



**YEREVAN STATE
UNIVERSITY**



WORLD BANK GROUP
Transport & ICT



Measuring Rural Accessibility in the GIS environment: Case Study of Armenia

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Yerevan, Armenia

Motivation behind the Study

The studies were conducted in the framework of the project

“Impacts of Roads on Poverty and Access”

carried out in cooperation with the **World Bank**

Motivation behind the Study

Study seeks to answer two questions:

- **how do we characterize physical accessibility in Armenia**
- **what are the main constraints for accessing markets and services?**

Motivation behind the Study

Armenia - Context

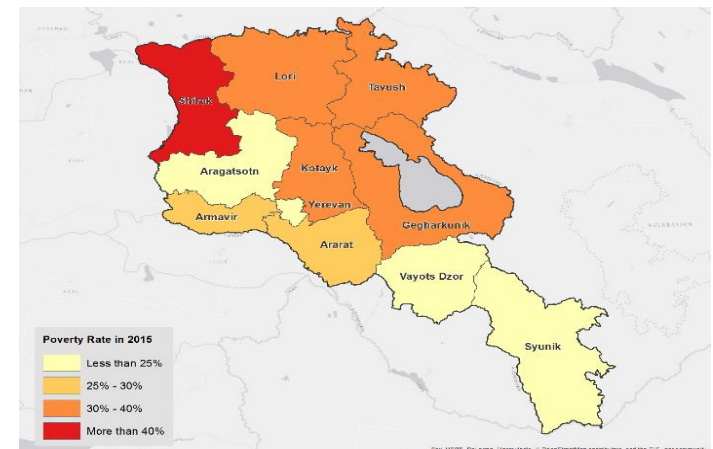
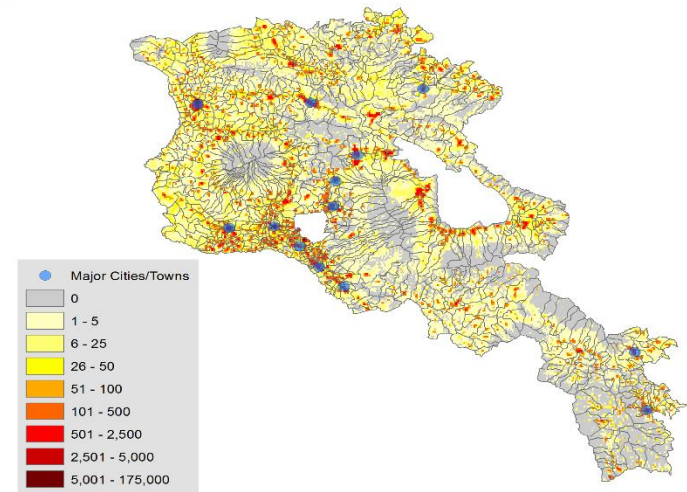
Compact size – Urban primacy but high share of rural population

Significant cross-regional disparities – lagging areas

Large migration flows and seasonal employment

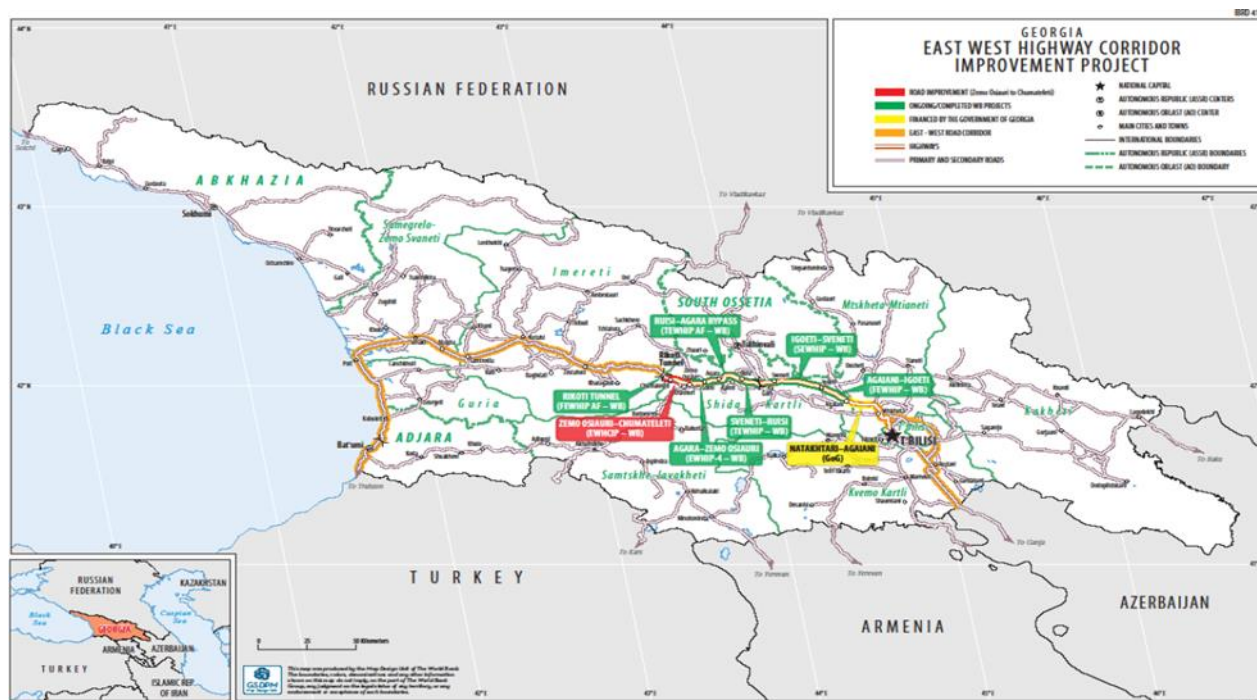
Dependence on remittances

Process of community consolidation



Evidence from the Literature – Georgia

- Georgia is upgrading 350 kilometers of principal highway between the Black Sea and Azerbaijan
- World Bank financed \$500 million of the total amount \$2.3 billion (14% of Georgia's 2014 GDP)
- Economy simulation - wide effects



Estimated Long-term Impact

- Georgia's real GDP would be 4.2 percent higher
- household income gains ranging from 2.6 percent to 4.4 percent



Tools and Methodologies

Three indices are proposed:

- (a) Rural Accessibility Index (RAI),
- (b) Market Accessibility Index (MAI),
- (c) Service Accessibility Index (SAI)

Tools and Methodologies

Accessibility Indicators – Rural Access Index

Where do people live?

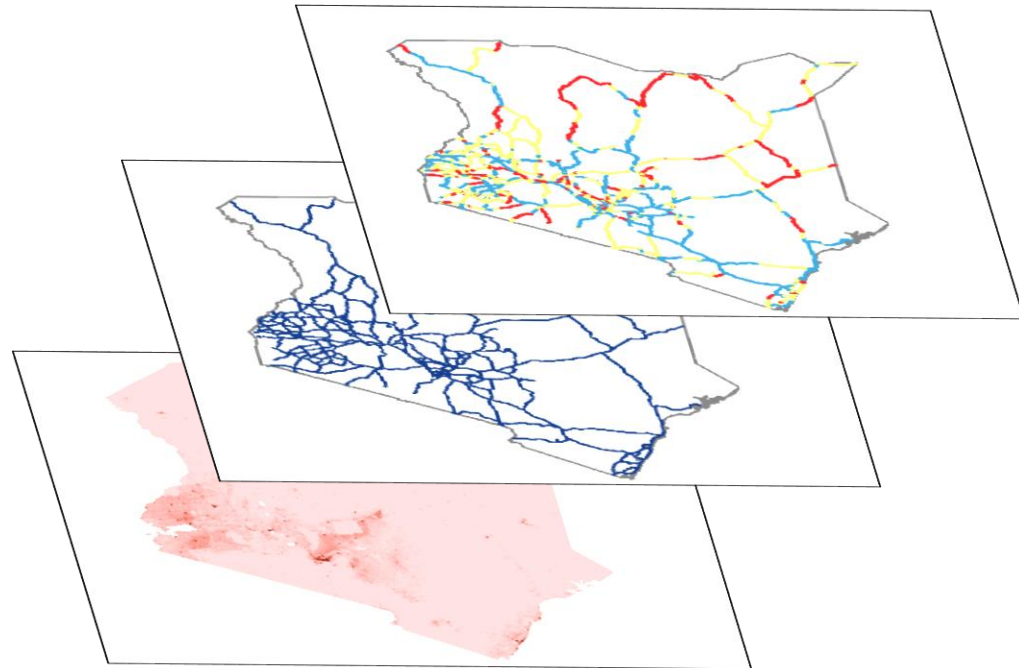
- Global Datasets of population are publicly available (ie. WorldPop)

Where does the road network exist?

- Georeferenced road network (government-owned, open source data)

In what condition?

