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Predicting Processing Results of Sale Lots. Part 2: Development of a Sale Lots Formula for Hauteur.

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SUMMARY

Five raw wool parameters (Decrimped Staple Length, Energy, Decrimped Staple Strength, Decrimped Staple Length Ratio and Mean Fibre Curvature) were investigated for their potential benefit in the Hauteur prediction of hard-to-predict wool types. Parameters were included to complement the TEAM-3 recommended Hauteur equation, while providing some level of "correction" for some extreme wool types.

The Decrimped Staple Length Ratio (RATIO) was found to improve the predictive capability of the TEAM-3 recommended equation for sale lots where the RATIO value was greater than 1.30. Other parameters provided little to no improvement in the predicted Hauteur of hard-to-predict wool types.

It is recommended that the industry consider including a modified Decrimped Staple Length Ratio in the industry TEAM-3 formula for predicting Hauteur to provide a better calculated Hauteur for Bellies and Stretchy Bellies wool types.

INTRODUCTION

Some wool types have been shown to process differently to their predicted Hauteur values when the TEAM-2 and proposed TEAM-3 processing prediction equations were used (Fish et al., 2004). In particular, top processed from sale lots of 100% Stretchy Bellies and Bellies process consistently longer to how they were predicted. The aim of this paper was to improve the Hauteur prediction performance of these wool types by introducing some new measurements to the regression equation.

Statistical regression techniques, similar to those used in the TEAM-3 analysis (TEAM-3 Final Report, 2004) were used to integrate the new measurements.

In order to ascertain whether particular parameters provided any improvements over those parameters that have been used now for some considerable time, measurements describing similar fibre attributes have been substituted for one-another. However, in contrast with the TEAM-3 approach, sale lots were used as the basis of the regression, not consignments. This approach was considered technically relevant, because both models forming the comparison were fitted to the same database.

To derive a formula that could find commercial use requires using data from a wide selection of commercial processors such as used in the TEAM projects. Such a technique is not possible with sale lots because they are not processed as individual lots commercially. Hence, a second technique, which involved the addition of terms to the TEAM-3 equation using the procedures described in the TEAM-3 Final report, was required.

The application of a prediction formula based on consignments to individual sale lots, and vice versa, is only justified if it can be demonstrated that the processing outcome is the sum of the individual components. This additivity has been demonstrated in earlier research (Rottenbury et al., 1987) but it has also been noted that prediction accuracy is likely to drop as one moves to the extremes of the population (Brown et al, 1985).

Previous attempts to predict the processing performance of single sale lots (Allen et al, 1990a/b; Hansford, 1997a/b) have provided, on average, little improvement over the TEAM-2 general formula. This is primarily due to the average effects introduced by combining a number of individual lots into consignments.

Brown et al (1985) indicated that for a prediction equation to be truly applicable, the sample used for the regression must be indicative of the population of values to be predicted. TEAM fits this requirement because it uses normal commercial consignments as the basis of the regression. In the case of any study on sale lots this becomes a more vexing question. Should the dataset be constructed with the individual wool types in the proportion that they appear in the total wool production (eg more fleece wool types than skirtings) or should the wool types be selected to have an equal weighting (eg similar numbers of fleeces and skirtings)? Strong arguments can be presented for both options. In the case of this study, the selection of wool types was set to address concerns that both exporters and some individuals were experiencing with Hauteur prediction of specific wool types.

The benefit of processing individual sale lots in the present study is to enable the wool characteristics of the selected wool types to exhibit their full impact without being diluted with the other wool types that are present in normal consignments. For example, it is not normal to process consignments consisting solely of Bellies wool.

Decrimped Staple Length (DSL) has previously been introduced as a potential measurement suitable for inclusion in processing prediction models to account for the hard to predict wool types (Fish et al., 2003). The current report also examines:

- Specific Work of Rupture (called Energy-to-Break (Energy) hereon in);
- Decrimped Staple Strength (DSS);
- Decrimped Staple Length Ratio (RATIO); and
- Mean Fibre Curvature (MFC)

as potential variables to improve the prediction model for sale lots.

The effect of incorporating these new measurements into the regression model was assessed for their appropriateness of prediction by comparing the residuals of select wool types.

DECRIMPED STAPLE LENGTH (DSL)

The use of Decrimped Staple Length (DSL) as an alternative staple length measurement to incorporate the normal variation exhibited in staple extensibility has previously been reported (Fish et al, 2003; Semmel, 2003). Wool types such as Stretchy Bellies and Bellies should, theoretically, be better described by DSL, whereas the wool types that exhibit less stretchiness should not be affected.

ENERGY-TO-BREAK (ENERGY)

A comparison of Energy and Staple Strength (Specific Peak Force to Rupture) to determine the parameter which best characterises the strength of a staple has previously been reported by Caffin (1980b). Staple Strength (SS) was chosen because in a large trial, it had a lower measurement CV compared to Energy in a large trial, it was not sensitive to gauge length and was "intuitively related to classical classing techniques with which it exhibits reasonable correlation". This evaluation, which pre-dated the development of ATLAS, occurred on an early prototype "Strength" machine (Caffin, 1980a).

Subsequent theoretical work by de Jong et al. (1985), highlighted the dependence of SS on the distribution of fibre lengths within a staple, and the non-dependence of Energy on this fibre length distribution.

Changes to the software that collects data from ATLAS (Semmel, 2003) enabled Energy to be calculated for the lots measured in this trial. Energy has been included as a parameter that may improve the

Hauteur prediction of specific wool types which may have unusual distributions of fibre length within their staples.

DECRIMPED STAPLE STRENGTH (DSS)

As Staple Length (SL) is used in the calculation of Staple Strength it could be assumed that if Decrimped Staple Length (DSL) were a better prediction parameter than the normal Staple Length then the measured Staple Strength of the sale lot should be corrected for the DSL. Any use of DSL makes it potentially necessary use of a modified staple strength, Decrimped Staple Strength (DSS) as the strength component coupled with Decrimped Staple Length (DSL). SS is calculated as the peak force required to break the staple, corrected for the length of the relaxed staple. Decrimped Staple Strength (DSS) was calculated as:

$$DSS = \frac{SS \times DSL}{SL} \quad (1)$$

This equation potentially changes the contribution of any strength component based on the extensibility of the staple. A higher DSL will result in a higher DSS value than a staple of lower DSL. This correction will be evaluated in the prediction of Hauteur.

