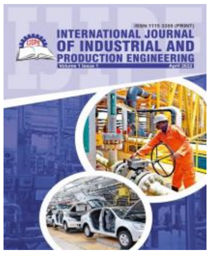

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Evaluation of Recycled Paper for Quality Toilet Tissue Paper Production Using Historical Data. A case of Anex Paper Industries.

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Abstract

The work focused on evaluating recycled paper for quality toilet tissue paper production at the Anex Manufacturing Industry. The company has no specific method of foreseeing and improving the quality of the production output in the future, and this study intends to address it. Data on the production yield was collected from the industry covering one year. The graphical models were developed by plotting the production input (raw material) against defective product-produced measures of model accuracy using Matlab and Linear regression techniques. The Matlab technique produced a model with a measure of accuracy (MSE) of 290.06 while the linear regression technique produced a measure of accuracy (MSE) of 268.86. From the results of the models, it can be deduced that the model with lesser error is the more appropriate method to achieve the best product quality analysis. The models were validated using response surface plots, which give the same accuracy measures.

Keywords: Recyclable paper, Production quality, Graphical models, Measures of accuracy.

1. Introduction

The word 'recycle' according to Oxford Advanced Learner's Dictionary of Current English is to treat things that have already been used so that they can be used again. Recyclable paper materials have proven to be an important source of raw materials in the toilet tissue paper manufacturing industries, yielding quality and affordable products (Bajpai, 2013). Tissue products such as toilet tissue, facial tissue, and paper towels, amongst others, are widely in use, and that is why most industries are now navigating toward the sourcing of their raw materials from cost-effective sources of raw materials which is very suitable for toilet tissue manufacturing (Skene & Vinyard, 2019). Tissue paper can be produced amongst other products with a small amount of recyclable paper, otherwise called used paper. However, it is possible to make tissue entirely out of recyclable paper using virgin pulp (Masternak-Janus & Rybaczewska-Błażejowska, 2015; Takala, 2021). Tissue paper production using recyclable paper is widely practiced in small and medium-scale enterprises where paper products are produced. Optimizing recyclable paper quality in toilet tissue manufacturing is quite efficient and this has made the raw material a viable material replacement in toilet tissue production than using just virgin pulp. The used paper (raw material) which has been proven to be a good raw material suitable for tissue production comes from offices' mixed waste papers. The recent digitalization by most offices, especially where the bulk of this raw material is gotten has reduced the supply of this raw material for years now. The COVID-19 pandemic however further worsened the situation by making working from home more common and this practice further reduced the supply of this material to most industries which further affected the market index and global manufacturing of tissue paper products. On the other hand, market demand for tissue paper skyrocketed early in the pandemic and has stayed relatively high ever since as most industries that thrived are eventually having a fair share in the toilet tissue paper market. The Chinese government stopped the importation of recyclable paper as well as the exportation of virgin pulp in the early years of the pandemic thus causing a systematic downward trajectory in the global paper for recycling business. Due to the Chinese Government's wastepaper import stoppage, most industries particularly small and medium-scale enterprises in recent times have considerably gained a relative market advantage due to the excess of recyclable paper material found in most establishments in Europe (Yoshida, 2021). The bulk of these unused raw materials is accessible for tissue production industries that now depend on Europe and neighboring continents for their raw materials. Improved tissue manufacturing procedure is needed to develop the quality of recyclable paper thus improving the properties of tissue production in small and medium scale enterprises. The market demand for toilet tissue revealed that there is room to produce more tissue from recyclable paper as the market is not saturated with the product, and due to its cost-effectiveness (*Securing Critical Raw Materials Supply Is Key to the Response to COVID-19 | UNECE,* 2020). Technological development, changing regulations, and the market's acceptance of recyclable products are deciding the future direction for tissue paper manufacturing, especially for small and medium-scale enterprises. Table 1 shows the quality categorization of various recyclable papers.

Table 1. Quality categorization of the various used papers for tissue production (Takala, 2021).

