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New Rural Access Index

Main Determinants and Correlation to Poverty

Atsushi Iimi
Farhad Ahmed
Edward Charles Anderson
Adam Stone Diehl
Laban Maiyo
Tatiana Peralta-Quirós
Kulwinder Singh Rao

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Abstract

Transport connectivity is essential to sustain inclusive growth in developing countries, where many rural populations and businesses are still considered to be unconnected to the domestic, regional, or global market. The Rural Access Index is among the most important global indicators for measuring people's transport accessibility in rural areas where the majority of the poor live. A new method to calculate the Rural Access Index was recently developed using spatial data and techniques. The characteristics of subnational Rural Access Index estimates were investigated in eight countries: Bangladesh, Ethiopia, Kenya, Mozambique, Nepal, Tanzania, Uganda, and Zambia. It was found that for the countries in Africa, road density and road condition are important determinants of the Rural Access Index. For the South Asian countries, improvement of road condition is particularly relevant. The evidence suggests that significant resources are likely to be required to achieve universal access through rehabilitating the existing road network and expanding the road network.

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NEW RURAL ACCESS INDEX: MAIN DETERMINANTS AND CORRELATION TO POVERTY

November 2016

Atsushi Iimi,[¶] Farhad Ahmed, Edward Charles Anderson, Adam Stone Diehl, Laban Maiyo, Tatiana Peralta-Quirós, Kulwinder Singh Rao

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The World Bank Group

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[¶] Corresponding author.

I. INTRODUCTION

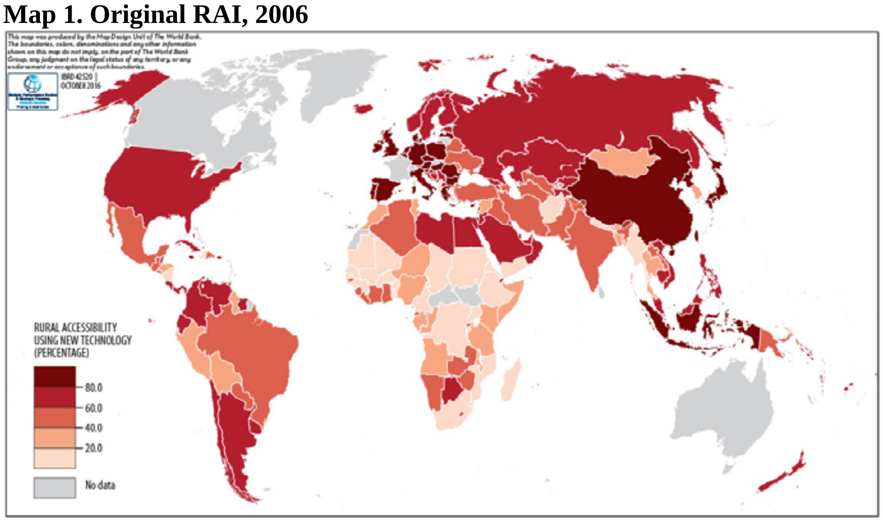
Among other factors, transport connectivity is an essential part of the enabling environment for sustained and inclusive growth. In developing countries, particularly in Africa, the vast majority of farmers does not have good access to the local, regional, or global market, and depends on subsistence farming with few advanced inputs. Limited connectivity is a critical constraint in accessing social and administrative services, especially in rural areas where the majority of the poor live. Africa's manufacturing and other local businesses are also lagging behind in the global market, except possibly for a few textiles, agrobusiness, and mining activities (Dinh et al. 2012).

The literature is supportive of the importance of transport connectivity. In the short term, transport costs and travel time can be reduced by improved road conditions (Lokshin and Yemtsov 2005; Danida 2010). Over the longer term, agricultural productivity will be increased (Khandker, Bakh, and Koolwal 2009; Bell and van Dillen 2012), and firms will become more profitable with more jobs created (Mu and van de Walle 2011). Poverty will then be alleviated (Dercon, Hoddinott, and Woldehanna 2008; Khandker and Koolwal 2011).