DERCRIMPED STAPLE LENGTH RATIO (RATIO)

The use of the Decrimped Staple Length Ratio (RATIO) has previously been investigated as a potential method of improving processing prediction (Fish *et al*, 2003). The RATIO value is calculated as the Decrimped Staple Length divided by Staple Length. A previous report (Fish *et al*, 2003) indicated that this RATIO could be used to identify the more extensible wool types such as Stretchy Bellies and Bellies, which were not well predicted by the TEAM equations.

Figure A4 (Appendix 1) shows the relationship between Ratio and the TEAM-3 residual for the 303 sale lots investigated. There is an apparent point of inflection in the relationship at Ratio = 1.30 (indicated on Figure A4). Less than 1.30, the scatter of the residuals appears random around zero, while greater than 1.30, there is a clearly increasing linear relationship.

For the Ratio above 1.30, the relationship is described by:

Residual = 48.2*RATIO – 59.46 (2)

such that the equation applied to sale lots of Ratio greater than 1.30 is:

Predicted Sale Lot Hauteur = TEAM-3 + 48.2Ratio – 59.46 + MA (3)

The application of RATIO* is strictly for sale lots of Ratio greater or equal to 1.30. Sale lots below 1.30 had the recommended TEAM-3 equation applied only. This two phased model is similar in approach to the M* component in the TEAM-2 model, in that the value of one of the components is used to determine the version of the model to use.

MEAN FIBRE CURVATURE (MFC)

The TEAM-3 final report (2004) indicated MFC did not contribute to the processing prediction of consignments. Today, processing consignments are rarely, if ever, constructed from sale lots of similar MFC in order to produce a particular product, rather it is common for different wool types of differing curvatures to be combined. The additivity of raw wool parameters consequently reduces the impact of MFC on the processing behaviour of these consignments.

In the single sale lot processing trial (Fish et al, 2004), wool types exhibiting both high and low MFC values were selected and processed on their own. This gave these lots the opportunity to express the full potential of each raw wool characteristic without being masked by the blending of different sale lots that is the normal commercial practise of top makers.

METHODOLOGY

Three hundred and eleven (311) sale-lot display samples were sampled in compliance with IWTO-38-91 and tested at AWTA Ltd, and subsequently processed at the CSIRO, Textile and Fibre Technology Mini-mill (Smith et al, 1982). The display samples were selected from commercial sale-lots and were a minimum greasy wool weight of 4kg.

Due to some sale lots having incomplete Decrimped Staple Length Data, only three hundred and three (303) samples were included in the analysis of these results.

SELECTION OF SALE-LOTS

Difficult-to-predict and control (normal fleece wool types) wool types were selected to provide comparisons for the interpretation of results. The control types were of similar MFD to the difficult-to-predict types and were representative of standard sale lines, for example Fleece or Pieces lines. The selection and measurement of the sale-lots has previously been reported (Fish et al, 2003).

MEASUREMENT OF RAW WOOL PROPERTIES

All but three of the sale-lots were purchased and assigned to the trial based on their Certified presale results sampled in accordance with the IWTO regulations (Core Test Regulation, 2.2, 1994; IWTO-38) and tested in accordance with IWTO Test Methods (Test Methods IWTO-19, 12, 7 and 30).

In order to collect the data for the new measurements of DSL, DSS, Energy and Ratio the sale lots were re-measured on two ATLAS machines using modified ATLAS software (Semmel, 2003), with twice the usual number of staples being measured, but still in compliance with IWTO-30-98. A data extraction macro was developed to translate the ATLAS output to an energy value suitable for analysis.

PROCESSING OF SALE-LOTS

Sale-lots were processed into top at the CSIRO Mini-mill in Geelong (Smith et al, 1982). The integrity of each sale-lot was maintained throughout the top-making process. Changes were not made to the machine settings during the processing of the sale lots because there was no commercial requirement to balance Noil/Top yields, or Hauteur/CVHauteur as may have been the case if some of these lots were being processed under normal commercial conditions.

Tops were measured for Hauteur, CVH, MFD and CVD in accordance with IWTO-17-85 (Hauteur), IWTO-12-01 (MFD) and IWTO-34-85 (Regain) at the AWTA Ltd Textile Testing Division.

DATA ANALYSIS

The regressions reported in this paper are standard multiple linear regression (MLR), as performed using S-Plus(Insightful Corp, 2002).

One of the major shortcomings in reports on difficult to predict sale lots is that the results of these earlier trials (Mooy et al., 1988; Rottenbury et al, 1987) are only reported as overall differences. In this report the differences are reported for 21 categories of wool types so that the impact of any analysis on each category is clearly defined.

Another issue considered important by the authors was the comparisons between different regression models needed to acknowledge where the data being presented had or had not been totally independent of the process of deriving the model (i.e. was it a true validation of the model with independent data or simply a fitting of the same data back on the model itself?). In many earlier trials, this was not the case and analyses tended to be simply fitting the data rather than true prediction models.

For each of the new characteristics two comparisons were made.

A regression model for the sale lot database was derived using the TEAM-3 parameters. This was compared to a model based on replacing one of the TEAM parameters with the new parameter that came closest to the existing parameter (for example, replacing Staple Length with Decrimped Staple Length). These comparisons are both based on fitting the model back over the same data that was used to derive the model. This comparison is useful from a scientific point of view to establish the impact of the new variables on the processing performance in a single mill. However, it does not have the benefit of including factors relevant to normal commercial processing practice over different processing mills.

An alternative approach is simply to add an additional variable to the TEAM-3 Formula for commercial blends. This has the benefit of including in the prediction equation the relative sensitivities of the reported parameters derived from a worldwide database. In this way it is possible to consider a process for updating the TEAM-3 formula for commercial blends as opposed to sale lots reported here in light of this new information.

