Road Network Upgrading And Overland Trade Expansion In Sub-Saharan Africa

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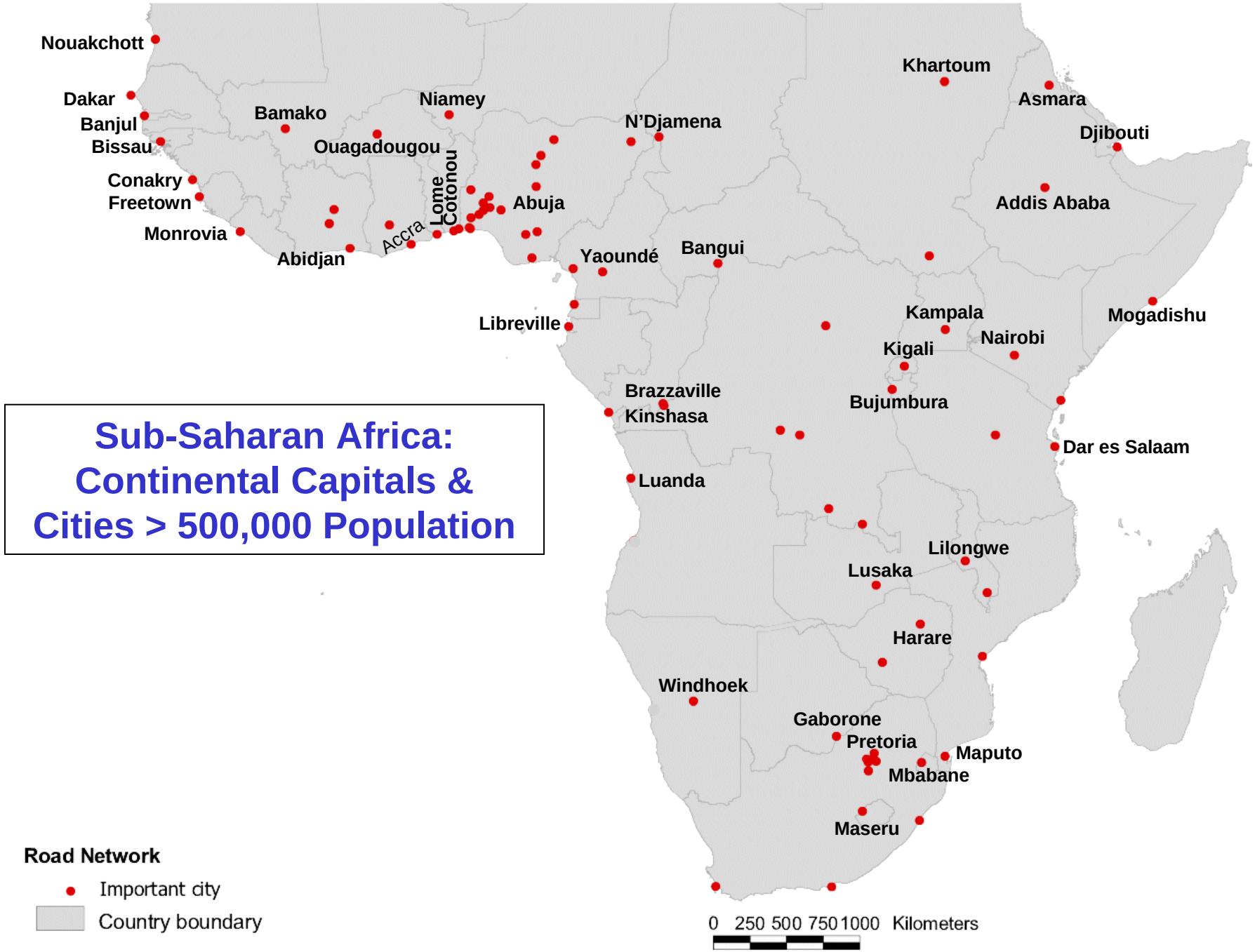
Policy research questions