Class	**Name**	**Material**
Class I	Mixed Grades	Waste and scrap paper or paperboard, including unsorted waste and scrap
Class II	Corrugated and Kraft	Unbleached kraft paper or paperboard or corrugated paper or paperboard
Class III	Newspapers and Magazines	Paper or paperboard made mainly of mechanical pulp,

		including old and unsold newspapers, magazines etc.
Class IV	High Grades	Other paper or paperboard made mainly of bleached chemical pulp, not colored in the mass

2. Research Methodology

The research method applied in this work is a qualitative research approach. The data collected were the weekly record of Jumbo reel production over the months for one year. The research method followed the steps shown in Figure 1.

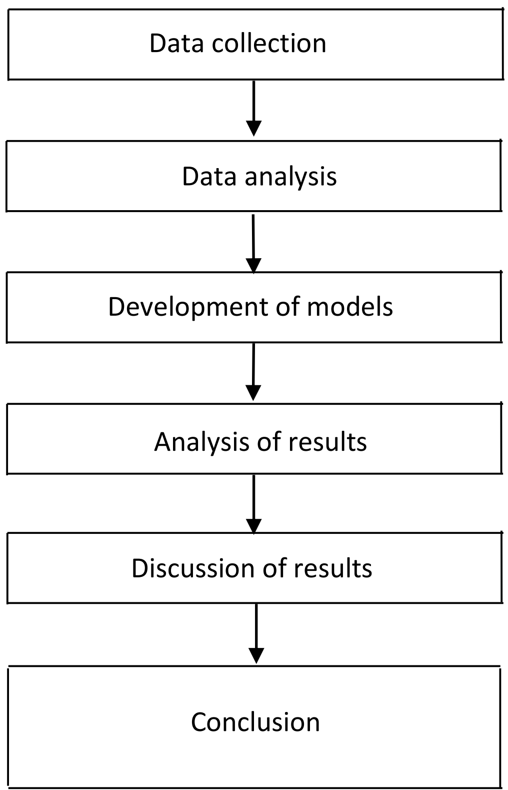

Figure 1. Method employed in the study.

2.1 Data Collection.

The data collection tool used in this research includes interview sessions with the production manager, occasional observation as well and participation in the production process. An interview session is a purposeful interview interaction in which one person obtains information from one or more individuals which essentially comes in the form of an oral, in-person questionnaire to each member. The production data was obtained by engaging the production manager together with other staff on the production floor as well as participating in the two shifts operations for six months. This afforded me the amazing opportunity to obtain first-hand data from the production floor. The data obtained from the weekly production activities are presented in Table 2.

Table 2. Data of Weekly Production Operations in the year 2022.

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste produts (Kg)*
15 / 01 / 22	222.6	150.31	19.2
	250.5	210.2	17.5
	278.54	190.9	15.4
	250.8	190.9	13.5
	245.8	167.7	16.3
	260.9	161.7	19.8
	198.6	200.8	21.4
	198.6	190.8	18.7
	243.0	112.5	23.6
22 / 01 / 22	202.8	156.2	69.2
	204.4	171.9	15.5
	241.71	223.4	14.4
	240.5	200.8	13.5
	255.9	181.8	13.7
	267.9	270.8	15.0
	140.3	120.6	11.8
	141.7	124.4	18.7
	203.1	151.3	23.6
28/01/22	222.3	204.3	12.8
	277.7	221.5	19.5
	180.4	132.1	17.6
	230.0	216.4	10.5
	135.8	115.4	11.6
	263.3	210.8	17.87
	244.5	210.5	17.45
	198.9	129.7	18.97
	247.8	210.4	21.66

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste products (Kg)*
05/02/22	220.2	202.37	9.2
	220.5	166.6	17.5
	287.8	235.3	15.4
	259.7	217.7	13.5
	275.8	221.48	16.3
	278.7	220.7	19.7
	285.3	240.8	20.8
	188.56	132.5	19.8
	255.7	210.2	22.3
12/02/22	188.6	143.7	20.8
	211.1	177.8	21.4
	199.7	153.9	21.8
	220.6	177.7	23.7
	266.9	221.88	20.2
	244.9	217.4	22.8
	256.8	231.5	20.0
	198.9	142.8	21.7
	273.7	250.8	13.8
19/02/22	270.8	211.82	21.4
	267.7	211.82	18.88
	190.7	146.9	25.5
	275.8	258.8	19.5
	295.6	261.7	23.8
	296.7	267.7	23.8
	275.5	238.3	23.8
	300.6	282.5	23.8
	294.3	276.6	19.6

