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ABSTRACT:

Rural roads are often the poor cousins in the road sub-sector, despite comprising the majority of the public road network, representing a considerable public investment. They have a profound impact on the quality of life for the significant rural population and economy; and directly impact urban citizens too, influencing the availability and price of many basic commodities. Rural roads have important economic, social, political, environmental and equity consequences that no successful country can ignore.

However, attracting and retaining the quality of professional staff required is challenging and funding is frequently woefully inadequate, exacerbated by weak planning due to inadequate data about these rural road assets.

Based on projects undertaken in Myanmar from 2016 and in Cambodia in 2018-9, the RoadMark system was developed to address the shortcomings common in managing rural roads, which were inadequately addressed by other existing systems. RoadMark provides:

- The ability to capture basic inventory and condition data for all the key types of road assets, using only a GPS-enabled Smartphones, thereby avoiding the requirement for specialised and expensive equipment and its ongoing servicing;
- Fast survey speeds (important for large rural networks);
- Minimal training, (avoiding reliance on specialised or expensive experts);
- No requirement for any network referencing system to be established beforehand;
- Ability to monitor surveys remotely;
- Surveys that require no internet or mobile signals, (often problematical in rural areas);
- Ability to map flexibly, all road assets;
- Permanent availability of data and use in other applications;
- Cost-effective, inexpensive and flexible licensing options.

Introduction to the RoadMark System: Low Cost, Fast & Flexible Data Collection for Rural Roads

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1. INTRODUCTION

This paper describes the significant benefits possible to road managers, from using a simple, low cost data collection system (RoadMark), to collect basic inventory and condition data about poorly defined road assets. This paper describes:

- How the system has been designed to accommodate the institutional and organisational weaknesses commonly found in the management of rural roads in many developing countries;
- The results from the system's use on rural roads in Myanmar and Cambodia;
- Examples of the much improved strategic network plans and budgeting developed using the data collected; and
- Examples of the reports and mapping that can be produced using the data, greatly assisting road network managers and funding agencies to better assess their network's needs and for network monitoring.

2. BACKGROUND

2.1. The Importance of Rural Roads

Rural roads are frequently viewed as the poor cousin in the roads sub-sector, receiving far less attention, funding and resources than National roads and even urban roads, where political pressures for improved road infrastructure are often greater. However, rural roads usually represent the majority of the public road network in any country by length; and they act as essential lifelines connecting the large rural population to cities, markets and government services.

Even where governments claim to understand their importance, their focus is frequently on the expansion of the rural road networks, with inadequate support to their subsequent maintenance and management. As any competent road manager knows, this represents a poor use of the substantial amounts of public resources invested in these road assets. Rural roads (and especially their maintenance) are politically unattractive: decision makers and funding agencies are often more focussed on other more urgent and higher profile causes instead. Nevertheless, the underlying realities of rural roads and their needs remains.

2.2. The Challenges Facing the Management of Rural Roads in Many Countries

Unfortunately, those institutions responsible for managing rural roads do not help themselves. Too often, their requests for funding are poorly justified and/or are insufficiently based on objective criteria. Similarly, their accountability is equally weak. In turn, this automatically presents potential funding agencies (e.g. Ministries of Finance) with a problem, as they too are unable to justify their decisions and have inadequate assurances about how their funds are being used. It is therefore easier for them to allocate funds elsewhere. Meanwhile, the state of the rural road assets continues to deteriorate from a lack of planning, inadequate funding and a poor allocation of the resources that are available.

Objective data about the rural road assets is the very basis for providing any sufficiently justified budget request; and for providing sufficient justification for any rural road expenditures. And yet too often, rural road agencies do not even have definitive inventory information, such as the extent of their road assets (e.g. how many kilometres of paved and unpaved roads they have), nor have any reliable details about their bridges or

culverts; let alone any objective information about their current condition. Very often, these road assets are not formally gazetted and are unreferenced.

