South Africa

COTO

Committee of Transport Officials

TMH 9

MANUAL FOR VISUAL ASSESSMENT OF ROAD PAVEMENTS

PART A: GENERAL

Committee Draft Final

May 2016

Committee of Transport Officials

TECHNICAL METHODS
FOR HIGHWAYS

TMH 9

MANUAL FOR VISUAL ASSESSMENT OF ROAD PAVEMENTS
Part A: General

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Compiled under auspices of the:

Roads Coordinating Body (RCB)
Committee of Transport Officials (COTO)
Road Asset Management Systems (RAMS) Subcommittee

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Synopsis

TMH 9 provides the procedures for the visual assessment of the condition of roads. Assessment procedures and requirements for road segment information data are specified. Different distress types are classified and detailed descriptions of degree of distress (including photographic plates illustrating condition) for each of the distress types are given. TMH 9 is a companion document to TMH 22 on Road Asset Management Systems.

Withdrawal of previous publication:

This publication replaces the previous Draft TMH9 "Standard Visual Assessment Manual for Flexible Pavements" published in 1992. This previous publication is effectively withdrawn with the publication of this document.

Technical Methods for Highways:

The Technical Methods for Highways consists of a series of publications in which methods are prescribed for use on various aspects related to highway engineering. The documents are primarily aimed at ensuring the use of uniform methods throughout South Africa, and use thereof is compulsory.

Users of the documents must ensure that the latest editions or versions of the document are used. When a document is referred to in other documents, the reference should be to the latest edition or version of the document.

Any comments on the document will be welcomed and should be forwarded to coto@nra.co.za for consideration in future revisions.

Document Versions

Working Draft (WD). When a COTO subcommittee identifies the need for the revision of existing, or the drafting of new Technical Recommendations for Highways (TRH) or Technical Methods for Highways (TMH) documents, a workgroup of experts is appointed by the COTO subcommittee to develop the document. This document is referred to as a Working Draft (WD). Successive working drafts may be generated, with the last being referred to as Working Draft Final (WDF). Working Drafts (WD) have no legal standing.

Committee Draft (CD). The Working Draft Final (WDF) document is converted to a Committee Draft (CD) and is submitted to the COTO subcommittee for consensus building and comments. Successive committee drafts may be generated during the process. When approved by the subcommittee, the document is submitted to the Roads Coordinating Body (RCB) members for further consensus building and comments. Additional committee drafts may be generated, with the last being referred to as Committee Draft Final (CDF). Committee Drafts (CD) have no legal standing.

Draft Standard (DS). The Committee Draft Final (CDF) document is converted to a Draft Standard (DS) and submitted by the Roads Coordinating Body (RCB) to COTO for approval as a draft standard. This Draft Standard is implemented in Industry for a period of two (2) years, during which written comments may be submitted to the COTO subcommittee. Draft Standards (DS) have full legal standing.

Final Standard (FS). After the two-year period, comments received are reviewed and where appropriate, incorporated by the COTO subcommittee. The document is converted to a Final Standard (FS) and submitted by the Roads Coordinating Body (RCB) to COTO for approval as a final standard. This Final Standard is implemented in industry for a period of five (5) years, after which it may again be reviewed. Final Standards (FS) have full legal standing.

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A GENERAL INFORMATION

A.1 Introduction

A.1.1 Purpose and background

This manual provides procedures for the visual assessment of the condition of roads.

This manual is both a training manual for assessors and a reference document for assessors in the field. It is the product of over 30 years of experience in the evaluation of the condition of roads as inputs for a Road Asset Management System (RAMS) at both a strategic and tactical level. The validity, usefulness and effectiveness of a RAMS rely on the quality of the data collected. This manual strives to ensure that data being collected is systematic, repeatable and consistent.

Formal assessment methods, relevant to the various types of paved and unpaved roads, have been refined to ensure that assessments produce predictable and repeatable data which will inevitably produce outputs from RMS's with a high level of confidence.

Visual assessments:

- determine Visual Condition Indices;
- determine maintenance and rehabilitation needs; and
- are used to prioritise projects in a decision support system.

TMH 9 Part A and its associated parts (B, C, D and E) are companion manuals to TMH 22 – Road Asset Management Manual. The data collected using the methods described in this document must be used to fulfil the purposes and requirements of TMH 22.

These manuals describe the various methods of assessment used.

A.1.2 Evaluation of the condition of the road

The condition of the road is considered from two points of view, namely that of the road engineer and that of the road user.

- The road engineer views the pavement as a load bearing structure to be maintained in good time if it is to remain serviceable at an optimal cost (engineering requirements).

- The road user, on the other hand regards the road as a service: the condition of the pavement is appraised in terms of the characteristics that affect quality of travel, notably comfort, safety and operating costs (functional requirements).

The assessment of the condition of the pavement is therefore based on both engineering and functional descriptions related to the condition of the pavement surfacing and pavement structure.

Visible distress is an important input in the assessment of the condition of a pavement structure. Distress is described by recording its main characteristics – the attributes of distress, namely the type, degree and extent of occurrence (Section A.2.)

To reduce the amount of subjectivity involved in the assessment, the assessor must follow the assessment procedures as set out in this manual.

A.1.3 Information to be obtained from visual assessment data

Visual assessment data is one form of input necessary for a RAMS. Visual assessment is by its very nature time-consuming and labour intensive. It is therefore imperative that the level of detail collected and stored in the RAMS is kept to a minimum. The data collected must be subject to strict quality assurance procedures so that RAMS users have confidence in the data provided.

As mentioned in section A.1.1, the following two main outputs are achieved by processing the visual assessment data:

- Visual Condition Indices;
- Maintenance and rehabilitation needs.

A.1.4 Layout of the manual

TMH 9 comprises five parts:

- **Part A** provides information to the assessor which should be studied as background to the detailed distress description in Parts B to E for the different pavement types. The Parts provide detailed descriptions of the various distress types and the descriptions of the various degrees of distress. Colour photographs of typical examples of each distress type are provided.
- **Part B**: Flexible Pavements
- **Part C**: Concrete Pavements
- **Part D**: Block Pavements
- **Part E**: Unpaved Roads

A.2 Attributes of distress

The appearance of distress is varied and often complex. The task of describing this is achieved by recording its main characteristics. The attributes referred to in this manual are the:

- type;
- degree;
- extent; and
- spacing or activity (where applicable)

These attributes are defined in Part A. Generic descriptions of degree and extent are presented in Parts B to E.

A.2.1 Different levels of assessment

Visual assessments are labour-intensive and time consuming and this manual strives to provide the minimum levels of assessment that are required for use in a RAMS. Individual authorities can add additional levels of sophistication should they deem it necessary for their specific purposes.

There is no difference in the methods used to capture visual assessment information at a network or project level except that a more detailed approach, in terms of distress extent and location, is required at project level.

A.2.2 Degree

The degree of a particular type of distress is a measure of its severity. Since the degree of distress can vary over the pavement segment, the degree must be recorded in conjunction with the extent of occurrence; this will provide the best average assessment of the seriousness of a particular type of distress.

The general descriptions of degree of each type of distress are presented in Table A.1.

Table A.1: General description of degree classification

Degree	Severity	Description*
0	-	No distress visible.
1	Slight	Distress difficult to discern. Only the first signs of distress are visible.
2	Slight to warning	Distress clearly visible but not at degree 3
3	Warning	Start of secondary defects. (Distress notable with respect to possible consequences).
4	Warning to severe	Secondary defects clearly visible but none at degree 5 yet.
5	Severe	Secondary defects are well developed (high degree of secondary defects) and/or extreme severity of primary defect.

*****Specific classifications for the various types of distress (primary defects) have been compiled, based on these general descriptions (see Parts B to E).

A flow diagram illustrating the use of the five-point classification system is shown in Figure A.1. The most important categories of degree are 1, 3 and 5. If there is any uncertainly regarding the condition between degrees 1 and 3 or 3 and 5, the defect may be assessed as 2 or 4, respectively.

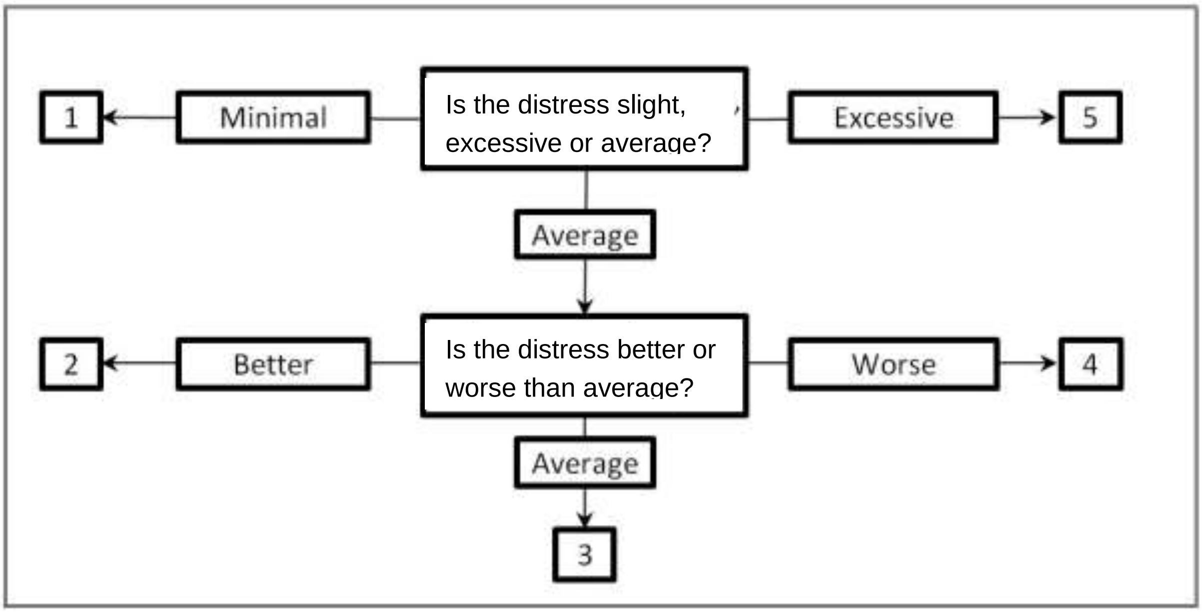

Figure A.1: Flow diagram for assessing the degree of defects

A.2.3 Extent

The extent of any distress is a measure of how widespread the distress is over the length of the road segment. These are summarised in Table A.2 and Figure A.3.