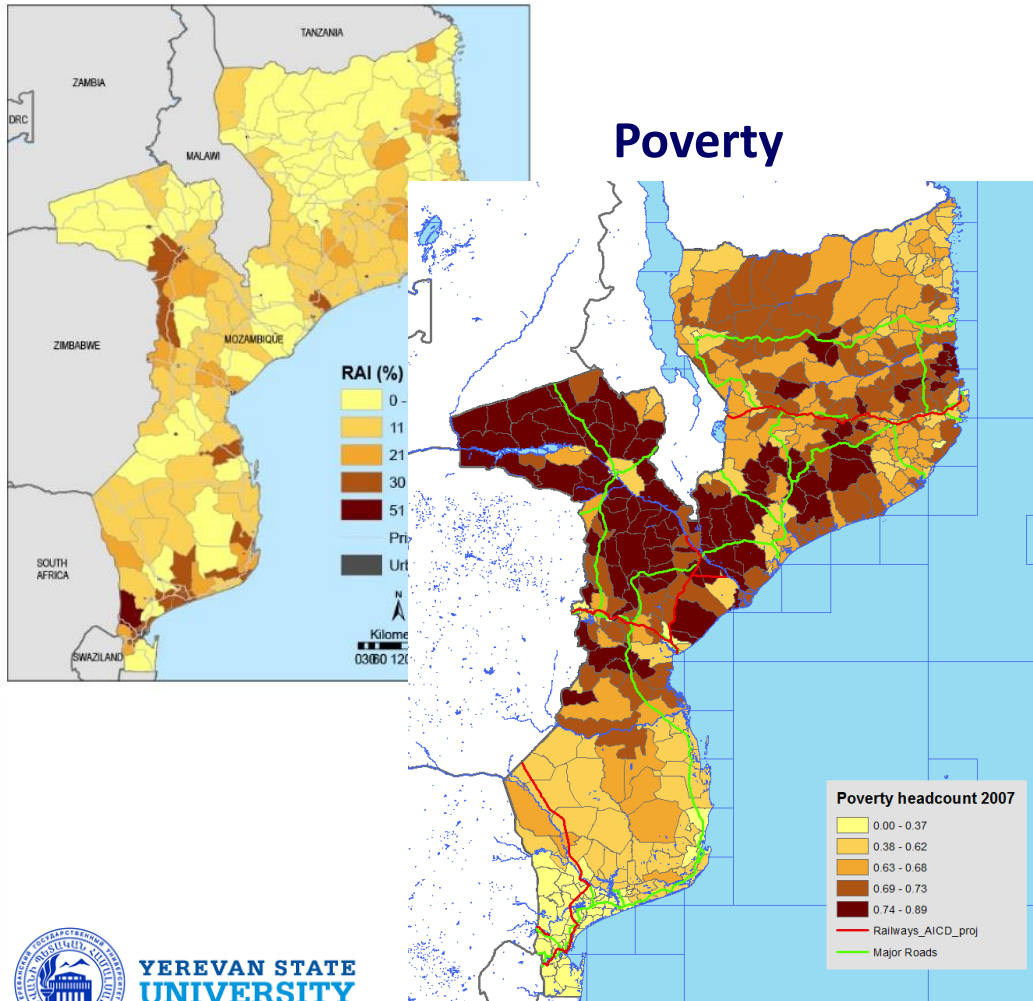
- Data exist, though often fragmented



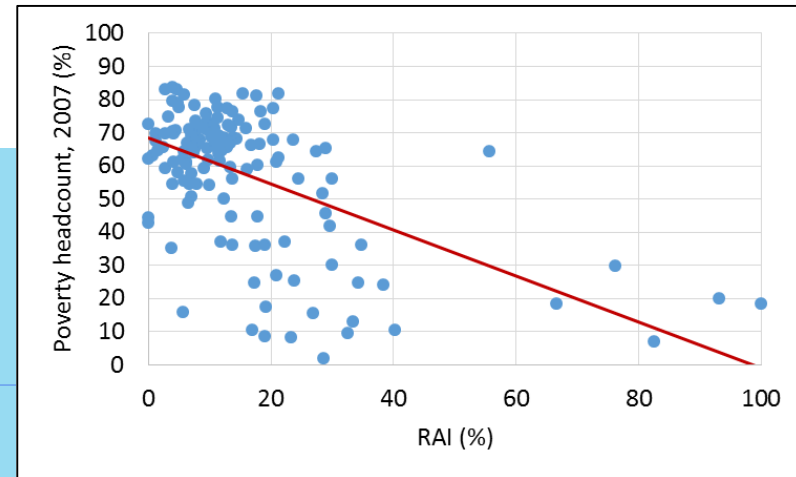
*Share of rural population living within 2
km of an all season road*

Tools and Methodologies

RAI



Poverty is high where RAI is low



Tools and Methodologies

Accessibility Indicators – MAI and SAI

MAI is defined as the travel time required for the population in a given area to reach a town, city, or any other high-density population center

SAI is shows the average time it takes for the population to reach social services, e.g health facilities, schools, universities.

(Yoshida and Deichmann 2009)

The simplest formula for an accessibility index

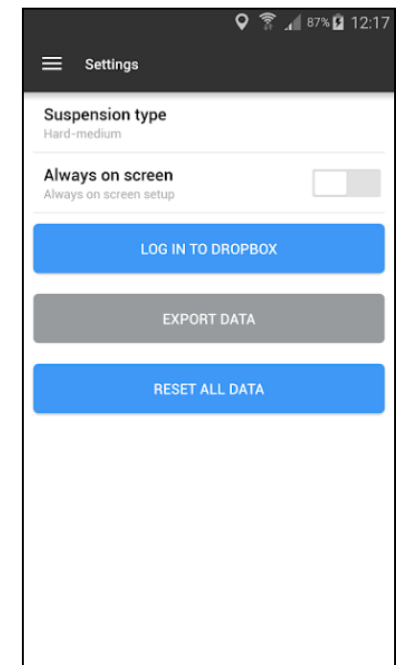
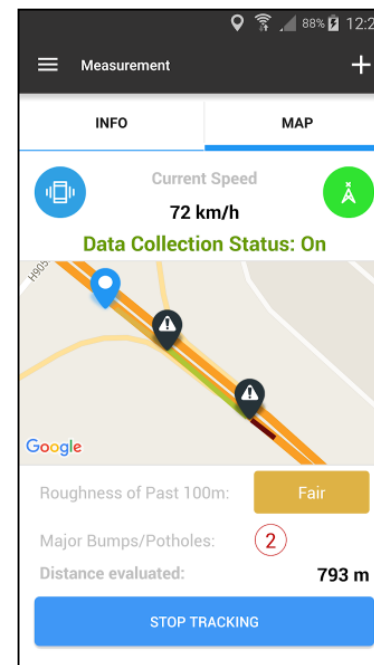
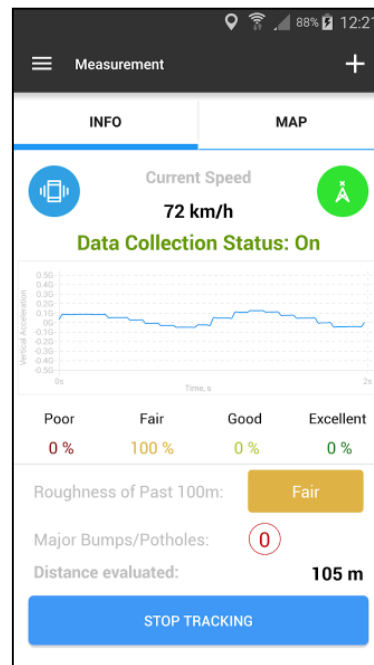
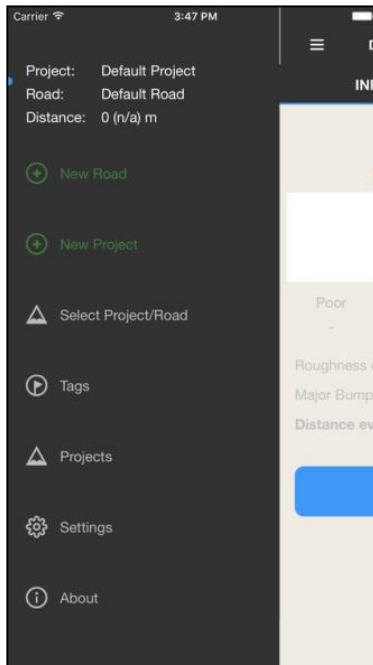
$$I_i = \sum_j \frac{S_j}{T_{ij}^\alpha}$$

where, S_j is a size indicator at target j (for example, population of large cities/towns), and T_{ij} is the distance (or travel time) between origin i and target j .