Starting date of weekly production	*Bale of raw material used* (*Kg*)	*Production output in jumbo roll* (*Kg*)	*Waste products* (*Kg*)
27/02/22	255.8	208.87	22.8
	177.9	121.6	24.8
	118.8	101.5	05.48
	247.4	217.6	23.7
	225.4	219.4	20.5
	270.7	211.78	21.8
	199.8	180.1	18.4
	298.6	252.9	19.8
	296.15	271.2	13.8
07/03/22	377.9	345.6	23.2
	313.9	291.8	27.4
	289.9	238.4	22.19
	378.8	278.9	40.8
	415.6	340.9	33.5
	408.7	333.4	35.8
	395.7	320.8	33.6
	408.7	382.5	28.9
	384.3	310.8	20.7
15/03/22	372.9	299.8	19.2
	320.5	300.2	17.5
	418.66	360.9	25.4
	400.4	357.7	27.5
	421.4	371.7	26.8
	420.9	390.8	25.8
	388.5	350.8	20.4
	348.6	324.5	20.7
	378.4	360.2	13.8

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste products (Kg)*
24/03/22	399.6	333.6	19.2
	309.8	271.2	17.5
	428.8	403.9	20.4
	405.7	377.7	23.5
	415.0	388.7	26.3
	422.9	401.8	20.8
	380.5	351.8	28.4
	378.7	347.5	24.7
	403.7	380.2	20.6
02/04/22	412.7	380.31	21.8
	309.9	285.2	20.5
	418.7	389.7	21.4
	450.8	420.7	23.5
	415.8	389.7	19.4
	399.9	360.8	20.8
	425.9	400.8	21.4
	408.2	380.5	18.7
	403.6	380.2	20.6
09/04/22	430.0	400.31	26.2
	401.5	381.2	19.8
	417.47	390.9	21.4
	425.8	397.7	26.5
	411.8	391.7	18.8
	412.9	387.8	23.4
	431.5	410.8	20.4
	422.6	400.5	20.7
	420.0	391.2	25.6

Starting date of weekly production	*Bale of raw material used* (*Kg*)	*Production output in jumbo roll* (*Kg*)	*Waste products* (*Kg*)
17/04/22	408.1	380.31	20.2
	420.5	401.2	19.8
	417.0	390.9	18.4
	425.8	403.7	21.4
	415.7	385.7	26.8
	420.3	401.8	17.8
	415.8	380.8	21.4
	409.8	388.5	18.7
	434.2	410.2	23.6
25/04/22	399.6	370.31	22.2
	400.5	381.2	18.5
	418.9	390.9	18.4
	435.8	407.7	23.5
	445.8	421.7	22.9
	406.9	380.8	21.8
	425.5	400.8	22.4
	428.6	402.5	24.7
	413.0	386.2	23.6
05/05/22	342.3	320.7	20.8
	330.5	312.2	16.8
	398.74	360.9	22.4
	358.8	327.7	13.5
	385.8	358.7	22.3
	360.3	348.8	12.8
	305.3	287.8	17.4
	308.8	280.5	25.7
	343.6	320.2	20.6

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste products (Kg)*
15/05/22	312.6	287.39	20.2
	310.0	291.2	18.5
	322.8	300.9	19.4
	290.8	267.7	23.8
	244.5	221.7	16.3
	246.9	229.8	18.8
	305.5	285.8	21.4
	388.2	362.5	18.7
	303.8	285.2	18.6
24/05/22	332.6	310.31	19.2
	308.5	281.2	18.5
	278.8	250.9	19.4
	290.8	267.7	19.5
	245.8	221.7	17.3
	268.9	240.8	19.8
	295.5	270.8	21.4
	398.6	372.5	14.7
	283.8	260.2	21.6
02/06/22	222.7	200.5	19.2
	300.7	281.2	18.5
	278.8	253.9	20.4
	250.8	232.7	15.5
	245.9	230.7	14.3
	260.9	240.8	19.8
	258.5	230.8	21.4
	309.6	281.5	18.7
	243.8	220.2	23.6