Table A.2: General description of extent classification (Figure A.3)

Extent	Description	Percentage of length*
1	Isolated occurrence Not representative of the segment length being evaluated	< 5
2	Occurs over parts of the segment length More than isolated	5 – 10
3	Intermittent (scattered) occurrence over most of the segment length (general), or Extensive occurrence over a limited portion of the segment length.	10 - 25
4	More frequent occurrence over a major portion of the segment length.	25 - 50
5	Extensive occurrence over the entire segment.	> 50

*** The percentage of extent is only a guide-line for the assessors and should not be literally interpreted.**

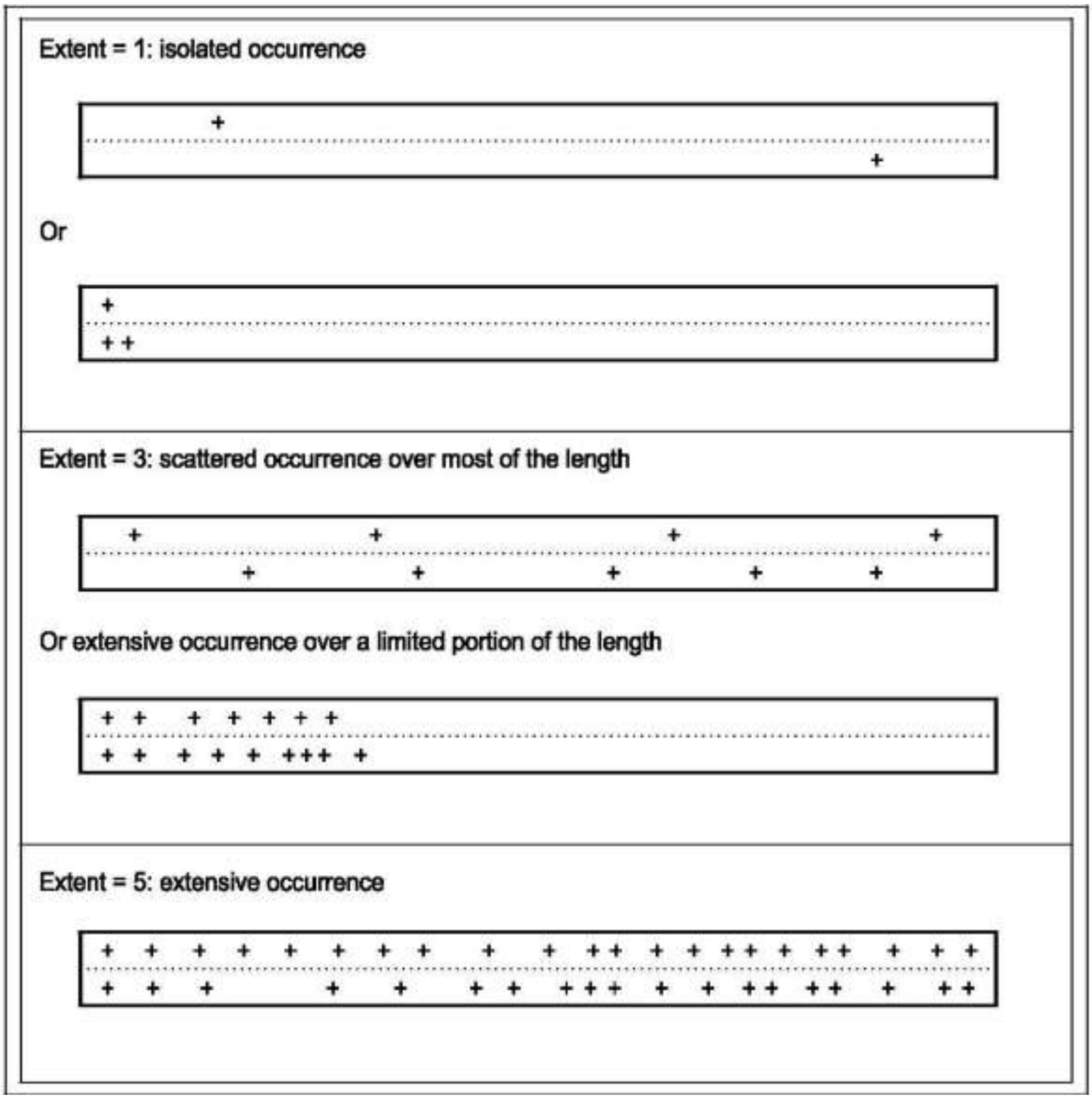

Figure A.2: Illustration of extent

Even experienced assessors generally tend to overestimate the extent of defects. This tendency increases with severity of the defect.

A.2.4 Examples of degree and extent

The following examples illustrate the combined use of degree and extent (the highest product of the two should be used):

- If a distress occurs intermittently at lengths of ±10m each, at about 20 locations over a 2km assessment segment, the extent is recorded as a 3 (20%).
- If a distress occurs intermittently at lengths of ±50m each at about 8 locations over a 2km assessment segment, the extent is recorded as a 3 (20%).

- If cracking of degree 5 occurs seldom (i.e. extent 1) and cracking of degree 3 occurs extensively (i.e. extent 5), the degree 3/extent 5 cracking is recorded as the best average indication of the severity of cracking over the specific pavement segment in terms of possible rehabilitation/reseal action. In such a case the degree 5 cracking will be viewed as an area of localised distress requiring routine attention.
- If cracking of degree 5 and extent 2, and cracking of degree 1 and extent 4 occurs, degree 5/extent 2 is recorded as the average indication of the problem that is most significant in terms of possible action. (Cracking of degree 1 is not considered significant in terms of possible action).
- If isolated potholing of degree 5 occurs (i.e. extent 1) and potholing of degree 3 occurs extensively (i.e. extent 5), the degree 3/extent 5 potholing is recorded as the prominent indication of the severity of potholing over the specific road segment in terms of possible maintenance action. In such a case, the degree 5 potholing will be viewed as an area of localised distress requiring routine attention.
- If potholing of degree 5 and extent 2, and potholing of degree 1 and extent 4 occurs, degree 5/extent 2 is recorded as the average indication of the problem that is most significant in terms of possible action.

It should be noted that this is generic and may be interpreted differently for different types of distress and different assessment requirements (i.e., network or project level). The combination of the degree and extent is extremely important depending on the distress and the type of pavement.

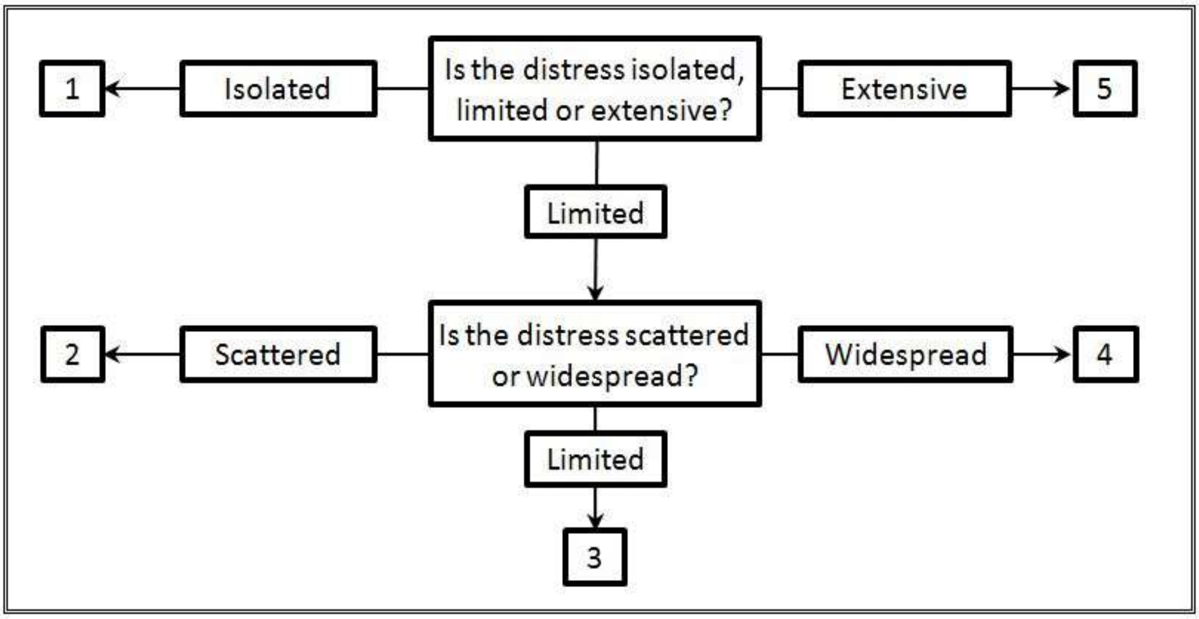

Figure A.3: Flow diagram for determining extent

A.3 Segment lengths

It is not the purpose of the assessment to identify uniform sections of distress on the road and to complete an assessment form for each of these uniform sections. The road network should be evaluated according to the standard segment lengths that are given in Table A.3. It is recommended that the authority predefined segments over their complete network, and not leave this to the individual assessors. This will ensure improved consistency from one assessment to the next.

Table A.3: Standard segment lengths for different types of roads

Type of Road Pavement	Standard Assessment Length (km)	
	Rural	**Urban**
Flexible	2.0	Block lengths (max 0.5 km)
Concrete	0.2	0.2
Block	0.2	0.2
Unpaved	5.0	Block lengths (max 0.5 km)
Note : Assessment lengths should not exceed ± 50% of standard		

Example of Typical Segments (Unpaved rural)

A segment is defined as a 5 kilometre length of road beginning at a multiple of five (e.g. km 5 or 10, etc.) and ending at a multiple of five (e.g. km 10 or 15, etc.). If the route/section begins, for example, at a municipal boundary and/or ends at a district boundary or crosses another route, the following rules apply where the distance from the boundary to the next multiple is less than 5 km. If the difference in distance is less than 2.5km, it is added to the next road segment and then the specific length is considered as, for example, km 3.46 to km 10 00. If the difference in distance is more than or equal to 2.5km, it is regarded as a separate segment, for example, km 0.98 to km 5.00. The same applies from the last 5km, multiple to the end of the route / section, municipal border or crossing of another route, for example, km 25.00 to km 32.33 or km 30.00 to km 34.01. The above-mentioned is illustrated in Figure A.4.

