CHAPTER 6

DUPLEX COATED BOARD: RESULTS AND MODELING

This chapter is presented essentially to describe the model for duplex coated board production (DP) for five different basis weights of DP, namely, DP 450, DP 400, DP 350, DP 310, and DP 270. The model has been developed to determine the patterns of variation among the use of material input and utility consumption for DP in order to be able to predict the interrelations among these variables and the resulting wastewater loads.

6.1 Model I: FA Input Model of DP

6.1.1 Correlation Matrix

For DP 450 (Table 6.1), there were poor correlations between most variables. It can be found that the correlated variables have correlation coefficients between |0.30| to |0.67|. The correlation among these variables in this correlation matrix indicated that it was possible to group these variables into the three different groups based on moderate to high degree of correlations. For group I, the moderate degree of correlations between variables in this group (0.67) consisted of water and electricity. For group II, the moderate degree of correlations between variables in this group (-0.68) was composed of A_9 and A_1. For group III, the lower degree of correlations between variables in this group (0.37 to 0.66) consisted of alum-clay-emulsifier, and clay-cato-A_6-color-latex-A_7. Some variables were in ungrouping, namely, A_8, A_5, starch, and other. This indicated low power or usefulness of factor analysis for this set of data that can affect to grouping the less number of variables in factors.

Table 6.1 Correlation Matrix of Material Input of DP 450

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Water	1															
2.Electricity	**0.67**	1														
3. A_6	**0.36**	**0.37**	1													
4. A_7	**0.37**	0.29	**0.43**	1												
5. A_8	0.17	0.22	0.08	0.04	1											
6. A_9	-0.22	-0.25	0.17	0.16	-0.26	1										
7. A_1	**0.47**	**0.37**	0.28	0.23	0.19	**-0.68**	1									
8. A_5	0.19	0.25	0.27	**0.40**	0.07	-0.13	0.11	1								
9.Clay	-0.18	-0.01	0.27	-0.07	0.03	0.08	-0.14	0.01	1							
10.Emulsifier	-0.11	0.12	0.27	-0.12	0.13	0.19	-0.25	0.02	**0.53**	1						
11.Cato	-0.21	0.18	**0.54**	0.09	-0.02	0.01	0.13	0.11	**0.56**	**0.49**	1					
12.Starch	**0.40**	0.26	0.11	0.27	0.05	-0.19	0.29	0.21	**-0.47**	-0.15	-0.14	1				
13.Color	**0.42**	**0.41**	**0.56**	**0.68**	0.04	0.11	0.25	**0.36**	0.03	-0.10	0.22	**0.35**	1			
14.Latex	**0.45**	**0.42**	**0.57**	**0.66**	0.05	0.11	0.26	**0.38**	0.01	-0.12	0.20	**0.36**	**1**	1		
15.Other	-0.01	0.04	0.27	0.11	-0.00	**0.46**	-0.11	-0.04	**-0.32**	0.02	0.07	-0.11	0.11	0.12	1	
16.Alum	-0.08	-0.01	0.17	0.03	0.13	0.17	-0.08	-0.07	**0.55**	**0.3**	0.17	-0.19	0.00	-0.00	-0.09	1

Table 6.2 Correlation Matrix of Material Input of DP 400

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Water	1															
2.Electricity	**0.85**	1														
3. A_6	**0.45**	**0.48**	1													
4. A_7	**0.57**	**0.45**	**0.42**	1												
5. A_8	0.2	0.09	**0.30**	**0.37**	1											
6. A_9	-0.23	-0.14	-0.29	-0.00	-0.02	1										
7. A_1	**0.52**	**0.42**	**0.6**	**0.43**	0.21	**-0.62**	1									
8. A_5	**0.38**	0.16	**0.39**	**0.40**	0.17	**-0.33**	**0.54**	1								
9.Clay	-0.05	-0.04	0.2	-0.04	0.15	-0.03	0.09	0.33	1							
10.Emulsifier	0.06	0.17	0.06	-0.05	-0.07	-0.19	0.14	0.04	0.25	1						
11.Cato	**0.40**	**0.33**	**0.55**	0.16	0.1	-0.25	**0.53**	**0.41**	**0.31**	-0.04	1					
12.Starch	**0.46**	**0.38**	0.09	**0.59**	0.1	-0.08	**0.33**	**0.34**	**-0.45**	0.01	-0.07	1				
13.Color	**0.62**	**0.55**	**0.51**	**0.73**	0.21	-0.2	**0.65**	**0.36**	-0.21	-0.06	0.29	**0.60**	1			
14.Latex	**0.62**	**0.55**	**0.52**	**0.74**	0.23	-0.22	**0.65**	**0.37**	-0.17	-0.06	**0.30**	**0.59**	**0.99**	1		
15.Other	-0.04	0.05	0.08	-0.09	-0.03	0.27	-0.08	0.01	**-0.34**	-0.07	0.01	0.11	0.07	0.06	1	
16.Alum	0.24	0.17	0.15	0.12	0.01	**-0.36**	0.20	0.15	**0.3**	**0.75**	0.08	-0.012	0.07	0.1	-0.13	1

For DP 400 (Table 6.2), the pattern of correlations was clear for only two groups of correlations. For group I, the moderate to high degree of correlations between variables in this group (-0.62 to 0.85) consisted of A_1- A_9, A_1-A_5, A_1-cato, A_1-water-electricity-color-latex, color- A_6, and color-starch- A_7-water. namely, emulsifier - alum, water – electricity, and color-latex. For group II, the moderate degree of correlations between variables in this group (0.75) consisted of emulsifier and alum. Some variables were in ungrouping, namely, A_5, clay, and other.

Table 6.3 Correlation Matrix of Material Input of DP 350

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Water	1															
2.Electricity	**0.66**	1														
3. A_6	**0.66**	**0.57**	1													
4. A_7	**0.30**	0.28	0.28	1												
5. A_8	-0.11	-0.15	-0.10	**-0.39**	1											
6. A_9	0.29	0.02	0.27	0.11	0.05	1										
7. A_1	0.17	0.14	0.23	0.11	-0.05	**-0.71**	1									
8. A_5	0.25	0.18	**0.40**	0.25	-0.1	0.1	0.25	1								
9.Clay	**0.38**	**0.40**	**0.38**	-0.1	0.04	**0.52**	-0.26	0.17	1							
10.Emulsifier	0.12	0.25	0.17	-0.04	0.21	0.18	-0.20	0.05	**0.47**	1						
11.Cato	**0.64**	**0.71**	**0.61**	0.19	-0.18	0.16	0.18	**0.37**	**0.52**	0.07	1					
12.Starch	**0.40**	0.27	0.19	**0.31**	-0.25	-0.22	**0.33**	0.08	-0.28	**-0.30**	0.14	1				
13.Color	**0.57**	**0.57**	**0.58**	**0.57**	-0.11	0.16	0.22	**0.43**	**0.33**	0.22	**0.59**	0.15	1			
14.Latex	**0.55**	**0.54**	**0.56**	**0.58**	-0.12	0.13	0.27	**0.43**	**0.3**	0.20	**0.56**	0.16	**0.99**	1		
15.Other	-0.15	-0.06	0.22	0.03	-0.17	-0.28	**0.36**	0.04	-0.26	0.01	-0.01	-0.26	0.16	0.15	1	
16.Alum	**0.56**	**0.5**	**0.54**	0.20	0.01	**0.39**	-0.03	0.12	**0.67**	0.05	**0.69**	0.01	**0.52**	**0.49**	-0.11	1

For DP 350 (Table 6.3), only one group of clear correlations were found based on the moderate degree of correlations between the variables in this group (-0.71 to 0.69). The correlations of these variables were water-electricity-latex- A_7- color-alum-clay- A_9- A_1, color- A_6-water, A_6-latex, and A_6-electricity. Some variables were in ungrouping, namely, A_8, A_5, emulsifier, starch, and other.

Table 6.4 Correlation Matrix of Material Input of DP 310

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Water	1															
2.Electricity	**0.72**	1														
3. A_6	0.06	0.16	1													
4. A_7	0.07	0.2	**0.61**	1												
5. A_8	0.15	0.08	0.00	-0.2	1											
6. A_9	-0.09	-0.04	0.03	-0.05	0.11	1										
7. A_1	0.08	0.18	**0.37**	**0.38**	-0.07	**-0.60**	1									
8. A_5	-0.04	0.08	0.05	0.05	**-0.31**	0.08	-0.21	1								
9.Clay	0.19	0.29	0.32	0.06	-0.01	**0.45**	-0.1	0.19	1							
10.Emulsifier	-0.12	0.17	0.27	0.04	0.05	**0.51**	**-0.3**	0.28	**0.68**	1						
11.Cato	-0.03	0.19	**0.3**	0.24	0.03	**0.31**	-0.06	-0.10	**0.42**	**0.35**	1					
12.Starch	0.13	-0.11	-0.30	-0.10	0.09	**-0.38**	0.03	-0.21	**-0.59**	**-0.61**	-0.28	1				
13.Color	-0.1	-0.02	**0.33**	-0.13	-0.16	-0.08	0.15	-0.08	0.08	0.08	0.17	-0.1	1			
14.Latex	-0.11	-0.02	**0.3**	-0.12	-0.18	-0.06	0.15	-0.08	0.07	0.08	0.17	-0.09	1	1		
15.Other	-0.1	-0.03	-0.05	-0.013	-0.2	-0.08	0.08	-0.01	-0.02	-0.12	-0.08	-0.17	0.06	0.06	1	
16.Alum	-0.04	0.08	0.2	0.10	-0.17	0.24	0.02	**0.32**	**0.44**	**0.47**	**0.33**	**-0.42**	0.02	0.06	-0.09	1

For DP 310 (Table 6.4), three groups of clear correlations were found based on moderate to high degree of correlations. For group I, the moderate degree of correlations between variables in this group (0.72) consisted of water and electricity. For group II, the moderate degree of correlations between variables in this group (0.61) was composed of A_6 and A_7. For group III, the lower degree of correlations between variables in this group (-0.59 to 0.69) consisted of A_6-A_7, A_6-emulsifier-clay-starch, and emulsifier-starch. Some variables were in ungrouping, namely, A_8, A_5, cato, alum, and other. This indicated low power or usefulness of factor analysis for this set of data that can affect to grouping the less number of variables in factors.

Table 6.5 Correlation Matrix of Material Input of DP 270

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.Mill water	1															
2.Electricity	**0.94**	1														
3. A_6	0.18	0.11	1													
4. A_7	-0.27	**-0.4**	**0.53**	1												
5. A_8	-0.12	0.08	-0.18	-0.18	1											
6. A_9	-0.15	-0.17	**0.37**	**0.35**	0.03	1										
7. A_1	-0.14	-0.24	-0.10	0.13	-0.24	**-0.70**	1									
8. A_5	-0.08	-0.09	-0.02	-0.25	-0.29	0.00	-0.08	1								
9.Clay	0.08	0.15	0.23	0.14	-0.06	**0.43**	-0.17	-0.01	1							
10.Emulsifier	**0.30**	**0.31**	0.26	-0.14	0.19	0.06	0.01	0.03	**0.51**	1						
11.Cato	0.08	0.17	0.12	0.18	0.001	0.19	-0.03	**-0.36**	**0.63**	**0.48**	1					
12.Starch	0.03	0.002	-0.06	0.00	**-0.37**	**-0.39**	**0.35**	-0.08	**-0.49**	**-0.69**	**-0.31**	1				
13.Color	**-0.85**	**-0.85**	-0.15	0.18	-0.13	0.04	**0.37**	-0.04	-0.01	-0.25	0.03	0.17	1			
14.Latex	**-0.86**	**-0.86**	-0.14	0.21	-0.14	0.05	**0.37**	-0.11	-0.03	-0.26	0.00	0.17	0.99	1		
15.Other	**-0.7**	**-0.64**	-0.29	0.13	-0.10	-0.12	0.29	0.27	-0.29	**-0.47**	- 0.11	**0.38**	**0.57**	**0.6**	1	
16.Alum	-0.07	-0.04	-0.21	0.03	- 0.17	0.08	0.08	0.08	0.49	0.07	0.24	-0.22	0.01	0.04	0.3	1

For DP 270 (Table 6.5), four groups of clear correlations based on moderate to high degree of correlations were found. For group I, the moderate to high degree of correlations between variables in this group (-0.85 to 0.99) consisted of water-electricity-latex-other-color-water, color-electricity, and color-latex. For group II, the moderate degree of correlations between variables in this group (0.53) was composed of A_6 and A_7. For group III, the moderate degree of correlations between variables in this group (-0.70) consisted of A_6-A_7. For group IV, the moderate degree of correlations between variables in this group (-0.69 to 0.63) consisted of clay-emulsifier-starch, and clay-cato. Some variables were in ungrouping, namely, A_8, A_5, and alum. This indicated low power or usefulness of factor analysis for this set of data that can affect to grouping the less number of variables in factors.

