18-02: HIGH PERFORMANCE BLADE EVALUATION

Quick Reference Guide

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[January 2023]

Published by:

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

ACKNOWLEDGMENTS

This project was conducted in cooperation with Montana Department of Transportation, Idaho Department of Transportation, and Clear Roads.

The authors would like to thank the members of Clear Roads Technical Panel:

- Craig Bargfrede, Iowa Department of Transportation
- David Gray, New Hampshire Department of Transportation
- James Morin, Washington Department of Transportation
- John DeCastro, Connecticut Department of Transportation
- Joseph Bucci, Rhode Island Department of Transportation
- Melissa Longworth, Michigan Department of Transportation
- Scott Lucas, Ohio Department of Transportation
- Tom Peters, Minnesota Department of Transportation
- Tom Renninger, Alaska Department of Transportation

The time and effort provided by the technical panel was greatly appreciated. In addition to the technical panel, the authors would like to thank Greg Waidley at CT and Associates for his input and assistance.

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1.1 TYPES OF STUDIES

Three types of studies are recommended in this reference guide: large-scale field testing, small-scale field testing, and laboratory testing. The combination of field testing and laboratory testing will completely encapsulate the wear of the blade.

1.2 LARGE-SCALE

Large-scale field tests may be conducted either nationally or statewide. Large-scale studies should be conducted using three blade types with five samples of each. Additionally, large-scale studies should be performed using multiple locations in order to obtain variations in weather and road conditions.

1.2.1 State Selection or County Selection

It is important to establish who should be conducting the study in order to collect data properly and efficiently. DOTs should seek these ideal components for the study:

1. GPS/AVL,
2. Plow up/down feature,
3. Interest in participating, and
4. Manpower and financial capability to work on project.

GPS/AVL with plow up/down feature is not necessary for conducting this testing; however, it does ease the time of data collection since the plowed mileage, truck location, and speed is collected by the technology. Garages are assumed to be willing to collect data in a timely and dedicated manner; therefore, this will ensure data collection and field testing are a priority. Aside from having the technical capabilities and an interest in participating, a DOT should seek a local garage that has the manpower and the financial ability to participate. This will ensure that the DOT participating has enough people to conduct the study properly but also has the financial assurance to be able to obtain blades and conduct the extra work necessary to complete the study.

The research team recommends selecting blades based on three factors:

1. Current blade inventory,
2. Financial capabilities, and
3. Current vendor contracts of the DOT.

For further details on blade selection see Chapter 4 of the report.

1.2.2 Large-Scale Field-Testing Protocol

Large-scale field collection will encompass two major roles for DOTs: statewide data collection and local garage participation. The state DOT will obtain the data for GPS/AVL for the trucks in the evaluations study and the GIS Roads layer for the state.

Garages will provide the state coordination with blade, mechanic, and operator collected data. In each section below, the deliverables, the frequency of delivery, and how the data should be transferred is described. The information expected to be collected may be seen in Figure 1.

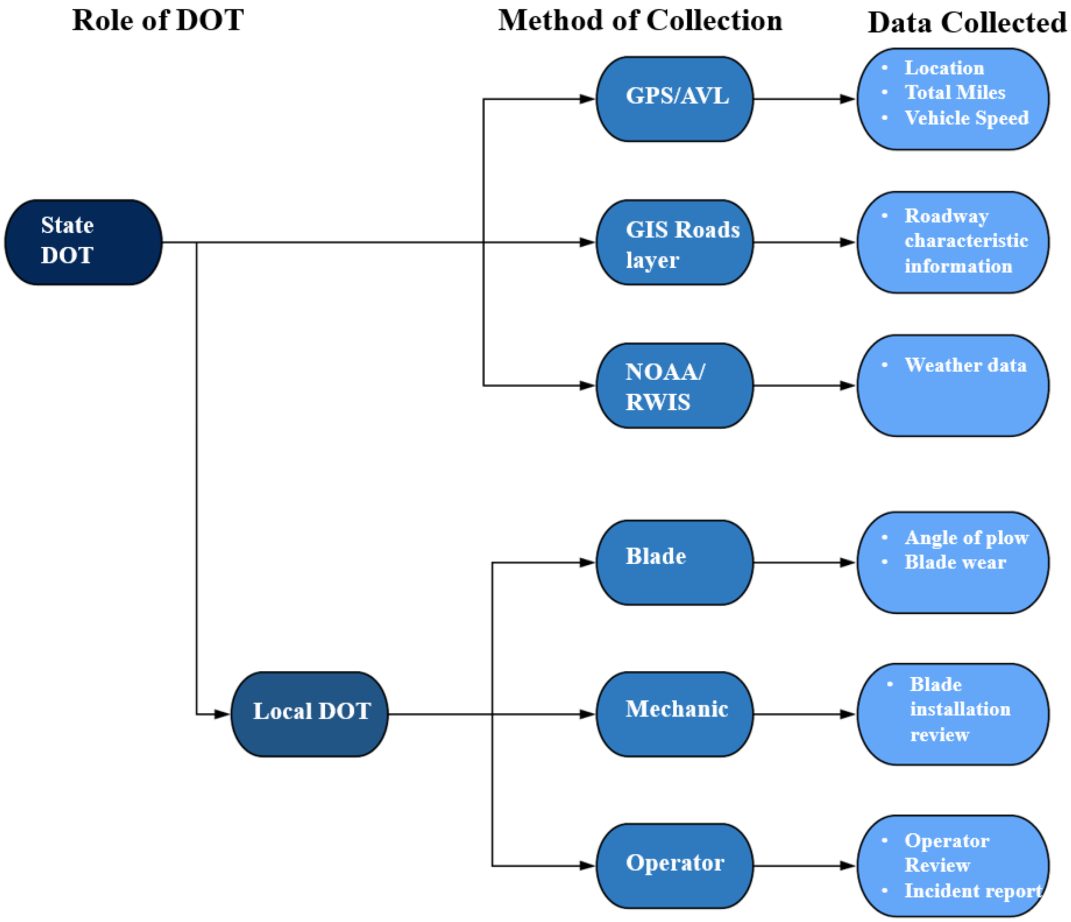


Figure 1: Blade Testing Protocol

Two main representatives are the state DOT and the site selected garages. Throughout this project, there should be constant communication between the two representatives. The state representative is responsible for less frequently needed data and cleaning of that data. The garage (Site Selected) DOT is responsible for more frequent blade wear specific data (i.e. measurement data).