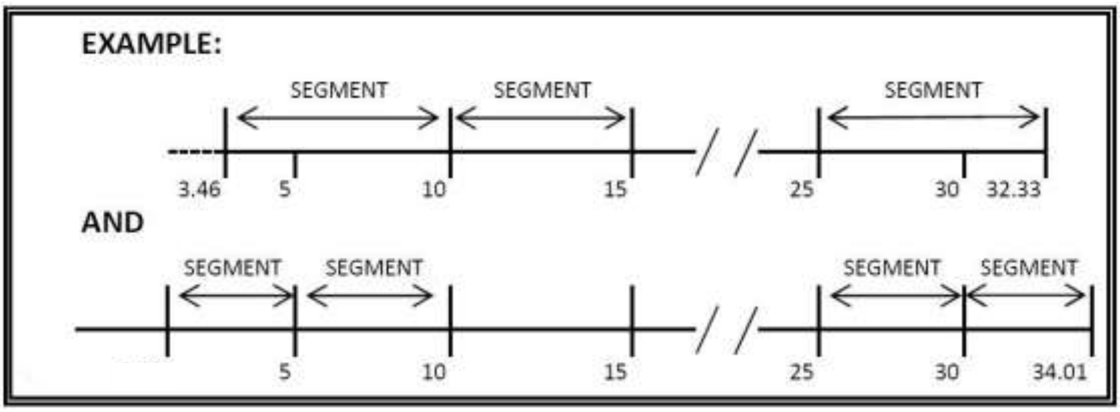

Figure A.4: Short and long assessment segments for an unpaved rural road

Example of Typical Segments (Urban)

A segment is defined from intersection to intersection, one street to the next or in layman's terms a 'block'. The length of the segment is then measured from mid intersection to mid intersection. In the case where the segment length is longer than 500m the same principle applies up to a maximum length of 750m.

A.4 Road Inventory Information

Certain road inventory information could be recorded or verified on site for each segment. This information is fully described in TMH 22 and may include the items described in Table A.4. Important to note that with each optional item added for recording/verification by the assessors, they get more distracted from their primary task which is the condition assessment.

Table A.4: Road Inventory Items (R = Required and O = Optional)

Item	Description	Status
Road Number/Road Name	Rural: MR16 (Main Road 16) Urban: Nelson Mandela Drive	R
Section Number / Link	Rural: MR16/10 (Main Road 16, Section 10) Urban: A link is usually the length of road or street from one intersection or interchange to the next.	R
Segment Start and End	Rural: Start and end distance of the segment for which one assessment rating (See Table A.3) is recorded, to the nearest 0.01 km. Urban: Physical description of the segment start and end points i.e. street names (if no kilometre distances are available)	R
Name of Assessor	Used for quality assurance purposes.	R
Date	Date of the assessment YYYY/MM/DD	R
Segment Length	Length of segment to the nearest 0.01 km. Urban: length is measured from mid intersection to mid intersection.	O
Segment Width	Average width recorded to the nearest 0.1m. For unpaved roads the width of the travelled way must be recorded.	O
Untraveled Way Width	The average width of the untraveled way must be recorded to the nearest 0.1 m.	O
Start Time	Time at start of the assessment for the road number	O
End Time	Time at end of assessment for the road number	O
Direction of assessment	Rural: Direction of Increasing or decreasing kilometres Urban: North / East / South / West	O
Road Classification	The road is classified according to the TRH 26 RCAM.	O
Ownership	The level of authority being National, Provincial or Local.	O
Terrain	Flat - The route mostly follows level areas with few inclines and grades less than 3%. Rolling - Grades are approximately 4% -7% with some curves. Mountainous - Grades are typically more than 7% with numerous sharp curves.	O

<table>
<tr><th>Item</th><th>Description</th><th>Status</th></tr>
<tr><td>Node Type</td><td>Abbreviated codes are used for identifying nodes:
<table>
<tr><td>Intersection</td><td>X</td><td>End of paved segment</td><td>EP</td></tr>
<tr><td>T-Junction</td><td>T</td><td>Start of paved segment</td><td>SP</td></tr>
<tr><td>T-junction left</td><td>TL</td><td>Start of segment (no node)</td><td>ST</td></tr>
<tr><td>T-Junction right</td><td>TR</td><td>End of segment (no node)</td><td>EN</td></tr>
<tr><td>Towns/villages</td><td>V</td><td>Borders/boundaries</td><td>BO</td></tr>
<tr><td>Change of pavement type</td><td>CP</td><td></td><td></td></tr>
<tr><td colspan="3">Maximum segment length used as segment end</td><td>MX</td></tr>
</table></td><td>O</td></tr>
</table>

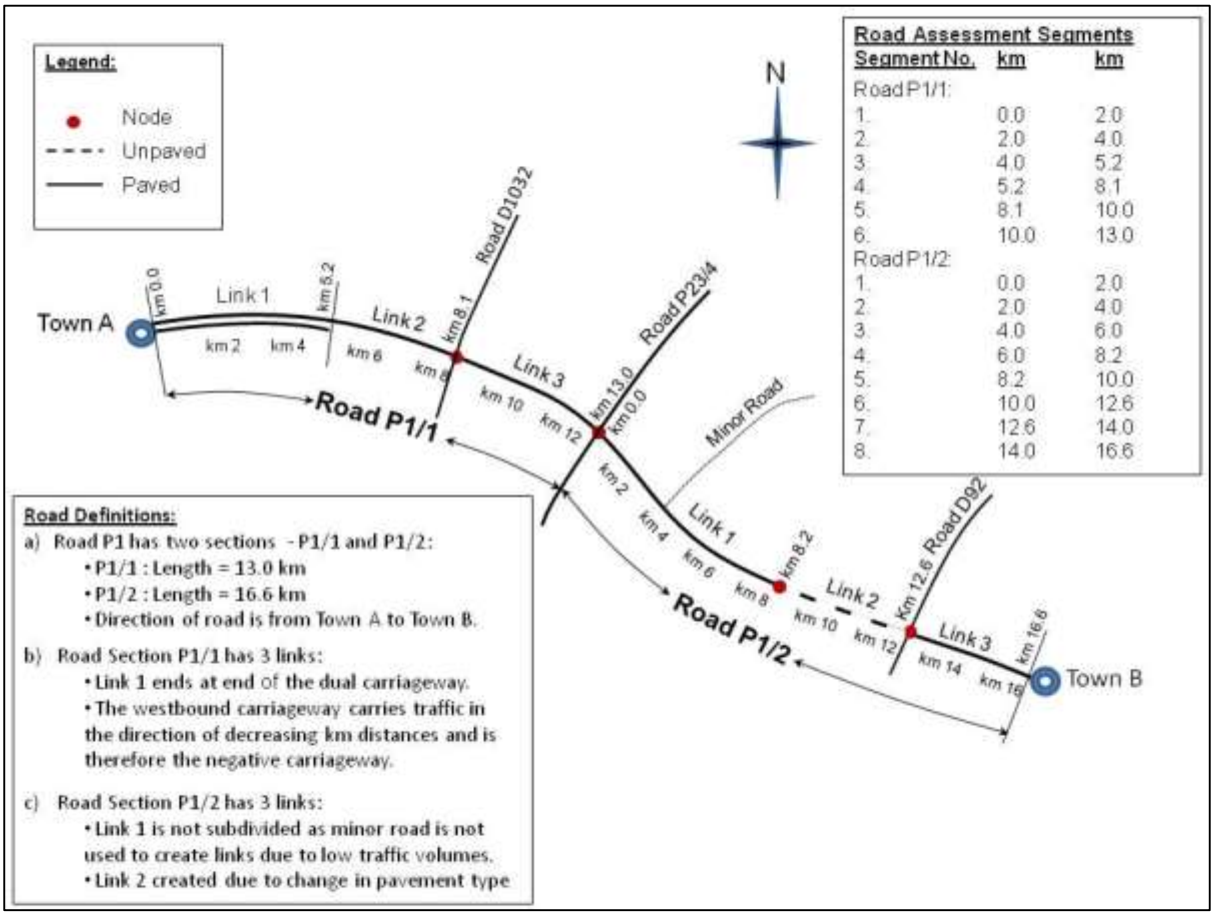

Figure A.5: Example of rural road definition

A.5 Assessment procedure and quality assurance

A.5.1 Procedure for visual assessment

Visual assessment should preferably be carried out in or towards the end of the rainy season and in the cooler months. Surveys should be completed within limited periods (preferably two to three months). Based on experience the average daily length of survey for rural roads should not exceed 100km for paved roads, 150 km for gravel roads and 20km for urban roads. Shorter daily lengths may be expected if the condition of the road is very variable, or in the case of shorter segment lengths. The assessors shall drive at a speed of less than 20km/h, and where possible, they shall drive on the shoulder.

Assessments can be carried out by one certified assessor or one certified assessor and an assistant. Assistants should be used when complexity or safety are an issue. If the assistant is a certified assistant assessor, then the assistant assessor is expected to carry out the assessments with the assessor providing guidance and checking quality.

The accuracy of the assessor’s rating will be influenced by the frequency of stops made to examine the road.

The first segment to be evaluated on a road requires a thorough orientation to adjust the assessor to the prevailing conditions and more stops may be required. This orientation must take into account the position of the sun (preferably from the rear), the amount and variability of cloud cover and localised moisture as these prevailing conditions will influence the visibility of some of the defects, (e.g. cracks).

When the road is wet, it is difficult to observe distress, and this leads to erroneous ratings; visual surveys shall therefore be carried out under dry conditions only. Similarly, when a road is under construction, assessment will only be carried out on completed sections of the new road and available portions of the existing road. The reason why certain segments cannot be assessed should be recorded on the relevant assessment form.