Data Collection



RoadLabPro - An Android app for evaluating road pavement quality



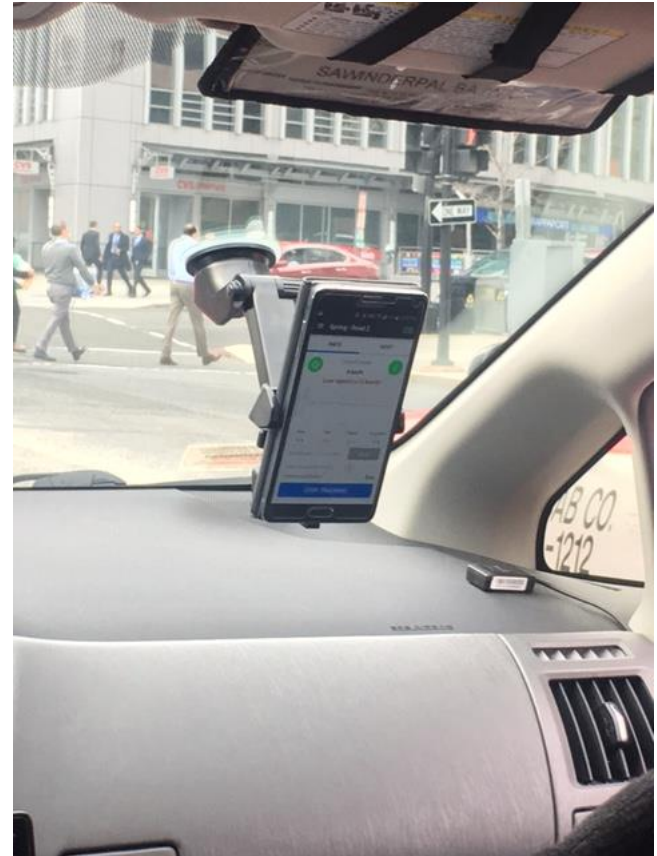
RoadLabPro uses **accelerometers, gyroscopes and GPS** to autonomously measure and evaluate **road roughness on IRI scale (International Roughness Index)**



RoadLabPro

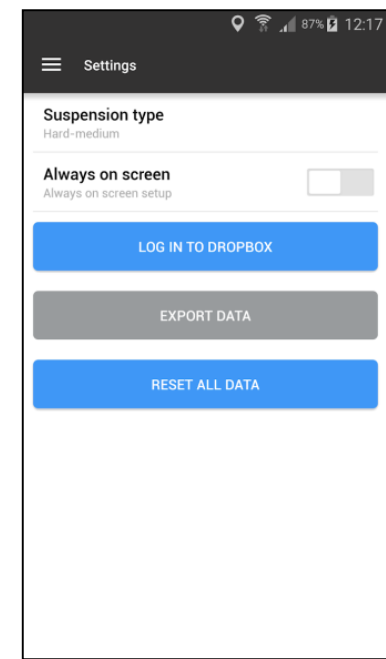
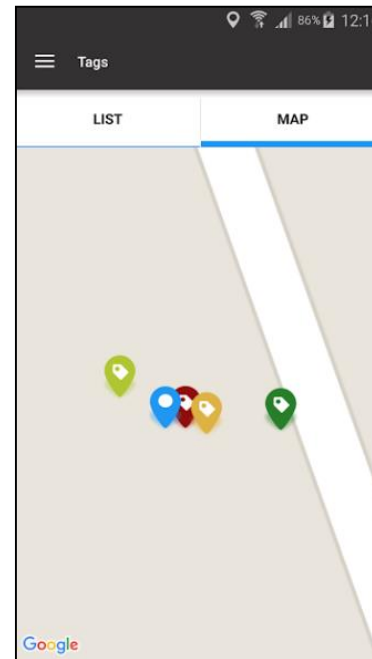
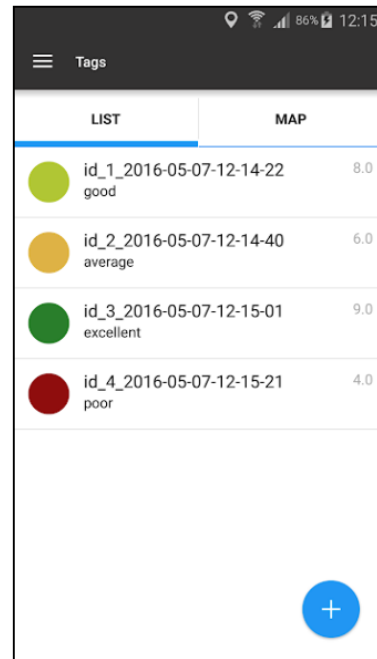
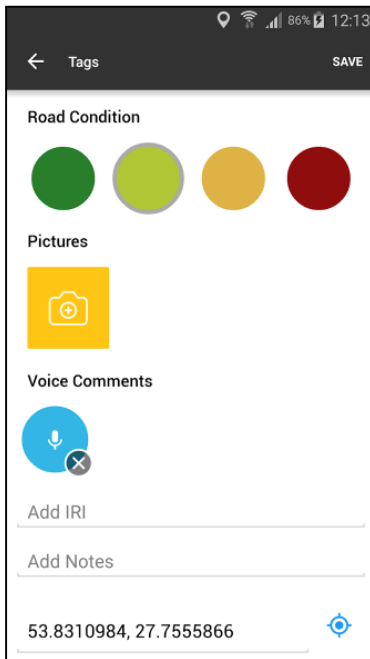
Required conditions

- Minimal speed of vehicle – **15 km/h**
- Suspension type – **Soft, medium, hard**
- Phone position – **Vertical, well fixed**



RoadLabPro

Other settings



- Possibility to upload a picture of potholes, black spots, or road accidents, etc with a simple tag.
- All data collected can be emailed to yourself or uploaded to your own Dropbox account when wifi is available.

RoadLabPro

Results

The screenshot displays a Windows desktop environment. At the top, a File Explorer window shows a folder structure: This PC > New Volume (D:) > Projects > road_project > Roads > roads > Tavush > Tavush1 > L034-17-April-2017 10-45-05. It lists two files: 'Bumps_LENОВО_Lenovo S650_2017041710450...' (14 KB, Microsoft Excel Com...) and another similar file (55 KB, KML).

In the center, Google Earth Pro is open, showing a satellite view of a mountainous region with a yellow line indicating a road route. The interface includes search, places, and history panels.

The foreground is dominated by an Excel spreadsheet titled 'RoadIntervals_LENОВО_Lenovo S650_201704171045004 - Microsoft Excel (Product Activation Failed)'. The spreadsheet contains a table with the following columns: time, speed, category, start_lat, start_lon, end_lat, end_lon, is_fixed, iri, distance, and suspension. The data rows show various road segments with their respective attributes.

