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DOES THE EXTENSION OF THE RURAL ROAD NETWORK HAVE A POSITIVE IMPACT ON POVERTY REDUCTION AND RESILIENCE FOR THE RURAL AREAS SERVED? IF SO HOW, AND IF NOT WHY NOT?

A SYSTEMATIC REVIEW, JULY 2016

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Conflicts of interest

The following studies have been included in this systematic review: Airey and Cundill (1998); Hine et al. (1983a,b).

During the screening and quality appraisal process, consensus on the relevance of studies for inclusion in the review was reached through discussion with all of the review authors. Where disagreements occurred, the final decision was made by either the lead (John Hine) or second review author (Masam Abedin). However, if a review author was an author of one of the studies, he was not involved in these final decisions; instead judgements were made by the remaining review authors.

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SUMMARY

INTRODUCTION

This systematic review asks, 'Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not?' It is funded by DFID and conducted by Cardno IT Transport. The objectives of this review include the systematic collection of evidence from existing reviews and rural road impact studies in low- and middle-income countries. By doing so, the review aims to answer the following sub-questions:

1. What are the conditions, and what type of rural road interventions, are most likely to have a positive, or minimal, impact on poverty reduction and resilience in the local population?
2. What is the likely range and scale of impact for different interventions?
3. What is the most appropriate theory of change of rural road impacts that can assist with planning rural road interventions?

This brief is designed to provide an overview of the key evidence identified in the systematic review and to assist policy makers and researchers in assessing that evidence. As the evidence is deeply contextual and this brief provides an overview, it is not designed to provide advice on which interventions are more or less appropriate in any given particular context.

SUMMARY CONCLUSIONS

This systematic review has been able to establish that the expansion of the rural road network has a positive impact on poverty reduction for the rural areas served. The evidence has provided a strong direct relationship between rural transport infrastructure and reducing transport costs and increasing traffic volumes. In addition, there is strong evidence that over the medium to long term, this leads to an increase in employment, income and consumption, and expansion of the agricultural sector. There is evidence to suggest that the health impacts are generally positive, but increased connectivity is also shown to lead to an increase in communicable diseases. With respect to marketing activity, the evidence base presents a mixed conclusion whereby communities closer to the transport improvement benefit but negative impacts are found in distant areas. There is a weak evidence base with regard to educational impacts, with no clear conclusions established.

Analysis has shown that some of the strongest impacts are experienced in countries with low road densities. Some studies indicate that providing feeder roads (basic access roads) provides greater social welfare gains than higher standard gravel or paved roads.

This systematic review has explored a 'theory of change' using the evidence base identified. This defines the linkages between outputs, outcomes and impacts and also highlights research gaps. However, due to the heterogeneity of the research and data outputs, it was not possible to establish the range and scale of outcomes and impacts.

Studies included in this review used a range of methodologies to assess the impact of extending the rural road network. This systematic review has revealed that researchers employ a great variety of methodologies. These range from simple comparisons and cross-sectional analysis to multistage

modelling. The choice of methodological approach may be a possible factor in the direction of findings, with complex modelling approaches leaning towards finding stronger benefits, particularly for identifying the effects on incomes and poverty reduction. However there is a worry that many of the econometric approaches are not transparent, and may be inaccessible to average policy maker. In addition, not enough studies provided a sufficiently long-term measurement of impacts to test the 'resilience' of local communities in their ability to absorb benefits over time and after periods of external shocks.

SYSTEMATIC REVIEW APPROACH

A structured search strategy was developed based on the principles of systematic reviews to identify relevant literature. This involved the development of a set of key words and filters most relevant to the review question. Sixty-one sources were searched, including traditional bibliographic databases, organisational websites, online book catalogues, dissertation listings and sources of grey literature. A total of approximately 5,500 separate research documents were found from the initial search. These references were then screened on title and abstract and 120 references were judged to be qualified for screening, data extraction and quality appraisal of full reports. Of these, a total of 56 studies were accepted for analysis in this systematic review.

The review then adopted a numerical narrative approach to the synthesis of findings - each study was analysed in depth with data recorded on a data extraction sheet detailing the specific attributes and findings of the study. This provided an overall framework for the studies to be considered holistically.

STUDIES INCLUDED IN THE REVIEW

The studies included in the review adopted a range of different approaches, data collection procedures and methodologies.

APPROACHES

The studies can be grouped into the following three general approaches:

- **Historical impact of road investment relating to specific roads and locations** - this may include a specific donor programme. In most instances, repeated specific surveys were commissioned (19 studies fall under this category).
- **Marginal impact of road investment based on historical national and regional data** - on-going national surveys such as the Living Standards Measurement Surveys are used to identify the impact of national road programmes. The International Food Policy Research Institute (IFPRI) has carried out a number of studies with this approach (9 studies fall under this category).
- **Cross-sectional accessibility models and comparisons** - this approach uses data from both study-specific surveys and from national surveys. Because data are collected at the same, time there is no historical analysis (28 studies).

METHODS OF ANALYSIS

A range of analysis methodologies have been used:

- **Simple historical, cross-sectional and stratified comparisons** – these provide both qualitative and quantified results.
- **The 'double-difference' approach** - a numerical effect is determined by the formal comparison of 'before and after' and 'with and without' project results. This approach can be incorporated into more complex econometric approaches that may involve the random selection of communities and households for data collection.
- **Simple regression analysis** - this was widely used in the cross-sectional approaches.
- **Multi-stage and more complex forms of econometric modelling**.

GEOGRAPHIC AREAS

The study countries include a wide representation of geographical areas. Sub-Saharan Africa is featured more commonly than any other region, with over 50% of the included references. The East Asia and Pacific region is represented by 12 references (approximately 20% of all the studies). Latin America and the Caribbean and South Asia are represented by five references each (together amounting to approximately 10% of all studies). There are two references from Middle East and North Africa and one reference from Europe and Central Asia.

SUMMARY MAP OF EVIDENCE

In terms of reporting results, the studies were found to be very heterogeneous. Apart from five studies carried out by Fan and colleagues of IFPRI, there were no consistent formats or measures for reporting the different types of outcome. Hence it was not possible to estimate 'average effects' or, in most instances, a 'range of effects'. However, the evidence based on studies judged to be of sound quality offer the following summary findings:

- **Traffic flows:** all five studies reporting data on traffic flows recorded an increase in traffic. However, there was a very wide range of response, ranging from a 312% increase in traffic volumes (over six years) for one study to a 21% increase for another study.
- **Transport costs and tariffs:** nine studies provided data on the change in transport costs, fares and tariffs derived from road improvements. The largest difference in tariffs was the 31-fold ratio in costs (per ton/km) between head-loading and transporting by truck. The range in changes in tariffs as a result of improving existing accessible roads varied from a 50% reduction in tariffs in one case to no change in another, with the lack of response put down to a lack of competition. Marked seasonal changes in transport tariffs were noted for unpaved roads, where tariffs were found to be up to 60% more in the wet season.
- **Income and consumption:** 27 studies investigated the impact of transportation on income and consumption. Of these, 21 (78%) reported significant increases in income and consumption, with the remaining six studies finding no significant change. The largest effects were found in African countries with low road densities; for example one study on Ethiopia found that good access could increase the consumption growth rate by 9% a year while

another study on Uganda found a benefit-cost ratio of 7.16, where spending US$10,000 (2013 prices) on rural roads would lift 261 people out of poverty.

- **Agricultural output:** 12 studies analysed the effects of rural roads on a range of agricultural outputs. A significant increase was found in seven studies; for example improved rural roads were estimated to lead to a 27% increase in output in Ethiopia. However, no significant change in agricultural output was found in three studies.
- **Agricultural inputs, costs and prices:** nine studies analysed the effects of improved accessibility on agricultural inputs, costs and prices. Significant beneficial effects were identified in all the studies, although with substantial variations. For example, a threefold comparative increase in extension services was found in Morocco, while a study in Ethiopia found that fertiliser use increased by 2.5 times between villages with poor and good accessibility. A study in Ghana found that bringing vehicle access closer by 5km would increase farm-gate maize prices by 11.4%; however improving an existing accessible road by the same distance would increase the prices by just 0.08%.
- **Agricultural land values:** four studies examined the effects of accessibility on land values. One study found no effect of improving roads on land values, while three studies found that better accessibility increased land values. For example, there was a 15% increase in land values associated with project roads compared with a control in Nicaragua.
- **Agricultural marketing:** six studies investigated the effects of accessibility on agricultural marketing. Two identified favourable effects of better accessibility on marketing (i.e. market frequency and range of goods on sale); two other studies found that communities on adjacent roads that had not been improved would suffer, with a decline in market activity and higher consumer prices. Finally, two studies identified substantial market inefficiencies that were not necessarily to do with road construction.
- **Employment:** 15 studies analysed the effects of accessibility on employment. With the exception of one study (on Honduras), all others found that better access led to much greater non-agricultural employment. This appears to be a key factor in the association between poverty reduction and road investment.
- **Health:** 15 studies investigated the effects of accessibility on health. Twelve identified the beneficial effects of improved accessibility on health outcomes. These included an increase in vaccination rates, attendance at hospitals, use of modern birth attendants and use of latrines, and lower leprosy incidence. However, three studies identified negative effects, principally an increase in HIV and diarrheal E coli infection rates.
- **Education:** Five studies considered the effects of better accessibility on education outcomes. Three found beneficial effects, with increasing school attendance, and greater school choice and school completion rates. However, two studies found no significant effect.

OUTLINE OF THE EVIDENCE

IMPACT OF RURAL ROAD INTERVENTIONS

In respect to the sub-question ‘what are the conditions, and what type of rural road interventions, are most likely to have a positive, or minimal, impact on poverty reduction and resilience in the local population?’**,** the results of the studies indicate a wide range of impacts in a diverse set of countries.

Most of the studies record positive impacts to better accessibility, with a minority recording weak or zero impacts. On balance, it appears that better rural accessibility will:

- positively increase incomes and consumption, reduce poverty, strongly increase traffic, reduce transport costs, increase the use of fertiliser and modern inputs and hence increase agricultural output, strongly increase the opportunity to gain non-agricultural work, increase access to health centres, improve the use of health services, and possibly increase school attendance and completion rates
- increase the risk of spreading infections such as HIV/AIDS and E coli for diarrhoea as well reduce economic activity in nearby communities located on routes that have not received road investment.

The highest positive impacts on poverty and incomes relate to improving accessibility in Ethiopia, Uganda, Tanzania, Madagascar and Peru. All of these countries have very low road densities and low rural access indicator (RAI) scores. In contrast, less impact was identified for Vietnam, Indonesia, Sri Lanka, the Philippines and Thailand, which have higher road densities and higher RAI scores. Hence there is some evidence to suggest that the greatest opportunities for a large impact are where the coverage of the existing road network is poor.

Unfortunately, the studies are very weak in their analysis of different road engineering solutions. None of the studies that investigated the effects of specific road investments or national road programmes examined how individual road length affected impact. However, this issue was covered by the cross-sectional approaches.

In general, the studies offer little guidance as to the standard of road interventions that would maximise income generation and reduce poverty. However, Fan et al. (2004a), on Uganda, suggest that money spent on feeder roads (i.e. basic access roads) would lift three times as many people per shilling out of poverty compared with building higher standard murram (gravel) or tarmac roads. An analysis presented for China (Fan and Chan-Kang, 2004) also suggests that lower-quality roads would be much more effective in reducing poverty than higher-standard ones. However, in both these cases, the function of roads cannot be separated from their engineering design. Escobal (2002) for Peru also explored the effects of improving trails, as well as motorised rural roads. However although a significant effect on incomes was identified for the latter, a positive but non-significant effect was observed for the former.

Unfortunately, there is insufficient evidence in the literature to adequately respond to issues pertaining to ‘resilience’, with particular emphasis on the ability of local beneficiaries to maintain benefits over the long term or to absorb exogenous shocks. The studies have not investigated the impact of the interventions over the long term, and of course, there is difficulty in evaluating the impact of ‘shocks’ with some methodologies, including the double-difference approach.

RANGE AND SCALE OF IMPACTS

Unfortunately, this review has not been able to provide a satisfactory conclusion to the question ‘what is the likely range and scale of impact for different interventions?’ because it was not possible to identify different outcomes sufficiently for different types of intervention in the vast majority of

studies. For improvements in accessibility, or rural road building in general, a very wide range of impacts was observed and the results were not expressed in a uniform way, so it was difficult to present a range or scale of impact. In addition, coupled with the very extreme heterogeneity of the data and findings it was not possible to compare the impacts of different interventions between the studies.

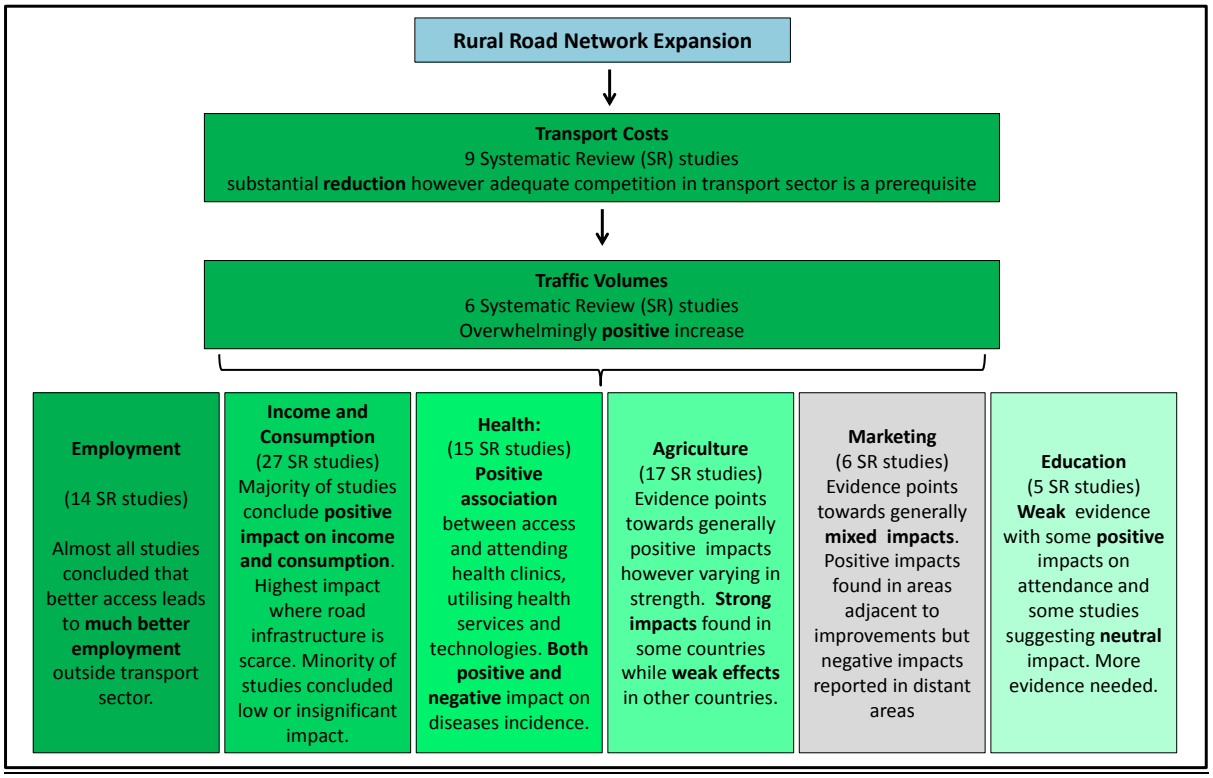
THEORY OF CHANGE

With respect to 'What is the most appropriate theory of change of rural road impacts that can assist with planning rural road interventions?' this review has been able to confirm some of the pre-existing theories based in the existing evidence.

The link between road interventions and transport costs has been established by this review. Road investment is shown to have a direct effect in reducing transport fares and tariffs. However, this is insufficient in itself to provide a strong mechanism of change that can be used for transport planning. Classic economic theory predicts the effect of reduction in transport costs to be an increase in supply, and this has been evidenced by at least five studies in this review. With regard to the longer-term impact on poverty change, the review has found very strong positive impacts on employment, income and consumption, and quite strong positive impacts on health care take-up (but with some negative impacts on disease incidence) and agricultural activity. Mixed conclusions can be reached with respect to marketing. The evidence base for an impact on education is weak.

From these connections, we can establish an appropriate theory of change as presented in the following diagram. The major weakness in the theory of change is the inability to link the causal relationships between the impacts.

Theory of change: Impact of road infrastructure expansion on poverty



RESEARCH GAPS

We have identified a weak evidence base with respect to education and the resilience of local communities as an outcome. In addition there is lack of research on the types of rural transport infrastructure most likely to reduce poverty.

1 BACKGROUND

1.1 THE NEED FOR A BETTER ANALYSIS OF RURAL ROAD IMPACT

A lack of access to basic services is an important characteristic of poverty. It is estimated that 58% of developing country population and 78% of the extreme poor live in rural areas (Olinto et al., 2013) while in total about a billion people live more than 2km from an all-season road. As a result, rural road investment is a significant component of government and aid agency budgets. The World Bank alone spends in the region of US$ 1 billion per year on rural roads; this excludes expenditure on main and secondary roads (World Bank, 2007).

Despite the importance of the topic, there has been some dissatisfaction with the evidence to demonstrate the impact of rural road investment. In 2008, one reviewer came to the conclusion that there were relatively few studies that had been carried out with proper controls and subject to rigorous analysis and statistical testing (van de Walle, 2008).

Although the evidence of impact studies has been broadly supportive of rural road investment, and will, as a result, have encouraged the case for intervention, nevertheless most studies tend to treat the topic as a 'black box', without identifying how, and in what circumstances, rural road investment is likely to have the most, or least, impact. Because of the lack of a consistent analysis, rural road impact studies have probably had little influence on the planning and choice of standards for rural road investment. For example, showing that rural road investment, in general, has an impact on rural development provides little or no guidance on exactly what engineering measures to take. In practice, the measures chosen tend to be driven by a combination of available budgets, rules of thumb, crude prioritisation indices and simple transport user cost analysis. In order to better inform decision makers, we need to develop a more appropriate planning methodology from the evidence of impact studies through an appropriate theory of change.

This review takes an in-depth look at the evidence and circumstances of the impact of rural road investment. Methodology, change in road condition and data analysis issues are reviewed. A synthesis of findings is presented covering effects on:

- traffic and transport;
- incomes, consumption and poverty reduction;
- agricultural output, marketing and land values;
- employment;
- health; and
- education.

1.2 INTERVENTION

Rural road investment can take many forms: spot improvements to an existing track (including the construction of small bridges and culverts), the construction or upgrading of an earth road, the new construction of a gravel road, or the construction of a bitumen sealed road. In most instances, road impact studies usually relate to the upgrading of an earth road to gravel standard or the

rehabilitation of a gravel road. Sometimes completely new vehicle access will be established. The condition of the road or track prior to the investment can be very variable, although the final engineering standards of newly constructed gravel roads might be relatively similar. From the users' point of view, the key issues are passability during the wet season and the roughness of the road (measured according to the international roughness index, IRI), which affect vehicle operating costs and transport fares and tariffs.

Earth and gravel roads deteriorate quickly with traffic and rainfall and they need frequent maintenance, such as drainage maintenance, surface grading and pothole filling. Unfortunately, there is no precise distinction between 'investment' and 'maintenance'. However, where comparisons are made between intervention and non-intervention roads, it is usually assumed that routine maintenance will be carried out on both categories of roads.

This systematic review has covered studies of all types of road investment, provided that the intervention studies cover a significant change in rural accessibility and that socio-economic data relating to the rural population is analysed. So studies relating to the impact of maintenance activity, where there appears to be little impact on accessibility, have been omitted.

1.3 THEORY OF CHANGE

The process of moving from initial rural road investment to the final impact on the livelihoods of the local population is thought to be relatively complex and not fully understood. The process, as articulated through a 'theory of change' may be broken down as listed below; however, it should be remembered that the outcomes are of variable magnitude and have variable time lags.

The initial construction process: the direct impact of construction may have a slightly disruptive effect on traffic flows as the road is being built. There will also be negative local effects on water courses, the establishment of borrow pits, disposal of spoil and the movement of materials. However, the main effects on livelihoods will arise from local employment during construction. These will obviously be greater if labour-intensive or labour-based methods of construction are employed. Incomes can result from employment, letting out rooms and providing food for construction staff. Sometimes significant incomes can be generated for the local population. It has frequently been observed that household ownership of assets such as bicycles can result.

