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FINAL REPORT

A34: Customer-based Levels of Service in Road Maintenance (2020/2021)

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SUMMARY

Road agencies have identified that there is a pressing need to link Customer-Based Levels of Service (CLoS) requirements related to road maintenance, to the intervention measures for maintenance (i.e., roughness, rutting, cracking, potholes, etc.) used by road asset managers, otherwise known as the Technical-Based Levels of Service (TLoS). Therefore, this project aimed to determine the existence of statistically significant relationships between CLoS and TLoS across two road classes, urban and rural, that will allow the determination of a customer acceptable level of TLoS.

This project was completed across three phases. Year 1 involved a literature review and a pilot study. Year 2 implemented the pilot study methodology on a wider scale, with an extended online video survey. Year 3 involved an in-depth statistical analysis of the data collected in the survey, to determine the relationship between CLoS and TLoS, along with implementation solutions.

The information collected as part of the literature review was used to develop a series of measures and indicators used to assess CLoS. Five indicators for CLoS were developed, each with a series of measures used for assessment. These indicators were:

- *Safety* – function, resilience (e.g., shoulder and lane width, safety features, texture, skid resistance)
- *Accessibility* – amenity/environment (drainage, all weather access, signage)
- *Condition* – structural, climatic factors (functional and structural measures)
- *Reliability* – traffic capacity (e.g., adequate number of lanes, traffic management)
- *Rideability* – travel experience (roughness).

The pilot study assessed two of these indicators, Safety and Accessibility, through the use of a series of individual measures. The initial results showed that there was a relationship between the CLoS and the TLoS. Therefore, a similar methodology to that used in the pilot study was used for the online video survey undertaken in Year 2.

The Year 2 online video survey expanded on the pilot study by assessing four of the five CLoS indicators. Participants in the online video survey were asked a series of open-ended questions, followed by a series of questions asking for ratings of DVR footage. Four urban roads, and four rural roads were assessed as part of the online video survey.

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The results of the survey showed that most of the measures used to assess each of the CLoS showed positive and statistically significant relationships. Overall, the results for each CLoS indicator were as follows:

- The Safety indicator presented a positive correlation and a statistically significant relationship in both the urban and rural environments, with the rural relationship being slightly stronger than the urban relationship.
- The Reliability indicator showed a positive and statistically significant relationship in both the urban and rural environments, while this correlation was stronger in the rural environments.
- The Condition indicator showed a positive correlation and a statistically significant relationship in both the urban and rural environments, again the rural relationship was stronger than the urban relationship.
- The Accessibility indicator also showed a positive correlation and a statistically significant relationship in both the urban and rural environments, while the urban environment correlation and relationship was slightly stronger than the rural relationship.

The linear equations developed through the statistical assessment were then used to develop a representative CLoS (on a scale of 1 to 5) for each value of TLoS (on a scale of 1 to 5), for the five CLoS indicators. A linear equation is also presented for Rideability, based on the literature findings.

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1 INTRODUCTION

1.1 PURPOSE

In the context of road maintenance, road agencies have identified that there is a pressing need to link Customer-Based Levels of Service (CLoS) requirements related to road maintenance, to the intervention measures for maintenance (i.e., roughness, rutting, cracking, potholes, etc.) used by road asset managers, otherwise known as the Technical-Based Levels of Service (TLoS). It has been hypothesised that an evidence-based re-justification of existing levels of service is required to provide a defendable position to Transport and Main Roads (TMR) Queensland in its decision to allocate funds and manage financial risks for the Department and potential road user impacts, and the extent to which they are consistent with whole-of-life-cycle costing based funding priorities. This allows for a transparent understanding for customers as to how their needs are being met.

In asset management, the term Level of Service, or LoS, describes how well an asset serves customers, or how well it meets customers' needs and wants (Cairney 2016). However, the relationship between the Customer Levels of Service (CLoS) and Technical Levels of Service (TLoS) is critical for a customer focussed approach to asset management in demonstrating that the CLoS are being met as much as practically possible within the confines of the available budget and the road agency's asset management strategy. This means that a strategic approach across the road network is needed to meet the CLoS once the relationships between CLoS and TLoS are found.

1.2 MAJOR DELIVERABLES AND ANTICIPATED BENEFITS

This project aims to find statistically significant relationships between CLoS and TLoS for an agreed set of road categories that will allow the determination of a customer acceptable level of TLoS. It is anticipated that this will provide benefit through:

- demonstrating a connection between the desired relevant CLoS and TLoS to find a customer acceptable TLoS
- conducting a literature review to determine the scope of the work involved in meeting TMR's requirements and documenting the methodology and the CLoS and TLoS relationships in a report which can be used for reference or implementation
- providing a rational guide for maintenance intervention that can be readily adopted by TMR and possibly by other road agencies that have similar road categories and conditions.

2 METHODOLOGY

2.1 YEAR 1 – LITERATURE REVIEW AND PILOT STUDY

Year 1 of involved a literature review with the support of the ARRB M.G. Lay Library. The scope of the literature review covered: previous research into customers' requirements, previous research into the technical standards used for TLoS, frameworks for CLoS used by various jurisdictions, previous work completed by TMR and Austroads.

The outcomes of the literature review were used to determine the elements for assessment in the pilot study.

The pilot study was developed to identify for TMR how extensive the CLoS and TLoS relationships could be, and which of the various road categories these could be applied to. Relationships between the CLoS and TLoS can be derived using panel ratings against the corresponding measured road conditions and features for defined road segments which can be compared to relevant and available AusRAP ratings. This was achieved through a video-based survey with a panel of road users to rate a range of measured road conditions on selected road segments as defined by the scope of the work. TLoS cannot always be reliably related to CLoS, as many TLoS indicators are not likely to be directly detectable or recognisable to average road users.

The study was separated into three stages:

- Stage 1: Completion of an online opinion survey for safety and reliability indicators
- Stage 2: Completion of a safety and reliability video-based experimental pilot study in a workshop setting (see method below)
- Stage 3: Completion of an extended survey on measures which were not able to be tested in the above experimental pilot study.

The following methodology was proposed and used as the framework for the workshop style video-based pilot study:

1. Selection of panel members
2. Selection of road segments
3. Selection of LoS indicators to be assessed
4. Community opinion survey
5. Assessment of safety as part of the experimental pilot study
6. Assessment of reliability as part of the experimental pilot study
7. Extended community expectations survey
8. Collection and recording of samples/results
9. Summary of results and comparison with literature findings from the literature review.

Due to the repeatability of this method, and the production of tangible results, this methodology was repeated for an extended online video survey completed in Year 2.

2.2 YEAR 2 – EXTENDED ONLINE VIDEO SURVEY

Year 2 involved undertaking an extended online video survey, based on the methodology of the pilot study in Year 1. This survey aimed to validate the outcomes of LoS indicators assessed in the pilot study, as well as expanding on this study by assessing more CLoS indicators. The survey was provided to participants in the *Survey Monkey* Platform. The participants completed an open-ended opinion survey and then watched pre-loaded DVR footage of road segments, rating various elements of these roads as CLoS measures. These ratings were used to further develop the relationships between CLoS and TLoS, as part of Year 3.

The survey panel was selected on the basis that it represented a broad range of the community's road users. To ensure a broad distribution, the requested participant sample was based on data from the Australian Bureau of Statistics (ABS) 2016 Census Data (ABS 2016). A panel of 50 participants was assembled by an external market research organisation, and these participants were reimbursed for their time in participating in the survey.

Road segments for inclusion in the survey were initially selected based on a combination of AusRAP, surface condition data and supplementary data including annual rainfall and video footage of each of the selected roads. A total of four urban roads and four rural roads were selected.

The participants were first asked to answer seven brief and open-ended questions regarding the LoS indicators to be assessed in the survey. These responses provided information on what was important to each participant, as well as information on measures which could be used for further consideration of CLoS indicators in future research. These questions were open-ended ensuring that the opinions of participants were qualitatively recorded rather than prompting participants to produce quantitative results.

The participants were then asked a series of demographic questions, to record information that may affect the results of the survey data analysis. Lastly, the participants viewed DVR footage of each of the selected road segments. Once the road segments were viewed, each of the participants rated the CLoS for several measures of each of the LoS indicators given on each of the road segments.

The detailed methodology for the development of the extended online video survey is outlined in Section 5.

2.3 YEAR 3 – ANALYSIS AND SYNTHESIS

Year 3 involved the analysis of the data collected as part of Years 1 and 2. This section provides an overview of the methodology, which was used to analyse the survey data, and aligns the survey data with the TLoS indicators identified. This method followed a process of:

- reviewing the responses to the open-ended questions
- aligning the CLoS indicators with relevant TLoS indicators
- undertaking a graphical analysis of the data by aligning the CLoS and TLoS in a linear regression model
- developing a relationship between CLoS and TLoS indicators using a statistical analysis.

2.3.1 REVIEWING OPEN-ENDED QUESTIONS

This analysis reviewed the information that was collected during Year 2 in the open-ended question responses.

These questions were asked to validate the topics which were selected to be used as measures (or measures of assessment) in the survey. For example, the survey asked about road signs. The open-ended questions confirmed or refuted whether road signs are a concern of the public.

As the measures used to assess each of the CLoS indicators were selected through previous research, and were based on the pilot study outcomes, it is hypothesised that the open-ended question responses would validate the measures selected.

2.3.2 ALIGNING TLOS WITH CLOS

The TLoS used in this project are based on the AusRAP rating system. However, where this information was unavailable, TLoS were developed based on ARRB's expert opinion and TMR data.

The CLoS rating scale consisted of a rating from 1 (very poor) to 5 (very good). The AusRAP rating system does not have the same consistency in the number of rating points or which end of the scale was 'good'. To ensure that the TLoS measures were meaningfully aligned with these CLoS ratings, some scales needed to be extrapolated and reversed.

2.3.3 GRAPHICAL ANALYSIS

As detailed in the Annual Summary Report for NACoE Project A34 Year 2, the results of the pilot study were analysed graphically. This was completed through the development of a trendline between the comparison data points of TLoS and CLoS. This process was repeated for all the measures assessed in the online-video survey. These graphs provided the statistical information for the development of the relationships between CLoS and TLoS.

2.3.4 DEVELOPING RELATIONSHIPS BETWEEN CLOS AND TLOS

The statistical results of the graphical analysis of the online-video survey data were used to develop a linear relationship between CLoS and TLoS. The relationship was based on the correlation between the CLoS rated by the public, and its relevant TLoS.

To determine the statistical significance of the correlation and therefore the goodness of fit of the CLoS and TLoS relationship to the data, a statistical assessment was completed. The following statistical measures were estimated for the linear regression equations that defined the relationship between CLoS and TLoS: multiple R, R^2, F-statistic, significant F *p*-value, t-value and *p*-value. These statistical measures are described in more detail in Section 6.3.

The linear regression equations developed through this statistical assessment were used as the basis for calculating a representative value for CLoS, based on TLoS.

3 LITERATURE REVIEW

Year 1 involved a literature review to gain an understanding of:

- previous research into customers' requirements to define CLoS indicators for assessment (Section 3.1)
- previous research into the technical standards used for TLoS (Section 3.2)
- Levels of Service (LoS) frameworks used in practice by Australian and New Zealand road agencies, including previous work undertaken by TMR, and assessments of LoS undertaken within local government (Section 3.3)
- previous work focused on customers' needs regarding road maintenance (Section 3.4)
- how constrained funding impacts the level of service that is provided (Section3.5)
- what road categories various levels of service are applied to (Section 3.6)
- previous recommendations which were made in research for the development of a customer-focused level of service (Section 3.7).

LoS, as defined in this project, includes the operating conditions encountered by traffic, based on the features and condition of the asset. It is both a qualitative and quantitative measure. In asset management, literature has shown that LoS indicators should be sensitive to budget decisions and the different asset management strategies used by the road agency. If a LoS indicator is derived solely from measures such as traffic volumes, terrain and model road states, there is not a way to improve the LoS rating of that road without significant capital investment. Therefore, literature identifies that LoS indicators should be based on several measures including ability to manoeuvre, comfort, convenience, freedom to overtake, interruptions, interference, rideability, reliability, road condition, safety, speed, trip time, and vehicle operating costs.

3.1 CUSTOMER BASED LEVELS OF SERVICE

CLoS was defined through an analysis of literature as being the service level for a road which is required or demanded by customers. There are two main categories of customers: freight transport customers, and non-freight transport customers. This study focused on non-freight road users (i.e., members of the public using the road for commuting and recreational purposes). To make the assessment of CLoS, five indicator categories were developed, based on literature review information. These were Safety (Section 3.1.1), Reliability (Section 3.1.2), Condition (Section 3.1.3), Accessibility (Section 3.1.4), and Rideability (Section 3.1.4).

3.1.1 SAFETY

Safety refers to the methods and measures in place to prevent road users from being killed or seriously injured. Road users include pedestrians, cyclists, motorists, vehicle passengers, horse-riders and passengers aboard road-based public transport (e.g., buses and trams).

Examples of measures which can be used for assessment of this indicator are:

- presence of safety features (e.g., guardrails, wire-rope barriers)
- presence of infrastructure for the separation of road users
- presence of sharp curves and skid resistance
- presence and quality of road signs
- presence and quality of line markings
- lane and shoulder width
- adequate street lighting
- overtaking opportunities

- presence of major intersections
- presence of pedestrian crossings
- presence of level crossings
- the grade of the road.

3.1.2 RELIABILITY

Reliability refers to the ability of a road or road network to perform its intended function, without any malfunctions, assuming the road is used within the conditions in which it was designed for (Austroads 2015).

Reliability is directly related to road capacity. Road capacity is referred to by Austroads as the maximum number of vehicles or pedestrians that can pass over a given section of a lane, road or footpath in one direction (or in both directions for a two-lane or three-lane road) during a given time period under prevailing road and traffic conditions. It is the maximum rate of flow that is expected to occur (Austroads 2015).

Examples of measures which can be used for assessment of this indicator are:

- adequate traffic capacity to support free-flow traffic
- acceptability of travel time
- availability of alternative travel modes
- number of access roads.

3.1.3 CONDITION

The condition of an asset is based on the combination of specific characteristics which are used to assess functionality. Examples of these characteristics include rutting, cracking, surface texture, pavement strength (deflection), skid resistance, edge break, edge drop off, local defects, and patching. Reporting on these issues tends to be by ‘bins’ or a distress rating (e.g., good, fair, poor, bad), or on a continuous numerical scale (e.g., IRI, rut depth, crack width, percentage area patched) (Austroads 2015).

Examples of measures which can be used for assessment of this indicator are:

- surface defects (e.g., edge break, potholes, patching, crack sealing)
- maintenance and aesthetics – cleanliness and uniformity of road appearance.

3.1.4 ACCESSIBILITY

Accessibility refers to mobility pathways, allowing for the continuity of useable routes between key locations of travel. This means that the road is always open for the use of customers. If the road is unavailable, there is an alternative route available, with an acceptable travel time.

Examples of measures which can be used for assessment of this indicator are:

- all weather access (e.g., presence of drainage infrastructure)
- adequate road width
- presence of encroaching roadside vegetation and overhanging trees.

3.1.5 RIDEABILITY

Rideability is directly related to the roughness of the road surface. Road roughness is defined by Austroads (2015) as:

- A condition parameter used to characterise deviations from the intended longitudinal profile of a road surface, with characteristic dimensions that affect vehicle dynamics (and hence road user costs), ride quality and dynamic pavement loading.

- A measure of surface irregularities with wavelengths between 0.5 and 50 m in the longitudinal profile of one- or two-wheel paths in a traffic lane, reported in dimensionless units as either International Roughness Index (IRI, m/km) or as NAASRA Roughness Meter (NRM) counts (NRM, counts/km) for the lane.

Examples of measures which can be used for assessment of this indicator are:

- ride quality/comfort (roughness).

The relationship between the CLoS rating with TLoS for Rideability (roughness) was previously well researched (Martin 2005). This work summarised a range of past studies that were conducted from 1998 to 2004, involving 128 selected road samples and 2,679 observations by 17 panels to produce 17 relationships between CLoS ratings and TLoS. These relationships were in the form of a roughness rating (CLoS) versus the measured roughness (TLoS). The goodness of fit (R^2) of these relationships ranged widely from 0.01 to 0.66 with a mean R^2 value of 0.33. The road samples ranged from unsealed rural local roads to urban freeways, including both urban and rural sealed local roads and urban arterials. Consequently, the current study did not research CLoS rideability indicator relationships with TLoS.

The relationship developed for the estimate of Acceptable Level of Roughness for a given road type is detailed in Equation 1 (Martin 2005).

$$y = k_1 \times R(t)_m + k_2 \qquad \mathbf{1}$$

where

y	=	the panel's (community) perception (value) of road roughness at time, t
$R(t)_m$	=	the measured road roughness, IRI (m/km), at time, t
k_1	=	the calibration factor for roughness
k_2	=	the calibration factor for effects other than roughness (lane width, edge condition, surface condition, etc.).

Each of the studies, outlined above, calculated the calibration factors for this relationship. For the A34 study, the equations with the most observations (i.e., most data), and with the highest correlation (i.e., high R^2) were selected for the relevant road categories. However, this equation is based on a measured rating scale of 1 to 10 with 1 being excellent and 10 being poor. Therefore, the equations needed to be adjusted to match the scale developed as part of A34.

This past research concluded the following:

- Due to the various types of roads examined in the above studies, with different posted speed limits, a relationship was derived between the acceptable measured level of roughness (TLoS) and vehicle speed. This relationship predicted that as the travel speed increased the acceptable measured level of roughness decreased (TLoS) for the same CLoS.
- The above outcome explains why users of high-speed freeways need a lower level of acceptable roughness (a high TLoS) compared with users of low-speed urban local roads for the same CLoS.
- The range in R^2 values of the relationships between CLoS and TLoS also suggests there are varying perceptions of acceptable roughness amongst the panels used in these studies
- In many cases it can be inferred that the relationships between CLoS and TLoS are likely to depend on the local nature of the demographics and factors other than rideability that were not considered. These factors could be the presence of oncoming vehicles, road width, current roughness expectations, individual differences in the perception of roughness and surface texture causing excessive noise.

In summary while the relationships found between CLoS and TLoS for the rideability indicator are neither highly precise nor include all the possible explanatory variables, these relationships do show the expected variation across a range of road types in a LoS road network framework.

3.2 TECHNICAL BASED LEVELS OF SERVICE

Research has shown that a high-quality LoS on local roads, from a road agency perspective, is one that provides (NAASRA 1984; cited in Martin et al. 1999):

- user safety and comfort (reduction in driver stress)
- reductions in vehicle wear and tear and travel time
- reductions in freight goods damage.

Literature which was investigated to define TLoS used in road maintenance included:

- Martin & Koh (2004)
- Martin et al. (1999)
- Austroads (2016)
- Department of Main Roads (2004).

Based on these studies, TLoS was defined as referring to the technical intervention requirements for road maintenance, and the standards to which road managers maintain their roads. These standards can be national, such as the Australian Road Asset Program (AusRAP) or can be statistically based and defined by the road agencies. The AusRAP program rates the safety of road segments based on 78 criteria. The AusRAP criteria to be used for TLoS ratings were selected based on the similarity of the criteria to the criteria used in the CLoS assessment (i.e., CLoS measure 'Presence and Quality of street lighting', was assessed against AusRAP criteria 'Adequate Street Lighting').

3.3 LEVELS OF SERVICE FRAMEWORKS

Various LoS frameworks were developed in recent years which provide insights into how LoS should be considered when determining the management needs of a road. Several of these frameworks were reviewed through this project to determine any common features and what the most important features were. The frameworks reviewed included:

- Queensland Department of Transport and Main Roads (Austroads 2016)
- New Zealand Transport Agency's State Highway Asset Management Plan (SHAMP) (NZTA 2011)
- Department of State Growth in Tasmania (DSG) (Austroads 2016)
- Main Roads Western Australia (Austroads 2016)
- Territory and Municipal Services' Strategic Asset Management Plan (SAMP), - Roads ACT (TAMS 2013)
- Randwick City Council, New South Wales (2012).

3.4 PREVIOUS WORK ON CUSTOMERS' NEEDS

As part of this literature review, several previous studies were investigated. Summaries of these studies are as follows.

In 2014, the Royal Automotive Club of Victoria (RACV) undertook a survey of the population's road and transport needs in regional Victoria. The survey aimed to determine the road, public transport, cycling and walking enhancements which would be needed to cope with the predicted increases in the population of regional towns and outer-suburban areas. The results of the survey showed that the major concerns for roads included:

- the condition and maintenance of roads
- the behaviour of drivers and/or riders
- the amount of traffic through towns
- the suitability of speed limits

- whether safe overtaking opportunities were available (Austroads 2016; RACV 2014).

From 1998-2016 the Australian Road Research Board (ARRB) undertook a road user survey on LoS expectations (Austroads 2016; Martin 2005). Eleven separate investigations were undertaken, across a range of communities in Australia. These investigations were comprised of road user groups (panels) containing 8 to 43 members, which represented their community on the use of a particular type of road. These road types ranged from unsealed rural roads to urban freeways. The results of this survey showed that different communities often had unique perceptions of the road environment and unique requirements with respect to LoS. The results of this survey are presented in Table 3.1, which shows the mean ranking across the communities, and the overall rank. As can be seen from Table 3.1, the highest-ranking elements of concern for drivers were related to road maintenance attributes.

Table 3.1: Community ranking of factors influencing perceptions of LoS

Factors influencing perception of service	Mean rank	Overall rank
Potholes	1.1	1
Safety	1.9	2
Rideability	2.0	3
Road signs	3.8	4
Drainage of surface	4.7	5
Road width	5.5	6
Rutting	5.7	7
Edge wear	5.7	8
Type of road surface	6.1	9
Road geometry	7.5	10
Roadside vegetation	8.7	11

Sources: Adapted from Austroads (2016); Martin (2005).