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste products (Kg)*
10/06/2022	312.3	290.9	19.2
	302.5	281.2	17.5
	278.54	250.9	20.4
	280.8	267.7	11.5
	285.8	271.7	13.3
	306.9	286.8	19.8
	305.5	280.8	21.4
	298.6	272.5	18.7
	292.4	270.2	20.6
18/06/22	302.6	280.6	18.2
	307.5	281.5	17.5
	378.4	354.9	16.4
	257.8	237.7	17.5
	245.6	221.7	20.3
	266.9	246.8	19.4
	275.5	255.8	21.4
	298.6	277.5	19.7
	293.1	270.2	20.7
26/06/2022	226.5	202.31	23.2
	300.5	281.2	18.5
	278.8	250.9	19.3
	240.8	227.7	12.5
	275.6	251.7	19.3
	298.6	240.8	19.8
	298.6	260.8	24.4
	298.6	272.5	22.7
	243.1	220.2	21.6

Starting date of weekly production	*Bale of raw material used (Kg)*	*Production output in jumbo roll (Kg)*	*Waste products (Kg)*
04/07/2022	242.4	220.31	20.2
	290.5	271.2	17.9
	284.4	266.9	17.4
	285.3	267.7	15.5
	285.3	263.7	21.3
	266.7	240.8	24.8
	244.5	220.8	21.4
	288.6	255.5	21.7
	263.3	240.2	21.6
12/07/2022	252.5	300.31	19.2
	270.5	321.2	17.5
	270.3	330.9	15.4
	275.8	367.7	13.5
	285.1	321.7	16.3
	286.9	270.8	19.8
	285.5	264.8	21.4
	299.6	279.5	19.7
	249.8	220.2	24.6
19/07/2022	288.8	267.31	19.2
	290.5	271.2	17.8
	378.4	349.9	23.4
	277.2	257.7	18.5
	265.3	247.7	17.3
	260.9	239.8	19.8
	257.5	234.8	21.4
	300.6	282.5	18.7
	273.3	251.2	23.6

2.2. Data Analysis / Model Development

The Matlab and Linear regression techniques were used to analyse and evaluate the production output of the company. The techniques produced a graphical model as well as a predictive model of surface plots. The graphical models developed using Matlab and Linear regression techniques in plotting production input (raw material) against defective product produced measures of accuracies of the production data. The Matlab technique produced a measure of accuracy (MSE) of 290.06 while that of Linear regression produced 268.86 measure of accuracy (MSE). The values are shown in Figures 2 and 4 respectively. From the results of the models produced, it can be deduced that the model with the lesser error is the more appropriate method to achieve the best product quality analysis. The models were validated using response surface plots of Figures 5 and 7 that gave the same measures of accuracy.

3. Results and Discussions.

Results of the MatLab and Linear analysis are presented and discussed.