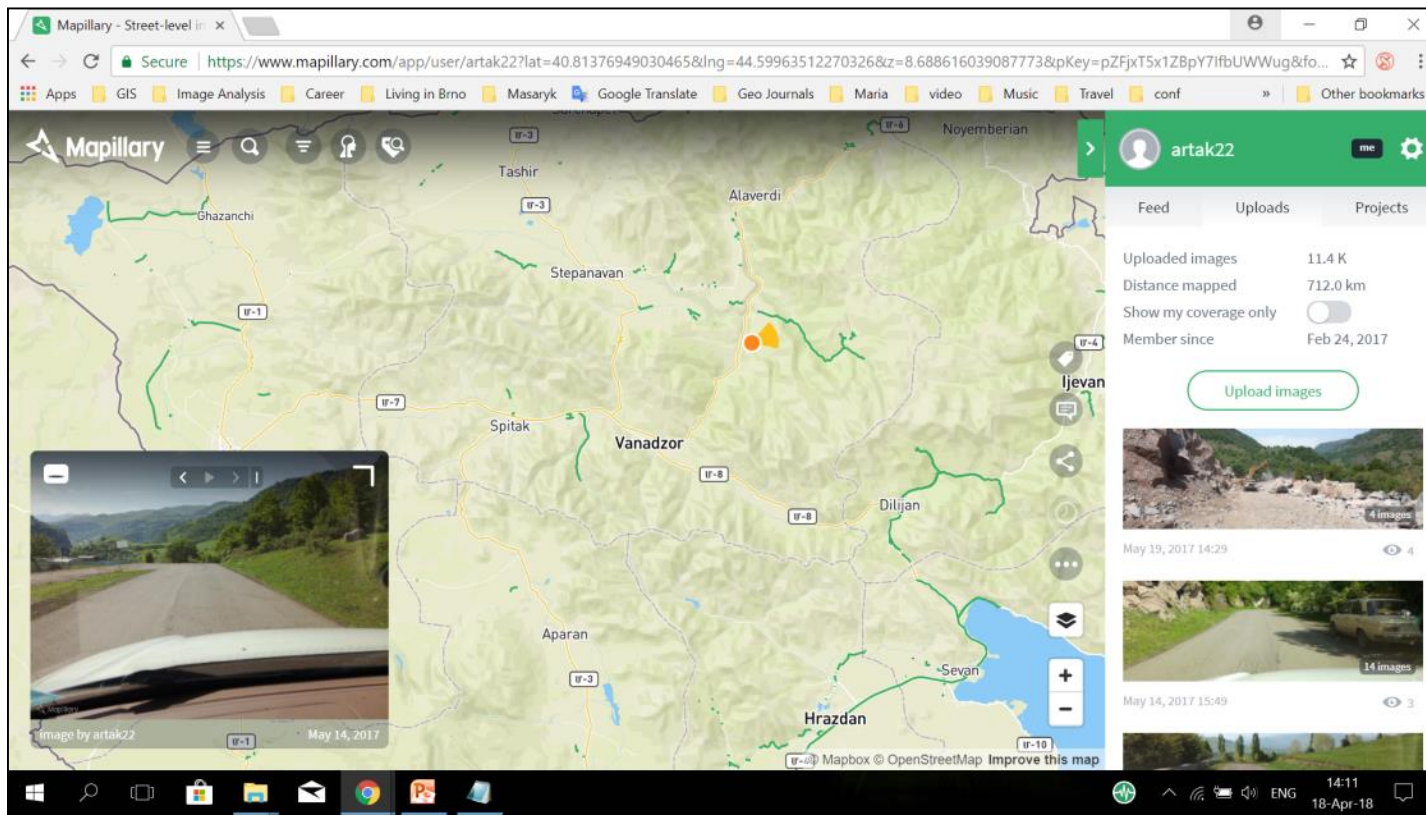
time	speed	category	start_lat	start_lon	end_lat	end_lon	is_fixed	iri	distance	suspension
10:45:17.2	22.25	GOOD	40.67999	44.87475	40.68002	44.87468	TRUE	2.48	101.66	SOFT
10:45:20.2	42.75	GOOD	40.68006	44.87461	40.68061	44.87374	TRUE	2.46	110.36	SOFT
10:45:28.2	47.32	GOOD	40.68007	44.87361	40.68136	44.87301	TRUE	3.45	105.36	SOFT
10:45:36.2	43.39	GOOD	40.68147	44.87304	40.68223	44.87289	TRUE	3.53	104.75	SOFT
10:45:45.2	47.83	GOOD	40.68225	44.87276	40.68209	44.87167	TRUE	2.71	107.79	SOFT
10:45:54.2	49.25	GOOD	40.68207	44.87151	40.6825	44.8706	TRUE	2.44	110.3	SOFT
10:46:01.2	50.83	GOOD	40.68261	44.87052	40.68331	44.87011	TRUE	2.15	100.25	SOFT
10:46:08.2	48.61	GOOD	40.68342	44.87001	40.68395	44.86917	TRUE	2.34	107.27	SOFT
10:46:16.2	52.09	GOOD	40.68404	44.86905	40.68465	44.8684	TRUE	2.47	102.02	SOFT
10:46:24.2	52.97	GOOD	40.68476	44.86829	40.68536	44.86761	TRUE	2.24	102.91	SOFT
10:46:31.2	47.39	GOOD	40.68546	44.86751	40.68623	44.86708	TRUE	2.76	108.21	SOFT
10:46:38.2	47.37	GOOD	40.68636	44.86707	40.6872	44.86712	TRUE	2.84	106.63	SOFT
10:46:46.2	36.64	GOOD	40.68732	44.8671	40.68812	44.8668	TRUE	2.55	107.92	SOFT
10:46:58.2	48.9	GOOD	40.68818	44.86669	40.68823	44.86559	TRUE	2.39	108.87	SOFT
10:47:05.2	43.55	GOOD	40.68822	44.86543	40.68871	44.86457	TRUE	2.98	112.39	SOFT
10:47:14.2	49.68	GOOD	40.68883	44.86456	40.6897	44.86459	TRUE	2.68	112.21	SOFT
10:47:22.2	35.86	FAIR	40.68984	44.86459	40.68986	44.86423	TRUE	4.08	109.52	SOFT
10:47:34.2	46.96	GOOD	40.68976	44.86423	40.68892	44.86413	TRUE	2.25	106.91	SOFT
10:47:42.2	33.05	GOOD	40.6888	44.8641	40.68805	44.86362	TRUE	3.11	110.95	SOFT
10:47:56.2	35.36	GOOD	40.68815	44.86359	40.68898	44.86392	TRUE	3.1	114.34	SOFT
10:48:04.2	51.17	GOOD	40.68914	44.86393	40.68995	44.86388	TRUE	2.27	102.94	SOFT
10:48:11.2	37.76	FAIR	40.69005	44.86383	40.69046	44.86289	TRUE	4.31	120.31	SOFT
10:48:28.2	34.12	GOOD	40.69042	44.86259	40.69015	44.86152	TRUE	2.53	107.83	SOFT
10:48:39.2	44.25	GOOD	40.69018	44.8614	40.69085	44.86087	TRUE	2.73	104.27	SOFT
10:48:46.2	58.32	EXCELLEN	40.69098	44.86081	40.6917	44.86053	TRUE	1.91	100.17	SOFT
10:48:52.2	55.64	GOOD	40.69183	44.86045	40.69259	44.85997	TRUE	2.35	108.17	SOFT
10:49:00.2	33.37	GOOD	40.69272	44.85996	40.69319	44.85966	TRUE	3.37	102.26	SOFT



Mapillary



Online is a service for sharing geotagged photos



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<https://www.mapillary.com/app/user/artak22>

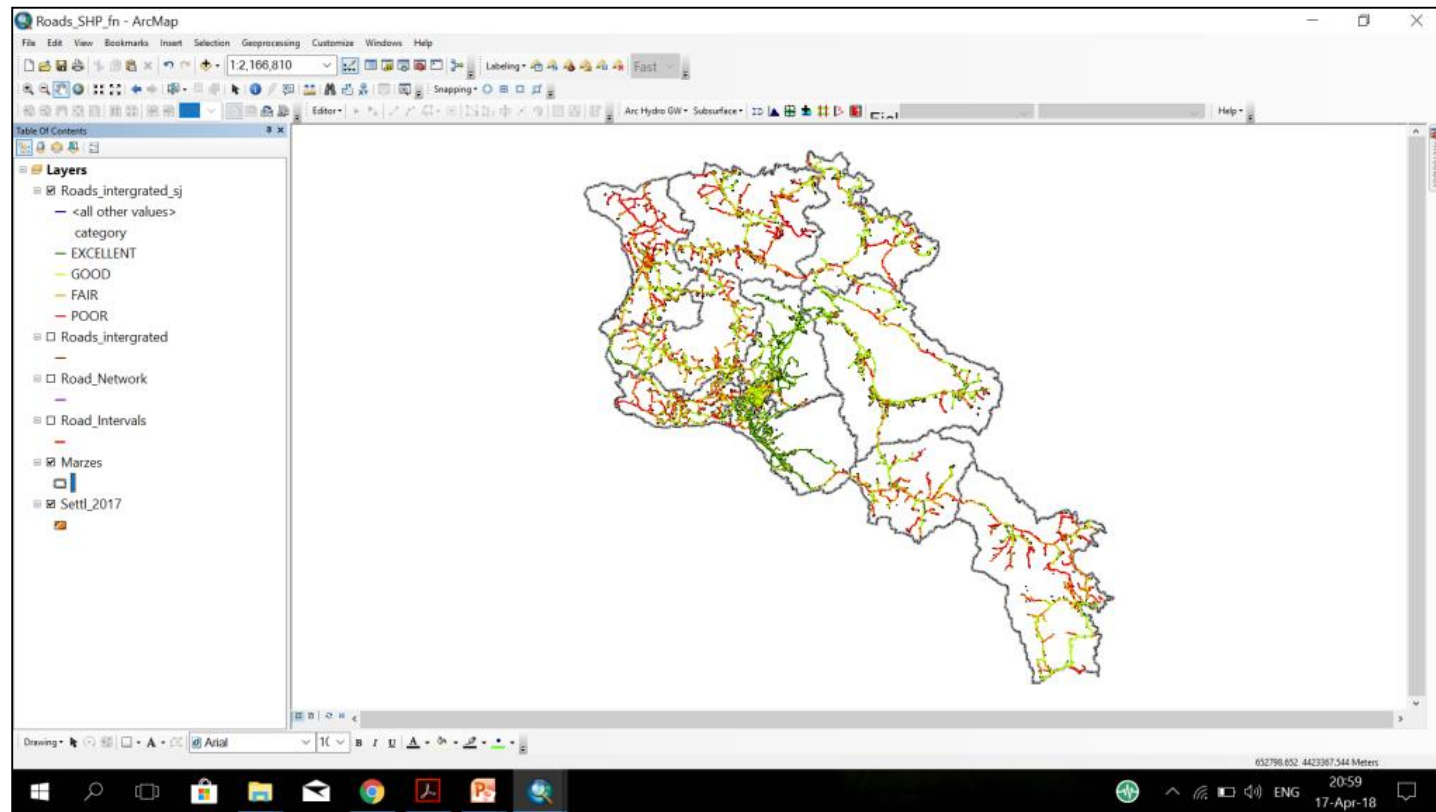


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Field work - Ground truthing