Change in transport costs, fares and tariffs: the main benefits from road investment are believed to result from an underlying change in transport costs; this may be from reduced travel times, a change in transport mode (e.g. from head-loading to vehicle transport) or from reduced vehicle operating costs arising from reduced road roughness or fewer delays or diversions because roads are seasonally closed or boggy. The Highway Development and Management Model (HDM4) provides a framework for predicting how underlying transport costs will change with road investment. The absolute change in transport costs will depend upon the difference in road condition, the length of the road improvement (the size of the impact will vary along the length of the road) and the possibility of a change in transport mode – for example, head-loading can cost, per ton/km, 30 times more than using a truck. Although the final condition of a typical gravel road construction may be fairly uniform across the world, the initial condition of the road or track before being improved will

be extremely variable. Lastly, the extent to which changes in underlying transport costs are passed on to customers will also vary because of the competitive nature of transport services.

Changes in the reliability of transport services: improved roads lead to improvement in the reliability of access and transport services; there may be far less chance of a road becoming impassable. This effect may not be captured by an analysis of transport costs. Improved resilience of the transport system may have wide-ranging effects on livelihoods, and may lead to a greater chance of employment outside the area.

Changes in transport volumes: often the most obvious change following road investment is an increase in traffic volumes. If underlying costs are cheaper and journeys quicker, there is often a strong incentive for transporters to offer more services and for the local population to travel more. In time, there may be a response in other areas of economic activity, which will also increase traffic volumes.

Changes in agricultural activity and produce marketing: if transport costs are reduced, transport channels more reliable and market prices in the towns remain broadly constant, then one may expect farm-gate prices to rise. Farmers are likely to respond by increasing agricultural production for external sale. However, these effects may be relatively small for small-scale road improvements. For example, it was estimated that, in Ghana, a 5 km improvement of an existing accessible vehicle track might only increase farm-gate prices by 0.08% for maize. However, the effect might be a hundredfold greater if a change in transport is involved. The extent to which farmers can respond to changes in farm-gate prices depends upon the gross elasticities of agricultural supply. These in turn will be dependent upon the availability of suitable agricultural land, labour credit and external markets.

Changes in non-agricultural activity: it is very common for villages and small towns to respond to increased passing traffic by increasing the selling of produce and services, such as shops, hairdressing, shoe repairs, mobile phone services and wood and metal working.

Changes in the quality and availability of government, NGO and extension services: improved roads can lead to improvements in the availability of external services. External organisations are unlikely to settle in locations that have unreliable access. They will be far more willing to locate in areas that have all-year-round vehicle access.

Changes in health and education outcomes: there is evidence to suggest that better access will lead to better supervision of schools and hence better educational outcomes. The same is likely to be true for health outcomes. Women frequently suggest that the biggest perceived benefit to them from improved roads is a better chance of getting to a health centre or hospital in times of an emergency, most obviously during childbirth. It can be a matter of life or death.

Possible adverse effects: beside possible environmental effects due to road construction, other adverse effects may be an increase in road accidents with more and faster traffic (accidents may also fall if there is better design), a possible increase in crime as more outsiders visit the area, an increase in prostitution (most likely in towns and around work camps) and an increase in the incidence of HIV/AIDS.

Changes in household incomes, expenditures, assets and livelihoods: the final impact of road investment on the local communities will be on incomes, expenditures, assets and livelihoods. Obviously if transport fares and tariffs fall and agricultural and non-agricultural activity increases, this will increase available expenditure and cash incomes which can be spent on other things. Livelihoods may also be improved by increased social mobility and improved education and health, through increasing social and physical capital.

1.4 OBJECTIVES

The objectives of this systematic review therefore include the systematic collection of evidence from existing reviews and rural road impact studies in low- and middle-income countries. By doing so, the review has attempted to answer the following questions.

- What are the conditions, and what type of rural road interventions, are most likely to have a positive, or minimal, impact on poverty reduction and resilience in the local population?
- What is the likely range and scale of impact for different interventions?
- What is the most appropriate theory of change of rural road impacts that can assist with planning rural road interventions?

In addition to the above conclusions, the strengths and limitations of the systematic review are analysed and recommendations provided for further research to advance the knowledge base and to offer advice on transferring it into practice.

2 OBJECTIVES

2.1 SYSTEMATIC REVIEW QUESTION

It is important to define the objective of the systematic review and identify the question:

> Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so, how, and if not, why not?

To conduct this analysis, the Review Team has adopted the PICO system(Richardson et al., 1995) to highlight the following most pertinent components:

- **Population:** The research question focuses on rural societies as the beneficiaries of the intervention. Although the question does not differentiate between the respective societies' levels of income, the relatively advanced status of rural development and rural incomes in developed nations, vis-à-vis developing nations, informs the focus mainly on developing countries. Therefore, the population of the systematic review question is **communities residing in rural areas of developing countries**.
- **Intervention:** The term 'extension of rural road network' has a clear focus on infrastructure, and in particular, road infrastructure in rural areas. However, 'extension' can be defined as an intervention that may improve the efficiency or reach of the rural roads; this includes bridges, which allow a road to be passable and functional. In this respect, the intervention in this systematic review is defined as **rural transport infrastructure**. However, as will be revealed, many research studies investigate the impact of a hypothetical expansion of the transport infrastructure, such as road density, travel time and accessibility.
- **Comparators:** In the most simplistic case, the comparators are 'with' intervention and 'without' intervention. However, 'extension' of the intervention can be applied to include 'more' or 'less' of the intervention. Therefore the comparators of this review include '**with and without'**, and '**more or less'**.
- **Outcomes:** The question includes the term 'poverty reduction and resilience'. Poverty can be further elaborated to include **income, consumption, production, education, health, social well-being** etc. Resilience, in this context is interpreted as the ability to maintain levels of poverty reduction over time and in the face of exogenous shocks, including climatic, economic and man-made.

2.2 PREVIOUS SYSTEMATIC REVIEWS

Our extensive research in this area revealed one previous systematic review broadly related to this topic: *What is the impact of infrastructure investment in roads, electricity and irrigation on agricultural productivity* (Knox et al., 2013).

This systematic review has some similarities in that 'roads' is included as an intervention and the population term 'agricultural' is broadly similar to 'communities residing in rural areas of developing countries'. However, the Knox et al. study does not exclusively focus on rural transport and considers a wider definition of interventions (including electricity and irrigation) and less depth into the transport sector. The study identified 47 relevant studies, of which 27 were relevant to the transport sector. Thus this systematic review is designed to capture more transport-related papers.

Additionally, the Knox et al. review investigated changes in agricultural productivity – this has a narrower outcome measure than this systematic review, which includes income, consumption, education, health and social well-being.

Another systematic review was picked up in the literature search: *Systematic review of barriers to surgical care in low income and middle income countries* (Grimes et al., 2011). This study is less relevant as it examines the qualitative literature on access to surgical care, in which distance to roads was one of the many study findings. Therefore, there was a significant difference with regard to the study outcome and minor similarity in the study's 'intervention'.

3 METHODS AND RESULTS OF THE SEARCH

3.1 SEARCH STRATEGY

The three main elements of the search strategy A, B and C (see Appendix 2) were used to capture references on the three concepts, 'rural', 'road' and 'poverty reduction OR resilience'. For the purposes of the search, it was thought unnecessary to make 'resilience' a separate concept from 'poverty reduction', but instead to group it with other terms denoting some sort of effect of an extension of the rural road network. Set D limited the search further to 'developing countries' only, year of publication (from 1980 to 2014) and language (English only).

In those bibliographic databases where it was possible, the four sets were combined as A+B+C+D[1] to arrive at the list of references screened for relevance. Where possible, the title (TI), abstract (AB) and any descriptor (DE) fields were searched. Where field searching was not possible or practical, then 'all text' of each record was searched.

The results of searching for A+B+C+D in each resource were screened in those cases where this had produced a manageable number of hits (defined as less than 500). Where A+B+C+D produced an unmanageable number of hits (defined as 500 or more), two further sets were added to reduce the search results. These were, firstly, A+B+C+D+E, and secondly, A+B+C+D+F. The purpose of Set E was to extract those references which definitely contained the word 'road'. It was thought that in most cases, relevant studies would include this word. The purpose of Set F was to find those references which did not necessarily mention the word 'road', but were still potentially relevant because they addressed infrastructure investment in general. From earlier study of the literature, it was known that discussions of general infrastructure investment sometimes included useful insight on road networks.

Where possible, the search was limited to developing countries by using a field-specific search, for example by combining the search with 'AND DE=developing countr*'. Although it was envisaged that in some cases it might be necessary to search for the full list of developing countries in the title, abstract and descriptor fields, in practice this was not done. In a few cases where it was difficult or impossible to isolate developing countries literature using descriptor or subject fields, it also proved problematic to search for the full list of countries by name (including all possible synonyms). In these cases, the search was left unlimited, potentially containing some studies not concerned with developing countries.

In some databases, websites or other resources containing a smaller amount of relevant literature, Sets C and/or Set D were not used. Instead, a simple 'A and B' search was used to gather a small number of potentially relevant resources on 'rural roads' for screening. C was not used in cases where its use would narrow the search so much that potentially useful

[1] + here refers to the Boolean function AND.

studies might have been lost. That is, although in a few cases the results of the A+B+C+D search was zero, the search was broadened to simply A+B as it was judged that the database might nevertheless contain a few relevant items which would otherwise not be captured.

A full list of the 61 resources searched can be found in Appendix 3.

Approximately of 5,500 references were found by the searches. These included traditional bibliographic databases, organisation websites, online book catalogues, dissertation listings and sources of grey literature. Detailed notes on the searching process were maintained and the results are summarized in Appendix 3.

3.2 SCREENING

SCREENING AT TITLE AND ABSTRACT

In order to screen the list of approximately[2] 5,500 references and identify the most relevant documents to read and analyse on full report, inclusion criteria were established based on the title of the document, the contents of the abstract and background information on the document. The following inclusion criteria were included:

- **Language:** studies presented in English were considered.
- **Country:** material relating to developing countries was included. This was defined according the World Bank Atlas definition: a GNI per capita of less than $12,616 in 2012, which includes both low- and middle-income countries (LMIC).
- **Geography:** studies relating exclusively or predominantly to rural areas were included. So, for example, studies relating exclusively to urban areas were excluded.
- **Interventions:** studies relating to the extension of, or significant longer-term improvement to the rural road network (including bridges) were included. So, for example, studies relating to improved rural transport infrastructure including the upgrading of roads or tracks were included. However, studies relating to the improvement of urban transport or the basic maintenance of the network were excluded. Similarly, studies relating to transport services were excluded unless they were associated with an improvement of the rural road network. Studies of secondary or main roads were included if the analysis of effect was rural-based. Additionally, studies which measured an improvement in outcomes that were associated with rural transport, such as improved accessibility or travel time, were included.
- **Comparators:** the studies had to make, or draw on, comparisons of socio-economic data relating to: (i) 'before and after' a road investment; (ii) 'with and without' a road investment; (iii) areas with different degrees of accessibility; or (iv) some combination of the above.

[2] Two result listings produced estimated results. See Appendix 3 for more details.

- **Methodology:** the studies had to include either pre- and post-evaluation studies of road investments, statistical analysis of road programmes, geographic studies and modelling of areas with different degrees of accessibility, or studies employing qualitative techniques such as interviews and focus groups. In addition, the studies were required to draw on data (quantitative or qualitative) from a sample of surveys pertinent to the geography of the intervention's beneficiary population – this included study-specific surveys, surveys from national databases, or data extracted from other studies or institutions.
- **Outcomes:** the studies had to directly measure changes in poverty or provide significant indicators related to poverty, including income, consumption, production, education, health or social well-being. Examples of outcome measures included cash incomes, food consumption, household expenditures, employment, agricultural output, produce sales, agricultural prices, agricultural inputs and use of technology, household assets, transport fares and tariffs, journey frequencies (for example to work, markets, clinics and schools), educational attainment, and infant and maternal mortality. Studies primarily relating to the incidence of road accidents were not included. It was felt that the study could not adequately cover this topic, which involves specialist knowledge and a detailed analysis of road engineering design and traffic engineering issues.

After screening the list of references on title and abstract based on the above inclusion criteria, a total of 120 references were identified for screening on full report.

SCREENING, DATA EXTRACTION AND QUALITY APPRAISAL OF FULL REPORTS

All references that passed the first round of screening of title and abstract were analysed in detail by reading the full text. The criteria applied at this stage included re-screening based on the scope of the review (see above) and judging the study's methodological suitability for answering the review questions.

Each text was read by the lead reviewer[3] and one other. A data sheet was developed covering the main characteristics of the study including study background detail, methodologies employed, types of primary and secondary data applied, types of interventions tested and the range of outcomes measured.

The decision on the study's classification was made during sessions involving all the reviewers, and a unanimous verdict was sought. In the absence of unanimity, the final decision rested with the lead reviewer.[3]

Based on the findings of the data extraction process, every study was classified accordingly:

- **INCLUDE: quantitatively suitable** - studies that specifically targeted the subject of this systematic review and collected primary data or approved national data sets of adequate sample sizes and applied a methodology based on a double-difference

[3] Except where he was author of the paper under consideration.

approach and/or regression based modelling to explain causality with endogeneity sufficiently accounted for. Baseline reconstructions were satisfactory. In addition, studies that tested for correlation (e.g. correlation coefficient, chi squared tests) have been included, but the shortfalls of not fully explaining causality have been considered. A total of 52 studies fell into this category.

- **INCLUDE: qualitatively suitable** - studies that drew on primary data but applied strictly qualitative methodology in a robust manner using the appropriate format of analysis, including semi–structured narrative interviews and/or participatory methods, correct identification of the baseline population, correct sampling, and suitable collection and interpretation of narrative data, with the weaknesses of the selected methodology accounted for. In addition, the study had to specifically target the subject of this review. Four studies fell into this category.
- **EXCLUDE: not meeting the review criteria** – studies that did not meet the review criteria for language, geography, interventions, comparators and outcomes and whether they were based on the PICO criteria as outlined in Chapter 2. A list of these are presented in Appendix 4. A total of 39 studies fell into this category.
- **EXCLUDE:** studies that specifically met the criteria for inclusion in this review, but **exhibited methodological shortfalls.** A list of these are presented in Appendix 4. These studies included at least one of the following biases:
    - poor selection of controls or lack of controls;
    - low samples sizes;
    - unreliable source of data;
    - incorrect hypothesis testing or no statistical testing;
    - clear presence of endogeneity.

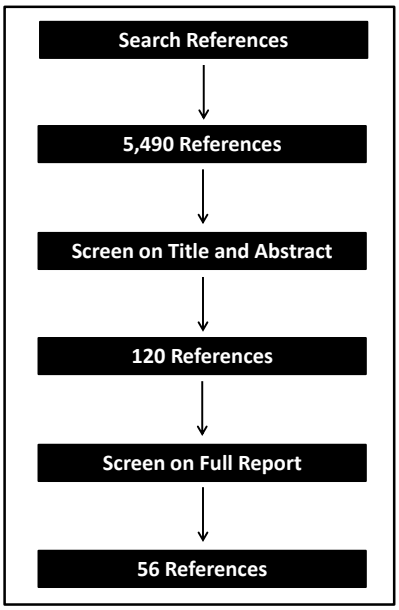
  Twenty studies fell into this category.

- **EXCLUDE: earlier linked studies** where the majority of data are also recorded in a later study. The earlier studies are therefore regarded as duplicates. A list of these is presented in Appendix 4. Five studies fell into this category.

RESULTS OF THE SEARCH AND SCREENING

The diagram on the right presents the search methodology and the volume of references searched, screened on title and abstract, and screened on full report.

In summary, 5,490 references were identified after searching through the 61 search portals. These references were then screened on title and abstract. After this process, 4,972 references were excluded (97.7% of identified references) and 120 references (2.4% of identified references) were judged to be qualified for screening and quality appraisal of full reports.



Of these 120 references, a total of 52 studies were classified as 'quantitatively suitable' and four as 'qualitatively suitable'. Therefore a total of 56 studies have been analysed in this systematic review.

A total of 64 studies were excluded; these included studies that did not meet the review criteria (39 studies), studies exhibiting methodological shortfalls in respect to the requirements of this systematic review (20 studies) and linked studies (5 studies).

3.3 METHODS OF SYNTHESIS

This systematic review has adopted the numerical narrative approach. Each study has been analysed in depth, with data extracted following development of a data extraction form which included:

- The study's background details, such as study name, researchers, dates and source/publication organisation;
- the adopted methodology, surveying methods and sample sizes;
- the value and unit of the intervention measurement, otherwise known as the independent variable, such as kilometre of road developed, accessibility index, metres of bridge;
- the value and independent variable of the dependent variable measurement or outcomes such as percentage increase income, incidence of HIV infections;
- causal pathways and relationships;
- significant test results;
- overall opinions of the study author(s); and
- any other noteworthy characteristics of the study.

This process was conducted by the lead reviewer[4] and at least one other reviewer. The completed data extraction sheet provided an overall framework for the studies to be considered holistically. Studies were then disaggregated with respect to their impact on:

- traffic and transport;
- income and consumption;
- agriculture and market change;
- employment;
- health; and
- education.

[4] Unless he was one of the authors.

The studies identified for inclusion in the review were heterogeneous in terms of the type of data, methodologies used and outcomes reported. It was therefore decided that employing statistical meta-analysis would not be appropriate or adequately capture and explain the results. Instead, a numerical narrative approach to synthesise the findings and explore their direction of effects has been used.

We achieved this by extracting relevant outcomes for each group (control and intervention). Where available, the effects of the intervention and statistical significance are reported in the review. These have been presented in the same form as they were reported in individual studies. Presenting the findings in this way has allowed the results from these outcomes to be interpreted as either 'having an impact' – i.e. the outcome favours the intervention – or 'not having an impact' – the outcome does not favour the intervention. Thus we are able to make summary statements about the overall evidence base for each outcome (e.g. transport, health, agriculture).

4 DESCRIPTION OF THE EVIDENCE

This chapter includes a description of the 56 studies included in the review. This includes a background of the geographical areas that the studies covered, the date of publication, the overall objectives of the studies, the principal methodologies adopted, the commonly identified changes in in road infrastructure and general issues of data analysis.

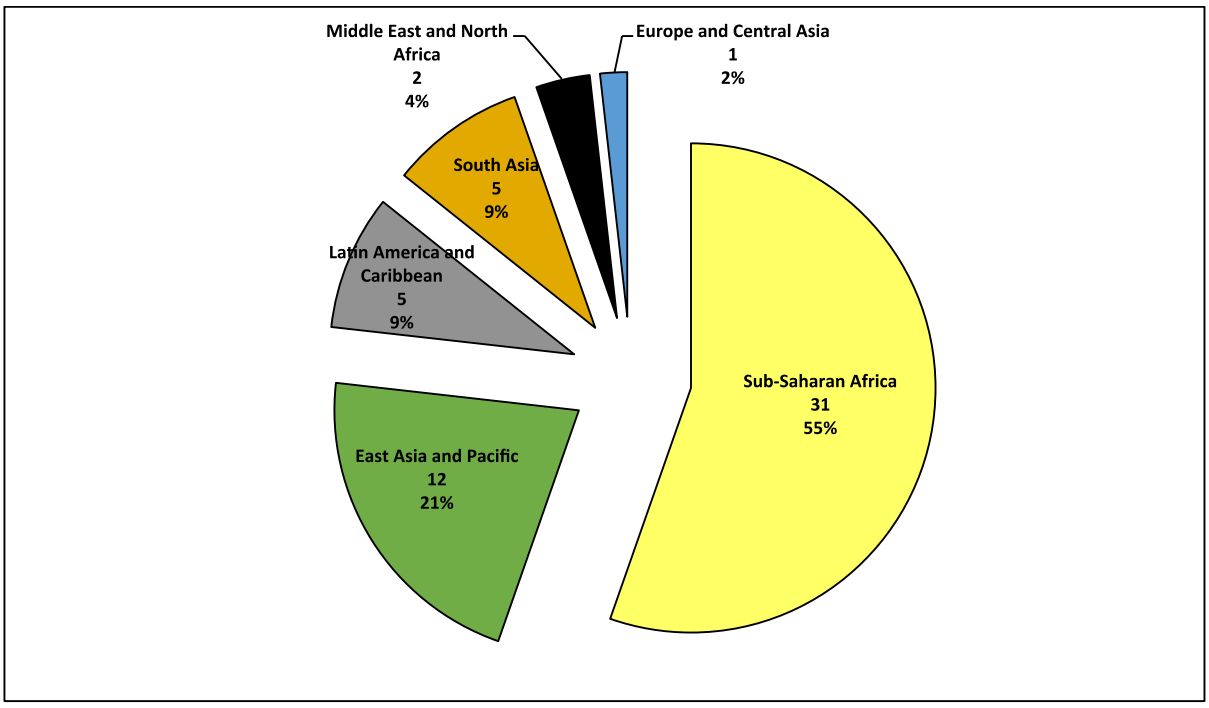
4.1 TYPES OF STUDIES

GEOGRAPHICAL AREAS

The study countries included a wide range of geographical, as shown in Figure 4.1. Sub-Saharan Africa features more commonly than any other region, with over 50% of the included references. East Asia and the Pacific is represented by twelve references (approximately 20% of all studies). Latin America and the Caribbean and South Asia are represented by five references each (approximately 10% of all studies). There are two references from the Middle East and North Africa and one reference from Europe and Central Asia.

