The Dyed–Yarn Quantity Estimation for a Cut Pile Carpet: A Case Study

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Abstract

The purpose of this paper is to create an equation that estimates the quantity of dyed-yarn needed for the cut pile carpet tufting process. Based on 2,694 collecting data, found that 75 percent of the orders using the current method were flawed. 45 percent of those errors came from overestimation-resulting in a waste of raw material and increase in inventory level and the 30 percent came from an underestimation-resulting in a raw material shortage. In the latter case, the problem was fixed by bringing in more of the raw material (dyed yarn). However, this affects the factory's capacity and wager cost. In addition, these problems affect the inventory management policy and make for a higher holding cost. In this paper, the CAT data (the difficulty levels of the tufting process) are changed form from a qualitative scale to a quantitative one. The author then created a dyed yarn estimation model where R = 0.734 and tested the equation by collecting the new 100 orders and compared the current method with the new method-finding an 11 percent decrease in the shortage cases (from 19 to 17 cases) and 30 percent decrease in the average return rate of dyed yarn from the processing (from 14 to 9.8 percent). When adjusted the equation with 5 percent tolerance, the number of shortage cases decreased to 9 orders. This resulted in a 53 percent reduction with the average percentage of unused dyed yarn at 14 percent.

Keywords: Cut Pile Carpet, Power Equation, Difficulty Level of the Tufting Process

Introduction

The factory in this case study manufactures both machine-tufted and hand-tufted carpets. Its main product is floor carpet using mainly fiber, backing, second backing and glue. Of all the raw materials used in the carpet industry, fiber or yarn is one of the most critical due to its high cost which accounts for up to 65% of the total raw materials cost. There are 2 types of yarn: raw yarn and color yarn. Color yarn (dyed yarn or raw dyed yarn) is raw yarn which was dyed and then used in

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the tufting process. After the tufting process was done, the leftover yarn is kept in storage for later use. However, when estimating for raw materials order, some extra quantity needs to be ordered as safety stock. Thus, quantity of the leftover yarn accumulates over time causing more raw material and storage expenses. In addition, leftover dyed yarn may be deteriorated and faded, therefore, can not be reused in production and finally thrown away.

There are variety of carpets manufactured by this factory, i.e. cut pile, loop pile, shaggy, and mix carpets. Other elements which make the various types of carpets are, for example, types of fiber, carpet density, difficulty level of the tufting process, fiber weight, and dyed yarn shades, etc. Each types of carpet consume different amount of yarn, therefore, requiring different amount of safety stock. The current calculation method for yarn ordering is shown in equation (1):

$$U = (D \times A) + 0.1(D \times A) \qquad (1)$$

Where

U : Amount of yarn to be dyed (pound)

D : Carpet density (pound per square yard)

A : Area of tufted carpet (square yard)

According to the above equation, the safety stock is 10% for all products, without considering the actual amount required for different types of carpet mentioned above. Considering the preliminary data from dyed-yarn for tufting process of 2,694 times, the data can be categorized into 3 groups: Group A, shortage of dyed-yarn 815 times; Group B, appropriate amount of dyed-yarn 663 times; and Group C, excessive amount of dyed-yarn 1,216 times. Thus, it is obvious that Group C accounts for up to 45% which results in overstock in storage.

Supachai (2004) It is critical to keep an appropriate stock level to ensure there is no shortage of products or raw material for production. On the contrary, an organization should not stock more than necessary because it would become an undesired extra cost. In this case study, the factory also follows such policy by promoting the slogan "too much is better than not enough", allowing the raw material forecast to be 10% extra to prevent stock shortage. This is because when there is stock shortage, there are much more serious consequences, e.g. the production needs to be stopped to wait for the new lot of raw materials, the yarns need to be dyed redundantly, etc. All of these would cause extra in dying, labor, and time costs. Additionally, in order to follow the 10%-safety-stock policy, more stock leftover from production was piling up in storage resulting in high holding cost.

To reduce such cost, this research aims to study various factors affecting dyed-yarn in the tufting process along with to create the dyed-yarn estimation model. The appropriate model which forecast the most accurate estimation would reduce holding cost for stock and products (Chumpol, 2002), as well as prevent raw materials shortage during production.