These problems are compounded by weak technical capacity, especially in the more remote, local offices (where any knowledge about the rural roads should be better than in regional or national offices). Attracting the skilled staff necessary to manage these rural road assets is a constant problem and competent staff are often attracted to better opportunities elsewhere. Access to working, specialised equipment (and knowledge about how to use it) is also often very limited and its maintenance is frequently not adequate, due to a lack of funds and organisational capacity.

Addressing these challenges effectively takes a long time, sustained commitment, funding and effort. Meanwhile, the local road assets continue to deteriorate from inadequate maintenance.

3. REQUIREMENTS FOR ANY DATA COLLECTION SYSTEM

For road managers, the starting point is to clarify the size of the current maintenance needs, based on the actual situation on the road network. This is the very basis for their competent management and provides a strong justification for any budget requests to meet these needs. Achieving this requires collecting and analysing data about these assets on a regular basis. Unfortunately, rural road networks are often extensive. With the often limited local technical, organisational and financial capacity available, even rudimentary data collection in a systematic and consistent standard (and at the necessary frequency) is often not undertaken as extensively as required. This significantly undermines the credibility of any plans and budget estimates made.

To maximise the likelihood that this necessary task will actually be carried out to necessary standards and frequencies, several conditions need to be in place:

- Data collection needs to be kept as simple as possible, so that it can be undertaken by local staff, who are frequently not specialised nor trained road engineers nor technicians.
- Where staff from local administrations are not available, external companies could be used instead, but consistent standards and survey monitoring is required to ensure acceptable delivery.
- Data collection also needs to be as fast as possible, to minimise the logistics and cost involved in undertaking the surveys, especially on such extensive networks.
- The need for specialised or expensive equipment or highly skilled or trained staff must be minimised, as these are simply unaffordable, unsustainable and unrealistic, given local constraints.
- The availability, reliability and cost of high capacity or high speed internet or mobile phone signals is often limited or non-existent in rural areas.
- Road managers need to know about all the relevant assets associated with their rural roads, including bridges, culverts, drainage and (perhaps) street furniture, local land use and so on. All these features about their rural roads are relevant to the cost of providing safe rural road access.

Traditionally, data has been collected manually, using paper based forms. However, this is relatively slow, prone to errors (and falsification) and difficult to verify or monitor. It also requires transferring the data into a computer system for subsequent analysis, which is both very time-consuming and prone to transcription errors.

Modern Smartphones offer a much more flexible, robust and readily available way to capture data about the road assets, to a consistent standard, which can be more easily managed, monitored and analysed. The RoadMark system which has been continually developed since 2015, was originally developed to address these specific challenges common on rural roads. It has subsequently been trialled in Myanmar and Cambodia.

4. APPROACH ADOPTED

Road management and the data needed to support it, can be immensely complex and expensive. This is frequently beyond both the financial and technical capacity of many rural road agencies. RoadMark has been developed in an attempt to provide a sustainable and affordable approach, achieving many of the most important benefits with minimal effort, (known as the 80:20 rule or Pareto principle).

The primary purpose of the RoadMark data collection software is to provide rural road managers with a quick, network-wide assessment of the extent and basic condition of their road assets, to a level sufficient to develop

medium term strategic plans and budget estimates. This includes other non-carriageway road assets (avoiding the need for separate surveys), giving road agencies a comprehensive assessment of the overall requirements for the network. These can then be reflected in the plans and budgets developed.

The level and accuracy of data collected by the RoadMark system is not therefore generally adequate for detailed designs or for Bills of Quantities to be developed: this level of accuracy and detail would be onerous for the extensive size of most rural road assets. However, it does help to locate specific projects for inclusion in annual Works Programmes and thus, specific areas where more detailed assessments might be necessary for these works. This approach helps scarce resources to be better focused and utilised by road managers.

The system also provides managers, non-technical decision makers (and the general public) with a wide range of reports and mapping options, giving a far greater understanding about the current status of the rural road network than is often currently available. These reports and maps can incorporate any or all of the road features surveyed.

When analysing and interpreting the data collected, the overall approach is to keep this as simple, as flexible and as transparent as possible, allowing local road managers to see and understand how the data they collect is reflected in their plans, budget and annual work programmes. Only the database management functions are protected (within RoadMark Analysis, RMA), as it is the most critical area to avoid accidental data corruption and loss. Nevertheless, all the data stored within the RMA database management system is fully available to local road managers in perpetuity.