Regarding individual countries, Ethiopia and Uganda are the most commonly featured, with five references each. Kenya, Tanzania, Ghana, Vietnam and Indonesia are featured in three studies. The two most populous countries in the world, China and India, are only included in one and two references respectively.

Figure 4.1: Geographic representation of references in systematic review

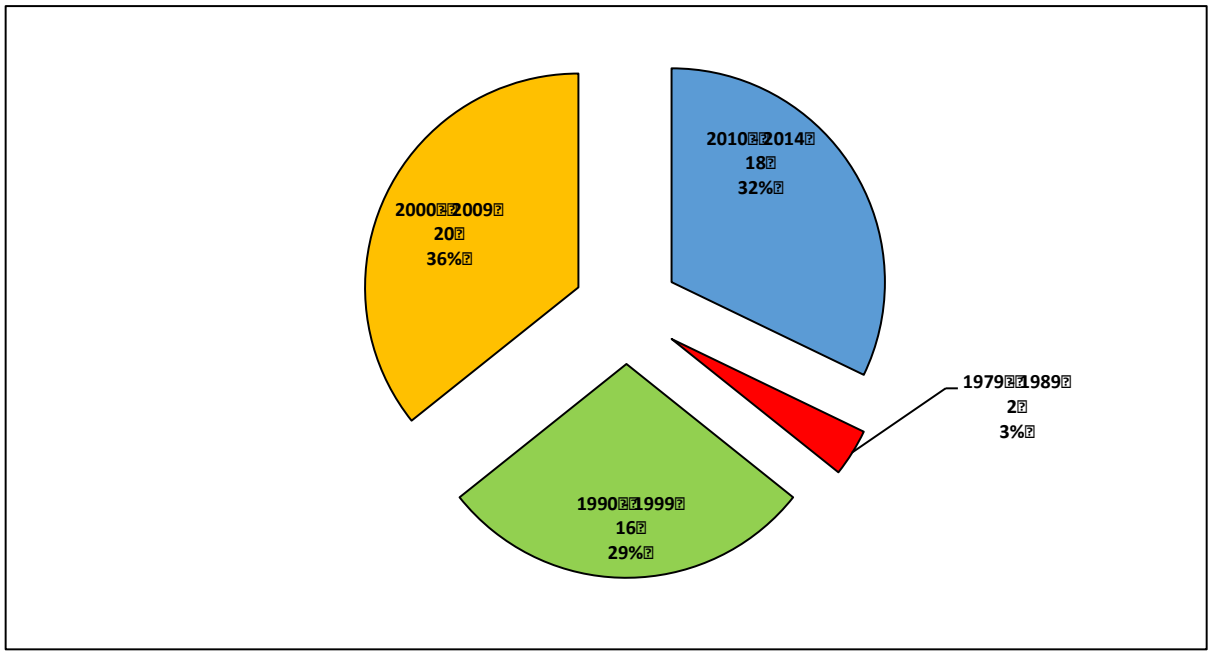


YEAR OF PUBLICATION

What is the evidence supporting the technology selection for low-volume, rural roads in low-income countries?

The year of publication is presented in Figure 4.2 in order to offer an analysis of the relative age of the studies. The analysis shows that there is a relatively wide spread of publication dates. However the concentration of studies has intensified over time thus exhibiting a pattern of increasing interest in the subject area. Approximately 36% and 32% of the studies were published between 2000 to 2009 and 2010 to 2014, respectively. In contrast only 3% of studies were published between 1979 and 1989. A total of 29% of the studies were published in the 1990s.

Figure 4.2: Publication date of references in systematic review



STUDY OBJECTIVES AND METHODS OF DATA COLLECTION

Different approaches were employed by the selected studies to establish impact. The study objectives and data sources are given in Table 4.1; each category cell reference is labelled (A1 to C4), together with the number of studies that fit into the different categories. These are given in brackets.

Table 4.1: Study objectives and methods of data collection

Study objective	Specific study survey		On-going national survey	
	Single survey	Repeat	One year	Multiple

		surveys		years
Historical impact of road investment relating to specific roads and locations	A1 (4)	A2 (12)	A3 (1)	A4 (2)
Marginal impact of road investment based on historical national and regional data	B1	B2	B3	B4 (9)
Cross-sectional accessibility models and comparisons	C1 (14)	C2 (4)	C3 (8)	C4 (2)

.

The study objectives identified were:

- **Historical impact of road investment relating to specific roads and locations**, often relating to a specific donor programme. Time-series and cross-sectional data were analysed using this approach, and in most instances, specific repeated surveys were commissioned.
- **Marginal impact of national road investment programmes derived from an analysis of historical national and regional data**. On-going national surveys such as the Living Standards Measurement Surveys were used to identify impact. IFPRI has carried out a number of studies using this approach.
- **Cross-sectional accessibility models and comparisons**. This approach uses data from both study-specific surveys and from national surveys. Variations of welfare outcomes are analysed and compared with variations in different indicators of accessibility.

4.2 PRINCIPLE METHODOLOGIES

In this section, the principle methodologies provided by the included studies are discussed. They include simple historic and geographical comparisons, the double- difference approach, models which identify the impact of interventions and models which employ longitudinal and cross-sectional data. An important consideration is that the methodologies are not mutually exclusive.

SIMPLE HISTORIC AND GEOGRAPHICAL COMPARISONS

Traditionally road impact was identified through looking at 'before and after' changes, or making comparisons at the same time on a 'with and without' basis, comparing a road investment with a control where no intervention had taken place.

In the selected studies, simple comparisons were used to provide important qualitative insights on the effect of roads, particularly for the studies Hettige (2006, covering Indonesia, Sri Lanka and the Philippines), Porter (1995, 1997, Nigeria) and Levy et al. (1996, Morocco). The studies by Porter used both time series and cross-sectional data, but Hettige and Levy et al. (1996) used participant recall to determine the situation before the road investments were made.

The obvious disadvantage of these approaches is that the simple 'before and after' approach will not pick up general trends over time. Similarly the intervention and control approach may provide distorted results if the control locations have different characteristics from the investment case.

THE DOUBLE-DIFFERENCE APPROACH

The double-difference approach to identifying impact formally combines an analysis of 'before and after' with 'with and without' cases, as described in Table 4.2.

Table 4.2: Double-difference approach

Characteristics		Cross-sectional comparison	
		With (project)	Without (controls)
Longitudinal Comparison	Before	Communities and households situated directly on the road.	Communities and households situated outside the road corridor/zone of influence.
	After	Communities and households situated directly on the road.	Communities and households situated outside the road corridor/zone of influence.

The first stage of the monitoring is the cross-sectional comparison of randomly selected communities and households, analysed as a baseline or benchmark before road improvements (the single-difference approach). This is followed up several years after the intervention with a longitudinal with/without comparison.

The net effect is calculated by subtracting the 'After minus Before' difference for the With (Project) case, from the same differences in the Without (Control) case. The approach is incorporated into some econometric approaches.

The double-difference approach is not mutually exclusive with the econometric methodologies (see below), and in addition, the approach should include significance testing as standard procedure. In this respect, the double-difference approach is among the most

important methods with respect to this systematic review as it allows for an unbiased quantitative analysis.

MODELS TO IDENTIFY IMPACT OF SPECIFIC ROAD INVESTMENTS

A range of econometric approaches has been adopted to identify the impact of specific road investments (overall 19 studies). Chen et al. (2008) for China, Lokshin and Yemtsov (2005) for Georgia, Mu and Van de Walle (2007) for Vietnam, and Orbicon and Goss Gilroy (2010) for Nicaragua, all adopt the double-difference approach. In these cases, propensity score matching is carried out to ensure that the controls reliably match the project cases.

To highlight one example, in an analysis of a 15-year longitudinal data set for Ethiopia, Dercon et al. (2012) used an empirical growth model whereby year-by-year differences in per capita consumption were related to a range of factors, including access to an all-weather road. To control for household heterogeneity, the model included household fixed effects. Similarly, Khandker and Koolwal (2011), for Bangladesh, used a dynamic panel model whereby household outcomes were dependent on a lagged outcome of the previous year together with the project's status. A generalised method of moments (GMM) approach and a fixed-effects approach were adopted.

To identify the impact in Sierra Leone, Casaburi et al. (2013), a regression discontinuity design (RDD) approach was adopted, whereby for a road programme, a comparison was made between roads 'just above' and 'just below' the cut-off for rehabilitation.

Airey and Cundill (1998) used cross-sectional regression analysis relating to different survey years to explore travel behaviour in Kenya, while NORC (2013) adopted an integrated road network model for the whole of Honduras to assess the impact of the road investment programme on average travel behaviour, employment and incomes, using regression analysis.

MODELS TO IDENTIFY THE MARGINAL IMPACT OF ROAD INVESTMENT USING TIME-SERIES NATIONAL AND REGIONAL DATA

Nine studies used national, regional and time-series data. For example, Fan and colleagues from IFPRI have carried out a number of studies using multi-equation models (simultaneous, two-stage or recursive modelling) to determine the proportion of the rural population in poverty, labour productivity and GDP per head. The have investigated a range of different forms of public expenditure, including agricultural R&D, education and literacy, power generation, irrigation, telephone coverage and rural roads. The overall approach is designed to capture the multiple pathways through which infrastructure influences income (Fan, et al., 1999, for India; Fan and Chan-Kang, 2004, for China; Fan et al., 2004a, for Uganda; Fan et al., 2008, for Thailand).

For Nepal, Dillon et al. (2011) adopted two parallel approaches to identifying the impact of rural infrastructure and extension services, one based on land values as adopted by Jacoby (2000), while the second, based on panel data, was similar to the consumption growth

model of Dercon et al. (2012) . Travel time was the key accessibility variable used in the analysis.

Mogues et al. (2008) adopted a three stage analysis for Ethiopia, firstly relating household expenditure to access to a range of public services, then estimating the effect of public expenditure on services and infrastructure to the poor; in the last stage, the results of the earlier stages were combined to determine the effects of an increase in per capita expenditure on household consumption.

Using national household data for Laos in 1997/8 and 2002/3, Warr (2005) undertook two separate cross-sectional regression analyses relating real per capita income to a range of household, community and provincial dummy variables together with a road accessibility class. Finally, the results of the two analyses were compared and tests were undertaken to see whether there was an endogenous placement problem. For example a cross-sectional correlation between road infrastructure and household incomes may not indicate that the infrastructure caused better economic performance but the reverse (i.e. locations with higher household incomes generated an increase in the provision of infrastructure). This may be overcome, through various statistical techniques, by analysing the effects over time.

As with the popular approach to identify impact for specific investments, Cuong (2011), for Vietnam, used the double-difference approach together with propensity score matching to identify the marginal impact of expenditure on rural roads.

Ruijs et al. (2004) developed a multi-period spatial price equilibrium model to analyse food marketing for 12 regional markets in Burkina Faso. Estimation of parameters was based on a wide range of data. In the model, prices were endogenously predicted, and the differences between producer and consumer prices were equal to the transport, storage and transaction costs. In the model, transport costs varied between wet and dry seasons, paved and unpaved roads and busy and less busy roads (busy roads were cheaper). The model predicted the prices and quantities transported for each regional market and for each season.

CROSS-SECTIONAL ACCESSIBILITY MODELS AND COMPARISONS

Cross-sectional accessibility models, which were applied by 28 studies, are a popular way to determine the influence of accessibility on a range of welfare indicators, including income, agricultural practice and health and medical risks and practices. The approach does not need to rely on time-series data. The assumption is that the effects of investment, over time, settle into a stable equilibrium. Most cross-sectional approaches involve regression models that examine the effect of distance, time or travel costs on a chosen indicator, although sometimes stratified comparisons are also used. One disadvantage of the approach is that it cannot pick up the short-term benefits of temporary increases in employment and expenditure in the local area while the road is under construction.

In assessing the impact of public investment in Tanzania, Fan et al. (2005) related household income and poverty to a range of household and community characteristics. To identify the effect of rural roads, the 'distance to a public transportation facility' was used. The procedure used probit analysis to analyse the data because many of the variables were binomial in nature, e.g. poverty was defined not in income terms but according to whether a household was above (0) or below (1) the government poverty line.

For Cameroon, Gachassin et al. (2010) carried out a three-stage regression model that related household consumption expenditure (per equivalent adult) to the occupation of the household head and to the distance to the nearest paved road. Owuor et al. (2007) for Kenya, used a probit regression model to determine the probability of chronic poverty; accessibility was determined by the distance to market.

The relationship between agricultural output and accessibility has been explored using a number of cross-sectional models. For example, to determine the effects on agricultural production and marketing In Ghana, Hine et al. (1983 a,b) related agricultural production, practices and marketing to transport costs to district and regional markets. In Nepal, Jacoby (2000) identified the benefits of changes in accessibility through the effects of distance to agricultural markets (measured in walking time) on the value of farm land.

Ahmed and Hossain (1990) in Bangladesh selected a carefully matched sample of 16 villages from a larger survey of 96 villages. Half of the selected villages had good and half had poor accessibility. They then compared the differences. Key differences in income and agriculture were identified.

For Madagascar, Stifel et al. (2003) and later, Jacoby and Minten (2009) identified the impact of accessibility through models of agricultural productivity that related transport costs to a main town with agricultural production and a range of variables, including rice yields, cultivated area, volume of goods moved, earnings and consumption expenditure. Similarly in Ethiopia, Stifel et al. (2012) calculated the willingness-to-pay of different households for transport cost reductions, based on a transport demand curve, taking into account household consumption. Production functions were estimated for different crops at five different levels of remoteness, expressed in terms of travel time and transport costs to a main market in west Ethiopia, where currently the main form of transport was by donkey.

Using GIS data, Dorosh et al. (2010) developed a detailed spatial crop production model for Mozambique and sub-Saharan Africa. The model incorporated demand from urban and rural areas and estimated surpluses and deficits together with data on the road network to estimate the elasticity of crop production with travel time to cities of 100,000 people. Chomitz and Gray (1996) also made use of GIS data for Belize. They adopted a spatial logit model to analyse how agricultural practice was determined by the effects of distance to market (built up from distance to the nearest road, together with different impedance factors for road quality for distance along the road).

Cross-sectional models were used to investigate the relationship between employment and accessibility in Indonesia by Cervero (1992) and later by Olivia and Gibson (2009), and also in

Pakistan by Jamal (1995). Cervero used discriminant analysis while the other two studies modelled household participation in non-farm work using a probit regression model. Olivia and Gibson measure accessibility by distance to the provincial capital, road speed and road type. Jamal used distance to the main market, while Cervero used straight line distance to the regional market or the provincial capital.

Regression analysis was the main method used to analyse the relationship between health outcomes and accessibility (Airey, 1991, Kenya; Al Taiar et al. 2010, Yemen; Buor, 2003, Ghana; Jenkins and Cairncross, 2010, Benin; Wawer et al., 1991 Uganda). Travel time and distance to health facility, to roads and to public transport were the common accessibility measures. McCray (2004, South Africa), adopted an approach based on discrete choice analysis combined with a multinomial logit model, while Eisenberg et al. (2006, Ecuador), used an odds ratio approach, in which villages were classified into distance categories; similarly Wawer et al. (1991) used stratified clusters of types of habitations.

4.3 IDENTIFIED CHANGES IN ROAD CONDITION

If we are to compare and understand the impact of different rural road projects, it is important to have an understanding of the engineering and road planning issues involved. For planning purposes, basic information on the exact nature of the change in condition, the length of the road and measures of transport demand (such as traffic volume and population affected) are essential.

Based on economic theory, conventional road project appraisal identifies the benefits of road investment in terms of the consumers' surplus generated by the project. This is a function of the unit reduction in transport costs per km of road, the length and type of road surfacing and the traffic volume. This transport cost analysis is incorporated into the road planning models, HDM4 and RED (Road Economic Decision model), that are widely used for planning rural roads.

The road investment model HDM4 calculates vehicle operating costs for different road surfaces and different maintenance programmes, based on a measure of road roughness, the International Roughness Index (IRI). Based on engineering and economic relationships, cost-benefit calculations can be carried out to identify when it would be appropriate to resurface or reconstruct a road. To add to the complication, there is often little distinction for unpaved roads between maintenance and investment. For example, an earth road can be kept in very good condition by intensive grading. If no surface maintenance is done, for earth or gravel roads, then roughness will quickly rise and the benefits of much of the investment will be lost.

However, the biggest change in transport costs occurs when a road intervention permits a change in transport mode. In Ghana, it has been calculated that there is over a hundred-fold difference in the change in transport costs between providing new vehicle access so that goods can travel by small and medium trucks rather than by headload, compared with just upgrading an earth to a gravel road. (Hine et al., 1983b).

Unfortunately, the impact studies provide very little systematic information on the engineering and traffic characteristics and the exact change in road condition being assessed, or on subsequent maintenance activity. Only eight studies provided details of individual road lengths being built or improved. Apart from two exceptions (Ahmed, 2010, Kenya; Casaburi et al., 2013, Sierra Leone), little detailed information is provided from road condition surveys, and none of the studies quote IRI road roughness measurements or provide specific traffic survey data showing periods of impassability. Evidence from Tanzania (and drawn from the wider literature) suggests that for many roads in poor condition during the wet season, traffic volumes will fall but often not cease entirely, as many drivers (but not all) prefer not to take the risk of getting bogged down in mud (Ellis and Hine, 1997). Hence impassability is often not very clear cut.

However, there are some estimates of periods of impassability (Cuong, 2011, Vietnam; Levy et al., 1996, Morocco; Warr, 2005, Laos). Casaburi (2013, Sierra Leone) used a road assessment scoring system in the impact analysis; this was based on seven parameters, including culverts, bridges, pavement surface and riding quality. Ahmed (2010, Kenya) provided photographs and descriptions of the road conditions and the improvement measures taken.

For a number of the studies there are occasional references to the road initially being in 'poor condition', but we don't know whether this means that the gravel surface had gone and the road was rough, whether no maintenance had been carried out, whether the road was seasonally impassable, or whether the road structures were missing or needed attention.

Mu and van de Walle (2007, Vietnam) reported that their study covered rehabilitated roads (including previously missing bridges and impassable sections) providing reliable access, as well as covering completely new roads, but in estimating benefits, no distinction was made. Escobal and Ponce (2002, Peru), separately identified the benefits for improving conventional roads and 'non-motorised' roads (animal trails and tracks), and Dercon and Hoddinott (2005, Ethiopia) identified some differences in roads of different quality, i.e. that were accessible by trucks and buses or only by carts, animals and people.

Although road maintenance was not covered in most studies it was discussed in some detail by Ahmed (2006, Kenya), Hettige (2006, Indonesia, Sri Lanka and the Philippines), Levy et al. (1996, Morocco) Orbicon and Goss Gilroy (2010, Nicaragua) and Escobal and Ponce (2002, Peru).

Another issue that needs to be considered is the classification of the network and network length. This is important because network length is one of the primary source of data used to determine the marginal impact of road investment used by the national studies using time-series data. Although cost-benefit ratios were quoted by Fan and colleagues in the IFPRI studies, actual historic expenditures on rural roads were not directly used in the analysis. Road length per worker (or similar measure) or distance to roads (from household surveys), was used instead. In general, starting from a track or a trail, small interventions are often made by local communities to make the route passable, until eventually the route is

legally adopted by the authorities and becomes part of the classified network. In Africa, the unclassified network is often estimated to be as large, or larger than, the classified network, although no accurate data is collected on it. For example, in Kenya the unclassified network was estimated to be 99,000 km compared with the classified network of 62,000 km.[5]

When the road is legally gazetted, it becomes formally part of the network and is included in the statistics. It is also then that the road authorities become formally responsible for maintenance. However, being legally gazetted does not mean that any major intervention has recently taken place. Similarly, although rural road authorities may now be responsible for the road, it also does not mean that the road will be maintained. In fact, in many countries, a large proportion of the formal rural road classified network is not regularly maintained because of a shortage of funds. The roads are also often described in annual reports as being 'unmaintainable', and only some emergency maintenance will take place.