During the visual assessment of a segment, dots must be made on the assessment form in the appropriate positions to indicate the degree of any type of distress that is observed. At the end of a segment, these dots are used to mark an average degree and extent of distress for each type of defect. After completing the form, the assessor should also check road segment inventory information, i.e. correct start and finish information, road width, etc.

Paved shoulders (untraveled ways) are inspected as part of the road surface. The assessment should cover the full paved width. On multi-lane roads, the assessment should concentrate on the worst lane, which typically is the slow lane.

A.5.2 Training of visual assessors

Training of candidate assessors must be undertaken before the Visual Assessor Accreditation. This training should be presented by accredited trainer who have at least 5 years of continuous assessment experience. A list of accredited trainers can be obtained from COTO.

First time candidates wishing to become assessors must have at least 2 years of appropriate road engineering experience and/or an S3 or Further Education and Training (FET) qualification in civil engineering. First time candidates must have a thorough understanding of the manuals before they start the training.

The training programme must include the following theoretical and practical aspects:

- An overview of the objectives of the visual assessment together with a brief description of the data processing procedures and applications of the final results.
- An overview of the method of assessment, including descriptions of various types of distress and ratings for each type. The use of colour slides to show examples is recommended.
- An overview of the format of the assessment sheets.
- The practical training consists of both combined assessments and practical informal testing. Combined assessments should cover three or four segments per pavement type, preferably showing different degrees of distress. The method of rating should be discussed and the ratings compared at the end of each segment between candidate and accredited trainer. If a candidate's ratings are not acceptable after these segments then additional segments should be rated together until there is a thorough understanding of the assessments. Once candidate achieves thorough understanding, then practical informal testing should cover three or four segments per pavement type. For these sections the candidate and the accredited trainer will individually rate each segment, and compare results at end of each segment. If a candidate's ratings are not acceptable after these segments then additional segments should be rated together until there is a thorough understanding of the assessments.

A.5.3 Accreditation of visual assessors and assistants

A national Visual Assessor Accreditation will be held annually. The accreditation programme will be for each pavement type will include the following:

- A written test to check on the candidates/assessor's knowledge of the standard visual assessment manual. Only candidates/assessors who pass these tests should be allowed to participate in the practical testing. The pass mark shall be a minimum of 80 %.
- The candidates/assessors should individually assess at least 10 road segments per pavement type showing varying degrees of distress. The results of these assessments must be within the criteria prescribed by the trainer.

No differentiation is made between candidates and assessors during the training as candidates must be just as competent as assessors, only lacking the required experience. First time candidates will initially be accredited as assistant assessors and only once they have successfully assessed at least 2 000km of rural or 500km of urban roads within two year period. These assessments must be performed along with an accredited assessor, and only once the accredited assessors certifies the practical experience of the assistant assessor, will they be able to be classified as assessors.

The accreditation will be for each pavement type and shall remain valid for a 3 year period provided that the assessor successfully carries out regular assessments each year. Only Accessors who have a valid accreditation will be allowed to carry out visual assessments.

A diagram of the path is illustrated in Figure A.6.

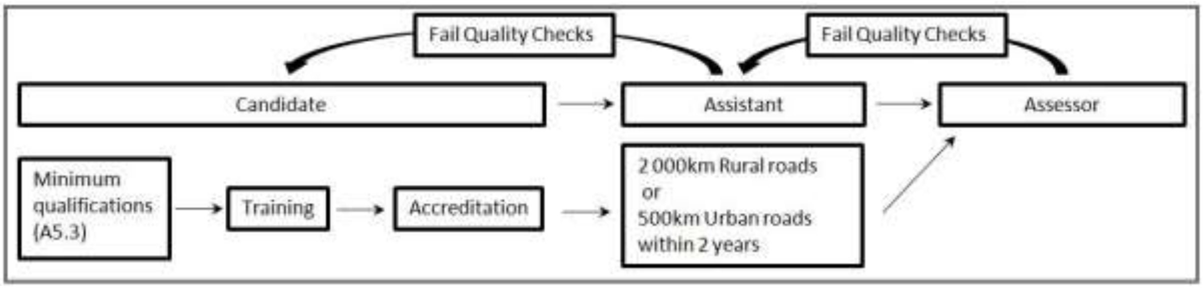

Figure A.6: Diagram showing accreditation path of assessors

A.5.4 Quality management plan

The Quality Management Plan (QMP) for visual assessments should include **Quality Control** and **Quality Acceptance** components.

Quality Control is an internal responsibility of the authority carrying out the assessment. These can be the authorities own teams carrying out an in-house assessment or external service providers procured for the quality control assessment.

Only Accessors who have a valid accreditation will be allowed to carry out quality control assessments.

Internal quality control must start with a calibration session that highlights issues specific to the network, lists any additional items to be collected and discusses challenges faced during previous assessments. A follow-up check of the assessments made in the first 5 days of the assessment must be carried out. This follow-up session must highlight errors and inconsistencies and correct any calibration problems.

Internal quality control must include allowances for contingencies regarding replacement of assessors, vehicles and data capture devices, safety of assessors, regular data backup and other operational issues.

Quality Acceptance comprises the assessment of a representative sample of at least 10% of all roads assessed. Roads selected for control assessment must include an equal distance per assessor and a range of different distress types. These independent assessments must be undertaken by experienced accredited assessors appointed for the task. Their results must be compared with the assessment results for accuracy.

The checking procedure can include checking of the calculated indices and the degree and extent for individual defects. Please see Annexure A for an example of such a procedure. The road network must be divided into manageable areas such as regions, districts or suburbs so that these areas can be resurveyed should they fail to meet the acceptability criteria. To ensure efficiency and minimise the losses that may be incurred, the quality assurance checks must be completed within 2 weeks of completion of the assessments in that area.

A.6 Risk Management

The majority of incidents can be prevented by introducing a risk management system which includes training, inspections, work procedures, assessor fitness, planned maintenance of equipment and ensuring sufficient and competent supervision. Conducting a Hazard Identification and Risk Assessment (HIRA) for Road Inspections will benefit in the following ways:

- Recognize and control hazards and exposures in the workplace;
- Create awareness among assessors that may be used as a training tool;
- Set risk management standards, based on acceptable safe practice and legal requirements;
- Reduce incidents in the workplace;
- Save costs by being proactive instead of reactive.

All individuals involved in the assessment must assist in the identification of hazards and assess risks.

A.6.1 Safety

Assessors must be made aware of the legal implications of complying with the relevant laws applicable to safety in the workplace relating to visual assessments:

- National Road Traffic Act (No. 93 of 1996);
- National Road Traffic Regulations (No. 93 of 1996);
- The Occupational Health and Safety Act (OHSA Act 85 of 1993).

A.6.2 Terminology

All assessors must understand the relevant terminology and concepts before starting their HIRA:

Table A.5: Hazard identification and risk assessment (HIRA) terminology

Term	Meaning
Hazard	A source of or exposure to danger - in other words - anything that can cause harm [OHSA]
Risk	The probability that injury or damage will occur - in other words - the chance, great or small, that someone will be harmed by the hazard [OHSA]
Exposure	To be exposed to a danger while at the workplace
Danger	Anything that may cause injury or damage to persons or property [OHSA]
Safe	Free from any hazard [OHSA]
Workplace	Any premises or place where a person performs work in the course of their employment.
Premises	Includes any building, vehicle, vessel, train, or aircraft [OHSA]
Risk management	The implementation of a formal system where hazards and risks are identified and actions taken to mitigate these risks.

A.6.3 Procedures

The following procedures should be adhered to. This is not a complete list and the relevant legislation should be complied with.

- Weekly safety checklists
- Monthly inspections
- Timely notices of violations
- Up to date permission forms for accessing roads and using hazards lights and markers
- Written procedure for routine inspection
- Written procedure for incidents
- Formal listing of elements that constitute safe driving:
  - Maximum number of hours in a duty period set at 8
  - Operating times set to between daybreak and sunset
  - Scheduled breaks every 3 hours
- Formal elements for vehicle safety:
  - Regular preventative maintenance checks
  - Regular checks on vehicles' safety equipment
  - Formal reports to supervisors on any shortcomings
  - Obeying the rules of the road at all times
- Formal elements on PPE:
  - Regular checks on the condition of PPE
  - Routine training of PPE usage
  - Medical aid kit always available and always kept fully stocked

A.6.4 Equipment and inventory

Table A.6: Assessment equipment

Vehicle Mounted	**Comments**	**Actions**
Flashing light	Amber or yellow rotating, strobe or LED light	Beware of slow moving vehicle, which may stop suddenly and unexpectedly
Signs	Black text on yellow background (adhesive or magnetic)	Usually "Road Inspection"
Permission Letter	Letter from relevant authority	Permission to assess roads in a certain area and for a predetermined time
Personal protection equipment	**Comments**	**Actions**
Footwear	Closed shoe.	No bare feet to minimise injury and reduce driving accidents
Safety Apparel	High visibility clothing or vests	Worn at all times when inspecting roads to alert road users of pedestrian on travelled way
Equipment	**Comments**	**Actions**
Maps of road network	Scale and detail to suit assessments	Size to suit assessments, usually A2 or A3 in size
Measuring Wheel	Short distance, low accuracy measuring	To measure width of road
Screw driver	Road surfacing assessments	Used to extract surfacing stone
Geological pick	Unpaved road assessments	Digging and loosening gravel
Stationery		

A.7 Glossary

Assessment segment: An assessment segment is the length of road for which one assessment rating is recorded. In the case of rural road networks, a road link is normally divided into road segments for visual assessment. For urban road networks where road links may be very short, links may be grouped together to form an assessment segment.

Earth road: An unpaved road in which the in situ material is directly travelled by vehicles.

Gravel Road: An unpaved road in which an imported material has been placed to provide a riding surface for vehicles.

Gravel Road Management System (GRMS): is part of a Road Management System, which is a set of procedures aimed at maximising the potential serviceability of a road network. These procedures are used by the managers of the road network (usually with the aid of computerised facilities) to evaluate maintenance, improvement and upgrading alternatives, and the establishment of new facilities when needed.

Gravel wearing course: Suitable imported material layer to protect the subgrade or pavement structure from wear by vehicles.

