A Prospective Evaluation of Afghanistan's National Emergency Rural Roads Project *

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1 Introduction

Transport infrastructure is critical for the effective functioning of product, labor and capital markets. Restrictions on mobility which arise from degraded transport infrastructure curtail the operation of such markets, increasing vulnerability to shocks and hindering participation in cultural, social, and political activities. Moreover, the efficiency of interventions to reduce poverty or provide services such as education, access to credit, healthcare, and even good governance are ordinarily dependent on the capacity of existing infrastructure to provide access to targeted areas. [1]

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[1]Studies by the World Health Organization provide some preliminary evidence that availability of transport infrastructure affects school attendance and school enrollment. Other studies by the World Bank indicate that a disproportionate amount of benefits from transport infrastructure accrue to the poor, to women and children given that distance plays a significant role in determining access to maternal and child care as well as school attendance for girls.

Despite the salience of transport in both economic theory and the practice of development, existing studies of the impact of rural roads construction and rehabilitation have failed to establish a causal link between transport and poverty reduction (Hettige, 2006). A critical failing of many studies is the lack of an adequate baseline survey conducted prior to the initiation of program activities (Galiani, 2007). Yet even where baseline surveys exist, the quality of inferences are generally hampered by the failure to resolve the significant yet unpredictable biases which arise from endogenous decisions concerning road placements and rehabilitation activities (de Walle, 2002; Galiani, 2007).

The capacity of existing studies to yield plausible inferences over program effects is further limited by a failure to systematically examine the mechanisms through which improvements of transport infrastructure can facilitate poverty reduction and development. This is often the result of a focus on correlations between aggregate measures of road density and outcomes of interest, to the neglect of micro-level transport data and associated inferences over the functioning of local markets for transport services. Ideally, evaluations of interventions targeted to improve the quality of transport infrastructure would aim to address the complete transport-development chain, mapping infrastructure development to changes in transport markets and from there to socioeconomic outcomes.

In this paper, we develop a research design for a prospective evaluation which aims to address some of the limitations of previous studies. As a means to draw improved inferences over the impact of rural roads on accessibility and social and economic outcomes of interest, we propose a matching design consisting of a comprehensive baseline survey and successive waves of follow-up surveys administered to a common set of respondents.

2 National Emergency Rural Access Project

The National Emergency Rural Access Project (NERAP) aims to help improve accessibility, integrate village economies with regional and national markets, and stimulate a more efficient allocation of resources, a heightened level of technology transfer, and an increased level of productivity and economic output.

NERAP exists as a component of the Government of Afghanistan's National Rural Access Program (NRAP), a multi-donor effort executed jointly by the Ministry of Rural Rehabilitation and Development (MRRD) and the Ministry of Public Works (MPW). The main objective of the program is to create rural access network that connects communities across all of Afghanistan's 34 provinces to essential services and markets. NRAP is implemented by the United Nations Office for Project Services (UNOPS), with works carried out by local contractors and communities.[2]

[2] In addition to NRAP, MRRD "implements rural access activities with funding from the European Commission (EC) and the Counter-Narcotics Trust Fund (CNTF), and, for Helmand province, from the UK

2.1 Road Conditions in Rural Afghanistan

The degraded state of Afghanistan's rural road network both reflects and reinforces the impoverished state of the countryside. Decades of conflict and the prolonged lack of maintenance resulted in damage to long stretches of roads and to many bridges and other critical structures. Motorized traffic is currently low, motorcycle and pickup traffic is expected to increase as soon as roads are passable. Non-motorized transport competes with motorized means in many parts of rural Afghanistan.

Of the 30,000 km of rural roads spread across the country, only 3,000 km are paved. The overall road network consists of about 6,000 km of national roads of which 3,300 km are primary highways, including 2,400 km that were originally paved. The remaining network comprising of 2,700 km secondary national roads and 15,000 km provincial roads, is either gravel or earthen. The tertiary road network consists of unpaved village access roads.

2.2 Project Background

In 2002, the National Emergency Employment Program (NEEP) was launched as one of the transitional administration's four National Priority Programs to provide targeted social protection for vulnerable groups throughout the country. NEEP, which later became the National Rural Access Program (NRAP), has been implemented through four major projects assisted by the World Bank:

- Labor Intensive Public Works Projct (LIWP - 2002-04; IDA funding of US$16.78 million: Provided employment in rehabilitation of irrigation capacity and provincial and district-level roads to rural laborers.

- National Emergency Employment Program-1 (NEEP-1 - 2002-2008), Afghanistan Reconstruction Trust Fund (ARTF) funding of US$51.9 million: Provided bridge funding until the National Emergency Employment Program for Rural Access (NEEPRA) was prepared. Designed to provide targeted social protection and strengthen key rural access infrastructure, with a focus on providing: (i) emergency short-term employment on labor -based subprojects; and (ii) technical assistance for program implementation.

- National Emergency Employment Program for Rural Access (NEEPRA - 2003-2007, IDA funding of US$39.2 million). Objectives and structure are similar to NEEP-1.

- National Emergency Employment Program for Reintegration and Alternative Livelihood (NEEP-RAL - 2004-08; Japan Social Development Fund Grant, US$19.6 million, administered by the World Bank): Supports the reintegration of ex-combatants

Department for International Development (DfID). The rural roads sector also receives funding from [ISAF Provincial Reconstruction Teams (PRTs)] but on an autonomous basis that complements the peacekeeping operations in Afghanistan".

into society and contributes to the Alternative Livelihood Program in poppy producing areas. Seeks to create opportunities for employment and development of vocational training and business management skills for the beneficiaries. Government also provided funds received from the Programmatic Support Institution Building (PSIB) project.

