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Development and Regression Modeling of Dirt Resistive Latex Façade Paint

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Received: 6 January 2019; Accepted: 19 February 2019; Published: 26 February 2019

Abstract: A highly dirt-resistant paint for building façades without chemicals harmful to nature and the environment would resolve the unattractive disfigurement of building walls caused by dirt. The current ranking of Pakistan in terms of air pollution is 139th. A set of dirt-resistant paint formulae was constructed with the aid of computer programming. From this set, the best dirt-resistant paint formula was explored and identified. The final determination of the optimum formulation was based on statistically planned experiments conducted in the laboratory and in a natural environment. In order to achieve high-quality results, the best available laboratory equipment were used. The results obtained were analyzed and conclusions were drawn using appropriate statistical techniques. The procedure started with the selection of appropriate raw materials and generation of a target population of 543,143 paint formulations by adopting Basic Language computer programming. The average pigment volume concentration (PVC) percentage was computed using theory and found to be 54.98% for the target population paint formulations, verifying the literature results. Experimentation and statistical analysis were performed to compare the classical conventional agitator with the latest lab equipment such as a nano mill, and it was concluded that the nano mill performs better on average than the conventional agitator in the preparation of paint formulations. Hence, the sample of paint formulations was prepared on a nano mill and tested in the laboratory using advanced available technology for the analysis and comparison of paint properties to determine the best paint formulation. The results were analyzed using the Analysis of Variance (ANOVA) technique, and it was concluded that the newly developed paint has the highest dirt resistance on average. The final selected formula, No. 50 (the newly developed paint), was compared with the three best conventional paints available in the Pakistan market in a natural environment for a period of almost one year. A regression model was also constructed to study the effect of environmental factors like time, temperature, and humidity on the dirt resistance of paints. It was found that the newly developed paint formulation is the most environmentally friendly. It performs equally well as one conventional paint and has higher dirt resistance than two other conventional paint formulations containing harmful chemicals. The regression model of dirt resistance involving variables including time, temperature, and humidity shows that these factors significantly affect the dirt resistance of a given paint at a 5% level of significance. For a given paint, 95.34% of the variation in the dirt resistance is due to and explained by the given factors. The regression model is useful for predicting the average dirt resistance of a given paint with a certain level of confidence. The project exemplifies the work of applied research from conceptualization to successful commercialization in the paint industry.

Keywords: agitator; dirt; humidity; nano mill; temperature; time

1. Introduction

Paint is a liquid which spreads over a substrate in the form of thin layer and transforms into a solid adherent film [1]. Paint comprises many constituents including solvent, pigment, filler, additives, and binder. An important issue in today's paint industry is to develop paint with dirt resistance properties. Dirt resistance has important applications in high-rise buildings where maintenance is not an easy task. The life of paint could be increased by improving dirt resistance [2]. Dirt is responsible for the growth of algae on surfaces [3]. Dirt present on façades' painted surfaces promotes microorganism growth by providing them nutrients and proves helpful for fungal growth [4]. Airborne yeast, fungi, and algae spores find nutrients in the dirt adhering to façade paint. Spores multiply and form unsightly colonies [5]. An estimated loss of about one million dollars per year has been recorded caused by the deterioration of façade painted surfaces due to colonies [6].

Environmental pollutants have a negative impact on human health and may cause different diseases like cancer, neuron disorders, immune system malfunctioning, hormonal disorders, etc. [7]. There are severe threats to human life due to environmental pollution and weather changes [8]. Environmental stresses are increasing with industrial development because of air pollution. It is very essential to control pollution sources for a healthy and clean world [9].

It has been observed that a waxy material present on leaves helps them to resist the penetration of dirt. If the surface of the paint film could be made similar to the surface of leaves then the chances of penetration of dirt particles would be less. Paints having a self-cleaning mechanism could keep the paint clean and dry. Figure 1 shows that the frictional force and interaction between water droplets and the surface of a paint film could be reduced by the flow of water droplets over the dirt particles, thus leaving a clean surface [10,11]. The deposition of dirt on a latex façade paint film also causes a color change of the paint film [12]. Dirt deposited on the surface of the paint is also a source of food for oligotrophic fungi over the surface of the paint [13–19].