Another approach is to develop the equations on one half of the dataset and then use the second half as a validation set. Whilst this may be considered the purest methodology, it does significantly reduce the number of lots and can reduce the sensitivity of the analyses.

RESULTS AND DISCUSSION

TECHNICAL

Multiple Linear Regression (MLR) was used to model the sale lots data set using different combinations of raw wool measurements. The 303 sale lots were first modelled using the recommended TEAM-3 raw wool variables. This regression (LOTS) was considered the control, against which all further models were compared. The coefficients for the regression models are listed in Table 1. A few coefficients are in brackets and italicised in order to identify those that were not statistically significant at the 5% level. The format of this table is used consistently throughout the paper. The recommended TEAM-3 equation for Hauteur has also been provided as a direct comparison with the LOTS model. The Correlation Coefficient (R^2) and Standard Error (SE) values were generated by applying the models back over the dataset. (The R^2 and Standard Error for the recommended TEAM-3 equation differs from that reported in the TEAM-3 final report, because it is being applied to a different dataset; the sale lot database instead of the TEAM-3 database).

The coefficients for the sale lot dataset (Table 1) differ to those reported in the TEAM-3 final report because coefficients are dependant on the data used to derive them (Marler, 2004). Also consistent with previous reports is the reduction in Standard Error (SE) when parameters are fitted to the dataset under investigation; the SE was reduced, from 6.55 when the recommended TEAM-3 equation was applied, and to 5.60 when the fitted parameters were applied to the dataset.

Table 1: Technical Models derived using the sale lots data set, by either replacing terms, or including additional terms.

Model	L	S	D	M	V	CVD	CVL	DSL	DSS	ENER	RATIO	MFC	R^2	SE
TEAM-3	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32						0.59	6.55
LOTS	0.61	0.20	0.78	-0.06	*(-0.23)*	-0.67	*(-0.19)*						0.70	5.60
(-L+DSL)		0.21	0.91	-0.06	*(-0.23)*	-0.55	-0.28	0.50					0.74	5.24
(-S+DSS)	0.62		0.77	-0.06	(-0.22)	-0.63	(-0.19)		0.18				0.71	5.52
(-S+ENER)	0.47		0.85	-0.07	*(-0.23)*	-0.64	*(-0.10)*			0.009			0.70	5.59
(+RATIO)	0.63	0.22	0.87	-0.06	*(-0.23)*	-0.54	*(-0.25)*				34.87		0.75	5.17
(+MFC)	0.62	0.19	0.96	-0.06	(-0.22)	-0.66	(-0.19)					-0.06	0.71	5.51

The lowest SE was achieved by including RATIO in the regression model, and a favourable result was noted when L was replaced with DSL. Replacing S with either DSS or Energy appeared to have little impact on the dataset, likewise the inclusion of MFC.

In most cases, V and CVL were found to be not significant in the regression. The inclusion of MFC in the regression was found to produce a statistically significant coefficient, which is in contrast to the results in TEAM-3 (2004). This indicates that MFC may influence the processing performance of a lot or consignment where the impact of MFC is not diluted by blending. This finding is consistent with earlier research reports where wool had been selected for specific characteristics, such as MFC, where results indicated MFC was a significant characteristic in fitted data results and where these characteristics fail to show significant effects when processed in blended commercial combing batches. This is not to say that V or CVL are not important variables in predicting other values such as CVH or Romaine, they did not show up as significant variables for predicting Hauteur in these sale lots.

Table 2 reports the residuals (that is, the differences as Actual Hauteur – Predicted Hauteur) and significance level for each wool type under the null hypothesis that there is no difference. Due to the small number of sale lots in some wool type categories, the 99.9% (***) statistical significance level was chosen for comparison between models. In addition to the statistical significance, a 3mm guide-line was used (Mooy et al, 1988; Fish et al, 2004) to determine which, if any, of the wool-types, were not well predicted by the model. All other results have been shadowed, for the convenience of the reader.

The aim of any modelling is to predict all wool types to demonstrate a mean residual of zero. However, Table 2 shows that this is clearly not the case. The lowest pooled mean residual ("All" in the table) is when L is replaced by DSL in the regression, closely followed by the addition of RATIO to the regression.

Table 2: The impact and significance of the Technical Models on the Mean Residuals.

Wool Type	n	LOTS		Replacement						Addition			
				DSL for L		DSS for S		ENER for S		+RATIO		+MFC	
		MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.
All	303	2.7	***	1.2	***	2.6	***	2.7	***	1.5	***	2.6	***
Pieces	21	1.3	ns	0.4	ns	1.3	ns	1.2	ns	0.7	ns	1.4	ns
Bellies	26	2.9	***	-1.3	ns	2.6	**	2.8	***	-0.7	ns	2.6	**
Stretchy Bellies	30	8.8	***	3.7	***	8.5	***	8.1	***	3.9	***	7.8	***
Variable Length Pieces	17	0.7	ns	-0.5	ns	0.6	ns	0.4	ns	-0.2	ns	0.6	ns
Variable Length Pieces with Locks	14	-0.1	ns	-1.7	ns	-0.2	ns	-0.4	ns	-1.4	ns	0.1	ns
Fleece	32	0.0	ns	0.0	ns	0.0	ns	0.0	ns	0.0	ns	0.0	ns
Elite-type	6	10.6	**	10.4	**	10.4	**	10.5	**	10.6	**	11.0	**
SRS®-type	6	7.6	ns	5.1	ns	7.1	ns	6.2	ns	5.7	ns	7.9	ns
High Fibre Curvature	14	4.0	*	1.8	ns	3.7	*	4.4	**	2.2	ns	2.6	ns
Low Fibre Curvature	16	2.2	ns	2.0	ns	2.2	ns	2.4	ns	2.1	ns	2.6	ns
Cotted Fleece	7	2.7	ns	0.9	ns	2.6	ns	3.2	ns	1.3	ns	2.8	ns
High Strength High Midbreaks	8	2.8	ns	2.3	ns	2.7	ns	2.9	ns	2.6	ns	3.0	ns
Short-and-Strong	14	-0.6	ns	-1.0	ns	-0.6	ns	-0.2	ns	-0.6	ns	-0.3	ns
Fine Fleece	11	0.0	ns	-0.8	ns	0.0	ns	0.2	ns	-0.5	ns	-0.3	ns
Superfine Fleece	13	2.0	ns	1.3	ns	2.0	ns	1.7	ns	1.6	ns	1.8	ns
High cvD	13	4.1	**	3.6	**	4.1	**	4.4	**	3.8	**	4.0	**
Low cvD	13	1.4	ns	0.9	ns	1.3	ns	1.6	ns	1.1	ns	1.3	ns
Long-and-strong	6	8.9	**	8.6	**	8.6	**	7.0	**	8.5	**	8.7	**
Low cvSS	7	5.5	***	4.0	**	5.3	***	6.0	***	4.4	**	5.1	***
Lambs Fleece	14	-0.6	ns	1.5	ns	-0.7	ns	0.3	ns	-1.1	ns	-0.4	ns
Weak fleece	15	1.5	ns	0.6	ns	1.7	*	2.6	*	0.9	ns	1.2	ns
Average of Type		3.1		2.0		3.0		3.1		2.1		3.0	
Min.for Type		-0.6		-1.7		-0.7		-0.4		-1.4		-0.4	
Max. for Types		10.6		10.4		10.4		10.5		10.6		11.0	
Range (Max - Min)		11.2		12.1		11.1		10.9		11.9		11.4	