Although it could be used for other road types, such as urban or national roads, RoadMark was primarily designed to be used on rural roads, where motorised traffic volumes are generally low (and are therefore of lesser importance in determining what actions to take).

4.1. Condition Ratings

Basic condition categories can be recorded for each type of road asset surveyed. These are deliberately kept as simple as possible to facilitate survey speeds and understanding, whilst minimising subjectivity. In Cambodia and Myanmar, each condition category (e.g. Good, Fair, Poor or Bad) was based on the estimated severity (i.e. cost) of any actions that would be required within the next 12-18 months, to restore the road asset into a “Good” condition. This approach was fast and relatively easy for non-engineering surveyors to understand and use. It significantly simplifies subsequent analysis and allows an estimate of the assets’ current values to be made (and compared to their “As new” value), providing important and worthwhile indicators for the overall condition of the rural road assets.

4.2. Asset Referencing & Road Sectioning

In many countries, the rural road assets often lack any consistent or widespread referencing system, providing unique reference numbering for each road asset. This is a major problem for storing data about these road assets, where a common referencing system is needed to cross-reference the assets and to compare data over time. Unfortunately however, establishing and implementing any systematic and widely used referencing system for such an extensive network is a major task, requiring long-term, high level and consistent commitment to implement across all types of rural road assets.

RoadMark does not require any referencing system, allowing surveyors to travel to any part of the network and start recording data straightaway. The system assigns unique references internally and all non-carriageway data is associated with the road along which the data is collected.

The carriageway is segmented using a combination of fixed and flexible criteria, providing maximum flexibility in dividing up the carriageways into homogeneous sections:

- Fixed criteria (which are flagged by the surveyor during the surveys), are those points along a road where certain rarely changing conditions occur, such as a change in road class, geometry or surface type, the presence of an administrative boundary, intersections or changes in adjacent land use.
- Flexible criteria (which are again indicated by the surveyors onsite) occur when there is a change in the condition of the carriageway.

Unfortunately however, the lack of a common referencing system (particularly for the carriageways) means that it is currently not possible to cross-reference specific parts of the network, from one year to the next. (An overall assessment of how the network's asset groups change over time can be made however.) Consequently, it is currently necessary to re-collect all the relevant data each year. However, because the surveys are kept as simple (and as fast) as possible, this additional requirement is not significant, given that condition data needs to be re-collected on a regular basis anyway. See also comments below (under future developments).

4.3. Recording Lengths & Dimensions

The RoadMark system calculates road lengths automatically, using the GPS coordinates that are continually recorded along each road. This is accurate to within about 3 metres and avoids the need for surveyors to measure any road lengths manually.

Based on feedback from pilot surveys, road widths are recorded as the number of traffic lanes possible (each being 3 metres wide), as this was deemed to be easier to estimate onsite.

Bridge dimensions (e.g. span length, footpath and deck widths) need to be measured (or estimated).

4.4. Scalability and Organisation of Data Collection

RoadMark is only a tool to allow road agencies to carry out their primary tasks more efficiently and effectively. It was therefore designed to mirror and accommodate how the road agency wishes to manage its functions. For example, road data could be collected locally or by external consultants, managed regionally and/or analysed centrally.