6.1.2 Factor Matrix and Description of Factor

Based upon the rotated factor matrix obtained with eigenvalues greater than 1 for all of the types of DPs, the result of factor extraction was shown in Table 6.6. It can be found that nine significant factors are extracted for DP 450, DP 400, DP 350 and DP 270 with cumulative percentages of variance of 75.91 %, 82.93 %, 78.67 %, and 90.45 %, respectively. In addition, ten significant factors were extracted for DP 310, with cumulative percentages of variance of 77.34 %. It was found that the numbers of significant factors from rotated factor extraction were more than those from un-rotated factor extraction as shown in Table 6.7. This indicated that the rotated factor extraction can provide the important input variable in each factor, just as not doing FA. This meant that there were the less number of important variables lost from the significant factors. It may affect the building of wastewater load model in the second phase. Therefore, factor loading of rotated factor matrix was used for DP.

Although, the eigenvalues of rotated factors were lower than those of un-rotated factors. However, most of variables can retain in factors as a single variable. This can be more useful for building the predictive model in the second phase. The eigenvalues are mostly in the same range of all of the types of DPs in this study as shown in Table 6.6. The eigenvalues, obtained by summing the squares of variances of each variable associated with a factor, can be said to compare the ability of a factor to explain the variance. The higher the explained variance, the better was the factor in capturing the relationships of the associated variables. The highest eigenvalue would represent the first factor with the highest explained total variance and the lowest total explained variance would represent the last factor. The communality values for all variables in the factors of all DPs were also equal to 1 as in Table 6.6.

This meant that the data set of all of the variables of each of the types of DPs share their variances with all of the factors. Therefore, the factors would be called "common factors" because each of the variables were involved with each of the factors, although they contributed differently to each factor. The factor loadings of all DPs can permit grouping of the variables that were more closely related to each other, but less closely related to other variables in different factors.

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Because the data set of all of the variables of each of the types of DPs shared their variances with all of the factors. Therefore, the factors would be called "common factors" as each of variable was involved with the factors, although they contributed differently to each factor. The factor loadings of all DPs can permit grouping of the variables that were more closely related to each other, but less closely related to other variables in different factors.

Table 6.6 Eigenvalue and Communality values of all DPs

Factors (F)	Eigenvalue and Communality for Variable in Significant Factor									
	DP 450		DP 400		DP 350		DP 310		DP 270	
	Eigen value	Com munali ty	Eigen value	Com munali ty	Eigen value	Com munali ty	Eigen value	Com munali ty	Eigen value	Commu nality
F_1	2.48	1.00	2.93	1.00	2.39	1.00	2.10	1.00	4.18	1.00
F_2	1.68	1.00	1.91	1.00	1.80	1.00	1.75	1.00	1.85	1.00
F_3	1.27	1.00	1.79	1.00	1.78	1.00	1.23	1.00	1.85	1.00
F_4	1.22	1.00	1.31	1.00	1.17	1.00	1.11	1.00	1.17	1.00
F_5	1.21	1.00	1.13	1.00	1.15	1.00	1.06	1.00	1.14	1.00
F_6	1.16	1.00	1.11	1.00	1.12	1.00	1.05	1.00	1.11	1.00
F_7	1.08	1.00	1.08	1.00	1.07	1.00	1.05	1.00	1.09	1.00
F_8	1.03	1.00	1.05	1.00	1.06	1.00	1.03	1.00	1.08	1.00
F_9	1.03	1.00	1.00	1.00	1.05	1.00	1.02	1.00	1.01	1.00
F_{10}	-	-	-	-	-	-	1.01	-	-	-

Table 6.7 Total variance obtained from un-rotated and rotated matrices of DPs

Factors (F)	Percentage of Total Variance Explained for Significant Factors (%)									
	DP 450		DP 400		DP 350		DP 310		DP 270	
	Un-rotate	Rotate	Un-rotate	Rotate	Un-rotate	Rotate	Un-rotate	Rotate	Un-rotate	Rotate
F_1	26.94	15.51	35.22	18.30	34.70	14.91	22.61	13.13	29.67	26.10
F_2	17.18	10.48	15.36	11.92	16.89	11.28	15.38	10.93	18.46	11.56
F_3	12.87	7.86	10.09	11.17	9.90	11.11	13.18	7.66	11.78	11.54
F_4	7.57	7.64	7.52	8.18	8.17	7.33	10.11	6.95	10.51	7.28
F_5	6.47	7.53	7.28	7.04	6.31	7.19	8.33	6.60	10.30	7.11
F_6	-	7.27	6.11	6.94	-	6.99	6.66	6.58	-	6.94
F_7	-	6.76	-	6.74	-	6.68	-	6.46	-	6.82
F_8	-	6.43	-	6.58	-	6.59	-	6.36	-	6.76
F_9	-	6.42	-	6.07	-	6.59	-	6.36	-	6.34
F_{10}	-	-	-	-	-	-	-	6.29	-	-
%Total	71.63	75.91	81.58	82.93	75.97	78.67	76.26	77.34	80.71	90.45

The results of factor loadings from the rotated factor matrix (Table 6.8-6.12) were used to interpret the physical meaning of the factor as discussed the following section.

6.1.2.1 Factor Loading Values

Based upon the cases where eigenvalues were greater than 1, the degree of correlations of all variables associated with each significant factor loadings were presented in Tables 6.8 to 6.12.

It can be seen that the factor loadings of all DPs were between (+1) to (-1). A positive loading indicates a correlation between the variable and the factor in the positive factor axis, and a negative loading indicates that there was a correlation in the negative factor axis. The higher the factor loadings were in absolute terms, the higher were the correlations between the variables and the factors.

If the variables of which factor loadings were higher than 0.5 are selected, it was found that each factor represents different variables or group of variables as shown in Figure 6.1 to 6.3. Notice that most of variables of DPs in the factors appeared however as a single variable. This showed highly degree of independency of variables in factors that may be influenced the predictive purpose of the model for wastewater load in the next part. If the model was specifically sensitive to a single variable in that factor, then, the manufacturers can pay their attention to this variable within that factor not only its function but also its events occurred in the process operation in order to manage their production.

Table 6.8 Factor Loadings of DP 450 Production

Variable	Factor Loadings								
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
1.Water	0.26	0.22	- 0.005	-0.0003	-0.00	0.176	-0.00	0.004	0.007
2.Electricity	0.25	0.19	0.007	0.003	-0.00	0.008	0.009	0.009	0.11
3.A_6	0.40	0.006	0.32	0.18	0.11	0.002	0.153	0.10	0.003
4.A_7	0.49	0.001	0.001	0.005	0.003	0.008	-0.005	0.19	0.002
5.A_8	0.001	0.13	-0.002	0.007	0.007	0.001	0.007	0.003	**0.98**
6.A_9	0.13	-0.81	-0.001	0.32	0.12	-0.006	0.008	-0.12	-0.17
7.A_1	0.15	**0.91**	0.006	0.0001	-0.001	0.112	-0.123	-0.001	0.005
8. A_5	0.21	0.005	0.003	-0.003	-0.004	0.007	0.002	**0.96**	0.003
9. Clay	0.006	-0.01	0.42	-0.34	0.42	-0.41	0.32	0.001	0.008
10.Emulsifier	-0.1	-0.16	0.28	-0.0001	0.15	-0.005	**0.92**	0.002	0.008
11. Cato	0.13	0.007	**0.93**	0.003	0.007	-0.009	0.25	0.0003	-0.004
12. Starch	0.22	0.13	-0.008	-0.007	-0.009	**0.94**	-0.003	0.007	0.001
13. Color	**0.95**	0.003	0.008	0.004	0.001	0.112	-0.004	0.12	0.002
14. Latex	**0.94**	0.002	0.007	0.005	0.001	0.125	-0.005	0.13	0.001
15. Other	0.006	-0.15	0.002	**0.98**	0.005	-0.005	-0.000	-0.003	0.001
16. Alum	0.007	-0.01	0.006	-0.005	**0.98**	-0.008	0.12	-0.004	0.007

Note : Factor loadings of water (0.88) and electricity (0.84) are in F_{10} and F_{11}, respectively.

Table 6.9 Factor Loadings of DP 400 Production

Variable	Factor Loadings								
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
1.Water	0.35	**0.84**	0.006	0.009	0.16	0.18	0.003	-0.005	-0.006
2.Electricity	0.30	**0.90**	0.11	0.003	0.11	-0.004	0.001	0.004	0.001
3.A_6	0.32	0.24	0.004	0.16	0.26	0.12	0.16	0.008	0.13
4.A_7	0.61	0.25	0.001	-0.11	-0.00	0.21	0.23	-0.11	-0.001
5.A_8	0.13	0.002	-0.002	-0.0003	0.002	0.005	**0.98**	-0.002	0.007
6.A_9	-0.008	-0.005	-0.16	**-0.95**	-0.009	-0.13	0.001	0.15	0.004
7.A_1	0.48	0.19	0.009	0.48	0.29	0.23	0.001	-0.003	0.004
8. A_5	0.21	0.007	0.003	0.18	0.18	**0.90**	0.006	0.003	0.19
9. Clay	-0.15	-0.003	0.2	-0.004	0.17	0.21	0.009	-0.22	**0.87**
10.Emulsifier	-0.006	0.006	**0.95**	0.003	-0.004	0.00	-0.005	-0.002	0.008
11. Cato	0.14	0.29	-0.003	0.12	**0.92**	0.16	0.02	0.002	0.15
12. Starch	0.44	0.22	0.001	0.002	-0.11	0.20	0.003	0.005	-0.27
13. Color	**0.92**	0.26	-0.002	0.008	0.009	0.01	0.006	0.003	-0.01
14. Latex	**0.92**	0.26	-0.001	0.11	0.01	0.01	0.009	0.004	-0.006
15. Other	0.003	0.001	-0.004	-0.14	0.002	0.002	-0.002	**0.98**	-0.15
16. Alum	0.006	0.009	**0.89**	0.20	0.003	0.005	0.003	-0.004	0.12