Financing for the Government's overall national rural access program has so far been provided by the following donors: ARTF $42.8 million, EC $ 10.6 million, Japanese Social Development Fund $21.6 million, WB-LIWP $14.2 million, WB-NEEPRA $39.2 million, USAID through UNDP $3.1 million, Counter Narcotics Trust Fund $5.3 million, and DFID (for Helmand Province) $15.4. million. Through mid-2007, total contributions reached US$ 177 million. NRAP is expected to require a budget of about $ 500 million over the next five years to achieve the objectives of the Afghanistan National Development Strategy (ANDS), which is expected to be finalized in March 2008.

2.3 Project Objectives

The "post-Bonn" Compact for Afghanistan, written at a high-level conference of international donors in London in January 2006, identified 27 benchmarks to be achieved within the next five years. The benchmarks specifically related to the rural roads sector are:

(i) Provision of road connectivity to 40% of the 38,000 villages (totaling 19 million rural inhabitants) by end-2010;

(ii) A fiscally-sustainable road maintenance system by end-2007.

To reach the target of the Compact, an additional 4,000 km of rural roads need to be rehabilitated over the next three years and included in the maintainable network, resulting in an annual rehabilitation target of 1,350 km. The NERAP program represents one of the government's major means to meet this target. It is envisaged that US$112 million will be allocated to the program from IDA over a four-year implementation period.

The motivating goals of the program are not focused on the rehabilitation of roads per se, but rather on the improvement of rural accessibility and the integration of Afghan communities into regional and national markets. Furthermore, it is expected that such improvements in accessibility will trigger second-order economic benefits, such as an improvement in the efficiency of resource allocation, increases in the pace of technology transfer, higher productivity and outputs, and the diversification of household income sources to reduce vulnerability to external shocks. In addition, it is anticipated that improved accessibility triggers increased access to basic services, such as education and health care.

The Project Development Objective (PDO) of NERAP is to "provide year-round access to basic services and facilities in the rural areas of Afghanistan covered by the project". The program's key performance indicators (KPIs) reflect the expectation that successful road rehabilitation projects provoke significant improvements in accessibility and the functioning of local markets. The KPIs for monitoring the achievement of the PDO include :

- After completion of a road, travel time of beneficiaries living along the improved road to the first available schools, health care facilities, and administrative services will be reduced by 30%;
- After completion of a road, the number of trips taken by beneficiaries living along the improved road to district centers will increase by 30%;
- Prices of key consumption and production commodities at beneficiary villages would be within 15% of the price in the nearest town.

The estimated total cost of the project is US$137 million. The IDA grant allocation of the project is US$112 million, with the government committing to provide the remaining US$25 million from its own resources or donor contributions. The duration of NERAP is estimated at 36-months and is expected that the project will finance about 20-25 percent of the total estimated cost of NRAP over the next five years.

One area of interest in the design of NERAP is potential linkages with the Government of Afghanistan's National Solidarity Programme (NSP), which provides for the creation of democratically-elected Community Development Councils (CDCs). CDCs are accorded responsibility for planning, implementing, and managing community development subprojects. In particular, the program principals of NERAP have expressed a desire to target NSP villages for road construction and maintenance and to incorporate CDCs into the management of these projects in order to support participatory and transparent management processes, consolidate the functioning and authority of CDCs, and promote community involvement and ownership for roads built under NERAP.

NERAP is to be jointly executed by the Ministry of Rural Rehabilitation and Development (MRRD), which oversees the rehabilitation of tertiary roads, and the Ministry of Public Works (MPW), which oversees the rehabilitation of secondary roads. The implementation of NERAP is supported by an Implementation Consultant, which was contracted to the United Nations Office for Project Services (UNOPS) during NEEPRA.

2.4 Project Components

The program will comprise the following three components:

(i) Improvement of secondary roads by the Ministry of Public Works (MPW);

(ii) Improvement of tertiary roads by the Ministry of Rural Rehabilitation and Development (MRRD);

Ministry	Cost	KM of Road	Bridges (Run. Meters)	Avg Cost(per KM)
Secondary Roads (MPW)	58.3 million	1,081 km.	658 rm.	0.054
Tertiary Roads (MRRD)	27.0 million	929 km.	8,201 rm	0.029
Total	85.3 million	2,010 km.	8,859 rm.	0.042

(iii) Institutional Strengthening, Project Management, and Program Development.

The investment program aimed to ensure balanced investment proposals between secondary and tertiary roads, and equity amongst regions, provinces and districts. Beyond this, the selection of sub-projects was guided by the following criteria:

1. Former Priorities

   a Former priorities still not financed from the Provincial Planning Process (PPP) of June 2003. MRRD had launched a bottom-up PPP nationwide in June 2003. During this exercise community representatives identified four priority projects per district based on criteria agreed among the representatives;

   b . Former priorities still not financed from the NEEP provincial planning exercise of September 2004. In September 2004, NEEP organized a planning workshop in 12 provinces affected by drought to identify priority roads to be rehabilitated selected on agreed criteria among the district representatives using the pair-wise ranking method at the district level;

2. Communities' Requests

   a Direct Requests from Communities. Community Requests (CR) were channeled through the planning departments of MPW and MRRD;

   b Community requests (CR) channeled though other administrative instances (e.g. local authorities, Governors, Parliament representatives) often with peace and reconciliation objectives in strategic areas;

3. Consolidation Works to Sustain Previous Rural Road Investments

   a Consolidation works for roads that were rehabilitated under National Emergency Employment Project for Rural Access (NEEPRA) (drainage, upgrade works, surfacing of road with double-bituminous surface treatment, etc.);

   b Completion of road works which were only partially funded under NEEPRA (e.g. an access road leading to a NEEPRA-funded bridge);

4. Connectivity for Isolated Areas

   a Access of isolated populated villages many of which may be highly poppy dependent to the road network to facilitate delivery of public and social services and access to markets;

5. Complementarities with other social and rural development projects

   a. Complementarities with e.g. NRAP, NSP, irrigation and agriculture investments.