Cohen (2007) has created a multiple regression and correlation analysis. In addition, he also gave a suggestion on how to create a model for non-linear data.

Porntep (1988) has studied male labor's muscle capacity according to different body proportions, by creating a power equation which estimates the maximum Oxygen consumption (VO_2 max). Factors influencing VO_2 max value in male labor are Oxygen consumption rate, heart rate, and age.

Supawan & Yuthana (2008) has studied and created an estimation model for the paddy's drying process. Factors influencing the drying process are moisture ratio, temperature, and initial moisture.

Marion and Black (1987) have created various mathematic equations, e.g. exponential equation, parabolic equation, power equation to study the impact of time and temperature on Nitrogen on Tundra soil in the Arctic.

Mita and Matsumoto (1981) had studied flow properties of gluten and methyl ester by using basic equations.

Kaliszan et al (2005) had studied the correlations between pig's body temperature and death time by using exponential and power equations.

Power equations are not only widely used in statistics and engineering fields, but they are also used for forecasting economically. Artit, Kallapapruek, & Supachai (2009) had created a linear approximation with LA-AIDS power model to estimate the demand for Thai rice export.

Methodology

Identification and Categorizing Focused Products

As mentioned above, there are varieties of products which can be categorized by raw materials used, tufting style, density, and difficulty level of the tufting process. After considering the data within each category, the result shows that the most used material is wool (68%), while the most popular carpet shade is earth tone (62%). The most popular tufting style is cut pile carpet (55%) and the most used Tex (Weight per length unit) is 380/1. Thus, the samples used to estimate dyed-yarn quantity in this research are earth-tone wool cut pile carpets with Tex 380/1

Data Collection & Analysis

From brainstorming sessions with the production department and from the Cause & Effect Diagram, the result showed that factors influencing the Use Rate (Y), calculated by the quantity of dyed-yarn in 1 square yard, are: Density (D), 15 levels of shade within the earth tone range (S), and 9 levels of difficulty of the tufting process (CAT, C).

However, the levels of shades and levels of difficulty of the tufting process are only code names which are qualitative data and should not be used in the estimation model. Therefore, it is necessary to adjust those data into quantitative ones. As a result, the analyzed factors are Density, adjusted Shade, and adjusted CAT, as shown in Table 1.

Verification of Correlations

All the adjusted factors mentioned were analyzed to verify their correlations (shown in Table 2). The result showed that correlations between each factors are rather low and the distribution of data was exponential. The data was then adjusted to be in natural logarithm (ln) and verified again for the correlations between Density in Natural Logarithm (ln D), Level of Difficulty in Natural Logarithm (ln C), and Shade in Natural Logarithm (ln S), to Actual Dyed-Yarn Used in Natural Logarithm (ln U). The program used for the test was SPSS Version 11.5. Results are shown in Table 3.

According to the correlation test, we have found that the coefficients of all the factors increased, compared to those before data adjustment. Both Density in Natural Logarithm and Level of Difficulty in Natural Logarithm have significant correlations to Quantity of Dyed-Yarn Used in Natural Logarithm. On the contrary, carpet Shade in Natural Logarithm has very small correlation to Quantity of Dyed-Yarn

Used in Natural Logarithm, hence was not included in the estimation model.

Normality Test

The adjusted data was tested in the Normality Assumption Test (Anek, 1998) by plotting between Residual (e_{ij}) and Cumulative Probability Point (P_k). Residual can be derived by deducting the average quantity of dyed-yarn used from Use Rate (Y), whereas Cumulative Probability Point can be derived from equation (2)

$$P_k = \frac{k - \frac{1}{2}}{N} \qquad (2)$$

Where:

k : Order of residual when sorting data ascendingly

N : Total number of residual

Results from the calculation, shown in Figure.2., was 0.939 which is close to 1 and can be concluded that adjusted data from step 2.3 is normally distributed and can be included in the estimation model.