Table 6.10 Factor Loadings of DP 350 Production

Variable	Factor Loadings								
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
1.Water	0.32	-0.005	0.28	0.006	0.29	0.008	-0.009	0.25	-0.004
2.Electricity	0.31	0.006	0.24	0.16	**0.84**	0.003	-0.005	0.12	-0.008
3.A_6	0.30	-0.003	0.29	0.08	0.24	0.22	0.19	0.11	-0.002
4.A_7	0.40	-0.003	0.002	-0.04	0.06	0.008	-0.008	0.14	-0.22
5.A_8	-0.004	-0.001	0.008	0.10	-0.06	-0.004	-0.009	- 0.10	**0.97**
6.A_9	0.01	**-0.89**	0.22	0.005	-0.08	0.009	-0.10	-0.008	0.003
7.A_1	0.17	**0.89**	0.005	-0.12	-0.02	0.153	0.18	0.14	0.002
8. A_5	0.24	0.005	0.003	0.02	0.32	**0.96**	-0.005	0.0009	-0.004
9. Clay	0.15	-0.27	0.60	0.36	0.15	0.01	-0.21	-0.21	-0.004
10.Emulsifier	0.12	-0.11	0.001	**0.96**	0.01	0.001	0.001	-0.13	0.11
11. Cato	0.32	0.003	0.49	-0.001	0.41	0.20	-0.000	0.003	-0.12
12. Starch	0.01	0.20	-0.005	-0.17	0.10	0.002	-0.19	**0.90**	-0.13
13. Color	**0.89**	0.003	0.22	0.01	0.28	0.17	0.008	0.005	-0.002
14. Latex	**0.90**	0.005	0.19	0.01	0.15	0.18	0.007	0.005	-0.003
15. Other	0.11	0.22	-0.008	0.05	-0.04	-0.004	**0.94**	-0.17	-0.01
16. Alum	0.28	-0.14	0.90	-0.004	0.17	-0.006	-0.45	-0.001	0.004

Table 6.11 Factor Loadings of DP 310 Production

Variable	Factor Loadings									
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}
1. Water	-0.07	**0.93**	0.000	-0.009	-0.007	0.0008	-0.004	-0.004	-0.005	0.006
2. Electricity	-0.003	**0.91**	0.009	0.008	0.13	0.0003	0.006	-0.001	0.004	0.003
3. A_6	0.27	0.005	0.49	0.14	0.11	0.007	0.004	0.001	-0.004	0.007
4. A_7	-0.12	0.008	**0.94**	0.003	0.13	0.003	0.002	-0.001	-0.000	-0.13
5. A_8	-0.12	0.008	-0.11	-0.002	0.002	-0.008	-0.16	0.005	-0.10	**0.96**
6. A_9	-0.005	-0.005	-0.000	0.17	0.14	0.009	0.008	**0.88**	-0.004	0.006
7. A_1	0.17	0.008	0.23	0.001	-0.004	0.004	-0.13	-0.32	0.004	-0.002
8. A_5	-0.006	0.002	0.002	0.007	-0.007	0.14	**0.96**	0.001	-0.001	-0.16
9. Clay	0.004	0.19	-0.000	0.29	0.20	0.19	0.008	0.21	-0.000	-0.001
10. Emulsifier	0.006	0.0001	0.003	0.31	0.15	0.22	0.15	0.22	-0.008	0.006
11. Cato	0.12	0.004	0.14	0.009	**0.94**	0.15	-0.01	0.12	-0.004	0.002
12. Starch	-0.005	0.002	-0.005	**-0.90**	-0.01	-0.18	-0.01	-0.15	-0.12	0.003
13. Color	**0.99**	-0.003	-0.005	0.004	0.006	-0.17	-0.003	-0.004	0.002	-0.005
14. Latex	**0.99**	- 0.003	-0.003	0.002	0.005	3.44	-0.003	-0.006	0.003	-0.007
15. Other	0.003	-0.004	-0.001	0.008	-0.003	-0.004	-0.001	-0.003	**0.99**	-0.009
16. Alum	0.001	0.0001	0.003	0.17	0.15	**0.93**	0.15	0.008	-0.006	-0.009

Table 6.12 Factor Loadings of DP 270 Production

Variable	Factor Loadings								
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
1.Water	-0.93	0.002	0.006	0.004	-0.002	-0.13	0.17	0.008	-0.008
2.Electricity	-0.93	-0.003	0.003	0.15	-0.001	-0.26	-0.005	0.007	-0.005
3.A_6	-0.13	0.009	-0.13	0.004	-0.14	0.30	0.11	**0.91**	0.003
4.A_7	0.21	-0.005	-0.006	0.008	0.05	**0.90**	0.008	0.31	-0.15
5.A_8	-0.003	0.19	-0.009	-0.002	-0.08	-0.008	**-0.96**	-0.009	-0.14
6.A_9	0.13	0.14	**-0.89**	0.004	0.08	0.21	0.003	0.20	-0.005
7.A_1	0.003	-0.004	**0.92**	-0.002	0.08	0.11	0.14	0.003	-0.008
8. A_5	-0.003	0.005	-0.005	-0.24	0.31	-0.16	0.18	0.003	**0.88**
9. Clay	-0.22	0.007	-0.20	0.36	0.24	0.004	0.007	0.11	-0.002
10.Emulsifier	-0.002	**0.83**	0.001	0.30	-0.003	-0.14	-0.007	0.21	0.006
11. Cato	0.003	0.23	0.11	**0.91**	0.13	0.007	0.003	0.004	-0.22
12. Starch	0.01	**-0.88**	-0.005	-0.007	-0.14	-0.006	0.21	0.006	-0.004
13. Color	**0.97**	-0.10	0.29	0.006	-0.001	-0.005	0.008	-0.001	-0.006
14. Latex	**0.98**	-0.009	0.11	0.003	0.002	-0.002	0.008	0.0007	-0.005
15. Other	**0.60**	-0.36	0.12	0.005	0.23	0.006	-0.003	-0.13	0.23
16. Alum	0.003	0.007	0.0009	0.13	**0.93**	0.005	0.008	-0.13	0.26

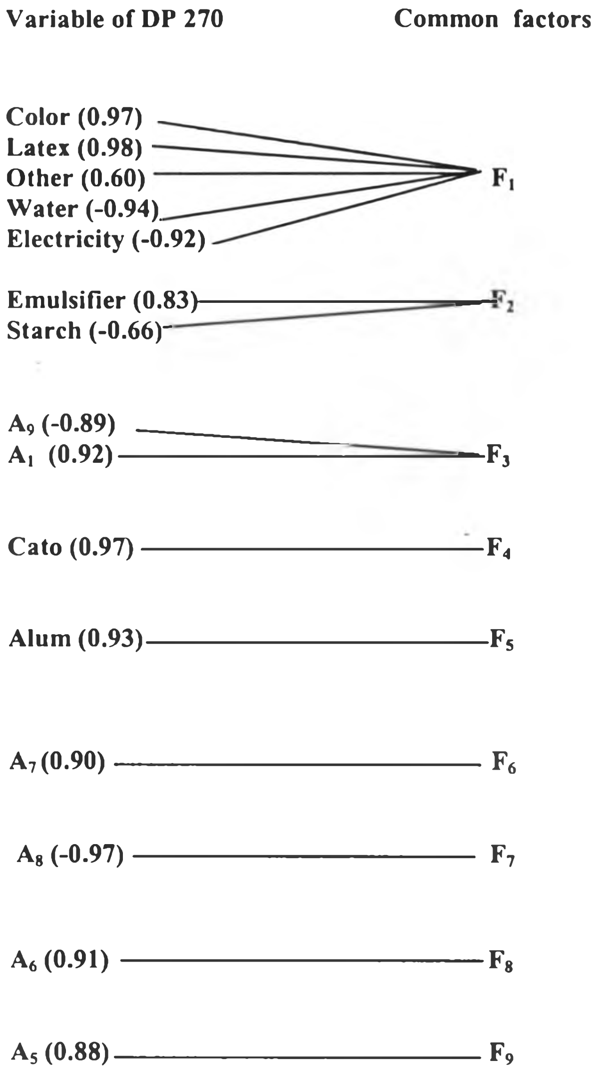
Figure 6.1 Common factors of DP 450 and DP 400 obtained through FA

Variable of DP 450	Common factors	Variables of DP 400
Color (0.95) Latex (0.94)	F_1	Color (0.92) Latex (0.92) A_7 (0.61)
A_9 (-0.81) A_1 (0.91)	F_2	Water (0.88) Electricity (0.90)
Cato (0.93)	F_3	Emulsifier (0.95)
Other (0.98)	F_4	A_9 (-0.95)
Alum (0.98)	F_5	Cato (0.92)
Starch (0.94)	F_6	A_5 (0.90)
Emulsifier (0.92)	F_7	A_8 (0.98)
Clay (0.96)	F_8	Other (0.98)
A_8 (0.98)	F_9	Clay (0.87)

Figure 6.2 Common factors of DP 350 and DP 310 obtained through FA

Variable of DP 350	Common factors	Variables of DP 310
Color (0.89) Latex (0.90)	F_1	Color (0.99) Latex (0.99)
A_9 (-0.89) A_1 (0.89)	F_2	Water (0.93) Electricity (0.91)
Clay (0.60) Alum (0.90)	F_3	A_7 (0.94)
Emulsifier (0.96)	F_4	Starch (-0.91)
Electricity (0.84)	F_5	Cato (0.94)
A_5 (0.96)	F_6	Alum (0.93)
Other (0.94)	F_7	A_5 (0.96)
Starch (0.90)	F_8	A_9 (0.88)
A_8 (0.97)	F_9	Other(0.99)
	F_{10}	A_8 (0.96)

Figure 6.3 Common factors of DP 270 obtained through FA



6.1.2.2 Physical Meaning of Factors

To be useful in understanding the relationships of factors to the actual operation of the paper mill, it is valuable to attempt to describe physical meaning to these abstract terms that are derived from combinations of data. The physical meaning of the factor can be seen as an extract of characteristics of change that are held in common for the variables associated in that factor. Because the number and type of variables grouped into the factors vary from one grade of duplex coated board to another, the physical meaning will thus be discussed for each grade case by case.

6.1.2.2.1 Physical Meaning of DP 450 Production

The relationship between variables and factors of DP 450 can be characterized as follows.

Within the factor F_1, the relationship between the variables (consisting of color and latex) can be explained through their properties and functions in coating preparation. Generally, color is a type of pigment that is mainly made from calcium carbonate and is applied to the surface of the web. It is added in a water suspension with an adhesive, such as, the latex groups to hold the pigment onto the surface of the web. Because the pigment particles are substantially smaller than the fibers, this type of coating can create a surface that is smoother than the uncoated surface and that also has a much finer pore structure. These properties of the surface can help to improve the printing characteristics of the paper web for packaging applications. From higher value of factor loadings, the color and latex are closely related to each other. This is understandable from their purpose of usage.

Within the factor F_2, the relationship between the variables (consisting of A_9, and A_1) can be described based upon their ratios and functions in the production process. Normally, the four layers of fibrous materials (Table 6.13) contain the various types of wastepapers although at different percentages. The first layer is called the "top ply" and consists of long fiber: A_6 and short fiber: A_7 at about a 30 – 40 to 60 -70 mix. The second layer, called the "under top ply" and the third layer, called the "filler ply," consist mainly of A_1/A_9 and other fiber sources such as A_8 and A_4 at a ratio of about 60 : 30 : 10. The fourth layer, the "bottom ply" consists of A_1/A_9 exclusively.

Table 6.13 Type of Wastepaper in the Layer of DPs

1. First layer called "Top ply"; Short fiber(A_7) : Long fiber (A_6) = 60-70 : 30-40
2. Second layer called "Under ply"; Secondary fibers (A_1/A_9: A_8: A_4/ A_5) = 60: 30 :10
3. Third layer called "Filler ply"; Secondary fibers (A_1/A_9: A_8: A_4/ A_5) = 60: 30 :10
4. Fourth layer "Bottom ply"; Old newspaper (A_1/A_9) = 100 %

Note : In real situation, A_4 can substitute for A_5. However, A_4 is excluded in this study.

Notice that in this relationship, the loadings of A_9 (-0.81), and A_1(0.91) is in different direction. Both A_9 and A_1 can substitute for each other.

Within factor F_3, there is a single variable, cato with a high loading (0.93). Based upon the correlation matrix, cato has a low correlation with clay, emulsifier, and A_6 (0.49 to 0.56), as it has different function from these variables. Thus, it remains as a single variable in this factor. Cato, a modified starch used in the form of cationic starch, is added to the stock similar to a retention agent. It influences the retention fines and fillers like clay and emulsifier during web formation.