2.4.1 Secondary Roads

The secondary roads component, to be implemented by MPW, has four sub-components:

(i) Rehabilitation and reconstruction of about 1,075 kilometers of secondary rural roads. The road selection was largely based on discussed and agreed criteria discussed below. The criteria include increasing access to isolated villages to the road network to facilitate delivery of public and social services and access to markets. IDA funding complements the ongoing programs financed under ARTF and takes into account as much as possible global equity parameters to ensure balanced investment proposals between the secondary and tertiary roads and equity amongst regions, provinces and districts;

(ii) Emergency repair works to roads and bridges following natural disasters such as heavy snow, rocks falls, landslide and rocks blockage, heavy rains and flooding. Specific criteria were defined at appraisal (covering e.g. proven exceptional event, re-opening of roads to link isolated areas, blockage o f heavy traffic road without possibility of road deviations);

(iii) Environmental and social sector management, and monitoring and evaluation; and

(iv) Project implementation assistance: services of an implementation consultant and financial contribution to incremental operating expenses required to run the program implementation unit of MPW, including project allowances for civil servants.

2.4.2 Tertiary Roads

The tertiary roads component, to be implemented by MRRD, has five sub-components:

(i) Rehabilitation and reconstruction of about 925 kilometers of tertiary rural roads. The project will aim at promoting the development of a professional labor-based contracting industry which is particularly suited for tertiary road improvements. The road selection was largely based on discussed and agreed criteria. IDA funding complements the ongoing programs financed under ARTF and takes into account as much as possible global equity parameters to ensure balanced investment proposals between the secondary and tertiary roads and equity amongst regions, provinces and districts;

(ii) Emergency repair works to roads and bridges following natural disasters such as heavy snow, rocks falls, landslide and rocks blockage, heavy rains and flooding.

Specific criteria were defined at appraisal (covering e.g. proven exceptional event, re-opening of roads to link isolated areas, blockage o f heavy traffic road without possibility o f road deviations);

(iii) Routine maintenance program on the already rehabilitated roads under the NEEP-I and NEEPRA. It was agreed during appraisal to implement this sub-component through the National Solidarity Program (NSP) which leverages synergies of these two priority programs. The Facilitating Partners (FP) of the NSP will provide technical advice to the communities and the Community Development Councils (CDC) will be the entry point for community contracting for routine maintenance works;

(iv) Environmental and social sector management, and monitoring and evaluation; and

(v) Project implementation assistance, including services of an implementation consultant and financial contribution to incremental operating expenses required to run the project implementation unit of MRRD

2.4.3 Institutional Strengthening, Capacity Building, and Project Implementation Assistance

This component, to be implemented by MRRD in coordination with MPW, has three sub-components:

(i) Rural roads management system including support for: (a) the development of a rural access strategy and its implementation through a national prioritized investment program for the next five years, including an assessment as to how NERAP may be able to maximize the Counter Narcotics Outcomes of its interventions; and (b) the setting up of maintenance mechanism, maintenance programming for the short and medium term and support for its first year of implementation, and routine and emergency maintenance works;

(ii) Capacity building activities for staff who will be tasked to manage the rural road sector, e.g. road network management (identification of a core rural road network, definition of appropriate service levels, data collection and analysis, and appropriate economic appraisal techniques), public procurement, financial management, upgrading of engineering skills, reporting, and geographic information systems. The project will finance internships for at least 100 engineering students and ten community development/social inclusion students annually. It is also planned to develop a program for managerial level staff who would receive on-the-job training in roads agencies in other countries. This sub-component will also include capacity building for contractors (national works contractors and engineering firms) which would target on-the-job training and business skills (bidding, contract management and community contract management, conflict resolution, works organization, and technical aspects); and

(iii) Project management, monitoring and evaluation and analysis of data for reporting purposes.

3 Methodological Framework

Evaluations of rural road projects present a unique set of challenges to generating an unbiased estimate of the interventions effect. Roads are designed to connect clusters of villages: lowering the cost of travel, increasing exchange, and providing access to previously remote resources (de Walle, 2002). As a result, any village's response to a road rehabilitation will depend upon the response of surrounding villages. The interactions between units violates the standard assumptions usually postulated to justify matching to identify causal effects (Rosenbaum and Rubin, 1983). Further, because road projects are targeted based upon the characteristics of a group of villages, failure to condition upon the aggregate characteristics of villages used when analyzing selecting the projects results in a biased measurement of the average treatment effect. In fact, we show that if the assignment to treatment occurs among clusters of villages, but matching is done as if individual villages were assigned to treatment then we may produce biased estimates of a causal effect of interest–even when *exact matching is performed on individual level covariates*.

3.1 Notation

Suppose that we have a set of M roads,$|M| = m$ indexed by $j = 1, \ldots, m$ of which a subset $T \subset M$, $|T| = t$ are to be rehabilitated. We index the villages 'near' road j by $i = 1, \ldots, n_j$ and assume there are $N = \sum_{j=1}^{m} n_j$ villages in total.[3] Suppose that within each village there are $h = 1, \ldots, i_h$ households, with $H = \sum_{j=1}^{m} \sum_{i=1}^{n_j} i_h$ representing the number of households in total.