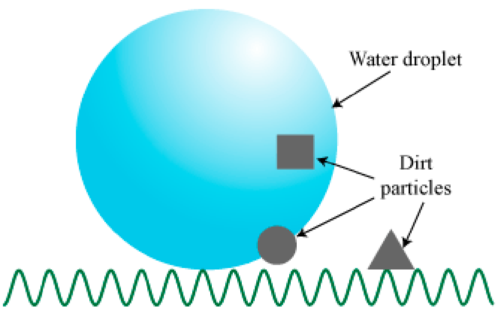

Figure 1. Self-cleaning effect on the surface of a leaf.

The glass transition temperature (T_g) of the binder and the pigment volume concentration (PVC) play a vital role in improving dirt resistance in the paint film. It has been observed that the dirt resistance is significant for paints that are formulated using polymers with higher T_g. If the T_g of acrylics is the same then styrene-acrylic-based latex paints offer more dirt resistance compared to acrylic-based latex paints [20]. Dirt resistance also increases in the case of cross-linked binders [21].

Another effect of dirt over the surface of latex façade paint film is a decrease in reflection coefficient, solar heat reflectance, and temperature reduction performance in the case of cool white coatings. The reflection coefficient represents the quantity of electromagnetic wave reflection by a medium [22]. Solar heat reflectance explains the medium's capability to reflect different sun wavelengths, which lowers the temperature of the painted surfaces [23]. It has also been observed that zinc oxide (ZnO) nanoparticles are efficient in the prevention of dirt accumulation over the surface of the paint [24].

It is internationally agreed that nanotechnology is a big revolution in production. Nanomaterials at present are being used in electronics and cosmetics. Many other sectors, for example, polymeric composite materials, are carrying out a lot of scientific and technological works and there are also plans for a wide range of projects using nanomaterials [25]. The promotion of nanostructured coatings has caught tremendous attention and interest [26,27]. All this is because of the unique properties that are at hand, offering possibilities of multifunctionality, reduction of thickness, and a great spectrum of applications relating technology [28,29].

However, recent works on nanoparticles introduced in thin layers showcase the potential risks of nanoparticle release and allow a more balanced benefit/risk analysis. For example, many studies highlight nanoparticle emissions from coatings, paints and tiles [30,31]. Cases of nanoparticle exposure in the field of occupational hygiene at coating production sites have been reported [32].

Many studies are being carried out internationally, keeping in view the hazards associated with the environment [33,34]. Studies are also being done with regards to nanoparticles present in the environment and instructions are being given regarding nano waste. Potential consumers are being made aware of the hazards of nanomaterials. Technology and industries play an effective role in this regard [35,36].

With the passage of time, atmospheric phenomena including humidity and temperature are major sources of dirt on façade paints. Multiple linear regression modeling is an appropriate technique to study the impact of two or more independent variables on a dependent variable [37]. In the present work, time (number of days), humidity, and temperature have been taken as the independent variables. The impact of these independent variables has been studied on the dirt collection index (Dc) taken as the dependent variable. Dc indicates the tendency of a surface to resist the accumulation of dirt. As such, Dc reveals average dirt resistance.

The current ranking of Pakistan in terms of air pollution is 139th [38]. The cadmium concentrations found in dust in Islamabad, the capital city of Pakistan, are 4.5–6.8 mg/kg, which is higher than those of many cities around the world [39–41]. Copper is present at levels from <6 to 412 mg/kg in dust in Pakistan and zinc is present at from >0.1 to 1193 mg/kg [42,43]. There is a high lead quantity found in the blood of 80% of the children of Karachi, Pakistan because of lead in the dusty air [44].

The present study comprises developing a new paint that could offer dirt resistance. In this work, different raw materials related to dirt resistance are suggested, including an advanced process of paint manufacturing. Dirt-resistive paint is developed and statistically modeled. The present study focuses on developing an environmentally friendly paint which may have the least negative impact on human health due to its dirt resistance.