Within the factor F_4, there is also only a single variable, other (other materials) with a high loading (0.98). Based upon the correlation matrix, the other category also has a correlation with A_9 and clay. However, its correlation coefficient is quite low and could not be extracted, as other has different function from these variables as well. Generally, the function of these other materials is use in the coating operation. They consist of a collection of materials ranging from LPG (Liquid Petroleum Gas) for heating, to lubricants, to polyvinyl alcohol. Without these materials, the coating operation can not be performed, explaining the high loading, however, the individual materials perform different functions and it is not possible therefore to discuss a single physical meaning for this factor.

Within the factor F_5, there is also only a single variable, alum with a high loading (0.98). Based upon the correlation matrix, alum also has a correlation with emulsifier and clay. Although alum and emulsifier should have higher correlation than emulsifier and clay due to their functions, their correlation coefficients are quite low and could not be extracted (0.3 to 0.55). It seems to indicate that alum is not added more due to its presence in white water. Alum is a water solution of aluminum sulfate added as a source of aluminum ions for retaining the rosin size in the paper web. After the emulsifier has been mixed with the fibers, alum is added to the stock until the pH of the stock is lowered to about 4.5-5. Then, the alum flocculates with the rosin size and with itself, creating flocs that adhere to the cellulose fibers because they fibers in water bear an overall negative electrical charge. As a result, the fibers have the ability to bind cations like the rosin-alum and alum flocs. These flocs are water resistant after drying, and help the web resist water penetration. When in the production process, reprocessed like white water is used as another source of materials for the middle and bottom layers of paper, the composition of alum remains sufficient composition. Therefore, it is usually not necessary to add alum more.

Within the factor F_6, there is another a single variable, starch with a high loading (-0.94). Notice that starch has a negative loading. This means that starch is mathematically related to the factor on a negative axis. Based upon the correlation matrix, starch also has a correlation with clay and water (0.40 to (-0.47)). This is possible if starch and clay are used less than usual while water is needed to add more due to the broke usage. Generally, starch can be used as sizing and adhesive during web formation. In the coating application, starch is used for pigmentizing as a pre-coat by adding pigment in the starch, and adding latex in the starch-pigment mixture in order to increase the internal bonding within the system and to tie up the pigment particles more effectively. Pigmentizing, when done with coarse pigments, gives a rough paper surface, which is advantageous for later coating. Such later coating may include addition of a top-coat, that gives better pick strength, more uniformity and better printability.

Within the factor F_7, there is also only a single variable, emulsifier with a high loading (0.92). Based upon the correlation matrix, emulsifier also has a correlation with clay. However, this correlation coefficient is quite low and could not extracted (0.53). This is because both emulsifier and clay are not directly related, but they are related to fibrous materials in wet end operations. Emulsifier or emulsion size, called rosin size, is a natural organic acid obtained from pine trees. In general, emulsifier and alum are added to the wet end operation in order to obtain resistance of the paper to water during web formation. The addition of these chemicals is called internal sizing. As for clay, it is the kaolin crystalline form that influences internal sizing by adsorbing sizing agents onto fibers and also extends the furnish component, reducing the need for some fibers.

Within the factor F_8, there is only a single variable, A_5, that has a high loading (0.96). Despite its correlation with other variable; A_7, A_5 has a low correlation coefficient between pairs of these variables (0.40). Thus, it remains as a single variable in this factor. As A_5 is a type of fibrous materials that is used in the second, third, and bottom layers of paper. It should not much correlated with A_7 because its composition is not in the first layer. It should not much correlated with A_7. In addition, its ratio varies according to the ratio of A_1/A_9 and A_8. In some situations,

A_4 can substitute for A_5, which is of the same type of fibrous material, then, A_5 is not used. However, it excludes in this study.

Within the factor F_9, there is a single variable, A_8 with a high loading (0.98). Usually, A_8 is a secondary fiber used in the second layer with a moderate ratio. Based upon the correlation matrix, A_8 has no correlation with any other variable. Therefore, it is remained as a single variable.

Note that through the pattern of inter-correlation between two variables in common factors of DP 450, some variables with low correlation coefficients were lost from one factor and appear in another factor such as water, emulsifier, and clay. This observation was the result of the pattern of variation in the data set which is used as the fundamental matrix for FA extraction.

6.1.2.2.2 Physical Meaning of DP 400 production

Within the factor F_1, the relationship among the variables (consisting of color, latex, and A_7) can be explained based upon the correlation relationship in the correlation matrix as discussed below.

1. The relationship between latex and color can be explained through the function of latex in the coating operation. Latex, which is a white and fluid liquid composed of polymer particles suspended in an aqueous phase, is used as a coating binder to form a homogeneous polymeric film, particularly at the film press section of the coating machine for the back coat and to wet the pigments in the coating. As for color, it is a kind of pigments that can be dispersed in water and is mainly used in coating. Generally, coating chemicals are used at a constant level. However, in some situations in coating preparation, the clean residuals of the coating chemicals (both color and latex) are recycled for continuing use in preparation. However, in coating application, it is needed to use latex more for binding color due to its usage in the previous application. Therefore, in this case, the pattern of inter-correlation between latex and color is in different direction.

2. The relationships between coating chemicals (color and latex) with a type of fibrous materials (A_7) in the first layer can be explained through their functions in paper production. In general, for all kinds of Duplex coated board, there

are three layers of coating chemicals: 1. Pre-coat, 2. Top coat, and 3. Back coat, and four layers of fibrous materials containing top, second and third layers and bottom layers as shown in Table 6.14. Notice that A_7 is the composition of fibrous materials that attached with coating chemicals in the top coat layer.

Table 6.14 The composition in each layer of DPs

1. Pre-coat; coating chemicals - fine pigment
2. Top coat; coating chemicals - coarse pigment
3. First layer of fibrous material - A_6, A_7 = 30-40 : 60-70
4. Second layer of fibrous material - $A_{1/9} + A_8 + A_{4/5}$ = 60 : 30 :10
5. Third layer of fibrous material – $A_{1/9} + A_8 + A_{4/5}$ = 60 : 30 : 10
6. Fourth layer of fibrous material - $A_{1/9}$ = 100
7. Back coat; coating chemicals – polymer film

Note : In real situation, A_4 can substitute for A_5. However, A_4 is excluded in this study.

Within the factor F_2, the relationship between the variables (consisting of water and electricity) can be described through their functions in the same as described in the case of gypsum product.

Within the factor F_3, the relationship between the variables (consisting of alum and emulsifier) can be described through their functions. Generally, emulsifier and alum are added to the wet end operation in order to obtain resistance of the paper to water during web formation. The addition of these chemicals is called internal sizing that can help the web resist water penetration after drying. Usually, the pattern of inter-correlation between these variables are in the same direction, either decreasing or increasing. However, the characteristic of white water containing different fibrous material and chemicals can affect the change of alum and emulsifier in different direction. In some situation, there are overuse of emulsifier due to the special treatment of product, thus, white water contains sufficient emulsifier but insufficient alum. Thus, it is needed to add alum more.

Within the factor F_4, the relationship between the variables (consisting of A_9, with loading of 0.95 and A_1 with loading of 0.50) can be described based upon their ratios and functions in the production process as mentioned in F_2 of DP 450.

Within factor F_5, there is a single variable, cato with a high loading (0.92). Based upon the correlation matrix, cato has a low correlation with water, electricity, A_6, A_1, A_5, clay and emulsifier (0.31 to 0.55). Thus, it remains as a single variable in this factor. The relationship of cato and this factor can be explained through its function as mentioned in F_3 of DP 450.

Within the factor F_6, there is only a single variable, A_5, that has a high loading (0.90). Despite its correlation with other variable; water, A_6, A_7, A_9, and A_1 has low correlation coefficient between pairs of these variables (-0.33 to 0.54). Thus, it remains as a single variable in this factor. Generally, A_5 is a type of fibrous materials that is used in the second, third, and bottom layers of paper. Its ratio varies according to the ratio of A_1, A_8 and A_4.

Within the factor F_7, there is a single variable, A_8 with a high loading (0.98). Usually, A_8 is a secondary fiber used in the second layer with a moderate ratio. Based upon the correlation matrix, A_8 has a low correlation with A_6, and A_7 (0.30 to 0.37) due to their different functions. A_8 is used in the second and third layers of paper, but A_6 and A_7 are used in the first layer. Thus, it remains as a single variable in this factor.

Within the factor F_8, there is also only a single variable, other (other materials) with a high loading (0.98). Based upon the correlation matrix, the other category also has a low correlation with clay (-0.34) and could not be extracted. As there is usually no relationship between other and clay. Generally, the function of these other materials is use in the coating operation. They consist of a collection of materials ranging from LPG for heating, to lubricants, to polyvinyl alcohol. Without these materials, the coating operation can not be performed.

Within the factor F_9, there is another a single variable, clay with a high loading (0.87). Based upon the correlation matrix, clay has a low correlation with A_5 (0.33). Although clay is related to fibrous materials in wet end operations, there is no directly relationship between clay and A_5. As A_5 is used in the least ratio in the layer of paper. It can be explained the relationship between clay and this factor through its function. Clay, as a kaolin crystalline form, is used to adsorb sizing agents onto fibers and also extends the furnish component, reducing the need for some fibrous materials.

Note that, through the pattern of inter-correlation between two variables in common factors of DP 400, some variables with low correlation coefficients were lost from one factor and appear in another factor, namely, water, A_5, A_6, A_7, and A_9. Also some additional variables should be included in the material input FA model of DP 400, namely, broke, and white water. Addition of these variables could contribute to a greater understanding of the large set of data from the DP 400 production.

Based upon the physical meaning of DP 400, it can be concluded that F_1 to F_9 are quite representative of the original set of data variables. Although there was a lack of a few variables in the FA material input model, it still can be used for further analysis and for developing a predictive model for wastewater from DP 400 production in the next phase of this study.

6.1.2.2.3 Physical Meaning of DP 350 production

The physical meaning of the variables in all significant common factors of DP 350 production were presented as discussed below.

Within the factor F_1, the relationship between variables (consisting of color and latex) can be explained through their functions as mentioned in F_1 of DP 450.

Within the factor F_2, the relationship between variables (consisting of A_9, and A_1) can be explained through their functions as mentioned in F_2 of DP 450.

Within the factor F_3, the relationships between variables (consisting of clay with loading of 0.60 and alum with loading of 0.90) are discussed below.

The relationship between clay and alum can be described through their correlation and function in the wet end operation. Generally, clay is used as a filler to adsorb fines onto the fibers with the addition of alum to lower pH at 4.5-5. Usually, if alum is insufficient added, clay may not be help in retention and formation of paper. The pattern of inter-correlation between clay and alum is in the same direction. However, in some situations, re-circulated water such as white water is used. Then the amount of alum is sufficient, but the amount of clay is insufficient. Thus, the pattern of inter-correlation is in the opposite direction.

Within the factor F_4, there is also only a single variable, emulsifier with a high loading (0.96). Based upon the correlation matrix, emulsifier also has a correlation with clay. However, this correlation coefficient is quite low and could not be extracted (0.47). This is because both emulsifier and clay are not directly related to each other but they are related to fibrous materials.

Within the factor F_5, there is another a single variable, electricity with a high loading (0.84). Based upon the correlation matrix, electricity has quite a medium correlation with water (0.66) but it could not be extracted. This may be the dominance of electricity due to its usage for the reprocessed product can separate it from water during extraction.

Within the factor F_6, there is a single variable: A_5 with a high factor loading (0.96). Based upon the correlation matrix, A_5 also has a low correlation with A_6 (0.40). Thus, it remains as a single variable. Because A_5 and A_6 are components in different layers of paper. This relationship should be low as well.

Within the factor F_7, there is also only a single variable, other (other materials) with a high loading (0.94). Based upon the correlation matrix, the other category also has a low correlation with A_1 (0.36) and could not be extracted. Because other has no directly relationship with A_1.