[5] http://www.krb.go.ke/road-network/road-conditions (accessed 14 July 2015)

5 SYNTHESIS OF FINDINGS

Chapter 4 presented a descriptive overview of the included studies. This section presents a synthesis of the studies to answer the review question.

All of the studies included in this section have been judged to be methodologically sound and appropriate for the review question. They are presented according to the most relevant outcomes, which include traffic and transport, income and consumption, agriculture and market change, employment, health and education.

A summary of findings is provided at the end of the chapter, along with some issues pertaining to data analysis. In general, the studies were found to be very heterogeneous in the way they reported results.

In Chapter 6, the synthesis of findings is concluded with respect to the overall objectives of the systematic review.

5.1 TRAFFIC AND TRANSPORT

Although road projects will often bring temporary employment benefits to local communities while construction is taking place, changes in traffic volumes and in transport fares and tariffs are often the first most obvious effects of road building. Of the five studies investigated in detail that collected traffic volume and personal trip data, a wide spread of impacts was identified. These are shown in Table 5.1.

The highest impacts are shown at the top of the table. All of the studies indicated some positive effects on traffic volumes relating to the roads improved, although there were some indications of traffic diversion away from other, unimproved roads. Very high traffic increases were recorded in Nicaragua (Orbicon and Goss Gilroy, 2010) and Kenya (Ahmed, 2010), and much lower increases in Indonesia, Sri Lanka and the Philippines. One reason for large changes in traffic volumes in Kenya (Ahmed, 2010) was put down to the effects of diversion from poorly maintained roads. In this example, there were both substantial traffic increases on newly completed project roads as well as substantial traffic decreases on the control roads. Obviously, this effect will vary considerably from place to place; where the rural road network is not densely interconnected local diversions will be limited or non-existent. Traffic declines on roads that had not been improved and were in the same area as those that were, were also identified in Nigeria by Porter (1997). A study in the Philippines, found that that the share of motorised traffic as a total of total volume increased (Mazlumolhosseini, 1990)

Table 5.1: Impact on traffic volumes and trip making

Country	Study	Changes in traffic volumes, and overall trip making

Country	Study	Changes in traffic volumes, and overall trip making
Nicaragua	Orbicon and Goss Gilroy (2010)	Between 2002 and 2008 motorised traffic volumes increased by 312% for projects in the Las Segovias area. Although no traffic data was collected for comparison communities, qualitative field work found no indication of increased traffic for the comparisons.
Kenya	Ahmed (2010)	Between 2007 and 2009, there was an increase of 157% in passenger movements and an increase of 42% in motorised freight. In comparison, there were declines of 32% for passengers and 84% for freight on control roads. Traffic diversion from poorly maintained roads was believed to be a major factor.
Kenya	Airey and Cundill (1998)	In the project area, travel rates increased from 5 journeys per month per household in 1983 to 11.2 journeys in 1986 (after the road investment). However, they later declined to 8.4 journeys in 1989.
Morocco	Levy et al. (1996)	There was an average traffic growth of 13% per year for project roads compared with a national trend of under 8%. With improved roads there was no road closure; previously the three project roads had been closed for 90 days, 60 days and for the rainy season respectively.
Indonesia, Sri Lanka, the Philippines	Hettige (2006)	For out-of-village travel, on average, 12 person trips per month were recorded for project sites compared with 9.9 for control sites.
Philippines	Mazlumolhosseini (1990)	Share of motorised transport increased and share of non-motorised transport decreased

Nine studies identified differences in transport costs, fares and tariffs relating to road investment. These are listed in Table 5.2. Four studies (Airey and Cundill, 1998, Kenya; Khandker and Koolwal, 2011, Bangladesh; Levy et al., 1996, Morocco; Ruijs et al., 2004, Burkina Faso) identified differences in costs between paved and unpaved roads. Seasonal increases in costs for unpaved roads were also identified by Airey and Cundill and Ruijs et al. A lack of impact of road improvements on transport fares and tariffs in Indonesia, Sri Lanka and the Philippines was put down to poor competition in transport services (Hettige, 2006). In addition transport costs reductions were found in Hine et al (1983b) and Casaburi et al. (2013). In Vietnam, Mu and van de Walle (2007) found no effect of road

projects on transport services, although there was evidence of project households renting or borrowing motorcycles and a rise in bicycle ownership. Significant time savings were also reported by Hettige (2006) but this was not significant for Lokshin and Yemtsov (2005).

Table 5.2: Impact on transport costs and tariffs

Country	Study	Changes in traffic volumes and overall trip making
Sierra Leone	Casaburi et al. (2013)	A 59% reduction in motorcycle tariffs for project roads compared with control roads.
Morocco	Levy et al. (1996)	For one road, transport tariffs declined from 300 Dh to less than 150 Dh once the road was improved to paved standard.
Kenya	Airey and Cundill (1998)	Fares on gravel and earth roads were 60% higher than fares on bitumen surfaced roads. In the wet season, the gravel and earth road fares rose by a further 39%, with no change on bitumen roads.
Burkina Faso	Ruijs et al. (2004)	Transport costs per ton/km were estimated at 20 FCFA for busy surfaced roads and 35 FCFA for less-busy surfaced roads. Unpaved roads costs were 50 FCFA in the dry season and 20% more in the rainy season. For dirt roads, the costs were 60 FCFA during the dry season and 60% more during the rainy season.
Bangladesh	Khandker and Koolwal (2011)	Over the duration of the study transport costs in the rainy season, were around 32% lower for (paved) project roads.
Ghana	Hine et al. (1983b)	The cost of transporting a bag of maize by head loading was 1.25 Cedis per km. In contrast, the cost of transporting by truck was 4.8 Cedis for an average distance of 120 km (0.04 Cedis per km), i.e. a ratio of 31:1.
Indonesia, Sri Lanka, Philippines	Hettige (2006)	For project roads, transport cost reductions in five out of six cases were perceived as being ‘small’ (two cases), ‘none’ (one case) or ‘moderate’ (two cases). Only in one case out of the six

		were they perceived as 'good'. The low effect was put down to poor competition.
Georgia	Lokshin and Yemstov (2005)	No significant reduction in travel times.
Vietnam	Mu & Van de Walle (2007)	No significant impact on road services

Note: FCFA=CFA Franc

Variations in household transportation expenditures were used in an estimation of road investment benefits in Honduras (NORC, 2013). Similarly transport costs were used as a key component in the cross-sectional analysis undertaken for Madagascar by Jacoby and Minten (2009) and Stifel et al. (2003), and for Ethiopia by Stifel et al. (2012).

5.2 INCOME AND CONSUMPTION

The main focus for many studies was the effect of rural road investment on the key welfare measurements of income and consumption. Data on these key measures from 27 studies are listed in Table 5.3. However, the impact measurements were not uniform; the studies varied greatly, with some giving very high positive impact on poverty reduction and income growth (Dercon et al., 2012, Ethiopia; Fan et al., 2004, Uganda; Fan et al., 2005, Tanzania; Wondemu, 2010, Ethiopia). However, other studies suggested much less impact (Gachassin et al., 2010, Cameroon; Owuor et al., 2007, Kenya). In other studies, the impact ranges were in between, such as for those investigating Vietnam and China. No studies suggested an overall negative impact of road investment.

In Table 5.3, the studies are grouped by country, ranging from high to low impact. The studies carried out by Fan et al. of the IFPRI provide benefit-cost ratios together with the number lifted out of poverty. However, for purposes of the table, the investment basis for the number lifted out of poverty has been converted at prevailing exchange rates at the time of the study to US $10,000 at 2013 prices.

Also are the Rural Access Index (RAI), published by the World Bank, and the overall road density of the country. The RAI gives an indication of the percentage of the rural population that lives within two kilometres of an all-season road. If the RAI is not available from surveys it is calculated from road length and population distribution data. The RAI figure for Thailand (33%) has been omitted from the table. It is almost certainly a mistake and based on erroneous road-length data, and does not match with the road density calculated from road-length data from the Ministry of Transport in Thailand (2013).

There is a strong indication that road impact is influenced by road density. For many years, Ethiopia has had one of the lowest road densities in the world and, unlike many desert countries, its rural population is very widely distributed across the country. With this combination, it is perhaps not surprising that the four Ethiopian studies all indicate a high impact. In contrast it may not be surprising that the impacts appear lower in Sri Lanka, the Philippines and Thailand, which have much

higher paved road densities. Thailand has a particularly high length of roads per person (6.9 km per 1,000).

In comparing the results between Ethiopia and other countries, it is worth bearing in mind that in most other countries, a significant part of a rural road investment programme may relate to rehabilitated roads that have subsequently fallen into disrepair, where perhaps many structures remain intact. In Ethiopia, this will not be the case, so the nature of the change in access may be very different.

The transport characteristics of Bangladesh are very different from other countries, and road density is not necessarily a good measure of accessibility. Based on a river delta, many communities are dependent on seasonal water transport, with seasonal flooding, and likewise many roads are broken by unbridged water crossings. With this environment, improved roads with new bridges may have a dramatic effect on accessibility, so one may expect incomes to be significantly improved by new road building.

Despite the high road density per unit area, for India part of the explanation for the relatively high returns from rural roads might be that because of its high population density, road length per head is not particularly high (3.7 km per 1,000), that is, just over half of that in Thailand.

Table 5.3: Road impact on income and poverty

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
Ethiopia	Dercon et al. (2012)	Good access increases consumption growth rate by 9% per year.			32%	0.04
	Mogues et al. (2008)	Road infrastructure gives high, but variable returns. A one Birr increase for Amhara increases per capita consumption by 12 Birr but for SNNPR it is -2.5.				
	Stifel et al. (2012)	Road construction that reduces transport costs by half will give an IRR of 27%.				
	Wondemu (2010)	Households that have access to all-weather roads generated 90% greater income.				
Tanzania	Fan et al. (2005)	A shilling spent on rural roads in Western Zone, Central Zone or Southern Highlands would give returns of 12 to 20 shillings. However, the returns in the North Zone, Northern Coast or Southern Coast would be below 2 shillings.	9.13	170	38%	0.09

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not?

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
Uganda	Fan et al. (2004a)	Basic feeder roads give higher returns than gravel or tarmac.	7.16	261	27%	0.1
Madagascar	Jacoby and Minten (2009)	If transport costs of the most remote households (to a major market) were reduced by $75 per ton, this would raise their incomes by about 50%.			25%	0.06
	Stifel et al. (2003)	The mean household per capital consumption in the most isolated quintile was less than half of that in least isolated quintile.				
Peru	Escobal and Ponce (2002)	The rehabilitation of motorised roads will increase household incomes by $120 per year equivalent to around 35% of average income.			43%	0.11
India	Fan et al. (1999)	Compared with other forms of public expenditure (e.g. agricultural R&D, irrigation, education, health, rural development) per Rupee, rural roads have the largest impact on poverty reduction.	3.03	32.9	61%	1.64

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
Bangladesh	Khandker and Koolwal (2011)	The long-term effect of providing paved roads is a 7.9% increase in income			37%	0.16
	Ahmed and Hossain (1990)	Incomes are 33% more in the most accessible villages; the poor also benefit.				
Sierra Leone	Casaburi et al. (2013)	Farmers receive 7% net increase in income following road improvements.			65%	0.16
Laos	Warr (2005)	Providing dry season access to the 31% of the rural population without road access would reduce poverty from 33% to 29.7%. Providing all rural households with all-weather access would reduce poverty to 26%.			64%	0.17

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
Nepal	Jacoby (2000) Dillon et al. (2011)	A 10% increase in walking travel time reduces wages by 0.5% 10% reduction in travel time reduces poverty by 0.5%			17%	0.07
China	Chen et al. (2008)	In 2000 project increased income by 182Y /yr by 2004 reduced to 43 Yuan per yr in 2004 but not significant	6.37	10.5	97%	0.44
	Fan and Chan-Kang (2004)	Low-quality roads have a much bigger effect on poverty than higher-quality roads.				
Vietnam	Cuong (2011)	All-weather road increases income by 8.8%. But the effect on expenditure is not significant.			84%	0.58
	Mu and van de Walle (2007)	Consumption is not a significant predictor of road impact.				

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
ndonesia	Cervero (1992)	For every 10% increase in distance to the nearest regional market place, household consumption falls by nearly 2%.			94%	0.23
Indonesia, Sri Lanka, the Philippines	Hettige (2006)	Road projects tended to have a net effect of increasing incomes from non-agricultural sources; however, 47% of project households and 58% of the control group reported no change in income.			94% 92% 80%	0.23 1.82 0.64
Thailand	Fan et al. (2008)	Road investment is less efficient than electricity, agricultural R&D, irrigation or education in reducing poverty.		5.4		0.87
Honduras	NORC (2013)	The income rise for the project was not significant.			40%	0.13
Cameroon	Gachassin et al. (2010)	Proximity to a paved road increases rural incomes; however, it is not a significant factor in explaining poverty when occupation is taken into account.			20%	0.11

Country	Study	Effect of rural roads	B/C ratio	No. lifted out of poverty per $10,000	RAI	Km/ sq km
Kenya	Airey (1998)	Major increases in incomes could not be attributed to road investment. Fluctuations in rainfall and world commodity prices for tea and coffee, were a more important explanation.			44%	0.28
	Owuor et al. (2007)	Increased distance to market is linked to greater poverty, but not significant.				

Notes. (i) The B/C ratio is the benefit-cost ratio; this is quoted in studies by Fan. (ii) The No. lifted out of poverty for $10,000 is the number of people lifted out of poverty by an expenditure of US $10,000 at 2011 prices. This is calculated from figures given by Fan et al. in different currencies at different dates. (iii) The RAI is the Rural Accessibility Index. This is from the World Bank website: http://www.worldbank.org/transport/transportresults/headline/rural-access/rai-updated-modelbasedscores5-20070305.pdf. (iv) Km/sq km is the road density. To calculate road density road lengths are from CIA World Factbook. The estimated density figure for Thailand is based on data from Ministry of Transport, Thailand (2013).

For Kenya, although not significant, distance to market is positively associated with poverty (Owuor et al., 2007). In the Cameroon example (Gachassin et al., 2010), the main conclusion is that once the head of household's source of income is controlled for, access to a paved road is not a significant determinant of poverty. Despite this, the analysis does show that overall, increased distance to a paved road is associated with reduced consumption. So, it may be argued that inaccessibility prevents the take-up of non-agricultural employment. The relationship between employment source and accessibility is further discussed below.

In comparing the results, there seems to be some tentative evidence to suggest that the simpler the model the lower the identified effect on income and in contrast, the greater the complexity of the model, the greater the identified impact on incomes. The multiple equation approach adopted by Fan and colleagues in India (1999), China (2004), Uganda (2004a) and Thailand (2008) models alternative pathways in which labour productivity is influenced by road investment and, perhaps, this might be part of the explanation.

Model form is certainly a major factor in influencing results. It is interesting to compare the results of Fan et al. (2004b) with the results of Fan et al. (2008). Both papers use data from 1977 to 2000 for Thailand for four regions, and both try to calculate marginal returns, and the number of poor lifted out of poverty per million Bhat (calculated for 1999) for public expenditure in agricultural R&D, irrigation, roads, education and electricity. In the former paper, there are nine exogenous and seven endogenous variables, while in the latter there are eleven exogenous and the same seven endogenous variables. So two completely new variables are introduced (land-labour ratio, and the ratio of non-agricultural to agricultural wages), while two others are replaced (percentage who can read and write replaces years of schooling of the rural population, and irrigated land area per person replaces the irrigation stock generated by past government expenditure). The road variable, the length of roads per agricultural worker, remains the same, as do six other variables. The results of these changes can be seen in Table 5.4.

Table 5.4: Comparison of marginal returns in rural Thailand calculated by Fan and colleagues

Investment	Cost-benefit ratio		No, of poor lifted out of poverty per million Bhat (1999)	
	2004 paper	2008 paper	2004 paper	2008 paper
Agricultural R&D	12.62	6.80	138.10	130.42
Irrigation	0.71	1.69	7.69	31.92
Roads	0.86	N/A	107.23	19.33
Education	2.12	4.09	22.75	77.10
Electricity	4.86	5.11	276.00	271.60

Source: Fan et al. (2004b, 2008)

The biggest changes resulting from the change in model specification are the five-fold reduction in the number of poor lifted out of poverty by rural road investment and the increases in the number of people lifted out of poverty for irrigation and education.

5.3 AGRICULTURE AND MARKETING

The studies provide evidence of impacts of road investment on agriculture and marketing. Because agriculture is both heterogeneous, and also part of the subsistence economy (and hence may not be directly valued in monetary terms), there can be difficulties in identifying effects on total agricultural output. The identified studies refer to a wide range of impacts covering individual crops and animal production and the income from produce sales, as well as the value of total agricultural output.

The different impacts on agriculture and marketing are provided in Tables 5.5-5.8. However, it has not been practical to include all the detailed effects on individual crops and animal husbandry. The tables consider the effects of rural roads and accessibility on agricultural output, on inputs and costs, on land values and on marketing and distribution.

Table 5.5: Impact on agricultural output

Country	Study	Impact on agricultural output
Bangladesh	Khandker and Koolwal (2011)	No significant long- or short-term changes in agricultural output from the project.
	Ahmed and Hossain (1990)	Agricultural productivity is 33% greater in accessible villages. Income from agriculture is 24% more and from livestock and fisheries 78% more.
Belize	Chomitz and Gray (1996)	Commercial agriculture is much more sensitive to distance from markets than semi-subsistence farming.
China	Chen et al. (2008)	Impact on income from animal husbandry experienced an increase to 136 Yuan per household.
	Fan and Chan-Kang (2004)	Each additional rural road km adds 0.29 m Yuan to agricultural GDP.
Ethiopia	Wondemu (2010)	Improving road access from bad to good increases agricultural output by 27%.
Ghana	Hine et al. (1983a)	A cross-sectional analysis of existing connected villages shows that most food crop production, yields and sales (cassava sales are an exception) are not significantly affected by variations in distance to regional and district markets.
Kenya	Airey and Cundill (1998)	In 1983, agricultural cash income was K£430 per household; this rose to K£574 in 1986 (one year after road investment) and to K£726 by 1989. However, there were major fluctuations in world commodity prices (peaking in 1986) and rainfall patterns, so it was difficult to establish any direct effect.
Madagascar	Stifel et al. (2003)	Improving feeder roads, leading to a 17% reduction in travel time, will give a 1% increase in rice production. Trail improvement, with a 3% reduction in travel time, gives a 0.2% increase in rice production.

Morocco	Levy et al. (1996)	As a result of the road investment, with reduced risks of perishability, in two of the three regions, land use increased by 40% for high-value fruit and vegetables and moved away from low-value cereals. Fruit yields increased by 31% in project zones. Pure breed cows increased by 150% in project areas compared with a 50% increase in control zones.
East Africa/ Mozambique	Dorosh et al. (2010)	There was an elasticity of -1.7 between total crop production and travel time to cities of 100,000 (maize elasticity -0.8) for East Africa. There was an elasticity of -2.8 for total crop production and travel time to cities of 50,000 (maize elasticity -1.6) for Mozambique.
Zambia	Kingombe and di Falco (2012)	It was estimated that cotton yield increased by 6% from the road programme, but it was not statistically significant.

Table 5.6: Effect on inputs, costs and prices

Country	Study	Impact on inputs and costs
Bangladesh	Ahmed and Hossain (1990)	In accessible villages fertiliser prices were 14% lower, and 92% more was used. 71% more high-yielding crops were grown. Labour costs were 12% higher.
Burkina Faso	Ruijs et al. (2004)	For a 25% fall in transport costs, consumer grain prices in the largest shortage region will fall by only 2.5%. If transport and transaction costs fall by 25%, then consumer grain prices will fall by 0.4% and producer grain prices will rise by 3.3%.
Ethiopia	Dercon (2005)	10% increase in distance to town will reduce the likelihood of fertiliser purchase by 23-34% and reduce sale of butter by 23%. Improving road quality increases the likelihood of crop inputs by 29-34%.