Period : **March-June, 2017**

About
9200 km
of roads
passed



Databases

Roads_SHP_fn - ArcMap

File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help

1:1,250,000

Labeling Fast

Snapping

Arc Hydro GW Subsurface

Table of Contents

- Layers
 - Roads_intergrated_sj
 - <all other values>
 - category
 - EXCELLENT
 - GOOD
 - FAIR
 - POOR
 - Roads_intergrated
 - Road_Network
 - Road_Intervals
 - Marzes
 - Settl_2017

Table

Roads_intergrated_sj

Join_Count	TARGET_FID	start_lat	start_lon	end_lat	end_lon	speed	category	is_fixed	iri	distance	
1	17123	40.278418	43.832445	40.279067	43.833448	80.01	EXCELLENT	TRUE	1.32	110.94	SC
1	17124	40.279067	43.833448	40.279538	43.834552	77.3	EXCELLENT	TRUE	1.4	106.79	SC
1	17126	40.27991	43.835665	40.280335	43.836912	69.67	EXCELLENT	TRUE	1.26	115.07	SC
1	17131	40.282873	43.840625	40.283712	43.841458	84.5	EXCELLENT	TRUE	1.3	118.19	SC
1	18455	40.273092	43.824655	40.273758	43.82571	69.5	EXCELLENT	TRUE	1.38	116.47	SC
1	18456	40.273758	43.82571	40.274498	43.826722	71.31	EXCELLENT	TRUE	1.86	119.13	SC
1	18457	40.274498	43.826722	40.2752	43.827718	69.14	GOOD	TRUE	2.11	115.08	SC
1	18466	40.283485	43.84115	40.282662	43.840325	82.93	GOOD	TRUE	2.49	114.98	SC
1	18478	40.273808	43.825753	40.273152	43.824777	79.84	GOOD	TRUE	2.49	110.46	SC
1	18937	40.280505	43.83728	40.280085	43.836292	35.96	EXCELLENT	TRUE	1.89	106.55	SC
1	18938	40.280085	43.836292	40.279707	43.835173	63.78	EXCELLENT	TRUE	1.83	108.88	SC
1	18940	40.279335	43.83408	40.278812	43.833042	76.55	EXCELLENT	TRUE	1.67	107.6	SC
1	18941	40.278812	43.833042	40.27814	43.832012	83.01	EXCELLENT	TRUE	1.02	116.76	SC
1	18946	40.275235	43.827737	40.274522	43.82672	84.16	EXCELLENT	TRUE	1.3	116.59	SC
1	18947	40.274522	43.82672	40.273808	43.825753	82.3	EXCELLENT	TRUE	1	113.22	SC
1	19104	40.334147	43.852348	40.33503	43.85213	52.05	GOOD	TRUE	2.79	101.14	SC
1	19105	40.33503	43.85213	40.335737	43.851177	51.22	GOOD	TRUE	2.16	112.88	SC
1	19729	40.351847	43.862892	40.352847	43.862833	49.66	EXCELLENT	TRUE	1.78	112.25	SC
1	19731	40.353758	43.86237	40.354715	43.861833	59.14	EXCELLENT	TRUE	1.69	116.28	SC
1	19734	40.356488	43.860838	40.357447	43.860462	66.36	GOOD	TRUE	2.52	111.72	SC
1	19735	40.357447	43.860462	40.35847	43.86058	68.47	EXCELLENT	TRUE	1.99	115.34	SC
1	19736	40.35847	43.86058	40.359517	43.86082	70.74	GOOD	TRUE	2.6	118.32	SC
1	21851	40.34467	43.857792	40.344442	43.85893	17.11	POOR	TRUE	6.14	121.62	HA
1	21864	40.352907	43.86294	40.353085	43.862768	45.63	GOOD	TRUE	2.89	100.61	HA

0 out of 83354 Selected

Roads_intergrated_sj

Drawing: Arial 10

Windows Taskbar: 20:15, 18-Apr-18

Databases

The screenshot displays a Microsoft Excel spreadsheet with a data table. The table has the following columns: Start longitude (*), End latitude (*), End longitude (*), Speed (km/h), Category (RoadLabPr..., Is Fixed, IRI, Distance (m), Suspension, Surface Type, Condition, Driving Tim..., Province, LRIP, LRNIP, Control Roads, Road Type, and Road Name. The data rows contain numerical values for most columns, with some cells containing text like 'FAIR', 'POOR', 'GOOD', 'Very Poor', and 'Local'. The spreadsheet interface includes the ribbon (File, Home, Insert, Page Layout, Formulas, Data, Review, View, Design) and the Windows taskbar at the bottom.

Start longitude (*)	End latitude (*)	End longitude (*)	Speed (km/h)	Category (RoadLabPr...	Is Fixed	IRI	Distance (m)	Suspension	Surface Type	Condition	Driving Tim...	Province	LRIP	LRNIP	Control Roads	Road Type	Road Name
44.5184	40.1505	44.5171	29.69	FAIR	TRUE	4.27	105.88	SOFT	paved	Fair	0.22	Yerevan	No	No	No	Local	
44.5171	40.1505	44.5159	31.06	FAIR	TRUE	4.78	103.87	SOFT	paved	Fair	0.28	Yerevan	No	No	No	Local	
44.5159	40.1505	44.5147	6.81	POOR	TRUE	6.81	107.6	SOFT	paved	Poor	0.19	Yerevan	No	No	No	Local	
44.5147	40.1505	44.5135	7.68	POOR	TRUE	7.68	101.58	SOFT	paved	Poor	0.14	Yerevan	No	No	No	Local	
44.5135	40.1505	44.5123	7.02	POOR	TRUE	7.02	100.09	SOFT	paved	Poor	0.12	Yerevan	No	No	No	Local	
44.5123	40.1505	44.5111	5.85	FAIR	TRUE	5.85	103.83	SOFT	paved	Fair	0.16	Yerevan	No	No	No	Local	
44.5111	40.1505	44.5099	6.37	POOR	TRUE	6.37	100.06	SOFT	paved	Poor	0.28	Yerevan	No	No	No	Local	
44.5099	40.1505	44.5087	4.66	FAIR	TRUE	4.66	109.99	SOFT	paved	Fair	0.16	Yerevan	No	No	No	Local	
44.5087	40.1505	44.5075	4.03	FAIR	TRUE	4.03	102.85	SOFT	paved	Fair	0.12	Yerevan	No	No	No	Local	
44.5075	40.1505	44.5063	2.67	GOOD	TRUE	2.67	111.75	SOFT	paved	Good	0.12	Yerevan	No	No	No	Local	
44.5063	40.1505	44.5049	4.32	FAIR	TRUE	4.32	111.68	SOFT	paved	Fair	0.11	Yerevan	No	No	No	Local	
44.5049	40.1505	44.5037	5.16	FAIR	TRUE	5.16	106.45	SOFT	paved	Fair	0.14	Yerevan	No	No	No	Local	
44.5037	40.1505	44.5025	10.72	POOR	TRUE	10.72	107.47	SOFT	paved	Very Poor	0.14	Yerevan	No	No	No	Local	
44.5025	40.1505	44.5013	4.97	FAIR	TRUE	4.97	110.73	SOFT	paved	Fair	0.11	Yerevan	No	No	No	Local	
44.5013	40.1505	44.5001	4.69	FAIR	TRUE	4.69	101.12	SOFT	paved	Fair	0.20	Yerevan	No	No	No	Local	
44.5001	40.1505	44.4990	3.69	GOOD	TRUE	3.69	100.21	SOFT	paved	Good	0.27	Yerevan	No	No	No	Local	
44.4990	40.1505	44.4978	5.16	FAIR	TRUE	5.16	105.33	SOFT	paved	Fair	0.22	Yerevan	No	No	No	Local	
44.4978	40.1505	44.4966	3.59	GOOD	TRUE	3.59	105	SOFT	paved	Good	0.24	Yerevan	No	No	No	Local	
44.4966	40.1505	44.4954	3.61	GOOD	TRUE	3.61	103.82	SOFT	paved	Good	0.24	Yerevan	No	No	No	Local	
44.4954	40.1505	44.4942	3.87	GOOD	TRUE	3.87	101.09	SOFT	paved	Good	0.27	Yerevan	No	No	No	Local	
44.4942	40.1505	44.4930	5.42	FAIR	TRUE	5.42	101.58	SOFT	paved	Fair	0.22	Yerevan	No	No	No	Local	
44.4930	40.1505	44.4921	4.18	FAIR	TRUE	4.18	110.06	SOFT	paved	Fair	0.20	Yerevan	No	No	No	Local	
44.4921	40.1505	44.4913	4.21	FAIR	TRUE	4.21	100.07	SOFT	paved	Fair	0.21	Yerevan	No	No	No	Local	
44.4913	40.1505	44.4904	3.03	GOOD	TRUE	3.03	105.49	SOFT	paved	Good	0.17	Yerevan	No	No	No	Local	
44.4904	40.1505	44.4895	4.12	FAIR	TRUE	4.12	100.47	SOFT	paved	Fair	0.19	Yerevan	No	No	No	Local	
44.4895	40.1505	44.4886	4.51	FAIR	TRUE	4.51	106.5	SOFT	paved	Fair	0.24	Yerevan	No	No	No	Local	
44.4886	40.1505	44.4878	4.13	FAIR	TRUE	4.13	103.57	SOFT	paved	Fair	0.13	Yerevan	No	No	No	Local	