In 2016, Austroads (2016) undertook a similar study of LoS for non-freight road users, to identify and define the asset management needs and LoS requirements for non-freight customers. This study queried participants on their opinions of the importance of different road attributes, introducing the importance of the CLoS concept. Further, this study asked respondents their opinions on how each of these different road attributes performed. This section of the study showed the importance of the interface between CLoS and TLoS, aligning the technical performance of road assets with the expectations which customers may have.

The results as demonstrated in Table 3.2 showed that when rating the importance of road attributes, the highest importance ratings were given to road condition, road signs, driving on wet roads, line markings and reflectors, and road width. When asked how well different road attributes performed, the highest ratings were given to road signs (91% acceptable or better), line markings and reflectors (84%), safety barriers (82%) and road width (80%).

Table 3.2: Importance ratings of road travel needs by region, Australia

LoS attributes	% Important			% Not important			% Unsure/no answer		
	% Metro	% Inner regional	% Outer /remote	% Metro	% Inner regional	% Outer /remote	% Metro	% Inner regional	% Outer /remote
Road surface	97	98	98	2	1	1	1	1	1
Roadside (e.g., vegetation, litter etc.)	89	92	90	10	6	8	2	2	2
Road signs	97	98	96	2	1	3	0	1	1
Driving on wet roads	97	98	98	2	1	1	1	1	1
Safety measures (e.g., barriers)	96	93	93	3	5	4	1	3	3
Rest areas	78	84	88	17	14	9	5	3	3
Line marking and reflectors	98	98	95	1	2	3	1	1	2
Safe overtaking opportunities on rural roads	89	94	96	4	5	2	6	1	1
Road width	96	97	98	3	3	2	1	1	1
Management of roads during significant incidents	88	90	90	8	8	8	4	2	2
Unexpected delays due to congestion	88	78	67	10	12	18	2	9	16
Delays and disruptions from roadworks	86	84	84	13	13	14	1	3	2

Source: Austroads (2016).

The results also showed that there was relatively little difference in the importance ratings given by respondents living in metropolitan, inner regional and outer regional/remote areas. This means that it should be possible to develop one LoS framework that covers metropolitan and regional roads, using the same measures for all roads.

Additionally, although the results of this study indicated that there were only relatively small differences between the regions in terms of importance ratings, there were marked differences in the ratings of how well the road attributes met the expectations of road users, as shown in Table 3.3. The general pattern was that metropolitan respondents gave higher percentages of acceptable or better ratings (as shown in Table 3.3), except for issues such as congestion and rest areas (for road attributes) and rest points with seating (for pedestrian facilities) where regional respondents gave higher percentages of acceptable or better responses for these attributes.

Table 3.3: Percentages of good and acceptable ratings of how well aspects of the road transport system meet respondents' needs by regions, Australia

LoS attributes	% Net good			% Acceptable			% Net good + acceptable		
	% Metro	% Inner regional	% Outer /remote	% Metro	% Inner regional	% Outer /remote	% Metro	% Inner regional	% Outer /remote
Road surface	43	28	26	34	30	31	77	58	57
Roadside (e.g., vegetation, litter etc.)	44	36	35	35	38	38	79	74	73
Road signs	59	51	60	32	39	31	91	90	91
Driving on wet roads	48	37	38	38	38	33	86	75	71
Safety measures (e.g., barriers)	52	40	43	35	41	36	87	81	79
Rest areas	34	38	39	29	32	29	63	70	68
Line marking and reflectors	54	46	52	31	37	32	85	83	84
Safe overtaking opportunities on rural roads	39	25	29	32	34	30	71	59	59
Road width	32	23	34	35	36	34	67	59	68
Management of roads during significant incidents	45	40	38	35	41	41	80	81	79
Unexpected delays due to congestion	24	31	37	37	42	34	61	73	71
Delays and disruptions from roadworks	32	36	37	45	41	44	77	77	81

Source: Austroads (2016).

3.5 IMPACT OF CONSTRAINED FUNDING

A major challenge in developing LoS for asset management is how to clearly define and articulate the achievable LoS within the funding options available. Providing this balance allows the community to make an informed decision on the LoS that they can receive and what LoS they are prepared to pay for (Duff 2007). Constrained funding in road maintenance is not a new concept. However, the pressures of demand always favour network expansions, safety improvements and other upgrades which require capital costs. Yet, it is generally seen that the funding allocations for road maintenance are the minimum (Henning et al. 2016). It is important when allocating funds to consider the whole of life cycle costs of the network; and whether investing now will reduce the likelihood of unacceptable LoS in the future in other areas of the network or investing in newly constructed network sections. There is the risk that waiting until a road is damaged before acting to maintain it will lead to increased road maintenance costs, and a long-term reduction in LoS (Henning et al. 2016), therefore decreasing the acceptable TLoS and subsequently the CLoS.

The literature identifies several frameworks for managing LoS needs and reaching performance goals within budget. In particular Bruun and Laumet (2016) present a framework which comprises a set of performance measures that are calculated based on data collected during maintenance condition surveys, analytical models that allow for the estimation of costs to achieve a certain desired LoS, and an integer programming-based optimisation model that helps in determining the best set of maintenance activities that can achieve performance goals given budget constraints.

The NZTA (Henning et al. 2013) have used performance indicator analysis and LoS reporting for many years to assist with funding allocations, monitoring the allocation of funding, and ensuring these are spent appropriately. Undertaking performance reporting assists in the funding decision process by using:

- trend monitoring to show the network 'health' of an agency
- benchmarking/relative comparisons with similar networks, as trend monitoring by itself cannot establish the appropriateness of funding levels.

3.6 ROAD CATEGORIES

As detailed in Section 3.4, studies (Austroads 2016) have assessed customers' needs across different road categories. Several studies have looked at the difference between rural and urban roads, and road classes within these road categories. Roads are generally classed based on their location, design, and available access as these factors are what is used to determine the level of periodic or routine maintenance required.

Queensland's road network creates vital links to connect communities with goods, services, and leisure activities. Transport and Main Roads (TMR) Queensland define these roads as either Local Roads, Collector and Distributor Roads, or Sub-arterial and Arterial Roads.

Local roads are defined by the neighbourhood street systems. These roads are mostly free of through traffic and are generally only used by those residing in the local area. The challenge with local roads is the provision of an appropriate level of safety and access within the constrained budget of local authorities. Local roads are generally lower volume roads and therefore, are prioritised lower for regular maintenance (TMR n.d.).

Collector and distributor roads are the roads which connect communities to major sub-arterial and arterial roads. These roads allow for the transportation of major agricultural goods to major highways. In urban areas, these roads tend to be roads which connect suburbs to major freeways (TMR n.d.).

Sub-arterial and arterial roads are the major connector roads across Queensland. This includes the highways, freeways, and motorways. These roads have high volume and carry both freight and passenger vehicles (TMR n.d.).

Although the location of a road can affect its performance ranking, it does not have a large impact on the importance of attributes of the road. Therefore, it was determined the same CLoS ranking scale would be used across urban and rural environments in this study. Further, only local and collector/distributor roads were used for this survey.

3.7 RECOMMENDATIONS FOR THE DEVELOPMENT OF CUSTOMER-FOCUSED LOS

The following list was developed by Austroads (2016) and highlights the suggested steps to guide the development of a customer focused LoS system:

1. Define and decide on the priority of all the possible user needs that will be included in the LoS framework.
2. Review these options and decide on the steps required to develop an acceptability function for each of the high-priority needs.
3. Define and undertake empirical studies of the type indicated to establish suitable acceptability functions.
4. Allocate LoS grades to each of the needs based on the acceptability functions.
5. Decide on the operational targets to be adopted for the different road categories using either road user panels or stakeholder representatives.

Based on the limitations of community expectation identified, Martin et al. (1999) identified the following guidelines to assist with the elimination of the potential misinterpretation of community expectations:

- Select generally representative members from the community that broadly reflect the socio-economic status and cultural values of the community or alternatively, select a large number of members of the community to include all the possible variations in the socioeconomic status and cultural values of the community.
- Confine the assessment of community expectations to separate rural and urban areas to eliminate areas with a rural/urban local roads mix.

Additionally, Martin et al. (1999) made the following recommendations for further work, which could be considered further within this current project:

- More sampling of unsealed rural local roads on a broader basis to confirm the estimated maximum level of acceptable community roughness.
- Broader based sampling of sealed rural local roads to confirm both the maximum level of acceptable roughness and the tentative conclusions about maintenance funding. The acceptable roughness was based on a CLoS rating of 5 out of 10, or 2-3 on the reduced scale when using the relationships found between ratings (CLoS) and the measured roughness (TLoS).
- Broader based sampling of urban and rural based sealed roads to confirm the maximum levels of community accepted roughness and tentative conclusions on maintenance funding.

These recommendations identified in the initial stages of the project (Year 1) were taken into consideration when developing the following elements of the project (Year 2 and Year 3).

4 PILOT STUDY

This section provides a summary of the pilot study completed as part of Year 1 of the project, based on the methodology outlined in Section 2.1.

4.1 ROAD SEGMENTS FOR ASSESSMENT

The location and road segments which were shown to survey participants as part of the pilot study are summarised in Table 4.1. Different roads were selected based on the indicators being assessed, and whether the road was urban or rural. The typical road segment length of 500 m was selected, based on relatively uniform conditions within each selected segment.

Table 4.1: List of roads included in the pilot study

Urban (guidance and delineation, and road geometry)					
Segment	**Road ID**	**Road name**	**Start chainage**	**End chainage**	**Comments**
Urban Segment 1	491	Kilcoy Murgon Road	25.6	26.75	Very curvy, no edge lines (delineation)
Urban Segment 2	104	Gold Coast Spring Brook Road	12.5	13.95	Very curvy
Urban Segment 3	205	Tamborine Mountain Road	8.7	10.00	Lots of gentler curves, some sharper ones,
Urban Segment 4	232	Texas Road	70.0	71.56	Gentler curves, large straight sections, rural highway.
Urban Segment 5	10B	Bruce Highway	36.0	37.18	Straight, with large curve at the end, between Glenwood and Gootchie
Urban Segment 6	13E	Landsborough Highway	0.89	2.03	Straight, rural highway, no curves.
Rural (guidance and delineation, and road geometry)					
Segment	**Road ID**	**Road name**	**Start chainage**	**End chainage**	**Comments**
Rural Segment 1	134	Mooloolaba Road	6.4	7.54	Curvy, undulating terrain, a number of intersections
Rural Segment 2	2015	Springbrook Road	4.5	6.0	Gentle curves, some sharper ones, one large straight section.
Rural Segment 3	3042	Mount Crosby Road	10.61	12.23	Gentle well protected curves
Rural Segment 4	2041	Worongary Road	8.4	9.8	Gentle curves, a number of intersections, undulating terrain
Rural Segment 5	4104	Murphy's Creek Road	10.5	12.0	Straight section with one big curve. Delineation problems, no edge lines, lack of road reflectors
Rural Segment 6	8565	Eimeo Road	1.4	2.7	Straight section, no curves, delineation moderate to good.
Rural (travel times)					
Segment	**Road ID**	**Road name**	**Start chainage**	**End chainage**	**Comments**
Rural Segment 1	18A	Warrego Highway	90	91.5	Good, smooth surface condition, wide winding road, overtaking lanes
Rural Segment 2	25B	Mount Lindsay Highway	51	52.1	Poor surface condition, patching, narrow winding road, potholes and shoving.

4.2 OPINION SURVEY RESULTS

As outlined in Section 2.1, an opinion survey was undertaken prior to the experimental pilot study. The following list outlines the priorities in terms of the highest to lowest importance of the measures for each of the two LoS indicators, safety and reliability, separated into urban and rural environments:

- Urban/rural safety
  1. presence of sharp curves (u/r)
  2. presence and quality of road signs (u/r)
  3. presence and quality of line markings (u/r)
  4. adequate street lighting (u)
  5. overtaking opportunities (r)
  6. presence of major intersections (u/r)
  7. presence of pedestrian crossings (u)
  8. presence of level crossings (u/r)
  9. steepness of road (r)
  10. rest area frequency (r)
- Urban/rural reliability
  1. all-weather availability (u/r)
  2. adequate traffic capacity to support free-flow traffic (u/r)
  3. acceptability of travel time (u/r)
  4. availability of alternative travel modes (u/r)
  5. number of access roads (u/r).

4.3 TECHNICAL LEVELS OF SERVICE FOR DATA ANALYSIS

Several measures of safety and reliability, in both urban and rural environments, were assessed as part of the experimental pilot study. The AusRAP data was used for the TLoS ratings of the road segments. CLoS ratings were scaled as follows:

1. Poor
2. Fair
3. Good
4. Very good
5. Excellent.

For several of the road measures assessed as part of the CLoS, the AusRAP ratings, or TLoS, were derived from a different rating approach. In some instances, the AusRAP rating scale describes lower values as ‘good’ and higher values as ‘poor’; whereas the CLoS rating scale describes 1 as ‘poor’ and 5 as ‘excellent’. Therefore, the AusRAP ratings were transformed and reversed where applicable (see below) to match with the CLoS rating system scale of 1 to 5. This transformation is shown in Equation 2, and Table 4.2.

$$Expanded\ AusRAP\ rating = \frac{4 \times AusRAP\ rating - 4}{Max.AusRAP\ rating - 1} + 1 \quad (2)$$

Table 4.2: Transformed, and where relevant reversed, AusRAP rating scale used for TLoS

AusRAP measure	Ratings scale	Transformed AusRAP rating	Reversed AusRAP rating
Curvature	1 - Straight or gently curving	1	5
	2 - Moderate curvature	2.33	3.67
	3 - Sharp curve	3.67	2.33
	4 - Very sharp	5	1
Grade	1 - Flat-to-moderate grade	1	5
	2 - Steep grade	3	3
	3 - Very steep grade	5	1
Delineation	1 - Adequate	1	5
	2 - Poor	5	1
Street lighting	1 - Not present	1	N/A
	2 - Present	5	N/A

4.4 CONCLUSIONS FROM THE PILOT STUDY

The detailed results of the pilot study are provided in Appendix A. The results for adequate street lighting, the presence of sharp curves, and the presence and quality of line markings all showed positive correlations for the urban road segments. The results for the presence of sharp curves, and the presence and quality of line markings showed a positive correlation for the rural road segments. However, the results for steepness on the rural road segments showed a negative correlation. This may have been was caused by survey participants being more accepting of steep inclines on roads in rural areas than the AusRAP rating system is.

The results show that there was a relationship between the CLoS assessed in the pilot study and the TLoS assessed by AusRAP. Therefore, a similar methodology to that used in the pilot study was used for the online video survey undertaken in Year 2.

Upon review, there were some amendments made to the methodology. These included a clearer specification of what the 1 to 5 rating meant for each CLoS category. For example, in regard to grade, rather than saying 1 is poor and 5 is excellent, this was redefined as 1 is dangerously steep and therefore a low CLoS, and 5 is an acceptable and easy-to-manoeuvre grade and therefore a high CLoS.

5 EXTENDED ONLINE VIDEO SURVEY

This section of the report details the extended online video survey, based on the methodology outlined in Section 2.2.

5.1 SELECTION OF LOS INDICATORS TO BE ASSESSED

The pilot study assessed two LoS indicators, safety and reliability. These LoS indicators were repeated for the online video survey. Further indicators were included, as agreed with TMR, namely accessibility and condition which are defined as follows:

- Accessibility – amenity/environment (e.g., drainage, all-weather access)
- Condition – structural and climatic factors (e.g., functional and structural measures).

5.2 PARTICIPANTS

The survey panel was selected on the basis that it was representative of the broad range of users of the community's local roads.

It was intended that the selection of the survey panel would be based on the following criteria (however, as discussed in Section 6.4 these criteria were not always met):

- a broad representation of socio-economic status and cultural values
- a broad range of locations including urban, rural and remote
- an equal number of males and females with a similar age distribution across four age groups of 18-24, 25-44, 45-60, and above 60.

A panel of 50 members was assembled to participate in the online video survey. The members were chosen through an external market research company. This company sourced members of the public to participate in the survey and managed the reimbursement of the participants. A pre-loaded Survey Monkey platform was provided to the market research company. Participants were only rewarded if they completed the entire survey.

The requirements for each participant were as follows:

- had access to both a computer and the internet to complete the survey
- held a current Queensland driver licence
- did not work in the transport sector (i.e., they are not employed as a truck driver, traffic/transport engineer or similar occupation).

To obtain a representative sample of the Queensland population, the Australian Bureau of Statistics (ABS) 2016 Census Data (ABS 2016) was consulted. This data showed that in 2016:

- Males made up 49.4% of the population.
- Females made up 50.6% of the population.
- The median age of the population was 37, with the following breakdown
  - 25.7% aged 0—19
  - 13.5% aged 20—29
  - 13.4% aged 30—39
  - 13.8% aged 40—49
  - 12.8% aged 50—59
  - 10.6% aged 60—69

– 6.5% aged 70—79
– 3.6% aged 80 and above.

Therefore, the breakdown of participants in each region was requested to be as follows:

- 50% male and 50% female
- 35% aged 18-40 (the age group of 0-19 years was excluded as only licensed drivers could be included)
- 35% aged 40-60
- 30% aged above 60.

In 2016, approximately 40% of the population of Queensland lived in Greater Brisbane. Therefore, 40% of survey participants were requested to be located in urban areas within Greater Brisbane, with 60% in regional and remote areas.

5.3 ROAD SEGMENTS

Road segments were selected for assessment in the survey based on a combination of AusRAP factors, surface condition data and supplementary data including annual rainfall amounts and video footage of each of the selected roads.

5.3.1 AUSRAP DATA FOR THE SELECTION OF ROAD SEGMENTS

The AusRAP data used to select the road segments in this study was based on 100 m sections, as baseline reference criteria. The selection criteria chosen included:

- presence and quality of line markings (delineation)
- adequacy of street lighting
- presence of sharp curves
- adequacy of shoulder width
- steepness of road
- adequacy of lane width
- roadside driver-side distance (distance from the edge of the paved shoulder to the nearest roadside obstacle i.e., trees, light poles, safety barriers etc.).

These criteria were chosen as they match the criteria determined for the LoS survey and have high visibility for a video survey (for example it is difficult to estimate travel time in a video survey).

The AusRAP rating scheme for these criteria is presented in Table 5.1.

Table 5.1: AusRAP criteria rating scheme

Criteria	Category	Criteria rating
Area type	Rural/open area	1
	Urban/rural town or village	2
Curvature	Straight or gently curving	1
	Moderate curvature	2
	Sharp curve	3
	Very sharp	4
Quality of curve	Not applicable	3
	Adequate	1
	Poor	2
Grade use Gipsi Trac data	0 to < 7.5% (flat-to-moderate grade)	1
	>= 7.5 to 10% (steep grade)	4

Criteria	Category	Criteria rating
	>= 10% (very steep grade)	5
Delineation	Adequate	1
	Poor	2
Street lighting	Not present	1
	Present	2
Paved shoulder – driver's side	None	4
	Narrow (≥ 0 m to < 1.0 m)	3
	Medium (≥ 1.0 m to < 2.4 m)	2
	Wide (≥ 2.4 m)	1
Lane width	Narrow (≥ 0 m to < 2.75 m)	3
	Medium (≥ 2.75 m to < 3.25 m)	2
	Wide (≥ 3.25 m)	1
Roadside severity – driver-side distance	0-1 m	1
	>1-5 m	2
	>5-10 m	3
	> 10 m	4

5.3.2 SURFACE CONDITION DATA

ARRB conducts yearly surveys on the TMR road network using the specialised Intelligent Pavement Assessment Vehicle (iPAVe). Data collected includes roughness, rutting depth, pavement deflections and cracking percentage which is logged in a database as well as video footage of the collection. For this study, roughness data presented as International Roughness Index (IRI) in metres per km, was used to select sections of road that had poor surfacing and good surfacing to represent how this could affect travel time (as outlined in Section 5.4.2).

5.3.3 SUPPLEMENTARY DATA

Supplementary data was primarily comprised of video footage collected from the iPAVe during ARRB's yearly survey on the TMR road network. This included evaluating whether the sections selected using the AusRAP data and surface condition data had issues with road signs, travel times, road capacity, overtaking allowances and visible surface conditions. Possible all-weather access issues were based on the geometry of the road and annual rainfall for these areas.