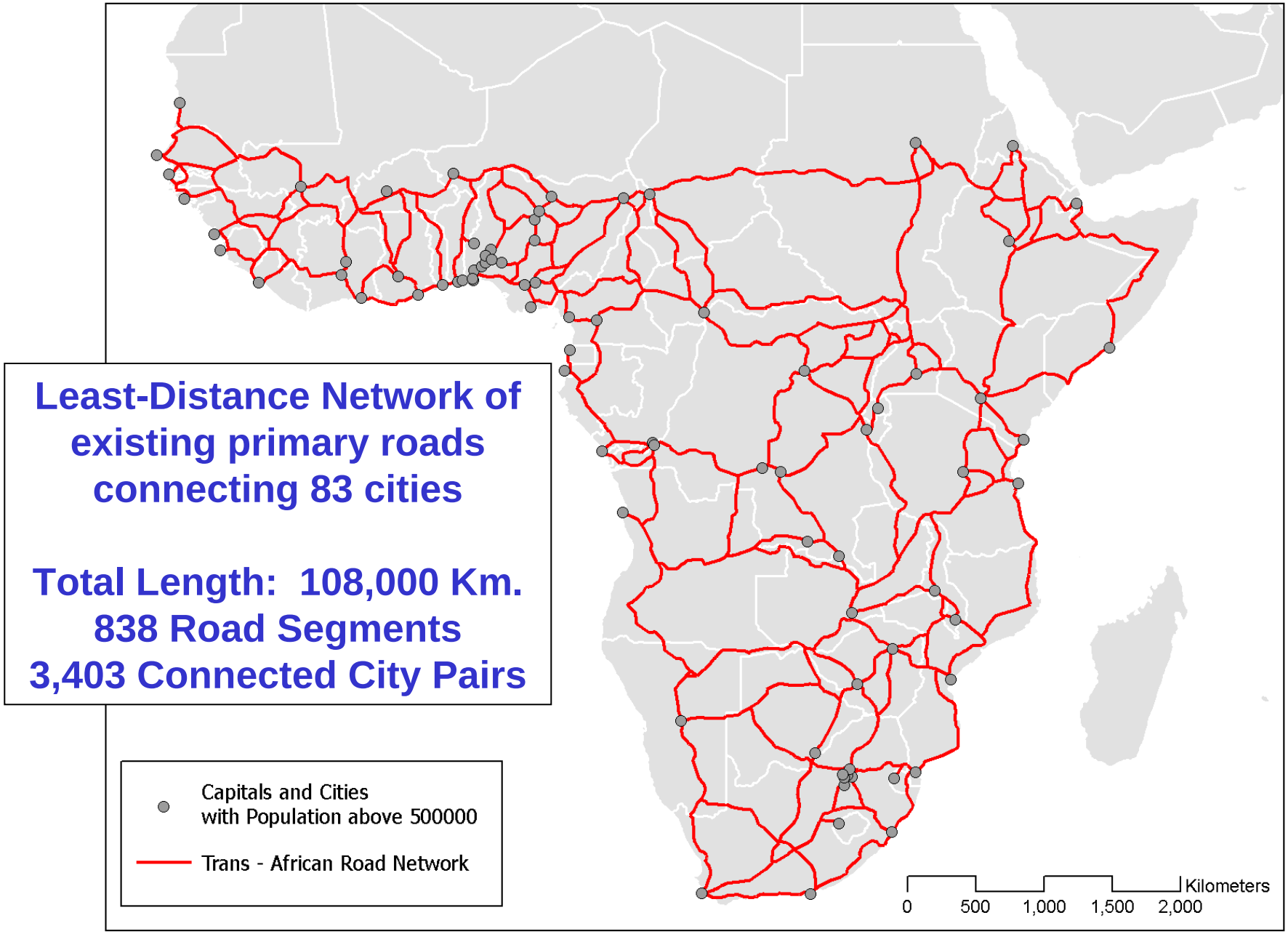
- By how much would intra-African trade increase with a major upgrading of the main continental highway network?
- How much would upgrading and annual maintenance of such a system cost?

Analysis

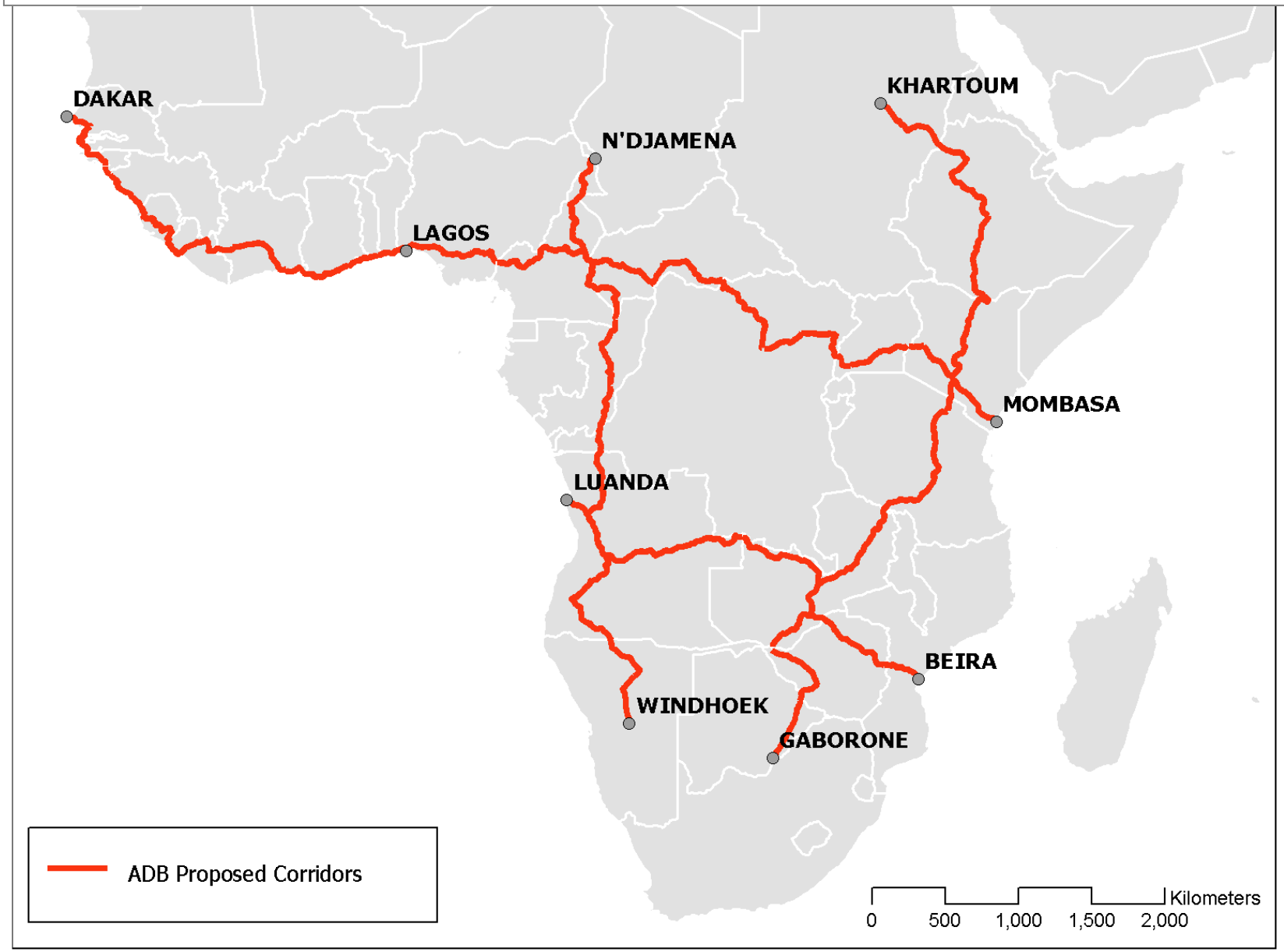
- Develop a spatially explicit model of pan-African highways
- Estimate benefits and costs based on a full network trade model connecting all major cities in continental sub-Saharan Africa