1.2.3 State Level

The state coordinator will be responsible for obtaining the GPS/AVL information and the GIS roads layer for trucks and counties participating. The GPS/AVL information should be collected during field testing and will provide information on the plowing location of a truck, total mileage, and vehicle speed. Truck location in conjunction with ArcGIS roads layer will allow the state to determine what type of road the blade is used on and for how long. GPS/AVL with plow up/down feature will allow the DOT to determine total lane miles. Vehicle speed will help with wear of blade by determining friction. The state coordinator will need the ArcGIS roads layer information for counties participating in this study to follow the trucks route to establish road type and mileage. The ArcGIS roads layer should contain information on road material, road location, and bridge locations. The GPS/AVL information once collected should be placed in ArcGIS as a shapefile and a polyline. After the GPS/AVL information has been added, a polyline and datapoints should be on the map to show the route that the truck took. Then python coding should be used in order to pull data on mileage plowing, road material, and bridge decks encountered. The third responsibility of the state DOT is obtaining the National Oceanic and Atmospheric Administration (NOAA) data which will determine the weather conditions while plowing. Lastly, the state coordinator will also need to select the counties who are to participate.

The garage(s) selected will need to have the capacity to do the study in terms of time and fleet size. This will be based off three factors: lane miles, average miles plowed per season, and if the garages have done previous blade tests. These recommendations are to help ensure that a variety of pavement types, optimal plowing routes, provide for adequate snow plowing during the winter season. Additionally, it is important to have highway maintenance personnel who are familiar with testing and methodology that is required with blade testing. The garage will be providing data to the state coordinator at the frequency that the coordinator establishes. The expectations of the garage are described in the following section.

1.2.4 Garage (Site Selection)

All data are expected to be provided by local DOT should be scanned or a photo taken of and emailed to the state representative. Garage personnel will provide measurements of blades. These measurements should be taken based on usage; therefore, more frequent blade use should result in more frequent measurements. The form that blade measurements should be written on may be is seen in Table 1.

Table 1: Blade Measurement Sheet Example

Date	Time	Truck Number	Measurement Location[1]					Measurements Taken By	Maintenance to Blade Between Measurements
			A	B	C	D	E		
Note: Above is a cut version of the form given to Site Selected DOTs. Blade form information is in section 5 “Testing Protocol.” [1] Measurement location is available in Appendix C Figure C-1. Below the figure is a description of how the measurements are to be taken.									

The measurement locations may be seen below in Figure 2.

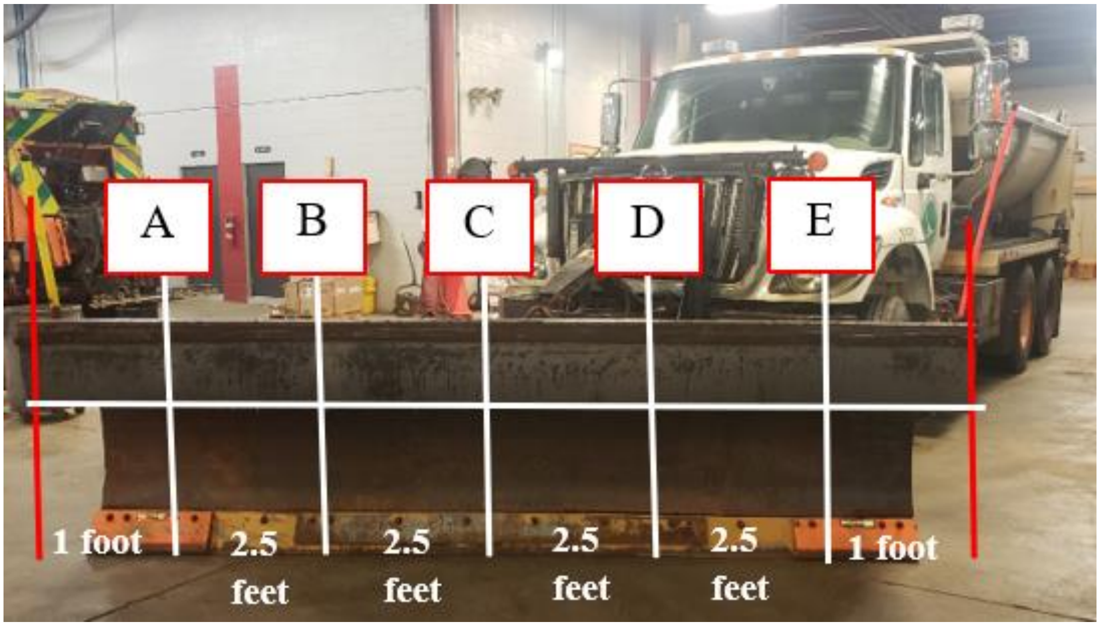


Figure 2: Blade Measurement Locations

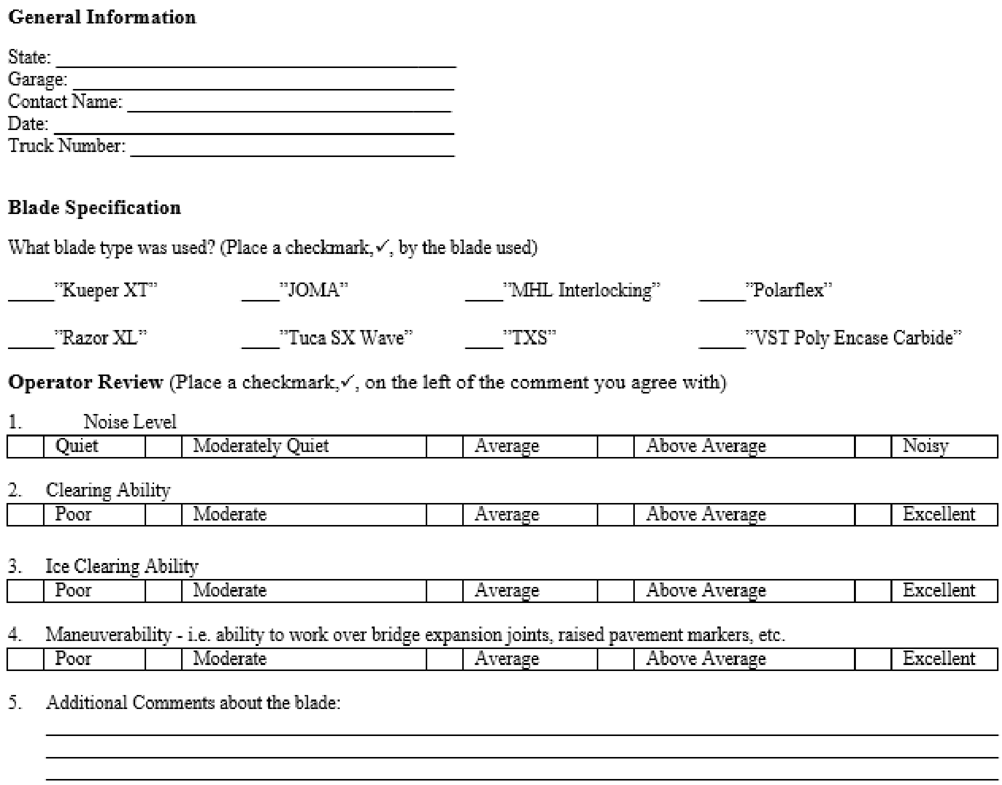
Blade measurements are important in understanding the physical wear on the blade. In addition to measuring blade wear, installation information should be written down. Garage mechanics will provide a survey after every blade installation. The appropriate forms may be found in Table 2.