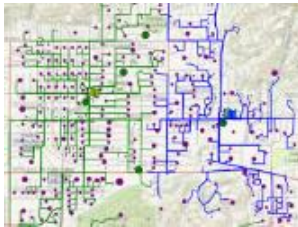


Databases - Attributes

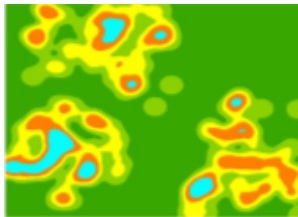
ՀՀ	FID
Սկզբնական լայնություն (°)	Start latitude (°)
Սկզբնական երկայնություն (°)	Start longitude (°)
Վերջնական լայնություն (°)	End latitude (°)
Վերջնական երկայնություն (°)	End longitude (°)
Արագություն (կմ/ժ)	Speed (km/h)
Կատեգորիա (ըստ RoadLabPro)	Category (RoadLabPro)
Ֆիքսված է	Is Fixed
ԽՄԻ	IRI
Երկարություն (մ)	Distance (m)
Կախոցի տեսակը	Suspension
Ծածկույթի տիպը	Surface Type
Վիճակը	Condition
Վարման ժամանակը (վրկ.)	Driving Time (sec.)
Մարզ	Province
ԿՆՃԲԾ	LRIP
ԿՆՃՑԲԾ	LRNIP
Վերահսկվող ճանապարհներ	Control Roads
Ճանապարհի տեսակը	Road Type
Ճանապարհի անվանումը	Road Name

Accessibility Analysis

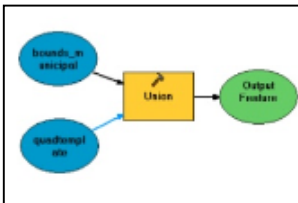
The **Geographic Information Systems** playing a key role in performing **Accessibility Analysis**



Network analysis



Spatial analysis



ModelBuilder

Accessibility Analysis

Rural access index tool

Rural Access Index

Population Raster File

Urban Raster File

Road Layer

Road Type Field

Road Type Value

IRI Field (optional)

IRI Value: Lower threshold (not inclusive) (optional)

IRI Value: Upper threshold (inclusive) (optional)

Road Condition Field1 (optional)

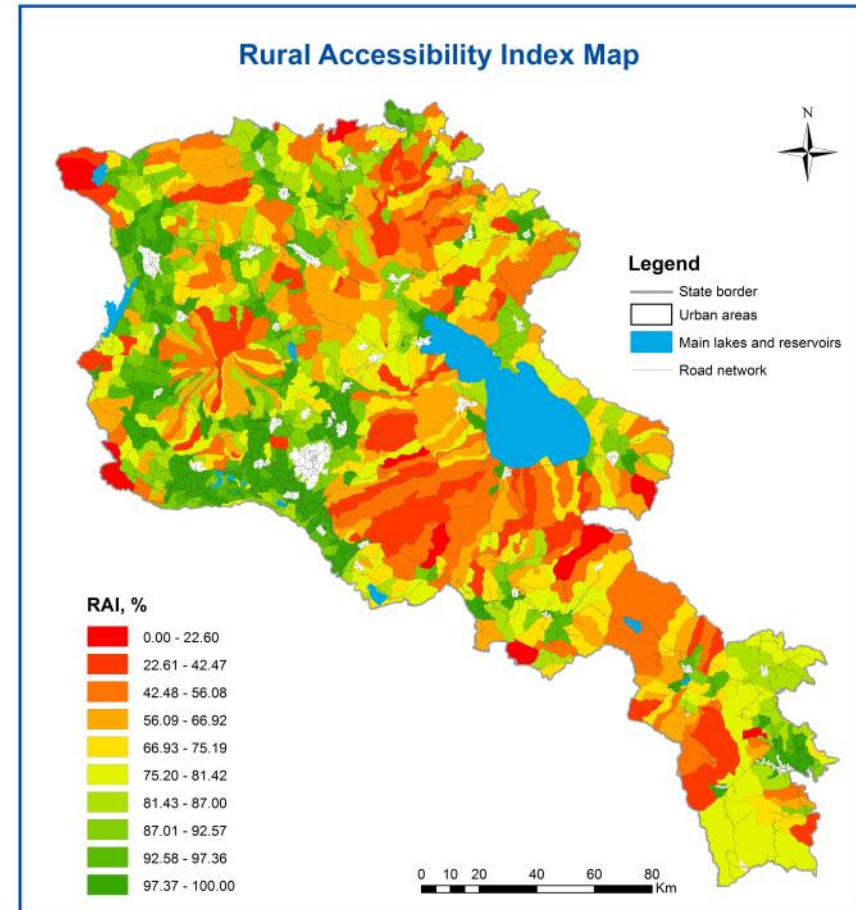
OK Cancel Environments... << Hide Help Tool Help

Rural Access Index

This tool computes rural access index indicator to focus on the critical role of access and mobility in the reduction of poverty in developing countries.

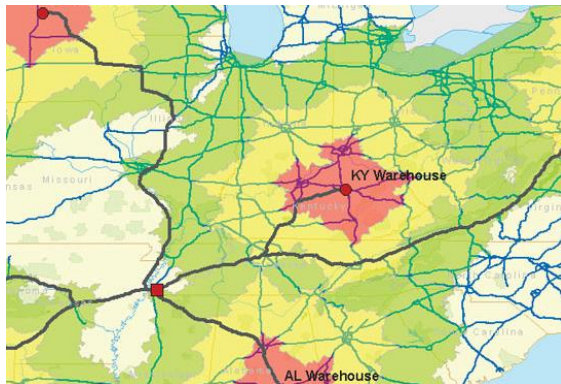


Condition	Minimum Roughness	Maximum Roughness
Category	(IRI)	(IRI)
Very good	1.0	2.0
Good	2.0	4.0
Fair	4.0	6.0
Poor	6.0	10.0
Very poor	10.0	16.0



Accessibility Analysis

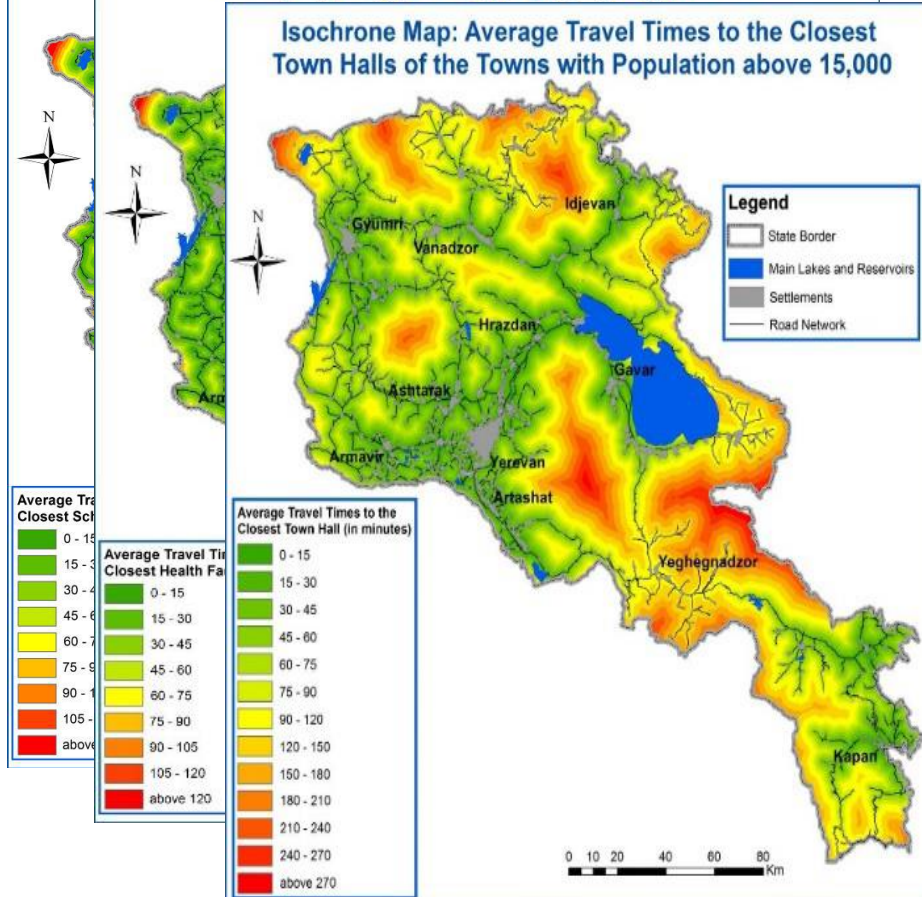
Network Analysis was used to create **MAI** and **SAI** maps