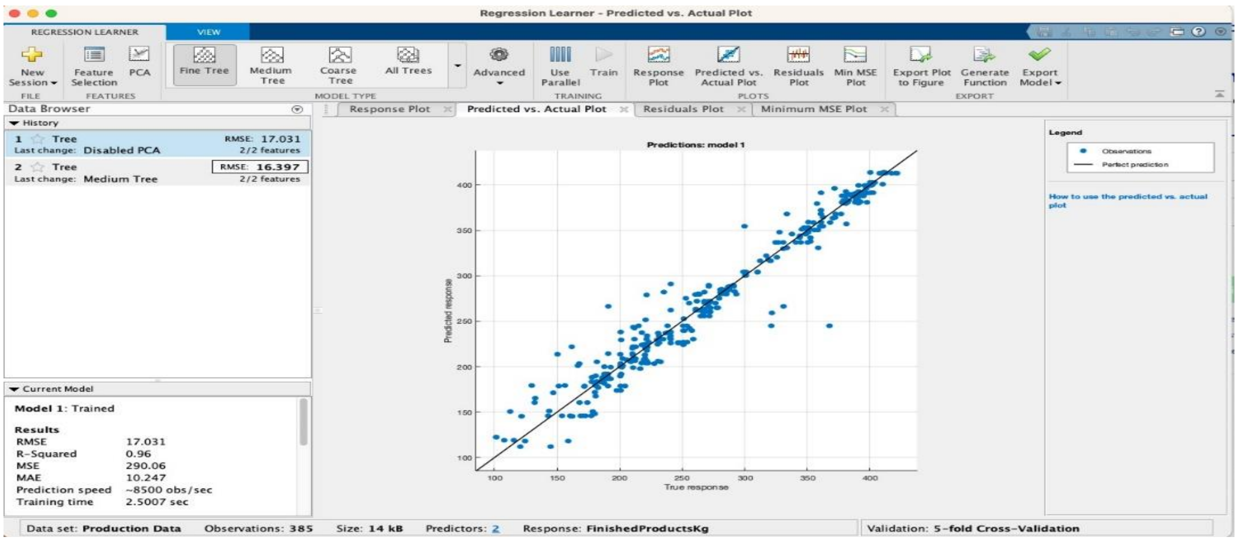

Figure 2. The MatLab interface plot of production input (raw materials) vs. Defective products.

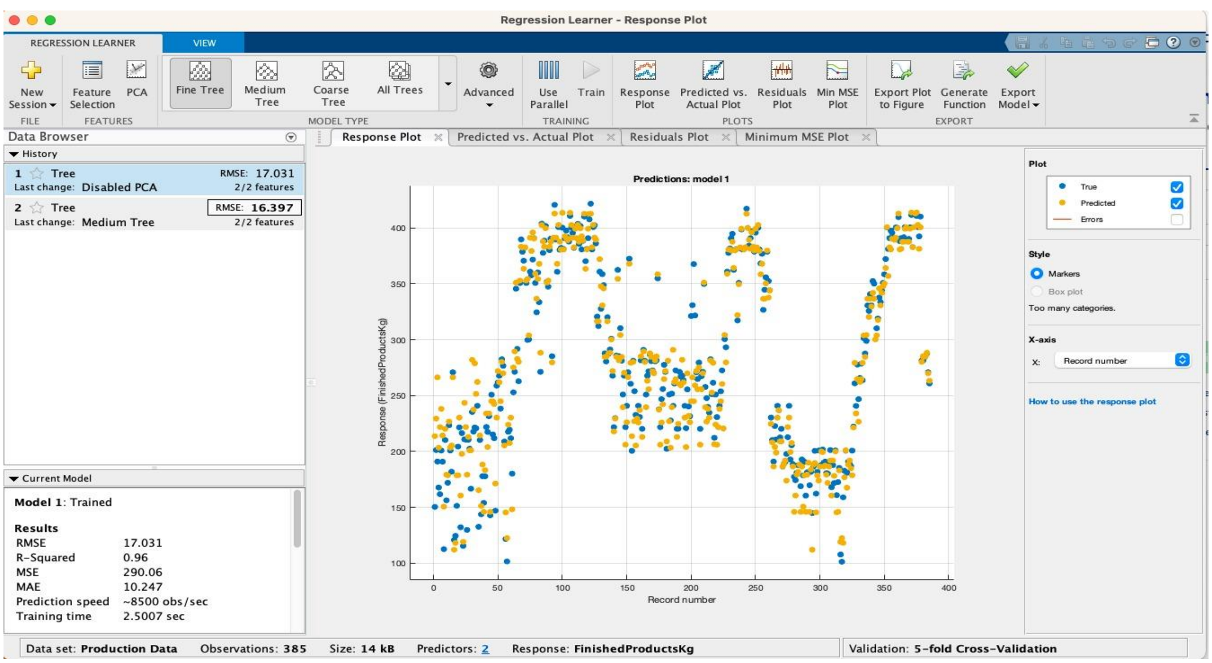

Figure 3. The MatLab interface for the validation plot of production input (raw materials) vs Defective Products.