Table 2: Installation Review

Date	Time	Truck Number	Blade Type	# of Person(s) for Installation	Tools and Equipment Used	Duration of Installation	Comment

Note: Above is a cut version of the form given to Site Selected DOTs.
Blade installation review information is in section 5 “Testing Protocol.”

Providing the state with installation information will help assist in the cost benefit analysis and assess the blade on a personal level (easy to install etc.). Mechanics forms will provide information on the duration and equipment used to install the blade. Establishing how the blade installation processes changes for different blades, learning how the blade performs on the road by those who plow is equally as important. Local DOT operators will provide a survey after a season of using a new blade. The appropriate form may be seen in Figure 3 below.



General Information

State: ________________________________
Garage: ______________________________
Contact Name: ________________________
Date: _________________________________
Truck Number: ________________________

Blade Specification

What blade type was used? (Place a checkmark,✓, by the blade used)

_____”Kueper XT” ____”JOMA” ____”MHL Interlocking” _____”Polarflex”

_____”Razor XL” ____”Tuca SX Wave” ____”TXS” _____”VST Poly Encase Carbide”

Operator Review (Place a checkmark,✓, on the left of the comment you agree with)

1. Noise Level

	Quiet		Moderately Quiet		Average		Above Average		Noisy

2. Clearing Ability

	Poor		Moderate		Average		Above Average		Excellent

3. Ice Clearing Ability

	Poor		Moderate		Average		Above Average		Excellent

4. Maneuverability - i.e. ability to work over bridge expansion joints, raised pavement markers, etc.

	Poor		Moderate		Average		Above Average		Excellent

5. Additional Comments about the blade:

Figure 3: Operator Review

From the literature review, a survey from the operators is important because it reflects the views of those who frequently use the plow blades. The blade type used in Figure 2 is input just as an example, whatever types of blade are being tested should replace the example types in the figure.

Lastly, the local DOT mechanic will provide a form after an incident has occurred in case of any damage to a blade. The appropriate forms may be seen in Table 3.

Table 3: Incident Report

<table>
<tr><th>Date</th><th>Time</th><th>Truck Number</th><th>Blade Type</th><th>Incident[1]</th><th>Comments[2]</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Note: Above is a cut version of the form given to Site Selected DOTs.
Incident report information is in section 5 “Testing Protocol.”
[1] The incident that occurred to damage the blade (ex. hit bridge deck, hit curb, etc.)
[2] Comments should include details of the damage to the blade (ex. there are major gashes out of blade, minor chips to middle location, etc.) and include images of the blade.</td></tr>
</table>

This form is important in understanding if a blade were to hit an obstacle and break, how it occurred to assess the blades durability and potential blade misuse. Please see Chapter 4 for more details.

1.3 LABORTORY TESTING

Lab testing is important because it evaluates the chemical and mechanical attributes of a plow blade. Laboratories selected for testing the products should be ISO/IEC 17025 certified. DOTs should seek laboratories that test metals, polymers, and nonmetals. If a DOT is unable to find a laboratory that is able to test metals, polymers, and nonmetals, it is recommended to seek more than one lab to conduct the separate materials testes necessary to complete assess the quality properties of a blade. After establishing a laboratory to test blades, a DOT should establish which blades to test.

1.3.1 What to Test

The materials of the blades should be tested to ensure the specifications provided by the vendor are true and representative. Carbide, steel, and rubber have distinct tests due to the different chemical, physical and mechanical properties of each material. Section 4.6.3 through 4.6.6, the individual specifications, test methods, and costs are suggested for braze, carbide, rubber, and steel, respectively. Figure 4, for example, is a flexible carbide blade that encompasses all the blade materials.

