costs for roads of state and local are factored according to:

- Inflation (Annual Production Cost Index);
- Road category; and
- Physical characteristics in each Oblast (climate, topography etc).

The estimates for routine maintenance of the public road network in 2017 were as shown in the table below.

Table 28 Routine Maintenance Costs Estimated by Ukravtodor, 2017

	Routine Maintenance Costs ('000 UAH)	
	Specified	Minimum
Roads of state significance	26 095 130	6 146 076
UAH/km	*554 775*	*130 664*
Roads of local significance	16 141 945	3 623 068
UAH/km	*143 704*	*32 240*
TOTAL	**42 244 075**	**9 769 145**

In Table 29 these estimates are disaggregated by network category and traffic volume category (I–V), and converted to USD for comparative purposes.

Table 29 Routine Maintenance Costs Disaggregated (USD)

Network Category	USD/km/year					Total Annual Cost	Average USD/km /year
	I	II	III	IV	V		
Specified 'Ideal' Scenario							
State significance	47 300	25 710	21 950	14 780	10 580	1 046 300 000	22 240
Local significance	16 590	9 360	8 120	5 830	3 870	647 500 000	5 760
TOTAL						**1 693 800 000**	**10 630**
Minimum 'constrained' scenario							
State significance	11 140	6 050	5 170	3 480	2 480	246 400 000	5 360
Local significance	3 720	2 100	1 820	1 310	870	145 300 000	1 290
TOTAL						**391 700 000**	**2 460**

Annex 5.1: Comparison of routine maintenance costs

Direct comparisons between countries are notoriously difficult (see 'Benchmarking of Expenditures and Practices of maintenance and operation -BEXPRAC, CEDR March 2010').

The M06 OPRC project in Ukraine covers a mix of Category I and II roads. The average cost of routine and winter maintenance is USD35,000/km/year. This is 'high end' maintenance and is more costly than in most other countries.

The BEXPRAC study highlighted the difficulty of comparing maintenance costs between countries with different network characteristics, traffic, climate etc. as well as differences in classification of maintenance/operation activities and accounting procedures.

As a guide, maintenance costs for a 2x2 lane road (4 lane equivalent) were found to be typically as follows, expressed in EUR as in the BEXPRAC document:

- Traffic management (signalling systems and information to road users) USD6,000/km
- Routine operations (patrolling/rescue) – too much variation to be useful
- Winter service highest USD11,600/km (for countries with most snow), lowest USD5,000/km
- Routine maintenance of roadway and structures: accounts for 25% of all costs
- Maintenance of equipment (lighting, traffic lights) less than USD5,000/km
- Maintenance of safety devices < USD5,000/km

In addition:

- Preventive or periodic maintenance accounts for about 60% of total expenditure in a country.
- Equivalence factor for 2-lane road, around 0.4.

Sweden is perhaps the most useful example to compare with Ukraine, although absolute costs should be adjusted for cost of living differences. Indicative annual costs are as follows, expressed in USD in line with other values in this report:

- Total cost around USD56,000/km for 4 lane equivalent (Cat I road)
- Management: USD6,700/km or 12%
- Routine maintenance: USD7,800/km or 14%

- Winter maintenance: USD14,000/km or 25%
- Periodic maintenance: USD25,000/km/year or 45%

On this basis routine (and winter) maintenance costs for a Category I road in Sweden would be around USD29,000/km. Sweden has a purchasing power parity (PPP) rating 5 times that of Ukraine so some adjustment is required to make comparisons.

If it is assumed that equipment and materials costs are similar, only management and labour costs should be adjusted. Equipment and fuel/materials typically make up 70% of costs, so roughly 30% needs to be adjusted for PPP.

$$C_{Ukaine} = C_{Sweden} (0.7 + 0.3/N_{PPP})$$

This translates to an adjustment factor of 0.76. The equivalent cost in Ukraine for Cat 1 routine maintenance would therefore be around USD22,000/km per year. Applying an equivalence factor of 0.4, single carriageway maintenance of a principal road would be around USD8,800/km per year.

By contrast, the M06 OPRC project in Ukraine covers a mix of Category I and II roads and the average cost of routine and winter maintenance has been estimated at USD35 000/km per year. This is 'high end' maintenance and is more costly than in most other countries.

Annex 5.2: Realistic operational maintenance costs for Ukraine

Comparison with the cost model for 'Specified' and 'Minimum' scenarios suggest that the cost of an acceptable maintenance strategy should lie between the 'Minimum' and 'Specified' UAD scenarios with Category 1 maintenance costing 100% more and Category 2 maintenance costing about 50% more than the 'Minimum'. If the same 50% factor is applied to the lower category roads, an acceptable maintenance strategy should cost in the region of around UAH15 billion per year which would be sufficient to cover operational maintenance needs to a reasonable level.

Table 30 Realistic Operational Maintenance Expenditure Scenario

Network Category	USD/km/year					Total Annual Cost	Average USD/km /year
	I	II	III	IV	V		
Realistic scenario based on cost comparison							
State significance	22 226	9 060	7 736	5 208	3 708	383 598 424	10 226[37]
Local significance	7 426	3 143	2 725	1 958	1 299	217 392 800	1 934
TOTAL USD						**600 991 225**	
TOTAL UAH						**15 024 780 642**	

[37] Weighted average