However, somewhat surprisingly, there are few global indicators that measure transport connectivity systematically. The traditional measurements are the total length of roads and the percentage of paved roads. The original data were sourced from the International Road Federation and were included in the World Bank's World Development Indicators until recently. However, these indicators are only collected at the national level, and it has long been argued whether they are actually meaningful for measuring development efforts made on the ground, because they cannot provide any granularity of local connectivity, and the indicators barely changed over time, despite significant resources spent to improve the road network on the ground.[1]

The Rural Access Index (RAI) developed by Roberts, Shyam, and Rastogi (2006) is perhaps among the most important global indicators for measuring transport sector development. The RAI was originally defined by the proportion of people who have access to an all-season road within an approximate walking distance of 2 kilometers (km). The original work relied on available household surveys and other modeling techniques. Although some methodological ambiguity remains, it was estimated that about one billion rural residents, or 68.3 percent of the rural population, were left unconnected to the road network in the world (map 1). There is significant inequality across regions: while nearly 90 percent of the rural population in East Asia and Pacific has 2-km access to the road network, the RAI in Sub-Saharan Africa is estimated at only 33.9 percent.

Map 1. Original RAI, 2006



Source: Based on Roberts, Shyam, and Rastogi 2006.

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[1] By definition, the total length of roads is not changed unless new roads are constructed. In many cases, however, road projects aim to rehabilitate, maintain, or upgrade the existing road network. In addition, even unpaved roads can be appropriate and function well. It is a matter of whether a road is properly maintained.

Unfortunately, the RAI has not been updated since the initial work, for various reasons. For instance, the original work used household surveys, which are normally costly to carry out. In Roberts, Shyam, and Rastogi (2006), RAIs based on household surveys were reported only for a handful of countries. In addition, household surveys normally do not have sufficient spatial representativeness. In reality, rural accessibility differs significantly from one location to another even within a country. Thus, it is difficult to have spatial representativeness when the data are sourced from household surveys. Finally, because of the differences in spatial representativeness and method, the measured RAIs are not necessarily comparable across countries. As a result, there was little sustainability of regular data updates with the previous method.

Given the renewed interest in the RAI in the context of the Sustainable Development Goals (SDGs), a more sustainable and consistent method for measuring rural access has been proposed using new spatial data and techniques.[2] The SDGs aim to develop quality, reliable, sustainable, and resilient infrastructure to support economic development and human well-being, with a focus on affordable and equitable access for all (Target 9.1).

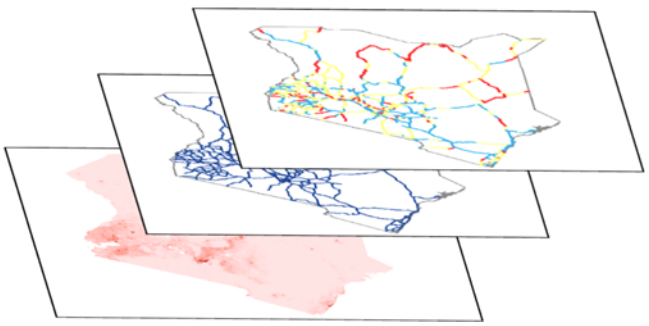
The new RAI method is conceptually the same as the previous work—that is, “share of the population who live within 2 km of the nearest road in good condition in rural areas”—but it uses newly emerging global data and advanced techniques. For instance, high-resolution population distribution data, such as WorldPop, developed by the international research community, can provide detailed information on where people live. Digitized road network data, including road conditions, are also often available at national road agencies. By virtually combining these data, the new method computes the RAI without counting households on the ground (figure 1).

The new method is expected to ensure the index’s sustainability as well as consistency across countries. Importantly, the new method allows the assessment of rural accessibility at any

[2] See World Bank (2016) for a more detailed discussion.

disaggregated subnational level (such as districts or villages). Therefore, it is more informative than the previous RAI and is expected to be highly relevant to road sector operations, for instance, for road planning, prioritization, and monitoring purposes.

Figure 1. Spatial Technique for the New RAI Method



Source: World Bank 2016.

The current paper aims to examine what the main determinants of the new RAI are, using subnational estimates in eight countries: Bangladesh, Ethiopia, Kenya, Mozambique, Nepal, Tanzania, Uganda, and Zambia. The paper investigates correlation, not causality, but there are several important characteristics of the measured RAI. The paper also examines correlation to poverty. Again, causality remains open to argument. There is often endogeneity between road infrastructure and poverty incidence, because governments may invest more in road assets where economic productivity is already high and people are already rich. Still, it is important to confirm that the new RAI is actually related to overall development objectives, such as poverty reduction.