Surfaced road: A road on which a bituminous, concrete or block layer has been placed to provide an all-weather surface for traffic.

Traffic volume: A single value representative of the quantity of/or type of traffic using a road. Different road authorities use different parameters, e.g. Annual Average Daily Traffic (AADT), Average daily traffic (ADT), Equivalent Vehicle Units (EVU) etc.

"Moderate": The condition of various defects is often referred to as "Moderate/ Fair/ Warning". This term indicates a condition that requires some action in the near future and/or a problem that may develop into a more serious one.

Unpaved Road: Unpaved roads can be categorised into three types, tracks, earth and gravel roads

Width: Two different road widths are normally considered during visual assessments on unpaved roads.

- Total width, which includes shoulders and is used for calculation of gravel quantities for regravelling
- The trafficked width often demarcated by windrows at each side or change in crossfall, which is used for assessment purposes.

A.8 Bibliography

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A.9 ANNEXURE A: Example of a Visual Training and Quality Control Procedure

WESTERN CAPE GOVERNMENT

DEPARTMENT OF TRANSPORT AND PUBLIC WORKS
ROADS INFRASTRUCTURE BRANCH

T-Test for the Evaluation of Visual Assessments as part of Visual Training and Quality Control in the Field

TABLE OF CONTENTS

A.9.1 Introduction

This report documents the t-test statistical method applied by the Western Cape Government (WCG) to evaluate the acceptability of its visual assessment data. This evaluation is done for both surfaced roads and gravel roads, however, in this report reference is primarily made to surfaced roads in order to demonstrate and explain the application of the t-test.

A.9.2 Description of the T-Test

The t-test is a statistical method that in essence is used to determine if two sets of data are significantly different. This is done by determining a "t_{value}" from the mean values of the two sets of data, and then testing for a level of significance between the two.

There are two types of t-tests that are commonly used, namely:

- the un-paired t-test, and
- the paired t-test.

The difference between the two test types is that the un-paired t-test is used when comparing two sets of independent data, i.e. comparing data collected on one subject to data collected on a different subject. The paired t-test however, compares two data sets that are dependent, i.e. data is collected on the same subject before and after some or other change has been made to that subject.

A.9.3 WCG Application of T-Test

A.9.3.1 Level of Significance

The WCG applies the t-test using three levels of significance:

1. Non-Significant – "NS" : No significant difference exists between two sets of data,
2. Possibly Significant - "PS": A possible significant difference exists between two sets of data, and
3. Highly Significant – "HS": A highly significant difference exists between two sets of data.

The significance levels are determined by comparing the determined "t_{value}" to "t_{95}" and "t_{99}". The t_{95} and t_{99} are the t values for the 95% and 99% confidence intervals. A significance rating of NS exists when t_{value} falls within the 95% confidence interval (i.e. $t_{value}<t_{95}$). A significance rating of PS exists when the t_{value} falls between the 95% and 99% confidence interval (i.e. $t_{95} \leq t_{value}<t_{99}$). Should the t_{value} be greater than or equal to the 99% confidence interval (i.e. $t_{value} \geq t_{99}$), then the significance level HS is assigned.

A.9.3.2 Evaluating Visual Assessments

To apply the t-test to the visual assessments, the WCG assigns a deduct value to each defect based on the degree and extent rating (the deduct value is a predefined value relating to the degree and extent rating that quantifies the defect in terms of a single number. This number when subtracted from 100 gives an indication of the condition of the road due to the defect). For each defect there are a total of 26 deduct values. The deduct values start at 0 for a degree/extent rating of 0/0 and can go up to 90 for a defect/extent rating of 5/5, depending on the defect. **Table A-7** presents the deduct values for the defect Failure Patching; for this defect the deduct values range between 0 and 65.

The deduct values of each defect are ranked from 0 to 25. Zero being a degree/extent rating of 0/0 (the lowest deduct value), and 25 a degree/extent rating of 5/5 (the highest deduct value). These rank values are then used to perform the t-test. This is because the deduct values are not sequential, i.e. they do not run 0, 1, 2, 3, etc, but rather 1, 5, 12, 20; where the rank values do run 0, 1, 2, 3, etc. Due to the nature of the t-test, using sequential values such as the rank values allows for a more accurate evaluation (an example of the rank values are presented in **Table A-7**). Therefore, given a degree/extent rating, a deduct value is first assigned, then the deduct value is substituted with the rank value and then the t-test is performed.

Table A-7: Deduct Values and the Corresponding Rank Positions for the Defect Failure Patching for Surfaced Roads

Deducts Values*						
		Degree				
		1	2	3	4	5
Extent	1	2	8	13	18	20
	2	18	24	30	35	40
	3	24	29	43	50	55
	4	30	35	50	55	60
	5	35	40	55	60	65
Rank Positions of the Deduct Values**						
		Degree				
		1	2	3	4	5
Extent	1	1	2	3	4	6
	2	4	7	10	12	15
	3	7	9	17	18	20
	4	10	12	18	20	23
	5	12	15	20	23	25

*For a degree/extent rating of 0/0 a deduct value of 0 is assigned

**The rank of deduct value 0 is 0

The evaluation of the visual assessments using the t-test is done in two phases. The first is the training phase. Here the assessors (called trainees during this phase) undergo theoretical training by the WCG before having to complete a practical evaluation. For the practical evaluation, the trainees are each assigned a set number of road segments that they have to visually asses. Each trainee's assessments are then compared to a "norm", which is set by the client (in this case the WCG). Should more that 30% of a trainee's defects have a "HS" result when compared to the "norm", the trainee is considered to have failed the practical evaluation (see **Appendix A**, **Flow Diagram 1** for a flow diagram of the process).

The next phase is the actual visual assessment of the road network; this is termed the Quality Control phase. During this phase a number of consulting firms are appointed to provide assessors who will assess the road network (In the Western Cape 5 firms are appointed and these firms can provide any number of assessors). Each firm is then assigned a region within the provincial borders, and each firm is then responsible for the visual assessments of the road segments within the assigned region. After the assessors from a consulting firm have assessed the road segments within the specific region, the results are compared to a 15 % control data set. I.e. for each consulting firm appointed, 15 % of the segments to be assessed by each firm are identified and are assessed by an independent assessor. This independent assessor is appointed by the client (WCG) to do quality control. During this phase, an allowable error ranging from 0.5 to 1 (depending on the defect) is provided for. A list of the defects and the allowable error for each is presented in **Appendix B**. This error is not allowed for during the training phase, as the training phase is done under more stringent conditions. Similar to the evaluation of the trainees, if an assessor has an "HS" score of more than 30%, the assessments are rejected (see **Appendix A**, **Flow Diagram 2** for a flow diagram of the process).

A.9.3.3 Paired or Un-Paired T-Test

Based on the above, the data of the trainees/consulting firms and the "norm"/15% control data set (depending on the phase) comes from the same segments with the only change being who performs the assessment. Due to this, the samples are considered to be paired, and hence a two-tailed paired t-test is performed.

A.9.4 T-Test Methodology

A.9.4.1 Visual Assessment Training

Given the following:

- The visual assessments of the trainee,
- The “norm” as set by the client.

The following steps are followed to perform the t-test:

Step 1: Segments assessed by the trainee and those assessed by the independent assessors are matched in terms of the road number and km markers. This is to ensure that the same segments are compared with each other.

Step 2: Deduct values are assigned to each defect based on the degree and extent rating. The corresponding rank values are then assigned.

Step 3: Data is grouped in terms of the defects, i.e. all crocodile cracks data are grouped together, all failure/potholing data are grouped together etc.; the road number and segment km markers are also included. This is done for both the trainee and the “norm”, but the two are kept separate.

Step 4: The following information is determined from the rank value:

- The difference between the rank value of the “norm” and that of the trainee for each time the defect is assessed (this is done for all the defects).
- The |average difference| for each defect (√)
- The standard deviation of the differences (σ)
- The sample size (n) – i.e. the count or number of assessments used for the t-test;
- The degree of freedom is determined as n-1.

Step 5: The t_{value} is determined as follows:

$$t_{value} = \frac{\bar{X} \times \sqrt{n}}{\sigma}$$

Step 6: t_{95} and t_{99} are assigned based on the sample size and degree of freedom.

Step 7: The t_{value} is compared to t_{95} and t_{99} as follows:

- If $t_{value} < t_{95}$ then Non-Significant (NS)
- If $t_{95} \leq t_{value} < t_{99}$ then Possibly Significant (PS)
- If $t_{value} \geq t_{99}$ then Highly Significant (HS)

This process is repeated for all the defects.

Step 8: A summary is compiled and the total number of NS, PS and HS is determined. Each count is divided by the total number of defects assessed (in the case of the WCG, the total number of defects assessed for surfaced roads is 20 and for gravel roads is also 20) to give the % occurrence of each significance. If the % HS is >30% then the trainee is considered to have failed.

Note: For surfaced roads, the physical value for the functionalities riding quality, skid resistance, surface drainage, unpaved shoulders and overall pavement condition are used in lieu of the rank value. This physical value for each of these functionalities is assigned as follows:

- Functionality condition is very good (VG) - 1
- Functionality condition is good (G) - 2
- Functionality condition is fair (F) - 3
- Functionality condition is poor (P) - 4
- Functionality condition is very Poor (VP) - 5

A.9.4.2 Visual Assessment Quality Control

Given the following:

- The visual assessment of a consulting firm for X number of segments,
- The visual assessment of the independent assessor for 15 % of the X segments.

The following steps are followed to perform the t-test:

Steps 1 through **4** as laid out in **Section 4.1**. Note that the trainee is now replaced by consulting firm and the “norm” by the 15 % assessment of the independent assessor.

Following **Step 4**, the procedure is a follows:

Step 5: In the case of quality control an allowable error (e-value) is assigned to each defect type (see **Appendix B**). This ranges between 0.5 and 1 depending on the defect.

Step 6: The average difference is then checked against the e-value as follows:

- If |average difference| ≤ e-value, then set the |average difference| to 0;
- If |average difference| > e-value, then subtract the e-value from the |average difference| (i.e. |average difference| – e-value)

Step 7: The t_{value} is then determined as follows:

$$t_{value} = \frac{\bar{X} \times \sqrt{n}}{\sigma}$$

Where √ is the adjusted |average difference| from **Step 6**, and
Where σ ≠ 0. Otherwise, if σ = 0, the t_{value} is taken as √.