We say that village i is near the j^{th} road project if $||i - j|| < \alpha$ where $|| \cdot ||$ is some measure of cost to travel to the project j from village i and α is some cutoff value to define precisely the cutoff for treatment reception. For our evaluation, we use 'as the crow flies' as our distance measure and set $\alpha = 1$. We say village i and i' are in the same cluster j if both $||i - j|| < \alpha$ and $||i' - j|| < \alpha$. The potential outcomes for household h in village i in cluster j will be given by $Y_{hij}(\boldsymbol{T})$ where $\boldsymbol{T}$ is an $m \times 1$ vector.[4]

[3] We make precise the definition of 'near' used in this project in the next paragraph. Suppose that each village is near only one road project. Only a small subset of villages lie 'near' one road project and future work will focus upon reexamining the assumptions when we have villages receiving many treatments

[4] For example, if there are three roads to be rehabilitated and three control roads, a typical treatment vector may be $\boldsymbol{T} = (1, 0, 1, 1, 0, 0)$. In usual circumstances for causal inference, $\boldsymbol{T}$ will be a vector for each observational unit. This emphasizes the interesting challenge of road projects: assignment to treatment occurs at a higher level in a hierarchy than the units of observation.

3.2 SUTVA

Because roads are designed to facilitate interaction, it is inappropriate to make the *Stable Unit Treatment Value Assumption* (SUTVA) originally postulated in Rosenbaum and Rubin (1983). This version of SUTVA restricts each unit's response to a treatment to be independent of the response of every other unit. The version of SUTVA used here allows for interaction among villages and households within the same road project, but assumes that the responses of villages that lie along different projects are independent. This assumption extends to clustered observational studies the SUTVA made in Imai, King and Nall (2008) for clustered randomized experiments.

Assumption 1 (SUTVA)**.** *Suppose $Y_{hij}(\boldsymbol{T})$ is the potential outcome for household h in village i in cluster j Assume that there are no hidden versions of the treatment. If $T_j = T_j^{'}$ then $Y_{hij}(\boldsymbol{T}) = Y_{hij}(\boldsymbol{T}^{'})$.*

Applying the SUTVA allows us to write $Y_{hij}(\boldsymbol{T})$ as $Y_{hij}(T_j)$. There are two primary threats to this assumption. If control roads are too close to treated road projects, they are likely to receive some of the benefits from the road rehabilitation. To limit the possibility of spillover we eliminate all control projects with villages within 10 km of any rehabilitated project. A second threat is that a village may reside within 1 km of more than one road project. This induces a dependence between clusters that share the village as a member. To cope with this problem, we collect all clusters with a village in common to one 'super-cluster' during analysis, but treat the clusters as separate during the matching stage.[5]

3.3 Ignorability

In this section we offer a rigorous definition for the covariates associated with a road project and then postulate the ignorability assumption used to identify causal effects.

3.3.1 Road Project Covariates

Suppose that each village i has a $1 \times k$ vector of covariates, $\boldsymbol{X}_{ij}$ and collect all the $\boldsymbol{X}_{ij}$ from road project j to form an $n_j \times k$ matrix $\boldsymbol{X}_j$. Further, we suppose that $\boldsymbol{R}_j$ is a $g \times 1$ vector of road covariates–such as road length, number of villages which lie upon the road, and the altitude of the road.

We assume that there is a function $f : \Re^{n \times k} \times \Re^{g} \rightarrow \Re^{b}$ which summarizes the characteristics of villages along the road and the road project into a vector. We then call $f(\boldsymbol{X}_j, \boldsymbol{R}_j)$

[5]Note that independence in assignment between units is not a strictly necessary assumption for matching to be reasonable. Another threat to the SUTVA used here is that there may be different versions of the treatment. In particular, it may be the case that the treatment is more 'potent' the closer a village is to the project. At the moment, we assume away this possibility (due to the absence of a reasonable instrument for distance from a roads projects we cannot model the different levels of 'dose')

the Road Project covariates, which play the same role as covariates in the case of matching at the individual level. For example, we may take the mean poverty level within the villages, or use the median household income.

3.3.2 Selection on Observables for Assignment at the Road Project Level

We can now use the village level covariates to formulate an ignorability assumption appropriate for the road project level data. The version of ignorability stated here is directly analogous to ignorability when assignment and analysis is at the individual level.

Assumption 2. *For each road project j suppose that the village level covariates are collected in the $n_j \times k$ matrix $\boldsymbol{X}_j$ and the road characteristics are collected in the $g \times 1$ vector $\boldsymbol{R}_j$, and that the cluster covariates are given by $f(\boldsymbol{X}_j, \boldsymbol{R}_j)$ for some function f.*

2.1 *(Overlap)* $0 < Pr(T_j = 1 | f(\boldsymbol{X}_j, \boldsymbol{R}_j)) < 1$ *for all* $j = 1, \ldots, M$

2.2 $(Y_{hij}(1), Y_{hij}(0)) \perp T_j | f(\boldsymbol{X}_j, \boldsymbol{R}_j)$, *for all* $h = 1, \ldots, i_h$, *for all* $i = 1, \ldots, n_j$, *for all* $j = 1, \ldots, M$.