The following sections are organized as follows: section II discusses our empirical models, section III provides the main results and some policy implications, and section IV concludes.

II. EMPIRICAL MODELS AND DATA

The new RAI is defined by the proportion of the rural population who live within 2 km of the nearest road in good condition. Road conditions are assessed in different ways, depending on the available data in the countries. In general, the assessment is conducted based on the surface type and roughness of each road. From an engineering point of view, the RAI only takes into account paved roads in good and fair condition and unpaved roads in good condition (see World Bank (2016) for further details).

Urban areas are excluded using the Global Rural-Urban Mapping Project (GRUMP) data set. The population distribution data come from WorldPop, which is available at a resolution of 100 meters and regularly updated whenever new data (such as national census data) become available.

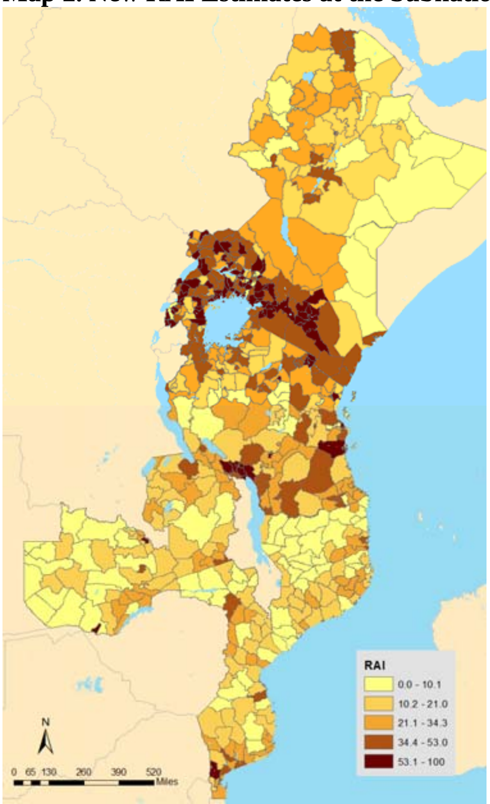
World Bank (2016) shows that the new RAI estimates are somewhat different from the original estimates in 2006, mainly because of methodological differences. Among the sample countries where results are available, rural access varies significantly, from 17 percent in Zambia to 56 percent in Kenya and 87 percent in Bangladesh (table 1). An advantage of the new RAI method is that the index is available not only at the national level, but also at the subnational level. The latter is the primary data source for the following empirical analysis (map 2).

Table 1. Summary of the New RAI Estimates

Country	Population (million)	Land area (1,000 km^2)	Population density	Road data length (km)	Original RAI, 2006	New RAI	Year
Bangladesh	159.1	130.2	1,222	250,688	37	86.7	2015
Nepal	28.2	143.4	197	77,819	17	54.2	2015
Ethiopia	97.0	1000.0	97	85,880	32	21.6	2015
Kenya	44.9	569.1	79	160,886	44	56.0	2009
Mozambique	27.2	786.4	35	29,614	27	20.4	2010
Tanzania	51.8	885.8	59	94,039	38	24.6	2008/2014
Uganda	37.8	199.8	189	140,910	27	53.1	2015
Zambia	15.7	743.4	21	51,070	64	17.0	2011

Source: World Bank 2016.

Map 2. New RAI Estimates at the Subnational Level



Source: World Bank 2016.

By definition, the RAI can be decomposed into four factors: (i) number of beneficiaries (*AccessPop*) per km, (ii) share of roads in good condition (*GoodRdKm*), (iii) rural road density (which is defined by the total road length (*TotalRdKm*) divided by rural land area (*RuralArea*), and (iv) population density (*RuralPop* / *RuralArea*):

$$\begin{aligned} RAI &= \frac{AccessPop}{RuralPop} \\ &= \left(\frac{AccessPop}{GoodRdKm}\right)\left(\frac{GoodRdKm}{TotalRdKm}\right)\left(\frac{TotalRdKm}{RuralArea}\right)\left(\frac{RuralArea}{RuralPop}\right) \\ &= Beneficiaries * Qualtity * RdDen * PopDen^{-1} \end{aligned} \tag{1}$$

The equation cannot be estimated because this is an accounting identity, which gives a perfect fit in the log linear model. From a policy point of view, however, two terms are of particular interest: *RdDen* and *Quality*. Important policy questions are: how the RAI could be improved, and whether universal access (that is, *RAI* = 1) would be achievable. Equation 1 indicates that in principle there are only two ways to achieve universal access: (i) extending the road network by constructing new roads or reclassifying previously unclassified roads into the official network, and (ii) improving the quality of the existing road network through rehabilitation or upgrading works. While the former is measured by road density (*RdDen*), the latter is primarily captured by the share of good roads (*Quality*).