Step 8: t_{95} and t_{99} are assigned based on the sample size and degree of freedom.

Step 9: The t_{value} is compared to t_{95} and t_{99} as follows:

- If $t_{value}<t_{95}$ then Non-Significant (NS)
- If $t_{95}\leq t_{value}<t_{99}$ then Possibly Significant (PS)
- If $t_{value}\geq t_{99}$ the Highly Significant (HS)

This process is followed for all the defects.

Step 10: A summary is compiled and the total number of NS, PS and HS is determined. Each count is divided by the total number of defects assessed (in the case of the WCG, the total number of defects assessed for surfaced roads is 20 and for gravel roads is also 20) to give the % occurrence of each significance. If the % HS for a consulting firm is >30 % then the assessments are rejected.

Note: For surfaced roads, the physical value for the functionalities riding quality, skid resistance, surface drainage, unpaved shoulders and overall pavement condition are used in lieu of the rank value. This physical value for each of these functionalities is assigned as follows:

- Functionality condition is very good (VG) - 1
- Functionality condition is good (G) - 2
- Functionality condition is fair (F) - 3
- Functionality condition is poor (P) - 4
- Functionality condition is very Poor (VP) - 5

An example is provided under **Section 5** to clarify the t-test procedure. This example is for the quality control application of the t-test for surfaced roads.

1 T-Test Example

DEFECT No. **1 : FAILURE PATCHING**

Road Number	Road 1	Road 2	Road 3	Road 4	Road 5	Road 6	Road 7	Road 8	Road 9	Road 10
Segment	km0 - km2	km2 - km4	km4 - km6	km6 - km8	km8 - km10	km10 - km12.34	km0 - km2	km2 - km4	km4 - km6	km6 - km8
Segment Number	1	2	3	4	5	6	7	8	9	10
15% Quality Control (Rank)	0	6	0	3	0	0	1	0	0	0
Consulting Firm 1 (Rank)	3	0	0	3	0	0	0	0	3	3

Delta										
15% Quality Control (Rank) - Consulting Firm 1 (Rank)	-3	6	0	0	0	0	1	0	-3	-3

Statistics	Average Delta	|Avg|	Std Dev Delta	e-value	Adjusted |Avg|	n	Degree of Freedom	t_{Value}	t_{95}	t_{99}	Significance
15% Quality Control (Rank) - Consulting Firm 1 (Rank)	-0.200	0.200	2.658	1.000	0.000	10	9	0.000	1.812	2.764	NS

DEFECT No. **2 :CRACKS**

Road Number	Road 1	Road 2	Road 3	Road 4	Road 5	Road 6	Road 7	Road 8	Road 9	Road 10
Segment	km0 - km2	km2 - km4	km4 - km6	km6 - km8	km8 - km10	km10 - km12.34	km0 - km2	km2 - km4	km4 - km6	km6 - km8
Segment Number	1	2	3	4	5	6	7	8	9	10
15% Quality Control (Rank)	0	0	0	0	0	0	0	0	0	0
Consulting Firm 1 (Rank)	0	0	0	0	0	0	0	0	5	5

Delta										
15% Quality Control (Rank) - Consulting Firm 1 (Rank)	0	0	0	0	0	0	0	0	-5	-5

Statistics	Average Delta	|Avg|	Std Dev Delta	e-value	Adjusted |Avg|	n	Degree of Freedom	t_{Value}	t_{95}	t_{99}	Significance
15% Quality Control (Rank) - Consulting Firm 1 (Rank)	-1.000	1.000	2.108	1.000	0.000	10	9	0.000	1.812	2.764	NS

This is repeated for each of the 20 defects on the WCG visual assessment form for surfaced roads. Following this, a summary is compiled.

SUMMARY OF THE EVALUATION OF CONSULTING FIRM 1 AGAINST THE 15% QUALITY CONTROL

	FAILURE PATCHING	CRACKS	AGGREGATE LOSS	BINDER CONDITION	BLEEDING FLUSHING	BLOCKSTAB. CRACKS	LONGITUDINAL SLIP CRACKS	TRANSVERSE CRACKS	CROCODILE FAILURE CRACKS	PUMPING	RUTTIN G	UNDULATION SETTLEMENT	PATCHING	FAILURES POTHOLING	RIDING QUALITY	SKID RESISTANCE	SURFACE DRAINAGE	UNPAVED SHOULDERS	EDGE BREAKING	OVERALL PAVEMNET CONDITION
15% Quality Control (Rank) - Consulting Firm 1 (Rank)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	HS	NS	PS	NS	NS

Significance Count						
No. NS	No. PS	No. HS		%NS	%PS	%HS
18	1	1		90%	5%	5%

From the example, Consulting firm 1 has a HS of 5%, which means that the visual assessments done by this specific firm are acceptable.

A.9.5 Information Derived from the Application of the T-Test

In the event that a trainee or an assessor has a final result of HS, the following information can be derived from the t-test data to evaluate the cause of such a result:

- The defects tendency;
- Rank position assessment;
- How assessors compare with each other.

Each of the items listed are described further in the subsection **6.1** through **6.3**. It should be noted that the information derived from the t-test data can be done during both phases, i.e. during the training phase and during the quality control phase.

A.9.5.1 The Defects Tendency

The defects tendency relates how “heavy” or “light” the assessors of a consulting firm assess a defect. This is evaluated in terms of both the “Degree” rating and the “Extent” rating that the assessors assigned to a defect. By using the defects tendency it can be identified whether or not the assessors of a consulting firm evaluated the degree too heavily or too lightly and the same for the extent.

The evaluation is done graphically by plotting the differences between the degree of the trainee/firm’s assessors and the degree of the “norm”/independent assessor on the “x” axis, and then by plotting the difference between the extent of the two on the “y” axis. Two figures are presented to demonstrate this, **Figure 1-1** and **Figure 1-2**. **Figure 1-1** is the defects tendency plot of the example presented in **Section 5**, where **Figure 1-2** is an additional example to demonstrate a different outcome. For each point plotted a number is indicated for that point. This number is the count of how many points are plotted at that position. This allows a person to see where the majority of the positions are plotted.

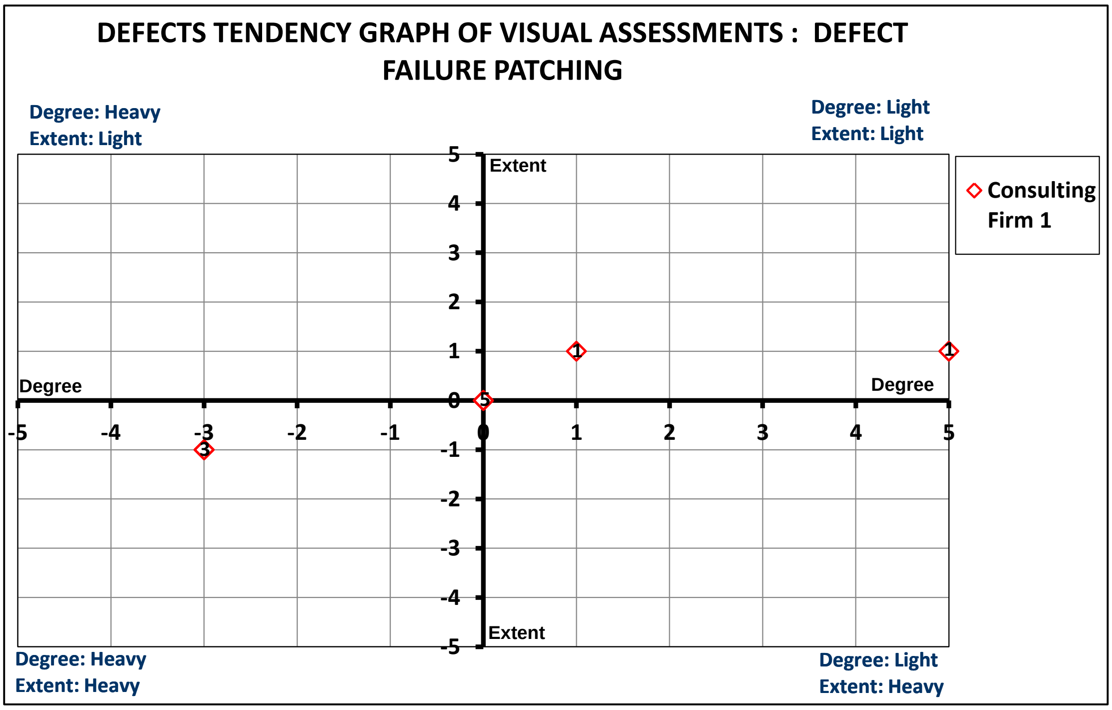


Figure 1-1: Defects Tendency Graph of Failure Patching for the Example under Section 5

Figure 1-1 shows that the majority of the differences between the degree/extent ratings of the firm's assessors and the independent assessor are 0. This is seen in that of the 10 points plotted, 5 plot at x=0 and y=0.