2. Application of Visual Basic Programming for Generating a Target Population of Paints

In this section the procedure adopted for generating the population of paint formulae and selection of the random sample is discussed.

2.1. Selection of Experimental Materials

Detailed research was done to select appropriate raw materials with a view to the development of dirt- and algae-resistant façade paint without using algaecides. The experimental work comprised the selection of appropriate raw materials to develop paint formulae which are dirt and algae resistant. After appropriate raw material selection, the ranges of percentage use levels of all the raw materials were determined from the literature, as shown in Table 1.

2.2. Selection of Raw Material Groups

On the basis of these ranges, a countable infinite number of paint formulae were generated by Visual Basic (VB) programming. However, the target population was taken from them by following the procedure discussed below.

These ranges were divided into three equal groups, i.e., the lowest percentage range group, the middle range group, and the uppermost range group. These groups were named Groups 1, 2, and 3, respectively, as shown in Table 2.

Table 1. Percentage levels of raw materials.

Raw Material	Range
A	4%–25% [45]
B	5%–10% [46]
AC and RC	25%–35% [47]
D	0.8%–3% [48]
E	0.1%–1% [49]
F	0.1%–0.6% [49]
G	0.4%–0.8% [49]
H	10%–30% [49]
I	20%–30% [50]
J	3%–6% [50]
K	1%–20% [51]

Table 2. Raw material groups (in percentage/100 g).

Raw Material	Lowermost Range Group	Middle Range Group	Uppermost Range Group
H	10–16.667	16.668–23.335	23.336–30
A	4–11	11.001–18.001	18.002–25
B	5–6.667	6.668–8.335	8.336–10
AC	18.75–21.25	21.251–23.751	23.752–26.25
RC	6.25–7.083	7.084–7.917	7.918–8.75
D	0.8–1.533	1.534–2.267	2.268–3
G	0.4–0.533	0.534–0.667	0.668–0.8
I	20–23.333	23.334–26.667	26.668–30
K	1–7.333	7.334–13.667	13.668–20
E	0.1–0.4	0.401–0.701	0.702–1
J	3–4	4.001–5.001	5.002–6
F	0.1–0.267	0.268–0.435	0.436–0.6

The program of paint formulations in Visual Basic (VB) was based on the following steps. The ranges of raw materials as per the literature were taken with an interval of 0.001% going from minimum to maximum. This led to 20,001 values of H, 21,001 values of A, 5001 values of B, 10,001 values of AC and RC, 2201 values of D, 401 values of G, 10,001 values of I, 19,001 values of K, 901 values of E, 3001 values of J, and 501 values of F. The tables of these ranges consist of over 700 pages stored in an EXCEL sheet, out of which ten formulae are shown in Table 3.

Table 3. Raw material ranges (in percentage/100 g).

H	A	B	AC	RC	D	G	I	K	E	J	F
10	4	5	18.75	6.25	0.8	0.4	20	1	0.1	3	0.1
10.001	4.001	5.001	18.75075	6.25025	0.801	0.401	20.001	1.001	0.101	3.001	0.101
10.002	4.002	5.002	18.7515	6.2505	0.802	0.402	20.002	1.002	0.102	3.002	0.102
10.003	4.003	5.003	18.75225	6.25075	0.803	0.403	20.003	1.003	0.103	3.003	0.103
10.004	4.004	5.004	18.753	6.251	0.804	0.404	20.004	1.004	0.104	3.004	0.104
10.005	4.005	5.005	18.75375	6.25125	0.805	0.405	20.005	1.005	0.105	3.005	0.105
10.006	4.006	5.006	18.7545	6.2515	0.806	0.406	20.006	1.006	0.106	3.006	0.106
10.007	4.007	5.007	18.75525	6.25175	0.807	0.407	20.007	1.007	0.107	3.007	0.107
10.008	4.008	5.008	18.756	6.252	0.808	0.408	20.008	1.008	0.108	3.008	0.108
10.009	4.009	5.009	18.75675	6.25225	0.809	0.409	20.009	1.009	0.109	3.009	0.109

One value from each group was selected randomly so that there were three different rows and twelve different columns corresponding to the twelve raw materials, as shown in Table 4.