5.4 DATA ANALYSIS

5.4.1 AUSRAP

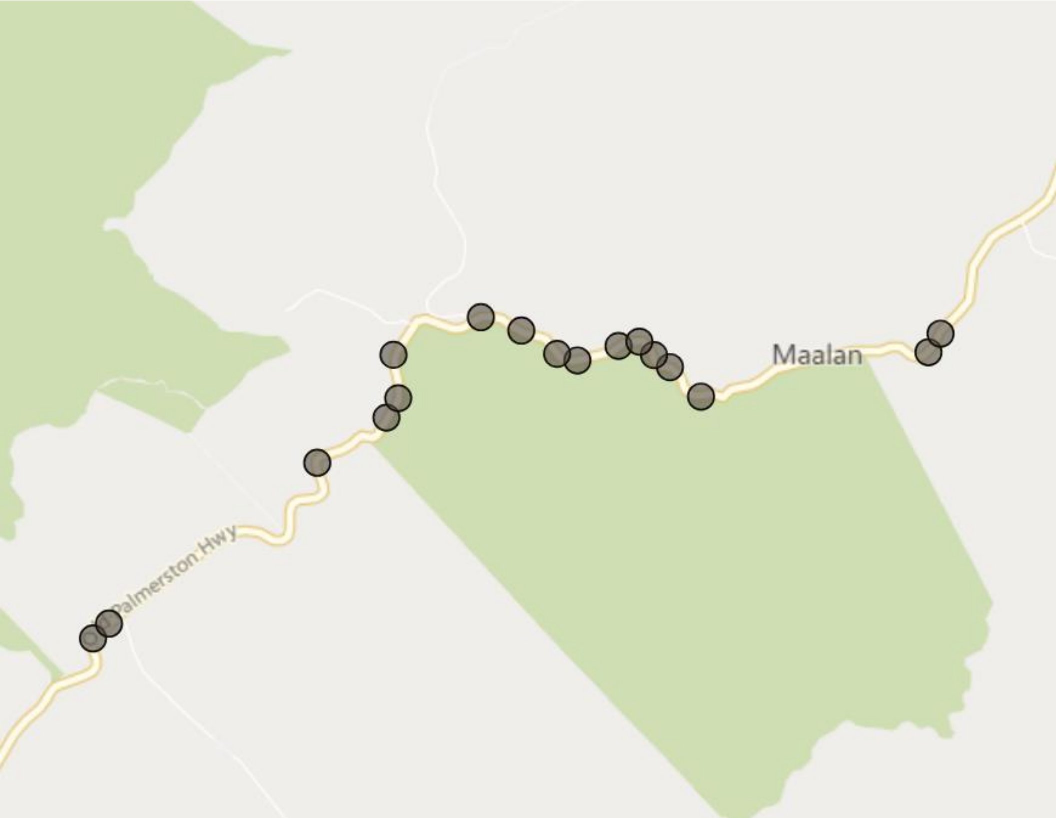
To assist choosing sections that are relevant to this study, the AusRAP data was filtered by flagging the 100 m sections as detailed below to answer the following questions:

1. Are sections adequately or poorly delineated?
   - sections that have a 'delineation' rated = 1 for adequate sections or rated = 2 for poor sections.
2. Do sections have adequate street lighting?
   - sections that have street lighting rated =2.
3. Are sections with sharp curves adequately managed?
   - sections that have a 'curvature' rated >= 3, as well as 'quality of curve' rated = 1
4. Are sections with sharp curves poorly managed?
   - sections that have a 'curvature' rated >= 3, as well as 'quality of curve' rated = 2

5. Do sections have adequate shoulder width?
   – sections that have a < 1.0 m paved shoulder on the driver's side rated = 3.
6. Do the sections have a flat or steep grade?
   – sections that have a 'grade' rated >= 4 for steep sections and rated = 1 for flat sections.
7. Do sections have an adequate lane width?
   – sections that have a lane width rated = 3 for 'narrow' < 2.75 m.
8. Do sections have an adequate clear zone between the roadside and vegetation?
   – filtered by flagging sections that have less than 5 m clearance between the road and vegetation rated either 1 or 2.

A final flag was used to highlight individual 100 m sections that had 3 or more flags. A pivot table was then used to sum the 100 m sections that had 3 or more criteria represented, to highlight roads that had large sections representing the criteria. The flagged sections could then be presented in Power BI and mapped using the GPS co-ordinates to narrow down the final selection. Figure 5.1 shows the 100 m sections along Old Palmerston Road, with filters applied to show a poorly delineated, very curvy section with steep grades, no shoulder and narrow lanes in a rural environment.

Figure 5.1: Power BI snapshot of a curvy section of Old Palmerston Highway



5.4.2 SURFACE CONDITION

To ascertain whether the road surface condition impacted the travel times along a road, the IRI roughness data was used to assist in selecting roads with visibly poor surfaces. As a starting point, the IRI data collated in 100 m sections was filtered by the following criteria:

- IRI count > 4 = poor surface condition.
- IRI count < 4 = good surface condition.

However, after analysing the sections with poor surface condition according to the above filter it was evident that most road sections did not show surface conditions poor enough to be easily visible in a video. Therefore, these criteria were used to help narrow down the selection process before visually selecting roads in poor condition. These roads were generally in rural areas with steep or very steep grades and low traffic volumes. A section along the Old Palmerston Highway (Figure 5.2) was selected to represent poor surface condition due to its high roughness as well as narrow lanes and lack of delineation compared to other sections identified as poor. It is postulated that narrow and winding lanes will also have an impact on the expected travel time.

Figure 5.2: Poor surface condition on the Old Palmerston Highway

The IRI data was then filtered for sections of road with good surface condition, which would also be evident in the video survey. As the objective was to investigate differences in travel time, it was determined that a site with visibly good surface condition should navigate similar terrain to the section along the Old Palmerston Highway with a reduced travel time. As a result, a section along the Gold Coast Springbrook Road was selected as it provided several advantages for the travel time measure including road signs, centreline delineation and gentler grades.

The objective was to compare urban sites in a similar manner, and a section of Wholey Drive/Queen Street was selected showing poor surface condition (Figure 5.3). This may be compared to the urban roads without any notable surface condition distress such as Mooloolaba Road (Figure 5.4) to compare how surface condition may affect travel time in urban areas.

Figure 5.3: Poor surface condition on Wholey Drive/Queen Street

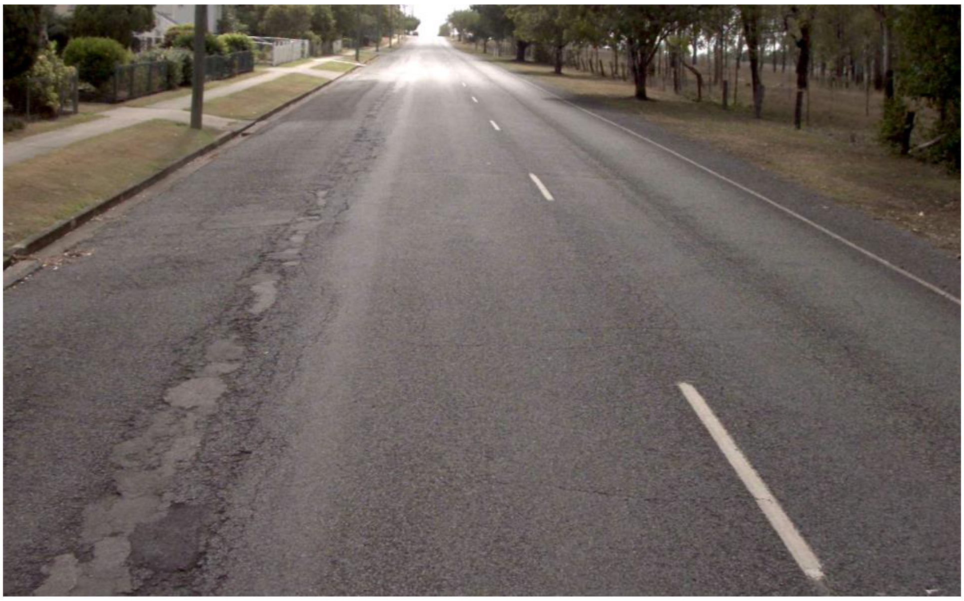


Figure 5.4: Good surface condition on Mooloolaba Road

5.4.3 FINAL SELECTION OF ROADS

The final selection of roads using the aforementioned methodology is summarised in Table 5.2 for each of the LoS indicators considered for this study. Local knowledge of some sections was drawn upon to assist in making the final selection.

Table 5.2: Selected road list for consideration

RURAL				
Road ID	**Road name**	**Start chainage**	**End chainage**	**Comments**
491	Kilcoy Murgon Road	26.1	26.3	Very curvy, steep grade, no edge lines, no shoulder, narrow lane and good surface condition.
104	Gold Coast Spring Brook Road	26.9	27.2	Very curvy, no edge lines, no shoulder, narrow lane and good surface condition.
2025	Lamington National Park Road	34.1	34.3	Very curvy, steep grade, single lane, lack of delineation and good surface condition.
205	Tamborine Mountain Road	10.3	10.5	Primarily gentle curves, some sharp curves, steep grade, no edge lines, no shoulder, narrow lane and good surface condition.
232	Texas Road	69.5	69.7	Gentle curves, steep grade, rural highway, no edge lines, no shoulder, narrow lane and good surface condition.
25B	Mount Lindsay Highway	51.3	51.5	Very curvy, steep grade, rural highway and poor surface condition.
21A	Old Palmerston Highway	67.0	67.3	Very curvy, steep grade, single lane rural highway, lack of delineation and poor surface condition.
536	Mirani Mount Ossa Road	20.8	21.0	Curvy, lack of delineation, poor surface condition and primarily single lane.
URBAN				
Road ID	**Road name**	**Start chainage**	**End chainage**	**Comments**
134	Mooloolaba Road	7.1	7.3	Curvy, a number of intersections with good surface condition.
2015	Springbrook Road	3.6	3.8	Primarily gentle curves, no edge lines, narrow lanes with good surface condition.
2041	Worongary Road	8.9	9.1	Gentle curves, a number of intersections, some steep grades with some surface texture issues.
3042	Mount Crosby Road	10.2	10.4	Primarily gentle, well protected curves with some surface condition issues.
216	Wholey Drive – Queen Street	5.2	5.4	Primarily straight, no edge lines, wide lanes with areas of poor surface condition.
412	Forest Hill Fernvale Road	28.5	28.7	Primarily straight, flat grade, no edge lines, wide lanes and poor surface condition.

Upon review of the length of the survey it was determined that four roads in each region would give sufficient duration within the overall hour limit of the survey. The four roads selected for each region are listed in Table 5.3. Further, screen-captured images from videos for each of these roads are provided in Appendix B.

Table 5.3: Final selection of roads for inclusion as videos in the survey

Road identification in survey	Road number
Urban Road 1	134
Urban Road 2	216
Urban Road 3	412
Urban Road 4	3042

Road identification in survey	Road number
Rural Road 1	104
Rural Road 2	2025
Rural Road 3	25B
Rural Road 4	21A

5.5 RESULTS

The detailed results of the online video survey are presented in Appendix D. The analysis of the data collected as part of the online video survey is described in Section 6.

6 DATA ANALYSIS

This section of the report details the analysis of the data collected through the online video survey, following the methodology outlined in Section 2.3. The detailed results of the extended online video survey are provided in Appendix D, as well as the accompanying detailed statistical analysis for each individual measure.

6.1 REVIEW OF OPEN-ENDED QUESTIONS

The survey, during both the pilot study and the extended online survey, began by asking the respondents a series of open-ended questions to gather information on what the most important aspects of the road corridor were to the participants. This information, summarised in Appendix D, was used to validate the appropriateness of the measures selected for each CLoS indicator. These responses also provided insight into further areas of research.

Most of the measures used to assess safety, reliability, condition, and accessibility were mentioned by the participants of the survey in the open-ended responses. This validated the outcomes of the literature review, and thus, the selection of measures used for the assessment. Additional factors were mentioned by participants, these are summarised in Appendix D.

6.2 ALIGNING TLOS WITH CLOS

Table 6.1 provides a summary of how the TLoS were aligned with the CLoS. As described in Section 4.3, the majority of the TLoS were based on the AusRAP rating system (extrapolated and/or reversed where applicable), as these factors were already classed into rating categories. Further, those measures which did not have a relevant AusRAP TLoS were assessed using rating categories negotiated with TMR.

Each road segment was 300 - 500 m long, with a TLoS rating provided per 100 m segment of road. These ratings were averaged for the length of the road segment used in the survey. Table 6.2 provides the TLoS ratings for each road segment and for each measure. This is the data which was used for comparison with the online-video survey data.

Table 6.1: Comparison between TLoS (extrapolated and reversed where relevant) and CLoS

A34 CLOS indicators	A34 CLoS measures	AusRAP measure or alternative	Source	TLoS scale	Description	Extrapolated to 5 (if required)	Reversed to match CLoS (if required)
Safety	Presence and quality of road signs	Road signs	Based on expert opinion	1	Not present	1	-
				2	Present	5	-
	Presence and quality of line markings	Delineation	AusRAP	1	Adequate	1	5
				2	Poor	5	1
	Adequate street lighting	Street lighting	AusRAP	1	Not present	1	-
				2	Present	5	-
	Presence of sharp curves	Curvature	AusRAP	1	Straight or gently curving	1	5
				2	Moderate curvature	2.33	3.67
				3	Sharp curve	3.67	2.33
				4	Very sharp	5	1
	Adequate shoulder width	Paved shoulder – (width)	AusRAP	1	Paved width >=2.4 m	1	5
				2	Paved width >=1 m to <2.4 m	2.33	3.67
				3	Paved width >0 m to 1 m	3.67	2.33
				4	none	5	1
	Steepness of road	Grade	AusRAP	1	0 to <7.5% (flat to moderate grade)	1	5
				2	>=7.5% to 10% (steep grade)	3	3
				3	>10% (very steep grade)	5	1
Reliability	Acceptability of travel time	Variation of average traffic speeds from the posted speed limits	Based on HERE data and TMR rating categories		**Arterial roads***		
				1	>60%	-	-
				2	>53% to 60%	-	-
				3	>45% to 53%	-	-
				4	>25% to 45%	-	-
				5	25% or less	-	-
	Adequate traffic capacity to support free-flow traffic	Segregation of lanes	Based on expert opinion	1	Undivided with no line markings	1	-
				2	Divided with a centreline	2.33	-
				3	Divided with centrelines and edge lines	3.67	-
				4	Divided with a median or barrier	5	-
Condition	Presence of visible surface texture	Road condition	AusRAP	1	Good	1	5
				2	Medium	3	3

A34 CLOS indicators	A34 CLoS measures	AusRAP measure or alternative	Source	TLoS scale	Description	Extrapolated to 5 (if required)	Reversed to match CLoS (if required)
				3	Poor	5	1
	Presence of patches and potholes			1	Good	1	5
				2	Medium	3	3
				3	Poor	5	1
	Presence of edge break			1	Good	1	5
				2	Medium	3	3
				3	Poor	5	1
	Cleanliness of road corridor			1	Good	1	5
				2	Medium	3	3
				3	Poor	5	1
Accessibility	Adequate lane width	Lane width	AusRAP	1	Wide (width >=3.5 m)	1	5
				2	Medium (width >=2.75 m to <3.25 m)	3	3
				3	Narrow (width <2.75 m)	5	1
	All-weather access	Flood hot spots	Based on TMR Data	1	Not a flood hot spot	1	5
				2	Noted as a flood hot spot	2.33	3.67
				3	Noted as a ‘high’ flood hot spot	3.67	2.33
				4	Noted as an ‘extreme’ flood hot spot	5	1
	Presence of encroaching roadside vegetation	Roadside severity — driver-side object	AusRAP	1	Distance to object 0-1 m	1	-
				2	Distance to object >1-5 m	2.33	-
				3	Distance to object >5-10 m	3.67	-
				4	Distance to object >10m	5	-
Rideability	Roughness	International Roughness Index (IRI)	Expert opinion	1	0-2 (IRI)	-	-
				2	2.1-3 (IR)	-	-
				3	3.1-4.5 (IRI)	-	-
				4	4.6-6 (IRI)	-	-
				5	>6 (IRI)	-	-

Notes:

**The travel time measure TLoS rating categories are based on arterial roads, as all of the roads in this study were arterial. This category may need to be adjusted for the TMR requirements for motorways.*

Table 6.2: TLoS ratings for each measure for each road segment (extrapolated and reversed where relevant)

Level of service measure	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Presence and quality of road signs	5	3.6667	1	5	5	1	3.6667	3.6667
Presence and quality of line markings	5	5	1	2.333	1	1	1	1
Adequate street lighting	5	5	3.6667	5	1	1	1	1
Presence of sharp curves	2.7778	4.5556	5	3.222	2.333	2.333	1.8889	2.333
Adequate shoulder width	2.333	1	1.8889	2.333	1	1	1	1
Steepness of road	3.6667	5	5	4.5556	2.6667	4.111	4.5556	5
Acceptability of travel time	4.8879	4.5046	4.9866	4.9694	4.9855	4.3258	2.9079	1.8261
Adequate traffic capacity to support free-flow traffic	5	2.333	2.333	3.6667	2.333	1	3.6667	1
Presence of visible surface texture	5	3	5	5	5	5	5	4.3334
Presence of patches and potholes	5	3	5	5	5	5	5	4.3334
Presence of edge break	5	3	5	5	5	5	5	4.3334
Cleanliness of road corridor	5	3	5	5	5	5	5	4.3334
Adequate lane width	5	5	5	5	5	1	5	1
All-weather access	3.6667	5	5	3.6667	3.6667	5	3.6667	5
Presence of encroaching roadside vegetation	2.333	2.333	2.7778	3.6667	1.6667	1	2.333	1.8889

6.3 STATISTICAL ANALYSIS OF CLOS MEASURES AND INDICATORS

Each of the measures within each CLoS indicator category was assessed through a graphical and statistical analysis. The detailed assessment of the individual measures is provided in Appendix D, this section of the report provides a summary of the outcomes.

6.3.1 STATISTICAL ASSESSMENT MEASURES

As described in Section 2.3.4, to determine the statistical significance of the correlation and therefore the goodness of fit of the CLoS and TLoS relationship to the data, a statistical assessment was completed. The statistical assessment measures selected were based on the outcome of the linear regression analysis. The following are the standard measures to review when undertaking a linear regression analysis.

The following statistical measures were estimated:

- Multiple R: this is the correlation coefficient, which measures the strength of the linear relationship between the two variables (i.e., CLoS and TLoS). An absolute value of 1 means a perfect positive relationship, and a value of zero means no relationship at all.
- R^2: this is the coefficient of determination; it is an indicator of the goodness of fit of the linear relationship to the data. This value can vary between 0 and 1, with the absolute value indicating the strength of the fit of the relationship to the data. For example, an R^2 value of 0.8 means that 80% of the data values fit the model.
- F statistic: This is an indication of how statistically significant the whole linear relationship is (see significance F *p*-value).
- t-value: This is the calculated difference in the units of standard error. The higher the t-value, the greater the statistical significance, with a minimum of 1.7 being required to state that the result is statistically significant.
- *p*-value: This value presents the statistical significance of the hypothesis assessed by the t-value. This value is computed by dividing the regression coefficient by the standards error. If the *p*-value is less than or equal to 0.05, then the model sits with the 95% confidence limits and the estimate is regarded as statistically significant
- Significance F *p*-value: This value presents the statistical significance of each of the independent variables, based on the t-value. If the *p*-value is less than or equal to 0.05, then the independent variable in the model sits within the 95% confidence limits and this independent variable is regarded as statistically significant.

The statistical assessment will be completed by identifying if the relationship between CLoS and TLoS is positive (based on the gradient of the linear relationship), the goodness of fit of the model (based on the R^2) and whether the independent variables and the model are statistically significant (based on the *p*-value of the t-value and the *p*-value of the significance F value, respectively). This statistical assessment was completed for all measures across all road categories within each CLoS indicator. This statistical analysis was investigated in further detail by separating out each measure by road category (i.e., this assessment was completed for urban and rural environments separately).

6.3.2 CLOS MEASURES

Table 6.3 provides a summary of the statistical analysis for each of the individual CLoS measures within each CLoS indicator assessed as part of the online video survey. This table details whether the correlation was positive or negative, and whether this correlation was statistically significant or insignificant. In addition, this table provides an overview of the differences in the statistical results for urban and rural environments.

A positive or negative correlation relates to the gradient of the linear regression assessment undertaken. A positive correlation implies that the expectations of customers using the roads are similar to the expectations set in the technical standards for the road. For example, a customer's opinion of the presence and quality of road signs, aligns with the requirements set out in the technical standards for where road signs need to be positioned, and how well these are maintained. If this correlation is negative, it will mean that road users have a difference in opinion to the technical standards. For example, customers may be more accepting of the gradient of a road than the technical standards allow for. Similarly, all-weather access showed a negative correlation, which could have been caused by the fact that the TLoS selected (i.e., the road segment was an identified flood hot spot) is not visible to the road user. These relationships are explored further in the analysis.

Correlations between CLoS and TLoS for each measure were determined to be statistically significant or insignificant, based on the statistical assessment elements detailed in Section 6.3.1.

Table 6.3: Summary of statistical analysis for CLoS measures

	CLoS measure	Positive or negative correlation?[1]	Goodness of Fit[2]	Statistically significant or insignificant?[3]	Urban	Rural
Safety	Presence and quality of road signs	Positive	Low	Significant	Significant	Significant
	Presence and quality of line markings	Positive	Low	Significant	Insignificant	Unavailable*
	Adequate street lighting	Positive	Low	Significant	Significant	Unavailable
	Presence of sharp curves	Positive	Low	Significant	Insignificant	Insignificant
	Adequate shoulder width	Positive	Low	Significant	Significant	Unavailable
	Steepness of road	Positive	Low	Insignificant	Insignificant	Insignificant
Reliability	Acceptability of travel time	Positive	Low	Significant	Insignificant	Significant
	Adequate traffic capacity to support free-flow traffic	Positive	Low	Significant	Significant	Significant
Condition	Presence of visible surface texture	Positive	Low	Significant	Significant	Significant
	Presence of patches and potholes	Positive	Low	Significant	Significant	Significant
	Presence of edge break	Positive	Low	Significant	Significant	Significant
	Cleanliness of road corridor	Positive	Low	Insignificant	Insignificant	Significant
Accessibility	Adequate lane width	Positive	Low	Significant	Unavailable	Significant
	All-weather access	Negative	Low	Not applicable	Significant	Significant

	CLoS measure	Positive or negative correlation?[1]	Goodness of Fit[2]	Statistically significant or insignificant?[3]	Urban	Rural
	Presence of encroaching roadside vegetation	Positive	Low	Significant	Insignificant	Significant

Notes:

**Unavailable – Due to the number of roads, all the roads within this measure had the same TLoS. This means that for the road category the results were too similar to determine the statistical significance of the relationship (i.e., no intercept).*

1. *Based on the Gradient of the Linear Relationship*
2. *Based on the R^2*
3. *Based on the t-value and the p-value*

As can be seen from Table 6.3, most of the CLoS measures against the TLoS show a positive correlation that was also statistically significant. This means that the current TLoS measures in place generally align with the opinions of the customers using the roads.