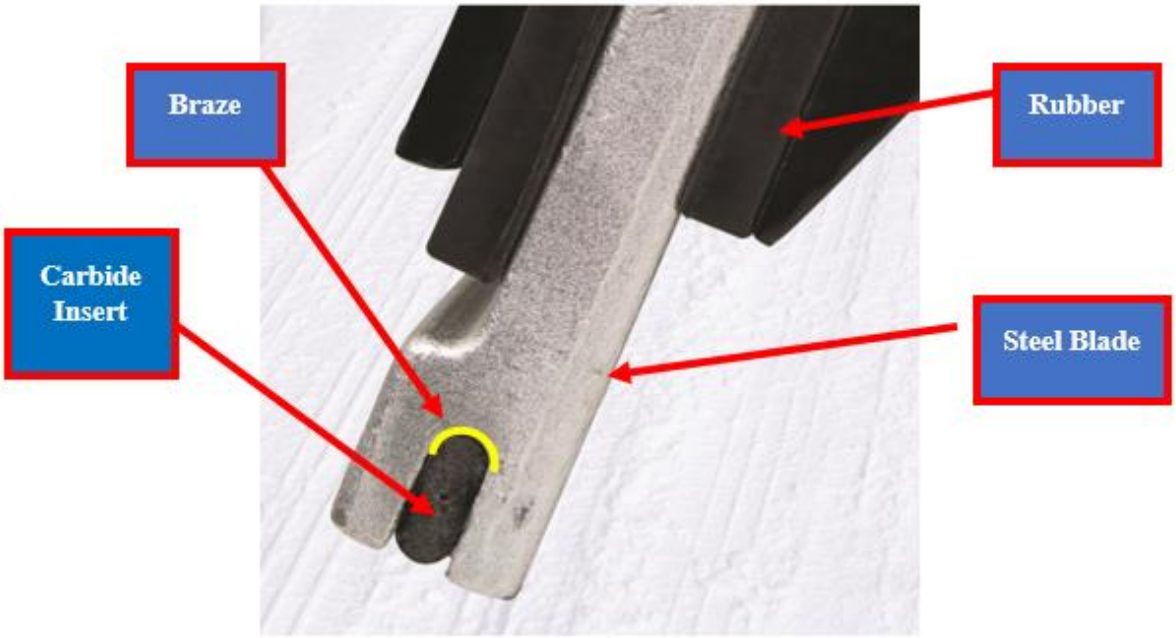


Figure 4: Polarflex Blade

This blade encompasses all four major components that specifications may be checked:

1. Braze,
2. Carbide,
3. Rubber, and
4. Steel.

The first material type is brazing which is the welding component that keeps the carbide insert in place in the steel blade. Therefore, typically, if a carbide insert is used, a brazing material is used to secure its placement. In addition to brazing, carbide insert is also utilized in some snowplow blades. The third component in this example is rubber which is used in flexible blades. Rubber encompasses the carbide insert blade to allow for flexibility as discussed in Chapter 2. The last material a snowplow blade is commonly made from is steel.

As discussed in Chapter 4 of the final report, plow blades require a certain hardness, toughness, and strength for the blade to resist wear, fracture, and deformation. The specific properties tested of a material indicate a blades resistance to wear, fracture, and deformation.

An example of the benefits of testing a blade in the lab is provided in this section. In this case, the evaluation was to include visual examination, spectroscopic and thermal analysis, hardness, and microhardness testing, scanning electron microscopy, energy dispersive spectroscopy, metallographic examination, and polymer mechanical testing. Tables 4 through 6 provide some guidance with respect to lab testing.

Table 4: General Overview of Testing

Test/Description	Results	Price	Priority
Chemical analysis of metallic components and alloy determination	What material is it made from	Low/Medium	Medium/High
ASTM B311: Carbide density evaluation	How dense/compact the carbides are	Low	Low/Medium
Metallographic cross-section preparation and evaluation of microstructure	Gives information about how the material was processed	Low/Medium	Medium/High
SEM/EDS of metallic components to determine relative chemical composition	What elements are present, in relative amounts	Medium/High	Low
Microhardness testing	Average hardness	Low	Medium/High
Fourier transform infrared spectroscopy (FTIR) of rubber components to identify base polymer, any additives, contaminants, etc.	What material/polymer is it made from	Low/Medium	Medium/High
Differential scanning calorimetry (DSC) of rubber components to determine thermal properties	Glass transitions, melting temperatures, etc. to confirm polymer used, identify any contamination, etc.	Medium/High	Medium/High
Thermogravimetric analysis (TGA) of rubber components to determine composition and thermal stability	Volatile, polymer, and filler contents; thermal stability temperatures	Medium/High	Medium/High
ASTM D2240-15e1: Durometer hardness of rubber components	Average hardness	Low	Medium/High
ASTM D412-A: Tensile testing of rubber components	Tensile strength and elongation	Medium/High	Low

ASTM D624-00 (2020), Die C: Tear resistance testing of rubber components	Tear strength	Medium/High	Low
ASTM D575-A: Compression testing of rubber components	Compressive strength	Medium/High	Low

Table 5: Polymer Evaluation Synopsis.

Polymer Evaluation		
$1,000(1), (2)		
FTIR and Durometer hardness	Determine base resin, additives, contaminants; determine relative hardness	Wrong compositional make up = different properties and performance; change in hardness = more or less susceptible to penetration or permanent indentations
$2,000(1), (2)		
$1,000 category plus DSC and TGA	Determine base resin, additives/filler contents, contaminants; cure/thermal stability; determine relative hardness	Wrong compositional make up, incorrect processing = different properties and performance; change in hardness = more or less susceptible to penetration or permanent indentations
$3,500(1), (2)		
Tensile, Tear, Compression, Durometer	Determine tensile, tear, and compressive strengths; determine relative hardness	Mechanical properties provide insight into yield and tensile strengths as well as elongation to compare strength, ductility, toughness of materials and changes to these properties can help determine how susceptible the materials are to failure in the field - environmental conditions can have an effect on these properties as well, e.g. temperature; change in hardness = more or less susceptible to penetration or permanent indentations
$6,500(1), (2)		
(All tests) FTIR, DSC, TGA, Durometer hardness, Tensile, Tear, and Compression	Determine base resin, additives/filler contents, contaminants; cure/thermal stability; determine relative hardness; determine tensile, tear, compressive strengths	Wrong compositional make up, incorrect processing = different properties and performance; change in hardness = more or less susceptible to penetration or permanent indentations; yield and tensile strengths, elongation provide comparisons of strength, ductility, toughness (same comments as above)

Notes:

1) Estimated cost (Approx. Total @ 2 samples, machining not included),
2) Can be presented as a cert style report (data only with minimal interpretation); additional cost for report style with full descriptions and interpretations. Machining time not included with prices, as this may change depending on how difficult cutting may be or the amount required for the specific test.

Table 6: Metallurgical Evaluation Synopsis.