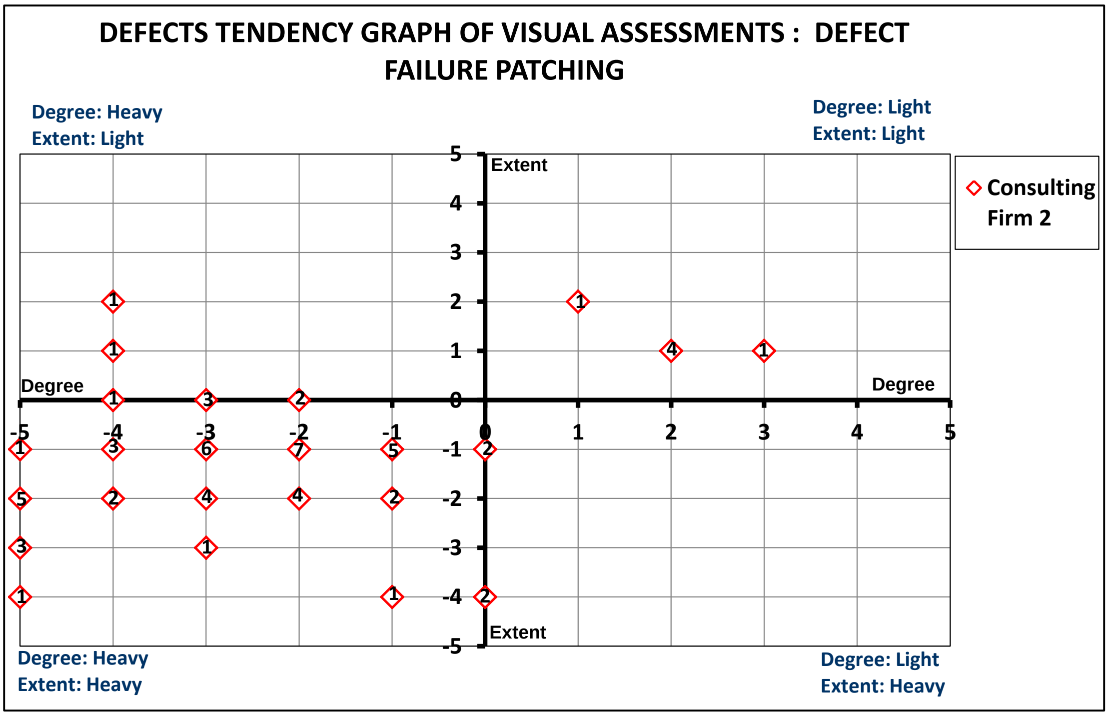


Figure 1-2: Defects Tendency Graph - Additional Example for Surfaced Roads

Figure 1-2 shows a different plot to that of **Figure 1-1**. Here the majority of the differences plot in the 3rd quadrant (both x and y are negative). This is an indication that the firm's assessors in question evaluated the defect heavily, i.e. the defect is given both a high degree and extent rating in relation to the independent assessor.

When assessing the defects tendency, the ideal is to have as many plots as possible close to or around 0 (i.e. where both x and y = 0). This assessment can be applied to all the trainees/consulting firms as a whole or to each trainee/firm individually.

A.9.5.2 Rank Position Assessment

The rank position assessment allows for the identification of the frequency with which a consulting trainee/firm's assessors and the "norm"/independent assessor agree on the assessment of a defect. **Figure 1-3** presents the rank position assessment for the example given in **Section 5**. This figure is for the defect Failure Patching.

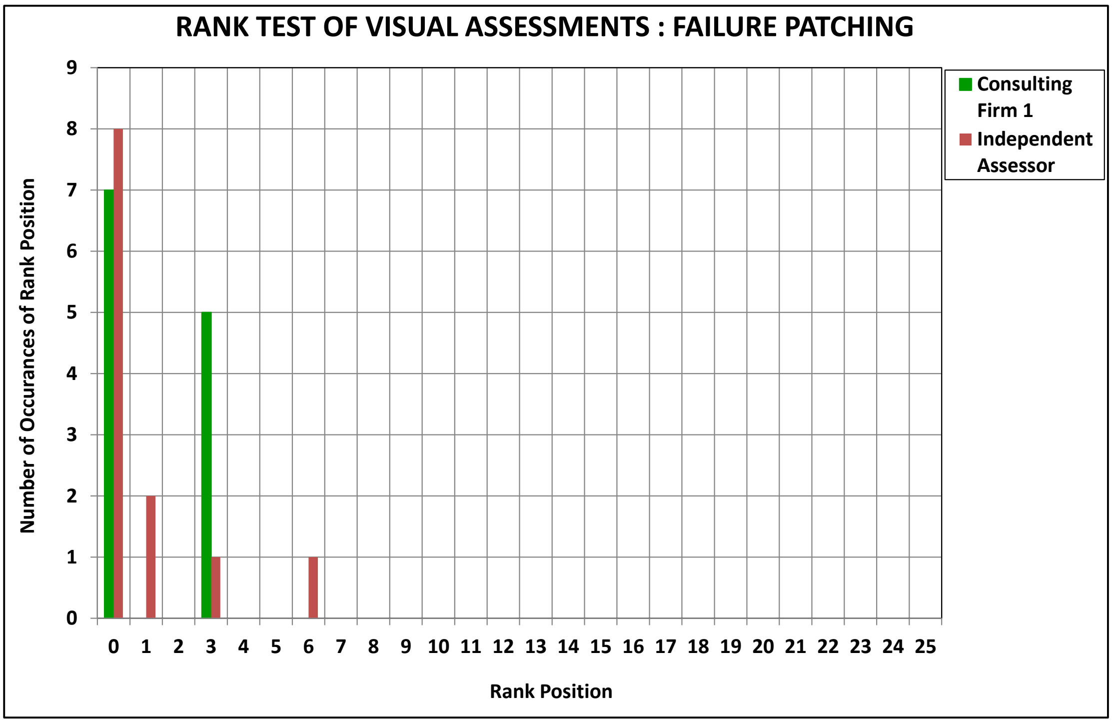


Figure 1-3: Rank Assessment of the Example Presented in Section 5

From the figure it is seen that for a rank position of 0 (indicating that the defect does not occur) the consulting firm's assessor and the independent assessor compare well, but for the remaining rank values the comparison is not as good. However, both have relatively low rank values, indicating that both agree the condition of the road as a result of the defect is generally acceptable (lower rank values relate to lower deduct values which in turn relates to a better pavement condition. In turn, higher rank values relate to higher deduct values which relates to a poorer pavement condition). An additional example of the rank assessment is presented in **Figure 1-4**. This example shows to what extent the trainee/firm's assessor and "norm"/independent assessor can differ in terms of the rank values.

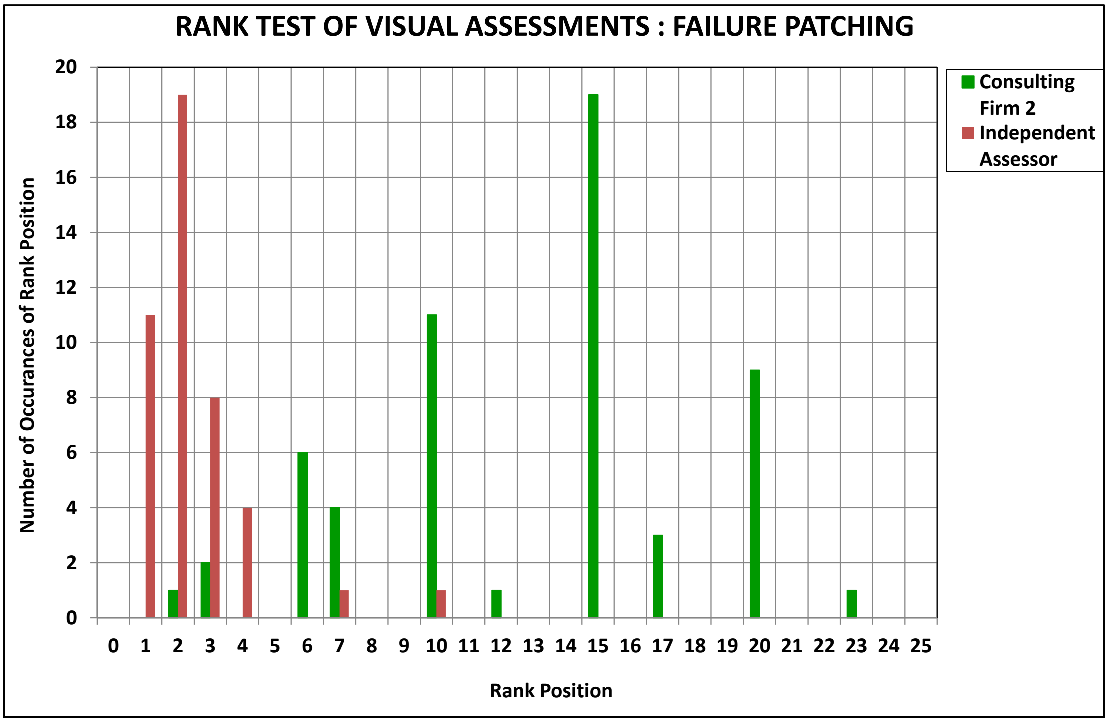


Figure 1-4: Additional Example of the Rank Assessment for Surfaced roads

A.9.5.3 How Consulting Firms Compare with Each Other

After the t-test has been performed on the visual assessments of all the trainees/consulting firms, the results can be summarised to give an assessment of how the trainees/firms compare with regard to each other.

This comparison is done by tabulating the results as per the "summary of the evaluations" presented in **Section 5**. An example of this is presented in **Table 1-1**.

Table 1-1: Comparison of Consulting Firms as Evaluated using the T-Test for Surfaced Roads

Defect	Consulting Firm				
	A	B	C	D	E
Failure Patching	NS	NS	NS	HS	NS
Cracks	NS	NS	HS	NS	NS
Aggregate Loss	NS	NS	HS	NS	NS
Binder Condition	NS	NS	HS	NS	NS
Bleeding Flushing	NS	PS	HS	HS	NS
Block Stabilisation Cracks	NS	NS	NS	NS	NS
Longitudinal Slip Cracks	NS	NS	NS	NS	NS
Transverse Cracks	NS	NS	NS	NS	HS
Crocodile Failure Cracks	NS	NS	HS	NS	NS
Pumping	NS	NS	NS	NS	NS
Rutting	PS	NS	NS	NS	HS
Undulation Settlement	NS	NS	NS	NS	NS
Patching	NS	NS	NS	HS	NS
Failures Potholing	NS	NS	NS	HS	NS
Riding Quality	NS	NS	NS	NS	NS
Skid Resistance	PS	NS	NS	NS	NS
Surface Drainage	NS	NS	NS	NS	NS
Unpaved Shoulders	HS	NS	HS	NS	NS
Edge Breaking	NS	HS	NS	HS	NS
Overall Condition	NS	NS	NS	NS	NS
No. NS	17	18	14	15	18
No. PS	2	1	0	0	0
No. HS	1	1	6	5	2
% NS	85%	90%	70%	75%	90%
% PS	10%	5%	0%	0%	0%
% HS	5%	5%	30%	25%	10%

This example demonstrates the extent to which firms can differ. This is seen in that firms C and D have higher HS results that the rest.