Country	Study	Impact on inputs and costs
	Wondemu (2010)	Households that already have all-weather access are more likely to use fertiliser (93%) than households with bad access (36%).
Ghana	Hine (1983a,b)	Agricultural finance was significantly adversely affected by inaccessibility. A 5km improvement of an accessible road will increase farm-gate maize prices by just 0.08% while a change from head loading to bringing vehicle transport closer by 5km will increase farm-gate prices by 11.4%.
Madagascar	Stifel et al. (2003)	Fertiliser use would increase by 4% if average travel time on rural roads was reduced by half.
Morocco	Levy et al. (1996)	There were substantial increases in use of modern inputs (including fertiliser, and improved seeds and fertiliser) in project areas. Use of extension services increased fourfold in project areas, while they only increased by 0.5 to 1.5 times in control areas.
Sierra Leone	Casaburi et al. (2013)	Road rehabilitation lowered price of cassava in local markets by 17.8%.
Zimbabwe	Dalton et al. (1997)	The elasticity of distance to a paved road to farm production costs was estimated at 0.07

Table 5.7: Effect on land values

Country	Study	Impact on land values
Nepal	Dillon et al. (2011)	The elasticity of travel time to land values was -0.26 in 1995/6. The elasticity of travel time to land values was -0.47 in 2003.
	Jacoby (2000)	A 10% increase in walking time reduced land value by 2.2%.

Country	Study	Impact on land values
Nicaragua	Orbicon and Goss Gilroy (2009)	The project roads increased land values by 15% relative to the control.
Vietnam	Mu and van de Walle (2007)	The project roads had no impact on land markets.

Table 5.8: Effect on agricultural markets and distribution

Country	Study	Market and distribution effects
Burkina Faso	Ruijs et al. (2004)	Improving only part of the road network may give unintended negative consequences of higher prices to consumers in shortage regions while producers in surplus regions may lose their competitive position.
Ethiopia	Wondemu (2010)	Through an analysis of regional price data in grain markets over 10 years, a high degree of market inefficiency was observed. Spatial price differences were found to be above estimated transaction costs in 41% of cases.
Georgia	Lokshin and Yemtsov (2005)	The share of villages reporting barter exchange dropped significantly in project villages but increased in control villages.
Ghana	Hine et al. (1983b)	Transport charges accounted for 6–10% of the difference in maize prices between the lowest and highest priced markets in Ashanti Region, indicating substantial inefficiencies in agricultural marketing.
Nigeria	Porter (1995)	Better main road access has led to a shift of population and the development of markets on main roads. This has led to a collapse of markets on unpaved rural roads, with substantial adverse effects on women located away from the main roads.

Country	Study	Market and distribution effects
Vietnam	Mu and van de Walle (2007)	The availability of markets and market frequency were greater in project communities. After construction, initially there was a greater range of produce available in project villages, but the advantages were short lived.

The results in Table 5.5 and Table 5.6 continue to confirm high impacts in Ethiopia, as with the discussion on incomes, consumption and poverty. The results also suggest high impacts in East Africa, Mozambique and Sierra Leone, but lower impacts in Burkina Faso, Ghana, Madagascar and Zambia. However the Ghanaian results indicate the importance of basic vehicle access to the success of agriculture, because alternative head loading is so expensive. Better accessibility has an effect on increasing agricultural production, through both increasing farm-gate prices and lowering the costs of fertiliser. The latter effect is mentioned by five studies, and appears particularly important in Ethiopia. In Zimbabwe, it was estimated that every 10% increase in distance from a farm to a paved road induces a 0.07% increase in farm production costs.

The results from Bangladesh are mixed. Khandker and Koolwal (2011) suggest that road improvements have increased income through other channels than agriculture (the effects on employment are discussed below). However, Ahmed and Hossain (1990) suggest that accessibility has a major impact on agricultural practices and output.

Table 5.7 indicates the effect on land values of better accessibility. The sensitivity of land values to proximity to markets appears to have increased between 1995/6 and 2003. Road building in Nicaragua has also had an effect on land values, although no effects were reported for Vietnam.

Table 5.8 examines the relationships between accessibility and agricultural marketing. In Vietnam, road construction appears to have had a temporary effect on produce availability. However in Georgia, better access reduced the practice of barter. Inefficiencies in regional agricultural marketing were observed in Ethiopia and Ghana. This reinforces work from the wider literature by Ahmed and Rustagi (1987), which also noted high marketing inefficiencies in Africa in comparison with Asia.

Overall, the studies demonstrate the positive effects of road investment on agriculture; however, as seen in Table 5.8 through the work by Ruijs et al. (2004) for Burkina Faso and by Porter (1995) for Nigeria, there can be negative effects on communities that have been left out of adjacent road programmes. This issue is rarely considered by planners.

5.4 EMPLOYMENT

The effects of rural road investment and changes in accessibility on employment are given in Table 5.9. The table indicates remarkable consistency, with the exception of Honduras, it shows how better accessibility tends to increase non-farm employment and reduce agricultural employment.

Table 5.9: Employment change

Country	Study	Effect on employment
Bangladesh	Khandker and Koolwal(2011)	The project was associated with a 20-22% decline in agricultural employment, coupled with a 14-17% rise in non-agricultural employment.
China	Fan and Chan-Kang (2004)	Each additional km of low-quality roads generated 1m Yuan of non-farm GDP (and Y0.29m of agricultural GDP).
Georgia	Lokshin and Yemtsov (2005)	The share of villages with SMEs significantly increased in the project compared with control villages .
Ghana	Hine et al. (1983a)	There was an inverse relationship between accessibility and both labour input into farms and farm size.
Honduras	NORC (2013)	Per household agricultural employment income rose by 72 lempiras while non-agricultural employment fell by 109 lempiras.
Indonesia	Cervero (1992)	Off-farm earnings increased when transmigrant households had access to motorcycles and bicycles.
	Olivia and Gibson (2009)	Upgrading rural road increases the likelihood of being engaged in non-farm employment by just over 4%.
Indonesia Philippines Sri Lanka	Hettige (2006)	To increase income, project households would find employment locally (7%) or expand a small business (22%). In contrast, control households would expand agricultural production (29%) or raise small animals (22%).
Kenya	Airey and Cundill (1998)	Non-agricultural income increased from 28% in 1983 to 32% in 1986-89.
Morocco	Levy et al. (1996)	Off-farm employment grew by more than six times in the project zones compared with only three times in the control zones.

Country	Study	Effect on employment
Nicaragua	Orbicon and Goss Gilroy (2010)	There was a net 17% increase in employment for project communities.
Nigeria	Porter (1995)	Remote village populations declined as inhabitants migrated to the roadside.
Pakistan	Jamal (1995)	The distance to market with no household member in off-farm job was 9.2km, while it was 8.5km with a household member in an off-farm job.
Peru	Escobal and Ponce (2010)	Improved motorised roads increased non-agricultural wage employment by 9% but agricultural self-employment declined by 8%. Non-agricultural wage income per capita increased by US $115 per year.
Vietnam	Mu and van de Walle (2007)	As a result of road investment, there was a 2% decline in households relying on farming and a 0.8% decline in those relying on forestry, but a 1.7% increase in those relying on service sector income. Men's and women's hairdressing services rose by 14% and 20% respectively.

5.5 EDUCATION AND HEALTH

A variety of studies have analysed the impact of rural transport on health and this systematic review has identified 15. The vast majority have identified positive effects, such as accessing health centres and modern health-care techniques and medicines, the diffusion of sanitation technology and improved mortality rates. Table 5.10 presents the findings where rural road investment is beneficial to health. However, in respect to infection, some studies have highlighted increasing accessibility to increasing rates of certain diseases; these are shown in Table 5.11.

It can be seen that the impact of rural roads significantly benefits rural society in access to health-care infrastructure and services, primarily through the reduction of transport costs (Airey, 1991; NORC, 2013). In relation to health-care services, examples include vaccination (Al-Taiar et al., 2010), modern birth attendants (Kunstadter et al., 1992) and efficiency of emergency services (Lokshin and Yemtsov, 2005). In addition, there is some evidence of rural roads facilitating a diffusion of technology, particularly latrines (Jenkins and Cairncross, 2010; Orbicon and Goss Gilroy, 2009), with

a possible explanation of opening societies to new processes and ideas (Jenkins and Cairncross, 2010).

However there is less evidence linking rural road improvements to health impact indicators such as mortality rates and life expectancy. In fact, the existing evidence reflects a mixed picture in respect to higher incidence of communicable diseases such as HIV (Wawer et al., 1991 and Smith et al., 1999) and diarrheal diseases (Eisenberg et al., 2006), but improvement in accessibility was found to lower the incidence of leprosy (Sterne et al., 1995). The presence of public transport was found to lower mortality rates, so if road improvements can trigger public transport provision, there is a potential positive yield in health outcomes. However, accessibility measured by distance to the nearest clinic or hospital was found not to influence mortality rates when all other variables were held constant (Swenson et al., 1993).

Table 5.10: Positive impacts rural transport on health

Access to health centres	Access to health services	Diffusion of sanitation technologies	Mortality and infection rates
Kenya: Transport costs to health centres dropped by 33%. 16% of households shifted from a government hospital to a close mission hospital as upgrading of rural roads widened the choice of hospital (Airey, 1991) **Ghana**: There was a negative correlation between health service utilisation and: distance (-0.55); travel time (-0.46); and travel cost (-0.19). The proportion of people visiting hospitals decreased from approx. 90% to 50% as the distance to hospital increased from 10 km to 16 km (Buor, 2003) **Indonesia, Sri Lanka and the Philippines**: Evidence from six road rehabilitation projects showed that access to a hospital or dispensary increased by 20% points, walking for treatment decreased by 20% points and the proportion staying at home in cases of poor health or	**Yemen**: Evidence that vaccination increases with shortening driving distance (increase of 33% vaccination for 2km reduction in driving distance) and reduced driving time (increase of 45% vaccination for 10 minutes' driving time reduction) (Al-Taiar et al., 2010) **Thailand**: Significant negative correlation between distance to hospital (-0.775) and dry season travel time (-0.640) to the incidence of modern birth attendant in community (Kunstadter et al., 1992) **Georgia**: Reaction time of ambulances decreased significantly by approximately 20% in villages with increased investment in roads (Lokshin and	**Benin**: Proximity of a village to paved road increase the chance of at least one latrine in the settlement (Jenkins and Cairncross, 2010) **Nicaragua**: Road rehabilitation increased the incidence of latrines by 10% points more than in villages with no road rehabilitation improvement (Orbicon and Goss Gilroy, 2009)	**Malawi**: Leprosy incidence rates increased with increasing distance to roads – doubling from 1.3% to 2.5% with an increase from 1 km to more than 4 km (Sterne et al., 1995) **Vietnam** : The presence of public transport was associated with a significantly lower mortality rate. However, this was independent of other variables. Differences in access to transport and distance to the nearest clinic or hospital were not significant related to mortality rates (Swenson et al., 1993)

emergency was halved (Hettige, 2006) **Honduras**: Road building reduced the cost of travel to hospital and health centre by 3.52 and 0.194 lempiras respectively (NORC, 2013) **South Africa**: Increases in travel time decreases the chance of attending health care clinic (McCray, 2004)	Yemtsov, 2005)		

Table 5.11: Negative impacts of rural transport on health

Mortality and infection rates
Uganda: HIV seroprevalence was 38.5% in the main road trading centre, 25% in trading villages and 8.6% in agricultural villages (Wawer et al., 1991)
Uganda: The incidence of HIV in communities in intermediate trading villages and in communities in trading centres on main roads was 1.9 and 3.3 times higher respectively, than in rural agricultural villages with little or no road connection (Smith et al., 1999)
Ecuador: Villages closer to roads have higher diarrheal rates. E coli infection rates were three to four times higher with proximity to roads and up to eight times higher comparing townspeople to the most remote rural villages (Eisenberg et al., 2006)

Note: No negative effects were recorded for access to health centres, access to health services or diffusion of sanitation technologies.

Fewer studies have investigated the impact of rural transport on education. This systematic review has identified five studies. Two of these found no impact on education, while the remaining found positive impacts on school attendance and enrolment. The results are shown in Table 5.12.

Table 5.12: Education change

Country	Study	Effect on education
Morocco	Levy et al. (1996)	After the development of rural roads, project zones experienced a 163% increase in school attendance. Suggested reasons include the efficiency benefits of females no longer collecting firewood (because butane gas could be delivered by vehicle)
Vietnam	Mu and van de Walle (2007)	After road rehabilitation and construction, project villages experienced a 30% increase in primary school completion rates and a 7% increase in secondary enrolment
Nigeria	Porter (1997)	Increasing accessibility offered more choice of schools

Country	Study	Effect on education
Ghana	Hine et al. (1983a)	No significant relationship between education levels and accessibility was found
Vietnam	Cuong (2011)	The presence of road open to traffic all year round produced no significant effect on the proportion attending school

5.6 ISSUES OF DATA ANALYSIS

A wide range of issues need to be recognised when assessing the impact of roads. The issues highlighted in this section are pertinent to studies included in this systematic review; however, to reinforce general issues in data analysis, some supporting evidence is provided from the wider literature – in such cases, the text clearly labels where the evidence is drawn from.

WHO ARE THE BENEFICIARIES OF RURAL ROAD INVESTMENT?

There is an underlying assumption in most rural road studies that the beneficiaries of rural roads investment can be identified as the adjacent communities of the roads in question. Of course, rural roads may have two functions, in both serving local communities adjacent to the road and in providing through access to more remotely located towns and villages. The second function is more associated with longer secondary and main roads but cannot be completely dismissed, as vehicles divert and take short cuts to make use of the shorter rural roads. Only a macro network study, such as that undertaken by NORC (2013) for Honduras can pick up these wider benefits.

Even if we just concentrate on the role of rural roads that serve adjacent communities, there is still an issue about the extent to which the transport benefits accrue to the local communities, rather than to transporters, middlemen and urban consumers. The assumption is that central market prices are fixed and that there is substantial competition in transport and distribution. However, more often, central market prices are not fixed. In fact, if a programme of rural road investment stimulates a rise in agricultural production there is every reason to believe that central market prices will fall and urban consumers will benefit. Both Ruijs et al. (2004) for Burkina Faso and Casaburi et al. (2013), for Sierra Leone, model the decline in local market prices.

Other identified studies have also identified a lack of competition and inefficiencies in marketing and transport (Hine et al., 1983b, Ghana; Wondemu, 2010, Ethiopia; Hettige, 2006, Indonesia, Sri Lanka and the Philippines). This is supported by studies in the wider

literature. For example, Ahmed and Rustagi (1987) found that food grain producers in Kenya and Malawi received just 45% of the retail price compared with 80% in Asia, with differential transport costs being a small part of the difference between producer and retail prices. Similarly, Teravaninthorn and Raballand (2009) have pointed to a huge disconnect between costs and prices in long distance transport markets in Africa. Inefficient practises and high tariffs for rural transport vehicles in Africa have also been identified by Ellis and Hine (1998). If road investment reduces underlying vehicle operating costs, then a substantial part of the benefits may be initially captured by transport operators or marketing middlemen, who are mostly located in the towns, or be transferred to consumers and producers in the towns. Hence, it may be a long time before a new equilibrium of transport fares and tariffs is established.

ISSUES TO DO WITH CONTROLS AND THE PROBLEM OF PLACEMENT

Most procedures to identify the specific effect of identified road programmes need to make use of control data. A number of problems arise with the use of controls. Firstly, how representative are control households with project households? Clearly it is important that they are as similar as possible and subject to the same economic climate. Propensity score matching (PSM) procedures have been carried out by a number of studies to ensure as close a match as possible.

Although references are made to PSM, it is often not clear exactly what is being matched. It is relatively easy to match household composition, and wealth and income source. It may be much more difficult to match farming practices and road characteristics.

One major issue that is frequently encountered and often commented on is that significant road interventions take place on the control roads after the initial range of survey data has been collected (Ahmed, 2010, Kenya; Levy et al., 1996, Morocco). As was mentioned before the state of most rural roads fluctuates with maintenance and rehabilitation activity. Work programmes can be unpredictable.

Rural road investments are not ‘dropped at random’ across the countryside. Within the confines of any given programme or district, road investments are likely to be chosen to have the largest local impact. The size of population to benefit and the traffic volume are likely to be key factors in the decision. Similarly, the most dynamic and wealthiest regions of a country may also be able to afford or push for road programmes to come to their area, (i.e. giving rise to reverse causality). These factors may be an important source of bias in interpreting results.

There are various techniques that are adopted to minimise the bias. By adopting household ‘fixed effects’ within the modelling, time-invariant placement effects, such as roads being built in predominantly rich areas, are dealt with (Dercon et al., 2012, Ethiopia). Similarly, the double- difference and PSM approaches can also deal with time-invariant placement effects (Chen et al., 2008, China). However, time-varying factors such as roads being built in areas of high growth potential cannot be addressed.

Another approach to deal with the issue is the adoption of 'discontinuity design' analysis, whereby within a road programme, roads that were 'just selected' are compared with those that 'just failed to be selected'. This approach can provide a relevant assessment of road planning because it deals with the most marginal road investments. Likewise, the two groups are likely to be close in their initial conditions and the unrepresentative best and worst examples of both project and controls are omitted. Such an approach was taken by Casaburi et al. (2013) in Sierra Leone.

Placement problems can also arise with cross-sectional modelling. For example, if a town develops in an area of high soil fertility, then the surrounding villages will also benefit; however more remote locations may not have this advantage. Hence any comparison of income at different distances to the town will not be just the result of differences in accessibility. Soil fertility and soil types were taken into account in the cross-sectional modelling by five studies (Hine et al. ,1983a, Ghana; Jacoby and Minten, 2009, Madagascar; Stifel et al., 2003, Madagascar; Stifel et al., 2012, Ethiopia; Wondemu, 2010, Ethiopia).

IMPACTS AND FACTORS VARYING OVER TIME

A major problem for most studies that deal with agricultural or economic impact is variability over time. Year-on-year changes in weather can have a huge impact on crop production, and international commodity price changes can also have an important effect. These issues played a very important part in the study in Kenya by Airey and Cundill (1998). Longitudinal detailed studies over many years are the only way to deal with variability over time. Long term studies were also carried out by Dercon et al. (2012), Khandker and Koolwal (2011) and Mu and van de Walle (2007).

Another issue that is not often discussed is the time period over which road impact develops. In the model of 25-year time-series data, for India, Fan et al. (1999) determined the time lag incorporated into the simultaneous model - for roads, the time lag found was seven years. For most studies, this time lag needs to be extremely long to identify most effects.

5.7 SUMMARY OF EVIDENCE

In the studies analysed, a wide diversity of impacts has been identified. This is only to be expected with the wide range of initial conditions, interventions and methods of analysis. In terms of reporting results, the studies were found to be very heterogeneous. Apart from five studies carried out by Fan and colleagues of IFPRI, there were no consistent formats or measures for reporting the different types of outcome. Hence it was not possible to estimate 'average effects' or, in most instances, a 'range of effects'.

- **Traffic volumes**: five studies provided data on traffic volumes and personal trip making. Compared to other sectors, the biggest proportionate effects of road investment have been on traffic volumes. The outcomes are overwhelmingly positive. All the studies recorded an increase in traffic, but there was a very wide

range of response, ranging from a 312% increase in traffic volumes (over six years) in one study to a 21% increase in another.

- **Transport costs:** nine studies provided data on the change in transport costs, fares and tariffs resulting from road investment**.** The largest difference in tariffs was the 31-fold ratio in costs (per ton/km) between head loading and transporting by truck. The range in changes in tariffs for improving existing accessible roads varied from a 50% reduction in one case to no change in another case, with the lack of response put down to a lack of competition. Marked seasonal changes in transport tariffs were noted for unpaved roads, where tariffs were found to be up to 60% more in the wet season.
- **Incomes and consumption:** 27 studies identified the effects of road investment and better accessibility on incomes, consumption and poverty. The results were mixed. Although 21 studies reported strong beneficial impacts, six suggested that the impacts were low or insignificant. The highest impacts were found to occur where the rural road infrastructure was particularly scarce, as in Ethiopia, Uganda, Tanzania, Madagascar and Peru. For example, one study, in Ethiopia, found that good access could increase the consumption growth rate by 9% a year, while another study, in Uganda, found a benefit-cost ratio of 7.16, where spending $10,000 (2013 prices) on rural roads would lift 261 people out of poverty. Lower effects appear in Thailand, Sri Lanka, the Philippines and Kenya, with intermediate effects in Vietnam and China. However, there was no exact correspondence between road density and impact. A low impact in Cameroon was found only after employment was controlled for. The relatively high impact found in India may be explained by the low road distance per head, despite its high road density per unit area.
- **Agricultural output**: 12 studies analysed the effects of rural roads on agricultural output. A wide range in response was identified. A significant increase was found in seven studies; for example, improved rural roads were estimated to lead to a 27% increase in output in Ethiopia. However, no significant change in agricultural output was found in three studies.
- **Agricultural inputs, costs and prices:** nine studies analysed the effects of improved accessibility on agricultural inputs, costs and prices. Significant beneficial effects were identified in all studies, although with a substantial variation between studies. A threefold comparative increase in extension services was found in Morocco, while a study in Ethiopia found that fertiliser use would increase by 2.5 times in villages with good accessibility compared to those without. Four other studies found an association between accessibility and fertiliser use. A study in Ghana found that bringing vehicle access closer by 5km would increase farm-gate maize prices by 11.4%; however, improving an existing accessible road by the same distance would only increase farm-gate maize prices by just 0.08%.
- **Agricultural land values:** four studies examined the effects of accessibility on land values. One study found no effect of improving roads on land values, while three studies found that better accessibility increased land values. For example, there was a 15% increase in land values associated with project roads compared with a control in Nicaragua.