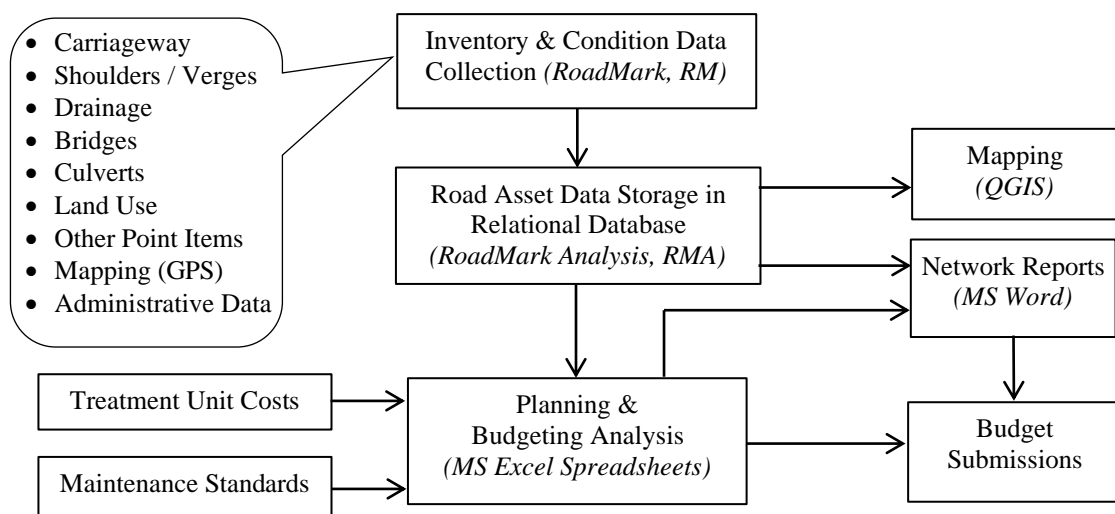
One weakness common in many road management systems has been that those expected to collect road data differ from those using this data. Those collecting the data therefore have no interest in the data they are expected to collect. RoadMark can however, be used at the most local of levels if desired, minimising this risk and promoting decentralisation.

Over time, the amount of data collected and stored is likely to grow significantly. RoadMark has been designed to be scalable and to manage multiple databases, in order to reflect these changing needs of road managers.

5. KEY FEATURES OF THE ROADMARK SYSTEM

Figure 1 shows the basic structure of the RoadMark system and how it can integrate with external applications.

Figure 1: Basic Structure of RoadMark System & Interactions with External Applications



RoadMark itself comprises of two key modules:

- The **RoadMark smartphone application**, which allows users to collect inventory and basic condition data about a wide range of road assets:
 - **Carriageway** (pavement type, width, administrative data, condition, dual or single);
 - **Shoulders** (type, width, condition);
 - **Culverts** (Type, size and condition);
 - **Longitudinal drainage** (type, condition);
 - **Bridges** (including type, dimensions and condition for the key components: substructure, superstructure, parapets, carriageway and footpaths);
 - **Other point items** including signs (type and condition), trees, access points (driveways), intersection, schools, markets, major structures and river crossings;
 - **Adjacent land use** (for each side) including any corridor restrictions (e.g. buildings and water features), and earthwork details.
- The **RoadMark Analysis (RMA) Windows10 application**, into which collected data is stored securely.

6. PILOT SURVEYS

In surveys undertaken on rural roads in Myanmar and Cambodia (covering a total of approximately 1,000km), the data stored in the RMA application was exported and analysed in Excel, to develop simple strategic network plans and budget estimates. This data was also mapped using the freely available, cross-platform QGIS software, (the data can also be imported into other common GIS applications).

These projects have provided valuable feedback that has guided subsequent developments of the system. The main findings from the surveys were:

- Training (which was provided onsite – any nearby roads can be used), only required a few hours before local surveyors (many of whom spoke limited English) were sufficiently familiar with the main features of the Android Smartphone App.
- The application was considered to be very easy to understand and use.
- Surveyors only required a GPS-enabled Android Smartphone and a vehicle/motorcycle, both of which are widely available, even in remote rural areas.
- Survey teams usually consisted of one surveyor and one vehicle operator only.
- Survey speeds varied (depending on the operator and the number of road features to be recorded on the network) but averaged between 15-20 kph.
- No local internet or mobile phone signal was required to use the RoadMark application, only a GPS signal.
- The application worked well, even if the data collection surveys were interrupted (for example from an empty battery or incoming call). The application was reliable and stable, storing the recorded data safely on the Smartphone (for later transfer).
- Data requirements were very small (about 10-15kb per kilometre surveyed), making the transfer of data from site to remote head office (as email attachments), simple and fast, even when internet connectivity was poor.
- All the data was time and date-stamped and geolocated, avoiding any falsification of the data. This also allowed survey managers to easily monitor and manage the data collection surveys. (RMA provides a report summarising the surveys carried out).
- The importation of survey data into the database application was fast and simple. This worked well, even when located in a different country to where the surveys were undertaken. (A batch loading option has been added subsequently.)
- A progressively larger number of reports and data outputs have been included from RMA, to increase the range of data analysis options available.
- Database integrity worked well and was scalable. (An ability for the user to switch between different databases has been provided subsequently.)