Creating the Estimation Model

The program used in this research was SPSS Version 11.5, which is used to calculate for constants, coefficient of ln D, coefficient of ln C, and correlations (R), as shown in Table 4 and 5, respectively. These calculated values were used to create the estimation model for dyed-yarn needed per 1 square unit, as shown in Equation 3.

$$y = e^{-0.112}\ x\ (Density)^{0.753}\ x\ (CatAdj.)^{0.07} \qquad (3)$$

Where:

y : Quantity of dyed-yarn (pound)

Density : Carpet density (pound per square yard)

CatAdj. : Adjusted difficulty level of tufting process

The estimation model created must be able to give estimate Figureures for actual carpet tufting process, i.e. when order a 1-square-yard carpet with density of 5.5 pound per square yard, at difficulty level 6 (Adjusted CAT of 3.25), we should be able to key-in these Figureures into equation 3 with expected result for quantity of dyed yarn needed at 3.50 pound.

Verification of the Estimation Model

Additional 100 sets of data were collected to be used in various types of yarn calculation methods: (1) Current Method, (2) Using equation $y = e^{-0.112}\ x\ (Density)^{0.753}\ x\ (CatAdj.)^{0.07}$ and increase the tolerance by 1 percent from the yarn quantity estimated from the equation to compares the number of the under-estimate case and average return rate of the various calculation methods. The result was then compared to the actual value and categorized into 3 cases: A) Under-Estimate Case (the estimated value is lower than that of the actual one); B) Acceptation Case (the estimated value equals to that of the actual one or within 10 percent acceptance level); C) Over-Estimate Case (the estimated value is more than 10% higher than that of the actual one). The various methods used are shown in Table 6.

Results

The equation $y = e^{-0.112}\ x\ (Density)^{0.753}\ x\ (CatAdj.)^{0.07}$ was used to estimate the dyed-yarn needed in the case study without adjusting the safety stock in 100 new orders and compared the current method with the new method

(Table 6). The result showed an 11 percent decrease in the shortage cases (from 19 to 17 cases) and 30 percent decrease in the average return rate of dyed-yarn from the process (from 14 to 9.8 percent).

When adjusted the equation with 5 percent tolerance, the number of shortage cases decreased to 9 orders, compared to those of 19 orders from the current method. This resulted in a 53 percent reduction with the average return rate of dyed-yarn at 14 percent.

At 12% tolerance, there was no shortage case. In other words, at 12% tolerance, the factory does not need to order additional dyed-yarn, which helps reduce cost. However, if we consider the leftover yarn from production, the average return rate of daey-yarn was as high as 20 percent compared to that of the current process which is only 14 percent. These leftover yarns will, in time, be difficult for the factory to manage and maintain.

Conclusion and Suggestions

The quantity estimation equation from this research can be applied for the dyed-yarn estimation in the case study, which can reduce the under-estimate cases, from 19 cases to 17 cases (11% reduction). This also helps decrease the average return rate of dyed-yarn by 30 percent, resulting in dye cost and stock management cost reduction.

After 5 percent tolerance adjustment, the shortage case decreased from 19 to only 9 cases (53% reduction). In the meantime, the average return rate was almost equal to that from the factory, which was 14 percent.

In this research, it was necessary to adjust the 9 difficulty levels from qualitative data to be quantitative one. From brainstorming sessions with several yarn calculation specialists, such as yarn calculation section and manager, the score data was collected before creating the estimation equation. However, those data from the sessions might be inaccurate and has an effect on the adjusted data (as shown in Table 1). Therefore, to achieve the most accurate dyed-yarn quantity estimation from the equation, the factory is suggested to thoroughly study and adjust the 9 difficulty levels appropriately.