- **Agricultural marketing:** six studies examined agricultural marketing. Two studies identified positive effects of better accessibility on marketing; two others found that communities on adjacent roads that had not been improved would suffer (i.e., there were substantial negative effects). Finally, two studies identified substantial market inefficiencies that were not necessarily to do with road construction.
- **Employment:** 15 studies examined the impact of road investment on employment. With one exception (Honduras), there was remarkable uniformity within the studies, which showed that better access leads to much greater employment outside the agricultural sector. This appears to be a key factor in the association between poverty reduction and road investment.
- **Health:** 15 studies investigated the effects of accessibility on health. Twelve identified the beneficial effects of improved accessibility on health outcomes. These included an increase in vaccination rates, attendance at hospitals, use of modern birth attendants and use of latrines, and lower leprosy incidence. However three studies identified negative effects principally, an increase in HIV and diarrheal E coli infection rates.
- **Education:** Five studies considered the effects of better accessibility on education outcomes. Three found beneficial effects, with increasing school attendance, and greater school choice and school completion rates. However, two studies found no significant effect.

Table 5.13 presents a summary of the effects and impacts due to an expansion of the rural transport network. The number of studies that investigated changes in the variables is presented, as well as the direction of change (beneficial or unfavourable). Highly beneficial impacts were reported with respect to transport costs, traffic volumes, employment, income and consumption, health and agricultural inputs, costs and prices – in all such variables, over 75% of the studies that investigated the aforementioned variable(s) cited a beneficial trend. On the other hand, unfavourable impacts were cited with respect to marketing and health. Unfavourable marketing impacts are that areas distance from the infrastructure incurred a dis-benefit. Examples of negative health outcomes include higher infection rates.

Table 5.13: Summary of effects and impacts

Effect / impact	No. of studies investigated	Beneficial effect/impact		Unfavourable effect/impact	
		No.	%	No.	%
Transport costs	7	6	86	0	0
Traffic volumes	5	5	100	0	0
Employment	14	13	93	1	7
Income and consumption	27	21	78	0	0
Health	15	12	80	3	20
Agriculture					
- Output	12	9	75	0	0
- Inputs, costs and prices	9	9	100	0	0
Land values	4	3	75	0	0
Marketing	6	2	33	2	33
Education	5	3	60	0	0

6 CONCLUSIONS AND IMPLICATIONS

This chapter produces a summary conclusion of the systematic review. In doing so, it provides fresh analysis for the review question. It begins by addressing the three essential objectives: i) the conditions and type of rural road interventions most likely to have an impact on poverty reduction and resilience on the local population; ii) the likely range and scale of impacts for different interventions; and iii) the most appropriate theory of change of rural road impacts that can assist with planning rural road interventions. To conclude, this chapter will also present: iv) the strengths and limitations of this systematic review and v) recommendations for further research.

6.1 IMPACT OF RURAL ROAD INTERVENTIONS ON THE LOCAL POPULATION

As stated in Section 0, the first main question to address is:

> What are the conditions, and what type of rural road interventions, are most likely to have a positive, or minimal, impact on poverty reduction and resilience in the local population?

The results of the studies indicate a wide range of impacts in a diverse set of countries. Most of the studies record positive impacts to better accessibility, with a minority recording weak or zero impacts. On balance, it appears that better rural accessibility will:

- positively increase incomes and consumption, reduce poverty, strongly increase traffic, reduce transport costs, increase the use of fertiliser and modern inputs and hence increase agricultural output, strongly increase the opportunity to gain non-agricultural work, increase access to health centres, improve the use of health services and possibly increase school attendance and completion rates
- increase the risk of spreading infections such as HIV/AIDS and E coli for diarrhoea as well as reducing economic activity in nearby communities located on routes that did not receive road investment.

The highest positive impacts on poverty and incomes relate to improving accessibility in Ethiopia, Uganda, Tanzania, Madagascar and Peru. All these countries have very low road densities and low Rural Access Indicator (RAI) scores. In contrast, less impact was identified for Vietnam, Indonesia, Sri Lanka, the Philippines and Thailand, which have higher road densities and higher RAI scores. Hence, there is some evidence to suggest that the greatest opportunities for a large impact are where the coverage of the existing road network is poor. Conversely, where road coverage is good, then diminishing marginal returns may result. However, the pattern is not uniform, with positive returns from India, which has a high road density, (per unit area) but a low road length per head of population. Similarly strong impacts were not recorded in several countries that do not have high road densities, such as Cameroon.

Economic theory would suggest that uncompetitive transport and marketing organisations will hinder the benefits of better accessibility for the rural population. In fact, the studies found evidence of a lack of competition and market inefficiencies; however, the direct effects on incomes and poverty in the rural population is lacking.

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not?

Unfortunately, the studies are very weak in their analysis of different road engineering solutions. None of the studies that investigated the effects of specific road investments or national road programmes examined how individual road length affected impact. However, this issue was covered by the cross-sectional approaches.

With the exception of Fan et al. (2004a) in Uganda, the studies offer little guidance as to the standard of road interventions that would maximise income generation and reduce poverty. This study suggest that, per shilling spent, providing feeder roads (i.e. basic access roads) would lift three times as many people out of poverty compared with building higher standard murram (gravel) or tarmac roads. An alternative analysis presented for China (Fan and Chan-Kang, 2004) also suggests that lower-quality roads would be much more effective in reducing poverty than higher-standard roads. However, in both these cases, the function of the road cannot be separated from its engineering design. Escobal and Ponce (2002), in Peru, also explored the effects of improving trails, as well as motorised rural roads. However although a significant effect on incomes was identified for the latter, a positive but non-significant effect was observed for the former.

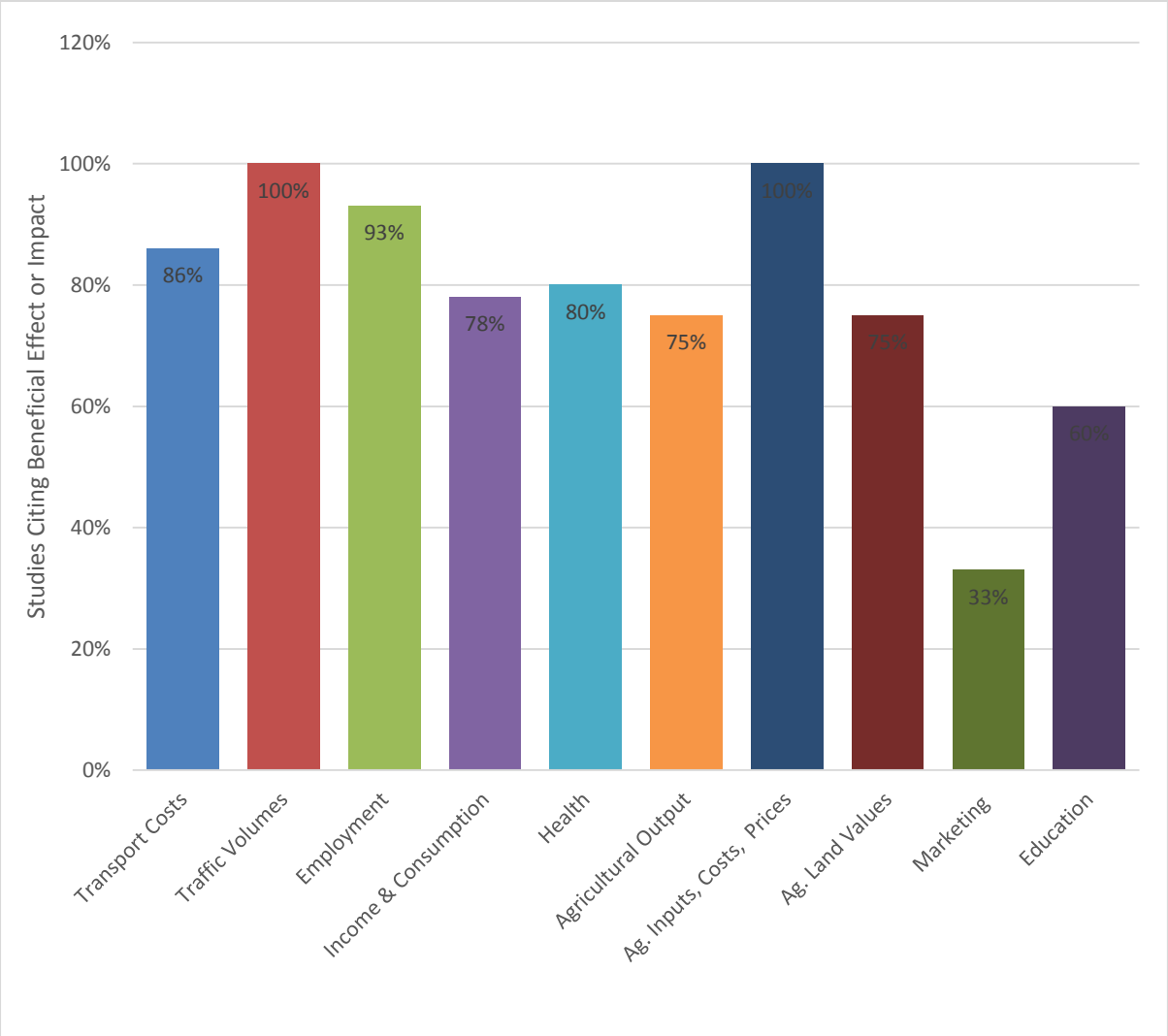
The high positive impacts in Ethiopia, Uganda, Tanzania, Madagascar and Peru overwhelmingly relate to unpaved road building. In contrast, at the time of the studies, a range of engineering designs were used for rural road building in Asia. So both India (a relatively high impact), and Vietnam (low impact) had a mixed rural road network including both gravel and paved roads, although increasingly in Asia, rural road networks are being upgraded to paved standard.

In contrast to the arguments supporting basic access, the findings of Dercon and Hoddinott (2005) in Ethiopia that 'better levels of past road quality increases growth' suggest that there may be additional benefits from higher-standard roads. However, whether the increased costs of building such roads warrant the increased benefits is not examined.

With respect to education, only five studies included an analysis of education, with some providing evidence of a positive impact on attendance rates; however, two of the five studies recorded no change in outcome. The impact on education outcomes such as literacy levels or other levels of educational attainment were not measured in any of the studies. On balance, neither the overall level nor the direction of impact that rural road interventions can have on education levels can be confirmed.

Figure 6.1 presents a summary of the effects and impacts due to an expansion of the rural transport network. Beneficial impacts were reported with respect to transport costs, traffic volumes, employment, income and consumption, health and agricultural inputs, costs and prices – in all such variables over 75% of the studies that investigated the aforementioned variable(s) cited a beneficial trend.

Figure 6.1: Percentage of studies showing a beneficial effect for each characteristic investigated.



Unfortunately, there is insufficient evidence in the included studies to adequately respond to issues pertaining to 'resilience', with particular emphasis on the ability of local beneficiaries to maintain benefits over the long term or their ability to absorb exogenous shocks. The studies have not investigated the impact of the interventions over the long term, and of course there is difficulty in analysing the impact of 'shocks' with some methodologies, including the double-difference approach.

6.2 RANGE AND SCALE OF IMPACTS

The second main question to address is:

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not?

What is the likely range and scale of impact for different interventions?

Unfortunately, other than the results presented by Fan et al. (2004a) for Uganda, we cannot identify different outcomes for different types of intervention. With regard to improvements in accessibility or rural road building in general, a very wide range of impacts were observed. However, other than the work by Fan and colleagues at IFPRI, the results were not expressed in a uniform way and so it was difficult to present range or scale of impact.

In addition, coupled with the very extreme heterogeneity of the data and findings, it is not possible to compare the impacts of different interventions between the studies. In fact very few studies even described the type of intervention adopted, for example type of road rehabilitation, length of road rehabilitated (see Section 0 for further clarification on this issue). In summary, it is not possible to draw conclusions on the range of impacts for different types of interventions.

6.3 THEORY OF CHANGE

The third main question to address is:

What is the most appropriate theory of change of rural road impacts that can assist with planning rural road interventions?

The connections between road investment and impact are not straightforward, and there are conceivably multiple pathways in which impact might arise. To develop a credible theory of change that is useful for road investment planning, we need to be able to connect variations in road engineering design with variations in impact. This can be achieved by establishing the links between inputs, outputs, outcomes and impact. Although issues remain over apparently wide variations in the costs of road construction, the first link, between road engineering inputs and outputs, is generally well understood and integral to the road engineering design process. The remaining links are perhaps less well understood and need to be recognised before we can develop an appropriate theory of change that is useful for road planning. Overall, a robust theory of change requires the following key components:

- evidence of the overall impact from road investment;
- a plausible mechanism of change linking road investment outcomes with impact backed by evidence;
- a plausible mechanism of change linking road investment outputs with outcomes backed by evidence;
- the link between engineering inputs and outputs; however, this is integral to the road design process and can be taken as a given.

The review provides plenty of evidence on the overall impact of road investment on income, consumption and poverty reduction from the historical impact of identified road investment and from the studies of marginal impact of national road investment given in Table 5.3.

A plausible mechanism of change linking road investment outcomes with impacts is established through the cross-sectional studies that relate changes in travel time and transport costs to changes in incomes and agricultural output. These are given in Tables 5.3 and 5.5.

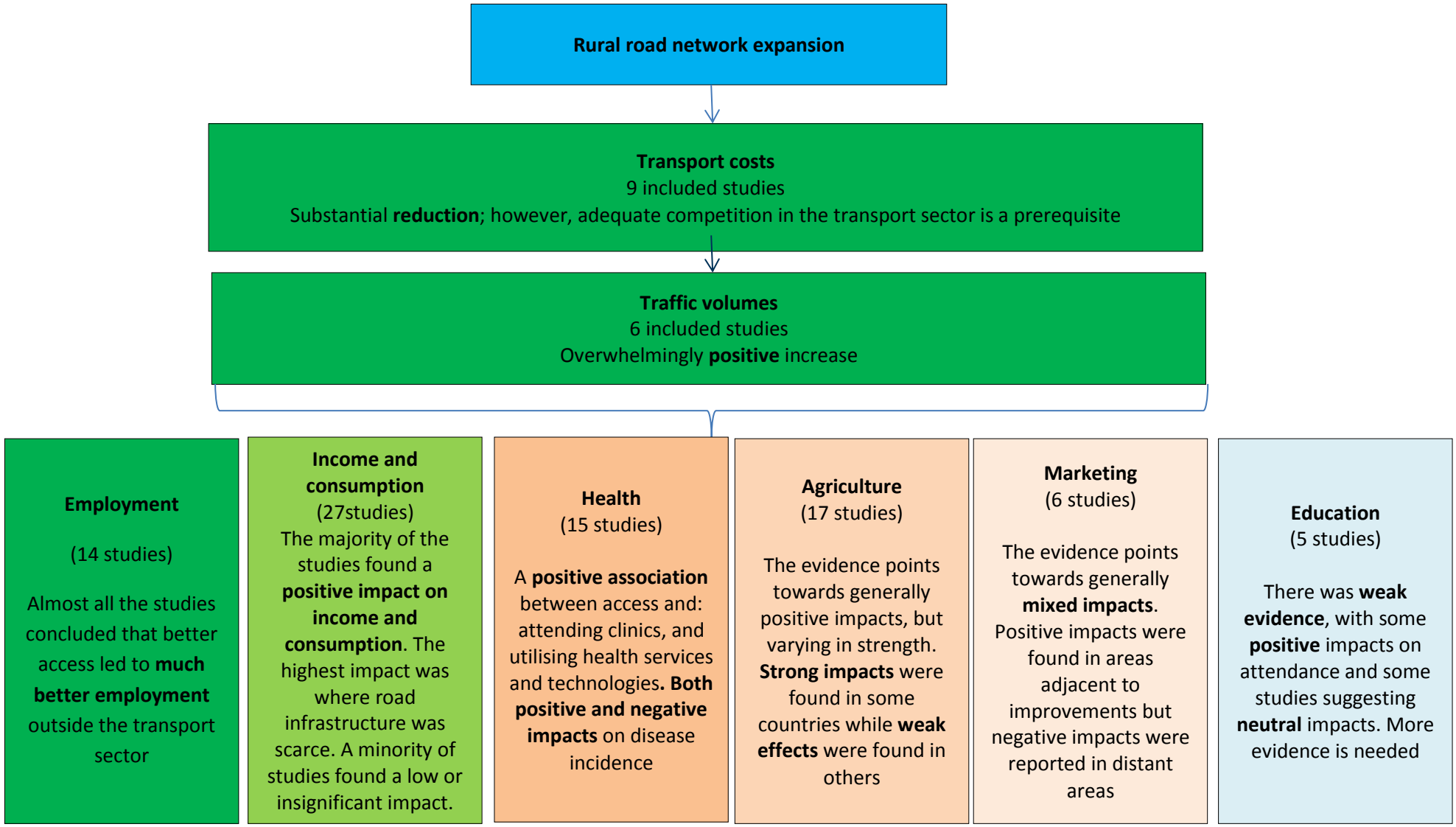
The link between road interventions and transport costs (including travel time) is provided by the evidence presented by the studies listed in Table 5.3. Here, road investment is shown to have a direct effect in reducing transport fares and tariffs. However this is insufficient in itself to provide a strong mechanism of change that can be used for transport planning. Further evidence that relates road investment to changes in transport costs is provided by the background studies that are incorporated into the road investment model HDM4 (World Bank, 2000) that relate vehicle operating costs and vehicle speeds to road alignment, width and roughness.

Classic economic theory predicts the effect of reduction in costs to increase in supply and this has been evidenced by at least five studies in the systematic review, which state that the direct outcome of rural road schemes has been an increase in traffic.

Following on from reduction in transport costs and increase in traffic volumes are the less immediate and slightly longer-term impacts on poverty. The literature has been able to demonstrate very strong positive impacts on employment, income and consumption, and quite strong positive impact on health take-up (but with some negative impacts on disease incidence); it has also presented a positive to neutral evidence base with respect to agriculture, marketing and education.

From these connections we can establish an appropriate theory of change, as presented in Figure 6.2. The major weakness in the theory of change is the inability to link the causal relationships between the impacts. For example, does the increase in employment lead to higher levels of health take-up and to what extent?

Figure 6.2: Theory of change showing the impact of road infrastructure expansion on poverty as evidenced from this systematic review



6.4 STRENGTHS AND LIMITATIONS OF THE SYSTEMATIC REVIEW

This is the first systematic review conducted in international development which exclusively attempts to identify and synthesise, in an explicit and transparent manner, findings from studies on the type of rural road interventions that are most likely to have a positive, or minimal, impact on poverty reduction and resilience in the local population.

We conducted a systematic search of electronic databases and key websites to identify published and unpublished research, investing time in hand searching key transport websites. However, despite our attempts to conduct a sensitive and comprehensive search, the review was limited to English language databases and studies written in English, and thus we may have missed relevant literature from LMIC published in other languages.

The majority of studies included in the review answered questions on impact. We therefore have limited data to help us understand the range and scale of impact for different interventions and what factors contribute to the success or failure of one intervention over another. Thus, discussions on the theory and delivery of the different types of intervention included in the review need further evidence from primary research to build a clearer picture of the mechanisms involved in implementation. Overall, the studies are very weak in identifying exactly what rural road interventions should be undertaken and in what circumstances. This will be disappointing to policy makers and engineers who have to take hard decisions on how to allocate funds and what type of road investment to make.

A wide range of methodologies were employed in the studies, from simple comparisons and cross-sectional analyses to multistage modelling. There is some tentative evidence to suggest that the more complex modelling approaches find stronger benefits, particularly for identifying the effects on incomes and poverty reduction. In part, this may be because multistage modelling that targets incomes and employment can more easily accommodate structural change in the economy, such as the rise of non-agricultural employment.