Table 4. Raw material value selection (in percentage/100 g).

H	A	B	AC	RC	D	G	I	K	E	J	F
16.05	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.25
23.17	16.64	7.47	22.8	7.86	2	0.6	25.4	11.9	0.69	4.85	0.39
27.16	23.96	9.35	25.38	8.68	2.98	0.79	29.9	19.82	0.844	6	0.556

2.3. Generation of the Paint Formulae Population

On the basis of Table 4, the population count consisting of the total possible number of formulae generated by VB programming was 3^{12} = 531,441. As there were 531,441 formulations generated encompassing more than 20,000 sheets/pages on excel programming, ten paint formulae are shown in Table 5 as an illustration of the concept.

Table 5. Population count (in percentage/100 g).

H	A	B	AC	RC	D	G	I	K	E	J	F	Total
16.1	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.25	85.85
16.1	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.39	85.99
16.1	10	5	20	7	0.84	0.52	20	2	0.37	3.82	0.56	86.16
16.1	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.25	86.88
16.1	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.39	87.02
16.1	10	5	20	7	0.84	0.52	20	2	0.37	4.85	0.56	87.19
16.1	10	5	20	7	0.84	0.52	20	2	0.37	6	0.25	88.03
16.1	10	5	20	7	0.84	0.52	20	2	0.37	6	0.39	88.17
16.1	10	5	20	7	0.84	0.52	20	2	0.37	6	0.56	88.34
16.1	10	5	20	7	0.84	0.52	20	2	0.69	3.82	0.25	86.17

2.4. Computation of the Average PVC% for the Population

Before computing the average PVC% for the population, the adjustments were made as per the following formula in every raw material to get a total of 100 in each formula, as shown in Table 6.

$$(\text{value of a raw material})/(\text{total sum of a particular formula}) \times 100 \quad (1)$$

Table 6. Total sum to 100 of population count (in percentage/100 g).

H	A	B	AC	RC	D	G	I	K	E	J	F	Total	PVC%
18.7	11.65	5.82	23.296	8.154	0.98	0.61	23.3	2.33	0.43	4.45	0.29	100	53.38
18.67	11.63	5.82	23.259	8.14	0.98	0.61	23.26	2.33	0.43	4.44	0.45	100	53.38
18.63	11.61	5.8	23.214	8.125	0.98	0.6	23.21	2.32	0.43	4.43	0.65	100	53.38
18.47	11.51	5.76	23.02	8.057	0.97	0.6	23.02	2.3	0.43	5.58	0.29	100	53.38
18.44	11.49	5.75	22.983	8.044	0.97	0.6	22.98	2.3	0.43	5.57	0.45	100	53.38
18.41	11.47	5.74	22.939	8.029	0.96	0.6	22.94	2.29	0.42	5.56	0.64	100	53.38
18.23	11.36	5.68	22.72	7.952	0.95	0.59	22.72	2.27	0.42	6.82	0.28	100	53.38
18.2	11.34	5.67	22.683	7.939	0.95	0.59	22.68	2.27	0.42	6.81	0.44	100	53.38
18.17	11.32	5.66	22.641	7.924	0.95	0.59	22.64	2.26	0.42	6.79	0.63	100	53.38
18.63	11.61	5.8	23.21	8.123	0.98	0.6	23.21	2.32	0.8	4.43	0.29	100	53.38

The PVC% of a system is defined as the volume percentage of solid particles in the system after film formation:

$$\text{PVC\%} = \frac{V_p + V_f}{V_p + V_f + V_b} \times 100\% \quad (2)$$

where V_p = total volume of all pigments in the system; V_f = total volume of all fillers in the system; V_b = volume of the non-volatile part of the binders in the system.

Considering these 531,441 paint formulations as a population, the PVC% and mean PVC% values were computed using the formula given above. The average PVC% for the population was computed as 54.98%.