Isochrone Map: Average Travel Times

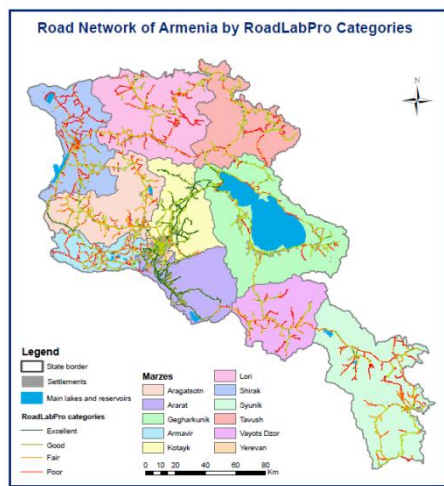
Isochrone Map: Average Travel Times

Isochrone Map: Average Travel Times to the Closest Town Halls of the Towns with Population above 15,000

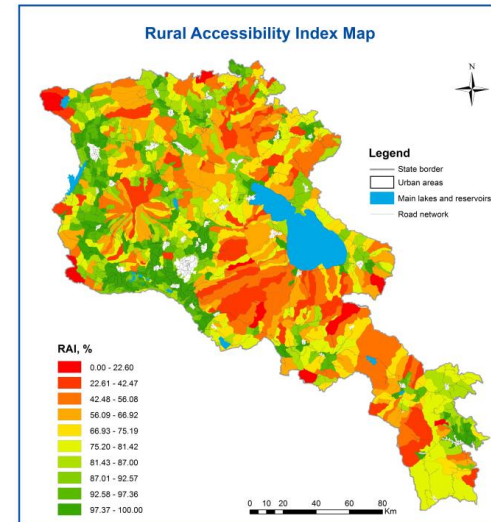


Accessibility Analysis – Conclusions

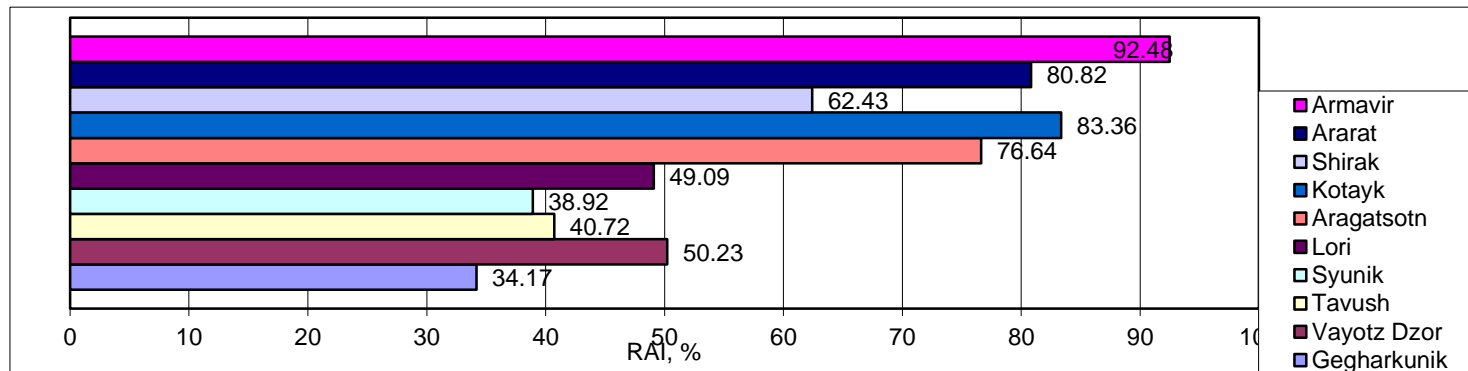
Road quality is a matter of concern...



At 66 percent, RAI is low compared to EU

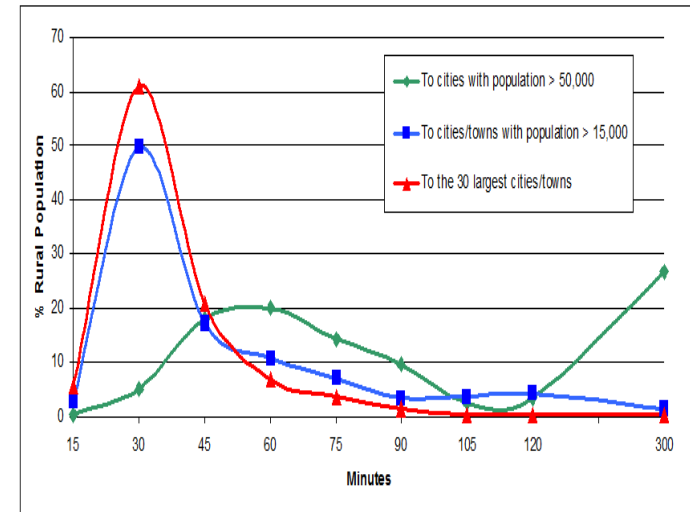
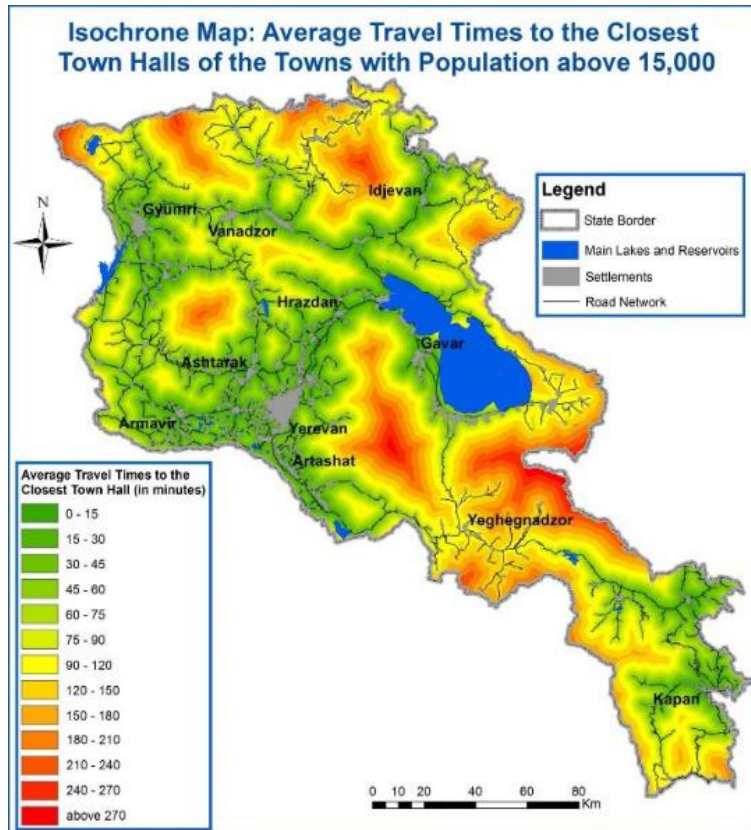