*Note: ns= not significant, * = significant at the 95% confidence level, ** = significant at the 99% confidence level, *** = significant at the 99.9% confidence level. For the purpose of any comparison, all shaded lots were considered to be well predicted.*

Bellies and Stretchy Bellies wool types were best predicted by the models, which included DSL or RATIO in the regression, whereas DSS, Energy and MFC provided little benefit to prediction of those wool types. Some wool types consistently processed longer than the models predicted, independent of the model used; High CVD, Long-and-Strong, Low CVSS and Elite-type wool processed longer than predicted by the models, despite being included in the regression used to devise the models.

When included in the regression, MFC produced a slight improvement on the residual for High Fibre Curvature wool types (2.6 compared with 4.0 for LOTS), however there was no improvement in the prediction of low Fibre Curvature wool by the inclusion of MFC (2.6 compared with 2.2 for LOTS). Elite-type and SRS®-type wool were unaffected by including MFC as a regression parameter, but a small improvement was noted when RATIO was included.

Table 2 shows that while all 303 sale lots reported were used to devise the regression equations used to predict the processing performance of the sale lots, there will always remain some sale lots existing at the extremes of the dataset that will be difficult to predict. An objective of any model is to reduce the magnitude of the differences of the extremes

Table 3: Comparison of the variation (SD) of the Technical Models under investigation.

Wool Type	n	LOTS	Replacement			Addition	
			DSL for L	DSS for S	ENER for S	+RATIO	+MFC
All	303	5.6	5.3	5.5	5.3	5.2	5.5
Pieces	21	4.9	4.9	4.9	4.6	4.9	5.0
Bellies	26	3.7	3.8	3.7	3.6	3.8	3.9
Stretchy Bellies	30	5.1	4.8	4.9	4.8	4.6	4.8
Variable Length Pieces	17	2.4	2.7	2.4	2.3	2.6	2.6
Variable Length Pieces with Locks	14	4.5	4.0	4.4	4.3	3.9	4.6
Fleece	32	6.3	6.2	6.3	6.1	6.2	6.3
Elite-type	6	5.4	5.0	5.3	4.9	5.0	5.3
SRS®-type	6	8.2	7.8	8.2	7.3	7.9	8.3
High Fibre Curvature	14	5.8	5.5	5.7	5.6	5.5	5.7
Low Fibre Curvature	16	5.9	6.4	6.0	6.1	6.3	6.0
Cotted Fleece	7	3.8	4.3	3.8	3.9	4.0	3.5
High Strength High Midbreaks	8	3.4	3.4	3.4	3.7	3.3	3.7
Short-and-Strong	14	6.7	6.4	6.7	6.4	6.3	6.5
Fine Fleece	11	4.6	4.5	4.7	5.1	4.6	4.8
Superfine Fleece	13	3.5	3.4	3.5	3.7	3.4	3.9
High CVD	13	4.1	4.0	4.0	4.0	4.0	4.2
Low CVD	13	4.6	4.8	4.6	4.1	4.6	4.4
Long-and-strong	6	3.7	3.8	3.6	3.8	3.7	3.8
Low CVSS	7	2.2	2.5	2.2	2.6	2.4	2.4
Lambs Fleece	14	3.2	3.4	3.2	2.9	3.4	3.3
Weak fleece	15	3.2	3.5	3.1	3.8	3.4	3.1
Average of Type		4.5	4.5	4.5	4.5	4.5	4.6
Min.for Type		2.2	2.5	2.2	2.3	2.4	2.4
Max. for Types		8.2	7.8	8.2	7.3	7.9	8.3
Range (Max - Min)		5.9	5.3	6.0	5.0	5.5	5.9

A comparison of the between-lot variation for the different models is reported in Table 3. This shows that between-lot variability is consistent across the models, and that there is very little differentiation between them on this basis. The lowest overall SD was achieved by including RATIO in the regression, although the differences between the SDs of all the models could not be considered overly different (range of 0.4).

COMMERCIAL

The Technical part of this paper has dealt with modelling the dataset using Multiple Linear Regression, and including different combinations of terms in the regression. While this method is very interesting from a Technical point-of-view, it is not what one would propose as an acceptable commercial alternative to the TEAM-3 recommended Hauteur equation. The equations have been derived in a non-commercial environment within a single research mill.

Thus, a commercial method of including potential new parameters, consistent with the method for including additional terms (TEAM-2 and TEAM-3 final reports), was used to determine how to include additional parameters. The TEAM-3 residual for Hauteur was plotted against each parameter, and an equation of the relationship was determined (the figures and equations for each relationship are reported in Appendix 1). Terms were then added to the recommended TEAM-3, such that the base equation remained unchanged, and additional terms were considered as small adjustments to the base equation.