To answer these questions, the following reduced form equation is considered:

$$\ln RAI_{ic} = \beta_0 + \beta_1 \ln RdDen_{ic} + \beta_2 \ln Quality_{ic} + \beta_3 \ln PopDen_{ic} + \beta_4 \ln PopConc_{ic} + \beta_5 \ln Urban_{ic} + v_c + \varepsilon_{ic} \qquad (2)$$

RAI is rural access measured in district *i* of country *c*. It is determined by road density, *RdDen*, and the share of good roads in the total road length in rural areas, denoted by *Quality*. Only rural areas are considered in our data. The RAI is also considered to be related to rural population density (*PopDen*). It is commonly expected that the RAI would be higher where population density is high, although it depends on the population distribution between near-road and far-road areas, which is expected to be captured by population concentration along the road network, *PopConc*. This is defined by the share of people who live within 2 km of the road network in the total population in rural areas. *Urban* is the usual urbanization rate, which is the share of urban population in the total population.

In addition, the relationship between the RAI and the poverty rate is also examined with data from Kenya, Mozambique, and Uganda, where poverty data are available at the subnational level:

$$\begin{aligned} POV_{ic} &= \gamma_0 + \gamma_1 \ln RAI_{ic} + \varepsilon_{ic} \\ &= \delta_0 + \delta_1 \ln RdDen_{ic} + \delta_2 \ln Quality_{ic} + \delta_3 \ln PopDen_{ic} + \delta_4 \ln PopConc_{ic} + \delta_5 \ln Urban_{ic} + v_c + \varepsilon_{ic} \end{aligned} \qquad (3)$$

It is expected that poverty is negatively correlated with rural access ($\gamma_1 < 0$): the higher the rural access is, the lower the poverty rate is. By using the same set of independent variables as in equation 2, the analysis examines which element is most important or relevant to poverty reduction.

Summary statistics are shown in table 2. The data cover 691 districts or counties in eight countries. In these districts and counties, about 11.4 percent of the total population lives in urban areas, which are excluded from the RAI calculation.[3] In rural areas, on average there are 236 persons per km^2, of which about 61.8 percent live within 2 km along the current road network. For road infrastructure, there are on average 50.9 km of roads per 100 km^2 of land in rural areas. About 33 percent of the rural road networks are in good or fair condition. As a result, the RAI is on average 37.2 percent, that is, 37.2 percent of the rural population has access to the road network in good condition.

Poverty data are only available for Kenya, Mozambique, and Uganda. On average about half of the population lives below the poverty line. But the poverty rate varies significantly, from nearly zero to 92 percent in the sample districts/counties.

[3] Technically, urban areas are spatially excluded from the RAI calculation, using GRUMP, which develops a rural-urban distinction extent in the disaggregation process.

Table 2. Summary Statistics

Variable	Abbr.	Obs	Mean	Std. Dev.	Min	Max
Rural Access Index (0 to 1)	*RAI*	691	0.372	0.280	0.009	1
Road density in rural areas (km per km^2 of land)	*RdDen*	691	0.509	0.706	0.004	4.163
Share of roads in good condition to the total road length in rural areas (0 to 1)	*Quality*	691	0.330	0.261	0.0001	1
Rural population density (per km^2 of land)	*PopDen*	691	236.7	393.9	0.9	4007.6
Share of population living within 2 km of a road to the total rural population (0 to 1)	*PopConc*	691	0.618	0.322	0.019	1
Urbanization rate (share of urban population) (0 to 1)	*Urban*	691	0.114	0.213	0	0.997
Country dummy for Bangladesh	*v*(*Bangladesh*)	691	0.093	0.290	0	1
Ethiopia	*v*(*Ethiopia*)	691	0.094	0.292	0	1
Kenya	*v*(*Kenya*)	691	0.064	0.244	0	1
Mozambique	*v*(*Mozambique*)	691	0.182	0.386	0	1
Nepal	*v*(*Nepal*)	691	0.074	0.262	0	1
Tanzania	*v*(*Tanzania*)	691	0.230	0.421	0	1
Uganda	*v*(*Uganda*)	691	0.161	0.367	0	1
Zambia	*v*(*Zambia*)	691	0.103	0.304	0	1
Poverty rate (0 to 1)	*POV*	281	0.499	0.210	0.00003	0.922