7. ANALYSIS OF DATA

The data collected during the surveys was exported from the RMA database and used to develop:

- Needs-based network maintenance plans (by asset class, administrative area, type of works, etc.);
- Budget and maintenance backlog requirements (using the same categories above);
- Development of various key performance indicators (KPIs), including an estimate of the network's current (and optimum) values and various condition indices;
- Sensitivity testing, to identify the impact of changing treatment standards and unit costs on the overall budget and works volumes.

Figure 2: Example of Current Surveyed Network Summaries

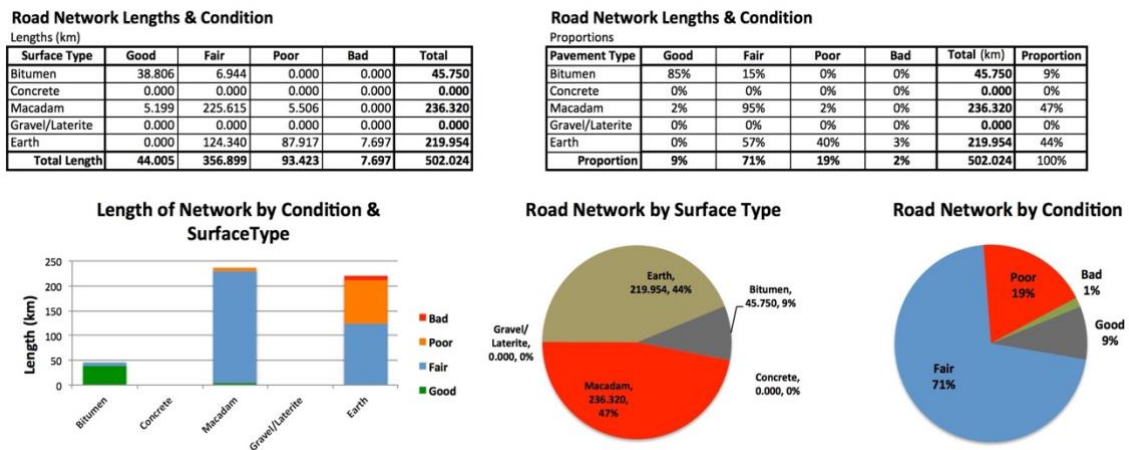


Figure 3: Development of Scheduled and Backlog Maintenance Requirements

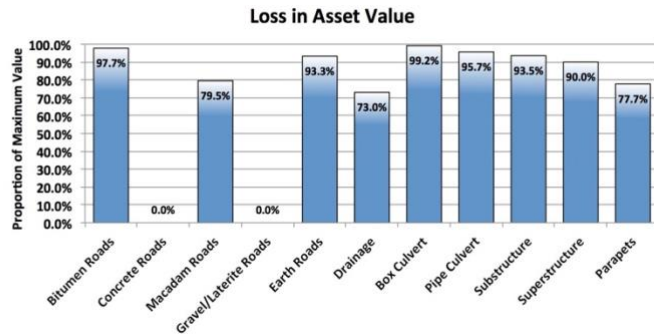
Overall Summary of Estimated Budget Needs per Year