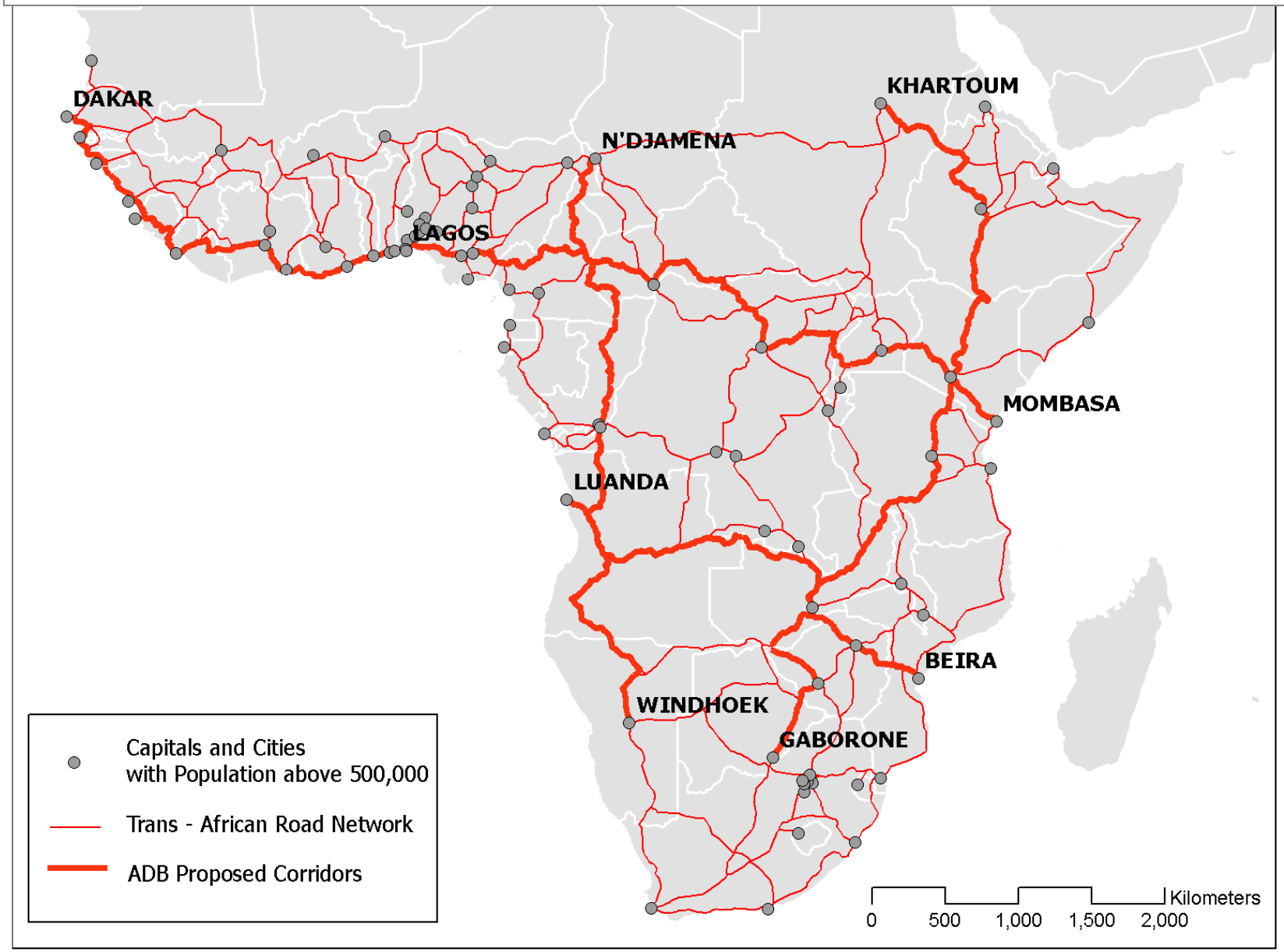
Sub-Saharan Africa: Continental Capitals & Cities > 500,000 Population


Least-Distance Network of existing primary roads connecting 83 cities
Total Length: 108,000 Km.
838 Road Segments
3,403 Connected City Pairs
Capitals and Cities with Population above 500000
Trans - African Road Network
0
500
1,000
1,500
2,000
Kilometers