However, there is a worry that many of the econometric approaches are not transparent, and may be inaccessible to the average policy maker. It is also a cause of concern that small differences in model specification (for example Fan et al., 2004b, compared with Fan et al. 2008 for Thailand) can have such large changes in effects.

One weakness of the cross-sectional approaches is that finding a difference in welfare outcomes with distance, travel time or transport costs is not enough. Another stage of analysis is required. The policy maker needs to know what the effects will be if road infrastructure is improved or new infrastructure built.

Most of the studies are consistent with the primary need to first ensure basic motor vehicle access. However this is not an end to the matter. The apparent benefits of improving roads to paved standards in Asia and the findings of Dercon and Hoddinott (2005) in Ethiopia suggesting that ‘better levels of past road quality increases growth’ are intriguing and

suggest that there may be increased benefits from higher road standards than perhaps we previously thought.

Lastly and disappointingly, the studies do little to tie up the association between immediate outcomes of projects such as traffic, fares, tariffs and market activity with long-term impacts on welfare. Local long-term impact studies that require repeat surveys and very highly qualified researchers are extremely expensive. So simpler methods are needed that can focus on looking at outcomes, but to do this we need to know what the relationship is between outcomes and the impact on welfare, in order to move forward.

On a positive note, this systematic review has managed to produce a thorough synthesis of findings on the impact of rural road schemes conducted in low- and middle-income countries. A theory of change derived from measured outcomes in a research setting has been established.

6.5 RECOMMENDATIONS FOR FURTHER RESEARCH

This theory of change has highlighted the focus and gaps of previous research into the subject area. This systematic review has failed to establish which types of interventions provide the most positive benefits – no study included in the review tested such a hypothesis. This area of research can be investigated in the future in order to provide planners with more contextual evidence.

In addition, not enough studies provided a sufficiently long-term measurement of impacts to test the 'resilience' of local communities in their ability to absorb benefits over time and after periods of external shocks. This can be done by measuring outcomes or impacts over the longer term and conducting research in areas which have previously experienced rural road infrastructure development but have since been subject to natural disasters, such as floods, drought, earthquakes. Such research needs to be designed with safeguards for ethics in place.

This systematic review has developed a theory of change based on the evidence available. There are many aspects of the theory of change that have been previously envisioned as possible triggers of change (these are listed in Section 0), but have not been confirmed adequately in this systematic review, examples include increasing transport reliability, increasing government and NGO provision of agricultural extension services, and health and education outcomes. With particular emphasis on health, not enough studies explicitly measure the impact in health outcomes, such as overall mortality rates. Also with regard to education, the evidence is weak and mixed, with only five studies investigating the impact on education; no study actually investigated the impact in education outcomes, such literacy levels or standards of numeracy. In addition, adverse effects of road transport provision, such as increases in accidents and local environmental effects were not cited as a principal finding in any of the systematic review studies. Finally, the theory of change requires further development to link the causal relationships between the impacts.

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not?

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6 APPENDICES

APPENDIX 1: AUTHORSHIP

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CONFLICTS OF INTEREST

The following studies have been included in this systematic review: Airey and Cundill (1998); Hine et al. (1983a,b).

During the screening and quality appraisal process, consensus on the relevance of studies for inclusion in the review was reached through discussion with all of the review authors. Where disagreements occurred, the final decision was made by either the lead (John Hine) or second review author (Masam Abedin). However, if a review author was an author of one of the studies, he was not involved in these final decisions; instead judgements were made by the remaining review authors.

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APPENDIX 2: SEARCH STRATEGY

Set A	(TI=transport* or TI=road* or TI=track* or TI=highway* or TI=bridge* or TI=infrastructure or TI=passab* or TI=impassab*) or (AB=transport* or AB=road* or AB=track* or highway* or AB=bridge* or AB=infrastructure or AB=passab* or AB=impassab*) or (DE=transport* or DE=road* or DE=track* or DE=bridge* or DE=infrastructure or DE=passab* or DE=impassab*)
Set B	(TI=rural or TI=village* or TI=settlement* or "remote area*") or (AB=rural* or AB=village* or AB=settlement or "remote area*") or (DE= rural* or DE=village* or DE=settlement* or "remote area*")
Set C	(TI=poverty or TI=impact* or TI=income* or TI=welfare or TI=agricultur* or TI="crop production*" or TI=wealth* or TI=economic* or TI=benefit* or TI=asset* or TI=employ* or TI=price* or TI=earning* or TI=wage* or TI=wealth* or TI=growth or TI=consumption or TI=salar* or TI=resilien*) or (AB=poverty or AB=income* or AB=welfare or AB=agricultur* or AB="crop production*"or AB=wealth* or AB=econom* or AB=benefit* or AB=asset* or AB=employ* or AB=price* or AB=earning* or AB=wage* or AB=wealth* or AB=growth or AB=consumption or AB=salar* or AB=resilien*) or (DE=poverty or DE=impact* or DE=income* or DE=welfare or DE=agricultur* or DE="crop production*" or DE=wealth* or DE=econom* or DE=development* or DE=benefit* or DE=asset* or DE=employ* or DE=outcome* or DE=price* or DE=earning* or DE=wage* or DE=wealth* or DE=growth or DE=consumption or DE=salar* or DE=resilien*)
Set D	(LA=ENG and PY>1979 and DE=developing countr*)
Set E	(TI=road* or AB=road* or DE=road*)

Set F	(TI="rural transport infrastructure" or "rural infrastructure" or "transport infrastructure" or "transport cost*" or "public investment" or accessib*) or (AB="rural transport infrastructure" or AB="rural infrastructure" or AB="transport infrastructure" or AB="transport cost*" or AB="public investment" or AB=accessib*) or (DE="rural transport infrastructure") or (DE="rural infrastructure" or DE="transport infrastructure" or DE="transport cost*" or DE="public investment" or DE=accessib*)

This basic search was modified to meet the requirements of the different databases and websites.

APPENDIX 3: SEARCH RESULTS

No.	Resource	Hits
1.	Scopus	488
2.	AFCAP (Africa Community Access Programme)	412
3.	CSIR (Council for Scientific and Industrial Research)	400
4.	IFRTD (International Forum for Rural Transport Development) [estimated number of hits]	400
5.	EuropeAid (European Commission Cooperation Office) [estimated number of hits]	330
6.	World Bank	322
7.	GEOBASE (Engineering Village)	302
8.	Foreign Affairs, Trade and Development Canada	293
9.	Web of Science	272
10.	Transport Database	266
11.	ELDIS (International Development)	243
12.	Dissertation abstracts (Proquest Dissertation Abstracts A&I)	214
13.	Transport Research Board	147
14.	EconLit	134
15.	JICA (Japan International Cooperation Agency)	112

No.	Resource	Hits
16.	Amazon.com	102
17.	Transport Research Laboratory (TRL) Ltd	85
18.	IADB (Inter-American Development Bank)	68
19.	CIS (Construction Intelligence Service)	65
20.	African Development Bank	61
21.	Zetoc	60
22.	SciDev.Net (Science and development network)	56
23.	ISI Proceedings: Science and Technology	56
24.	Google Scholar	55
25.	International Food Policy Research Institute (IFPRI)	54
26.	Millennium Challenge Corporation	50
27.	Asian Development Bank	46
28.	SLoCaT (Partnership on Sustainable Low Carbon Transport)	46
29.	PsycINFO	44
30.	ProQuest Dissertations & Theses A&I: Science & Technology	39
31.	Irish Aid	32
32.	WRA (World Road Association - PIARC)	28
33.	AusAID (Australian Government Overseas Aid Program)	25

No.	Resource	Hits
34.	CAB Abstracts	23
35.	Cardno IT Transport	19
36.	Transport Links (TRL)	17
37.	US Agency for International Development	17
38.	Intute (all subjects)	12
39.	DANIDA (Danish International Development Agency)	12
40.	SSATP (Sub-Saharan Africa Transport Policy Program)	12
41.	TRID (Transport Research Information Services)	10
42.	R4D (Research for Development - DFID)	10
43.	Index to theses	10
44.	CDB (Caribbean Development Bank)	7
45.	IRC (Indian Roads Congress)	6
46.	Open Grey	6
47.	COPAC Book Catalogue	5
48.	World Health Organization	5
49.	Environmental Sciences and Pollution Management	4
50.	DFID Systematic Reviews	4
51.	International Fund for Agricultural Development (IFAD)	4

No.	Resource	Hits
52.	ANTE (Abstracts in New Technologies and Engineering)	0
53.	Bubl	0
54.	AGORA (Access to Global Online Research in Agriculture)	0
55.	ASANRA (Association of National Road Agencies)	0
56.	Campbell Collaboration database of systematic reviews	0
57.	German Technical Cooperation, GIZ	0
58.	gTKP (global Transport Knowledge Partnership/Practice)	0
59.	IRF (International Road Federation)	0
60.	REAAA (Road Engineering Association of Asia and Australasia)	0
61.	Tanzania Transportation Technology Transfer (TanT2) Centre	0
Total hits		5490

APPENDIX 4: EXCLUDED STUDIES

The following studies passed the screening on title and abstract phase but after screening for data extraction and quality appraisal of full reports was excluded for the following reasons.

NOT MEETING REVIEW CRITERIA

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APPENDIX 5: REFERENCE DATA

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Ahmed (2010) Kenya A2	Traffic counts and transport user surveys were carried out in 2007 and 2009 on 8 project roads and 3 control roads. A double-difference analysis was undertaken to identify the impact of upgrading the roads.		On average there was a 157% increase in motorised passenger movements on the project roads compared with a 32% decline on the control roads. Similarly, there was 41% increase in motorised freight volumes on project roads compared with an 84% decline			

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
			in control roads. Overall, average tariffs on improved roads rose faster than prices on control roads. This was probably due to the shift to motorcycles, which provided more expensive transport services.			
Ahmed and Hossain (1990) Bangladesh C1	Cross-sectional study of 16 villages selected on the basis of key characteristics. An infrastructure index was developed	The most accessible villages had: 1) household income 33% higher; 2) income from agriculture 24%		More accessible villages had: Fertiliser prices 14 lower; 92% more fertilisers used; labour costs 12%		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	based on the generalised cost (of accessibility) to the six most important services in a village. Half of the villages had good, and half poor accessibility.	higher; 3) income from livestock and fisheries 78% greater. The greatest benefits were experienced by poorer households.		higher; 105% more farmland irrigated; 71% more high-yielding variety crops sown; agricultural productivity 32% greater.		
Airey (1991) Kenya A2	Household survey data were collected in 1983, 1986 and 1989 from 12 rural communities situated on feeder roads and tracks in the different agro-ecological zones affected by the upgrading of the					The new road (which was 33 km shorter than the original road) significantly widened the choice of hospitals and catchment area of the different hospitals by shortening journey

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	Embu–Meru road. Regression analysis was used to investigate the incidence of ill health among the sample population, the treatment strategies used and the resultant travel characteristics.					times and costs. Overall transport fares per km, to Chagoria hospital fell by 33% in real terms. Average transport costs (Ksh5) were some 5% of the treatment costs (Ksh101) at fee paying hospitals and 42% of treatment costs at a government hospital (with limited drugs).

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Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Airey and Cundill (1998) Kenya A2	Household panel data were collected in 1983, 1986 and 1989 from 12 rural communities situated on feeder roads and tracks in the different agro-ecological zones affected by the upgrading of the Embu–Meru road. Regression analysis was used to investigate travel behaviour and expenditure of the sample rural households.	Between 1983 and 1986, total household income rose by 45% and between 1986 and 1989 it had increased by a further 23%. These changes were not attributed to the road investment. During the period, there were major fluctuations in both rainfall and world prices of coffee and tea. Prices peaked in 1986.	In 1983, the average trip was 42 km long and cost Ksh17 (Ksh 0.4 per km). By 1989, the average trip was 37 km and cost Ksh14 (Ksh 0.38 per km at 1983 prices). Household travel journeys per month were 1983 : 5; 1986: 11.2; 1989: 8.4. Fares on gravel or earth roads were 60% higher than fares on bitumen surfaced roads. In		In 1983, non-agricultural income accounted for 28% of overall income; however this increased to 32% for both 1986 and 1989.	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
			the wet season, the former rose a further 39% but there was no change on bitumen roads.			
Al-Taiar et al. (2010) Yemen C1	1,044 household subjects. Logistic regression was used. Variations in straight line distance (km), driving distance (km) and driving time (minutes) were analysed.					The greater the driving distance to the nearest health centre, the greater the chance of non-vaccination (OR = 1.48 for >2km, 2.49 for >7km and 1.69 >12km). The greater the driving time to nearest health centre, the greater

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
						the chance of non-vaccination (OR = 1.86 for >10 mins, 2.55 for >17 mins, 1.96 >29 mins).
Buor (2003) Ghana C1	A cross-sectional household survey of 400 people was analysed using regression techniques to determine factors that influenced the use of health services. Transport costs, travel time and distance were considered in the					The correlation between health service utilisation and distance was −0.55, for travel time −0.46, and for travel costs −0.19. For the last three illnesses, the proportion visiting hospital at least once was 94.1% for those living up to 10km away, for

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	analysis.					those 10-15km away it was 72.7% and for those 16+km away it was 51.5%.
Casaburi et al. (2013) Sierra Leone A3	Data were collected from national agricultural surveys (2010) and specific transport and trader surveys (2011/22). A regression discontinuity design was used. Market price data was analysed, together with	Farmers received a 7% increase in net revenues, after transport costs and price changes were taken into account.	Road improvements led to a 59% reduction in motorcycle transport costs per km.	Road rehabilitation significantly lowered the price of cassava in local markets by 17.8%.		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	transport data. Road rehabilitation programme effects were identified through vehicle speeds and transport costs.					
Cervero (1992) Indonesia C1	Data were collected from 275 householders, and 75 villages in Sumatra. Regression analysis was undertaken to see how distance to market affected income and consumption.	For every 10% increase in distance to the nearest regional marketplace, average household consumption fell by nearly 2%.			Off-farm earnings increased when transmigrant households had access to both motorcycles and bicycles.	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Chen et al. (2008) China A2	A study of 2,000 households in 200 villages in poor parts of South West China using 1996 and 2004 surveys. Double-difference, propensity score matching and regression analysis were used. Rural roads were improved (a range of other multi-sectoral interventions were also involved in the project).	Compared with 1996 the household income increase calculated as a result of the project was 182.7 Yuan in 2000, but this had fallen back to 43 Yuan by 2003/4 The study concluded that the null hypothesis cannot be rejected that the long-term average impact on poverty was zero.		Income from animal husbandry increased to 136 Yuan per household in 2000.		

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Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Chomitz and Gray (1996) Belize C3	GIS land use data were digitally coded into 1 km rectangular grids. A spatial logit model was constructed to determine how land use was affected by distance to market, soil characteristics rainfall etc. 'Distance to market' was a function of distance to the nearest road together with different impedance factors			Commercial agriculture (coefficient of -1.99) was much more sensitive to distance from markets than semi-subsistence farming (a coefficient of -0.55).		

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not? 96

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	for road quality.					
Cuong (2011) Vietnam B4	Data from the Viet Nam Household Living Standards Measurement Surveys for 2004 and 2006 were analysed using econometric techniques to determine the effect of improved roads on income and consumption. The key measure of accessibility was the presence of a road open to traffic throughout the	The analysis showed that the presence of an all-weather road increased per capita income by VND 858,000 (2006 figures) or 8.8%. The effect on per capita expenditure was positive but not statistically significant.			Households in a village with a good road were more likely to have more working hours than those without one. The effect was around 37 hours per year.	The analysis showed no significant effect on the proportion attending school.

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	year in the village.					
Dalton et al. (1997) Zimbabwe C4	A cross-section of 65 small holder farmers was drawn from six survey sites. Data were collected during the 1988-89 and 1990-91 crop years. Regression analysis and logistic regression were used Distance from nearest paved road was analysed.		The further the farm was from paved road the higher the probability of draft animal ownership (coefficient was +0.07).	The further the farm was from a paved road, the higher the cost of production (coefficient of the log of distance was +0.07).		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Dercon and Hoddinott (2005) Ethiopia A2	A study of 15 villages, with repeat surveys between 1994 and 2004. Regression analysis was used.			A 10km increase in the distance to a local market town would reduce the likelihood of purchasing fertiliser by 23-34% and reduce the sale of butter (by 23%) and other products. Improving road quality increased the likelihood of purchasing crop inputs by 29-34% and of women selling artisanal products by 39%. But it also reduced the likelihood of		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
				selling sheep and livestock products.		
Dercon et al. (2012) Ethiopia	A study of 15 villages, with repeat surveys between	Access to all-weather roads increased the				

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
A2	1994 and 2009. An econometric growth model was used, and access to an all-weather road was analysed	growth rate by 9% per year. Having a good road reduced the likelihood of being chronically poor (i.e. for a household being in poverty over an extended period of time) by 36%; similarly reducing the distance to a town by 12km reduced the probability of being poor by 35%.				
Dillon et al. (2011) Nepal	Drawing on national living standards measurement	The likelihood of escaping poverty increased by 0.51% for a 10% reduction		In 1995/96, the elasticity of travel time on plot value was -0.26, implying		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
B4	survey data for 2004 and 2006, an econometric analysis was undertaken in which land values, poverty and income growth were analysed. Household travel time to market was the key road-related variable.	in travel time.		that a 10% reduction in travel time would increase plot value by 2.61%. By 2003, the elasticity was −0.47.		
Dorosh et al. (2010) Sub-Saharan Africa, Mozambique C3	A cross-sectional analysis was carried out using an econometric crop-production model based on GIS data,			In East Africa, the elasticity of total crop production to travel time to cities with 100,000 people or more,		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	with national data on road networks, and agricultural output and potential.			was -1.7 (and -0.8 for maize). For Mozambique, the elasticity between crop production and travel time to cities of 50,000 or more was -2.8 (-1.6 for maize).		
Eisenberg et al. (2006) Ecuador C1.	Data and stool samples were collected from 1,312 people in 21 remote villages and the town on Borbón. The samples were tested for rotavirus, E. coli and Giardia. Infection rates were					Villages farther from the road had lower infection rates for all types of diarrhoea than villages closer to the road. The E coli infection rate increased 3-4 times with proximity to the main road and

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	analysed for the relationship with 3 categories of remoteness (close, medium, far), based on travel time and cost to Borbón.					up to 8 times when comparing the most remote with the town of Borbón.
Escobal and Ponce (2002) Peru A1	Cross-sectional data were collected from 2,038 households, covering both treated and non-treated tracks and trails and conventional roads. Regression analysis was undertaken to identify impact.	For road improvements, incomes increased by $122 per year, of which $115 came from non-agricultural waged activities. Track and trail improvements increased incomes by $67, of which $61 came from non- agricultural			Non-agricultural wage employment increased by 9% for the improved conventional roads. There is evidence to suggest that agricultural self-employment declined by 8%.	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
		wages. The analysis suggested that most increases in income were saved rather than spent on consumption.				
Fan and Chan-Kang (2004) China B4	Using provincial-level data from 1982 to 1999, an econometric analysis was undertaken to investigate the returns from expenditure on high- and low-quality roads.	For each 1% increase in high-quality roads, GDP per worker grew by 0.036% while for a 1% increase in low-quality roads, GDP per worker grew by 0.165%. For each additional km of high-quality		For low-quality roads, each additional km generated 0.29 m Yuan of agricultural GDP.	Each additional km of high-quality road yielded 0.73m Yuan of non-farm GDP, while for low quality roads 1m Yuan of non-farm GDP was generated.	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	Road data were based on road length for different categories of worker.	road, 9 rural poor were lifted out of poverty. For each additional km of low-quality road, 22 rural poor were lifted out of poverty.				
Fan et al. (1999) India B4	Using provincial-level data from 1970 to 1995, an econometric analysis was undertaken to investigate the effects of different forms of public expenditure, including roads.	There was an elasticity of -0.066 between poverty and road expenditure. The impact of spending Rs 100bn would be to reduce poverty by 0.87%. Alternatively, 165 people would be				

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	The effects of roads were determined by road length per unit area.	lifted out of poverty per Rs million spent. Of the 8 forms of public expenditure considered, roads had the greatest effect in reducing poverty.				
Fan et al. (2004a) Uganda B4	A range of data (1992, 1995 and 1999) from national, regional and districts was used in an econometric analysis to identify the effects of public expenditure, including roads,	The benefit-cost ratio for feeder roads was 7, compared with 2.7 for education, 0.9 for health and 12.4 for agricultural R&D. Per million shillings spent, the number				

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	education, health and agricultural R&D. The effects of roads were determined by the average distance to the nearest feeder road, and to all-season murram and tarmac roads.	of poor lifted out of poverty were: feeder roads, 33.8; murram roads, 9.7; tarmac roads, 9.73; education, 12.8; health, 4.6; agricultural R&D, 58.4.				
Fan et al. (2005) Tanzania C3	Drawing on the Household Budget Survey (22,178 households) a cross-sectional econometric analysis was undertaken to	Each km reduction of distance to public transport increased per capita income by 13,479 shillings (an 8.5% increase).				