However, there was one exception to the straight term addition described above. Figure A4 shows that the relationship between the TEAM-3 residual Hauteur, and RATIO were not linearly nor curvilinearly related over the entire range, but were best described by a “bent-stick” model. Below a RATIO value of 1.30, the relationship between the residual and RATIO is parallel to the x-axis, indicating the addition of an equation would have no effect on the prediction below this value. Above 1.30, a relationship exists, which can then be included as a correction term. As a result, RATIO* is defined as the equation to be used only when the RATIO value is greater than 1.30, else the recommended TEAM-3 equation is used for all RATIOs less than 1.30.

It should be noted that in the case of the TEAM-3 model in Table 4, the R^2 and SE have been determined for the sale lots data and hence are different than that reported in the TEAM-3 Reports which were based on commercial consignments. In addition, the results in Table 4 differ slightly from a previously published report (Fish et al., 2004) because the earlier report used the Certified test data whereas this report is based on the new staple measurement data with increased precision.

Table 4: Commercial Models derived by adding a single component to the TEAM-3 equation.

Model	L	S	D	M	V	CVD	CVL	DSL	DSS	ENER	RATIO*	MFC	R^2	SE
TEAM-3	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32						0.59	6.55
(+DSL)	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32	0.16					0.67	5.90
(+DSS)	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32		-0.19				0.63	6.26
(+ENER)	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32			-0.001			0.59	6.53
(+RATIO*)	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32				48.20		0.63	6.21
(+MFC)	0.43	0.35	1.38	-0.15	-0.45	-0.59	-0.32					0.12	0.61	6.46

The lowest SE (5.90) (see Table 4) is achieved when DSL is included as an additional term with the TEAM-3 recommended equation, followed by the inclusion of RATIO*(6.21). The lowest overall mean residual (1.2mm) (Table 5) is however achieved by applying RATIO* to the dataset (1.2mm), followed by MFC (1.5mm).

Comparing the effect on individual wool types by the models used (Table 5), shows that Bellies and Stretchy Bellies are predicted the best by the inclusion of RATIO*. However no effect was noted for most other wool types. This is to be expected, because only those sale lots whose RATIO value is greater than 1.30, typically Bellies and Stretchy Bellies, will change. The addition of DSL to the TEAM-3 equation has caused the Bellies and Stretchy Bellies to predict even shorter than predicted by the TEAM-3 recommended equation (a positive residual (Actual minus Predicted) indicates the wool has processed longer than predicted whereas a negative residual indicates the wool has processed shorter than predicted). In addition, the inclusion of DSL has caused a number of wool types to predicted shorter than they have processed, resulting in a higher mean residual value when compared to the residual of the recommended TEAM-3 equation.

Table 5: The impact of the Commercial Model on the Mean Residuals, and the level of Significance associated with the Residuals.

Wool Type	n	TEAM-3		+DSL		+DSS		+ENER		+RATIO*		+MFC	
		MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.	MEAN	SIG.
All	303	2.6	***	4.6	***	2.2	***	2.2	***	1.2	***	1.5	***
Pieces	21	2.0	ns	4.6	***	1.0	ns	1.6	ns	1.8	ns	1.5	ns
Bellies	26	3.5	***	5.1	***	0.8	ns	2.8	**	-1.7	ns	2.6	**
Stretchy Bellies	30	9.7	***	12.3	***	8.2	***	8.8	***	2.1	**	6.5	***
Variable Length Pieces	17	0.4	ns	3.5	***	-0.3	ns	-0.1	ns	-0.1	ns	-0.8	ns
Variable Length Pieces with Locks	14	1.2	ns	4.1	**	-0.6	ns	0.6	ns	0.1	ns	0.1	ns
Fleece	32	0.0	ns	0.0	ns	0.0	ns	0.0	ns	0.0	ns	0.0	ns
Elite-type	6	9.0	**	11.6	***	11.3	**	9.0	**	9.0	**	7.7	*
SRS®-type	6	6.5	ns	7.9	ns	8.6	*	6.7	ns	5.2	ns	5.1	ns
High Fibre Curvature	14	3.0	ns	5.2	*	3.2	ns	2.7	ns	1.2	ns	-1.2	ns
Low Fibre Curvature	16	2.9	ns	3.5	*	2.4	ns	2.8	ns	2.9	ns	3.7	*
Cotted Fleece	7	5.7	*	4.7	**	3.0	ns	5.2	*	4.5	*	6.0	*
High Strength High Midbreaks	8	0.6	ns	3.0	ns	2.9	ns	0.6	ns	0.6	ns	0.7	ns
Short-and-Strong	14	-6.5	*	-1.4	ns	-3.6	ns	-6.7	*	-6.8	**	-7.0	**
Fine Fleece	11	1.4	ns	2.6	ns	0.7	ns	1.1	ns	0.8	ns	-0.2	ns
Superfine Fleece	13	4.4	**	7.2	***	3.2	**	4.0	**	4.0	**	1.0	ns
High cvD	13	3.6	*	5.9	***	2.7	*	3.2	*	3.6	*	2.4	ns
Low cvD	13	0.2	ns	1.4	ns	2.3	ns	0.3	ns	0.2	ns	-0.5	ns
Long-and-strong	6	7.7	***	7.0	**	9.7	**	7.8	**	7.7	**	7.4	**
Low cvSS	7	4.4	***	5.1	***	5.0	***	4.2	***	4.4	***	2.3	**
Lambs Fleece	14	-4.4	*	0.2	ns	-3.1	*	-4.8	*	-4.4	*	-5.2	**
Weak fleece	15	4.5	**	5.3	**	0.8	ns	3.8	*	4.5	**	3.7	*
Average of Type		2.8		4.7		2.8		2.6		1.9		1.7	
Min.for Type	6	-6.5		-1.4		0.0		-6.7		-6.8		-7.0	
Max. for Types	32	9.7		12.3		-3.6		9.0		9.0		7.7	
Range (Max - Min)		16.3		13.6		11.3		15.8		15.8		14.7	

*Note: ns= not significant, * = significant at the 90% confidence level, ** = significant at the 95% confidence level, *** = significant at the 99% confidence level. For the purpose of any comparison, *** was considered appropriate.*

The addition of DSS or Energy to the TEAM-3 Hauteur equation had little impact on the residual compared across wool types.