Model 1: Trained

Results

RMSE	17.031
R-Squared	0.96
MSE	290.06
MAE	10.247
Prediction speed	~8500 obs/sec
Training time	2.5007 sec

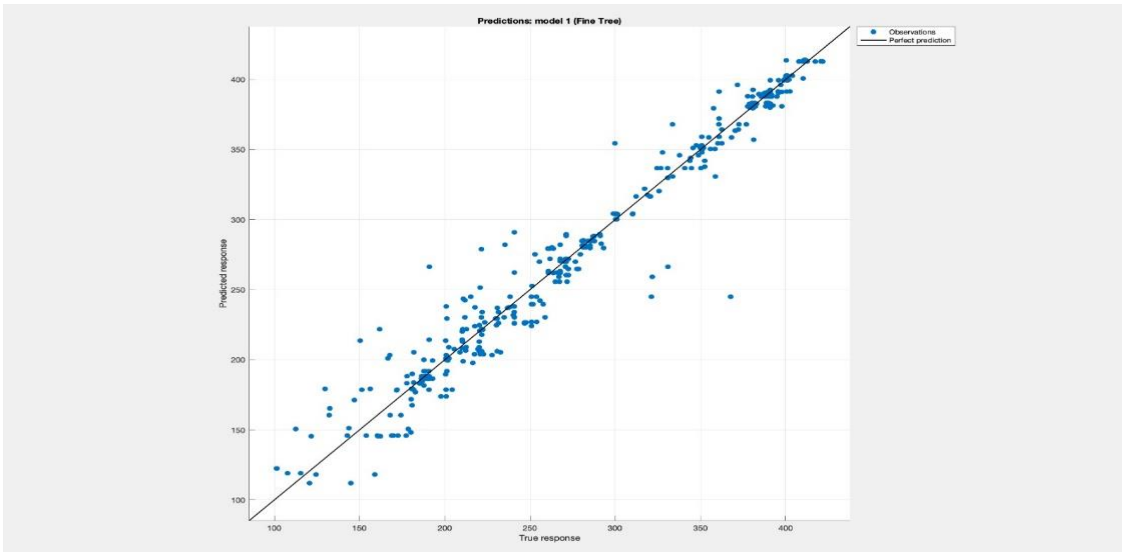

Figure 4. The linear Regression response model indicates the relationship between the (raw material and the defective product).

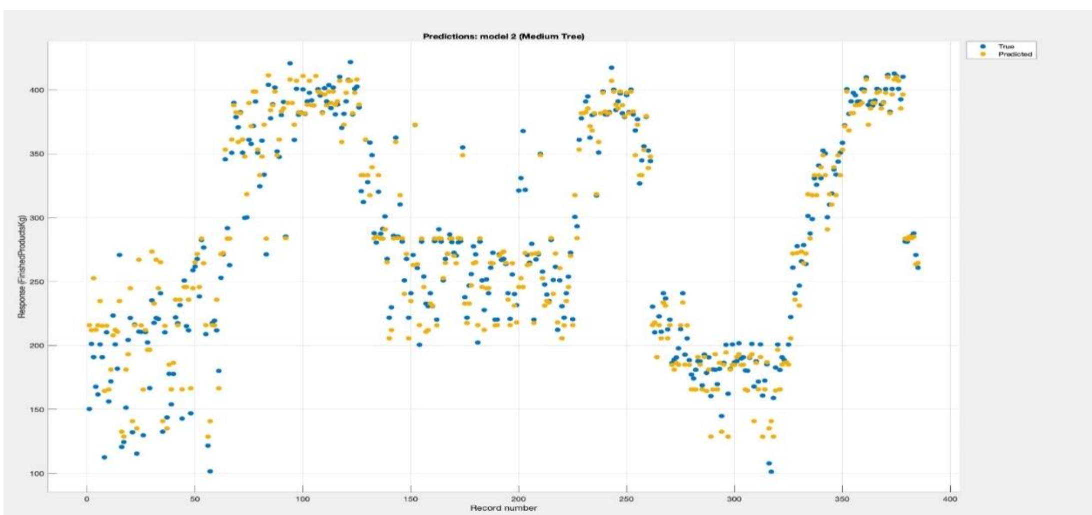

Figure 5. The linear Regression surface profile predictive model shows the relationship between the amount of input vs the defective product.