6.3.3 CLOS INDICATORS

This section details the relationships between CLoS and TLoS developed based on the survey data from Year 2.

The overall statistical assessment for each indicator was completed by combining and aligning the results of all the individual measures within that category (i.e., reliability covers travel time and the capacity to support free-flow traffic). The measures which make up each indicator are shown in Table 6.1.

Figure 6.1 provides a summary of all linear trendlines that emerged for each CLoS indicator. Figure 6.1 also provides a comparison between the linear relationships developed by using the CLoS and TLoS data points. Table 6.4 provides an overview of the number of data points which were available to produce the linear relationship shown in Figure 6.1.

Figure 6.1: Summary of all LoS relationships

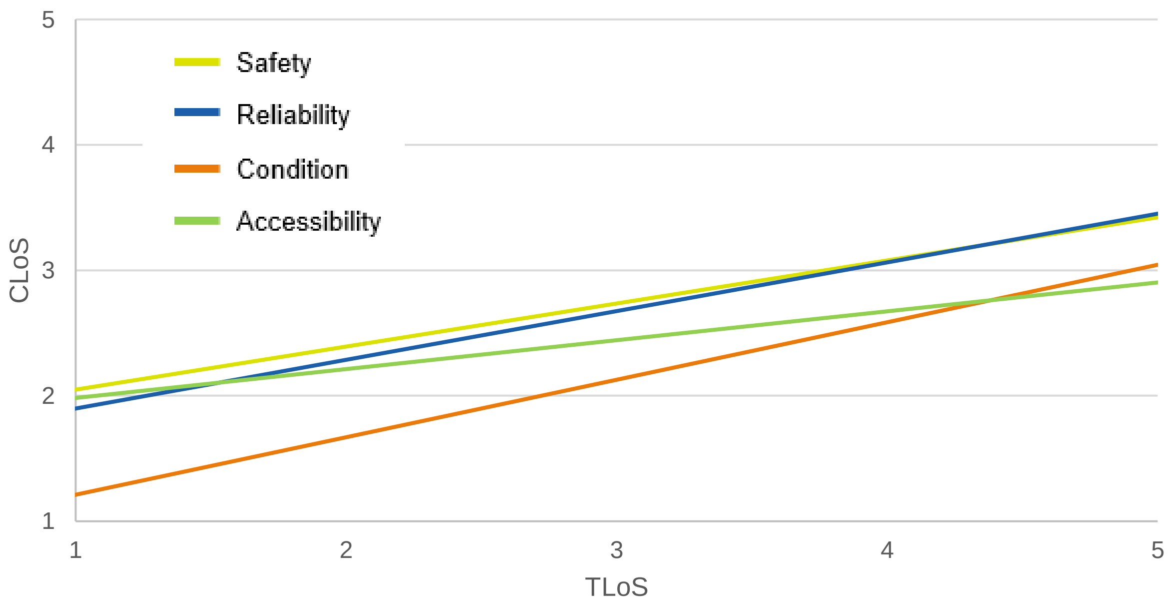


Table 6.4: Data Points for CLoS/TLoS Linear Relationships

TLoS*

Safety

CLoS	1	1.89	2.3	2.67	2.78	3.22	3.67	4.11	4.56	5
1	254	23	26		1	3	58	3	5	63
2	194	58	98	20	8	22	94	12	46	134
3	213	60	207	36	39	39	159	33	153	324
4	100	72	212	68	92	72	168	48	216	592
5	75	5	125	5	50	30	105	40	45	510

Reliability

CLoS	1	1.83	2.33	2.91	3.67	4.33	4.50	4.89	4.97	4.99	5
1	53	20	17	4	5	13	3	1	0	9	1
2	76	46	96	20	44	36	32	16	8	40	22
3	24	24	156	54	99	39	48	18	39	105	27
4	12	0	100	72	124	28	44	88	88	116	64
5	0	0	55	5	55	0	25	70	60	45	70

Condition

CLoS	3	4.33	5
1	47	85	168
2	166	134	448
3	108	93	948
4	100	56	1256
5	65	35	1010

Accessibility

CLoS	1	1.89	2.33	3.67	5
1	65	15	3	13	102
2	56	42	2	78	236
3	24	36	15	171	432
4	4	8	36	300	452
5		5	10	100	165

*Notes: *TLoS derived as described in Section 6.1.*

Table 6.5 provides a summary of the statistical assessment which was undertaken for each CLoS, in both urban and rural environments. This summary includes the key statistical measures, with additional statistical measures provided in Appendix D.5. Table 6.5 shows there is a statistically significant relationship between the CLoS and the TLoS measures for each of the indicators. This statistical significance is based on the statistical assessment measures detailed in Section 6.3.1. The coefficients of determination (R^2) show that there is not a strong goodness of fit in the linear relationships. This is because the survey was an opinion poll, producing a wide variance in responses. However, the R^2 values are likely to increase with more survey responses.

This result shows that the lack of statistical significance for individual measures within an indicator category has not affected the overall statistical significance of the indicators. This is because the quantity of data for the indicator is significantly increased by combining all ratings of the individual measures assessed. This was deemed a suitable assessment, and most of the measures within an indicator category had a statistically significant positive correlation.

This initial outcome means that the TLoS are considered relevant to assess the needs of the customer (CLoS). The results of the statistical analysis shown in Table 6.5 were aimed at determining the difference between the CLoS and TLoS relationships on urban and rural road segments for each of the CLoS indicators. In summary, the results for each indicator were as follows:

- The safety indicator presented a positive correlation and statistically significant relationship in both the urban and rural environments, with the rural relationship being slightly stronger than the urban relationship.
- The reliability indicator showed a positive correlation and statistically significant relationship in both the urban and rural environments, while this correlation was stronger in the rural environments.
- The condition indicator showed a positive correlation and statistically significant relationship in both the urban and rural environments, again the rural relationship was stronger than the urban relationship.
- The accessibility indicator also showed a positive correlation and statistically significant relationship in both the urban and rural environments, while the urban environment correlation and relationship was slightly stronger than the rural relationship.

Table 6.5: Statistical analysis information for CLoS indicators

Statistical analysis components	Safety	Reliability	Condition	Accessibility
		Overall		
Linear trendline equation	$y = 0.343x + 1.706$	$y = 0.388x + 1.511$	$y = 0.458x + 0.753$	$y = 0.230x + 1.752$
R^2	0.17	0.21	0.05	0.07
F-statistic	360.91	212.54	93.89	65.74
Significance of F (*p*-value)	$1.49{*}e^{-73}$	$6.03{*}e^{-43}$	$1.26{*}e^{-21}$	$1.70{*}e^{-15}$
t-value	19.00	14.57	9.69	8.11
p-value	$1.49{*}e^{-73}$	$6.03{*}e^{-43}$	$1.26{*}e^{-21}$	$1.70{*}e^{-15}$
		Urban		
Linear trendline equation	$y = 0.198x + 2.416$	$y = 0.265x + 2.166$	$y = 0.475x + 0.956$	$y = -0.237x + 4.235$
R^2	0.05	0.07	0.10	0.05
F-statistic	62.52	28.45	89.09	29.06
Significance of F (*p*-value)	$5.86{*}e^{-15}$	$1.60{*}e^{-7}$	$3.85{*}e^{-20}$	$1.00{*}e^{-07}$
t-value	7.91	5.33	9.44	-5.39
p-value	$5.86{*}e^{-15}$	$1.60{*}e^{-7}$	$3.85{*}e^{-20}$	$1.00{*}e^{-07}$
		Rural		
Linear trendline equation	$y = 0.288x + 1.793$	$y = 0.358x + 1.44$	$y = 1.424x - 4.195$	$y = 0.144x + 1.859$
R^2	0.10	0.19	0.10	0.04
F-statistic	107.84	96.29	94.53	26.80
Significance of F (*p*-value)	$5.18{*}e^{-24}$	$1.54{*}e^{-20}$	$3.27{*}e^{-21}$	$3.07{*}e^{-07}$
t-value	10.38	9.81	9.72	5.18
p-value	$5.18{*}e^{-24}$	$1.54{*}e^{-20}$	$3.276{*}e^{-21}$	$3.07{*}e^{-07}$

6.4 DEMOGRAPHIC ANALYSIS

As detailed in Appendix B, the extended online video survey began by asking the participants a series of demographic related questions. These included: occupation, gender, age range, and location.

The results of the demographic questions are provided in Table 6.6.

Table 6.6: Summary of demographic information

Category		Results (Percentage of participants)
Occupations	White-collar worker (office-based non-managerial role)	16%
	Professional (such as doctor, lawyer, accountant)	12%
	Retired	22%
	Sales/service worker (sales representative, checkout operator, sales assistant, waitress)	12%
	Self-employed	8%
	Middle management (such as department head, senior manager)	10%
	Unemployed	4%
	Community or personal service worker (waitress, support worker, police, fitness instructor, athlete)	8%
	Technician or trades worker (builder, electrician, plumber, hairdresser, chef, gardener, ICT support)	2%
	Full-time home duties	2%
	Student	6%
Age group	18—24	18%
	25—40	25%
	41—60	29%
	More than 60	27%
Gender	Male	69%
	Female	31%
Residence	Urban (suburban/Greater Brisbane)	45%
	Rural	53%
	Remote	2%
Road type most travelled on	Urban/suburban (within Greater Brisbane)	45%
	Rural - including highways and freeways outside of Brisbane	50%
	Remote - including dirt roads	5%
Average weekly km car travel	0 to 49 km	0%
	50 to 99 km	33%
	100 to 200 km	39%
	More than 200 km	27%
Average weekly km other travel modes	0 to 49 km	86%
	50 to 99 km	12%
	100 to 200 km	2%
	More than 200 km	0%

Table 6.6 shows that there is a relatively equal spread of participants across the four age ranges. However, most participants (69%) were male, and from urban and rural areas, with only a small minority from remote locations (2%). Further, the largest proportion of participants were retired (22%), followed by white-collar workers (16%), professional (12%) and sales workers (12%).

An analysis was completed of the effects of the varying demographic on the ratings given by participants, and therefore, the results of the survey. The analysis results showed:

- Female respondents tended to provide a slightly narrower range of responses across the CLoS indicators, when compared with male respondents whose ratings were more evenly distributed.
- Females were more likely to give higher ratings than lower ratings, whereas males, overall, tended to give lower ratings.
- In the 18-24 years of age group most respondents provided CLoS ratings of 2 or 3 across all four of the CLoS indicators. This age group was also the least likely to provide a CLoS rating of 5.
- In the 24-40 years of age range, most respondents also provided CLoS ratings of 2 or 3 across all four of the CLoS indicators.
- In the 41-60 years of age and over 60 years of age ranges, the responses were even more widespread, with 17-27% of respondents across all Indicators, providing CLoS ratings of 1-4.
- Ratings provided for respondents residing in urban and rural/remote regions were similar.
- There were no obvious strong trends across the different occupations.
- Looking at the responses for each of the CLoS indicators across gender, age group and location, it was evident that the strongest responses, that is, where one or two ratings were clearly preferred, were seen in the Reliability indicator. This shows that a judgement was either easier to make, or there is less diversity of opinion on the contributing factors across the respondents.
- The Condition and Safety CLoS indicators showed the least strength of opinion, conversely showing that either these factors were not easy to judge or there is a wider range of tolerance.

This demographic analysis is summarised in Table 6.7. The most common rating selected for each indicator in each demographic category has been highlighted.

Table 6.7: Demographic analysis summary

Rating	Accessibility	Condition	Reliability	Safety
		Female		
1	15%	14%	14%	19%
2	20%	20%	26%	16%
3	26%	25%	27%	25%
4	27%	22%	19%	24%
5	11%	19%	14%	15%
		Male		
1	23%	20%	16%	25%
2	23%	24%	27%	19%
3	25%	23%	25%	22%
4	21%	21%	24%	22%
5	8%	11%	7%	11%
		18 – 24 years of age		
1	20%	16%	16%	21%
2	26%	27%	36%	20%
3	28%	31%	31%	27%
4	19%	19%	13%	16%
5	6%	7%	4%	11%
		25 – 40 years of age		
1	15%	13%	11%	14%
2	22%	26%	30%	18%
3	26%	24%	25%	22%
4	27%	22%	22%	20%
5	10%	16%	12%	10%
		41 – 60 years of age		

Rating	Accessibility	Condition	Reliability	Safety
1	24%	23%	18%	25%
2	19%	19%	23%	13%
3	27%	23%	26%	20%
4	22%	23%	25%	23%
5	9%	14%	10%	9%
More than 60 years of age				
1	22%	21%	17%	23%
2	24%	22%	22%	16%
3	21%	19%	23%	16%
4	22%	22%	27%	21%
5	11%	16%	11%	13%
Rural & Remote				
1	17%	16%	14%	21%
2	24%	23%	25%	15%
3	28%	24%	26%	20%
4	23%	21%	24%	21%
5	9%	16%	10%	11%
Urban				
1	20%	18%	15%	21%
2	22%	23%	27%	16%
3	25%	23%	26%	21%
4	23%	22%	23%	20%
5	9%	14%	9%	11%
Itinerant workers (self-employed/trades, community workers, students, etc.)				
1	28%	25%	22%	18%
2	27%	27%	32%	19%
3	27%	27%	27%	15%
4	16%	14%	12%	16%
5	3%	8%	8%	7%
Unpaid work (retired, unemployed & home duties)				
1	14%	15%	13%	22%
2	23%	22%	21%	14%
3	24%	19%	24%	17%
4	25%	25%	30%	22%
5	14%	20%	13%	18%
White-collar and sales				
1	24%	22%	19%	27%
2	21%	22%	28%	18%
3	26%	22%	26%	24%
4	21%	22%	19%	20%
5	7%	12%	8%	7%
Middle management and professionals				
1	21%	18%	11%	20%
2	21%	25%	30%	18%
3	25%	26%	28%	23%
4	25%	23%	28%	21%
5	7%	7%	3%	7%

Table 6.8 provides an indication of the strength of the responses determined by counting the top three highest rating results in each set of demographics.

Table 6.8: Strength of response for each CLoS Indicator across all genders, ages, locations, and occupations

CLoS indicator	Accessibility	Condition	Reliability	Safety
Count of highest responses	13	5	23	5

7 RELATIONSHIPS BETWEEN CLOS AND TLOS

This section examines the results of the statistical analysis and relationships between CLoS and TLoS and makes an initial comparison with the findings from the earlier literature review.

7.1 DISCUSSION OF THE STATISTICAL ANALYSIS

Section 6 and Appendix D present the results of the graphical and statistical analysis of the CLoS indicator categories and the associated individual CLoS measures.

As outlined in Section 6.3, most of the individual CLoS measures (e.g., road signs, line markings, potholes, etc.) when compared against the TLoS show a positive correlation that was also statistically significant. This means that the current TLoS measures in place generally are reflective of the opinions of the customers using the roads. However, as seen from the tables presented in Appendix D, there was less consistency in the ratings for CLoS than there was for the TLoS ratings. This means that the customers viewing the road videos had varying opinions, as expected. However, it could also mean that the TLoS measures were not fully covering all the factors that could be impacting on the assessment of the CLoS indicators component of a road condition assessment.

For example, line markings, road signs, and street lighting were all assessed on a rating scale of 1 to 2 (which was extrapolated to match the CLoS scale of 1 to 5). Whereas the CLoS indicator measures were assessed based on their presence and their quality. The open-ended questions revealed that customers viewing the roads were concerned with the quality of line markings and road signs. Therefore, the quality of these road features should also be assessed as part of TLoS, rather than just their presence. These factors are likely to be too complex for this type of study, as measures which the customer would like to see may not be necessary. These are areas which could be researched as part of further work. Additionally, consideration could be given to weighting the individual measures prior to assessing the overall indicator categories.

Another item to note from Table 6.3 is that the statistical relationship could not be calculated for certain CLoS measures when the data was separated by road category. This is because, due to the number of the roads, all the roads within this measure had the same TLoS, as seen in Table 6.2. To rectify this issue in a further study, more roads should be assessed. In addition, a wider variety of roads should be selected, if DVR footage can be obtained. The roads in this survey were selected based on the availability of suitable footage, and several other factors, relating to the measures to be assessed.

As seen from Figure 6.1, overall, there is a positive correlation between the CLoS and TLoS for each of the indicator categories (i.e., safety, accessibility, condition and reliability). As noted in Table 6.5, all four CLoS indicator categories show a positive correlation that is statistically significant. When separated by road category, all indicators show a positive and statistically significant relationship in urban and rural environments. However, as these linear relationships (Figure 6.1) have a low gradient it may suggest that road users have a lower sensitivity to the technical performance of the road, especially for the Accessibility indicator. Further, this low gradient could also mean that road users have higher performance standards and demands than that which the technical standards currently provide (a TLoS of 5 may only be CLOS of 3 for the road users, meaning even if all roads were maintained to a technically high standard, this would not be acceptable to the road users). This could mean that road users are more heavily focused on the factors mentioned in the open-ended question responses, that were not included in the survey.

7.2 DETERMINING CLOS FROM TLOS

As described in Section 6.3.3, linear relationships were derived from a correlation between the resulting CLoS from the survey, and the relevant TLoS for the road segments. These equations can be used to determine a representative CLoS for values of TLoS across the 5 indicator categories. Table 7.1 details the calculated CLoS (on a scale of 1 to 5), for a TLoS (on a scale of 1 to 5), for urban roads and rural roads.

Safety, Condition, Accessibility and Reliability were determined using the survey data analysis. Rideability was included based on literature review information detailed in Section 3.1.5 'Rideability'.

Further, Figure 7.1 provides a graphical depiction of the CLoS indicator equations for all roads, Figure 7.2 provides a graphical depiction of the CLoS indicator equations for urban roads, and Figure 7.3 provides a graphical depiction of the CLoS indicator equations for rural roads

Table 7.1: CLoS rating derived for each indicator, based on TLoS rating, using the linear regression relationships developed

	TLoS	Calculated CLoS		
		Overall (Figure 7.1)	Urban (Figure 7.2)	Rural (Figure 7.3)
Safety		$y = 0.343x + 1.706$	$y = 0.198x + 2.416$	$y = 0.288x + 1.793$
	1	2.05	2.61	2.08
	2	2.39	2.81	2.37
	3	2.74	3.01	2.66
	4	3.08	3.21	2.94
	5	3.42	3.41	3.23
Reliability		$y = 0.388x + 1.511$	$y = 0.265x + 2.166$	$y = 0.358x + 1.44$
	1	1.90	2.43	1.80
	2	2.29	2.70	2.16
	3	2.68	2.96	2.51
	4	3.06	3.23	2.87
	5	3.45	3.49	3.23
Condition		$y = 0.458x + 0.753$	$y = 0.475x + 0.956$	$y = 1.424x - 4.195$
	1	1.21	1.43	-2.77
	2	1.67	1.91	-1.35
	3	2.13	2.38	0.08
	4	2.59	2.86	1.50
	5	3.04	3.33	2.92
Accessibility		$y = 0.230x + 1.753$	$y = -0.237x + 4.235$	$y = 0.144x + 1.859$
	1	1.98	4.00	2.00
	2	2.21	3.76	2.15
	3	2.44	3.52	2.29
	4	2.67	3.29	2.43
	5	2.90	3.05	2.58
Rideability		$y = 0.443x + 2.203$	$y = 0.425x + 2.295$[1]	$y = 0.46x + 2.11$ [2]
	1	2.65	2.72	2.57
	2	3.09	3.15	3.03
	3	3.53	3.57	3.49
	4	3.97	3.995	3.95
	5	4.42	4.42	4.41

Notes:

- *Where, y = CLoS and x = TLoS*
- *Relevant TLoS values are provided in Table 6.1*
- *Rideability equations sourced from literature outlined in Section 3.1.5. Equations selected were for the highest number of observations, and the strongest correlation (R^2).*
- *Equations for Rideability were based on a roughness measurement scale of 1 (excellent) to 10 (poor). Therefore, the equations needed to be adjusted to match the CLoS scale.*
  1. *Equation sourced from Mornington Peninsula (2004; cited in Martin 2005) – for local urban (sealed/urban) roads*
  2. *Equation sourced from Swan (2003; cited in Martin 2005) – for local rural (sealed/rural) roads.*

Figure 7.1: Graph of CLoS Indicator equations (all roads)

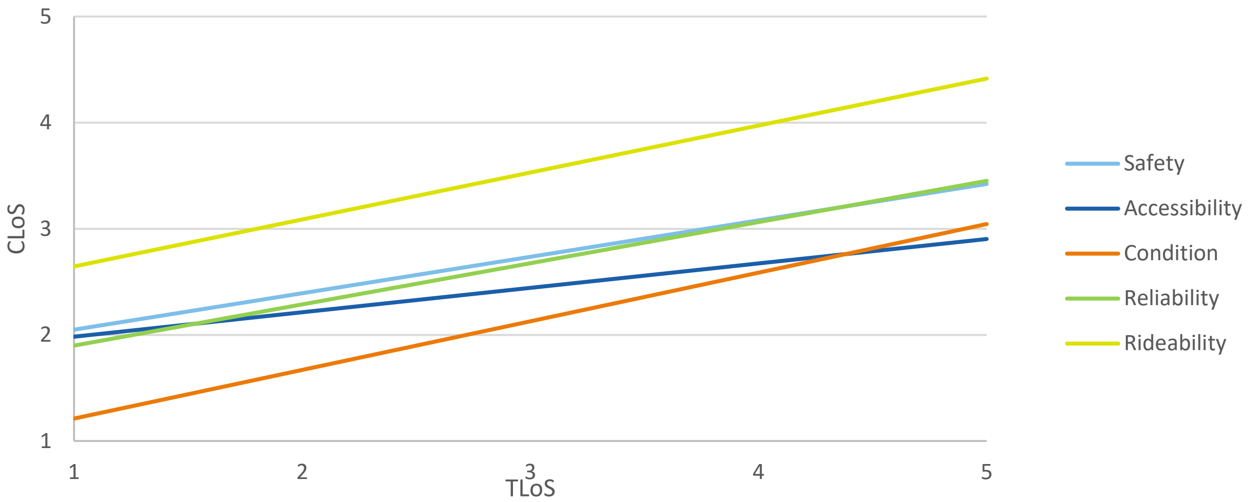


Figure 7.2: Graph of CLoS Indicator equations (urban roads)