Comparison of the variation across models (Table 6) shows that the addition of the RATIO* term to the TEAM-3 Hauteur equation given the lowest variation across all sale lots (6.2) however there is little variation across the models, consistent with the findings in Table 3.

Table 6: Comparison of the variation (SD) of the Commercial Models under investigation.

Wool Type	n	TEAM-3	+DSL	+DSS	+ENER	+RATIO*	+MFC
All	303	6.7	6.3	6.3	6.6	6.2	6.5
Pieces	21	5.4	5.1	5.6	5.5	5.4	5.5
Bellies	26	4.7	4.3	4.7	4.7	5.1	5.0
Stretchy Bellies	30	4.8	5.4	5.3	4.6	4.1	4.0
Variable Length Pieces	17	2.9	2.3	2.5	3.0	3.2	3.2
Variable Length Pieces with Locks	14	4.5	4.6	4.4	4.5	4.1	4.9
Fleece	32	6.3	5.9	6.0	6.3	6.3	6.5
Elite-type	6	5.0	4.0	5.4	5.2	5.0	4.9
SRS®-type	6	9.7	9.6	8.9	9.8	9.2	10.0
High Fibre Curvature	14	6.0	6.4	6.5	6.0	6.0	5.6
Low Fibre Curvature	16	6.0	5.7	5.5	6.0	6.0	6.6
Cotted Fleece	7	5.0	3.3	5.0	5.0	4.1	4.8
High Strength High Midbreaks	8	5.5	4.2	5.2	5.6	5.5	6.0
Short-and-Strong	14	8.2	7.9	7.6	8.2	8.1	7.6
Fine Fleece	11	6.6	6.4	5.7	6.5	6.3	7.3
Superfine Fleece	13	3.7	3.4	3.0	3.7	4.5	4.4
High CVD	13	4.3	4.1	4.8	4.4	4.3	4.7
Low CVD	13	8.7	6.7	7.1	8.7	8.7	8.1
Long-and-strong	6	3.4	3.8	4.1	3.7	3.4	3.2
Low CVSS	7	1.3	1.8	1.1	1.1	1.3	1.0
Lambs Fleece	14	5.9	5.6	4.9	6.0	5.9	5.8
Weak fleece	15	5.1	5.1	5.5	5.2	5.1	5.0
Average of Type		5.4	5.0	4.5	5.4	5.3	5.4
Min.for Type	6	1.3	1.8	1.1	1.1	1.3	1.0
Max. for Types	32	9.7	9.6	8.9	9.8	9.2	10.0
Range (Max - Min)		8.4	7.8	7.8	8.7	7.9	9.0

CONCLUSION

Five potential raw wool measurements have been assessed for suitability in correcting the processing prediction equations for hard-to-predict wool types, for Hauteur at sale lot level.

The inclusion of DSS or Energy in the sale lots prediction equation provided no improvement to the predictive capacity of TEAM-3 for sale lots. DSL and MFC provided limited improvement, however gains in the prediction of Stretchy Bellies sale lots were offset by losses for more common wool types.

The inclusion of RATIO* in the TEAM-3 equation for sale lots of RATIO greater than 1.30 seems to be the most appropriate method of correcting the processing predictability of some hard-to-predict sale lots, decreasing the mean residual form 2.6mm to 1.5mm.

While the information here has been provided to the industry, it is now in the hands of the industry whether or not it wishes to proceed further. A method for assessing new measurements for incorporation into the TEAM-3 recommended equation needs to be developed. It is unlikely that the industry would bear the expense of another TEAM-type review in the future, however the inclusion of new parameters must be assessed as they become available in future.

While MFC did not improve the prediction of Hauteur, it is possible that in the future, an effect may become obvious through the extension of datasets through breeding programs. These are likely to push the limits for fibre curvature, therefore it is possible that this situation may need to be reviewed in 5-10 years.

Similarly, this work could be extended to examine and develop sale lots equations for CVH and Romaine, the two other important parameters.

RECOMMENDATIONS

The authors recommend:

1. If the industry accepts the proposed TEAM-3 equation, then it should plan to extend the equation by adding an additional parameter, RATIO*, to correct for the effect of wool type where the Ratio exceeds 1.30.
2. The most efficient method to validate this for processing consignments is probably via an ongoing benchmarking scheme rather than a new TEAM trial.