The Proposed Pan-African Highway Corridors



The Proposed Pan-African Highway Corridors



Gravity trade model

- Standard tool in trade economics (and in transport sector analysis)
- There will be more trade between countries with larger economies
- There will be less trade between countries that are further apart
- But distance is not the only factor – *quality* of roads also matters as do institutional factors such as trade agreements

Road Network:
Current Network Quality

- Very little reliable data on road quality
- Instead, we estimate road quality:

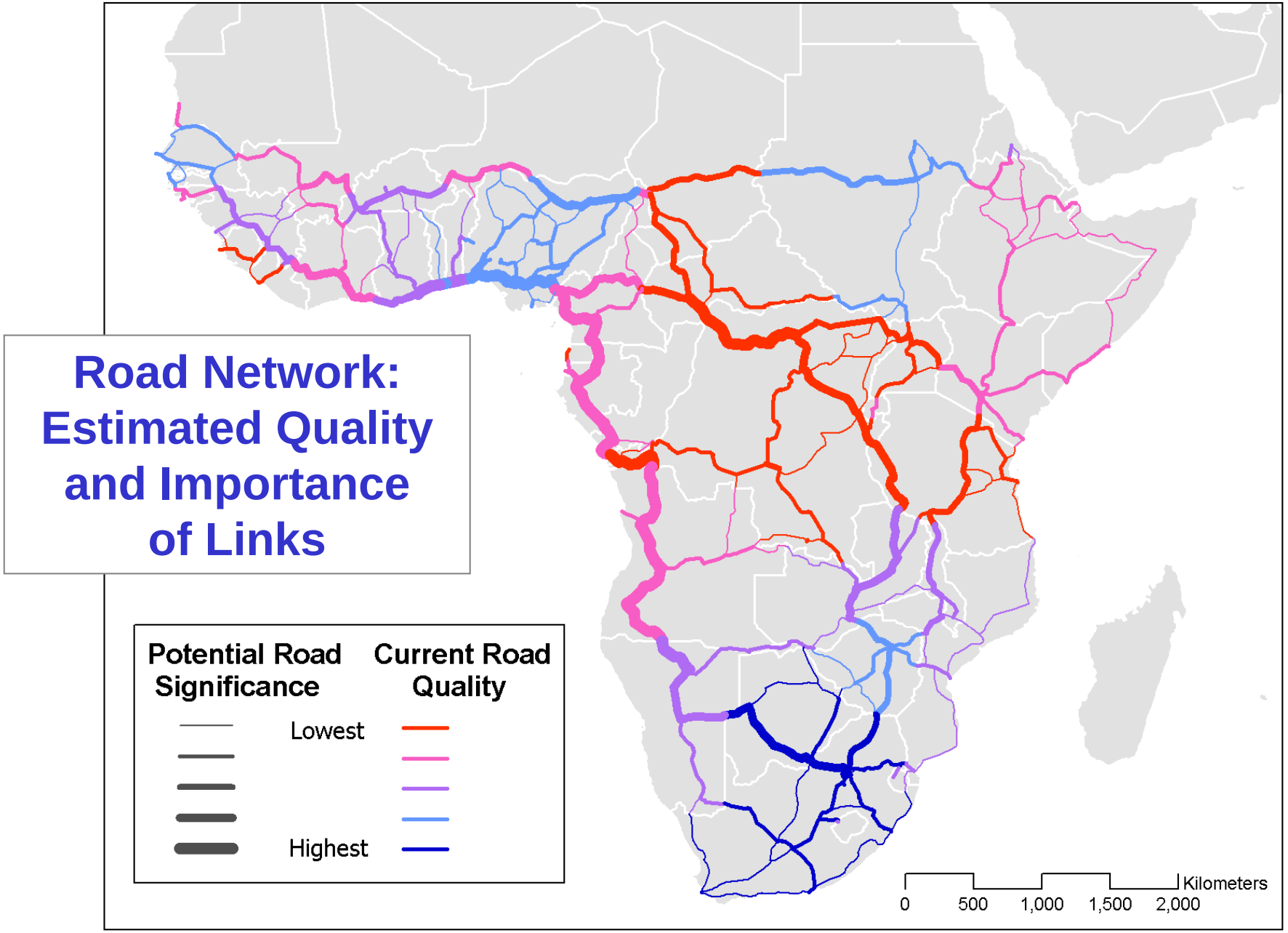
Quality Index

$$Q_j = P_j^{\alpha_P} Y_j^{\alpha_Y} G_j^{\alpha_G}$$

P_j = Percent of roads paved
G_j = GDP per capita
C_j = CPIA governance index

$[\alpha_P=0.8 , \alpha_Y=0.2, \alpha_G=0.2]$

- Index corresponds well with observed road conditions information from ADB pan-African highways study

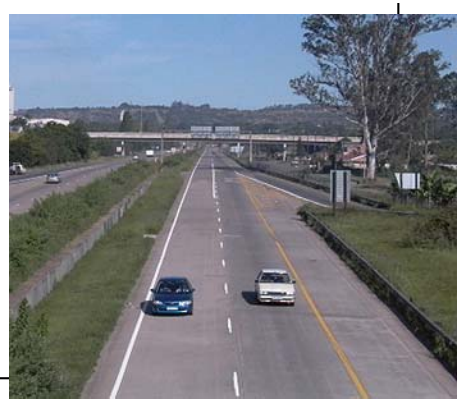


Road significance: number of times segment is used when connecting each city with all other cities

Mali-
Cote d'Ivoire
Border

Toleka Traders, Ituri
Forest, Congo D.R.