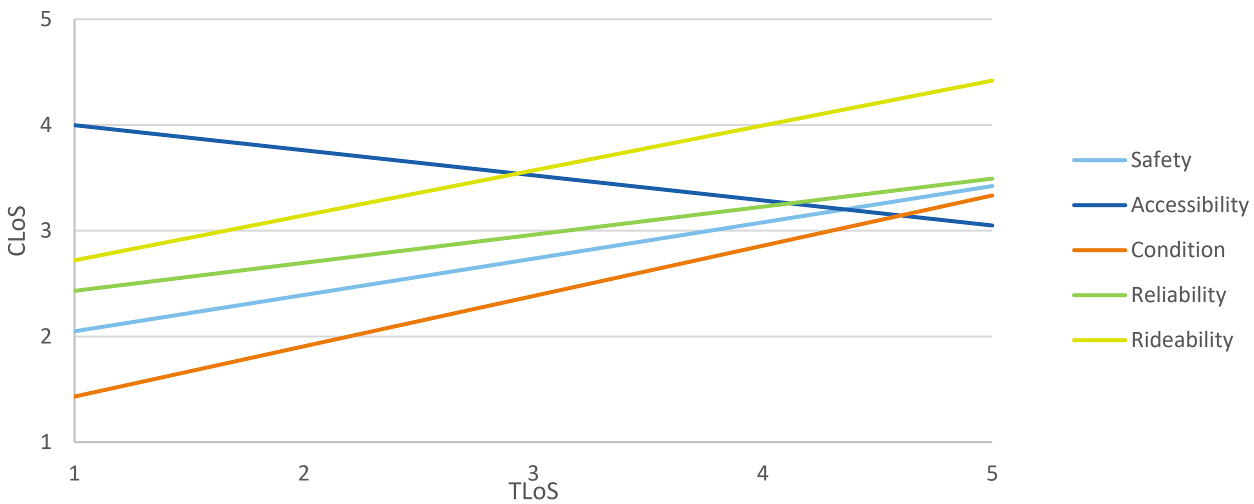
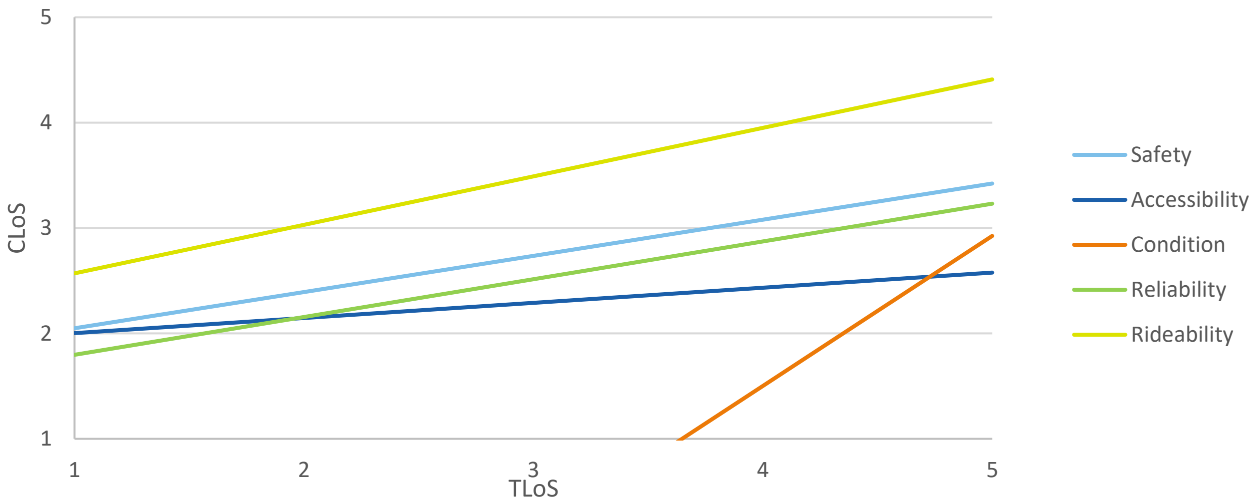


Figure 7.3: Graph of CLoS Indicator equations (rural roads)



7.3 COMPARISON TO RACQ UNROADWORTHY ROADS SURVEY 2018

To raise awareness on the condition of roads across Queensland, the Royal Automotive Club of Queensland (RACQ) conducted their ‘Unroadworthy Roads’ survey. This survey asks respondents to nominate roads on the Queensland network which they identify as being in poor and inadequate condition. This means that these roads are unfit to perform the functions which they were designed to perform. Therefore, they are not providing an acceptable level of service to the road user (RACQ 2018).

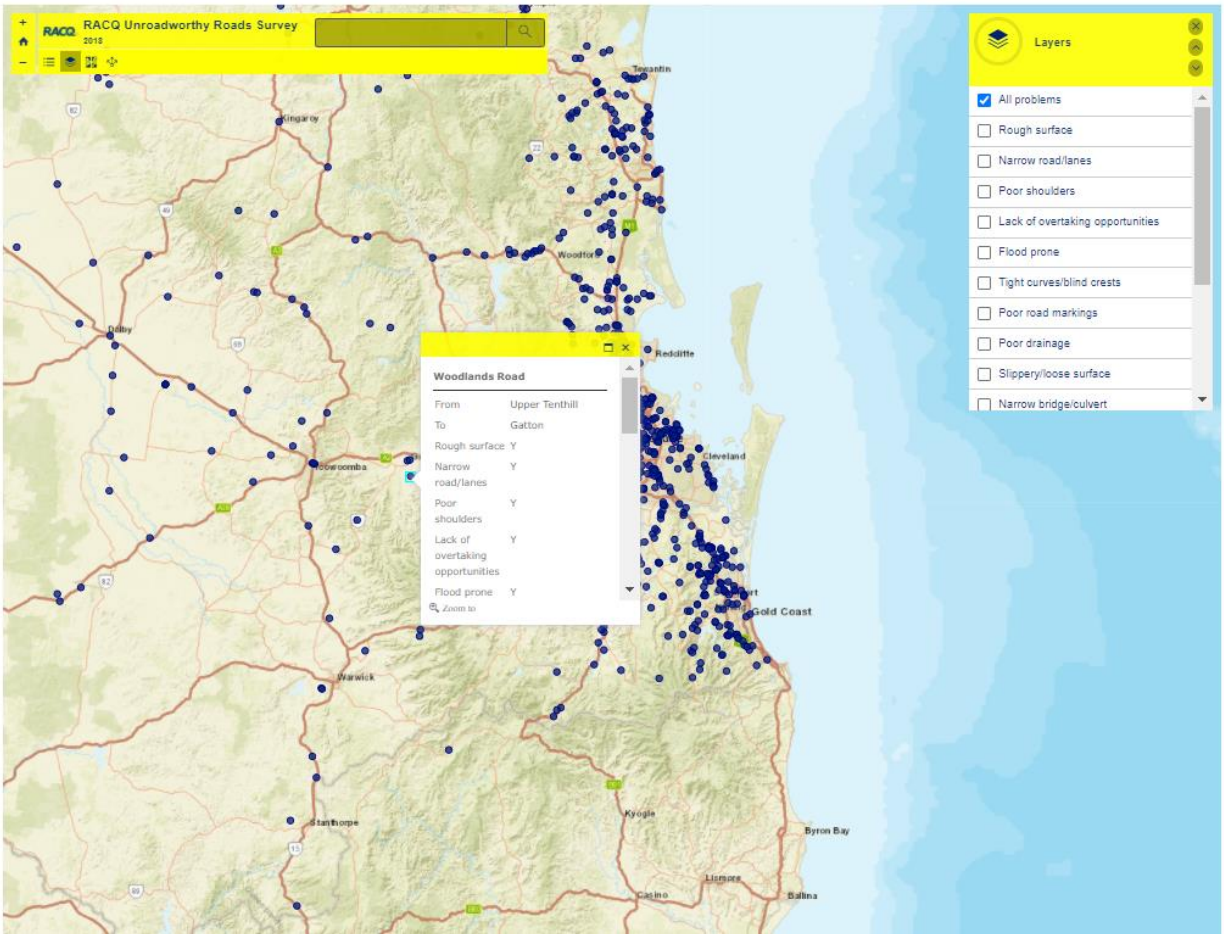
The main aims of the survey were:

- identify the worst roads on the Queensland network, according to the opinion of RACQ members, for the purpose of providing governments with an opportunity for increased funding
- identify the major deficiencies associated with Queensland’ road infrastructure
- provide a comparison to the previous year’s results (RACQ 2018).

The RACQ survey asks road users a series of Yes/No questions across several road factors. Direct comparison was able to be made from the RACQ survey to some of the CLoS measures (where available) assessed as part of the A34 project.

The outcome of the comparison varied, with some aspects being similar across the surveys and others not. Overall, for roads that were given a Poor rating for the CLoS in the A34 project, the answer was Yes for the RACQ survey (i.e., agreed that the condition of the road was poor). However, the results for the RACQ survey are presented on the website (RACQ 2018) as the raw results on a map for each road that a road user provided a rating on. Therefore, the data points shown are specific to one road user’s opinion. This data presentation is shown in Figure 7.4. Whereas the results for the CLoS ratings in the A34 project were based on an average of the opinions of all participants in the survey.

Figure 7.4: RACQ Unroadworthy Roads Survey Results Presentation



Source: RACQ (2018)

The results of the comparison showed that Rural Road 4 and Urban Road 3 had the highest correlation between the survey responses from the A34 project and the RACQ survey.

7.4 SUMMARY OF RELATIONSHIP BETWEEN CLOS AND TLOS

Participants were asked open-ended questions prior to the survey to validate the measures which were selected for each CLoS indicator. This section has outlined the major themes which emerged from these questions and has indicated that most of the measures selected for each indicator were appropriate, based on the opinions of the participants. Additional factors which were mentioned by participants were also outlined, e.g., the presence of speed cameras, overtaking opportunities, the variability in posted speed limit along a single stretch of road, the presence of road works, number of lanes, and poor drainage. These factors may provide a basis for further research.

Each of the measures assessed in the survey were analysed against the relevant TLoS. The following measures showed a positive correlation between CLoS and TLoS:

- presence and quality of road signs
- presence and quality of line markings
- adequate street lighting
- presence of sharp curves
- adequate should width
- steepness of the road
- acceptability of travel time
- sufficient road capacity of support free-flow traffic
- presence of visible surface texture
- presence of potholes and patches
- presence of edge breaks
- cleanliness of road corridor
- adequate lane width
- presence of encroaching roadside vegetation.

However, it should be noted that each of these positive correlations had varying strengths, as shown by the statistical analysis. The only measure to have a statistically insignificant positive correlation was the steepness of the road.

The only measure to show a negative correlation was all-weather access. The TLoS selected for all-weather access was whether the road segment was a flood hot spot. However, this is something which would be difficult for road users to discern. Therefore, a more appropriate measure may be the presence or absence of drainage infrastructure.

Table 7.1 detailed how CLoS can be calculated from any TLoS (on a scale of 1 to 5), using the linear relationships developed as part of the statistical assessment.

8 CONCLUSIONS

8.1 PROJECT SUMMARY

Road agencies have identified that there is a pressing need to relate Customer-based Levels of Service (CLoS) requirements related to road maintenance, to the maintenance intervention measures (roughness, rutting, cracking, potholes, etc.) used by road asset managers, or the Technical-based Levels of Service (TLoS). This project aimed to determine the existence of statistically significant relationships between CLoS and TLoS for an agreed set of road categories that will allow the determination of a customer acceptable level of TLoS.

This project was completed across three phases:

> **Year 1** involved a literature review and a pilot study. This work was undertaken to focus the research completed in Years 2 and 3.
>
> **Year 2** implemented the pilot study methodology on a wider scale, with an extended online video survey.
>
> **Year 3** involved an in-depth statistical analysis of the data collected in the survey, to determine the relationships between CLoS and TLoS, along with implementation solutions.

The literature review was focused on identifying CLoS indicators, and associated measures.

The information collected as part of the literature review was used to develop a series of measures and indicators used to assess CLoS. Five indicators for CLoS were identified, each with a series of measures for assessment. These indicators were:

- *Safety* – function, resilience (e.g., shoulder and lane width, safety features, texture, skid resistance)
- *Accessibility* – amenity/environment (drainage, all weather access, signage)
- *Condition* – structural, climatic factors (functional and structural measures)
- *Reliability* – traffic capacity (e.g., adequate number of lanes, traffic management)
- *Rideability* – travel experience (roughness).

The pilot study assessed two of these indicators, Safety and Accessibility, by using several measures associated with each indicator. The results for adequate street lighting, the presence of sharp curves, and the presence and quality of line markings all showed positive correlations for the urban road segments. The results for the presence of sharp curves, and the presence and quality of line markings showed a positive correlation for the rural road segments. However, the results for steepness on the rural road segments showed a negative correlation. This may have been caused by survey participants being more accepting of steep inclines on roads in rural areas than the AusRAP rating system is.

The results show that a relationship existed between the CLoS assessed in the pilot study and the TLoS assessed by AusRAP. Therefore, a similar methodology to that used in the pilot study was used for the online video survey undertaken in Year 2.

The online video survey was aimed at validating the outcomes of the LoS indicators assessed in the pilot study, as well as expanding on the pilot study by including two additional CLoS indicators of Condition and Reliability, as well as the indicators assessed in the pilot study, Safety and Accessibility. Each of these CLoS indicators was assessed through a series of measures. Participants in the online video survey were asked a series of open-ended questions, followed by a series of questions asking for ratings of DVR footage. Four urban roads, and four rural roads were assessed as part of the online video survey.

The results of the survey showed that most of the measures used to assess each of the CLoS showed positive and statistically significant linear relationships. Overall, the results for each CLOS indicator were as follows:

- The Safety indicator had a positive correlation and statistically significant relationship in both the urban and rural environments, with the rural relationship being slightly stronger than the urban relationship.
- The Reliability indicator showed a positive correlation and statistically significant relationship in both the urban and rural environments, while this correlation was stronger in the rural environments.
- The Condition indicator showed a positive correlation and statistically significant relationship in both the urban and rural environments, again the rural relationship was stronger than the urban relationship.
- The Accessibility indicator also showed a positive correlation and statistically significant relationship in both the urban and rural environments, while the urban environment correlation and relationship was slightly stronger than the rural relationship.

The linear equations developed through the statistical assessment were then used to develop a representative CLoS (on a scale of 1 to 5) for each value of TLoS (on a scale of 1 to 5), for the five CLoS indicators as described in Section 8.3.

Based on the results of this study, the following overarching observations were made:

- The relative importance of various LoS criteria from the customer perception can vary.
- The opinion of customers on the performance of a road varies based on location (i.e., urban or rural).
- Some quantitative relationships had been previously established between community tolerance (CLoS) and road roughness (TLoS), allowing for the hypothesis of a correlation between CLoS and TLoS.
- Constrained funding needs to be included when considering LoS as inferred by the different CLoS ratings given in rural and remote areas. For example, higher volume roads, with stronger traffic demand will need to be considered at a high level of LoS to provide for the higher volumes of customers.

8.2 ALIGNING THE SURVEY RESULTS WITH THE LITERATURE REVIEW RESULTS

Austroads (2016) studied LoS for non-freight road users, to identify and define the asset management needs and LoS requirements for non-freight customers. This was a major reference study used when developing the CLoS measures to be assessed as part of the pilot study and extended online video survey.

The 2016 study asked respondents their opinions on the importance of different road attributes. The study then asked respondents their opinion of how different road attributes performed.

The study results showed that the highest importance ratings were given to road condition, road signs, driving on wet roads, line markings and reflectors, and road width. These results strongly aligned with the results of the open-ended opinion section for the online video survey, validating the measures used for both the pilot study and the extended online video survey rating components.

In addition, the results of the Austroads (2016) study indicated that there were only relatively small differences between the urban and rural regions in terms of importance ratings of CLoS indicators, however, there were marked differences in the ratings of how well the road attributes performed. The general pattern was that metropolitan respondents gave higher percentages of acceptable or better ratings, except for issues such as congestion and rest areas (for road measures) and rest points with seating (for pedestrian facilities) where regional respondents gave higher percentages of acceptable or better responses for rest areas and congestion. Consequently, it was important that the surveys completed by participants in this project were identified to be from varying regions across Queensland (urban/rural classifications).

The results from this study suggest that it should be possible to develop one LoS framework covering both metropolitan and regional roads, using the same indicator measures for all roads. However, because the study showed that there were some pronounced differences between regions in terms of how well these assessment measures performed during a road review, it is important to define the road categories in a LoS assessment. Consequently, the participants of both the pilot study and the extended online video survey were informed whether they were assessing either a rural or urban road. In addition, the AusRAP ratings scales take the road category into consideration.

8.3 IMPLEMENTATION SOLUTIONS

This project aimed to determine statistically significant relationships between CLoS and TLoS, to assist with the determination of a customer accepted level of TLoS. This was completed through a demonstration of the connection between the desired relevant CLoS and TLoS by: a literature review, the implementation of a survey methodology and a statistical assessment of the data collected to determine linear relationships between the resulting CLoS survey ratings and the relevant TLoS for the road segments. The outcome of this project was the provision of a rational guidance for maintenance intervention that could be readily adopted by TMR and possibly by other road agencies.

The CLoS and TLoS relationships were used to determine a representative CLoS for values of TLoS across the five indicator categories. Table 7.1 details the calculated CLoS (on a scale of 1 to 5), for a TLoS (on a scale of 1 to 5), for urban and rural roads. These values can give a road manager an indication of the level of CLoS for the provided TLoS on a road segment, across the five major indicator categories.

8.4 RECOMMENDATIONS FOR FURTHER RESEARCH

The research has provided key insights into the needs of customers, and how these relate to the technical standards road managers use to assess the quality and condition of their roads. There were limitations to this research, however, these limitations provide opportunities for further refinement in future research.

This study separated the roads used for the assessment into two classes, urban and rural. However, there are several road classes across Queensland which were not included such as unsealed roads, motorways, and high-traffic urban arterial roads. These roads were not included due to the unavailability of DVR footage, and the privacy requirements for the videos.

The correlations for some measures should be further investigated. Specifically, the all-weather access measure showed a negative trend. As this TLoS is not something visible to the driver on the videos, it did not make for a strong correlation. It is recommended that a more visible feature be used to address this TLoS, such as adequacy of drainage infrastructure, presence and quality of culverts, etc.

Another correlation to be further investigated would relate to the steepness of the road. This measure showed a very weak correlation between CLoS and TLoS. This could mean that either customers were more accepting of the steepness of a road than the technical standards are, or the steepness of the road was not clearly visible to the participants of the survey.

These issues could be resolved through an improved simulation method for the participants who are rating the road attributes. There are available driving simulators across Australia, which could be used for this type of study. However, this would likely be expensive to do on a wide scale.

A further limitation of the study was the sample size. The online video survey included 50 members of the public. For a sample to be representative of the entire Queensland population (5 million people), there would need to be approximately 380 participants, for a confidence level of 95%.

This study overall did show the correlations and statistically significant relationships between the CLOS and TLoS for the five CLoS indicator categories of Safety, Reliability, Accessibility, Condition and Rideability. Further, these findings generally aligned with the findings of previous studies reviewed as part of the literature review component of this project.

Based on these limitations, recommendations for further research as part of Year 4 of this study include:

- Discussions with TMR regarding the confidence levels of the relationships between CLoS and TLoS, found as part of this study, for the five indicators.
- A review of TMR's current LoS specifications and arrangements to see if the findings from this study could be readily implemented into TMR practices.
- An examination of other methodologies for developing relationships between CLoS and TLoS. This would require a thorough investigation of feasibility and costs.

- The development of an approach for assessing unsealed roads, urban motorways, and high-traffic urban arterial roads.

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ACRONYMS

ARRB	Australian Road Research Board
AusRAP	Australian Road Assessment Program
CLoS	Customer-based Levels of Service
DVR	Digital Video Recorder
GPS	Global Positioning System
iPAVe	Intelligent Pavement Assessment Vehicle
IRI	International Roughness Index
LoS	Levels of Service
NACoE	National Assets Centre of Excellence
NAASRA	National Association of Australian State Road Authorities (now Austroads)
NRM	NAASRA Roughness Meter
NZTA	New Zealand Transport Agency
R	Rural
RACQ	Royal Automotive Club of Queensland
TLoS	Technical-based Levels of Service
TMR	Transport and Main Roads Queensland
U	Urban

GLOSSARY

Accessibility	Accessibility is an indicator that refers to mobility pathways, allowing for the continuity of useable routes between key locations of travel.
Condition	The condition of an asset is an indicator that is based on the combination of characteristics which are used to assess functionality.
Coefficient of determination (R^2)	Squaring the correlation coefficient produces a metric known as the coefficient of determination, R^2. This statistical measure represents the proportion of the variance for a dependent variable (CLoS) that is explained by the independent variable (TLoS) in a regression model.
Customer-based Levels of Service (CLoS)	Customer-based Levels of Service refer to how well assets service customers, or how well customers' needs and wants are met.
Indicators	In this project, indicators are specified to be the overarching categories of the assessment of levels of service. Each indicator refers to a type of Customer-based Level of Service. Within each indicator is a series of measures which are quantitative attributes for assessment.
Measures	Measures are the quantitative parameters, used for the assessment of each indicator.
Pearson Product Moment correlation (r)	Otherwise known as the correlation coefficient. This is generally represented by the symbol 'r'. The correlation coefficient varies from an r of –1, which indicates a perfect negative correlation to 1, which means a perfect positive correlation.
Reliability	Reliability is an indicator that refers to the ability of a road or road network to perform its intended function, without any malfunctions, assuming the road is used within the conditions it is designed for.
Rideability	Rideability is an indicator directly related to the roughness of the road surface.
Safety	Safety is an indicator that refers to the methods and measures in place to prevent road users from being killed or seriously injured.
Technical-based Levels of Service (TLoS)	Technical-based Levels of Service are the maintenance intervention standards for various road condition parameters (roughness, rutting, cracking, potholes, etc.) used by road asset managers.