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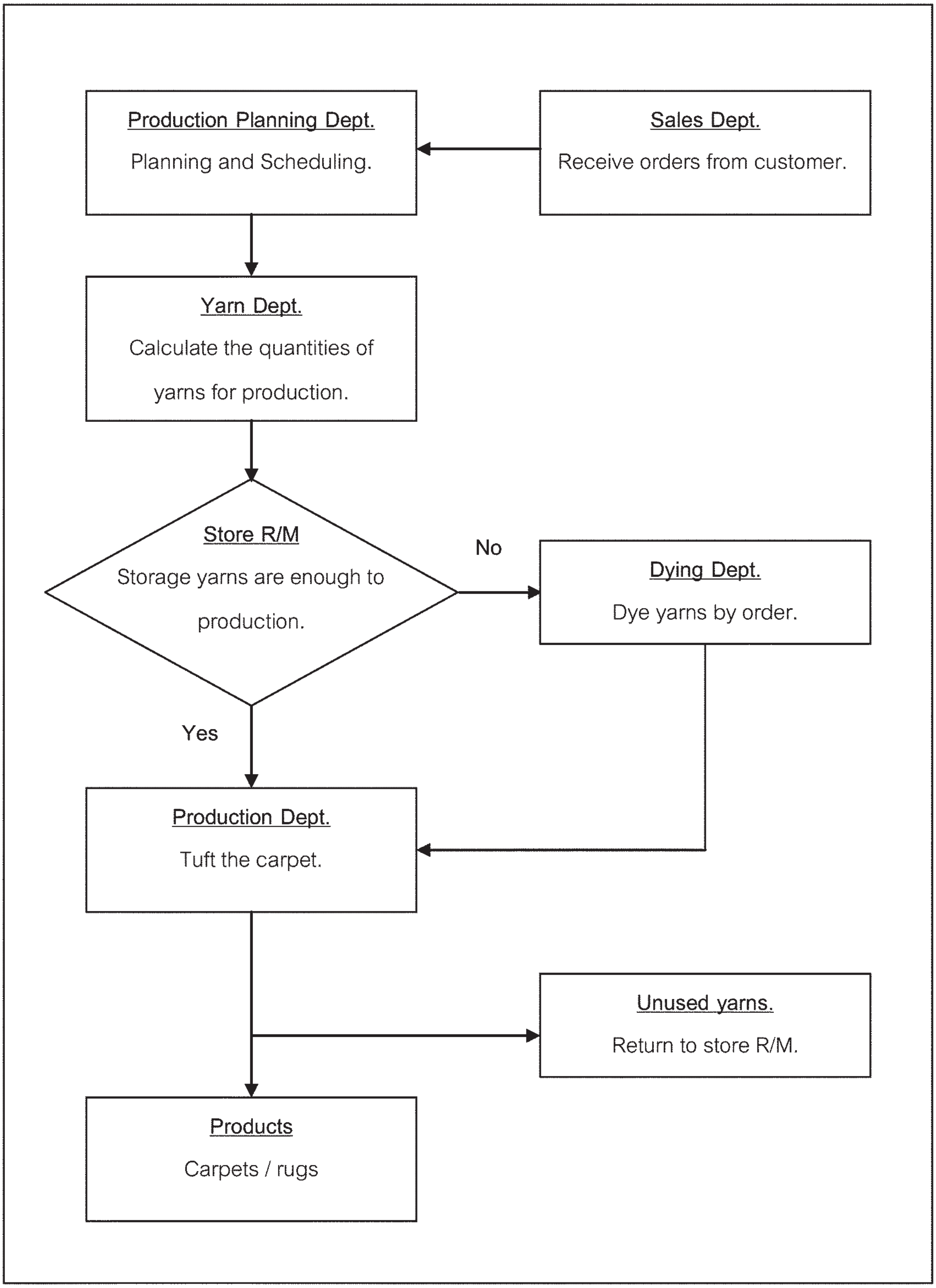

Figure 1. Yarn Flowchart

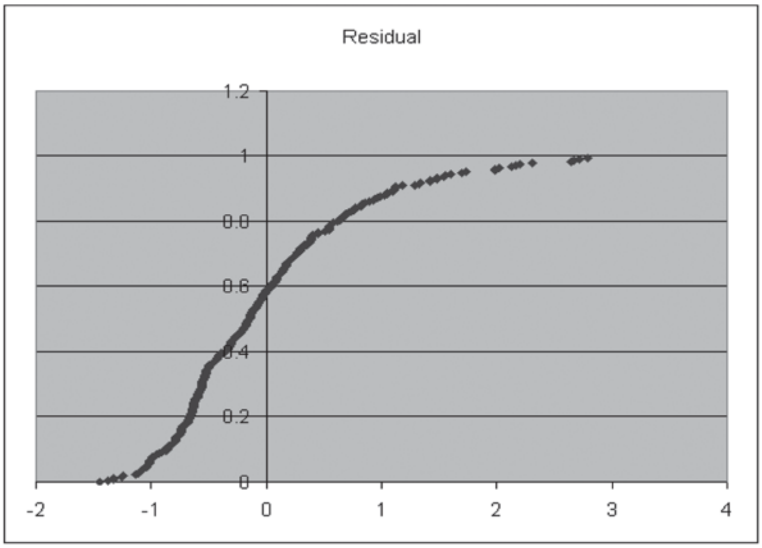

Figure 2. Residual Plot

Table 1. Qualitative Data adjusted into Quanittative Data: Carpet Shade and Level of Difficulty in the Tufting Process