Within the factor F_8, there is another a single variable, starch with a high loading (0.90). Based upon the correlation matrix, starch also has a correlation with water, A_7, A_1, and emulsifier (0.40 to (-0.30)). Because starch is usually related to cato but it is no directly relationship with other variables.

Within the factor F_9, there is a single variable: A_8 with a low factor loading (0.97). Based upon the correlation matrix, A_8 also has a low correlation with A_7 (-0.39). Because A_8 is used in the second and third layers of paper, but A_7 is used in the first layer. Thus, there is no directly relationship.

It is noted that, through the pattern of inter-correlation between two variables in common factors of DP 350, some variables were lost from one factor and appeared in another factor, namely, A_7, A_1, A_5, A_8, A_9, and clay. Also some variables should be included in the material input FA model of DP 350 to improve its effectiveness, namely, broke, and white water. This would allow the model to use the best information for a deeper understanding of a large set of data from the DP 350 production.

6.1.2.2.4 Physical Meaning of DP 310 production

Within the factor F_1, the relationship between variables (consisting of color and latex) can be explained through their functions as mentioned in F_1 of DP 450.

Within the factor F_2, the relationship between variables (consisting of water, and electricity) can be explained through their functions as mentioned in F_2 of DP 400.

Within the factor F_3, there is a single variable, A_7 ,with a high loading (0.94). Usually, A_7 is a short fiber used in the first layer with high ratio. Based upon the correlation matrix, A_7 has quite a medium correlation with A_6 (0.61), but it could not be extracted. This may be the dominance of A_7 due to its higher ratio than A_6 in the first layer of paper can separate it from A_6 during the extraction.

Within the factor F_4, there is also a single variable, starch with a high loading (-0.90). Notice that starch has a negative loading. This means that starch is mathematically related to the factor on a negative axis. Based upon the correlation matrix, starch also has a correlation with A_6, A_9, and clay (-0.30 to (-0.59)), and quite a medium correlation with emulsifier (-0.61). This is due to there are no directly relationship among these variables.

Within factor F_5, there is a single variable, cato with a high loading (0.94). Based upon the correlation matrix, cato has a low correlation with A_6 , A_9, clay, and emulsifier (0.30 to 0.42). This is also due to there is no directly relationship among these variables. Thus, it remains as a single variable in this factor.

Within the factor F_6, there is also only a single variable, alum with a high loading (0.93). Based upon the correlation matrix, alum also has a correlation with A_5, clay, emulsifier, cato and starch. However, their correlation coefficients are quite low and could not be extracted (-0.42 to 0.47). This is because alum is usually related to emulsifier, but it may be not to be added due to the use of white water more than usual. Thus, it remains as a single variable.

Within the factor F_7, there is only a single variable, A_5, that has a high loading (0.99). Despite its correlation with other variable; A_8 has low correlation coefficient between pairs of these variables (-0.31). This is possible due to their different ratios in the same layers as shown in Table 6.12.

Within the factor F_8, there is only a single variable, A_9, that has a high loading (0.88). Based upon the correlation matrix, A_9 has no correlation with any other variable. However, the factor loading value of A_9 can be explained by its relation in production. A_9 is a composition of fibrous materials in the middle and bottom layers of paper. If A_9 is used in the highest ratio, another fiber, A_1 is not used in its ratio. Thus, it remains as a single variable in this factor.

Within the factor F_9, there is also only a single variable, other (other materials) with a high loading (0.98). Based upon the correlation matrix, the other category has no correlation with any other variable.

Within the factor F_{10}, there is a single variable, A_8, with a high loading (0.96). Usually, A_8 is a secondary fiber used in the second layer with a moderate ratio. Based upon the correlation matrix, A_8 has also no correlation with any other variable.

Note that data variability of DP 310 that was paper grade between the high basis weight and the lowest basis weight, was widest. This may affect the extraction of these factors. Also note that, through the pattern of inter-correlation between two variables in common factors of DP 310, some variables were lost from the factors.

6.1.4.2.5 Physical Meaning of DP 270 production

Within the factor F_1, the relationships among the variables in this factor (consisting of water, electricity, color, latex, and other) can be described as the following. Generally, coating chemicals contain three groups of materials; 1.Color or pigment; calcium carbonate, 2. Latex (binder), and 3. "Other" (other materials) that are used for coating such as lubricants that are used to help the flow of the coating chemicals in the pipe system and liquid petroleum gas that is used as fuel for infrared drying. Coating application plays a major role for the lowest basis weight grade or the thinnest paper like DP 270. Higher levels of coating chemicals are needed to increase the coated weight and to minimize the loss of fibers from their layers because the layer of fibers is thin when it is made. Therefore, the use of these other materials are also high. The pattern of inter-correlation between these variables is in the same direction. However, in some situations, this pattern is in the opposite direction. If there are some leaks and spillages during coating preparation and application, "other" is not consumed but coating chemicals still must be added due to their losses in these operations.

The relationship among coating chemicals, water and electricity can be found in the step of coating preparation and application. In these steps, water and electricity are consumed for mixing and transport these substances through the process system. Changes of water use affects the change of electricity in the same direction. In some situations, cleaning residual of coating chemicals from coating preparation can be recycled for usage. In such cases, electricity is more consumed than water. Thus, the pattern of inter-correlation between water and electricity is in a different direction.

Within the factor F_2, the relationship between emulsifier and starch can be explained through their functions. In general, emulsifier is used to help fiber for its retention and formation, while starch is essentially used for coating preparation of coated paperboard after its formation. In some situations, re-circulated water such as white water is used as a water source for the starch-pigment mixture. Both starch and emulsifier are present in the white water in sufficient amounts. Thus, it is unnecessary to add more.

Within the factor F_3, the relationship between variables (consisting of A_9, and A_1) can be explained through their functions as mentioned in F_2 of DP 450.

Within the factor F_4, there is a single variable, cato with a high loading (0.91). Based upon the correlation matrix, cato has low correlation with A_5 and clay (-0.36 to 0.48), and quite a medium correlation with emulsifier (0.63). This may be the dominance of cato due to special treatment of product can separate it from other variables during the factor extraction. Thus, it remains as a single variable.

Within the factor F_5, there is also only a single variable, alum with a high loading (0.93). Based upon the correlation matrix, alum has a low correlation with clay. However, their correlation coefficients are quite low and could not extracted (0.49). This is because alum has no directly relationship with clay in the wet end operations.

Within the factor F_6, there is a single variable, A_7, with a high loading (0.90). Usually, A_7 is a short fiber used in the first layer with highly ratio. Based upon the correlation matrix, A_7 has a correlation with electricity and A_6 (-0.40 to 0.53). This situation can occur when broke is used as the middle and bottom layers of paper and electricity is more consumed. In addition, A_7 has higher ratio than A_6 in the first layer of paper. Thus, A_7 is dominant and remains as a single variable.

Within the factor F_7, there is a single variable, A_8 with a high loading (-0.96). Notice that A_8 has a negative loading. This means that A_8 is mathematically related to the factor on a negative axis. Usually, A_8 is a secondary fiber used in the second layer with a moderate ratio. Based upon the correlation matrix, A_8 has also no correlation with any other variable.

Within the factor F_8, there is a single variable, A_6 with a high loading (0.91). Usually, A_6 is a long fiber used in the first layer with a moderate ratio. Based upon the correlation matrix, A_6 has no correlation with any other variable.

Within the factor F_9, there is only a single variable, A_5, that has a high loading (0.88). Despite its correlation with other variable; A_5 has a low correlation coefficient with A_8 (-0.30). This is because A_5 is used as the lowest ratio in the same layers of A_8 as shown in Table 6.12. Thus, it remains as a single variable.

Note that, through the pattern of inter-correlation between two variables in common factors of DP 270, some variables were lost from one factor and appear in another factor, namely, A_5, A_7, A_8, clay, emulsifier, cato, and starch. The explanation of the phenomena by the model could be enhanced if information about additional variables could be included in the material input FA model for DP 270, namely, broke and white water.

6.1.3 FA Equation of DPs

The final factor scores model of material input and utility consumption for each of DP 450, DP 400, DP 350, DP 310, and DP 270 was dependent on the same variables for each of the individual models, although they each have different score coefficients (Table 6.15-6.19)

It was found that all of the significant factors depend on 16 variables: water, electricity, A_6, A_7, A_8, A_9, A_1, A_5, clay, cato, color, latex, "other" and alum in the standardized form for all DPs. The factor score values for all DPs varied with the value of variables, used as standardized variables, in each observation.

6.1.4 Factor Scores

From the factor score equation, the factor score matrices of all DPs were obtained (Appendix A) and were graphically displayed for some factors that relate to wastewater model as shown in Figures 6.9 to 6.18. The factor scores showed the degree to which each case or observation scores high on the group of variables that have a high association to a factor. These scores explained the conditions of material input and utility consumption for production of all of the DPs. The higher scores meant higher use of these raw materials and higher resource consumption. The lower scores meant lower levels of these types of consumption. The patterns of the score levels for material input conditions of all of the varieties of DPs were discussed in the following section. Also some factors that relate to wastewater model were discussed in the following sections.

Table 6.15 FA Input Model of DP 450

Duplex Coated Board	FA Model
1. DP 450	1. $F_1 = -0.07\ Z_1 - 0.13\ Z_2 - 0.14\ Z_3 - 0.19\ Z_4 - 0.01\ Z_5 - 0.05\ Z_6 + 0.03\ Z_7 - 0.1\ Z_8 - 0.03\ Z_9 + 0.14\ Z_{10} - 0.1\ Z_{11} - 0.15\ Z_{12} + 0.69\ Z_{13} + 0.68\ Z_{14} - 0.03\ Z_{15} - 0.004\ Z_{16}$ 2. $F_2 = -0.12\ Z_1 - 0.12\ Z_2 - 0.07\ Z_3 + 0.01\ Z_4 - 0.14\ Z_5 - 0.49\ Z_6 + 0.83\ Z_7 - 0.02\ Z_8 + 0.03\ Z_9 + 0.21\ Z_{10} - 0.14\ Z_{11} - 0.09\ Z_{12} + 0.04\ Z_{13} + 0.04\ Z_{14} + 0.18\ Z_{15} + 0.05\ Z_{16}$ 3. $F_3 = 0.12\ Z_1 - 0.04\ Z_2 - 0.22\ Z_3 + 0.01\ Z_4 + 0.1\ Z_5 + 0.09\ Z_6 - 0.13\ Z_7 - 0.01\ Z_8 - 0.04\ Z_9 - 0.34\ Z_{10} + 1.32\ Z_{11} + 0.12\ Z_{12} - 0.09\ Z_{13} - 0.08\ Z_{14} - 0.04\ Z_{15} - 0.01\ Z_{16}$ 4. $F_4 = 0.02\ Z_1 - 0.05\ Z_2 - 0.16\ Z_3 - 0.02\ Z_4 - 0.04\ Z_5 - 0.1\ Z_6 + 0.13\ Z_7 + 0.04\ Z_8 + 0.1\ Z_9 + 0.03\ Z_{10} - 0.03\ Z_{11} + 0.1\ Z_{12} - 0.02\ Z_{13} - 0.02\ Z_{14} + 1.14\ Z_{15} + 0.08\ Z_{16}$ 5. $F_5 = 0.02\ Z_1 + 0.003\ Z_2 - 0.06\ Z_3 - 0.04\ Z_4 - 0.08\ Z_5 - 0.04 Z_6 + 0.03\ Z_7 + 0.06\ Z_8 - 0.04\ Z_9 - 0.1\ Z_{10} - 0.01\ Z_{11} + 0.07\ Z_{12} - 0.03\ Z_{13} -0.004\ Z_{14} + 0.08\ Z_{15} +1.09\ Z_{16}$ 6. $F_6 = -0.11\ Z_1 - 0.01\ Z_2 - 0.01\ Z_3 - 0.02\ Z_4 + 0.01\ Z_5 + 0.05\ Z_6 - 0.07\ Z_7 -0.04\ Z_8 + 0.08\ Z_9 - 0.05\ Z_{10} + 0.11\ Z_{11} + 1.19\ Z_{12} - 0.13\ Z_{13} - 0.13\ Z_{14} + 0.11\ Z_{15} + 0.08\ Z_{16}$ 7. $F_7 = 0.02\ Z_1 - 0.15\ Z_2 - 0.11\ Z_3 + 0.05\ Z_4 - 0.13\ Z_5 - 0.13\ Z_6 + 0.19\ Z_7 - 0.05\ Z_8 - 0.07\ Z_9 + 1.32\ Z_{10} - 0.35\ Z_{11} - 0.06\ Z_{12} + 0.13\ Z_{13} +0.13\ Z_{14} + 0.03\ Z_{15} - 0.12\ Z_{16}$ 8. $F_8 = 0.04\ Z_1 - 0.06\ Z_2 - 0.05\ Z_3 - 0.13\ Z_4 - 0.02\ Z_5 + 0.03\ Z_6 - 0.01\ Z_7 +1.11\ Z_8 - 0.002\ Z_9 - 0.04\ Z_{10} - 0.01\ Z_{11} - 0.03\ Z_{12} - 0.08\ Z_{13} - 0.08\ Z_{14} + 0.05\ Z_{15} + 0.06\ Z_{16}$ 9. $F_9 = -0.02\ Z_1 - 0.06\ Z_2 - 0.000\ Z_3 - 0.004\ Z_4 + 1.06\ Z_5 + 0.08\ Z_6 - 0.1\ Z_7 -0.02\ Z_8 - 0.002\ Z_9 - 0.10\ Z_{10} + 0.08\ Z_{11} + 0.01\ Z_{12} - 0.002\ Z_{13} - 0.003\ Z_{14} - 0.04\ Z_{15} - 0.08\ Z_{16}$