2.5. Preparation of Sample Paint In a Nano Mill and an Agitator Mill

In order to compare the processing mills, a sample of paint formulation was prepared in nano and agitator mills simultaneously. As an example, the preparation procedure for one formula is given below.

2.5.1. Procedure for the Nano Mill

In the nano mill, the pneumatic pump pressure was adjusted between 0.2 and 0.4 MPa. H, D, and G were placed in the agitated tank of the nano mill mixer and the revolutions per minute (RPM) was adjusted to 500 rpm. A, B, AC, and RC were added into the tank under constant agitation. The dispersion was continued for 5 min at 1000 rpm. The whole material was then shifted to the nano mill grinding chamber which was operated at 2500 rpm. The output of the nano mill was fed to the nano mill mixer, where the remaining raw materials (I, K, E, J, and F) were added successfully under agitation. The whole material was mixed for 5 min at 500 rpm.

2.5.2. Procedure for the Conventional Agitator Mill

In the conventional agitator mill, the process was started by placing H, D, and G in the agitated tank and adjusting the revolutions per minute (RPM) to 500 rpm. A, B, AC, and RC were added into the tank. Dispersion was continued for 15 min at 1400 rpm. The remaining raw materials (I, K, E, J, and F) were added successfully under agitation at 700 rpm. The whole material was mixed for 5 min.

2.6. Selection of Paint Samples for Comparison of Processing Mills

In order to determine the best processing mill, three paint samples were randomly selected and prepared 5 times on each of the two available mills as per the procedure described above. Paints were applied on panel cards to test their gloss using a Tri-Glossmaster, Sheen, London, UK, and their particle size using a Malvern Mastersizer, Malvern Instruments Ltd., Worcestershire, UK.

The results were analyzed using SPSS 22 [52] and are given in Tables 7 and 8.

Table 7. Gloss test analysis results.

Property	Mean Difference	Bootstrap Sample Results			
		Std. Error	*p*-Value	95% Confidence Interval	
				Lower	Upper
Gloss (at 85° angle)	24.92	2.05	0	20.8527	28.8806

Table 8. Particle size analysis results.

Property	Mean Difference	Bootstrap Sample Results			
		Std. Error	*p*-Value	95% Confidence Interval	
				Lower	Upper
Particle size (µm)	4.3393	1.0457	0.001	2.32375	6.38765

The following research hypotheses were to be tested:

- Research hypothesis 1: The average gloss of a given paint is higher when prepared in a nano mill than when prepared in a conventional agitator mill.

- Research hypothesis 2: The average particle size of a given paint is higher when prepared in a conventional agitator mill than when prepared in a nano mill.

Referring to Table 7, the results based on 10,000 bootstrap samples gave a *p*-value less than 0.05. Hence, it was concluded that the average gloss of paint is higher for those prepared in a nano mill than for those prepared in a conventional agitator mill at a 5% level of significance. There is 95% confidence that the mean gloss for nano mill paints is higher by at least 20.85 and at most 28.88 than the mean gloss for conventional agitator mill paints.

Referring to Table 8, the results based on 10,000 bootstrap samples gave a *p*-value less than 0.05. Hence, it was concluded that the average particle size of paint is smaller for paints prepared in a nano mill than for those prepared in a conventional agitator mill at the 5% level of significance. There is 95% confidence that the minimum particle size resulting from a conventional agitator mill exceeds by 2.32 that from a nano mill and that the maximum particle size resulting from a conventional agitator mill exceeds by 6.38 that from a nano mill.

On the basis of the above discussion, it was concluded that the nano mill outperforms the conventional agitator in the preparation of latex façade paint.

2.7. Lab Experimentation and Statistical Analysis to Determine Highly Dirt-Resistant Paint

In order to determine a highly dirt-resistant paint from the target population, due to certain constraints including cost, time, and resources available, a sample of 70 paint formulations (coded Formula 1 to Formula 70) was selected randomly from the given population of 531,441. These paints were prepared in a nano mill to compare the mean Dc values among the paint formulae population. Dirt collective index values (Dc values) were taken according to ASTM D-3719 [53]. The one-way Analysis of Variance (ANOVA) technique was used to compare the differences among the 70 sample paint formulations with respect to average Dc values, as shown in Table 9.