III. Main results

The ordinary least squares (OLS) method is applied to estimate equation 2. The findings show that road density and quality are both important determinants of the RAI (table 3). The coefficient of *RdDen* is significantly positive at 0.324, and the coefficient of *Quality* is also significant. The latter has a greater coefficient of 0.543, indicating its relative importance for improving the RAI. Even if the country-specific fixed effects are taken into account, the result remains unchanged. Both are significant, and the effect of road quality is greater than the road density effect.

The findings also show that the RAI is affected by population distribution patterns. It tends to be higher where more people live along the road network: the coefficient of *PopConc* is positive and significant. Contrary to our prior expectation, however, population density, which is often used as a proxy to measure the efficiency of rural road investment, turned out to be insignificant unless country-specific fixed effects are taken into account. The evidence suggests that the RAI is determined specifically by the relative population distribution between near-road and far-road areas, not the general population density in a broad area.

Urbanization has a positive but insignificant coefficient in the model without fixed effects. When country fixed effects are included, the urbanization effect is significant. A possible reason may be that the sample countries are highly heterogeneous in level of urbanization. Technically speaking, urban areas are excluded from the RAI calculation. However, there is normally endogeneity between urbanization and road investment: urban areas are often more productive than rural areas, possibly because of agglomeration economies. At the same time, urban areas often receive more investments in road infrastructure. Therefore, peri-urban areas that are not included in urban areas tend to have high accessibility. As a result, high rural access and high urbanization coexist.

The policy implication is complex, because the evidence indicates that the urban-rural divide could be widened: road accessibility would likely be higher where larger urban areas exist nearby. Thus, there is a risk that remote rural areas located away from major urban areas would be left behind further.

Table 3. OLS Regression of the RAI

Variable	Coef.	Std.Err.		Coef.	Std.Err.	
ln *RdDen*	0.324	(0.031)	***	0.272	(0.046)	***
ln *Quality*	0.543	(0.035)	***	0.564	(0.040)	***
ln *PopDen*	-0.0001	(0.017)		0.001	(0.021)	
ln *PopConc*	0.746	(0.048)	***	0.759	(0.060)	***
ln *Urban*	0.005	(0.003)		0.013	(0.004)	***
v(*Ethiopia*)				-0.391	(0.096)	***
v(*Kenya*)				0.014	(0.055)	
v(*Mozambique*)				-0.039	(0.095)	
v(*Nepal*)				0.001	(0.069)	
v(*Tanzania*)				0.005	(0.084)	
v(*Uganda*)				0.142	(0.056)	**
v(*Zambia*)				-0.217	(0.083)	***
Constant	0.530	(0.139)	***	0.574	(0.163)	***
Obs.	691			691		
R squared	0.8763			0.8923		
F statistics	985.68			542.54		

Note: The dependent variable is the log of *RAI*. Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent, respectively.

One may wonder if there is any systematic difference between Africa and South Asia, because the two regions have several different characteristics. For instance, population density in Africa is generally much lower than in South Asia, and so is road density. The conventional structural model is used to test this hypothesis. The test statistic is estimated at 23.32, well above the critical value, suggesting that there is a systematic difference in the RAI determinants between the two regions.

Several specific differences are found, although they cannot be overgeneralized because our sample of countries is limited (table 4). First, road density and quality are both important to improve the RAI in Africa. However, road density does not matter for South Asia: the coefficient of *RdDen* is not statistically significant. This may be because Bangladesh and Nepal already have high road densities. In African countries, the current road networks may remain to be developed.

The evidence provides different policy implications for the two regions. For South Asia, a remaining challenge to improve rural access is primarily to improve the quality of the existing road network. For Africa, where the existing road networks are often narrowly defined, not only quality improvement, but also network expansion is needed. The road network can be expanded by new road construction or reclassification of unclassified or informal roads into the official network. Both options would require more resources in the road sector and, possibly, institutional rearrangements, such as expansion of the road authority's responsibility.

