Over the years there has been, and still is, much debate regarding survey methodologies, the accuracies that can be achieved and the equipment to be used. Every time a new survey instrument or methodology is introduced, the argument starts from scratch again.

At present the debate is focusing on 3D mobile mapping and terrestrial scanning methodologies. This article aims to provide some clarification.

Background
Without accurate geographical (survey) information no construction project, whether it be roads, civil works, buildings, plant, electricity or any other project, can proceed. All professionals need reliable data for planning, design, execution and as-built purposes.

Historically the surveyor supplied this data by means of ground survey with conventional equipment and aerial survey methods. Over the past few years, the construction industry has been introduced to airborne lidar mapping and terrestrial (ground based) lidar mapping. The latest development to be introduced is high resolution 3D mobile mapping.

Survey work on most construction projects can be categorised as:
- Pre-construction – this is the planning and design phase
- Construction – this consists mostly of setting out quantities and confirmation of construction.
- Post-construction – Supply of as-built plans and data

The methodology for pre-construction surveys is outlined below.

SANRAL specification
Most road construction surveys need to adhere to SANRAL specifications, especially accuracies. These accuracies are summarised in Table 1.

The most stringent specification is 10 mm and therefore equipment and work execution should be conducted to achieve these accuracies.

Existing information
Prior to survey it is necessary to gather and investigate existing information including:
- Aerial or lidar surveys and data of survey
- Existing ground surveys if any
- Existing SANRAL benchmark data
- Existing SANRAL surveys
- Cadastral/road reserve data

Benchmarks
An accurate benchmark system is the basis of any survey. The benchmark system ensures that the pre-construction, construction and as-built surveys are all on the same system.

The benchmark survey typically consists of:
- Confirmation of existing benchmarks x and y by GPS or total station and z by electronic levelling
- Building of new or re-building of existing benchmarks. SANRAL specifies that the existing benchmark system must be confirmed and used. This must be included in the survey quote.
- If existing information needs to be used, it must be confirmed by ground checks.

Strip survey
This must be tied in to the benchmark system and consists of two types of survey which are detailed below:
- Road prism which includes kerbing, edge of road, topographic detail of road prism and asphalt surface. This is high accuracy (10 mm) survey. These accuracies cannot be achieved by aerial survey and so ground survey methodologies are necessary. In the past, this was only done by total station equipment but recent technological developments have enabled this to be done by lidar scanning equipment, including mobile or terrestrial scanners.
- Road corridor which is the area between the edge of road and road reserve boundary.

Ground survey methodology
The advantages of ground survey are
that it is relatively cheap, especially on smaller projects, and that the surveyor is on the ground ensuring that very little detail is missed.

The biggest disadvantages of current ground survey methods are:
- Safety: roads are busy and extensive traffic control measures are necessary to ensure safety of personnel and road users. These measures slow down the survey process.
- Completion time: the survey process is always on the critical path because the engineer needs the design data.
- Cross sections at 20 m intervals: road surface data between cross sections is seldom recorded.
- For surveys outside the road reserve it is necessary to obtain access from property owners.

**Mobile mapping solution**

In general the mobile mapper is used for road prism surveys but with its reach it can easily cover most of the road reserve of up to 50 m depending on the terrain. This reduces the ground survey part to infill surveys only.

The most significant advantages of the mobile mapping option are:
- Independent tests have proved that certain mobile mapping systems can achieve accuracies that comply with the TMH11 specification of which the most stringent is 10 mm height accuracy.
- Turnaround time of projects is reduced due to the speed of travel and less safety requirements.
- High resolution (10 megapixel) photography which reduces site visits.
- The survey of the road surface can be done from the safety of a vehicle. The vehicle is travelling at a speed of up to 70 km, minimising impact on traffic flow.
- The density of the points is well distributed, with typical densities of 1000 pnts/m² on the road surface.
- The survey platform enables the use of heavier equipment and certain mobile mapping systems are equipped with a laser sensor which has a useful range of up to 200 m.
- The scanner is mounted on a vehicle and can be lifted using a lifting platform to increase the angle of incident of the laser sensor. This increases the accuracy of the survey and enhances the ability of the scanner to penetrate through vegetation and grass.
- Mobile mapping was developed with roads in mind and the software is well suited for the creation of line maps, contour drawings, break line creation, intelligent point thinning and so on.
- A typical strip survey using the mobile mapper is a continuous
point cloud with a high degree of accuracy. The military grade IMU ensures that the data set is homogeneous and the typical up-down effect of a registered terrestrial laser scan is largely eliminated.

A disadvantage of the mobile mapping option relates to infill surveys. Infill surveys off the road prism are still necessary, especially in areas of dense vegetation. Fortunately traffic control measures are a minimum in this area.

As for deliverables, the data is available in any industry standard format and will be processed up to the level required by the engineer:

- Vector data is available in 2 or 3D CAD format and exportable to AutoCAD, Microstation, Smallworld, Civil Designer, Modelmaker, Caddy or any other industry standard software.
- 3D – point clouds to be exported to AutoCAD or Microstation 3D format.
- Triangles are exported to GMS or TOT file standards
- Georeferenced high resolution photography with index of photography in CAD and Google Earth.