Assumption 2.1 states that at each level of the cluster's covariates there is a positive probability of a road project receiving treatment. Assumption 2.2 states that the distribution of potential outcomes for households is independent of the treatment assignment at each level of the cluster covariates, $f(\boldsymbol{X}_j, \boldsymbol{R}_j)$. This could be violated in two ways. Similar to matching at the individual level, if we fail to condition upon a covariate that was used to determine treatment assignment and covaries with the outcome of interest, then Assumption 2.2 is violated. Second, if we use the wrong function to summarize the covariates, then it may be the case that there is still some dependence between the treatment assignment and the potential outcomes. Notice, that we do not need to include household level of information nor information summarizing information in covariates because we know assignment was based solely upon the characteristics of villages, rather than particular households within the village. Conditioning upon household characteristics during the analysis stage, however, allows us to increase the precision of our estimates.

3.4 Unbiased Estimation of Average Treatment Effects

We are interested in identifying the average treatment effect on the treated–or the effect of the road rehabilitation on villages and households that actually were near treated roads. Formally we define this quantity as

$$\text{ATT} = \text{E}\left[\boldsymbol{Y}_{hij}(1) - \boldsymbol{Y}_{hij}(0) | T = 1\right] \tag{3.1}$$

for household level treatment effects. Of course, a naive difference in means, $\text{E}\left[\boldsymbol{Y}_{hij}(1) | T = 1\right] - \text{E}\left[\boldsymbol{Y}_{hij}(0) | T = 0\right]$ does not necessarily provide an unbiased estimate of Equation 3.1. Road projects were targeted that are likely to provide the largest gains in social welfare (de Walle, 2002) and therefore the projects selected for rehabilitation are far from a random sample.

But, we can use a subset of our control population to create a comparison group that can provide an unbiased estimate of Equation 3.1.

Define the probability that each road project is treated, the propensity score, as $e\left(f(\boldsymbol{X}_j, \boldsymbol{R}_j)\right) = \Pr(T_j = 1 | f(\boldsymbol{X}_j, \boldsymbol{R}_j))$. We can now state the most important theorems from Rosenbaum and Rubin (1983) as they follow directly from our assumptions.

Theorem 1. *If treatment assignment is strongly ignorable given $f(\boldsymbol{X}_j, \boldsymbol{R}_j)$ then it is strongly ignorable given $e\left(f(\boldsymbol{X}_j, \boldsymbol{R}_j)\right)$. Further, conditioning upon $e\left(f(\boldsymbol{X}_j, \boldsymbol{R}_j)\right)$ provides an unbiased causal estimate of the ATT (Equation 3.1 at $e\left(f(\boldsymbol{X}_j, \boldsymbol{R}_j)\right)$*

Proof. Follows directly from Rosenbaum and Rubin (1983). Proof available upon request. □

The key to Theorem 1 is that we have a set of covariates at the cluster level are sufficient to identify Equation 3.1.
When examining road projects, a natural temptation might be to assume villages were selected for treatment based upon their individual characteristics, performing design and analysis at the same level of hierarchy in the data. In this case, we condition upon each village's covariates $\boldsymbol{X}_{ij}$ alone, without considering the characteristics of surrounding villages. In the following remark we show that under general conditions exact matching on individual covariates is insufficient to identify Equation 3.1.

Remark 1. *Suppose Assumptions 1 and 2 hold, but we use the village level covariates $\boldsymbol{X}_{ij}$. Suppose treatment assignment is at least in part based upon road characteristics $\boldsymbol{R}_j$ or the characteristics of surrounding villages in the cluster. Then conditioning upon $\boldsymbol{X}_{ij}$ is not sufficient to provide an unbiased estimate of Equation 3.1*

Proof. Suppose treatment assignment depends solely upon one road characteristic $f(\boldsymbol{X}_j, \boldsymbol{R}_j) = r_j$. Then,

$$\mathrm{E}\left[\boldsymbol{Y}(1) | T = 1, \boldsymbol{X}_i\right] - \mathrm{E}\left[\boldsymbol{Y}(0) | T = 0, \boldsymbol{X}_i\right] \neq \mathrm{E}\left[\boldsymbol{Y}(1) - \boldsymbol{Y}(0) | \boldsymbol{X}_i\right]. \tag{3.2}$$

The case of surrounding villages follows similarly. □

Remark 1 shows that when assignment occurs at the road-project level, matching at the individual level can result in biased estimates of causal effects, even when exact matching is performed on the village level covariates.

4 Matching

To select road projects–and subsequently villages to be sampled– we used nearest neighbor propensity score matching as implemented in the `MatchIt` package for `R`(Ho et al., 2007). Table 1 enumerates the covariates, along with providing a summary statistic used to generate the 'road' level covariates. In addition to the variables listed in the table below, we also included squared, logged, and interaction terms to help ensure that we obtained the best balance possible on all moments of the data.

Table 1: Covariates Used in Matching

Covariate	Summary Function
No Villages Along Road	*
Mean Density Villages Along Road	*
Length of Project	*
Closest Hospital	*
No. Hospitals < 5 km	*
Total Population w/in 1 km of road	Sum of Villages' populations
Distance to district center	Closest Village on Project
Household size	Average over Villages
Dari	Proportion of Villages Speaking Dari
Pashto	Proportion of Villages Speaking Pashto
Flat	Proportion of Villages Near 'Flat' Terrain
Mountain	Proportion of Villages Near 'Mountainous' Terrain
Cars All Season	Proportion of Villages with Car Access All Season
No Roads	Proportion of Villages with No Roads
Literacy < 5km	Proportion of Villages with Lit Center W/in 5 km
Health < 5 km	Proportion of Villages with Health Center W/in 5 km
School < 5 km	Proportion of Villages with School W/in 5 km
Radio < 5 km	Proportion of Villages with radio access
TV < 5 km	Proportion of Villages with TV access
Altitude	Standard Deviation of Villages' Altitude
River	Proportion of Villages with River Village Access
Potato	Proportion of Villages Growing Potatoes
Rice	Proportion of Villages Growing Rice
Industrial	Proportion of Villages with other (non-farming)Industry