SHADE		DIFFICULTY LEVEL	
Qualitative Data	Quantitative Data	Qualitative Data	Quantitative Data
Shade 01	5.00	CAT 1	1.00
Shade 02	5.00	CAT 2	1.50
Shade 03	4.25	CAT 3	2.00
Shade 04	3.75	CAT 4	2.50
Shade 05	3.50	CAT 5	3.00
Shade 06	3.00	CAT 6	3.25
Shade 07	3.00	CAT 7	4.00
Shade 08	3.00	CAT 8	4.25
Shade 09	3.00	CAT 9	5.00
Shade 10	3.00		
Shade 11	2.75		
Shade 12	1.75		
Shade 13	1.75		
Shade 14	1.00		
Shade 15	1.00		

Table 2. Correlation Test in multi-linear regression form

Correlations

		USERATE	DENSITY	CATADJ	SHADEADJ
USERATE	Pearson Correlation	1	.706**	.176**	-.010
	Sig. (2-tailed)	.	.000	.004	.872
	N	268	268	268	268
DENSITY	Pearson Correlation	.706**	1	.063	-.027
	Sig. (2-tailed)	.000	.	.302	.664
	N	268	268	268	268
CATADJ	Pearson Correlation	.176**	.063	1	-.021
	Sig. (2-tailed)	.004	.302	.	.731
	N	268	268	268	268
SHADEADJ	Pearson Correlation	-.010	-.027	-.021	1
	Sig. (2-tailed)	.872	.664	.731	.
	N	268	268	268	268

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlation Test in Natural Logarithm form

Correlations

		LNU	LND	LNC	LNS
LNU	Pearson Correlation	1	.722**	.203**	.035
	Sig. (2-tailed)	.	.000	.001	.571
	N	268	268	268	268
LND	Pearson Correlation	.722**	1	.101	-.014
	Sig. (2-tailed)	.000	.	.098	.817
	N	268	268	268	268
LNC	Pearson Correlation	.203**	.101	1	-.012
	Sig. (2-tailed)	.001	.098	.	.844
	N	268	268	268	268
LNS	Pearson Correlation	.035	-.014	-.012	1
	Sig. (2-tailed)	.571	.817	.844	.
	N	268	268	268	268

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Calculations of Constant and Coefficients of ln D & ln C

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.112	.075		-1.499	.135
	LND	.753	.045	.709	16.910	.000
	LNC	.070	.022	.132	3.143	.002

a. Dependent Variable: LNU

Table 5. Calculation of Correlations

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.734[a]	.539	.535	.15948403

a. Predictors: (Constant), LNC, LND

Table 6. Comparison between Current Method & Created Equation

Method	Yarn Calculation	Number of Cases				% Reduction of A	Average Return Rate
		A	B	C	Total		
1	Current Method	19	37	44	100	-	14.00%
2	Created Equation	17	42	41	100	11%	9.80%
3	Created Eq. + 2% tolerance	14	34	52	100	26%	11.70%
4	Created Eq. + 3% tolerance	12	31	57	100	37%	12.5%
5	Created Eq. + 4% tolerance	11	25	64	100	42%	13.4%
6	Created Eq. + 5% tolerance	9	24	67	100	53%	14.2%
7	Created Eq. + 6% tolerance	7	16	77	100	63%	17.3%
8	Created Eq. + 7% tolerance	7	9	84	100	63%	18.6%
9	Created Eq. + 8% tolerance	6	9	85	100	68%	19.7%
10	Created Eq. + 9% tolerance	4	10	86	100	79%	20.5%
11	Created Eq. + 10% tolerance	2	12	86	100	89%	21.4%
12	Created Eq. + 11% tolerance	1	11	88	100	95%	22.5%
13	Created Eq. + 12% tolerance	0	14	86	100	100%	20.14%

Note:

A : Under-Estimate Case

B : Acceptation Case

C : Over-Estimate Case