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	investigate the returns on expenditure on education, roads, agricultural research and electricity. To estimate the effects of roads, the household distance to public transport was used.	The benefit-cost ratio for roads was 9.13, for education 9.0, and for agricultural research 12.46. For every million shillings invested in roads 26.5 people were lifted out of poverty. There was a wide diversity of impacts in different parts of the country.				
Fan et al. (2008)	Using national survey of regional	For every million Bhat spent, 19.3				

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Thailand B4	data from 1977 to 2000, an econometric analysis was undertaken to investigate the returns from public expenditure, including roads. Road data were based on the length of rural road per agricultural worker.	poor were lifted out of poverty (1999 costs). Road improvements were less efficient than spending on electricity, agricultural R&D, irrigation or education in lifting people out of poverty. The road cost-benefit ratio could not be calculated. This gave very different results from the 2004				

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		study (Fan et al. 2004b).				
Gachassin et al. (2010) Cameroon C3	Drawing from the National Household Survey of 2001, a three-stage regression analysis was carried out to identify the impact of proximity to a paved road; this included binary variables relating to the activity of the household head.	Once the occupation and activity of the household head was taken into account, proximity to a paved road was not a significant factor in explaining poverty.				
Hettige (2006) Indonesia, Sri	A cross-sectional study using participant recall	58% of the control group and 47% of the project group	Project households reported an average of 12		To increase income, control households would look to	For basic needs 53% of the control and 76% of the project

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Lanka, Philippines A1	involving 457 house-hold interviews from 6 road rehabilitation project areas in 3 countries. The study provided useful detailed descriptions of how the improvements had affected peoples' lives.	reported no change in income, while 23% of the project group reported less income from agriculture and more from other sources, against 14% of the control group.	external trips per month, with an average of 40 minutes per trip. Control households reported 9.9 external trips per month, with an average of 109 minutes per trip.		expand agricultural production (29%) or raise small animals (22%), while project households would find employment locally (7%), or expand a small business (25%).	households would access a hospital or dispensary, while 14% of the control and 7% of the project households said they would stay at home in cases of poor health or emergency. 50% of the control and 32% of the project households would walk for treatment.
Hine et al. (1983a) Ghana C1	Cross-sectional data were collected from 491 households in 33 villages in Ashanti Region.		Variations in transport costs were very small in relation to commodity prices.	For existing connected villages, cocoa, maize and food crop sales and animal husbandry	Labour input into farms and farm size significantly increased with inaccessibility.	No significant relationship was found between education levels and accessibility.

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	Regression analysis was carried out to identify the impact of changes in accessibility – principally determined by transport costs to the district centre and regional capital, Kumasi.		By subtracting transport costs from the farm-gate prices, it was estimated that the decline in farm-gate prices for maize and plantain for a 100km vehicle journey would be just 6.5% and 5.2% respectively.	were not significantly affected by distance to the main markets. Cocoa and maize yields and extension contact were not significantly affected by transport costs. However agricultural finance, and cassava sales were significantly adversely affected.		
Hine et al. (1983b)	Cross-sectional data were collected from		A 50km road improvement of an	An analysis of market prices in 16		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Ghana C1	491 households in 33 villages in Ashanti Region. Market price data and wholesale transport charges were collected from the Ministry of Agriculture. The data were analysed to see how transport costs affected farm-gate and market prices.		accessible road will increase farm-gate maize prices by 0.8%, and for 5km, 0.08%, while a 5km change from head-loading to vehicle transport will increase farm-gate prices by 11.4%. So basic vehicle access is crucial for agricultural development.	different market centres at the same time showed considerable variation that could not be accounted for by transport charges. In Ashanti Region, transport charges accounted for just 6-10% of the difference in maize prices between the lowest- and highest-priced markets.		
Jacoby (2000)	Using national survey data from 4600 households in	A 10% increase in (walking) travel time reduced		A 10% increase in (walking) travel time reduced land		

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Nepal C1	1995/6, a cross-sectional regression analysis was undertaken to determine the factors influencing plot values and agricultural wages. Accessibility was measured by reported walking travel time to market centres and agricultural cooperatives.	agricultural wages by 0.5%. Extending road length to all households in the sample would raise real incomes by an average of 10% and by 6% for median.		values by 2.2%.		
Jacoby and Minten (2009) Madagascar	This was a cross-sectional econometric study of 1,761	The most remote households were the poorest and had most to gain				

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C1	households, zoned by remoteness in 2005 and 2006. A hypothetical transport cost analysis was carried out. Variation in transport distance and costs from Antsirabe town was analysed.	from lower transport costs. If the transport costs of the most remote households were reduced by around 75 USD/ton, this would raise their incomes by about 50%.				
Jamal (1995) Pakistan C3	Data were drawn from a cross-sectional survey for 1986/7. An econometric analysis was carried out to determine				The average distance to market for households with no member in an off-farm job was 9.2km but it was 8.5km for	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	off-farm work participation. Accessibility was measured by the distance to the nearest market.				households with someone in an off-farm job.	
Jenkins and Cairncross (2010) Benin C3	521 village records across Benin were analysed for latrine diffusion. Logistic regression and spatial analysis were undertaken Road and urban proximity were measured					If the village was located within 2km of a paved road, there was a 60% increase in the chance that the village would have one or more latrines.

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Khandker and Koolwal (2011) Bangladesh A2	Surveys were carried out in 1997, 2001 and 2005. An econometric analysis was carried out to determine the effects of upgrading roads for two road programmes (RDP and RRMIMP).	The overall long-run effect on per capita expenditure was an increase of 7.9%, with larger short-run increases of 14.6% or 19.5 depending on the model applied.	The long-term savings in transport costs per trip were around 32%.	There were no significant long- or short-term changes in agricultural output.	Estimated from the previous month, there was a long-term decline in agricultural employment of 20-22% and an increase in non-agricultural work of 14-17%.	
Kingombe and di Falco (2012) Zambia A4	Using national agricultural data from 1996/7 to 2001/2, a regression model of cotton productivity was used, with a double-difference			It was estimated that the average cotton yield increased by about 6% due to improved rural transport infrastructure development. But		

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	approach. Based on variations in district characteristics, cotton production was related to the Eastern Province Feeder Road Project.			the coefficient was both fairly small and statistically insignificant.		
Kunstadter et al. (1992) Thailand C2	A sample of 1,014 households was analysed using a correlation coefficient test. Variation in access distance was assessed.					The number of modern birth attendants per community was strongly and significantly associated with distance to hospital (r= −0.775) and dry season travel time to hospital (r=

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
						−0.640).
Levy et al. (1996) Morocco A1	189 household interviews involving participant recall were carried out in 1995, covering 3 project roads and 3 controls.		Truck tariffs declined from 300Dh to less than 150Dh once the road was open. From 1982 to 1995, traffic growth on project roads was 23.8%, 4.8% and 10.3% per year. There was no road closure; previously, the roads were closed per year for 90 days, 60 days and for the rainy season respectively.	A shift to fruit trees and high-value vegetables was reported. Fruit yields increased by 31%.		For project zones, there was a 163% increase in girls going to school. Other data suggested that roads had a big impact on education: women didn't have to collect firewood because butane gas could be distributed by vehicle.

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Lokshin and Yemtsov (2005) Georgia A4	National survey data and a specific study of comparison communities were used. A regression analysis was undertaken to investigate the impact of investment in schools, roads and water systems.		There was a 36 minute reduction in travel time to the District Centre for the road treatment group, compared with a 27 minute reduction for the control group (not statistically significant).	The share of villages reporting barter exchange dropped significantly in project villages, but increased in control villages.	The share of villages with small and medium enterprises significantly increased in project compared with control villages.	Time for an ambulance to arrive decreased in 23% of the beneficiary villages compared with an increase in this indicator in control villages.
Mazlumolhosseini (1990) Philippines C1	The household sample size was 1,002. A chi-squared test for independence		As accessibility increased, the share of trips by car, taxi, bus, Jeepney or trimobile rose sharply. The share		As accessibility increased, the proportion of households engaged in farming activity decreased.	

Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
	was carried out. The accessibility index of villages (rated 1 - 4) was assessed.		of trips by walking fell dramatically.		This suggested that other income-earning opportunities had opened up.	
McCray (2004) South Africa C1	327 samples from a thesis were added to 646 samples from another study. Discrete choice modelling was used. Variation in travel time was analysed.					An increase in travel time decreased the chance of attending a health-care clinic.
Mogues et al. (2008)	Regional-level data from 1993/4 to 2000/1 was used in	A 1% increase in road density (1,000km per				

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Ethiopia B4	an econometric analysis to identify the effects of public expenditure, including roads, education, health and agricultural R&D. The effects of roads were measured as km per 1,000 people.	person) led to an 0.066% increase in household consumption. A 1 Birr increase in spending on roads led to increases in consumption of 12 Birr in Amhara, 14.5 Birr in Somale and a 2.5 Birr **reduction** in SNNPR (all significant coefficients).				
Mu and van de Walle (2007) Vietnam	A study of 3,000 households in 200 communes, using surveys in 1997,	Some evidence was found that poorer communes experienced greater positive impacts.	Ownership of bicycles significantly increased for 6% more households relative to	Available markets and market frequency were greater in project	For project villages there was a 2% decline in households relying on farming and a	For project villages there was a 30% increase in primary

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A2	2001 and 2003. Double-difference, propensity score matching and a multiple indicator multiple cause (MIMIC) model were used. Road rehabilitation and construction were analysed.	But if commune characteristics were controlled for, consumption was no longer a significant predictor of road impacts.	comparison areas. No impacts were found in transport services, but significantly more project households rented or borrowed motorcycles.	communities. Although there was a range of initial differences in the availability of different goods (rice, green beans, pork etc.) these advantages were short lived. No impacts were found on land markets.	0.8% decline in households relying on forestry, but a 1.7% increase in those relying on service-sector income. The probability of men and women's hairdressing services rose by 14 and 20% respectively.	school completion rates and a 7% increase in secondary school enrolment.
NORC at University of Chicago (2013) Honduras A2	A nationwide household survey was carried out in 2008 (1,600 interviews) and	The analysis indicated that total net household income per year in the country rose by			Per household income from agricultural employment rose by 71.9 lempiras	For each household in the country, travel costs to hospitals and health centres fell by 3.52

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	repeated in 2011. This was supplemented with traffic surveys. Data were analysed to determine the national impact (on each household) of upgrading 107km of main, 495km of secondary and 459km of rural roads. A continuous travel time variable was used to identify the effects of road improvements.	692m lempiras (US$ 35m) as a result of the $125m project. But the results were not significant.			while non-agricultural employment fell by 109 lempiras.	and 0.194 lempiras respectively.

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Study Country Data categorisation*	Approach Road network/ transport change	Income, poverty and consumption change	Change in traffic and transport costs	Agricultural and marketing change	Employment change	Education and health change
Olivia and Gibson (2009) Indonesia C4	National survey data for 1993 and 2005 were used from 3,951 households in 130 villages. Cross-sectional and historical, econometric analysis was undertaken. Road quality was recorded.				Upgrading the local road increased the likelihood of a household being engaged in a non-farm employment (NFE) by just over 4%, i.e. one-tenth of the mean NFE participation rate.	
Orbicon and Goss Gilroy (2009) Nicaragua	A survey was undertaken in 2009 (796 observations) with a reconstructed		For treatment communities traffic intensity increased: cars by 389%, bicycles 319%,	Land values increased by 262% for treatment communities while they rose by 228%	There was a net 17% increase in employment for treatment	An increase was reported in the number of latrines in treatment communities, from

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A1	baseline from 2005, for 31 municipalities and 110 communities. Propensity score matching and double-difference were used. Road rehabilitation was analysed.		buses 312%,	for the comparison communities. The number of crops grown for market reduced from 3 in 2005 to 2 in 2009 for both treatment and comparison communities.	communities.	81% to 94%, while in the comparison communities, they increased from 84% to 87%. There was a net difference of 5.9 minutes per km to walk to the closest health centre.
Owuor et al. (2007) Kenya C1	Household surveys of 600 rural smallholder farmers were conducted in 2006. Probit modelling was used and distance to market	Distance to market was not significantly linked to the probability of living in poverty (measured as the average adult income in a				

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	(km) was recorded.	household of less than US$ 1 per day).				
Porter (1995) Nigeria A2	3,800 interviews were held in Borno and the Jos Plateau from 1977 to 1991. The study presented a mainly qualitative analysis of the effects of road construction on market development and decline and the effects on women market traders.		In Borno, 91% of women travelled on foot, compared with 49% of men. In both areas, men travelled further and were more likely to travel by vehicle.	In Borno, between 1977 and 1984, 7 of 35 markets collapsed. In the 5 of the 'off-road' cases the collapse was because of a lack of water or a reorganisation of settlements with the pull of migration towards the main roads. In the Jos area, the 'off-road' markets were stagnant or in decline. The largest	In Borno, remote village populations declined as inhabitants migrated to the roadside.	

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				markets were all roadside and the markets identified as growing were, with 2 exceptions, located on all-weather roads. The impact of market loss was particularly substantial for women, given their tendency to concentrate activity close to home.		
Porter (1997) Nigeria	The study drew on 804 interviews in the Jos Plateau area. A mainly		Vehicle services had declined in 'off road' markets since 1980. In one	The contraction of 'off-road' was particularly serious for small growers		On the Plateau, declining accessibility in off road areas was

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A2	qualitative analysis presented the issues facing 'off-road' communities.		market, only 4-5 vehicles came on market day, and on non-market days during the rains, no vehicles visited because of the poor state of the route. In another village, sometimes no vehicles arrived, even on market day.	and those with restricted mobility, and the reduction of locally available incentive goods may have contributed to lower agricultural production.		accompanied by a deterioration in community services. In Barakin Choji, a school building collapsed in the late 1980s and teachers were posted elsewhere. Children then had to travel 8km to a to school in a roadside settlement in the dry season when access was possible.
Ruijs et al. (2004) Burkino Faso	A range of data sources was used for the study, including national		A reduction in transport costs by 25% implied that cereal transport	If transport costs decreased by 25%, consumer grain prices in the largest		

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B4	household and farm data. A multi-period and spatial price equilibrium econometric model of grain marketing was used. Transport costs on different components of the road network were used in the analysis.		flows would rise by just 1.2%.	shortage region (Sahel) decreased by only 2.5%. If both transport and transaction costs fell by 25%, consumer grain prices would fall by 0.4% and producer grain prices would rise by 3.3%, on average. Improving only part of the road network may give unintended negative consequences to consumers (higher prices) in shortage		

Does the extension of the rural road network have a positive impact on poverty reduction and resilience for the rural areas served? If so how, and if not why not? 131

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				regions and to producers in surplus regions who may lose their competitive position.		
Smith et al. (1999) Uganda C1	Hypothesis on roads with different access levels (measured as an index) were tested, and changes to HIV levels were investigated. The access levels compared were trading centres on main roads, intermediate trading villages on					The incidence of HIV in communities in intermediate trading villages was 1.9 times higher than in rural agricultural villages with little or no road connection. The incidence of HIV in communities in trading centres on main roads was 3.3 times higher

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	secondary roads and rural agricultural villages with no road or a minor road. A total of 3,102 people were surveyed, including 1,397 women and 1,705 men.					than in rural agricultural villages with little or no road connection. The results were statistically significant.
Sterne et al. (1995) Malawi C2	The incidence of leprosy was studied in Karonga District between 1979 and 1989. Over 100,000 people were initially examined and a follow up surveys made. 332					The incidence of leprosy was found to significantly rise with increasing distance to the main road. Controlling for age, sex, BCG, schooling housing and other

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	people were diagnosed with leprosy. The incidence of leprosy was related to different factors including distance from main roads.					variables the incidence rose by more than 7-fold comparing those who lived adjacent to the road compared with those living more than 10 km away.
Stifel et al. (2003) Madagascar C3	Data were drawn from a sample of 5,080 nationally representative households in 2001. Econometric analysis, estimation of production function and input demand function,			Improvements in feeder roads that provided a 17% reduction in travel time resulted in a 1% increase in rice yield. Improvements in trails that provided a 3% reduction in		

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	and simulation of model results were undertaken. Reduction in travel time was analysed.			travel time resulted in a 0.2% increase in rice yield.		
Stifel et al. (2012) Ethiopia C1	A study of data from 851 households in 5 zones at different distances from a market town was undertaken. An experimental model was used to estimate the benefits from reduced transport costs, based on transport demand	Reducing transportation costs by US 5 cents/kilo for the most remote households would result in benefits worth roughly 35% of household consumption.	It was estimated that a hypothetical gravel road (at Birr 1 million per km) that reduced travel costs by half would have an IRR that ranged from 27% for a 7km road to 14% for a 35km road, assuming that consumption and agricultural benefits were taken into			

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	and agricultural output. Most of the area did not have direct access and relied on donkey pack transport for moving goods.		account.			
Swenson et al. (1993) Vietnam C3	A sample of 4,807 from national surveys was analysed using logistic regression. Distance from nearest clinic or hospital (whether <10km or => 10 km) was assessed.					The presence of public transport in a rural village was associated with a significantly lower mortality rate for children. However, distance to the nearest clinic or hospital was not significant

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						independent of other variables, suggesting that distance may not be a deterrent if people have the means to reach a clinic or hospital with an ill child.
Tanaka and Munro (2013) Uganda C2	Data were analysed from 1,289 household surveys conducted in 2003, 2005 and 2009. Risk games and regression analysis were used. The presence of a			Villages with tarmac roads to the district town had greater risk aversion and lower loss aversion. For villages with tarmac roads, the proximity of the district town also correlated with a		

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	tarmac road from the village to the district town and proximity to the district town (distance) were recorded.			lower discount factor but greater risk aversion.		
Warr (2005) Laos B4	Using national expenditure and consumption surveys for 1992/3, 1997/8 and 2002/3, a regression analysis was undertaken to identify how per capita expenditure varied with road access. Three classes of access	Between 1997/8 and 2002/3, rural poverty declined by 9.5%. 13% of the decline can be attributed to improved road access to areas already having dry season access. However, 31% of rural households				

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	were identified: no access, dry season access, and wet and dry access.	were without any road access, and by providing just dry season access, poverty could be reduced from 33% to 29.7%. A further 26% reduction could be achieved by providing all rural households with all- weather access.				
Wawer et al. (1991) Uganda C2	1,292 people aged over 13 were tested for HIV in 21 clusters in Rakai district. The results were					HIV seroprevalence was 38.5% in the main road trading centres, 25.4% in the trading villages and 8.6% in the

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	analysed by regression to determine how accessibility affected the incidence of HIV. This was defined in terms of a main trading centre, a rural trading centre and a rural agricultural village.					agricultural villages.
Wondemu (2010) Ethiopia A2	A sample of 1,927 from surveys conducted in 1989 and 1994 was analysed using regression analysis and income model	Households that have access to all-weather roads generated 90% greater income generally (38% of this was due to productivity gains,		Improving road access from bad to good could produce a 27% increase in agricultural output. Households that had all-weather		

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	construction. Access to all-weather roads was assessed	62% to resource endowment gains). Moreover, the poor benefited disproportionally.		road access were more likely to use fertiliser (93%) than households with bad access (36%).		

ABBREVIATIONS AND ACRONYMS

BCR	Benefit cost ratio
CFA	West African CFA Franc
DD	Double Difference
DFID	Department for International Development (UK)
Dh	Dirham
GDP	Gross domestic product
GIS	Geographic information system
GMM	Generalised methods of moments
GNI	Gross national income
HDM4	Highway Development and Management Model
HIV	Human immunodeficiency virus
IDA	International Development Agency
LMIC	Low- and middle-income countries
IFPRI	International Food Policy Research Institute
IRI	International roughness index
IRR	Internal rate of return
Km	Kilometre
NGO	Non-governmental organisation
NORC	National Opinion Research Center (University of Chicago)
PICO	Population, intervention, comparators and outcomes
PSM	Propensity score matching
RAI	Road Accessibility Index
R&D	Research and development
RCD	Regression continuity design

RED	Road economic decision model
SNNPR	Southern Nations Nationalities and Peoples (Ethiopia)
SR	Systematic review
TOC	Theory of change
US$	United States Dollar
Yr	Year