APPENDIX A PILOT STUDY RESULTS

A.1 URBAN ROAD SEGMENTS

This section outlines the relationship between CLoS and TLoS for street lighting, line markings and sharp curves, respectively. Table A.1 provides a summary of the linear regression equations and the coefficients of determination for each of the relationships.

Table A.1: Best-fit equations and coefficients of determination for urban CLoS/AusRAP relationships

A34 CLoS	AusRAP category	Best-fit linear equation	Coefficient of determination (R^2)
Adequate street lighting	Street lighting	$y = 0.9286x + 0.5174$	0.16
Presence and quality of line markings	Delineation	$y = x - 1.2143$	0.32
Presence of sharp curves	Curvature	$y = 0.09911x + 2.8054$	0.007

For the adequacy of street lighting in urban environments, the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for street lighting for each of the road segements. The AusRAP rating of street lights is defined as 1 (not present) or 2 (present). The AusRAP scale was transformed to match the scale of 1 to 5 developed for CLoS. The results showed that there was a very weak positive correlation between the CLoS and the TLoS.

For the presence and quality of line markings on urban roads the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for delineation for each of the road segments. The AusRAP rating of delineation is defined as 1 (adequate) or 2 (poor). The AusRAP scale was transformed and inverted to match the scale of 1 to 5 developed for CLoS. The results showed that there was a positive correlation in the relationship between CLoS and TLoS.

For the curvature of the road, the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for curvature for each of the road segements. The AusRAP rating of curvature is defined as 0 (straight) to 4 (very sharp). The AusRAP scale was transformed and inverted to match the scale of 1 to 5 developed for CLoS. The results showed that there was a positive correlation in the relationship between CLoS and TLoS.

Most of these equations have a very low R^2 value, therefore, do not have a high reliability of predictive ability. However, these equations show the hypothesised correlation between TLoS and CLoS. It was noted that the R^2 value would likely increase with more survey responses. Therefore, this methodology was continued for the online extended video survey.

A.2 RURAL ROAD SEGMENTS

Several measures of Safety and Reliability, in rural environments, were assessed as part of the experimental pilot study. AusRAP data was used for the TLoS of the road segments.

This section details the relationship between CLoS and TLoS for steepness, sharp curves and line markings, respectively. Table A.2 provides a summary of the linear regression equations and the coefficients of determination for each of the relationships.

Table A.2: Best-Fit Equations and Coefficients of Determination for Rural CLoS/AusRAP plots

A34 CLoS	AusRAP category	Best-fit linear equation	Coefficient of determination (R^2)
Steepness	Grade	$y = -0.0714x + 3.1964$	0.003
Presence of sharp curves	Curvature	$y = 0.8681x + 0.5495$	0.16
Presence and quality of line markings	Delineation	$y = 0.619x + 0.3333$	0.07

For the steepness/grade of the road for the assessed rural road segments, the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for grade for each of the road segments. The AusRAP rating of grade is defined as 1 (flat) to 3 (steep). The AusRAP scale was transformed and inverted to match the scale of 1 to 5 developed for CLoS. Theresults showed an apparent negative correlation in the relationship between CLoS and TLoS. There are several reasons why this could have occurred. Firstly, there may have been a lack of clarity in the survey (i.e., it may have been assumed that 5 meant the road was steep rather than flat). An alternative reason could be that steepness was difficult to visualise in the DVR footage. Lastly, this correlation could have been caused by participants being more accepting of steep roads than the AusRAP rating system is.

For the curvature of the road for the assessed rural road segments, the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for curvature for each of the road segments. The AusRAP rating of curvature is defined as 0 (straight) or 4 (very sharp). The AusRAP scale was transformed and inverted to match the scale of 1 to 5 developed for CLoS. The results showed that there was a positive correlation in the relationship between CLOS and TLoS.

For the presence and quality of line markings for the assessed rural road segments, the CLoS was developed based on the results of the pilot study, on a scale of 1 (poor) to 5 (excellent). The TLoS was developed based on the AusRAP rating for delineation for each of the road segments. The AusRAP rating of delineation is defined as 1 (adequate) or 2 (poor). The AusRAP scale was transformed and inverted to match the scale of 1 to 5 developed for CLoS. The result showed that there was a positive correlation in the relationship between CLoS and TLoS.

APPENDIX B ROADS INCLUDED IN THE SURVEY

B.1 RURAL ROADS

Figure B.1: Rural Road 1 – 104

Figure B.2: Rural Road 2 – 2025

Figure B.3: Rural Road 3 – 25B

Figure B.4: Rural Road 4 – 21A

B.2 URBAN ROADS

Figure B.5: Urban Road 1 – 134

Figure B.6: Urban Road 2 – 216

Figure B.7: Urban Road 3 – 412

Figure B.8: Urban Road 4 – 3042

APPENDIX C ONLINE VIDEO SURVEY CONTENT

Initially, the participants were asked to answer seven brief and open-ended questions regarding the LoS indicators to be assessed in the survey. This provided information on what was important to each participant, as well as information on measures which could be used for further consideration of CLoS indicators in future research. These questions are open-ended to ensure that the opinions of participants were qualitatively recorded rather than prompting participants to produce quantitative results.

The participants then viewed DVR footage of each of the selected road segments. Once the road segments had been viewed, each of the participants rated the CLoS for several measures of each of the LoS indicators given on each of the road segments.

The survey content provided to participants (demographics, open-ended questions, and rating scales for DVR footage) is outlined below.

C.1 DEMOGRAPHIC QUESTIONS

The demographics of each participant were recorded, similar to the pilot study. This assisted in data analysis and was used to review the representativeness of the sample participants. There was also an 'undisclosed' option for those who wished for details to remain private.

Demographic information requested included:

- occupations
- gender (male/female/undisclosed)
- age group (18-24/25-44/45-60/above 60/undisclosed)
- residence (urban/rural/remote)
- road type most commonly travelled on (urban/rural)
- average weekly km in car travel
- average weekly km in other travel modes.

C.2 DEFINITIONS

A list of definitions for key technical terms used in the survey was provided to the participants. These definitions included:

- Carriageway — That portion of a road or bridge devoted particularly to the use of vehicles, inclusive of shoulders and auxiliary lanes.
- Edge break — A pavement surface defect in which the edge of the bituminous surface is fretted, broken or irregular.
- Lane — A portion of the paved carriageway marked out by kerbs, painted lines or barriers, which carries a single line of vehicles in one direction. A lane is generally between 3.0 and 3.5 m wide. A single-carriageway road normally has at least one lane in each direction.
- Line marking — Lines, painted or otherwise applied, that delineate lane boundaries and guide traffic with respect to overtaking and the like.
- Patches — The filling up or repair of depressions, holes, or other defective places in a carriageway to restore the surface.
- Pothole — A hole in a pavement, frequently rounded in shape, resulting from the loss of pavement material under traffic.
- Shoulder — The portion of formed carriageway that is adjacent to the traffic lane and flush with the surface of the pavement.

- Surface texture — A condition parameter to characterise the average height between peaks and troughs in the pavement surface. Macrotexture depth is usually the reported condition parameter for surface texture.

In addition, images outlining what these features are on the road were provided, to assist the participants in understanding the videos. The images included in the survey are shown in Figure C.1.

Figure C.1: Descriptive images for survey

C.3 OPEN-ENDED QUESTIONS

The open-ended questions designed to gauge customer expectations of LoS are listed below.

1. What attributes of road delineation and guidance infrastructure most affect your sense of safety while driving on the road? Examples include high-quantity of street lighting, freshly painted line markings, the readability of road signs.
2. What attributes of road geometry affect your sense of safety while driving on the road? Examples include the presence of sharp curves, the steepness of the road, the width of the road shoulders.
3. What attributes of the road concern you in terms of travel time? Examples include traffic jams, impeding the ability for traffic to flow freely.
4. What road attributes are most noticeable to you in terms of road condition? Examples include patches, potholes, edge breaks.
5. What attributes of road maintenance and aesthetics are most important in your driving experience? Examples include cleanliness of the road corridor and the condition of roadside furniture.
6. What attributes of road geometry affect your opinion of the accessibility of a road? Examples include road lane width and presence of obstacles.
7. What attributes of environmental hazards most impact your opinion on the accessibility of a road? Examples include encroaching roadside vegetation, quantity of rainfall.

C.4 QUESTIONS FOR RATING DVR FOOTAGE

Each participant was asked to rate each of the attributes within the LoS indicators on the road categories for the assigned road segments by a rating of 1 to 5, as follows:

- Excellent – 5 – almost no defects visible and providing a safe and comfortable road to travel on. No remedial action is required.
- Very good – 4 – minor defects are visible; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required.
- Good – 3 – minor defects are increasingly visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action is required.
- Adequate – 2 – defects are starting to become more frequent. Routine maintenance is required to keep the road corridor in adequate condition. The road is still comfortable to drive on with isolated weak spots.
- Poor – 1 – the road requires possible rehabilitation to eradicate the now even more frequently occurring issues or defects. The road is uncomfortable or unsafe to drive on.

It should be noted that the survey prompted the participant as to what these ratings mean, specific to the attribute being assessed. For example, in regard to road signs, a rating of 5 was described as: 'Excellent – road signs are adequate in quantity, and in well-maintained condition'.

Parts A to D set out in Table C.1, Table C.2, Table C.3 and Table C.4 respectively provide ratings for each of the indicators included in the assessment. These forms are a representation of the questions which were provided in Survey Monkey.

Table C.1: Part (A) – Safety indicator for the online video survey

Attribute	Ratings
	Guidance and delineation
Presence and quality of road signs	• Excellent – 5 – no defects visible on road signs, providing a safe road to travel on. No remedial action is required. • Very good – 4 – minor defects are visible on road signs; however, the road corridor is still providing a safe road to travel on. No remedial action is required. • Good – 3 – minor defects are becoming more visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action is required on signs. • Adequate – 2 – defects on road signs are starting to become even more frequent. Sign maintenance is required to keep the signs in the road corridor in adequate condition. • Poor – 1 – the road signs require restoration or replacement to eradicate the now more commonly occurring defects.
Presence and quality of line markings	• Excellent – 5 – no defects visible in line markings, providing a safe road to travel on. No remedial action is required. • Very good – 4 – minor defects are visible in line markings; however, the road corridor is still providing a safe road to travel on. No remedial action is required. • Good – 3 – minor defects in line markings are more visible, however, the road corridor is still providing a safe road to travel on. Minor remedial action is required on line markings. • Adequate – 2 – defects in line markings are becoming more frequent. Line marking maintenance is required to keep the road corridor adequately delineated. • Poor – 1 – the line markings require renewal to eradicate the now more commonly occurring defects.
Adequate street lighting	• Excellent – 5 – no defects in street lighting, with an appropriate number of lights for the location, providing a safe road to travel on. No remedial action is required. • Very good – 4 – minor defects are visible in street lighting, with an appropriate number of lights for the location. No remedial action is required. • Good – 3 – minor defects are more visible in street lighting, with a slightly inadequate number of lights for the location, however, the road corridor is still providing a safe road to travel on. Minor remedial action is required for lighting. • Adequate – 2 – defects in street lighting are starting to become more frequent, with an inadequate number of lights for the location. Lighting maintenance is required to keep the road corridor with an adequate amount of illumination. • Poor – 1 – the street lighting requires replacement to eradicate the now more commonly occurring lack of illumination with the possible installation of additional lighting.
	Road geometry
Presence of sharp curves	• Excellent – 5 – curves are adequate for the entire length of the road, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – curves are adequate for most of the length of the road, providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – curves are inadequate for the short lengths of the road; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action on curves is required. • Adequate – 2 – curves are too sharp, and therefore are inadequate, in some areas. Curve maintenance is required to keep the road corridor in a safe condition • Poor – 1 – curves are too sharp, remedial works are required.
Adequate shoulder width	• Excellent – 5 – shoulders are wide enough for the entire length of the road, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – shoulders are wide enough for most of the road length, providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – shoulders are of just adequate width for most of the road length. The road corridor is still providing a safe and comfortable road to travel on. Minor remedial action on shoulders is required. • Adequate – 2 – shoulder widths are inadequate in some areas. Shoulder maintenance is required to keep the road corridor in a safe condition • Poor – 1 – shoulders are too narrow, remedial works on shoulder required.
Steepness of road	• Excellent – 5 – the road is flat for the entire length of the road, providing a safe and comfortable road to travel on. No remedial action is required.

Attribute	Ratings
	• Very good – 4 – the road has a slight incline but is still providing a safe and comfortable road to travel on. • Good – 3 – the road is steep for some of its length; however, the road corridor is still providing a safe and comfortable road to travel on. • Adequate – 2 – the road is steep. Maintenance is required to keep the road corridor in a safe condition for travel. • Poor – 1 – the road is too steep, remedial works are required to reduce the effects of steepness for travel.

Table C.2: Part (B) - Reliability indicator for the online video survey

Attribute	Ratings
Travel time	
Acceptability of travel time	• Excellent – 5 – no surface defects visible that could impact on the travel time of the journey. No remedial action is required. • Very good – 4 – minor surface defects are visible that could impact on the travel time of the journey; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – minor surface defects are more visible that could impact on the travel time of the journey; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action on surface defects is required. • Adequate – 2 – surface defects that could impact on the travel time of the journey are starting to become more frequent. Routine maintenance is required on surface defects to keep the road corridor in adequate condition. • Poor – 1 – the road requires possible resurfacing or rehabilitation to eradicate the now more commonly occurring surface defects that impact the travel time of the journey.
Sufficient road capacity to support free-flow traffic	• Excellent – 5 – the road is wide enough to support free-flow traffic. • Very good – 4 – the road is wide enough to support free-flow traffic for most of the road length. • Good – 3 – the road can adequately support free-flow traffic for the entire length of the road, with only minor capacity issues at certain locations. • Adequate – 2 – the road is not wide enough to adequately support free-flow traffic, however, it still provides a manoeuvrable environment. • Poor – 1 – lanes are too narrow to support free-flow traffic; remedial works are required for road widening.

Table C.3: Part (C) - Condition indicator for the online video survey

Attribute	Ratings
Road pavement condition	
Presence of visible surface texture	• Excellent – 5 - all surface texture is visible, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor areas of reduced surface texture visible; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – loss of surface texture is more visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action to improve texture is required. • Adequate – 2 – loss of surface texture is starting to become frequent. Routine maintenance to improve texture is required to keep the road corridor in a safe condition. The road has less than adequate surface texture for safe driving. • Poor – 1 – the road requires possible resurfacing or rehabilitation to reinstate adequate levels of surface texture. The road is not safe to drive on.
Presence of potholes and patches	• Excellent – 5 – no potholes and/or patches visible, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor potholes and/or patches are visible; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – minor potholes and/or patches are more visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action is required on potholes and patches. • Adequate – 2 – potholes and/or patches are starting to become more frequent. Routine maintenance is required to keep the road corridor in adequate condition. The road is just adequate for safe and reasonably comfortable driving. • Poor – 1 – the road requires possible resurfacing to eradicate the now more commonly occurring potholes or patches. The road is uncomfortable to drive on and is unsafe.
Presence of edge break	• Excellent – 5 – no edge break visible, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor edge break is visible; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – edge break is becoming more visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action to repair edge break is required. • Adequate – 2 – Edge break is becoming more frequent. Edge break maintenance is required to keep the road corridor in adequate condition. The road is just adequate for comfortable driving. • Poor – 1 – The road requires major edge repairs to eradicate the now more frequently occurring edge break. The road is uncomfortable to drive on and is unsafe.
Maintenance and aesthetics	
Cleanliness of road corridor	• Excellent – 5 – almost no litter (environmental or human-made) visible and providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor litter (environmental or human-made) is visible; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – litter (environmental or human-made) is increasingly visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action for cleaning is required. • Adequate – 2 – litter (environmental or human-made) is starting to become more frequent. Litter removal is required to keep the road corridor clean. The road is still comfortable to drive on. • Poor – 1 – the road requires major attention to litter removal of the now more frequently occurring litter and eradication of its causes.

Table C.4: Part (D) - Accessibility indicator for the online video survey

Attribute	Ratings
	Road geometry
Adequate lane width	• Excellent – 5 – lanes are wide for the entire length of the road, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – lanes are adequate enough for most of the road length, providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – lane widths are just adequate for the entire length of the road; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action is required. • Adequate – 2 – lane widths are inadequate in some areas. Maintenance is required to restore lane width and keep the road corridor in a safe condition. • Poor – 1 – lanes are too narrow, major remedial works are required to gain adequate lane width.
	Potential environmental hazards
All-weather access	• Excellent – 5 – no visible defects that could cause loss of safety in poor weather are present, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor visible defects that could cause loss of safety in poor weather are present; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – minor defects that could cause loss of safety in poor weather are becoming more visible; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action on defects is required. • Adequate – 2 – visible defects that could cause loss of safety in poor weather are starting to become more frequent. Routine maintenance is required to keep the road corridor in adequate condition. The road is still comfortable to drive on. • Poor – 1 – the road requires possible resurfacing to eradicate the now more frequently occurring visible defects that could cause loss of safety in poor weather. The road is uncomfortable to drive on and is unsafe.
Presence of encroaching roadside vegetation	• Excellent – 5 – no encroaching roadside vegetation visible, providing a safe and comfortable road to travel on. No remedial action is required. • Very good – 4 – minor encroaching roadside vegetation is present; however, the road corridor is still providing a safe and comfortable road to travel on. No remedial action is required. • Good – 3 – encroaching roadside vegetation is more evident; however, the road corridor is still providing a safe and comfortable road to travel on. Minor remedial action on roadside vegetation is required. • Adequate – 2 – encroaching roadside vegetation is becoming more frequently present. Maintenance is required to keep the road corridor in adequate condition. The road is still comfortable to drive on but with isolated areas of encroachment. • Poor – 1 – the road requires major maintenance to eradicate the now more frequently occurring roadside vegetation.

C.5 IN-HOUSE SURVEY TRIAL

Prior to undertaking the online video survey, ARRB completed an internal trial of the survey. As it was the intention for the survey to be completed by members of the public, ARRB engaged members of the corporate staff and interns to complete the survey.

Each participant provided feedback on the usability of the Survey Monkey platform, the readability of the background information and questions, and their level of comprehension of the technical terms used.

A key piece of feedback provided was that one of the videos was lagging, and having trouble loading. This made it difficult for this participant to clearly view the road. It was recommended that screen-shot images from the video be included as a back-up, in case of technical difficulties. Additional feedback was that descriptive images with the definitions would be useful. These were generated and included in the survey.

The survey took each participant less than the allocated hour. Therefore, it was concluded that allowing one hour for the public would be sufficient. Overall, feedback on the survey was positive. All feedback which was received was incorporated.

APPENDIX D DETAILED RESULTS

D.1 SAFETY

Safety refers to the methods and measures in place to prevent road users from being killed or seriously injured. For the survey, safety was assessed using measures across two categories: guidance and delineation, and road geometry.

D.1.1 OPEN-ENDED RESPONSES

Participants were asked what aspects of road guidance and delineation and road geometry most affect their sense of safety when driving on the road. The responses included topics such as line markings, street lighting, road signs, road geometry factors, high-quality roads, and the presence of speed cameras.

> Those who referenced line markings in their response mentioned aspects such as clean lines, fresh (i.e., new) lines, limited interference from previous line markings, the presence of audio-tactile line markings and the clear marking of pedestrian crossings.
>
> Those who referenced street lighting indicated its importance and having better street lighting on quieter streets. Further, the importance of having traffic lights at large intersections was noted.
>
> Road signs were referenced for the readability of the sign, including a lack of graffiti, and a lack of vegetation blocking the sign. The following types of signs were listed as important for safety: indication of sharp bends in the road, directional signs, changes to speed zones, warnings for speed humps, and one-way bridge signage. Lastly, guideposts were indicated to provide the participants with a greater sense of safety.
>
> Further, the presence of speed cameras was noted as providing an increased level of safety when travelling on a road.
>
> Several aspects of road geometry were noted by participants. These included aspects of the road shoulders, the presence of sharp curves, the steepness of the road, the width of the road, and edge drop-off.
>
> When referencing road shoulders, participants indicated the importance of the width, as when shoulders are wider all types of road users feel less vulnerable. Further, it was noted that wide road shoulders provide space for overtaking and allow for vehicles to pull over safely in an emergency.
>
> Sharp curves are a safety concern for participants when they are unmarked, unlit, winding, or turn into a major blind spot. Steep roads are a safety concern to participants when there is a steep gradient, or there are unpredictable hill crests.

The CLoS measures which were assessed as part of the Safety indicator were:

- presence and quality of road signs
- presence and quality of line markings
- adequate street lighting
- presence of sharp curves
- adequate shoulder width
- steepness of road.

Each of these factors was mentioned by the participants in their open-ended responses prior to the video rating which validates the use of these factors in the survey. Additional factors which were mentioned by the participants, which could be considered as part of a further study, were: the presence of speed cameras, and edge drop-off.