4.1 Balance Improvement

Using the covariates in Table 1, we used nearest neighbor propensity score matching to generate a matched sample. To measure the success of our matches, Figure 1 displays the standardized bias before and after matching. The standardized bias in the covariates–the average difference between treatment and control covariates scaled by the standard deviation of this difference–is a metric commonly used to assess the balance found in the data(Rubin, 2001). The black dots in the figure represents the pre-matching standardized bias, while the red dots represent the post-matching difference. Our goal is to move the red dots as close to zero as possible.

Figure 1 displays the substantial differences between treatment and control roads before matching. For example, treated roads were much more likely to have potato farming in villages along the projects and tended to be much longer than the control projects.

Figure 1: Assessing Balance After Matching

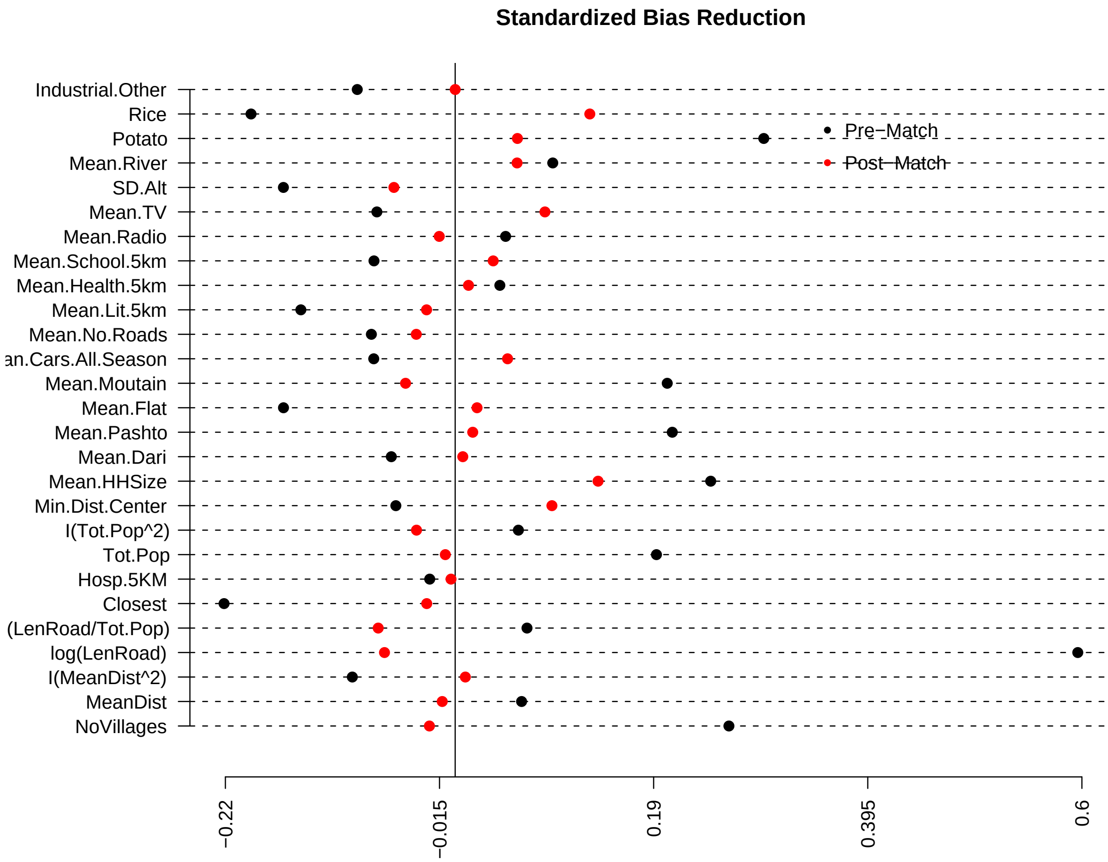


Figure 1 presents the standardized bias before and after matching. The standardized bias is the difference in means of the treatment and control covariates, scaled by their means. The black dots are the biases before matching, the red dots the biases after matching. Substantial differences existed before matching, but matching appears to ameliorate these differences.