Metallurgical Evaluation		
$1,500 (1), (2)		
OES of Blade Rockwell Hardness Testing	Alloy determination Average material hardness determination	Different materials = different properties and performance, may have overlaps with properties and performance, the alloy and elemental additives allow for the differences by changing the properties; Rockwell Hardness = resistance to deformation, HRC range higher is harder, HRB range softer than HRC and similarly higher is harder
$3,250 (1), (3)		
$1,500 category plus icp-oes of carbide, density of carbide	Verification/characterization of carbide composition, determination of carbide density	Different materials = different properties and performance; density = mass/volume, a higher density has a higher mass to volume ratio, likely indicates that there is less porosity assuming same chemistry. Theoretically a fully dense part with zero porosity (not possible), will result in the best properties.
$5,000 (1), (4)		
$3,250 category plus metallographic cross-section preparation and evaluation of microstructure	determine the microstructural constituents present within the metal and carbide	metallography of metal = gives you information about how it was manufactured and processed, depending on the manufacturing and processing you can tailor the properties and performance, could be overlap between materials that would be able to be differentiated, cheaper material with more expensive processing and heat treatment might be similar to more expensive material with less post processing and heat treatment metallography of the carbide - rate microstructure for apparent porosity, uncombined carbon, grain size, carbide grain size, eta phase, gamma phase, and alpha phase = effectiveness of the processing of the carbide and identification/rating of deleterious phases that may adversely affect properties and performance
7500+ (1), (5)		
$5,000 category plus tensile testing of	Determine mechanical properties of blade component	Tensile testing = gives mechanical properties such as yield strength, tensile strength, elongation, and reduction of area, which will

blade component, Charpy impact testing of blade component		allow for comparisons in strength, toughness (combination of strength and ductility), and ductility (how much something stretches), example being ceramics have high strength but low ductility in general very strong but brittle, metals are not as strong as ceramics but significantly more ductile, polymers are not as strong as metals but usually more ductile; depends on additives) impact testing = gives the amount of energy absorbed during impact (a measure of toughness), some metals will have better or worse impact properties at cold, room temperature, and elevated temperatures

Notes:

1) Estimated cost (per sample basis/machining included (unless otherwise noted), additional samples will likely be less that full tier price as there is savings when prepping in multiples/batches).
2) Can be presented as a cert style report (data only), additional cost for report style with full descriptions and interpretations
3) Can be presented as a cert style report (data only), additional cost for report style with full descriptions and interpretations. Isolation of the carbide from the remainder of the blade requires extensive saw cutting and consumables due to the extreme hardness of the carbide.
4) Can be presented as a cert style report (data only), Can be presented as a cert/letter report (data and minimal interpretation); can be presented as report style with full descriptions and interpretations. Priced middle of the road.

Will only be presented as report with full descriptions and interpretations. As the rubber would need to be removed and excised sections machined into tensile specimens and Charpy impact specimens some time has been added for machining however it has been left open ended as it is unclear how much machining it would take but is an approximate estimation.

1.4 INTEGRATION OF FIELD AND LABORATORY INTEGRATION

Integration of lab and field testing is discussed below in terms of formally testing and informally testing. Formal testing is recommended by the research team and follows the field and lab testing suggested in section 4 of the research report. The breakdown of lab and field testing is seen in Figure 4 below.

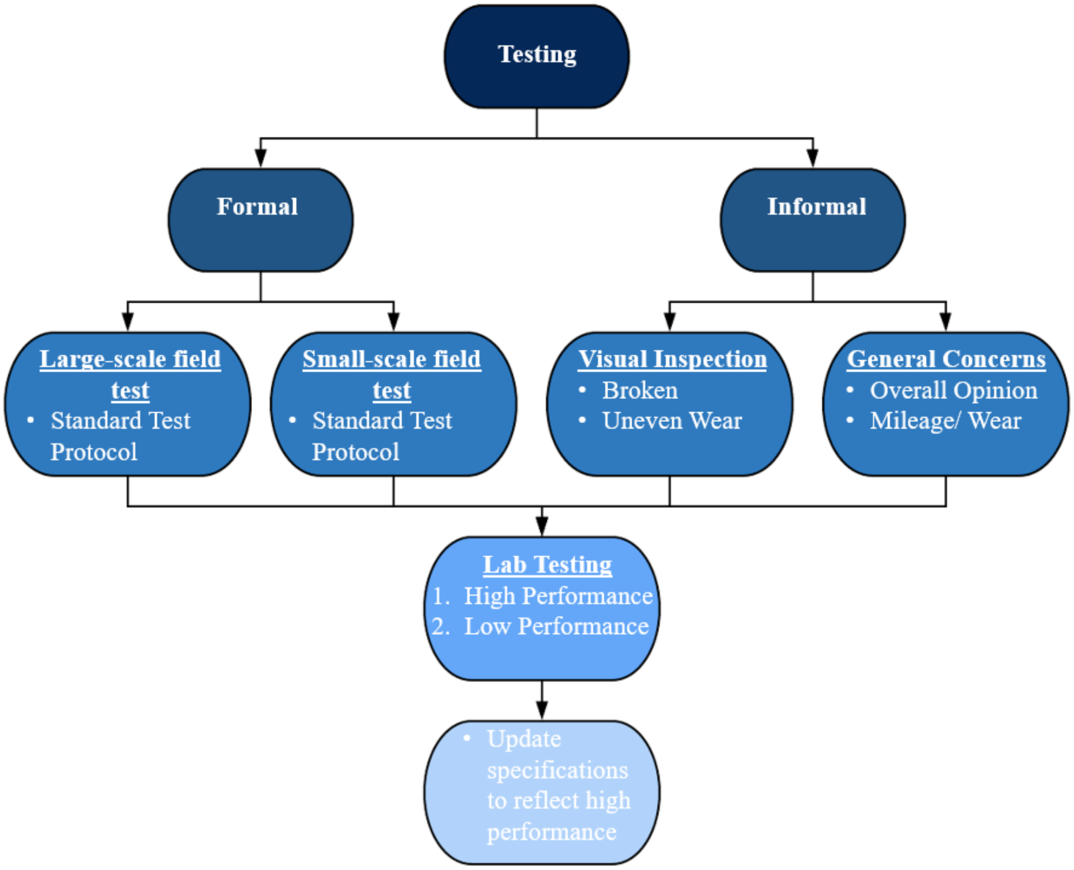


Figure 5: Integration of Lab and Field Testing

Starting from the left of Figure 5, formal testing is the recommended method of testing. Formally testing the blades is conducted utilizing either large-scale or small-scale field testing or laboratory testing. Performing large-scale or small-scale field tests will provide chronological information on the wear of the blade and the conditions which the blade encountered (weather or road material). Laboratory testing may be conducted pre or post field testing to establish blade qualifications. Having the wear information on multiple blades will help over time establish the appropriate range of specifications.

Informal testing of snowplow blades may allow a DOT to conduct testing without costing time or finances. If a DOT would like to participate but does not have the ability to commit to a large scale or small-scale field test with lab testing, the research team recommends testing blades through visual inspections and general concerns as seen in Figure 4. More details may be seen in Chapter 4 of the report.