Note : Z_1 = water, Z_2 = electricity, $Z_3 = A_6$, $Z_4 = A_7$, $Z_5 = A_8$, $Z_6 = A_9$, $Z_7 = A_1$, $Z_8 = A_5$, Z_9 = clay, Z_{10} = emulsifier, Z_{11} = cato, Z_{12} = starch, Z_{13} = color, Z_{14} = latex, Z_{15} = other, Z_{16} = alum.

Table 6.16 FA Input Model of DP 400

Duplex Coated Board	FA Model
2. DP 400	1. F_1 = -0.11 Z_1 – 0.17 Z_2 – 0.15 Z_3 – 0.03 Z_4 – 0.07 Z_5 + 0.04 Z_6 - 0.07 Z_7 - 0.06 Z_8 + 0.11 Z_9 + 0.05 Z_{10} – 0.06 Z_{11} - 0.17 Z_{12} + 0.71 Z_{13} + 0.71 Z_{14} - 0.02 Z_{15} + 0.001 Z_{16} 2. F_2 = 0.58 Z_1 + 0.79 Z_2 – 0.12 Z_3 - 0.08 Z_4 + 0.04 Z_5 – 0.004 Z_6 - 0.03 Z_7 +0.04 Z_8 + 0.02 Z_9 - 0.08 Z_{10} – 0.15 Z_{11} – 0.12 Z_{12} – 0.15 Z_{13} - 0.15 Z_{14} + 0.02 Z_{15} - 0.06 Z_{16} 3. F_3 = -0.05 Z_1 – 0.07 Z_2 – 0.002 Z_3 - 0.001 Z_4 + 0.03 Z_5 + 0.13 Z_6 – 0.04 Z_7 + 0.04 Z_8 – 0.16 Z_9 + 0.68 Z_{10} + 0.07 Z_{11} - 0.04 Z_{12} + 0.03 Z_{13} + 0.03 Z_{14} – 0.02 Z_{15} + 0.48 Z_{16} 4. F_4 = 0.01 Z_1 + 0.00 Z_2 – 0.13 Z_3 + 0.13 Z_4 + 0.01 Z_5 – 1.26 Z_6 - 0.06 Z_7 - 0.22 Z_8 + 0.22 Z_9 - 0.1 Z_{10} – 0.06 Z_{11} + 0.04 Z_{12} – 0.03 Z_{13} – 0.03 Z_{14} + 0.27 Z_{15} - 0.14 Z_{16} 5. F_5 = -0.11 Z_1 - 0.13 Z_2 – 0.18 Z_3 + 0.04 Z_4 + 0.04 Z_5 + 0.07 Z_6 - 0.09 Z_7 - 0.16 Z_8 – 0.15 Z_9 + 0.08 Z_{10} + 1.3 Z_{11} + 0.14 Z_{12} – 0.04 Z_{13} – 0.04 Z_{14} - 0.05 Z_{15} + 0.05 Z_{16} 6. F_6 = 0.01 Z_1 + 0.05 Z_2 – 0.02 Z_3 – 0.13 Z_4 – 0.01 Z_5 + 0.26 Z_6 – 0.08 Z_7 + 1.41 Z_8 – 0.43 Z_9 + 0.05 Z_{10} – 0.17 Z_{11} – 0.32 Z_{12} – 0.04 Z_{13} – 0.04 Z_{14} – 0.17 Z_{15} + 0.03 Z_{16} 7. F_7 = 0.01 Z_1 + 0.03 Z_2 – 0.1 Z_3 – 0.09 Z_4 + 1.07 Z_5 - 0.01 Z_6 – 0.03 Z_7 + 0.00 Z_8 – 0.09 Z_9 + 0.03 Z_{10} + 0.03 Z_{11} – 0.02 Z_{12} - 0.04 Z_{13} - 0.04 Z_{14} + 0.001 Z_{15} + 0.02 Z_{16} 8.F_8 = 0.02 Z_1 + 0.01 Z_2 - 0.12 Z_3 + 0.1 Z_4+ 0.001 Z_5 – 0.24 Z_6 + 0.01 Z_7 - 0.13 Z_8 + 0.27 Z_9 - 0.02 Z_{10} – 0.04 Z_{11} + 0.01 Z_{12} – 0.01 Z_{13} – 0.01 Z_{14} + 1.15 Z_{15} - 0.03 Z_{16} 9. F_9 = 0.03 Z_1 + 0.003 Z_2 – 0.16 Z_3 + 0.05 Z_4 – 0.13 Z_5 – 0.28 Z_6 + 0.001 Z_7 - 0.47 Z_8 + 1.57 Z_9 - 0.19 Z_{10} – 0.17 Z_{11} + 0.39 Z_{12} + 0.1 Z_{13} + 0.09 Z_{14} + 0.39 Z_{15} - 0.17 Z_{16}

Note : Z_1 = water, Z_2 = electricity, Z_3 = A_6, Z_4 = A_7, Z_5 = A_8, Z_6 = A_9, Z_7 = A_1, Z_8 = A_5, Z_9 = clay, Z_{10} = emulsifier, Z_{11} = cato, Z_{12} = starch, Z_{13} = color, Z_{14} = latex, Z_{15} = other, Z_{16} = alum.

Table 6.17 FA Input Model of DP 350

Duplex Coated Board	FA Model
3. DP 350	1. $F_1 = -0.11 Z_1 - 0.13 Z_2 - 0.03 Z_3 - 0.33 Z_4 - 0.07 Z_5 + 0.02 Z_6 - 0.06 Z_7 - 0.2 Z_8 - 0.08 Z_9 - 0.12 Z_{10} - 0.08 Z_{11} - 0.04 Z_{12} + 0.76 Z_{13} + 0.78 Z_{14} - 0.17 Z_{15} - 0.18 Z_{16}$
	2. $F_2 = 0.05 Z_1 - 0.09 Z_2 + 0.06 Z_3 + 0.06 Z_4 - 0.05 Z_5 - 0.64 Z_6 + 0.64 Z_7 - 0.05 Z_8 + 0.05 Z_9 + 0.09 Z_{10} - 0.02 Z_{11} - 0.19 Z_{12} - 0.04 Z_{13} - 0.04 Z_{14} - 0.22 Z_{15} + 0.1 Z_{16}$
	3. $F_3 = -0.13 Z_1 - 0.12 Z_2 - 0.2 Z_3 + 0.001 Z_4 - 0.07 Z_5 - 0.11 Z_6 + 0.1 Z_7 + 0.13 Z_8 + 0.11 Z_9 + 0.14 Z_{10} - 0.1 Z_{11} + 0.15 Z_{12} - 0.17 Z_{13} - 0.18 Z_{14} + 0.13 Z_{15} + 1.35 Z_{16}$
	4. $F_4 = -0.4 Z_1 - 0.16 Z_2 - 0.04 Z_3 + 0.03 Z_4 - 0.12 Z_5 - 0.06 Z_6 + 0.07 Z_7 + 0.01 Z_8 - 0.05 Z_9 + 1.16 Z_{10} + 0.05 Z_{11} + 0.17 Z_{12} - 0.08 Z_{13} - 0.08 Z_{14} - 0.01 Z_{15} + 0.11 Z_{16}$
	5. $F_5 = -0.19 Z_1 + 1.54 Z_2 - 0.19 Z_3 - 0.01 Z_4 + 0.11 Z_5 + 0.13 Z_6 - 0.07 Z_7 + 0.12 Z_8 - 0.06 Z_9 - 0.24 Z_{10} - 0.17 Z_{11} - 0.11 Z_{12} - 0.14 Z_{13} - 0.14 Z_{14} + 0.13 Z_{15} - 0.13 Z_{16}$
	6. $F_6 = 0.01 Z_1 + 0.08 Z_2 - 0.16 Z_3 - 0.03 Z_4 + 0.04 Z_5 + 0.03 Z_6 - 0.04 Z_7 + 1.16 Z_8 - 0.01 Z_9 + 0.01 Z_{10} - 0.08 Z_{11} + 0.05 Z_{12} - 0.14 Z_{13} - 0.14 Z_{14} + 0.1 Z_{15} + 0.10 Z_{16}$
	7. $F_7 = 0.07 Z_1 + 0.09 Z_2 - 0.27 Z_3 + 0.06 Z_4 + 0.2 Z_5 + 0.18 Z_6 - 0.18 Z_7$ $0.1 Z_8 + 0.12 Z_9 - 0.01 Z_{10} + 0.02 Z_{11} + 0.34 Z_{12} - 0.2 Z_{13} - 0.12 Z_{14} + 1.32 Z_{15} + 0.1 Z_{16}$
	8. $F_8 = -0.22 Z_1 - 0.08 Z_2 - 0.16 Z_3 - 0.11 Z_4 + 0.16 Z_5 + 0.17 Z_6 - 0.17 Z_7 + 0.06 Z_8 + 0.12 Z_9 + 0.20 Z_{10} + 0.03 Z_{11} + 1.41 Z_{12} - 0.03 Z_{13} - 0.03 Z_{14} + 0.38 Z_{15} + 0.13 Z_{16}$
	9. $F_4 = 0.01 Z_1 + 0.07 Z_2 - 0.05 Z_3 + 0.22 Z_4 + 1.14 Z_5 + 0.03 Z_6 - 0.03 Z_7 + 0.04 Z_8 + 0.05 Z_9 - 0.12 Z_{10} + 0.07 Z_{11} + 0.13 Z_{12} - 0.05 Z_{13} - 0.05 Z_{14} + 0.18 Z_{15} - 0.04 Z_{16}$

Note : Z_1 = water, Z_2 = electricity, $Z_3 = A_6$, $Z_4 = A_7$, $Z_5 = A_8$, $Z_6 = A_9$, $Z_7 = A_1$, $Z_8 = A_5$, Z_9 = clay, Z_{10} = emulsifier, Z_{11} = cato, Z_{12} = starch, Z_{13} = color, Z_{14} = latex, Z_{15} = other, Z_{16} = alum.