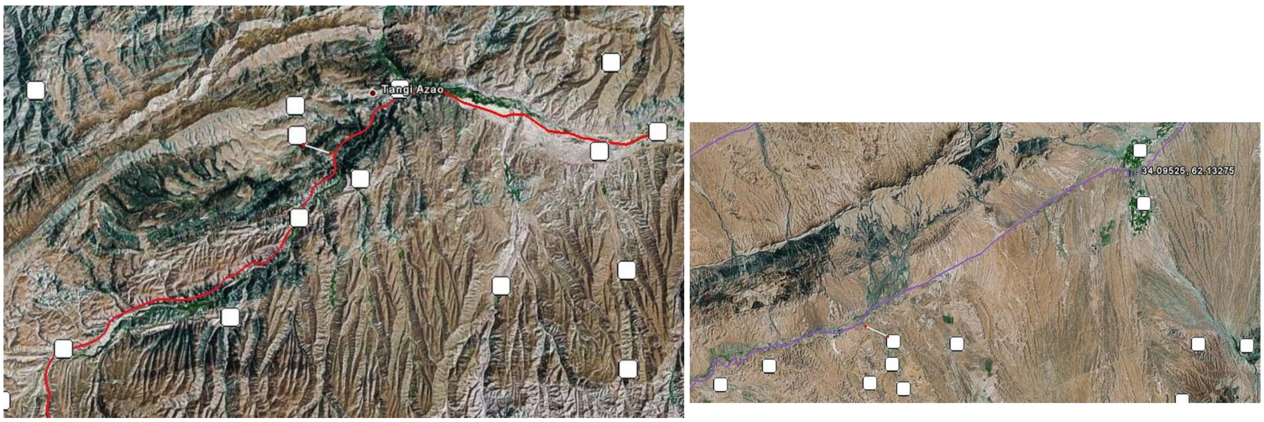
Matching reduces the bias substantially–which is represented by the close proximity of the red dots to the vertical line at zero. We suspect that matching is so successful here because the use of summary statistics, in particular the average of village characteristics, makes our data closer to normally distributed. It is well known that normally distributed data fall into an important class of covariates where matching is able to perform best (Rubin and Thomas, 1992).

4.2 Example of Matched Pair

While we are interested in the balance of the sample, it is instructive to offer an example of the matches we generate above. In figure 2, below, we display two matched roads.

The road on the left-hand side is an MoPW road that is found in the Ghor province, and the road on the right-hand side is a control road from the Herat province. The white dots represent villages from CSO3 and the white line (barely visible) represents 1 KM. We captured this image from Google Earth.

Figure 2: Example of a Matched Pair



The figure on the left represents a treated road, while the figure on the right is the matched control road. The white dots represent villages from the CSO3. Notice, that both roads are located in similar terrain, both have a similar number of villages along the road and the villages seem to have similar spread.

A visual check illustrates surprising similarities between the two projects: both reside in a pass surrounded by mountains and both appear to have similar numbers of surrounding villages that are spread apart. This is confirmed by looking at the covariates for the treated and control projects: the mean density of villages along the road in both villages is about 10 km, both are far from the district center (302 and 206 km, respectively), both Speak Dari, and have average households of about 5 individuals.

5 Estimation of Causal Effects

After matching the road projects and collecting survey data, we can use covariates to increase precision of the estimates of Equation 3.1. When constructing the model to include these parameters, it is important to note that road projects result in a natural hierarchy within the data. Households are nested in villages and villages within road projects. To attend to this hierarchy, we estimate the ATT using a Bayesian hierarchical model, with data at all three levels of the hierarchy (Gelman and Hill, 2007). In this section we provide a brief discussion of the hierarchical model that will be fit to the data and the benefits the model provides to the analysis.[6]

5.1 Defining the Model

We describe the full model for outcome data measured at the household level, but the general approach could be applied to outcome data at the village or project level. Also, for ease of notation we assume that data have only been collected at one time period. But the model stated here can be easily generated to incorporate the robust information from a panel data set. Suppose that we have a $1 \times c$ vector household characteristics $\boldsymbol{Z}_{hij}$. We model the additional heterogeneity implied by the interactions between units by allowing intercepts to vary across villages and across road projects. At one extreme, we could include an indicator variable for each road project and each village. At the other, we could include only one intercept. To compromise between the two extremes, we use a hierarchical model to estimate the intercepts. The hierarchical model pulls villages with only a few observations closer to the population estimate–the estimate from the single intercept model. But, if a village or road project has many observations then the estimated intercept will be closer to the estimate produced after including an indicator for each village and road (Gelman and Hill, 2007).

We include additional covariates at each level of the hierarchy. The additional covariates, while not reducing bias if Assumption 2 holds, will allow us to more precisely estimate our quantity of interest. The full model can be stated as,

$$\boldsymbol{Y}_{hij} \sim \mathcal{N}(\alpha_i + \boldsymbol{\beta}\boldsymbol{Z}_{hij} + \theta T_j, \sigma_y^2) \tag{5.1}$$

$$\alpha_i \sim \mathcal{N}(\boldsymbol{\gamma}\boldsymbol{X}_i + \eta_j, \sigma_\alpha^2) \tag{5.2}$$

$$\eta_j \sim \mathcal{N}(\boldsymbol{\mu} f(\boldsymbol{X}_j, \boldsymbol{R}_j), \sigma_\eta^2) \tag{5.3}$$

where $\mathcal{N}(\cdot,\cdot)$ is a normal distribution and α_i and η_j are intercepts which vary by village and road projects, respectively. $\boldsymbol{\beta}$ is a vector of coefficients relating household covariates to the response, $\boldsymbol{\gamma}$ are covariates relating village covariates to the village intercept, and $\boldsymbol{\mu}$ are covariates which relate road project covariates to the road project intercept. $\sigma_\eta^2, \sigma_\alpha^2, \sigma_y^2$ are the variances for the road project, village, and household level data, respectively. Finally, θ is the coefficient on the treatment indicator and because we have assumed normal distributions is the causal quantity of interest. If we change the distributional assumptions, we simply average the differences between treated and control values, as predicted from the model, to generate causal estimates.

5.2 Estimation

We use a fully Bayesian approach to estimate the system of Equations 5.1, 5.2, 5.3. A set of vague normal priors on the coefficient and intercept terms and a gamma distribution

[6]These sorts of models take on a number of different names–including fixed effects and random effect models. Given the confusion surrounding these labels, we will call the model hierarchical (Gelman and Hill, 2007).

is used as a prior for the variance components. The posterior distribution is summarized in the `R` programming language. See Gelman and Hill (2007) for details.