Terrestrial laser scanning

Detailed design of bridges and tunnels are required for most projects. Terrestrial laser scanning is used where the mobile mapper cannot reach or enter. Terrestrial laser scanning can also be used for the road prism survey because the accuracies are better than 10 mm.

The advantages of terrestrial laser scanning are as follows:

- Detail – high density data ensures that bridges, tunnels and structures can be accurately modelled.
- Reach – the scanners can reach areas where no survey prism can be held.

Aerial lidar survey

Where re-routes are required or where access is not available yet, it might be necessary to use airborne lidar. (Note: It is essential that enough ground control and ground truthing surveys are executed to ensure the aerial model is on the ground.)

The advantages of aerial lidar survey are as follows:

- It covers a wider strip than necessary and wider mapping is possible where re-routes are necessary.

The disadvantages of aerial lidar survey are as follows:

- For record and information purposes, the photography is a valuable tool.
- It is necessary for overall planning and can be used for other purposes such as route planning, EIA studies, and stormwater design to name but a few.

The equipment used should be suitable for the project. Ask for specifications of equipment to be used and confirm with suppliers that the equipment can achieve the accuracies claimed. This is essential with GPS and lidar equipment because there are literally hundreds of

<table>
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<td><strong>Laser scanner</strong></td>
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<tr>
<td>Standard pulse rate and range</td>
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<tr>
<td>Range accuracy (at mid-range)</td>
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<td>Precision / repeatability</td>
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<td>Environmental rating</td>
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<tr>
<td>Eye safe</td>
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<td>Online waveform analysis</td>
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**Inertial Measurement Unit (IMU)**

- Update rate 250 Hz
- Velocity accuracy 0,005 m/s
- Pitch and roll accuracy 0,004°
- True heading accuracy 0,01°
- Gyro bias 0,03° per hour
- Random drift 0,005° per hour

**GPS**

- Horizontal 1 cm + 1 PPM
- Vertical 1 cm + 2 PPM

**Ground control**

- Benchmark system check levelled to a 2 mm/km closure.
- Pre-marks or lidar control (similar to photo control points) at regular intervals to be specified per project but not more than 500 m apart.
- These should be connected to the BM system and check levelled to a 2 mm/km closure.
- This is not necessary for unpaved road surfaces.
- It is a client’s right to ask for quality control reports and check values.

Table 2: Typical mobile mapping specifications.
different types of equipment designed for different levels of accuracy and applications.

**Benchmarks**

It must be understood that an accurate benchmark network is the backbone of every survey. The engineer must clearly specify at what density benchmarks should be erected and what accuracies need to be achieved. TMH11 covers this extensively.

**Strip survey**

For the ground survey, it must be clearly stated at what density and accuracy the topographical grid should be surveyed. It is of little use to specify 1 m, 0,5 m or 0,25 m contours because that merely determines the level of interpolation.

A useful guideline is as follows:

- **0,25 m contours**: survey grid of 5 m (400 pts per Ha) to 10 m (100 pts per Ha) depending on terrain
- **0,5 m contours**: survey grid of 10 m (100 pts per Ha) to 20 m (25 pts per Ha)
- **1 m contours**: survey grid of 20 m or more depending on terrain.

Note: Take note of the work load between 400 pts per Ha and 25 pts per Ha. If you do not specify the survey grid, surveyors might calculate costs on incorrect assumptions.

**3D mobile survey**

There are many factors that influence mobile surveys and accuracies are a combination of:

- GPS post processing accuracies
- Laser sensor range accuracies
- IMU angular accuracies
- IMU drift rates
- IMU initialisation quality
- System calibration accuracy
- Survey tie-point interval and accuracy

Typical specifications for a 3D high definition mapping system are outlined in Table 2.

**Terrestrial scanning**

The benchmark system should be sufficient to cover overlaps of set-ups but not more than 200 m apart. The benchmark system must be check levelled to a 2 mm/km closure.

With regard to the scanner it is important to specify what accuracies are needed and to insist that the scanner, make, model and specifications be part of the project proposal.

**Airborne lidar surveys**

An airborne lidar system also consists of a scanner, IMU and GPS. Due to the accumulative error in these three instruments, it is very difficult if not impossible to get better than 10 cm accuracies which is outside most SANRAL specifications. It is essential that a benchmark system is surveyed on site and that the survey is connected to the benchmark system.

The ideal is that the benchmarks are pre-marked and surveyed to a height accuracy of better than 33% of the specified survey accuracy. For example: for 10 cm accurate ground points the benchmarks need to be surveyed to 3 to 4 cm accuracy.

After data has been supplied, it is advisable to do a “ground truthing survey” such as at least one cross section at each benchmark.

**Photography (air or ground survey)**

A big advantage of scanning whether it is aerial, mobile or terrestrial is that there are normally cameras attached to the system.

Ask for sample photography to ensure that you get the quality needed. It is of little use if you want to capture road furniture and you cannot zoom in to identify street names.

**Conclusion**

Clearly there is no ultimate survey methodology and every project needs be judged according to its requirements. Mobile and terrestrial scanning are “new tools in the toolbox” and certainly assist surveyors, engineers and planners in executing their tasks more effectively. The challenge therefore is whether surveyors, engineers and planners can adapt to these new technologies.

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