Durban-Johannesburg
Highway, South Africa



Potential Road Significance		Current Road Quality
	Lowest	
	Highest	

Estimating Trade Flows: Econometric Analysis via Gravity Modeling

Data Source: IMF Directions of Trade, 2000-2003
merchandise imports/exports
Sample Size: 1128 Observations
All parameters are highly significant

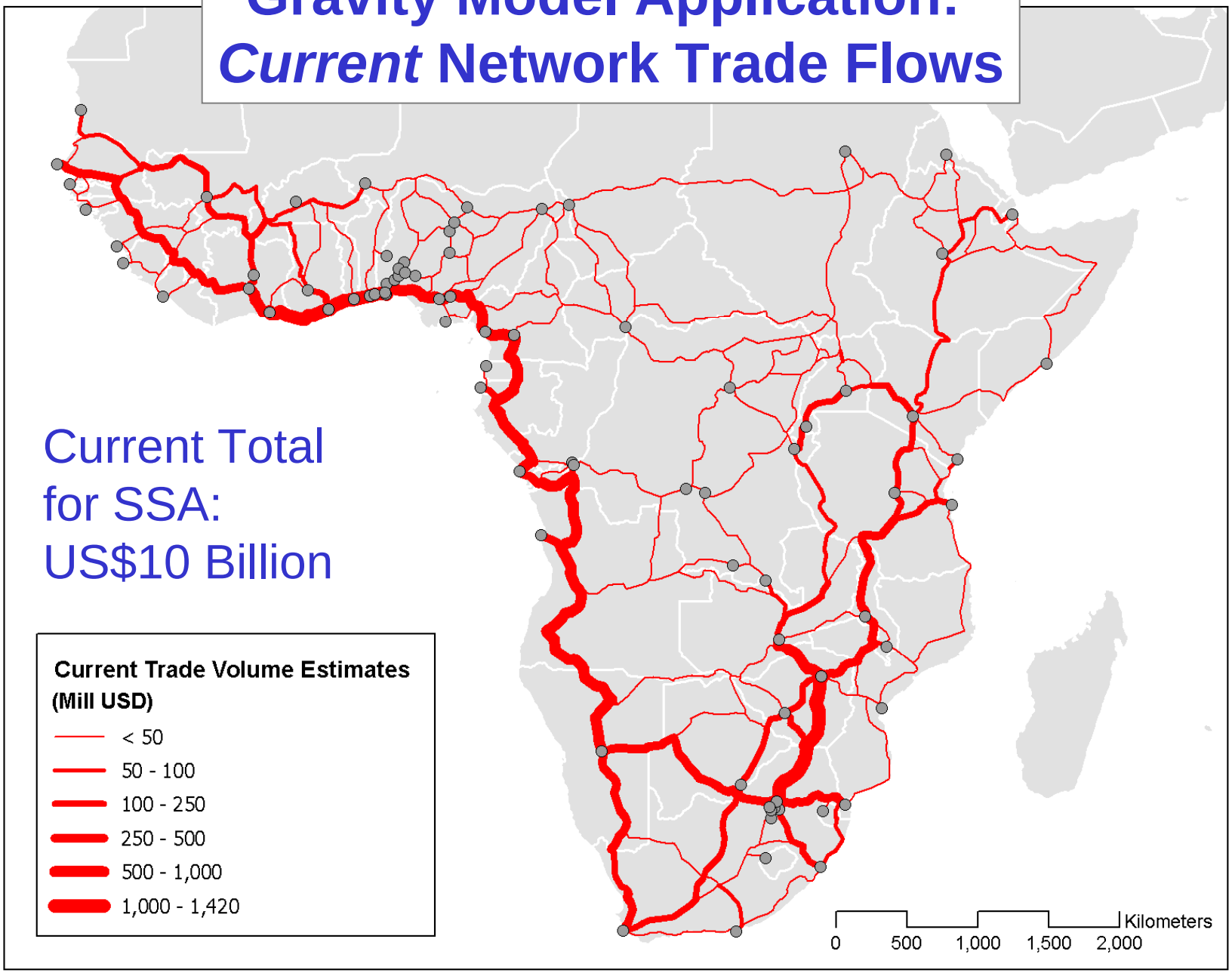
$$\hat{T}_{ij} = K \frac{A_{ij}^{2.74} E_i^{1.71} M_j^{1.44} q_{ij}^{1.93}}{d_{ij}^{2.10}}$$

A_{ij} = Membership in WAEMU, CEMAC or EAC
E_i = Exporter economic scale
M_j = Importer economic scale
q_{ij} = Quality index for the network road link
d_{ij} = Network road distance