1.5 COST NEUTRALITY

The research team created standard graphs for DOTs to be able to assess mileage, wear and cost for points of neutrality. The research team utilized data from Schneider et al. 2015 and the Idaho case study to create simulated models for DOT use. Figures 6 through 8, will provide DOTs with a standard on wear/mile to see if a blade is wearing normally or abnormally quantitively. In addition to DOTs being able to establish if a blade is wearing normally or abnormally, the research team determined what mileage or wear is possible to obtain. The x-axis is the mileage on the blade. The y-axis is the wear in inches on the blade. The dotted line is the upper bound average wear per mile. The dashed line is the average wear per mile. The bottom line is a dashed and dotted line which represents the lower bound average wear per mile. If a blade is within the lower and upper bound, the blade is worn as anticipated and no action should occur.

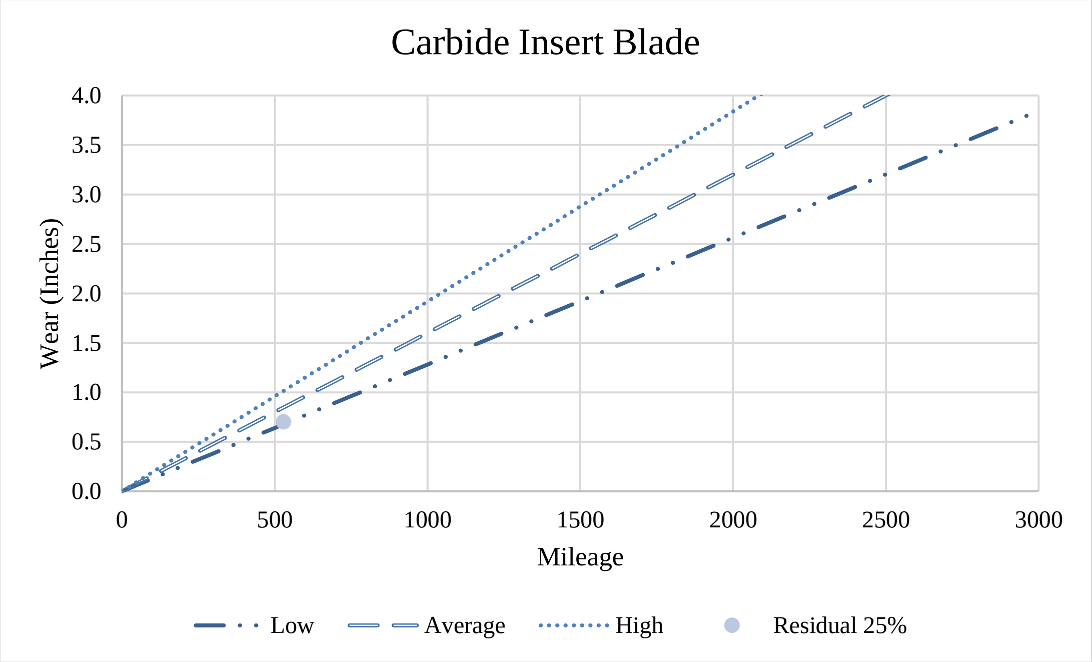


Figure 6: Carbide Insert Blade

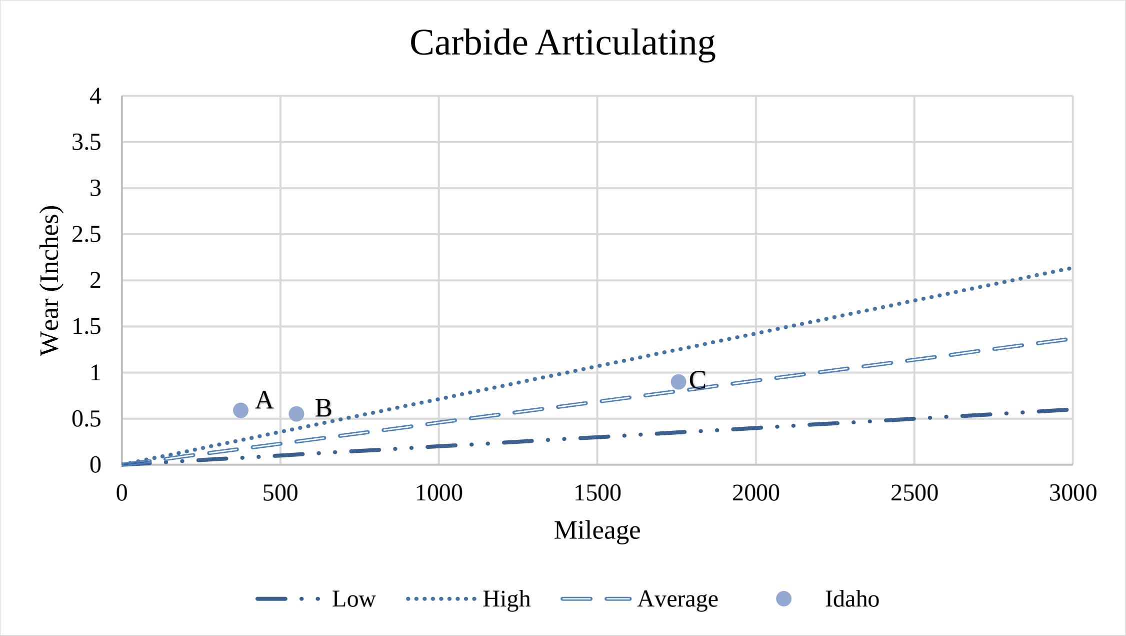


Figure 7: Carbide Articulating Blade

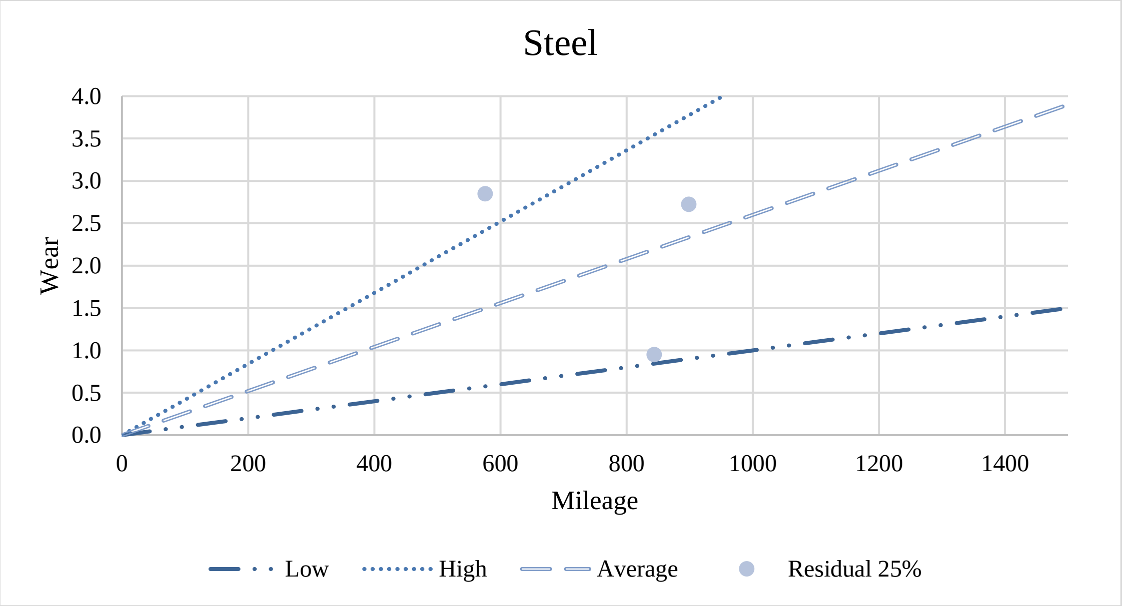


Figure 8: Steel Blades

For further details on normal blade wear, please see section 5.3 of the final report.

1.5.1 Cost Benefit

The purpose of the cost benefit section is for DOTs to be able to assess a new blade in order to see if the blade is a cost-effective purchase or are at least cost neutral. The goal of this section is to create a standard that is both useful currently and in the future. The research team describes how to create the standard graphs, Figures 9 – 11, for cost neutrality and the equations to utilize in section 5.5 of the report. Please see section 5.5 for more details. The x-axis is cost difference between a new blade to an old blade. The y-axis is the wear rate in inches per 100 miles. There are two distinct lines which represent the cost neutral blades in units of cost inch per 100 miles. The expected wear and cost are the dotted and dashed lines. When the cost is less than expected, it is in the upper left of the graph, which is where the cost is negative and the wear rate is positive. This means the cost is less than average and the anticipated wear is more than average. When the cost is more than expected, it is in the bottom right, which is where the cost is positive, and the wear rate is negative. This means the cost is more than expected and the anticipated wear should be less than expected. Therefore, anything between the dotted and dashed line are cost neutral, anything above the dotted and dashed lines are not a cost-effective purchase, and anything below the dotted and dashed lines are a cost-effective purchase.