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APPENDIX 1

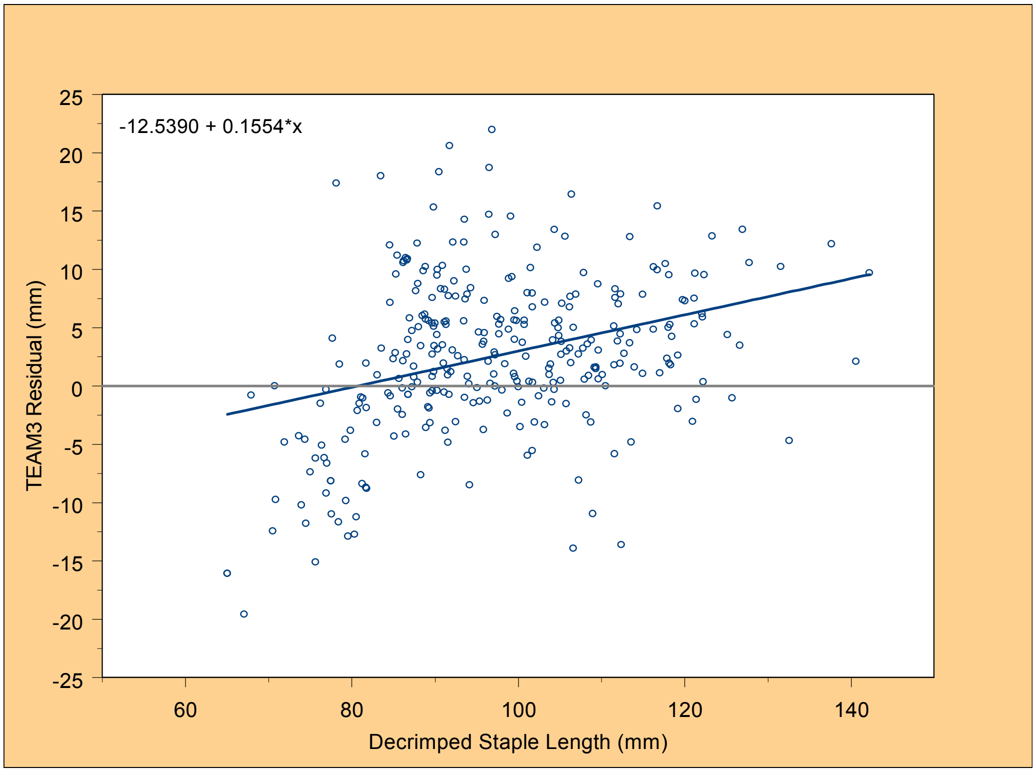

Figure A1: The relationship between Decrimped Staple Length (mm) and the TEAM3 residual for the 303 sale lots under investigation.

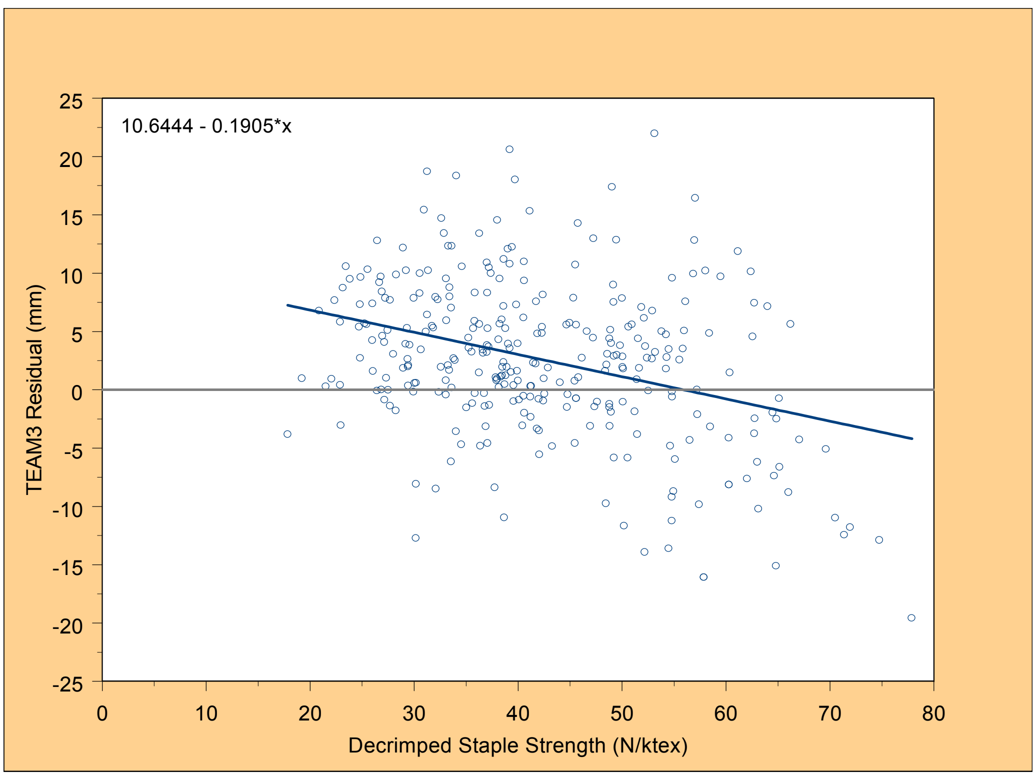

Figure A2: Relationship between DSS and TEAM-3 Residual Hauteur for the 303 sale lots under investigation.

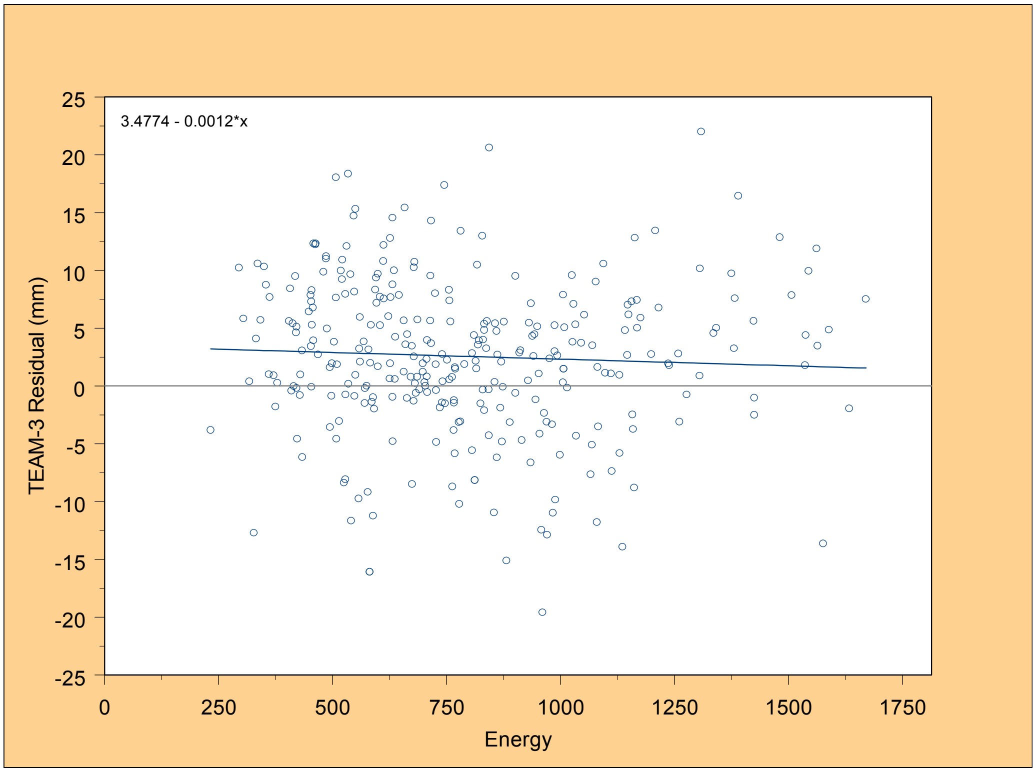

Figure A3: Relationship between Energy and TEAM-3 Residual Hauteur for the 303 sale lots under investigation.