Results

RMSE	16.397
R-Squared	0.96
MSE	268.86
MAE	10.134
Prediction speed	~53000 obs/sec
Training time	0.67109 sec

From the plot in Figures 2 and 4, a linear correlation between the volume of raw material injected into the machine and that of the defect is depicted. The Root mean square error (RMSE) of 17.031 shows that the graphical model (production vs. defective product) can predict the data accurately, therefore monitoring and minimizing the production cost and maximizing the workforce as well as the input raw material.

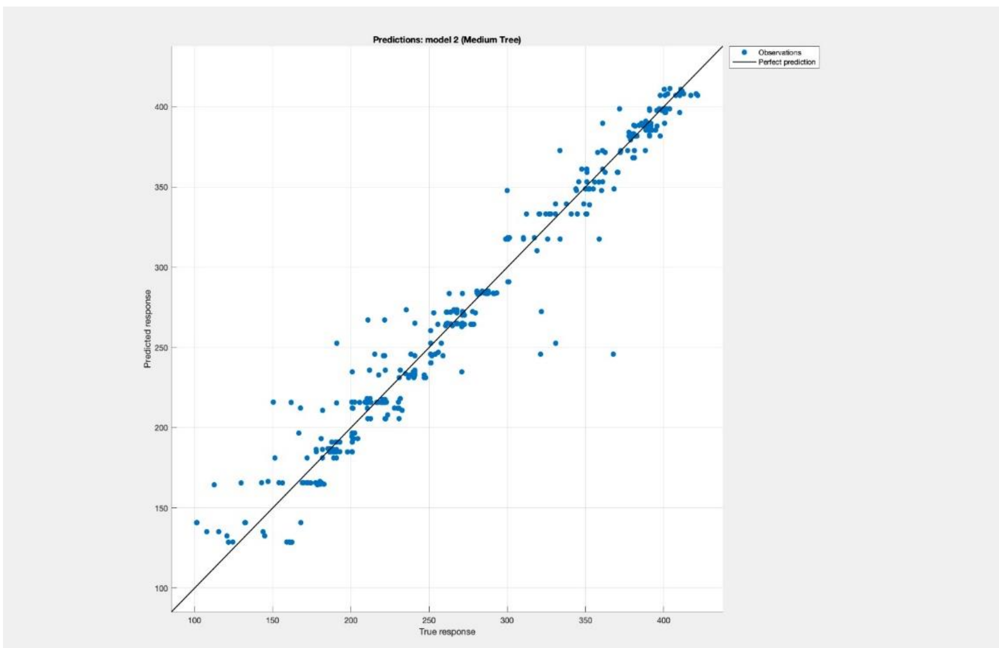

Figure 6. The linear Regression predictive model indicates the relationship between the (raw material and the defective product).

From the plot of Figure 6 is a linear correlation between the volume of raw material injected into the machine and the defects. The Root mean square error (RMSE) of 16.397 conforms to the rule of thumb which is indicative of the fact that the model can predict the data accurately therefore monitoring and minimizing the production cost and maximizing the workforce as well as the input of raw material.

4. Conclusion

The existing production model was studied and analysed through participation in the production process. It was discovered that there was no quality control measure that was in place, rather manual checking by visual examination and texture feeling were in use. From the results of the models produced, it can be deduced that the model with the lesser error is the more appropriate method to achieve the best product quality analysis. Figure 5 shows the graphical model of the production input and the defective products. Figure 6 is the validation plot response surface with coefficient of determination (R^2) 0.96 showing the goodness of fit between the predicted values and the observed data points. Figure 6 is the linear regression model of the production input vs. the defective products. Figure 8 is the linear response surface plot with the coefficient of determination (R^2) 0.96 showing the goodness of fit between the predicted values and the observed data points.

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