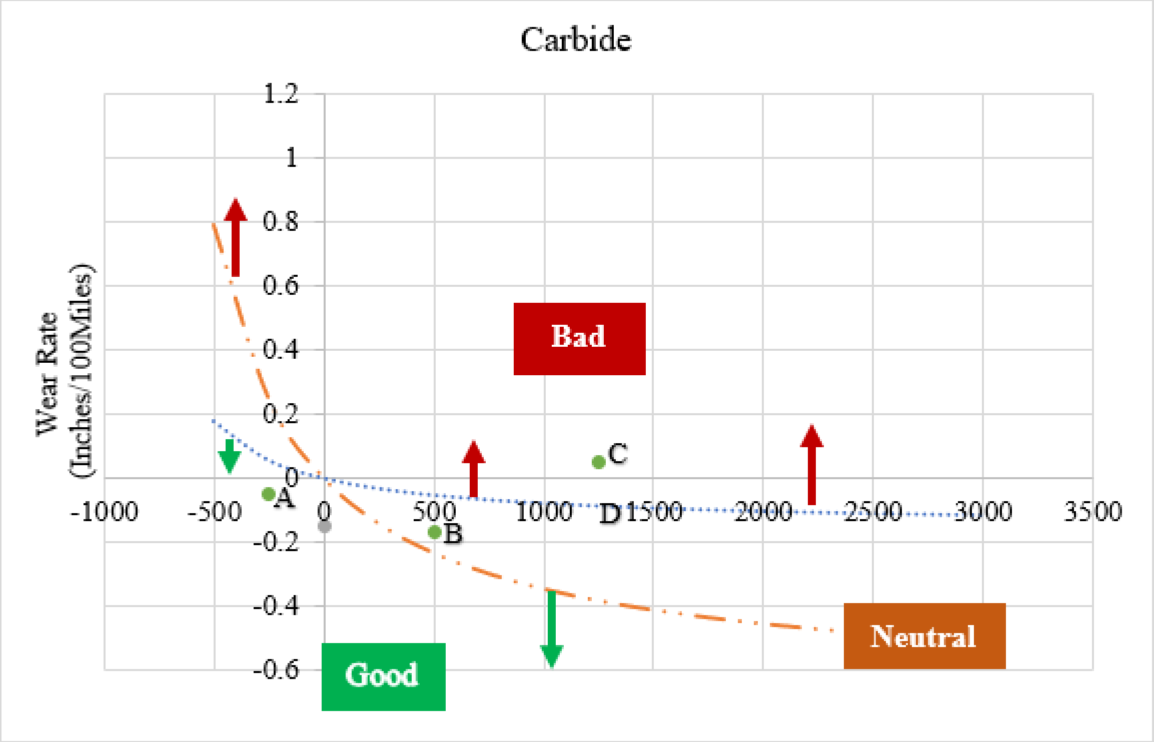


Figure 9: Carbide Blade Cost Neutrality

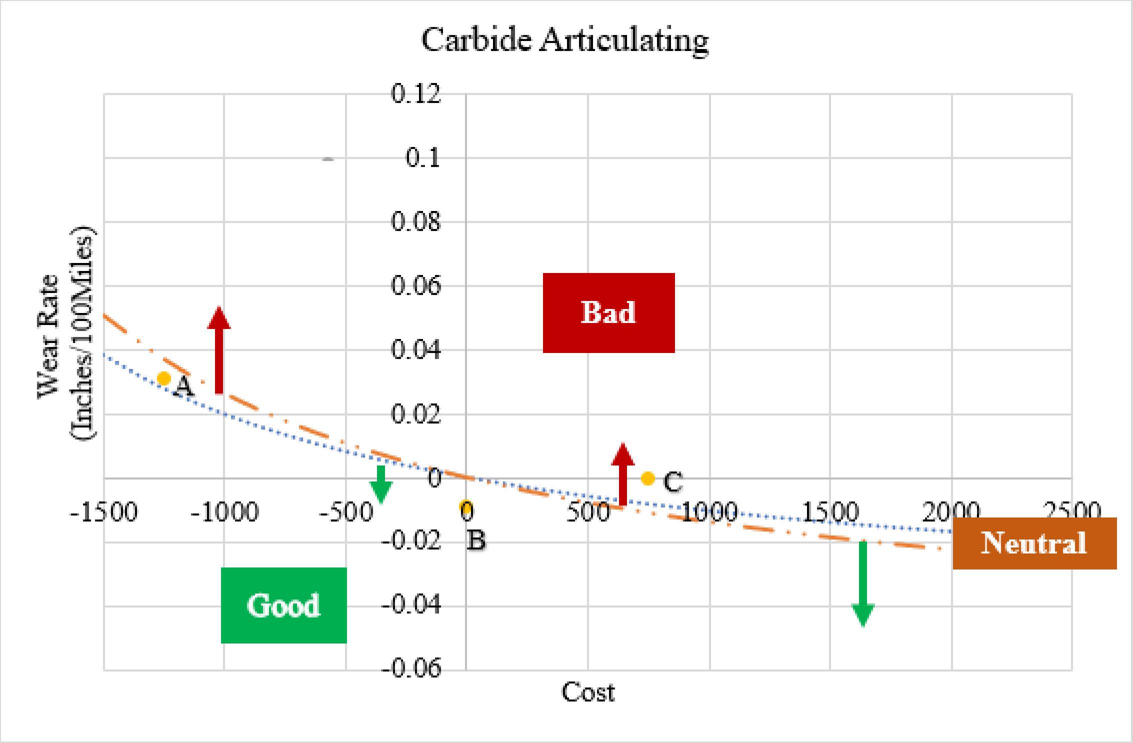


Figure 10: Carbide Articulating Blade Cost Neutrality

For further detail on the cost benefit analysis see section 5.5 of the final report.

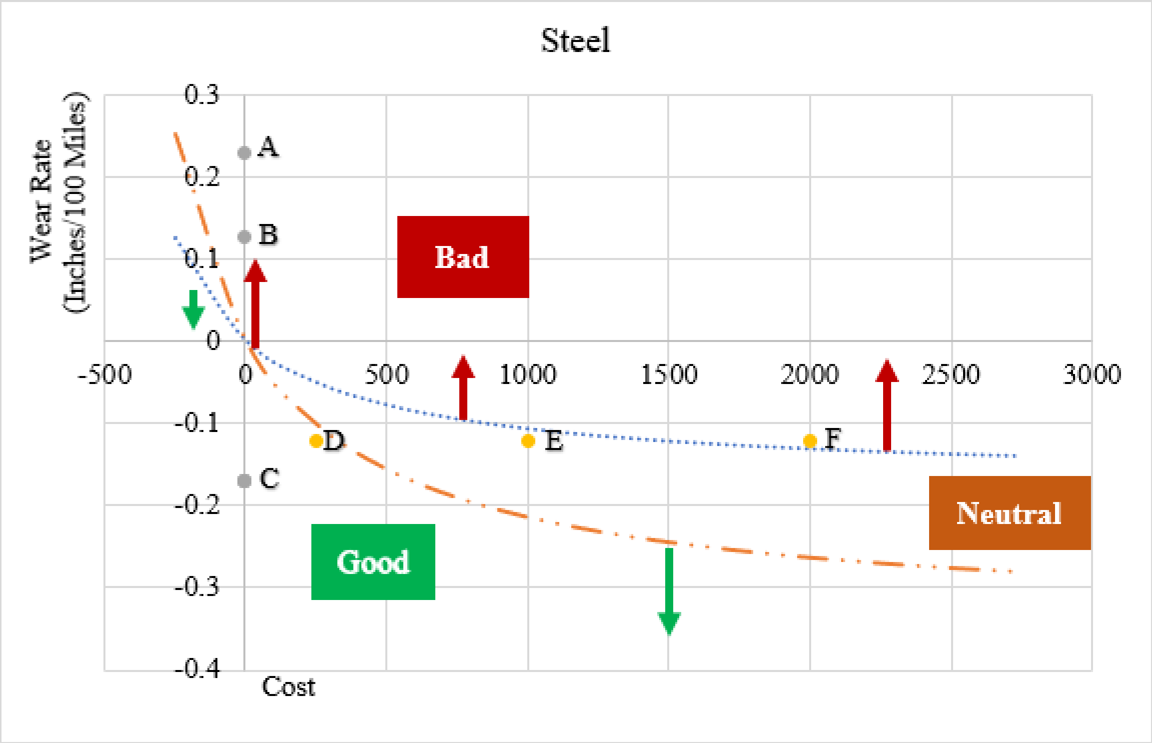


Figure 11: Steel Blade Cost Neutrality

1.6 DATA WAREHOUSING

There are three main reasons for recommending data warehousing. Having an increased amount of data will create higher quality graphs, will create better performance for testing and aid in rationale for new data. The data warehouse should be comprehensive and searchable for DOTs to find blades that they are interested in testing and past research studies conducted. The second purpose of data warehousing would be to educate DOTs. Data warehousing will help DOTs have guidelines and show standard methods for testing blades. The last purpose of data warehousing will provide research opportunity to DOTs. Eventually DOTs have the potential to specify previous studies due to DOT size, lane miles, average winter temperature, average snowfall, and roadway material. This will allow for easy comparisons if a DOT is financially unable to test blades. The potential benefits of data warehousing is one central location for plow blade data, consistent testing practices, potentially a large data bank for blade data, and modify plow blade specification. Over time, less data collection will be needed because variability will become so small that testing will be a want, not a need. Data warehousing may also utilize data from previous years and adjust to whatever the current economic conditions. The methodologies created in this study help provide DOTs with a tool for standard field and laboratory testing. For further detail see Chapter 6 of the report.