A.9.6 Further Application of the T-Test

A.9.6.1 Condition Indices

From the visual assessments various indices are determined for each segment. This is done for each trainee/consulting firm, as well as for the "norm"/independent assessors. The indices that are determined are the following:

- Visual Condition Index;
- Surfacing Condition Index;
- Structural Condition Index;
- Functional Condition Index;
- Cracking Condition Index;
- Maintenance Need Index, and
- Reseal Need Index.

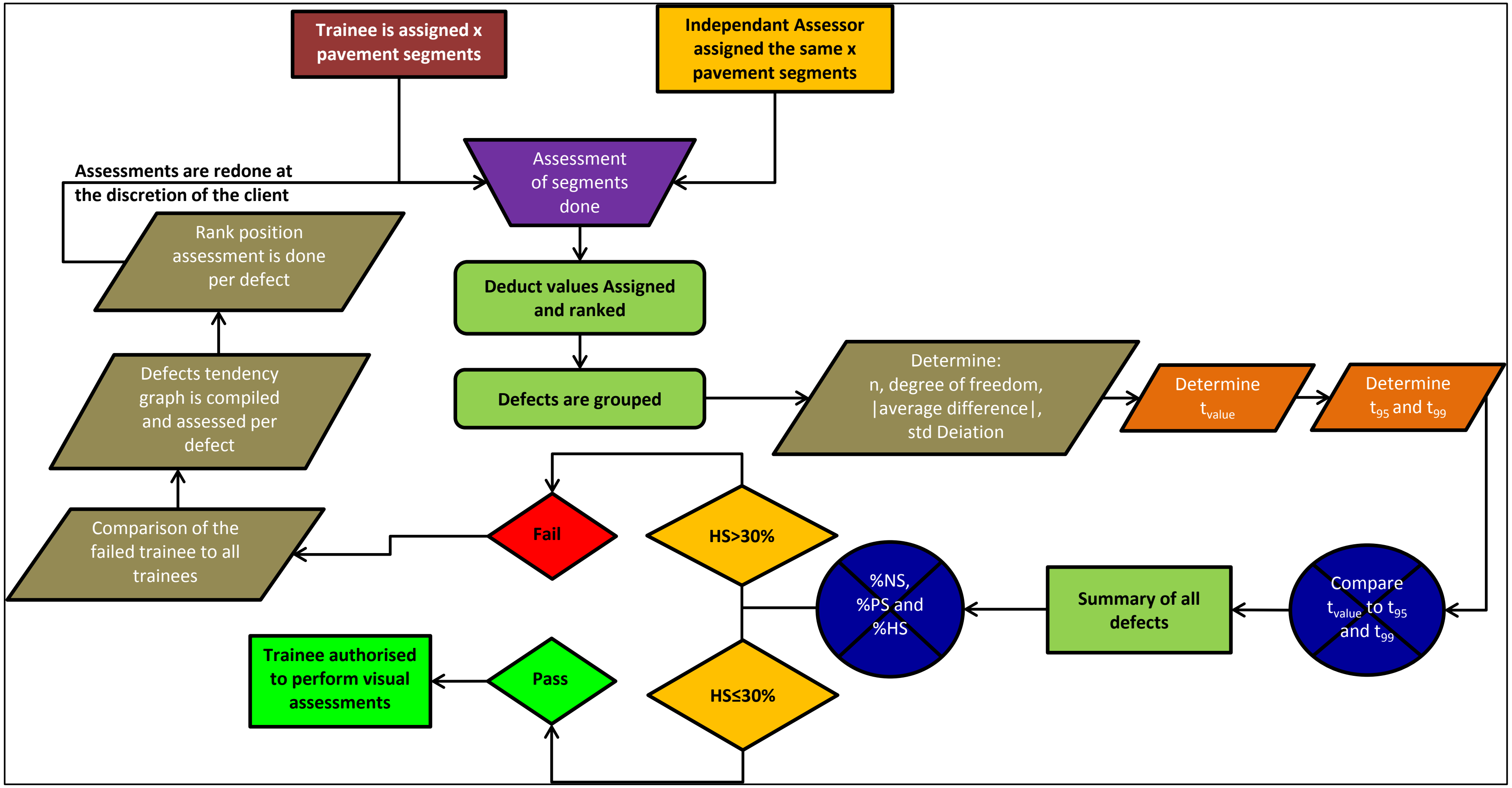
The t-test can be applied to evaluate the indices determined from each trainee/firm. This is done in the same manner that the visual assessments are evaluated, except that no rank values are used, but rather the index itself is used. An example of this assessment is presented in **Table 1-2**.

Table 1-2: Assessment of Indices using the T-Test

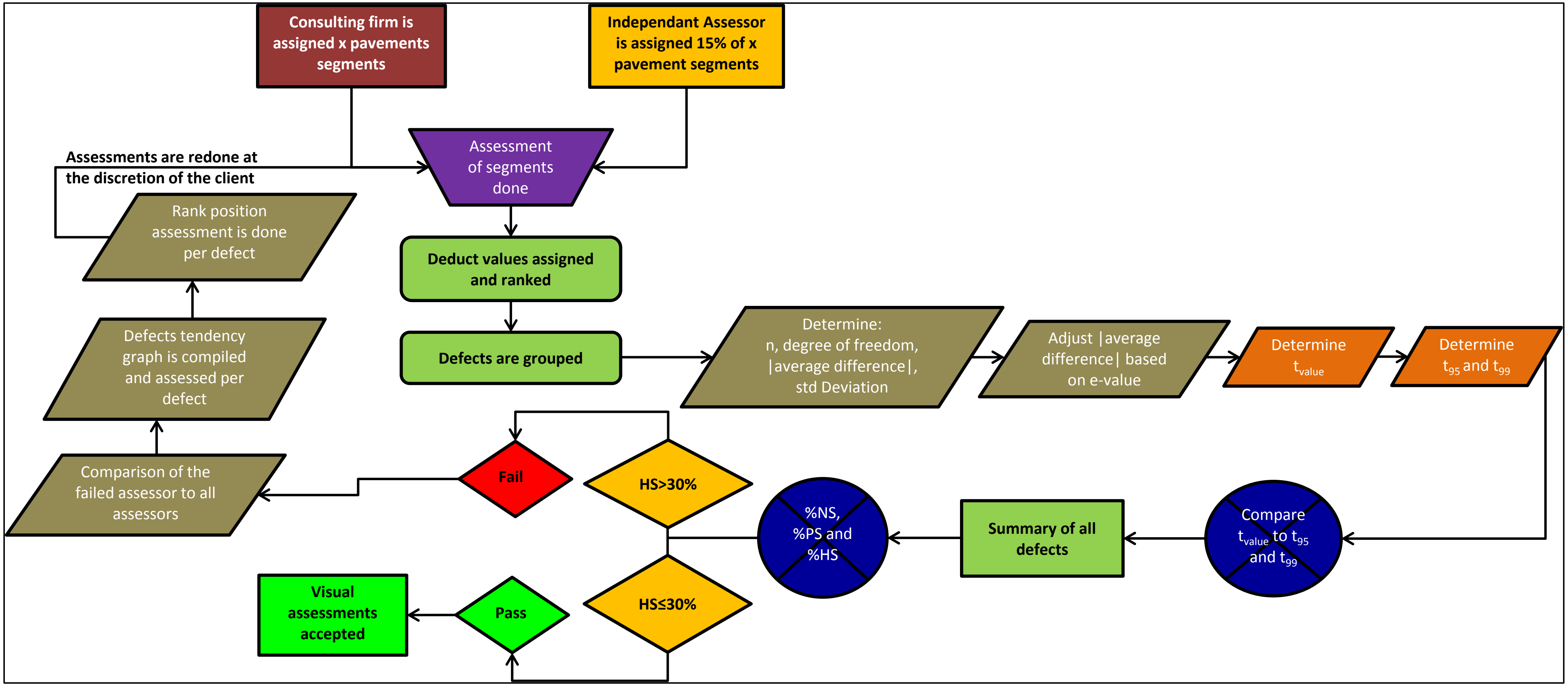
Index Type	**Consulting Firm**				
	A	B	C	D	E
Visual Condition Index	**NS**	**NS**	**PS**	**HS**	**NS**
Surfacing Condition Index	**NS**	**NS**	**NS**	**NS**	**NS**
Structural Condition Index	**NS**	**NS**	**PS**	**NS**	**NS**
Functional Condition Index	**NS**	**NS**	**PS**	**HS**	**NS**
Cracking Condition Index	**NS**	**NS**	**NS**	**NS**	**NS**
Maintenance Need Index	**NS**	**NS**	**PS**	**PS**	**NS**
Reseal Need Index	**NS**	**NS**	**NS**	**NS**	**NS**
No. NS	7	7	3	4	6
No. PS	0	0	4	1	0
No. HS	0	0	0	2	1
% NS	100	100	43	57	100
% PS	0	0	57	14	0
% HS	0	0	0	29	0

Appendix A

Flow Diagrams of the T-Test Method



Flow Diagram 1: Flow diagram of t-test method applied during the visual assessment training phase



Flow Diagram 2: Flow diagram of t-test method applied during the quality control phase of visual assessments

Appendix B

Error Values Used During the Quality Control Phase

Table 1-3: Error Values Applied to T-Test for Surfaced Roads

Defect No.	Defect Type	Error Value
1	Failure Patching	1.0
2	Cracks	1.0
3	Aggregate Loss	1.0
4	Binder Condition	1.0
5	Bleeding Flushing	1.0
6	Block Stabilisation Cracks	1.0
7	Longitudinal Slip Cracks	1.0
8	Transverse Cracks	1.0
9	Crocodile Failure Cracks	1.0
10	Pumping	1.0
11	Rutting	1.0
12	Undulation Settlement	1.0
13	Patching	1.0
14	Failures Potholing	1.0
15	Riding Quality	0.5
16	Skid Resistance	0.5
17	Surface Drainage	0.5
18	Unpaved Shoulders	0.5
19	Edge Breaking	1.0
20	Overall Pavement Condition	0.5