Expenditure Item	Asset Type		Scheduled Costs	Backlog Costs
Paved Roads				
Routine Maintenance	Bitumen Roads	US\$	18,300	0
Routine Maintenance	Concrete Roads	US\$	0	0
Special Maintenance	Macadam Roads	US\$	315,093	0
			US\$ 333,393	0
Paved Roads in Good Condition				
Surface Treatment	Bitumen Roads	US\$	91,500	12,660
Surface Repairs	Concrete Roads	US\$	0	0
Surface Treatment	Macadam Roads	US\$	1,102,827	3,409,473
			US\$ 1,194,327	3,422,133
Paved Roads in Fair Condition				
Overlay	Bitumen Roads	US\$	183,000	0
Special Overlay	Concrete Roads	US\$	0	0
Overlay	Macadam Roads	US\$	1,417,920	0
			US\$ 1,600,920	0
Paved Roads in Poor Condition				
Rehabilitation	Bitumen Roads	US\$	0	0
Rehabilitation	Concrete Roads	US\$	0	0
Reconstruction	Macadam Roads	US\$	0	0
			US\$ 0	0
			US\$ 3,128,640	3,422,133
Unpaved Roads				
Routine Maintenance	Gravel/Laterite Roads	US\$	0	0
Routine Maintenance	Earth Roads	US\$	24,745	0
Regrading	Gravel/Laterite Roads	US\$	0	0
Regrading	Earth Roads	US\$	6,186	12,465
Regravelling	Gravel/Laterite Roads	US\$	0	0
Regravelling	Earth Roads	US\$	54,989	32,929
Rehabilitation	Gravel/Laterite Roads	US\$	0	0
Rehabilitation	Earth Roads	US\$	0	230,910
			US\$ 85,920	276,303
			US\$ 3,214,560	3,698,437
Drainage Maintenance Costs	Drainage	US\$	393	52,556
Culvert Maintenance Costs	Culverts	US\$	6,858	2,600
Bridge Maintenance Costs	Bridges	US\$	15,078	115,075
			US\$ 3,236,888	3,868,668
			US\$ 3,236,888	455,650