Table 6.18 FA Input Model of DP 310

Duplex Coated Board	FA Model
4. DP 310	1. $F_1 = 0.02 Z_1 + 0.01 Z_2 - 0.13 Z_3 + 0.15 Z_4 + 0.11 Z_5 + 0.02 Z_6 - 0.05 Z_7 + 0.04 Z_8 + 0.02 Z_9 - 0.03 Z_{10} - 0.08 Z_{11} + 0.01 Z_{12} + 0.55 Z_{13} + 0.55 Z_{14} - 0.02 Z_{15} + 0.01 Z_{16}$ 2. $F_2 = 0.6 Z_1 + 0.54 Z_2 + 0.001 Z_3 - 0.06 Z_4 - 0.07 Z_5 + 0.05 Z_6 - 0.03 Z_7 - 0.02 Z_8 - 0.14 Z_9 + 0.03 Z_{10} - 0.02 Z_{11} - 0.04 Z_{12} + 0.02 Z_{13} + 0.02 Z_{14} + 0.02 Z_{15} + 0.01 Z_{16}$ 3. $F_3 = -0.05 Z_1 - 0.06 Z_2 - 0.33 Z_3 + 1.37 Z_4 + 0.24 Z_5 - 0.07 Z_6 - 0.25 Z_7 - 0.02 Z_8 + 0.14 Z_9 - 0.04 Z_{10} - 0.2 Z_{11} - 0.003 Z_{12} + 0.16 Z_{13} + 0.16 Z_{14} + 0.01 Z_{15} + 0.04 Z_{16}$ 4. $F_4 = 0.05 Z_1 + 0.02 Z_2 - 0.07 Z_3 + 0.003 Z_4 + 0.03 Z_5 - 0.16 Z_6 - 0.1 Z_7 - 0.06 Z_8 - 0.21 Z_9 - 0.23 Z_{10} - 0.03 Z_{11} - 1.35 Z_{12} - 0.01 Z_{13} - 0.01 Z_{14} - 0.19 Z_{15} - 0.13 Z_{16}$ 5. $F_5 = 0.01 Z_1 - 0.03 Z_2 - 0.02 Z_3 - 0.19 Z_4 - 0.04 Z_5 - 0.07 Z_6 + 0.1 Z_7 + 0.16 Z_8 - 0.15 Z_9 - 0.03 Z_{10} + 1.2 Z_{11} + 0.02 Z_{12} - 0.08 Z_{13} - 0.08 Z_{14} + 0.03 Z_{15} - 0.16 Z_{16}$ 6. $F_6 = 0.001 Z_1 + 0.02 Z_2 + 0.001 Z_3 + 0.04 Z_4 + 0.11 Z_5 - 0.07 Z_6 - 0.14 Z_7 - 0.17 Z_8 - 0.08 Z_9 - 0.13 Z_{10} - 0.17 Z_{11} + 0.12 Z_{12} + 0.02 Z_{13} + 0.02 Z_{14} + 0.08 Z_{15} + 1.22 Z_{16}$ 7. $F_7 = -0.01 Z_1 - 0.03 Z_2 - 0.05 Z_3 - 0.02 Z_4 + 0.19 Z_5 + 0.07 Z_6 + 0.17 Z_7 + 1.2 Z_8 - 0.04 Z_9 - 0.08 Z_{10} + 0.15 Z_{11} + 0.05 Z_{12} + 0.04 Z_{13} + 0.04 Z_{14} + 0.02 Z_{15} - 0.16 Z_{16}$ 8. $F_8 = 0.06 Z_1 + 0.04 Z_2 - 0.02 Z_3 - 0.1 Z_4 - 0.09 Z_5 + 1.44 Z_6 + 0.53 Z_7 + 0.1 Z_8 - 0.2 Z_9 - 0.08 Z_{10} - 0.08 Z_{11} + 0.17 Z_{12} + 0.02 Z_{13} + 0.02 Z_{14} + 0.03 Z_{15} - 0.09 Z_{16}$ 9. $F_9 = 0.02 Z_1 + 0.01 Z_2 + 0.02 Z_3 + 0.01 Z_4 + 0.1 Z_5 + 0.03 Z_6 - 0.02 Z_7 + 0.02 Z_8 - 0.02 Z_9 + 0.07 Z_{10} + 0.03 Z_{11} + 0.14 Z_{12} - 0.01 Z_{13} - 0.01 Z_{14} + 1.05 Z_{15} + 0.07 Z_{16}$ 10. $F_{10} = -0.06 Z_1 - 0.05 Z_2 - 0.12 Z_3 + 0.22 Z_4 + 1.16 Z_5 - 0.07 Z_6 - 0.03 Z_7 + 0.19 Z_8 + 0.05 Z_9 - 0.09 Z_{10} - 0.03 Z_{11} - 0.02 Z_{12} + 0.10 Z_{13} + 0.01 Z_{14} + 0.11 Z_{15} + 0.1 Z_{16}$

Note : Z_1 = water, Z_2 = electricity, $Z_3 = A_6$, $Z_4 = A_7$, $Z_5 = A_8$, $Z_6 = A_9$, $Z_7 = A_1$, $Z_8 = A_5$, Z_9 = clay, Z_{10} = emulsifier, Z_{11} = cato, Z_{12} = starch, Z_{13} = color, Z_{14} = latex, Z_{15} = other, Z_{16} = alum.

Table 6.19 FA Input Model of DP 270

Duplex Coated Board	FA Model
5. DP 270	1. $F_1 = -0.27 Z_1 - 0.25 Z_2 + 0.08 Z_3 - 0.11 Z_4 + 0.01 Z_5 - 0.004 Z_6 - 0.04 Z_7 - 0.2 Z_8 - 0.03 Z_9 + 0.03 Z_{10} + 0.02 Z_{11} + 0.02 Z_{12} - 0.01 Z_{13} + 0.31 Z_{14} - 0.06 Z_{15} + 0.04 Z_{16}$ 2. $F_2 = -0.01 Z_1 + 0.01 Z_2 - 0.06 Z_3 + 0.02 Z_4 - 0.3 Z_5 - 0.04 Z_6 + 0.03 Z_7 - 0.23 Z_8 - 0.16 Z_9 + 0.64 Z_{10} - 0.29 Z_{11} - 0.85 Z_{12} + 0.02 Z_{13} + 0.02 Z_{14} + 0.16 Z_{15} - 0.02 Z_{16}$ 3. $F_3 = 0.01 Z_1 + 0.01 Z_2 + 0.07 Z_3 + 0.05 Z_4 + 0.1 Z_5 - 0.54 Z_6 + 0.64 Z_7 + 0.08 Z_8 + 0.11 Z_9 - 0.01 Z_{10} + 0.02 Z_{11} - 0.04 Z_{12} - 0.03 Z_{13} - 0.03 Z_{14} - 0.03 Z_{15} - 0.05 Z_{16}$ 4. $F_4 = -0.01 Z_1 - 0.03 Z_2 - 0.06 Z_3 + 0.02 Z_4 + 0.18 Z_5 + 0.01 Z_6 + 0.03 Z_7 + 0.54 Z_8 - 0.31 Z_9 - 0.19 Z_{10} + 1.5 Z_{11} + 0.23 Z_{12} + 0.01 Z_{13} + 0.01 Z_{14} - 0.18 Z_{15} - 0.24 Z_{16}$ 5. $F_5 = -0.04 Z_1 - 0.03 Z_2 + 0.35 Z_3 - 0.25 Z_4 + 0.01 Z_5 + 0.02 Z_6 - 0.06 Z_7 - 0.52 Z_8 - 0.06 Z_9 - 0.52 Z_{10} - 0.27 Z_{11} + 0.02 Z_{12} + 0.04 Z_{13} + 0.03 Z_{14} - 0.09 Z_{15} + 1.45 Z_{16}$ 6. $F_6 = 0.1 Z_1 + 0.08 Z_2 - 0.57 Z_3 + 1.44 Z_4 + 0.12 Z_5 - 0.04 Z_6 + 0.03 Z_7 + 0.4 Z_8 + 0.04 Z_9 + 0.04 Z_{10} + 0.02 Z_{11} + 0.003 Z_{12} - 0.1 Z_{13} - 0.08 Z_{14} - 0.08 Z_{15} - 0.3 Z_{16}$ 7. $F_7 = -0.01 Z_1 + 0.02 Z_2 - 0.09 Z_3 - 0.2 Z_4 - 1.21 Z_5 + 0.05 Z_6 - 0.09 Z_7 - 0.3 Z_8 - 0.08 Z_9 + 0.17 Z_{10} - 0.15 Z_{11} - 0.21 Z_{12} - 0.01 Z_{13} - 0.01 Z_{14} + 0.09 Z_{15} - 0.01 Z_{16}$ 8. $F_8 = -0.07 Z_1 - 0.06 Z_2 + 1.43 Z_3 - 0.55 Z_4 + 0.1 Z_5 - 0.06 Z_6 + 0.05 Z_7 - 0.27 Z_8 - 0.12 Z_9 - 0.06 Z_{10} - 0.06 Z_{11} + 0.02 Z_{12} + 0.06 Z_{13} + 0.06 Z_{14} + 0.07 Z_{15} + 0.37 Z_{16}$ 9. $F_9 = 0.03 Z_1 + 0.01 Z_2 - 0.29 Z_3 + 0.42 Z_4 + 0.38 Z_5 - 0.04 Z_6 + 0.10 Z_7 + 1.70 Z_8 + 0.05 Z_9 - 0.18 Z_{10} + 0.59 Z_{11} + 0.21 Z_{12} - 0.01 Z_{13} - 0.01 Z_{14} - 0.22 Z_{15} - 0.62 Z_{16}$

Note : Z_1 = water, Z_2 = electricity, $Z_3 = A_6$, $Z_4 = A_7$, $Z_5 = A_8$, $Z_6 = A_9$, $Z_7 = A_1$, $Z_8 = A_5$, Z_9 = clay, Z_{10} = emulsifier, Z_{11} = cato, Z_{12} = starch, Z_{13} = color, Z_{14} = latex, Z_{15} = other, Z_{16} = alum.

6.1.3.1 Factor Scores of DP 450

In order to move toward the building of a predictive model using MRA, it was necessary to convert to a different form the information about the relationships of the variables to the factors. This new type of information was called "factor score". The details of the mathematical conversion were already presented in this dissertation and only significant factors that relate to wastewater load will be mentioned.

For the factor score in F_1 of DP 450 (-2.78 to 3.06), the variation within this factor score was well balanced in both positive and negative directions as shown in Figure 6.4.