Table 9. ANOVA.

Source	DF	Adj SS	Adj MS	*F*-Value	*p*-Value
Formula	69	5193	75.26	11.00	0.000
Error	630	4310	6.842	–	–
Total	699	9503	–	–	–

Since the *p*-value was less than 0.05, it was concluded that there was a significant difference among the population of paints with respect to mean Dc values at a 5% level of significance, and a hypothesis of equal Dc value means was rejected. In other words, the sample evidence supports the claim that there is a difference between at least two of the paint formulations in the population of paint formulae with respect to average dirt collective index values. Tukey's test was used for the evaluation of significant differences among the mean Dc values.

It was concluded that the mean Dc value of paint formula No. 50 (referred to as the newly developed paint) was significantly the highest among those of all paint formulae. It had an estimated mean Dc value of 95.07. There is 95% confidence that the highest mean Dc value for the population of paint formulae lies in the interval (94.096, 97.345). The paint formulation (Formula 50) with the highest Dc value is given in Table 10.

This formula was then compared under natural weather conditions with the three best conventional paints available in the market in Pakistan.

Table 10. Composition of the newly developed latex paint (in percentage/100 g).

Ingredients	Quantity
H	27.16
D	0.84
G	0.6
A	10
B	5
AC	20
RC	7
I	20
J	6
K	2
E	0.844
F	0.556
Total	100

3. Comparison of the Newly Developed Paint with Conventional Paints under Natural Atmospheric Conditions

Four slabs were painted with the newly developed paint and conventional paints. The slabs were placed in an open area where they were exposed to sunlight and a humid environment. The slabs were placed in external conditions for about one and a half years. Dc readings were taken according to ASTM D-3719 [53] at least every 10 days along with temperature and humidity (Pakistan Meteorological Department).

3.1. Results

The data generated on the newly developed paint and three conventional paints as per the experimentation described above were analyzed using SPSS 22 and Minitab-V-17 [54] and are discussed below. The following notation was used for analysis purposes.

Y = Dirt Collection Index, Dc
X_1 = Number of days
X_2 = Temperature, °C
X_3 = Humidity, %
X_4 = 1, Newly developed paint (NDP); = 0, other paint
X_5 = 1, Conventional paint A (CPA); = 0, other paint
X_6 = 1, Conventional paint B (CPB); = 0, other paint

In the multiple regression model, Y was taken to be the dependent variable while X_1, X_2, X_3, X_4, X_5, and X_6 were taken to be the independent variables.

The results are given below in Tables 11–13.

Table 11. Analysis of variance.

Source	DF	Adj SS	Adj MS	*F*-Value	*p*-Value
Regression	6	768.754	128.126	223.91	0
X_1	1	253.486	253.486	442.99	0
X_2	1	13.068	13.068	22.84	0
X_3	1	0.832	0.832	1.45	0.23
X_4	1	15.14	15.14	26.46	0
X_5	1	7.169	7.169	12.53	0.001
X_6	1	9.149	9.149	15.99	0
Error	113	64.66	0.572	–	–
Total	119	833.414	–	–	–

Table 12. Model Summary.

R^2	R^2 (adj)
92.24%	91.83%

Table 13. Coefficients.

Term	Coef	SE Coef	T-Value	p-Value	VIF
Constant	95.576	0.772	123.77	0.0000	
X_1	−0.01846	0.000877	−21.05	0.0000	2.05
X_2	0.0613	0.0128	4.78	0.0000	2.36
X_3	0.00867	0.00719	1.21	0.23	1.37
X_4	1.005	0.195	5.14	0.0000	1.5
X_5	0.691	0.195	3.54	0.001	1.5
X_6	−0.781	0.195	−4	0.0000	1.5

3.2. Conclusions

Referring to Tables 11–13, it was concluded that for the newly developed paint, the regression model of Dc values with relation to humidity, temperature, and time is significant at a 5% level of significance. The fitted regression model for the newly developed paint is given by

$$Y = 96.581 - 0.018463X_1 + 0.0613X_2 + 0.00867X_3 \quad (3)$$

The regression model given by Equation (3) was used to predict the average dirt resistance of the newly developed paint for given number of days, temperature, and humidity level.