Second, the relationship with urbanization is relatively weak in Africa, although still statistically significant. The coefficient of *Urban* is 0.012 in Africa and 0.083 in South Asia. This may reflect that Africa's level of urbanization is still relatively low, although it is projected to accelerate quickly in the future.

Table 4. OLS Regression of the RAI with African and Asian Countries Differentiated

Variable	Coef.	Std.Err.	
*dAFR**ln *RdDen*	0.275	(0.053)	***
*dAFR**ln *Quality*	0.598	(0.049)	***
*dAFR**ln *PopDen*	0.001	(0.023)	
*dAFR**ln *PopConc*	0.754	(0.065)	***
*dAFR**ln *Urban*	0.012	(0.004)	***
(1-*dAFR*)*ln *RdDen*	0.120	(0.084)	
(1-*dAFR*)*ln *Quality*	0.407	(0.040)	***
(1-*dAFR*)*ln *PopDen*	-0.078	(0.066)	
(1-*dAFR*)*ln *PopConc*	4.889	(1.055)	***
(1-*dAFR*)*ln *Urban*	0.083	(0.026)	***
Constant	1.163	(0.470)	**
Obs.	691		
R squared	0.901		
F statistics	427.8		
Structural test (*F* stat.)	23.32	***	

Note: The dependent variable is the log of *RAI*. Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent, respectively.

Finally, the subnational poverty rates are regressed on the RAI and other relevant indicators. There is no doubt that poverty is relevant to the RAI (table 5). The coefficient is estimated at -0.103.

Among the RAI determinants, road density is found to be significant, but road quality is not correlated significantly with poverty. These results seem to be consistent with the above-mentioned twin challenges in Africa. African countries need not only road rehabilitation, but also network expansion. The evidence reconfirms the particular importance of road network expansion to reduce poverty in rural areas. The poverty regression is only focused on three countries in Africa: Kenya, Mozambique, and Uganda. Therefore, the results can be interpreted to mean that many of the rural poor in these countries live beyond the current road networks. Thus, significant efforts would likely be required to provide them better access to the road network.

Table 5. OLS Regression of the Poverty Rate

Variable	Coef.	Std.Err.		Coef.	Std.Err.	
ln *RAI*	-0.103	(0.020)	***			
ln *RdDen*				-0.133	(0.033)	***
ln *Quality*				-0.011	(0.015)	
ln *PopDen*				0.020	(0.021)	
ln *PopConc*				-0.075	(0.037)	**
ln *Urban*				-0.014	(0.002)	***
v(*Mozambique*)	-0.008	(0.035)		-0.354	(0.076)	***
v(*Uganda*)	-0.076	(0.026)	***	-0.155	(0.031)	***
Constant	0.399	(0.025)	***	0.235	(0.121)	*
Obs.	285			281		
R squared	0.3215			0.4418		
F statistics	35.66			51.77		

Note: The dependent variable is the poverty rate. Robust standard errors are shown in parentheses. *, **, and *** indicate statistical significance at 10, 5, and 1 percent, respectively.

IV. CONCLUSION

Transport connectivity is essential to sustain inclusive growth in developing countries. Many rural populations are still considered to be unconnected to the domestic, regional, or global market. In the context of the SDGs, the RAI has an important role to play as a global indicator to measure people's transport accessibility in rural areas where the majority of the poor live.

With sustainability of data updates, consistency across countries, and operational relevance taken into account, a new method to calculate the RAI was developed using spatial data and techniques. The resultant RAI estimates vary significantly across countries and across districts in a given country. The estimates are already useful for road planning and prioritization purposes. But an important policy question may be how the RAI could be improved. In theory, there are only two ways: (i) improving the road condition of the existing road network, and (ii) expanding the road network through new road construction or reclassification.

The paper investigated the characteristics of the subnational RAI estimates in eight countries. It was shown that road density and road condition systematically influence the RAI. For South Asia, improvement of road condition is particularly important, possibly because road density is already high. In Africa, road network expansion and improvement are both important to raise the RAI. In some African countries, in fact, road classification is still imperfect and the current road network is defined narrowly. In such a case, new road construction and/or reclassification of unofficial feeder or local paths is needed. All the indications are that significant resources are likely to be required to achieve "universal access."

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