D.1.2 PRESENCE AND QUALITY OF ROAD SIGNS

Table D.1 presents the results for the presence and quality of road signs. The cells highlighted in yellow indicate the majority result for the ratings for each of the road segments. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.2. Table D.3 provides the statistical analysis components for presence and quality of road signs.

Table D.1: Presence and quality of road signs – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	17.65%	21.57%	11.76%	27.45%	17.50%	2.50%	7.50%	2.50%
Very good – 4	41.18%	11.76%	7.84%	33.33%	35.00%	2.50%	12.50%	5.00%
Good – 3	29.41%	33.33%	13.73%	23.53%	20.00%	7.50%	42.50%	17.50%
Adequate – 2	7.84%	17.65%	23.53%	7.84%	20.00%	10.00%	15.00%	32.50%
Poor – 1	3.92%	15.69%	43.14%	7.84%	7.50%	77.50%	22.50%	42.50%

Table D.2: CLoS and TLoS ratings counts for the presence and quality of road signs

		TLoS		
		1	**3.67**	**5**
CLoS	**1**	53	34	9
	2	16	28	16
	3	10	41	35
	4	5	13	52
	5	7	15	30

Table D.3: Statistical analysis information for the presence and quality of road signs

Statistical analysis components	Value
Linear trendline equation	$y = 0.41x + 1.34$
Multiple R	0.46
R^2	0.21
F-statistic	98.81
Significance F	$9.56{*}e^{-21}$
t-value	9.94
p-value	$9.56{*}e^{-21}$

As can be seen from Table D.3, there is a positive correlation and a statistically significant relationship between the CLoS and the TLoS. Therefore, it can be said that the expert opinion on road signs used for the TLoS is appropriate. However, this rating does not consider the quality of the road signs in the same way that the CLoS does. There were varying responses in the CLoS which is likely based on the quality of road signs, and if participants felt that the road signs were where they needed to be.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.4. As can be seen from this table, the relationship between the CLoS and TLoS, in both the urban and rural environments is significant.

Table D.4: Statistical analysis information by road category for the presence and quality of road signs

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.35x + 1.84$
Multiple R	0.42
R^2	0.18

Statistical analysis components	Value
F-statistic	44.20
Significance of F	$2.70*e^{-10}$
t-value	6.65
p-value	$2.70*e^{-10}$
Rural roads	
Linear trendline equation	$y = 0.45x + 1.86$
Multiple R	0.50
R^2	0.25
F-statistic	50.31
Significance of F	$4.39*e^{-11}$
t-value	7.09
p-value	$4.39*e^{-11}$

D.1.3 PRESENCE AND QUALITY OF LINE MARKINGS

Table D.5 presents the results for the presence and quality of line markings. The cells highlighted in yellow indicate the majority result for the ratings for each road segment. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.6. Table D.7 provides the statistical analysis components for presence and quality of road signs.

Table D.5: Presence and quality of line markings – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	37.25%	3.92%	9.80%	35.29%	35.00%	2.50%	17.50%	2.50%
Very good – 4	47.06%	13.73%	17.65%	39.22%	25.00%	2.50%	32.50%	0.00%
Good – 3	13.73%	27.45%	21.57%	15.69%	27.50%	10.00%	45.00%	10.00%
Adequate – 2	1.96%	37.25%	35.29%	9.80%	10.00%	12.50%	5.00%	15.00%
Poor – 1	0.00%	17.65%	15.69%	0.00%	2.50%	72.50%	0.00%	72.50%

Table D.6: CLoS and TLoS ratings counts for the presence and quality of line markings

		TLoS		
		1	**2.33**	**5**
CLoS	**1**	67	0	9
	2	35	5	20
	3	48	8	21
	4	33	20	31
	5	28	18	21

Table D.7: Statistical analysis information for the presence and quality of line markings

Statistical analysis components	Value
Linear trendline equation	$y = 0.18x + 2.60$
Multiple R	0.23
R^2	0.05
F-statistic	19.40
Significance F	$1.40*e^{-05}$
t-value	4.40
p-value	$1.40*e^{-05}$

As can be seen from Table D.7 there is a positive correlation and a statistically significant relationship between the CLoS and TLoS for the presence and quality of line markings. The AusRAP rating used as the TLoS for the presence and quality of line markings is based on the presence of line markings, however, this TLoS fails to consider the opinion of road users as to whether these line markings are adequate and in good condition. There is a wide range of responses for CLoS not accounted for. This means there was a varying opinion across the participants of whether the line markings were adequate.

Presence and quality of line markings was also assessed as part of the pilot study in Year 1. Similarly, there was a positive correlation between CLoS and TLoS in the pilot study.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.8. The urban relationship is still positive, but statistically insignificant. Further, the gradient (or x value) of the linear regression for the rural relationship, although positive, is vertical (i.e., all TLoS were of the same rating). This measure is best viewed as a combination of urban and rural, as line markings tend to be of equal importance across urban and rural environments.

Table D.8: Statistical analysis information by road category for the presence and quality of line markings

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.07x + 3.1$
Multiple R	0.10
R^2	0.01
F-statistic	1.85
Significance of F	0.18
t-value	1.36
p-value	0.18
Rural roads	
Linear trendline equation	$y = 2.57$
Multiple R	0.12
R^2	0.02
F-statistic	2.39
Significance of F	0.12
t-value	Unavailable
p-value	Unavailable

D.1.4 ADEQUATE STREET LIGHTING

Table D.9 presents the results for the presence of adequate street lighting. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.10. Table D.11 provides the statistical analysis components for presence of adequate street lighting.

Table D.9: Adequate street lighting – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	27.45%	13.73%	3.92%	3.92%	2.50%	2.50%	2.50%	2.50%
Very good – 4	37.25%	7.84%	3.92%	19.61%	10.00%	0.00%	5.00%	0.00%
Good – 3	19.61%	17.65%	17.65%	21.57%	12.50%	5.00%	20.00%	10.00%
Adequate – 2	7.84%	31.37%	27.45%	17.65%	12.50%	17.50%	17.50%	7.50%
Poor – 1	7.84%	29.41%	47.06%	37.25%	62.50%	75.00%	55.00%	80.00%

Table D.10: CLoS and TLoS ratings counts for the adequacy of street lighting

		TLoS		
		1	**3.67**	**5**
CLoS	**1**	109	24	38
	2	22	14	29
	3	19	9	30
	4	6	2	33
	5	4	2	23

Table D.11: Statistical analysis information for the presence of adequate street lighting

Statistical analysis components	Value
Linear trendline equation	$y = 0.30x + 1.24$
Multiple R	0.42
R^2	0.18
F-statistic	76.95
Significance F	$6.99*e^{-17}$
t-value	8.77
p-value	$6.99*e^{-17}$

As can be seen from Table D.11, there is a positive correlation and the relationship between the CLoS and TLoS is statistically significant, indicating that the AusRAP ratings for the TLoS are relevant to the opinion of customers. However, the AusRAP rating for street lighting only indicates whether it is present, not whether it is adequate or not. There is much less consistency in the responses for the CLoS, which means that the survey participants had varying opinions on the adequacy of street lighting for different locations.

Adequate street lighting was assessed as part of the pilot study in Year 1. Similarly, in the pilot study adequate street lighting showed a positive correlation between CLoS and TLoS.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.12. The relationship for the urban road segments is both positive and statistically significant. As with line markings, the rural road segments all had the same TLoS rating, therefore, it was not possible to estimate the significance of the relationship.

Table D.12: Statistical analysis information by road category for the presence of adequate street lighting

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.70x - 0.65$
Multiple R	0.29
R^2	0.08
F-statistic	18.48
Significance of F	$2.67*e^{-05}$
t-value	4.30
p-value	$2.66*e^{-05}$
Rural roads	
Linear trendline equation	$y = 1.60$
Multiple R	0.04
R^2	0.01
F-statistic	0.30
Significance of F	0.58
t-value	Unavailable
p-value	Unavailable

D.1.5 PRESENCE OF SHARP CURVES

Table D.13 presents the results for the presence of sharp curves. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.14. Table D.15 provides the statistical analysis components for presence of sharp curves.

Table D.13: Presence of sharp curves – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	19.61%	7.84%	11.76%	11.76%	5.00%	5.00%	2.50%	5.00%
Very good – 4	45.10%	31.37%	41.18%	35.29%	35.00%	22.50%	25.00%	12.50%
Good – 3	25.49%	41.18%	35.29%	25.49%	35.00%	35.00%	37.50%	20.00%
Adequate – 2	7.84%	11.76%	7.84%	21.57%	20.00%	22.50%	30.00%	45.00%
Poor – 1	1.96%	7.84%	3.92%	5.88%	5.00%	15.00%	5.00%	17.50%

Table D.14: CLoS and TLoS ratings counts for the presence of sharp curves

		TLoS					
		1.89	**2.33**	**2.78**	**3.22**	**4.56**	**5**
CLoS	**1**	2	15	1	3	4	2
	2	12	35	4	11	6	4
	3	15	36	13	13	21	18
	4	10	28	23	18	16	21
	5	1	6	10	6	4	6

Table D.15: Statistical analysis information for the presence of sharp curves

Statistical analysis components	Value
Linear trendline equation	$y = 0.17x + 2.62$
Multiple R	0.17
R^2	0.03
F-statistic	10.99
Significance F	0.001
t-value	3.32
p-value	0.001

As can be seen from Table D.15, there is a positive correlation and a statistically significant relationship between CLoS and TLoS for the presence of sharp curves. However, this is not a strong correlation as there was a variety of responses received from participants. Curvature was also assessed as part of the pilot study; the results showed a similar positive correlation but not a strong one. The likely weakness of the correlation is caused by the interpretation of curves by participants of the survey.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.16. When viewed as separate categories the relationships between TLoS and CLoS and not statistically significant either for the urban or the rural road segments.

Table D.16: Statistical analysis information by road category for the presence of sharp curves

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = -0.09x + 3.77$
Multiple R	0.08
R^2	0.01

Statistical analysis components	Value
F-statistic	1.32
Significance of F	0.25
t-value	-1.15
p-value	0.25
Rural roads	
Linear trendline equation	$y = -0.24x + 3.36$
Multiple R	0.04
R^2	0.002
F-statistic	0.32
Significance of F	0.57
t-value	-0.56
p-value	0.57

D.1.6 ADEQUATE SHOULDER WIDTH

Table D.17 presents the results for the presence of adequate shoulder width. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.18. Table D.19 provides the statistical analysis components for presence of adequate shoulder width.

Table D.17: Adequate shoulder width – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	31.37%	3.92%	0.00%	5.88%	0.00%	0.00%	2.50%	2.50%
Very good – 4	25.49%	3.92%	15.69%	23.53%	12.50%	0.00%	17.50%	0.00%
Good – 3	23.53%	19.61%	9.80%	41.18%	22.50%	12.50%	37.50%	7.50%
Adequate – 2	17.65%	39.22%	33.33%	9.80%	35.00%	20.00%	25.00%	17.50%
Poor – 1	1.96%	33.33%	41.18%	19.61%	30.00%	67.50%	17.50%	72.50%

Table D.18: CLoS and TLoS ratings counts for adequate shoulder width

		TLoS		
		1	**1.89**	**2.33**
CLoS	**1**	92	21	11
	2	59	17	14
	3	42	5	33
	4	14	8	25
	5	4		19

Table D.19: Statistical analysis information for the presence of adequate shoulder width

Statistical analysis components	Value
Linear trendline equation	$y = 0.86x + 1.04$
Multiple R	0.42
R^2	0.17
F-statistic	75.61
Significance F	$1.22{*}e^{*-16}$
t-value	8.70
p-value	$1.22{*}e^{*-16}$

As can be seen from Table D.19, there is a positive correlation and a statistically significant relationship between TLoS and CLoS. This is a relatively strong relationship, when compared with other indicators.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.20. The relationship for urban roads is statistically significant. However, the rural relationship is statistically insignificant due to the spread of results. Therefore, this measure is best viewed as a combination of both urban and rural environments.

Table D.20: Statistical analysis information by road category for presence of adequate shoulder width

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.90x + 0.94$
Multiple R	0.38
R^2	0.15
F-statistic	34.30
Significance of F	$1.89{*}e^{-08}$
t-value	5.86
p-value	$1.89{*}e^{-08}$
Rural roads	
Linear trendline equation	$y = 1.92$
Multiple R	0.01
R^2	0.0001
F-statistic	0.02
Significance of F	0.89
t-value	Unavailable
p-value	Unavailable

D.1.7 STEEPNESS OF ROAD

Table D.21 presents the results for the steepness of the road. The cells highlighted in yellow indicate the majority result for the ratings for each road segment. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.22. Table D.23 provides the statistical analysis components for the steepness of the road.

Table D.21: Steepness of road – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	7.84%	37.25%	45.10%	5.88%	2.50%	20.00%	5.00%	2.50%
Very good – 4	52.94%	29.41%	27.45%	49.02%	42.50%	30.00%	32.50%	32.50%
Good – 3	29.41%	19.61%	13.73%	23.53%	30.00%	27.50%	45.00%	20.00%
Adequate – 2	9.80%	11.76%	7.84%	21.57%	25.00%	15.00%	15.00%	20.00%
Poor – 1	0.00%	1.96%	5.88%	0.00%	0.00%	7.50%	2.50%	25.00%

Table D.22: CLoS and TLoS ratings counts for the steepness of the road

		TLoS				
		2.67	3.67	4.11	4.56	5
CLoS	**1**	0	0	3	1	14
	2	10	5	6	17	18
	3	12	15	11	30	25
	4	17	27	12	38	42
	5	1	4	8	5	43

Table D.23: Statistical analysis information for the steepness of the road

Statistical analysis components	Value
Linear trendline equation	$y = 0.10x + 3.03$
Multiple R	0.07
R^2	0.004
F-statistic	1.68
Significance F	0.20
t-value	1.29
p-value	0.20

As can be seen from Table D.23, there is a positive correlation, however, the relationship between CLoS and TLoS is not statistically significant. The responses from the survey indicate that the participants were generally accepting of the steepness of the road, even in instances where the TLoS rated the gradient as steep.

In addition, it should be noted that the correlation between CLoS and TLoS in the pilot study was negative. This again indicated that customers were more accepting of the steepness of the road, than the TLoS allowed for.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.24. Although the relationship in both urban and rural environments is positive, both were statistically insignificant. This leads to the view that the TLoS may not accurately represent the needs of customers.

Table D.24: Statistical analysis information by road category for steepness of the road

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.26x + 2.54$
Multiple R	0.14
R^2	0.02
F-statistic	3.82
Significance of F	0.05
t-value	1.95
p-value	0.05
Rural roads	
Linear trendline equation	$y = -0.16x + 3.80$
Multiple R	0.13
R^2	0.02
F-statistic	2.80
Significance of F	0.10
t-value	-1.67
p-value	0.10

D.2 RELIABILITY

Reliability refers to the ability of a road or road network to perform its intended function, without any malfunctions, assuming the road is used within the conditions it was designed for (Austroads 2015). For the survey, reliability was assessed using measures of travel time.

D.2.1 OPEN-ENDED RESPONSES

The main features of the road corridor which influence participants' opinions of how long it will take to travel on the road and therefore the reliability of the journey included road geometry, a lack of alternative routes, traffic congestion, overtaking opportunities, the variability of speed on the road, the condition of the road, and the presence of road works.

Road geometry featured where participants noted roundabouts, road width, narrow lanes, or one lane roads. Further, participants noted that traffic which merges from multiple lanes into less lanes will slow the traffic down, as well as parked cars on the roads and school zones. Participants noted that road work zones also affected their perception of travel time.

Travel time concerns such as traffic congestion, traffic delays, traffic jams, and travelling at peak times were all noted by several participants. Further, it was noted that several traffic lights in a series along a single stretch of road can impede traffic flow along with broken down vehicles.

Overtaking opportunities were also noted to improve traffic flow as they allow impatient drivers to pass vehicles that they may be following too closely.

The CLoS measures used to assess the reliability indicator were:

- the acceptability of travel time
- the adequacy of the road to support free-flow traffic.

These were mentioned by participants, also validating the categories used in the survey. However, rather than the acceptability of travel time or the adequacy of the road to support free-flow traffic, it may be better suited to use the ability of the road to minimise traffic congestion. Additional measures which could be assessed included overtaking opportunities, the variability in posted speed limit along a single stretch of road, and the presence of road works.

D.2.2 ACCEPTABILITY OF TRAVEL TIME

Table D.25 presents the results for the acceptability of travel time. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.26. Table D.27 provides the statistical analysis components for the steepness of the road.

Table D.25: Acceptability of travel time – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	27.45%	9.80%	3.92%	23.53%	13.73%	0.00%	1.96%	0.00%
Very good – 4	43.14%	21.57%	29.41%	43.14%	27.45%	13.73%	35.29%	0.00%
Good – 3	11.76%	31.37%	31.37%	25.49%	37.25%	25.49%	35.29%	15.69%
Adequate – 2	15.69%	31.37%	21.57%	7.84%	17.65%	35.29%	19.61%	45.10%
Poor – 1	1.96%	5.88%	13.73%	0.00%	3.92%	25.49%	7.84%	39.22%

Table D.26: CLoS and TLoS ratings counts for the acceptability of travel time

		TLoS						
		1.83	**2.91**	**4.33**	**4.50**	**4.89**	**4.97**	**4.99**
CLoS	**1**	20	4	13	3	1	0	9
	2	46	20	36	32	16	8	40
	3	24	54	39	48	18	39	105
	4	0	72	28	44	88	88	116
	5	0	5	0	25	70	60	45

Table D.27: Statistical analysis information for the acceptability of travel time

Statistical analysis components	Value
Linear trendline equation	$Y = 0.42x + 1.22$
Multiple R	0.39
R^2	0.15
F-statistic	73.81
Significance F	$1.87*e^{-16}$
t-value	8.59
p-value	$1.87*e^{-16}$

As can be seen from Table D.27 there is a positive correlation that is statistically significant between the CLoS and TLoS for travel time. The TLoS is based on the absolute value of the percentage difference between the posted speed limit, and the average speed travelled and the road. This calculation method was used, as it takes into account any factors which may affect travel time, rather than just congestion. For example, on rural roads the average speed travelled may be lower than the posted speed limit due to road geometry factors, obstacles, etc. The percentage difference rating is a strong indicator of the opinion of road users on the expected travel time of the journey when using this stretch of road.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.28. As can be seen from Table D.28 there is a positive correlation between the TLoS and the CLoS for travel time in both the urban and rural environments. However, the correlation is only statistically significant in the rural environment. This is likely because the rural roads are more affected by factors, other than traffic, which would affect travel time for example, road curvature or encroaching vegetation.

Table D.28: Statistical analysis information by road category for the acceptability of travel time

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.90x - 0.99$
Multiple R	0.16
R^2	0.02
F-statistic	5.08
Significance of F	0.03
t-value	2.25
p-value	0.03
Rural roads	
Linear trendline equation	$y = 0.31 + 1.49$
Multiple R	0.35
R^2	0.12
F-statistic	27.67
Significance of F	$3.66*e^{-7}$
t-value	5.26
p-value	$3.66*e^{-7}$

D.2.3 SUFFICIENT CAPACITY TO SUPPORT FREE-FLOW TRAFFIC

Table D.29 presents the results for sufficient capacity to support free-flow traffic. The cells highlighted in yellow indicate the majority result for the ratings for each road segment. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.30. Table D.31 provides the statistical analysis components for sufficient capacity to support free-flow traffic.

Table D.29: Sufficient road capacity to support free-flow traffic – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	27.45%	9.80%	1.96%	15.69%	9.80%	0.00%	5.88%	0.00%
Very good – 4	31.37%	13.73%	21.57%	31.37%	13.73%	5.88%	29.41%	0.00%
Good – 3	17.65%	33.33%	29.41%	35.29%	39.22%	13.73%	29.41%	1.96%
Adequate – 2	21.57%	33.33%	35.29%	17.65%	25.49%	37.25%	25.49%	37.25%
Poor – 1	1.96%	9.80%	11.76%	0.00%	11.76%	43.14%	9.80%	60.78%

Table D.30: CLoS and TLoS ratings counts for the capacity to support free-flow traffic

		TLoS			
		1	**2.33**	**3.67**	**5**
`CLoS	**1**	53	17	5	1
	2	76	96	44	22
	3	24	156	99	27
	4	12	100	124	64
	5		55	55	70

Table D.31: Statistical analysis information for the capacity to support free-flow traffic

Statistical analysis components	Value
Linear trendline equation	$y = 0.5x + 1.36$
Multiple R	0.53
R^2	0.28
F-statistic	158.92
Significance F	$5.60*e^{-13}$
t-value	12.61
p-value	$5.60*e^{-13}$

As can be seen from Table D.31, there is a positive correlation and a statistically significant relationship between the CLOS and the TLoS for the capacity of these roads to support free-flow traffic. The TLoS for this measure was based on, visually, how the road is segregated and therefore, how easily the traffic would flow through the road corridor. In addition, this TLoS could include the number of lanes on the road. However, the roads selected for this study were all one lane to ensure uniformity. This positive correlation indicates that this visual assessment is representative of the customer's opinions. However, as can be seen from Table D.29, there was variation in the ratings by the survey participants.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.32, which shows that the relationship in both urban and rural environments is positive and statistically significant.

Table D.32: Statistical analysis information by road category for capacity to support free-flow traffic

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.35x + 1.98$
Multiple R	0.34
R^2	0.11
F-statistic	26.08
Significance of F	$7.55*e^{-07}$
t-value	5.12
p-value	$7.55*e^{-07}$
Rural roads	

Statistical analysis components	Value
Linear trendline equation	$y = 0.541x + 1.177$
Multiple R	0.523
R^2	0.28
F-statistic	76.85
Significance of F	$7.61*e^{-16}$
t-value	8.77
p-value	$7.6*e^{-16}$

D.3 CONDITION

The condition of an asset is determined based on the combination of characteristics which are used to assess functionality (Austroads 2015). For the survey, condition was assessed in the categories of road pavement conditions, maintenance and aesthetics.