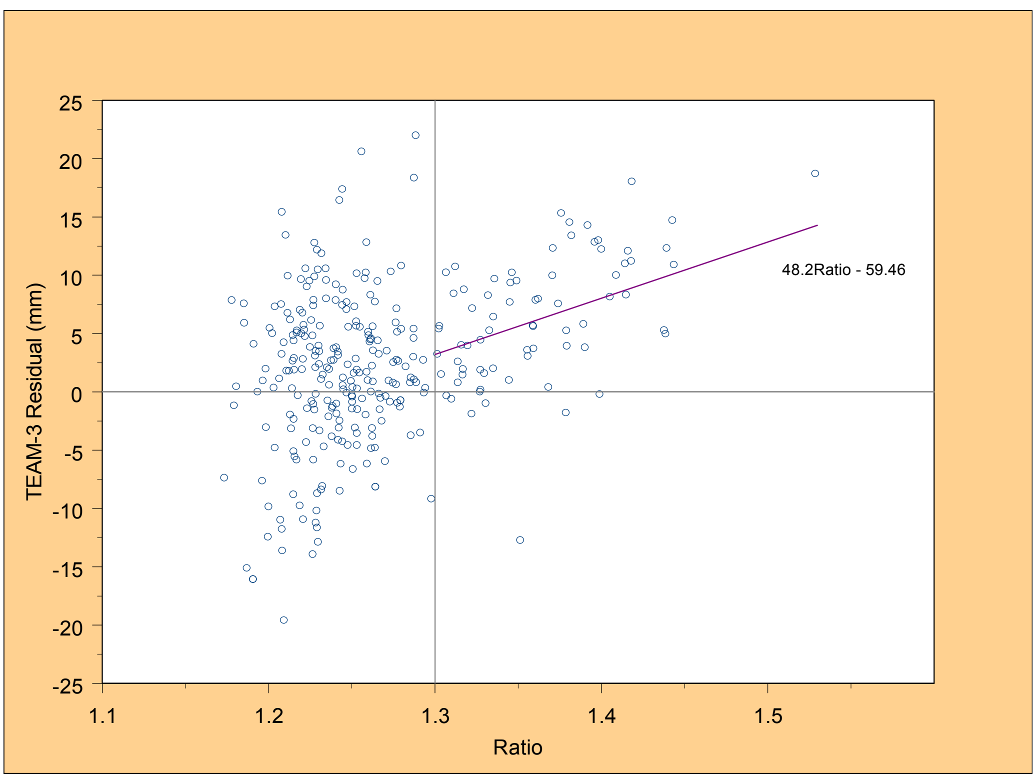

Figure A4: The relationship between RATIO and TEAM-3 residual for the 303 sale lots. The line at RATIO = 1.3 indicates the point-of-inflection of the relationship.

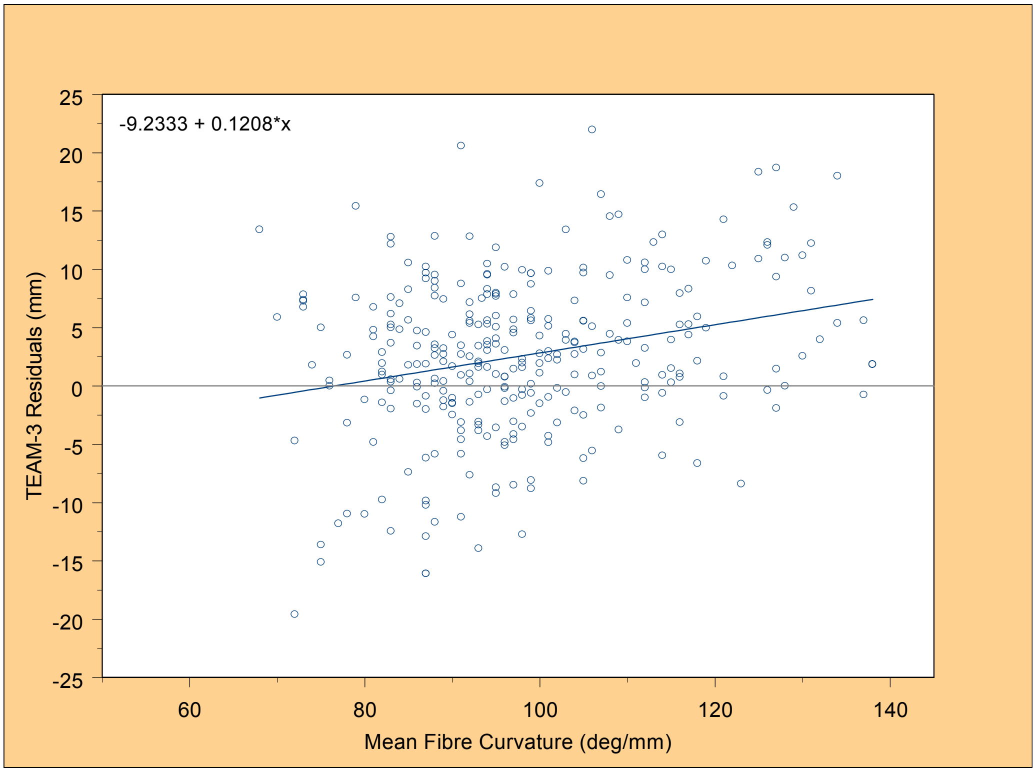

Figure A5: Relationship between TEAM-3 Residual, and Mean Fibre Curvature for 303 sale lots.