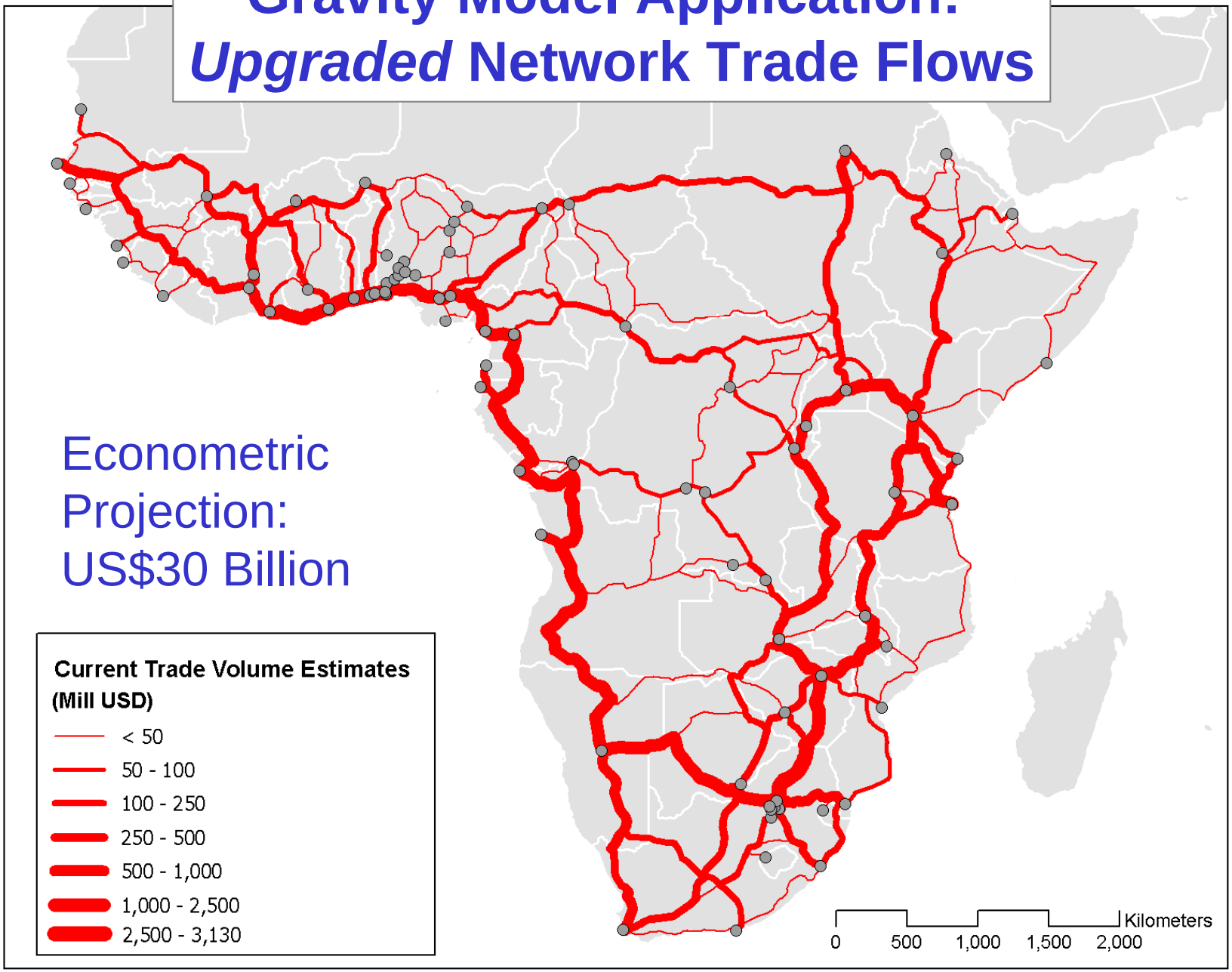
Estimating Trade Flows: Econometric Analysis via Gravity Modeling

- Model is estimated based on **country-to-country trade flows**
- Parameters are then applied to estimate **city-to-city flows** along the least-cost path through the highway network
- This yields estimates of current trade volumes on each road link
- We can then predict future trade volume after road upgrading

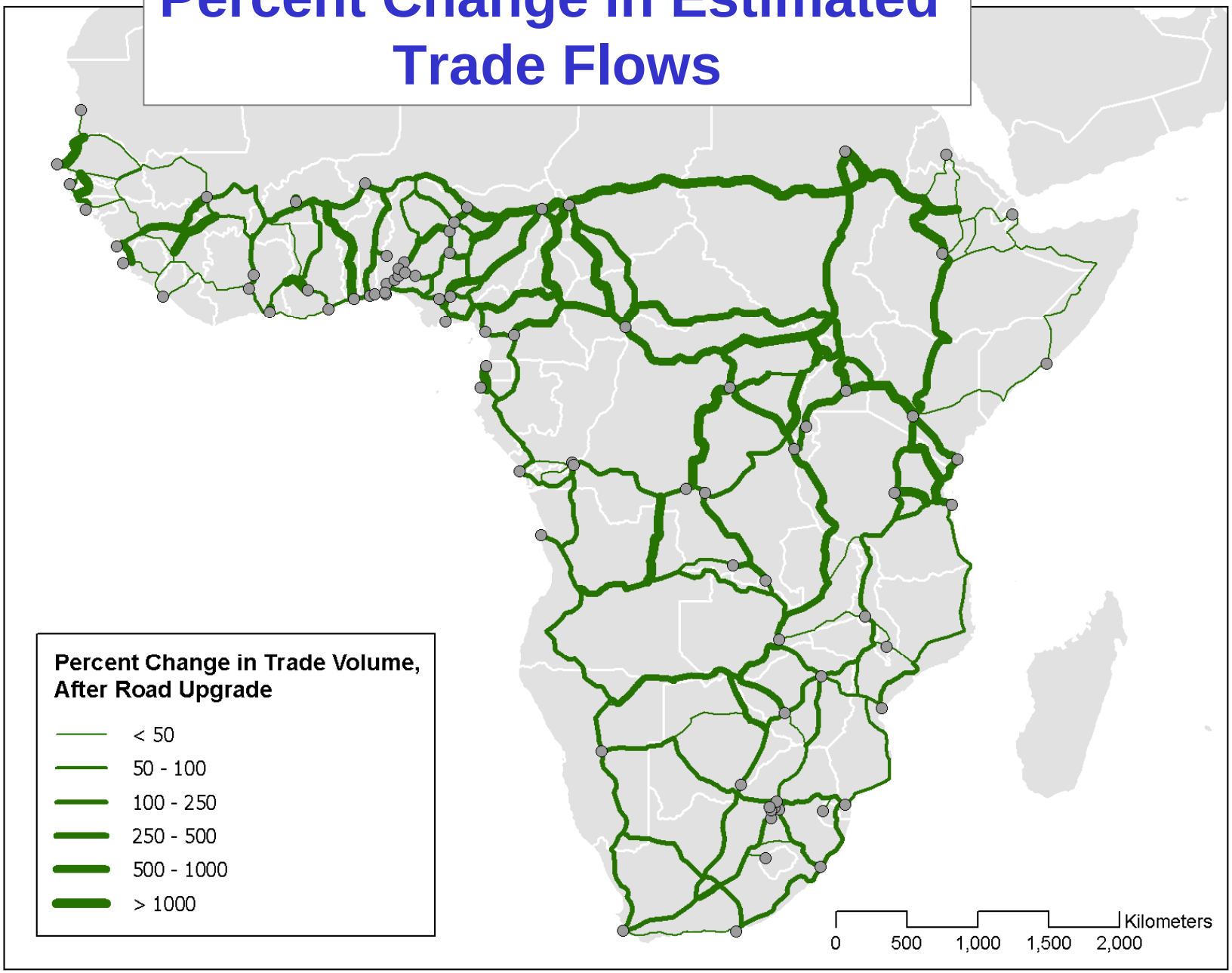
Gravity Model Application: *Current* Network Trade Flows