Figure 4: Example of Asset Values Reporting Possible from RoadMark System

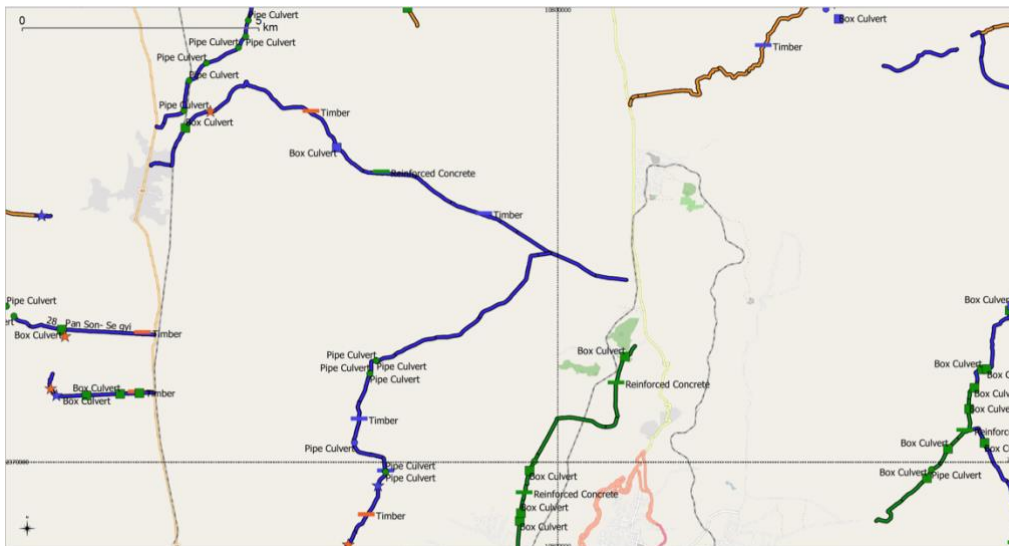
Asset Values

Asset Type	Replacement Value US\$	Current Value US\$	Proportion (%)
Paved Roads	28,207,000	23,260,180	82.5%
Bitumen Roads	4,575,000	4,470,840	97.7%
Concrete Roads	0	0	0.0%
Macadam Roads	23,632,000	18,789,340	79.5%
Unpaved Roads	6,598,620	6,155,453	93.3%
Gravel/Laterite Roads	0	0	0.0%
Earth Roads	6,598,620	6,155,453	93.3%
Sub-Total for All Roads	34,805,620	29,415,633	84.5%
Drainage	27,425	20,030	73.0%
Culverts	267,600	261,025	97.5%
Box Culvert	143,600	142,400	99.2%
Pipe Culvert	124,000	118,625	95.7%
Bridges	1,716,095	1,590,757	92.7%
Substructure	1,420,000	1,328,250	93.5%
Superstructure	264,345	237,832	90.0%
Parapets	31,750	24,675	77.7%
Total (US\$):	36,816,740	31,287,445	85.0%



Extensive and flexible reports and maps were also developed, providing road managers with a comprehensive assessment and reporting capability for their rural road assets. These all represented a significant and considerable improvement on their previous planning and reporting capabilities.

Figure 5: Example of Mapping of Rural Road Assets using RoadMark Data



8. FURTHER SYSTEM DEVELOPMENTS

RoadMark was designed to be as simple and as robust as possible, reflecting the realities of many rural environments in many countries. Nevertheless, continuing advances in mobile technologies, together with changes in communication and computers capabilities mean that the software requires continual development to keep up with these changes and make use of the new opportunities they present. The system also continues to undergo developments as resources allow, to extend its usability and capabilities, in response to user comments. At present, the following areas are under consideration or development:

- The remote management of the system via a RoadMark Central module, providing automatic software updates and differential levels of access to different databases for different users. This module (which is currently under development) will also streamline the transfer of data between the mobile phone app and the RMA application, allowing larger data transfers (including the storage of photographs for various road assets).
- Tighter/smoothier integration with GIS (including the two-way transfer of data, so that users can use the GIS capabilities to update the RMA databases).

- Development of an automatic network referencing system (NRS) around which all existing road data is structured. This is a significant and complex development and would require users to provide various rules to be applied. However, it would allow data on the network to be cross-referenced over time and allow previous survey data to be downloaded to the mobile application, further reducing future data entry requirements.
- Other developments include proposals to
 - Provide the ability to quickly define the network, at normal driving speeds;
 - Overcome the currently limited accuracy in the vertical (altitude) reading of the GPS system, which in more hilly or mountainous areas can result in a noticeable underestimation of network lengths.

9. LICENSING ARRANGEMENTS

RoadMark should prove to be especially useful for road managers responsible for rural road networks, where current limitations mean that more complex or sophisticated data collection (and analysis) options are unrealistic or unaffordable.

The system would also allow this data collection function to be outsourced to local private suppliers, whilst still providing significant quality control and oversight by managers remotely.

The licensing arrangements allow the data collection to be undertaken at no extra cost on multiple mobile smartphones (for which the application is free), with only a single centralised RMA Windows 10 application licence.

The system would also be suitable for companies (or funding agencies) to quickly assess or check the current condition and extent of the various road assets. This can be useful for funding and monitoring purposes.

Licensing can be provided for permanent use or for a limited time at lower cost. (The user will however, always have access to any data that they have already collected and stored in the RMA database). Multiple licensing discounts are available for larger users. These arrangements are designed to be as flexible as possible, to meet the specific needs of different clients.

10. CONCLUSIONS

The RoadMark system was developed because no other cost-effective data collection systems appeared to effectively address the most common institutional, organisational, funding and technical weaknesses that are endemic in managing rural road assets in many countries. A trade-off is always necessary between data collection requirements and its accuracy and usefulness. RoadMark aims to maximise the use of any road data, given what can realistically be collected in the situation prevailing on many rural road networks. Its simplicity and fast survey speeds, together with avoidance of specialised equipment, excessive training or the need for any network referencing system to be established beforehand, means that road managers should be able to collect a considerable amount of necessary data about their road assets, allowing far more robust and justified, needs-based strategic plans and budget estimates to be developed quickly and simply.

Following use in Cambodia and Myanmar, the system continues to undergo further developments, in order to provide additional flexibility and usability for road managers, without increasing its complexity or data demands for users.

For further information, please contact the author or see www.Penhallow.ltd.uk