D.3.1 OPEN-ENDED RESPONSES

When asked about what aspects of road condition were most important, participants cited patches, potholes, edge break, poor drainage, the road geometry, damaged line markings and damaged road signs.

> Participants mentioned that **multiple patches on the road, and crack fixes** can make the road look like it is in a worse condition than it actually is. Further, participants noted that potholes on the road can sit unrepaired for weeks and fill with water when it rains.
>
> Regarding **road geometry**, participants noted no curb or poor road shoulders affect their opinion of the condition of the road. Further, if the road surface is uneven, or if there are dips in the road surface, the participants saw this as a road in poor condition. Participants also mentioned edge break, and how, if the road does not have a smooth edge, it looks like it is in poor condition.
>
> In addition, participants noted that dirty **line markings** and dirty **road signs** make a road appear to be in poor condition and make these delineation measures less effective.
>
> When asked about what factors of **road maintenance and aesthetics** are most important to their driving experience participants noted clean gutters, a clear road surface, vegetation, and road condition.
>
> Regarding **vegetation**, participants said that they prefer the road to be clear of tall grass, environmental litter and tree branches overhanging the road.

The CLoS measures used to assess the Condition indicator were:

- presence of visible surface texture
- presence of patches
- presence of potholes
- presence of edge break
- cleanliness of road corridor.

The majority of these were mentioned by participants in their open-ended responses. However, the presence of visible surface texture was not mentioned. This measure may have been too technical for the understanding of survey participants.

D.3.2 PRESENCE OF VISIBLE SURFACE TEXTURE

Table D.33 presents the results for the presence of visible surface texture. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.34. Table D.35 provides the statistical analysis components for the presence of visible surface texture.

Table D.33: Presence of visible surface texture – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	19.61%	0.00%	0.00%	23.53%	13.73%	1.96%	0.00%	0.00%
Very good – 4	43.14%	7.84%	5.88%	39.22%	31.37%	11.76%	25.49%	0.00%
Good – 3	31.37%	23.53%	27.45%	21.57%	29.41%	35.29%	37.25%	13.73%
Adequate – 2	5.88%	50.98%	37.25%	13.73%	21.57%	21.57%	21.57%	35.29%
Poor – 1	0.00%	17.65%	29.41%	1.96%	3.92%	29.41%	15.69%	50.98%

Table D.34: CLoS and TLoS ratings counts for presence of visible surface texture

		TLoS		
		3	4.33	5
CLoS	1	9	26	41
	2	52	36	124
	3	36	21	279
	4	16		320
	5			150

Table D.35: Statistical analysis information for the presence of visible surface texture

Statistical analysis components	Value
Linear trendline equation	$y = 0.49x + 0.44$
Multiple R	0.27
R^2	0.07
F-statistic	32.67
Significance F	$2.12*e^{-08}$
t-value	5.72
p-value	$2.12*e^{-08}$

As can be seen from Table D.35, there is a positive correlation and a statistically significant relationship between the CLoS and TLoS for the presence of surface texture, although it is not a particularly strong correlation.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.36 which shows that for both urban and rural environments the relationship has a positive correlation and is statistically significant.

Table D.36: Statistical analysis information by road category for presence of visible surface texture

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.48x + 0.77$
Multiple R	0.35
R^2	0.12
F-statistic	28.30
Significance of F	$2.75*e^{-07}$
t-value	5.32
p-value	$2.75*e^{-07}$
Rural roads	
Linear trendline equation	$y = 0.72x - 0.36$
Multiple R	0.48
R^2	0.23

Statistical analysis components	Value
F-statistic	59.14
Significance of F	$6.33*e^{-13}$
t-value	7.69
p-value	$6.33*e^{-13}$

D.3.3 PRESENCE OF POTHOLES AND PATCHES

Table D.37 presents the results for the presence of potholes and patches. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.38. Table D.39 provides the statistical analysis components for the presence of potholes and patches.

Table D.37: Presence of potholes and patches – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	33.33%	0.00%	0.00%	25.49%	21.57%	3.92%	5.88%	0.00%
Very good – 4	31.37%	0.00%	3.92%	47.06%	37.25%	21.57%	19.61%	1.96%
Good – 3	29.41%	11.76%	17.65%	21.57%	27.45%	33.33%	33.33%	19.61%
Adequate – 2	5.88%	56.86%	45.10%	3.92%	11.76%	23.53%	21.57%	39.22%
Poor – 1	0.00%	31.37%	33.33%	1.96%	1.96%	17.65%	19.61%	39.22%

Table D.38: CLoS and TLoS ratings counts for presence of potholes and patches

		TLoS		
		3	4.33	5
CLoS	1	16	20	38
	2	58	40	114
	3	18	30	249
	4		4	328
	5			230

Table D.39: Statistical analysis information for the presence of potholes and patches

Statistical analysis components	Value
Linear trendline equation	$y = 0.74x - 0.67$
Multiple R	0.39
R^2	0.15
F-statistic	73.76
Significance F	$1.91*e^{-16}$
t-value	8.59
p-value	$1.91*e^{-16}$

As can be seen from Table D.39, there is a positive correlation and a statistically significant relationship between the CLoS and TLoS for the presence of potholes and patches. This is a relatively strong correlation and relationship.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.40 which shows that the relationships for both urban and rural environments have a positive correlation and are statistically significant.

Table D.40: Statistical analysis information by road category for the presence of potholes and patches

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.72x - 0.36$
Multiple R	0.48
R^2	0.23
F-statistic	59.14
Significance of F	$6.33*e^{-13}$
t-value	7.69
p-value	$6.33*e^{-13}$
Rural roads	
Linear trendline equation	$y = 1.77x - 5.80$
Multiple R	0.42
R^2	0.18
F-statistic	43.53
Significance of F	$3.59*e^{-10}$
t-value	6.60
p-value	$3.59*e^{-10}$

D.3.4 PRESENCE OF EDGE BREAK

Table D.41 presents the results for the presence of edge break. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.42. Table D.43 provides the statistical analysis components for the presence of presence of edge break.

Table D.41: Presence of edge break – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	45.10%	0.00%	0.00%	19.61%	5.88%	1.96%	3.92%	0.00%
Very good – 4	27.45%	5.88%	5.88%	35.29%	19.61%	5.88%	29.41%	1.96%
Good – 3	21.57%	17.65%	13.73%	25.49%	25.49%	17.65%	27.45%	5.88%
Adequate – 2	5.88%	39.22%	29.41%	15.69%	23.53%	27.45%	21.57%	29.41%
Poor – 1	0.00%	37.25%	50.98%	3.92%	25.49%	47.06%	17.65%	62.75%

Table D.42: CLoS and TLoS ratings counts for presence of edge break

CLoS	TLoS			
		3	**4.33**	**5**
	1	19	32	74
	2	40	30	126
	3	27	9	201
	4	12	4	252
	5			195

Table D.43: Statistical analysis information for the presence of edge break

Statistical analysis components	Value
Linear trendline equation	$y = 0.52x + 0.07$
Multiple R	0.26
R^2	0.07
F-statistic	29.70

Statistical analysis components	Value
Significance F	$8.78*e^{-08}$
t-value	5.45
p-value	$8.78*e^{-08}$

As can be seen from Table D.43, there is a positive correlation and a statistically significant relationship between CLoS and TLoS for the presence of edge break, although it is not a strong correlation.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.44 which shows that the relationships for both urban and rural environments have a positive correlation and are statistically significant.

Table D.44: Statistical analysis information by road category for the presence of edge break

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.60x + 0.12$
Multiple R	0.37
R^2	0.14
F-statistic	32.64
Significance of F	$3.93*e^{-08}$
t-value	5.71
p-value	$3.93*e^{-08}$
Rural roads	
Linear trendline equation	$y = 1.42x - 4.69$
Multiple R	0.35
R^2	0.12
F-statistic	28.22
Significance of F	$2.85*e^{-07}$
t-value	5.31
p-value	$2.85*e^{-07}$

D.3.5 CLEANLINESS OF ROAD CORRIDOR

Table D.45 presents the results for the cleanliness of the road corridor. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.46. Table D.47 provides the statistical analysis components for the cleanliness of the road corridor.

Table D.45: Cleanliness of road corridor – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	17.65%	25.49%	29.41%	47.06%	37.25%	13.73%	25.49%	13.73%
Very good – 4	33.33%	35.29%	27.45%	29.41%	23.53%	25.49%	35.29%	23.53%
Good – 3	41.18%	17.65%	17.65%	19.61%	27.45%	21.57%	15.69%	21.57%
Adequate – 2	5.88%	15.69%	19.61%	3.92%	7.84%	25.49%	19.61%	27.45%
Poor – 1	1.96%	5.88%	5.88%	0.00%	3.92%	13.73%	3.92%	13.73%

Table D.46: CLoS and TLoS ratings counts for the cleanliness of the road corridor

		TLoS		
		3	**4.33**	**5**
CLoS	**1**	3	7	15
	2	16	28	84
	3	27	33	219
	4	72	48	356
	5	65	35	435

Table D.47: Statistical analysis information for the cleanliness of the road corridor

Statistical analysis components	Value
Linear trendline equation	$y = 0.08x + 3.17$
Multiple R	0.04
R^2	0.002
F-statistic	0.78
Significance F	0.38
t-value	0.88
p-value	0.38

As can be seen from Table D.47, there is a positive correlation, however, the relationship between CLoS and TLoS for the cleanliness of the road corridor indicator is not statistically significant.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.48. Although the relationships have a positive correlation in both urban and rural environments, the relationship is only statistically significant in rural environments.

Table D.48: Statistical analysis information by road category for the cleanliness of the road corridor

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.10x + 3.30$
Multiple R	0.07
R^2	0.01
F-statistic	1.12
Significance of F	0.29
t-value	1.06
p-value	0.29
Rural roads	
Linear trendline equation	$y = 0.76x - 0.35$
Multiple R	0.17
R^2	0.03
F-statistic	6.31
Significance of F	0.01
t-value	2.51
p-value	0.01

D.4 ACCESSIBILITY

Accessibility refers to mobility pathways, allowing for the continuity of useable pathways between key locations of travel. For the survey, Accessibility was assessed across the categories of road geometry and potential environmental hazards.

D.4.1 OPEN-ENDED RESPONSES

When asked what factors of road geometry affect their opinion of the accessibility of a road, participants cited lane width, the number of lanes, the ability to pass other vehicles, the condition of the road, the presence of sharp curves, the presence of road shoulders, the width of road shoulders and the presence and quality of line markings.

> **Lane width** was important to participants so that large vehicles can pass oncoming traffic safely. Further, a wide enough road to provide proper bike lanes and adequately sized merging lanes were noted. In addition to merging lanes, participants mentioned passing lanes and the ability to overtake other vehicles.
>
> When asked what types of **environmental hazards** influence their opinion of the accessibility of a road, participants noted weather, poor drainage, and encroaching roadside vegetation.
>
> Participants noted that **heavy rainfall** can affect the ability to use a road, and **poor drainage** can exacerbate this issue. Further, participants noted that long-grass, overgrown bushes, fallen branches, trees blocking signs and dangerous embankments all influence their opinion of the accessibility of the road.

The CLoS measures used to assess the accessibility indicator were:

- adequate lane width
- all-weather access
- the presence of encroaching roadside vegetation.

All these aspects were mentioned by the participants of the survey, therefore, validating the measures included in the survey. Additional factors mentioned by participants included the number of lanes, the presence and quality of line markings and poor drainage. These factors could be considered in future research.

D.4.2 ADEQUATE LANE WIDTH

Table D.49 presents the results for adequate lane width. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.50: CLoS and TLoS ratings counts for adequate lane width. Table D.51 provides the statistical analysis components for adequate lane width.

Table D.49: Adequate lane width – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	27.45%	1.96%	5.88%	19.61%	3.92%	0.00%	1.96%	0.00%
Very good – 4	47.06%	31.37%	21.57%	31.37%	19.61%	1.96%	37.25%	0.00%
Good – 3	19.61%	29.41%	29.41%	37.25%	33.33%	11.76%	39.22%	3.92%
Adequate – 2	5.88%	29.41%	25.49%	7.84%	25.49%	27.45%	11.76%	27.45%
Poor – 1	0.00%	7.84%	17.65%	3.92%	17.65%	58.82%	9.80%	68.63%

Table D.50: CLoS and TLoS ratings counts for adequate lane width

CLoS \ TLoS	1	5
1	65	29
2	56	108
3	24	288
4	4	384
5		155

Table D.51: Statistical analysis information for adequate lane width

Statistical analysis components	Value
Linear trendline equation	$y = 0.42x + 1.04$
Multiple R	0.58
R^2	0.34
F-statistic	205.98
Significance F	$4.52*e^{-38}$
t-value	14.35
p-value	$4.52*e^{-38}$

As can be seen from Table D.51, there is a positive correlation and a statistically significant relationship between CLoS and TLoS for adequate lane with.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.52. Although there is a positive correlation in both urban and rural environments, it only has a statistically significant relationship in rural environments.

Table D.52: Statistical analysis information by road category for lane width

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 3.28$
Multiple R	0.12
R^2	0.01
F-statistic	2.39
Significance of F	0.12
t-value	Unavailable
p-value	Unavailable
Rural roads	
Linear trendline equation	$y = 0.36x + 1.10$
Multiple R	0.62
R^2	0.39
F-statistic	128.57
Significance of F	$2.22*e^{-23}$
t-value	11.34
p-value	$2.22*e^{-23}$

D.4.3 ALL-WEATHER ACCESS

Table D.53 presents the results for all weather access. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.54: CLoS and TLoS ratings counts for all-weather access. Table D.55 provides the statistical analysis components for all weather access.

Table D.53: All-weather access – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	15.69%	1.96%	1.96%	17.65%	3.92%	0.00%	1.96%	0.00%
Very good – 4	52.94%	15.69%	9.80%	37.25%	29.41%	5.88%	27.45%	1.96%
Good – 3	17.65%	37.25%	27.45%	29.41%	25.49%	21.57%	39.22%	7.84%
Adequate – 2	13.73%	25.49%	31.37%	11.76%	31.37%	29.41%	19.61%	39.22%
Poor – 1	0.00%	19.61%	29.41%	3.92%	9.80%	43.14%	11.76%	50.98%

Table D.54: CLoS and TLoS ratings counts for all-weather access

		TLoS	
		3.6667	5
CLoS	**1**	13	73
	2	78	128
	3	171	144
	4	300	68
	5	100	10

Table D.55: Statistical analysis information for all-weather access

Statistical analysis components	Value
Linear trendline equation	$y = -0.88x + 6.47$
Multiple R	0.49
R^2	0.24
F-statistic	129.29
Significance F	$3.39{*}e^{-26}$
t-value	-11.37
p-value	$3.39{*}e^{-26}$

As can be seen from Table D.55, there is a negative correlation between the CLoS and the TLoS for all-weather access. The TLoS for all-weather access was developed based on TMR's rating system for flood hotspots. This negative correlation indicates that while driving along the road, the customer cannot visualise the likelihood of flooding in the region. This implies that the customer will interpret all-weather access based on their perception of road quality and the drainage infrastructure. Although knowing flooding hotspots is imperative for asset management planning, it is not a strong indicator for understanding how the customer will perceive the all-weather access of a road corridor.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.56. In both the urban and rural environments, the relationships between CLoS and TLoS have a positive correlation and are statistically significant.

Table D.56: Statistical analysis information by road category for all-weather access

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = -0.92x + 6.99$
Multiple R	0.52
R^2	0.27
F-statistic	74.24

Statistical analysis components	Value
Significance of F	1.99*e[-15]
t-value	-8.62
p-value	1.99*e[-15]
Rural roads	
Linear trendline equation	$y = -0.84x + 5.95$
Multiple R	0.51
R^2	0.26
F-statistic	70.62
Significance of F	7.67*e[-15]
t-value	-8.40
p-value	7.67*e[-15]

D.4.4 PRESENCE OF ENCROACHING ROADSIDE VEGETATION

Table D.57 presents the results for the presence of encroaching roadside vegetation. The cells highlighted in yellow indicate the majority result for the ratings. The number of data points for the linear relationship between CLoS and TLoS are summarised in Table D.58: CLoS and TLoS ratings counts for presence of encroaching roadside vegetation. Table D.59 provides the statistical analysis components for the presence of encroaching roadside vegetation.

Table D.57: Presence of encroaching roadside vegetation – percentage of participants per rating

Row labels	Urban road 1	Urban road 2	Urban road 3	Urban road 4	Rural road 1	Rural road 2	Rural road 3	Rural road 4
Excellent – 5	13.73%	27.45%	29.41%	29.41%	11.76%	0.00%	5.88%	1.96%
Very good – 4	37.25%	25.49%	25.49%	29.41%	23.53%	3.92%	29.41%	3.92%
Good – 3	35.29%	21.57%	25.49%	15.69%	33.33%	9.80%	29.41%	23.53%
Adequate – 2	13.73%	17.65%	13.73%	23.53%	17.65%	23.53%	21.57%	41.18%
Poor – 1	0.00%	7.84%	5.88%	1.96%	13.73%	62.75%	13.73%	29.41%

Table D.58: CLoS and TLoS ratings counts for presence of encroaching roadside vegetation

		TLoS					
CLoS		1	1.67	1.89	2.33	2.7	3.67
	1	32	7	15	11	3	1
	2	24	18	42	54	14	24
	3	15	51	36	132	39	24
	4	8	48	8	188	52	60
	5		30	5	120	75	75

Table D.59: Statistical analysis information for the presence of encroaching roadside vegetation

Statistical analysis components	Value
Linear trendline equation	$y = 0.78x + 1.21$
Multiple R	0.44
R^2	0.19
F-statistic	96.72
Significance F	1.29*e[-20]
t-value	9.83
p-value	1.29*e[-20]

As can be seen from Table D.59, there is a positive correlation and statistically significant relationship between CLoS and TLoS for the presence of encroaching roadside vegetation. The AusRAP rating category for this measure was the roadside severity or the distance to the roadside objects. This means that the AusRAP rating scale for the roadside object severity (distance to object) identifies what customers believe to be a concern.

Further statistical analysis was completed to determine if there was a difference in the correlation between the urban and rural road segments. This analysis is detailed in Table D.60. Although the relationship between CLoS and TLoS has a positive correlation in both urban and rural environments, it is only statistically significant in rural environments.

Table D.60: Statistical analysis information by road category for

Statistical analysis components	Value
Urban roads	
Linear trendline equation	$y = 0.09x + 3.30$
Multiple R	0.04
R^2	0.002
F-statistic	0.35
Significance of F	0.55
t-value	0.59
p-value	0.55
Rural roads	
Linear trendline equation	$y = 0.91x + 0.82$
Multiple R	0.37
R^2	0.13
F-statistic	31.39
Significance of F	$6.85{*}e^{-08}$
t-value	5.60
p-value	$6.85{*}e^{-08}$

D.5 CLOS INDICATORS SUMMARY

The overall statistical assessment for each indicator was completed by combining and aligning the results of all the individual measures within that category (i.e., reliability covers travel time and the capacity to support free-flow traffic). The measures which make up each indicator are outlined in Table 6.1.

Table D.61 provides a summary of all the statistical assessment measures which were calculated for each CLoS, overall and in both urban and rural environments. This included the linear trendline equation, the Multiple R, the R^2, the F-statistic, the Significance of F, the t-value and the p-value.

Table D.61: Statistical analysis information for CLoS indicators

Statistical analysis components	Safety	Reliability	Condition	Accessibility
		Overall		
Linear trendline equation	$y = 0.343x + 1.706$	$y = 0.388x + 1.511$	$y = 0.458x + 0.753$	$y = 0.230x + 1.752$
Multiple R	0.41	0.45	0.23	0.26
R^2	0.17	0.21	0.05	0.07
F-statistic	360.91	212.54	93.89	65.74

Statistical analysis components	Safety	Reliability	Condition	Accessibility
Significance of F	$1.49*e^{-73}$	$6.03*e^{-43}$	$1.26*e^{-21}$	$1.70*e^{-15}$
t-value	19.00	14.57	9.69	8.11
p-value	$1.49*e^{-73}$	$6.03*e^{-43}$	$1.26*e^{-21}$	$1.70*e^{-15}$
Urban				
Linear trendline equation	$y = 0.198x + 2.416$	$y = 0.265x + 2.166$	$y = 0.475x + 0.956$	$y = -0.237x + 4.235$
Multiple R	0.22	0.26	0.31	0.21
R^2	0.05	0.07	0.10	0.05
F-statistic	62.52	28.45	89.09	29.06
Significance of F	$5.86*e^{-15}$	$1.60*e^{-7}$	$3.85*e^{-20}$	$1.00*e^{-07}$
t-value	7.91	5.33	9.44	-5.39
p-value	$5.86*e^{-15}$	$1.60*e^{-7}$	$3.85*e^{-20}$	$1.00*e^{-07}$
Rural				
Linear trendline equation	$y = 0.288x + 1.793$	$y = 0.358x + 1.44$	$y = 1.424x - 4.195$	$y = 0.144x + 1.859$
Multiple R	0.32	0.44	0.32	0.21
R^2	0.10	0.19	0.10	0.04
F-statistic	107.84	96.29	94.53	26.80
Significance of F	$5.18*e^{-24}$	$1.54*e^{-20}$	$3.27*e^{-21}$	$3.07*e^{-07}$
t-value	10.38	9.81	9.72	5.18
p-value	$5.18*e^{-24}$	$1.54*e^{-20}$	$3.276*e^{-21}$	$3.07*e^{-07}$