Low rural access in least populated regions



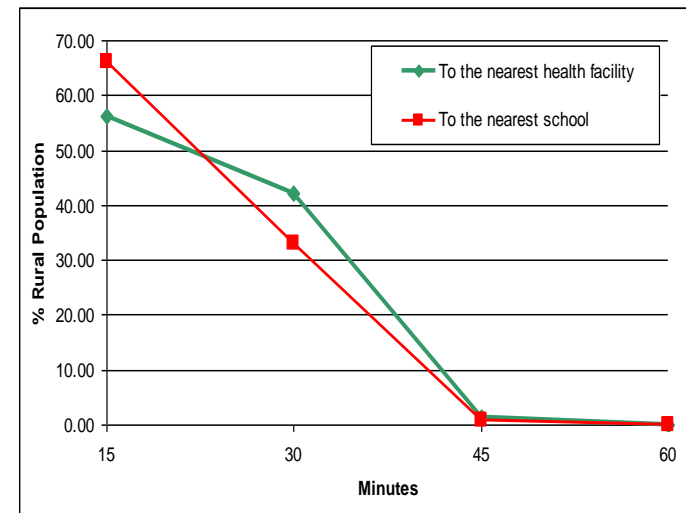
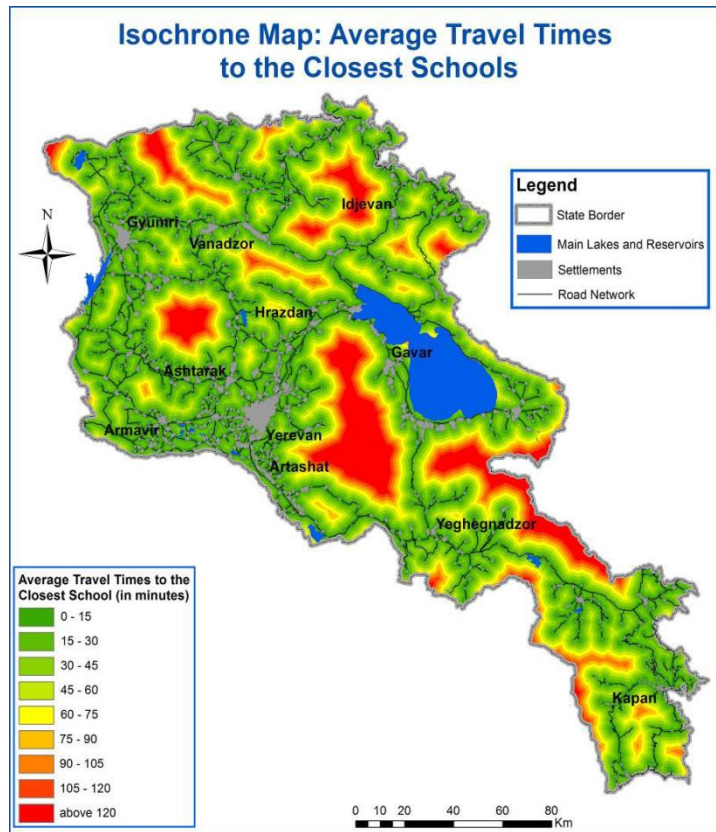
Accessibility Analysis – Conclusions

Overall, high market and service accessibility



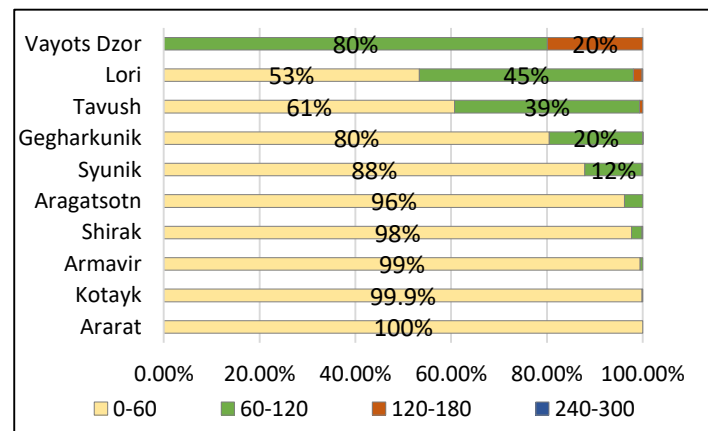
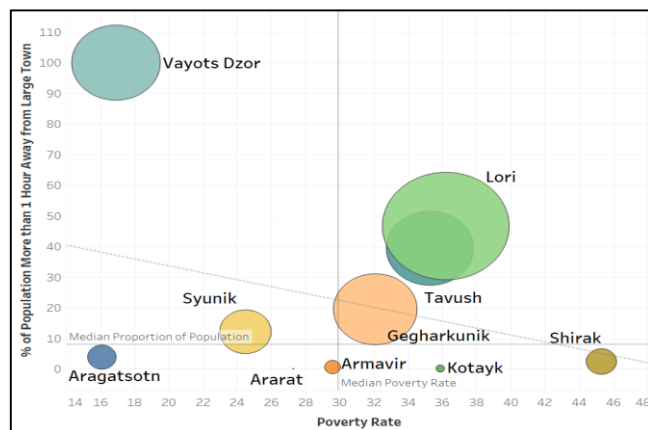
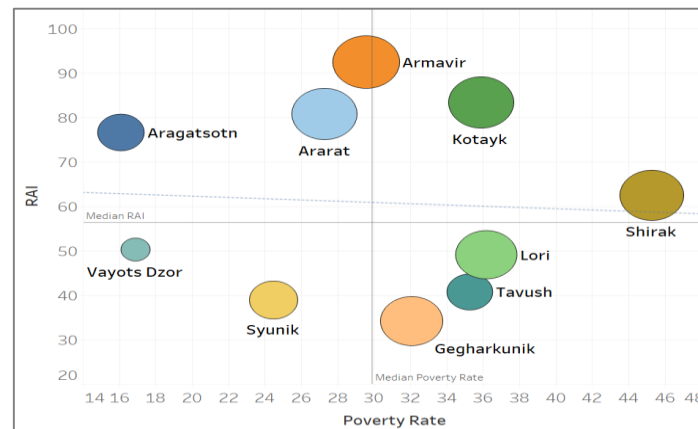
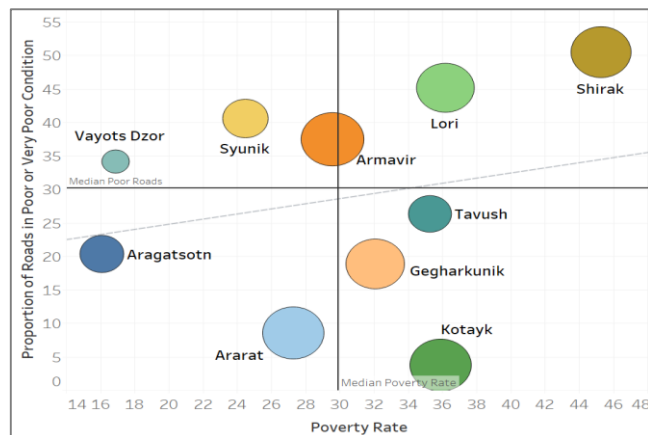
Accessibility Analysis – Conclusions

Overall, high market and service accessibility



Accessibility Analysis – Conclusions

Poorest regions generally rank low in road quality and in market access

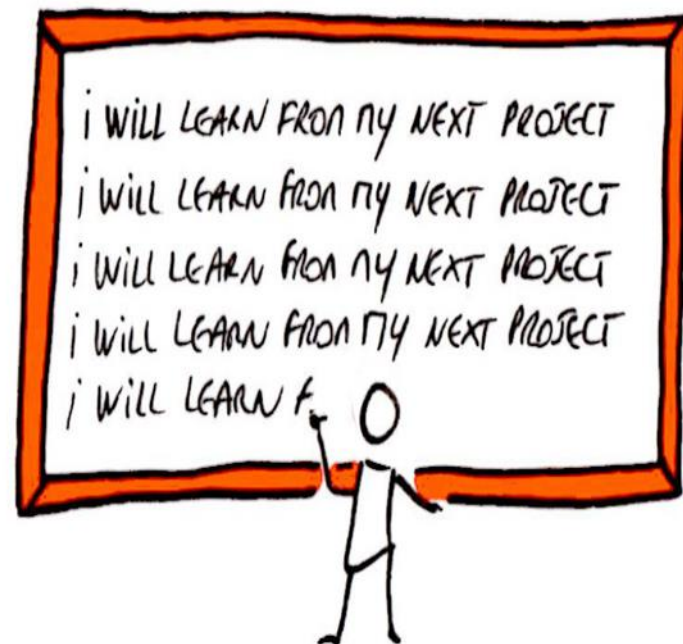


Lessons and Directions for Future Research

Choice of rigorous impact evaluation over other approaches to assess project outcomes

Understanding of the theory of change linking transport interventions and other high level outcomes

Timing for data collection and evaluation window



Further reading

- 1. Artak Piloyan, Aram Gevorgyan.** Measuring Rural Accessibility in the GIS environment: Case study of Armenia. Proceedings, 7th International Conference on Cartography and GIS, 18-23 June 2018, Sozopol, Bulgaria ISSN: 1314-0604, Eds: Bandrova T., Konečný M. 417-425 pp.
- 2. Connecting the Dots: Transport, Poverty, and Social Inclusion - Evidence from Armenia.** December 2017. Transport and ICT Global Practice, The World Bank

Thank you !!!
Շնորհակալություն !!!



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