6 Design of Impact Evaluation

The following section aims to provide an outline of how the methodological framework developed in the preceding section will be operationalized to deliver a rigorous impact evaluation of the NERAP program.

6.1 Unit of Analysis

In existing evaluations of rural road construction or rehabilitation programs, the unit of analysis is often the community or a larger geographic entity (district or county) affected by the roads. The outcomes of interest in this case are either measured directly at the appropriate geographical area (e.g. price level in the district) or constructed by aggregating individual or household level data (e.g. average consumption in a village).

This approach, however, does not allow us to address the question of the distribution of project benefits across individuals and households. To identify who benefits the most from the projects and their effect on wealth and income distribution within villages and districts, it is essential to combine the analysis at the village and district level with individual or household level information. For this reason, special attention should be paid to collecting information at the individual and household-level during the baseline and follow-up surveys.

6.2 Channels of Influence and Outcomes of Interest

Road rehabilitation projects generally deliver a series of multi-faceted interventions to villages selected to receive the program. In addition to the core function of delivering road rehabilitation activities, project activities ordinarily provide infusions of financial resources in the form of wages and sourcing of inputs, physical materials, and technical capacity into affected areas. Such ancillary consequences of project activities can lead to pronounced impacts on outcomes of interest independent of those of the core rehabilitation activities. For instance, it can be expected that wages paid to local workers participating in rehabilitation activities will have an impact on consumption and other economic outcomes at the household and village level and that this impact will exist irrespective of the indirect and direct effects of the actual rehabilitation.

In so far as it is generally not possible to physically separate the actual rehabilitation from the infusion of financial resources, physical materials, and technical capacity that comes along with rehabilitation, it can be very difficult to identify the different mechanisms through which the project affects outcomes of interest. However, provided that these different program effects are adequately monitored, observed and measured, it is possible to chart the various channels through which project activities affect outcomes of interest, while obtaining evidence on the importance of each channel. In the event that the channel through which the project affects the outcome cannot be established, serious doubts arise as to the validity of the estimated effect.

In order to identify channels through which the program is affecting outcomes of interest, it is necessary to collect information on direct (or 'intermediate outcomes') and indirect effects (or 'final outcomes') of road rehabilitation. Direct effects include the decrease in travel time and cost to markets, hospitals, work, schools, as well as the wages distributed through the road rehabilitation itself. Indicators that account for direct effects of the project include traffic density, time and monetary costs of trips to markets, the location of health and education facilities, road passability (number of days of road closure), the number of days worked on the project, and the total wages received for working on a project. Indirect effects include the impact on trading and production activities (agricultural and non-agricultural activities, activity mix, off-farm employment), income structure, composition of expenditure, health and education status, political participation, etc.

7 Data Collection

Data for this evaluation will be obtained through three sources: (1) successive annual administration of household surveys and community focus groups; (2) collection of traffic and road monitoring data through 'spot survey's administered by the Monitoring and Evaluation (M&E) structures of NERAP; and (3) existing secondary data sources. A detailed description of each source is provided below.

7.1 Household and Focus-Group Surveys

The principal source of data for the evaluations will be a series of three or four large-scale household and focus-group surveys, to be conducted at one-year intervals before, during, and after the implementation of program activities in areas selected to receive NERAP projects (treatment group) and areas not selected to receive NERAP projects (control group). The round of surveys will commence with a baseline survey, tentatively scheduled to be administered between April and June of 2008, and will be succeeded by a series of follow-up surveys conducted at intervals of approximately one-year. If feasible, the heads-of-household surveys will focus on compiling a panel of response data by interviewing the same individuals in each round of the survey. In addition to the heads-of-household surveys, focus group surveys will be conducted of females and male village leaders. A tentative agreement has been reached with the Vulnerability Analysis Unit (VAU) of MRRD to administer the baseline survey.

The purpose of the baseline and follow-up surveys will be to elicit information on both direct and indirect outcomes of interest, such as agricultural output and productivity, farm-gate prices, employment levels, income levels, wage levels, access to education and health services, health and education outcomes, transport costs, and mobility. In addition, household surveys will focus on exploring the role of travel in fulfilling the basic needs, wider socio-economic needs, and social and leisure activities of members of the household. As well as providing data on which to calculate outcomes of interest and estimate program and treatment effects, the baseline survey will generate control variables that will form the basis for identifying artificial control groups, which can reduce the variability in final outcomes and thereby improve the power of the given sample size.

7.2 Spot Surveys

One of the most critical shortcomings of existing evaluations of rural roads is the absence of transport data, such as traffic counts, vehicle operating costs, transit times and road quality indicators. Changes in transport infrastructure should have a first order impact on these indicators and we hope to collect regular information on these at bi-monthly intervals in conjunction with the NERAP M&E structure. In addition to transport indicators, we hope that the NERAP M&E structure will support the administration of spot surveys to monitor prices of the main goods traded in each village. This can be achieved by having survey teams attempt to purchase the goods in the market or by asking a sample of market-going individuals about the last price paid for each good.

7.3 Existing Secondary Data

Over recent months, the Evaluation Team has collected a rich array of secondary data from sources such as the 2005 national census conducted by the Afghanistan Central Statistics Office (CSO) and Geographic Information System (GIS) data compiled by the International Security Assistance Force (ISAF) and the Ministry of Public Works (MPW) and MRRD. It is hoped that these data sources will inform the selection of candidate units for the artificial control group, all of which will be surveyed during the baseline household and focus-group surveys. In addition, this data can potentially assist in the matching procedures, representing covariates to control on when estimating program and treatment effects.

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