Gravity Model Application: *Upgraded* Network Trade Flows



Percent Change in Estimated Trade Flows



Gravity Model Application: Network Trade Flows ($US)

Program: Network Upgrade to Class 2

Econometric Projection: Annual Trade ($billion)

Current	Upgraded	
10.1	29.8	55.5 [+1 Std. Error]
		16.4 [-1 Std. Error]

Almost half of increase is *between* major regions (West, Central, East, Southern, South Africa)

Costs

Econometric estimation of upgrading and maintenance costs

Data Source: World Bank ROCKS Database

Sub-Saharan Africa: 470 Road Projects
Costs in $US '000/Km. of Improvement

			Percentiles				
Work Type	Class	#	10.0	25.0	50.0	75.0	90.0
Grading	Maintenance	3	0.2	0.2	0.5	0.9	0.9
Routine Maintenance	Maintenance	22	0.6	1.7	2.0	3.0	3.5
Unsealed Preventive Maintenance	Maintenance	98	2.8	3.3	4.3	5.1	5.7
Bituminous Pavement Preventive Treatment	Maintenance	39	2.3	3.3	5.0	7.7	18.8
Gravel Resurfacing	Maintenance	112	3.9	7.1	10.1	17.4	37.9
Surface Treatment Resurfacing	Maintenance	26	13.0	18.4	20.3	32.2	38.5
Asphalt Mix Resurfacing	Upgrading	27	22.7	39.2	54.7	70.4	95.1
Reconstruction	Upgrading	88	22.8	78.6	128.9	218.1	333.8
Strengthening	Upgrading	14	80.8	103.0	130.3	162.1	203.7
Partial Widening	Upgrading	1	136.0	136.0	136.0	136.0	136.0
Upgrading	Upgrading	35	53.0	109.1	262.5	331.1	473.3
New Two-Lane Highway	Upgrading	2	660.2	660.2	1,023.4	1,386.5	1,386.5
Widening and Reconstruction	Upgrading	3	989.1	989.1	1,331.1	1,568.4	1,568.4
Total		470					

ROCKS does not include all countries, so we use data to estimate a generic cost function