The regression coefficients for dummy variables indicate the mean D_c values for the given paint types. For instance, the average D_c value of the newly developed paint is 1.005 units more than those of conventional paints.

The regression coefficients for X_1, X_2, and X_3 indicate the average rates of change of the Dc value due to a unit change in the respective variable. For instance, there is a decrease of 0.1846 units in the average Dc value of a given paint after every 10 days. An increase of 10 °C in temperature increases the D_c value of a given paint by 0.613 units. An increase in 10 units of the humidity level increases the D_c value of the paint by 0.0867; however, this change is statistically insignificant.

Referring to Table 12, the adjusted R^2 value (R^2 (adj)) indicates the variation in the dependent variable explained by the fitted model for the population. It was concluded that 91.83% of the variation in the Dc value is due to the factors temperature, humidity, and number of days. In other words, the aforementioned atmospheric conditions significantly affect the dirt resistance of a given paint by 91.83%.

In this research, various innovative objectives were targeted and achieved in the context of façade paints. A target population of 513,441 paint formulae was actually generated by using theoretical references and the Visual Basic language. The mean PVC% was determined as 54.98% for the target population, verifying the literature reference [55] in this context. Experimentation to assess the performance of processing mills yielded the nano mill as the best processing mill for paint preparation.

By using random sampling, 70 sample paint formulations were selected for the comparison of paint formulae with the aim of high dirt resistance compared to the average. This yielded a highly dirt-resistant paint, referred to as the newly developed paint, with a true estimate of population mean D_c value as 95.07.

Lab experimentation was conducted again by incorporating statistical theory to compare the newly developed paint with conventional paint samples. The results were statistically analyzed, and it was concluded that the newly developed paint performed better on average than the conventional paints with respect to its dirt resistance properties.

A regression model for the newly developed paint was also developed to study and predict the average Dc value for any given level of temperature and humidity and for a certain time period. It was found that the fitted regression model based on atmospheric and time factors significantly explained the change in the Dc value of a given paint for the population of paints. This model for the newly developed paint is also useful for predicting the average Dc value of the newly developed paint for any given level of temperature and humidity and for a certain time period.

Author Contributions: Conceptualization, S.A.Q.; Methodology, S.A.Q., A.S. and A.I.; Software, S.A.Q. and M.M.B.; Validation, S.A.Q. and M.M.B.; Formal Analysis, S.A.Q. and M.M.B.; Investigation, S.A.Q. and M.M.B.; Resources, S.A.Q. and M.M.B.; Data Curation, S.A.Q. and M.M.B.; Writing—Original Draft Preparation, S.A.Q., A.S. and A.I.; Writing—Review and Editing, S.A.Q., A.S., A.I. and M.M.B.; Visualization, S.A.Q. and M.M.B.; Supervision, A.S., A.I. and M.M.B.; Project Administration, S.A.Q., A.S., A.I. and M.M.B.

Funding: This research received no external funding.

Acknowledgments: The support from Brighto Paints Private Limited Pakistan to conduct this research work is gratefully acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

Notation

A	Magnesium silicate
B	Zinc oxide
AC	Anatase titanium dioxide
RC	Rutile titanium dioxide
D	Dispersant
E	Hydrophobically modified alkali swellable emulsion
F	Mineral hydrocarbons and silicone-based surfactant
G	2-amino-2-methyl-1-propanol
H	Reverse osmosis water
I	Styrene acrylic
J	Propylene glycol
K	Polysiloxane emulsion
DF	Degree of freedom
Adj SS	Adjusted sum of squares
Adj MS	Adjusted mean square
Coef	Coefficient
SE Coef	Standard error of coefficient
VIF	Variance inflation factor

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