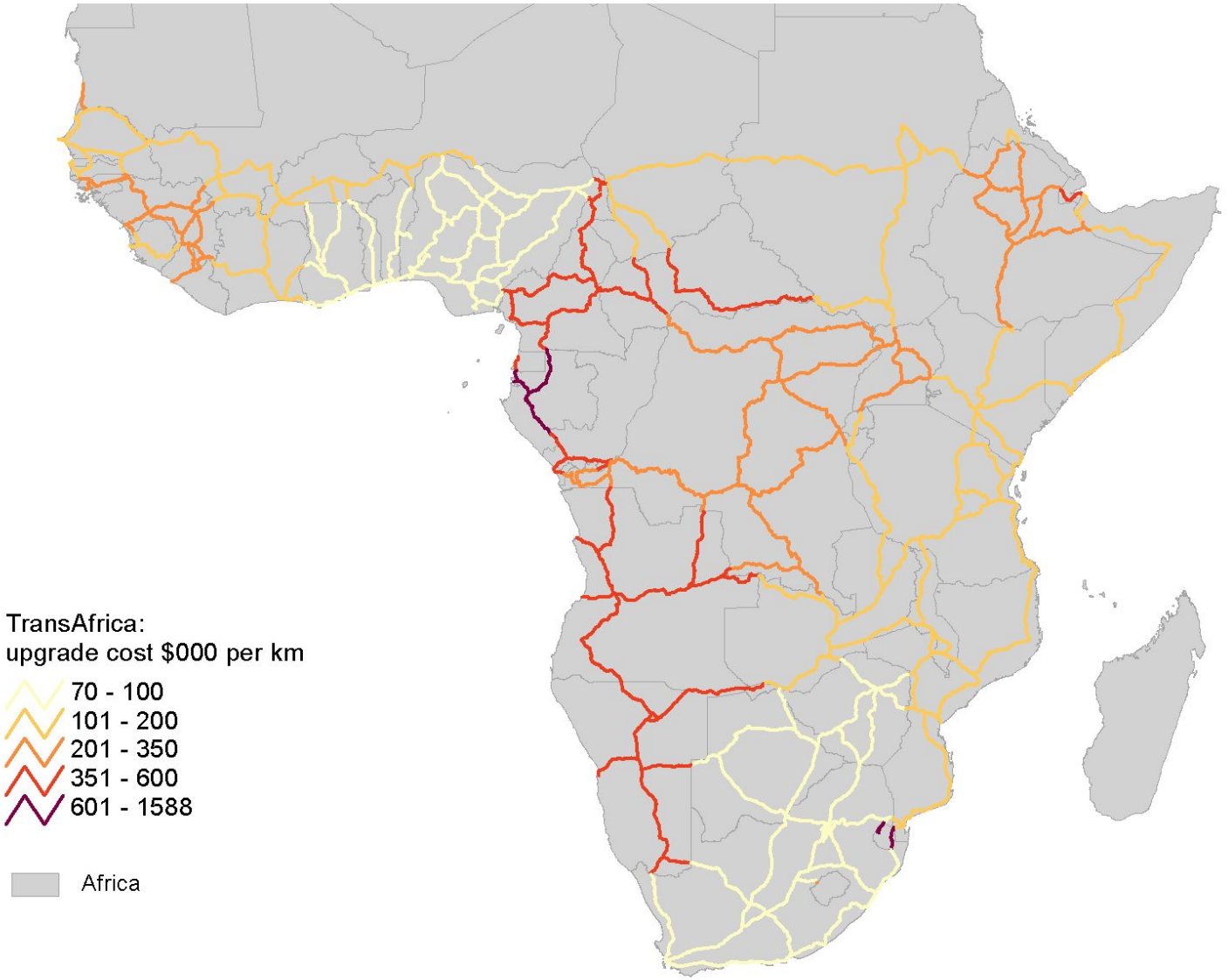
Cost Function Estimation

Dependent Variable: Unit Improvement Cost

Independent Variables:

- Existing road condition (percent paved)
- Wage rates (per capita income)
- Governance (CPIA for accountability, corruption)
- Rainfall intensity (mm per day of rainfall along network)
- Regional controls (West, Central, East Africa)
- Project type controls:
  - 7 Upgrading categories
  - 6 Maintenance categories

Projection From Estimated Cost Function



Program: Network Upgrade to Class 2

Econometric Projection: Upgrade Cost ($billion)

Upgrade		Annual Maintenance	
20.7	28.4 [+1 Std. Error]	0.9	1.2 [+1 Std. Error]
	15.6 [-1 Std. Error]		0.7 [-1 Std. Error]

Network Upgrade Program:
5-Year Upgrade; 10-Year Operation

Trade Category	Annual Trade Growth ($Bill.)	Upgrade Cost Category	Upgrade Cost ($Billion)	Maint. Cost Category	Maint. Cost ($Bill.)	Total Trade Growth ($Bill.)	Total Cost ($Bill.)	Net ($Bill.)
Low	6.2	High	28.4	High	1.2	77.5	43.4	34.1
Low	6.2	Benchmark	20.7	Benchmark	0.9	77.5	32.0	45.6
Low	6.2	Low	15.6	Low	0.7	77.5	24.4	53.2
Benchmark	19.7	High	28.4	High	1.2	246.25	43.4	202.9
Benchmark	**19.7**	**Benchmark**	**20.7**	**Benchmark**	**0.9**	**246.25**	**32.0**	**214.3**
Benchmark	19.7	Low	15.6	Low	0.7	246.25	24.4	221.9
High	45.3	High	28.4	High	1.2	566.25	43.4	522.9
High	45.3	Benchmark	20.7	Benchmark	0.9	566.25	32.0	534.3
High	45.3	Low	15.6	Low	0.7	566.25	24.4	541.9

Benchmark 15 year scenario suggests almost $ 250 billion of additional intra-African trade at a cost of $ 32 billion

Trade expansion vs. welfare gain

- Value of increased trade does not equal welfare gain
- But most studies show a link between trade and growth, and between growth and poverty reduction
- Our benefit estimates are probably conservative as they do not include:
  - Rural and inter-city trade expansion within countries
  - Additional trade with the rest of the world
  - Induced growth as economies become more dynamic
  - Rural labor benefits from labor intensive construction

Summary

- If African economies respond to opportunities in the same way as the rest of the world, upgrading of a pan-African highway network could yield tremendous benefits
- $215 billion “surplus” over 15 years

Summary

- Key assumptions
  - Implementation as a *network* approach
  - Physical improvements are accompanied by removal of non-physical trade barriers

Summary

- Implementation
  - Possibly tremendous employment benefits from labor intensive construction methods
  - 8.4 million person years employment for upgrading
  - 365,000 permanent jobs for maintenance
  - Estimates based on other labor intensive infrastructure projects

Thank you!

For a copy of the paper or presentation, email

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