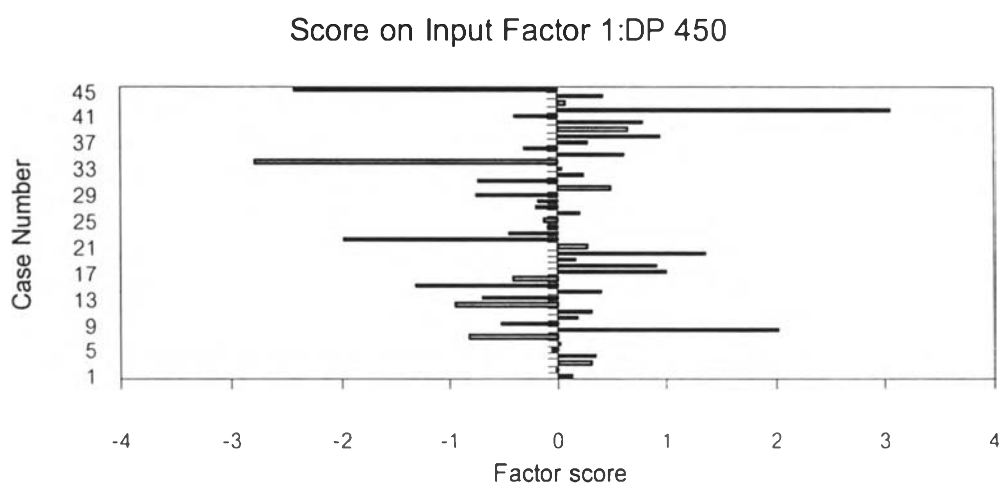


Figure 6.4 Factor Scores of DP 450 for F_1

Table 6.20 Cases of Highly Magnitude of Factor Score for F_1 of DP 450

Input Variables	Case Number				
	8	22	34	42	45
1. Water	-0.40	0.25	0.49	**5.62**	**1.56**
2. Electricity	-0.36	-0.90	-0.27	**4.44**	**0.37**
3. A_6	0.87	-1.22	-0.45	**3.04**	-0.83
4. A_7	1.74	-0.92	-1.14	**3.51**	**-1.14**
5. A_8	0.16	-0.85	0.79	**1.42**	-0.85
6. A_9	0.30	-1.16	-1.16	-1.16	-1.16
7. A_1	0.93	0.78	-0.01	**3.25**	**2.02**
8. A_5	2.46	-0.86	-0.86	**1.91**	**-0.58**
9.Clay	1.40	-0.65	-1.06	-1.06	-1.06
10.Emulsifier	-0.69	-0.69	-0.69	-0.69	-0.69
11.Cato	1.02	-1.33	-1.36	0.43	-0.46
12.Starch	0.45	-1.32	0.61	**2.37**	**0.42**
13.Color	**2.25**	**-2.12**	**-2.40**	**4.08**	**-2.03**
14.Latex	**2.29**	**-2.06**	**-2.30**	**4.17**	**-1.94**
15.Other	-0.11	-0.64	-0.51	0.68	-0.57
16.Alum	0.23	-0.51	-0.51	-0.51	-0.51
F_1	2.02	-1.97	-2.79	3.06	-2.42

Based upon the cases of highly magnitude of F_1, it is found in Table 6.20 that these unusual cases were due to the large changes of coating chemicals (color and latex) from different events occurred in the process. In case # 42, the large consumption of water and electricity indicates that it was used in unusually operation due to the occurrence of broke and increased use of broke resulting some wastepapers and chemicals increase. Thus, not only wastepapers used for the top layer (A_6 and A_7) increase but also some types of wastepapers used in the middle and bottom layers increase was clearly found associated with some starch and coating chemicals. In case # 8, 22, 34 and 45, the large changes of coating chemicals indicated the variation of coating operation due to the broke usage. It should be appropriated to name F_1 as "variations of broke generation and usage and variations of coating chemicals".

For factor scores in F_2 of DP 450 (-1.89 to 2.01), the variation of this factor score was also well balanced in both the positive and negative directions as in Figure 6.5.

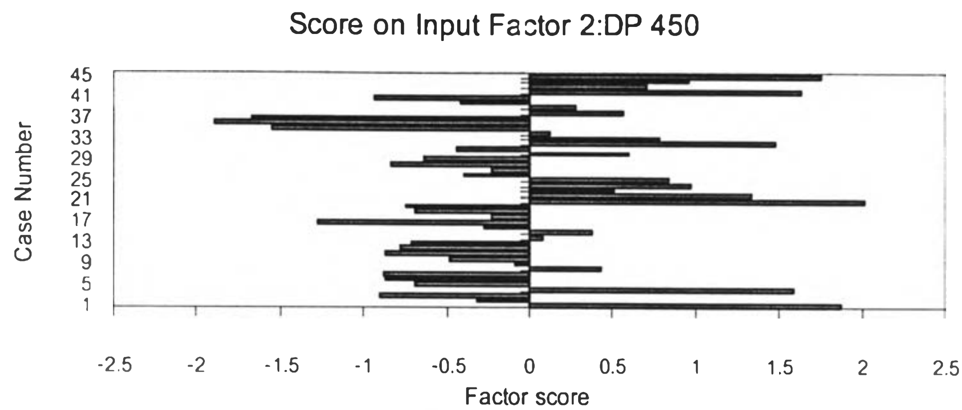


Figure 6.5 Factor Scores of DP 450 for F_2

Table 6.21 Cases of Highly Magnitude of Factor Score for F_2 of DP 450

Input Variables	Case Number			
	1	21	36	45
1. Water	-0.64	-0.07	-0.07	1.56
2. Electricity	-0.50	-0.53	-0.28	0.37
3. A_6	0.71	-0.06	-0.83	-0.83
4. A_7	-0.47	-0.03	1.08	-1.14
5. A_8	-0.73	-0.85	-0.85	-0.85
6. A_9	-1.16	-1.10	**1.82**	-1.16
7. A_1	**1.37**	**1.67**	-1.24	**2.02**
8. A_5	-0.03	-0.86	0.52	-0.58
9.Clay	0.75	0.81	-1.05	-1.06
10.Emulsifier	0.68	-0.69	-0.69	-0.69
11.Cato	1.28	-0.22	-0.95	-0.46
12.Starch	-0.71	-0.58	0.76	0.42
13.Color	-0.10	0.00	-0.01	-2.03
14.Latex	-0.09	-0.00	-0.01	-1.94
15.Other	-0.39	-0.64	-0.28	-0.57
16.Alum	0.24	0.53	-0.51	-0.51
F_2	1.87	2.01	-1.89	1.75

Based upon the cases of highly magnitude of F_2, it was found in Table 6.21 that these unusual cases were due to the large change of A_1 and A_9. While, there were no large changes of water and electricity from the use of broke more than usual. Thus, the variation of these types of wastepapers was due to the inconsistent usage of wastepapers (A_1 and A_9). It should be then named F_2 as "inconsistent usage of wastepapers (A_1 and A_9)".

For factor scores in F_3 of DP 450 (-1.07 to 2.71), the results indicate that there was variation of factor scores in this factor as shown in Figure 6.6.

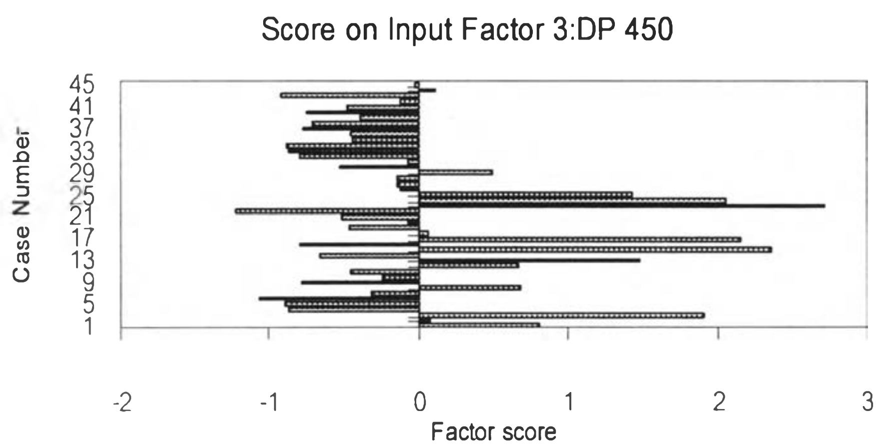


Figure 6.6 Factor Scores of DP 450 for F_3

Based upon the cases of highly magnitude of F_3, it is found in Table 6.22 that these unusual cases were due to the large change of cato. There were no large changes of water and electricity from the broke usage more than usual. Thus, the large change of cato indicated that there was requirement to treat the product for binding property. Thus, it should be appropriated to name F_3 as "special treatment of product for binding property".

Table 6.22 Cases of Highly Magnitude of Factor Score for F_3 of DP 450

Input Variables	Case Number				
	3	15	17	23	24
1. Water	-0.72	-0.72	0.66	-0.24	-0.56
2. Electricity	-0.22	0.93	0.56	-0.13	-0.19
3. A_6	0.71	-0.06	1.87	-0.06	-0.06
4. A_7	-0.25	0.41	-1.58	-1.58	1.96
5. A_8	-0.85	0.92	0.16	-0.22	-0.85
6. A_9	0.74	-0.94	0.56	-0.83	-0.35
7. A_1	-0.50	0.14	-1.19	0.63	0.73
8. A_5	-0.86	2.46	-0.86	-0.58	-0.86
9.Clay	0.55	0.48	-1.58	0.84	0.97
10.Emulsifier	-0.69	1.97	2.87	-0.69	0.85
11.Cato	**1.50**	**2.36**	**2.59**	**1.96**	**2.03**
12.Starch	-0.55	-0.74	0.12	0.40	-0.44
13.Color	0.31	-0.85	0.67	-0.38	0.28
14.Latex	0.29	-0.79	0.75	-0.40	-0.13
15.Other	-0.39	-0.36	0.01	-0.31	-0.29
16.Alum	0.26	-0.51	-0.51	0.28	0.62
F_3	1.90	2.36	2.15	2.71	2.05

For factor scores in F_4 of DP 450 (-0.75 to 4.29), it is seen from Figure 6.7 that the values of factor score in this factor were quite consistent, except for some usual cases (case # 26 to 29).

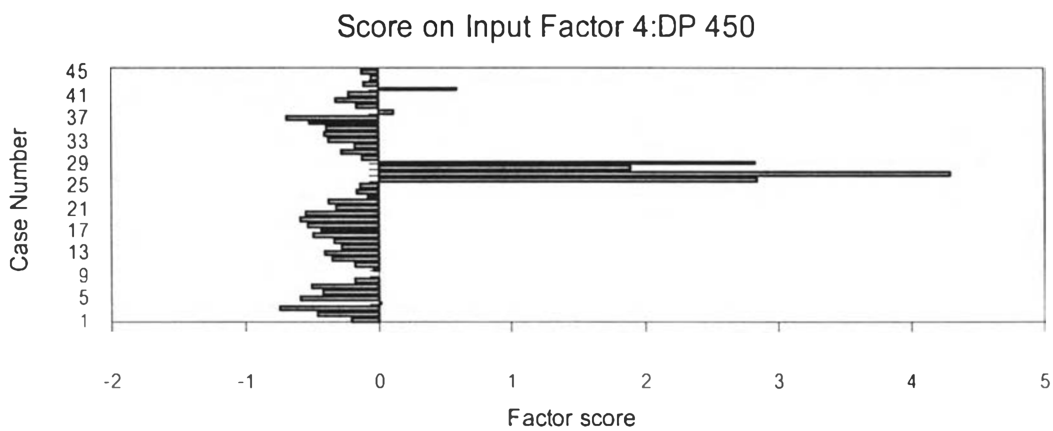


Figure 6.7 Factor Scores of DP 450 for F_4

Table 6.23 Cases of Highly Magnitude of Factor Score for F_4 of DP 450

Input Variables	Case Number		
	26	27	29
1. Water	-0.48	-0.56	-0.72
2. Electricity	-0.50	-0.16	-0.51
3. A_6	0.33	-0.06	-0.06
4. A_7	-0.25	0.19	-0.25
5. A_8	-0.35	-0.48	1.04
6. A_9	1.39	1.55	1.33
7. A_1	-0.55	-0.60	-0.40
8. A_5	-0.86	-0.44	-0.28
9.Clay	-1.06	- 1.06	-1.06
10.Emulsifier	-0.19	0.15	0.04
11.Cato	- 0.00	0.02	0.12
12.Starch	-1.58	-1.58	0.69
13.Color	-0.10	-0.26	-0.56
14.Latex	-0.02	-0.30	-0.52
15.Other	**3.00**	**4.22**	**2.74**
16.Alum	-0.51	-0.51	-0.51
F_4	2.85	4.29	2.84

Based upon the cases of highly magnitude of F_4, it is found in Table 6.23 that these unusual cases were due to the large changes of variables in the group name “other”. While the small change of water and electricity was also found for other; other materials that were used for coating in F_4. It should then be appropriated to name F_4 as “special treatment of product using other for coating”.

For factor scores in F_5 of DP 450 (-1.1 to 5.08), it is seen that the values of factor score in F_5 were quite consistent with the occurrence of some unusual case as shown in Figure 6.8.

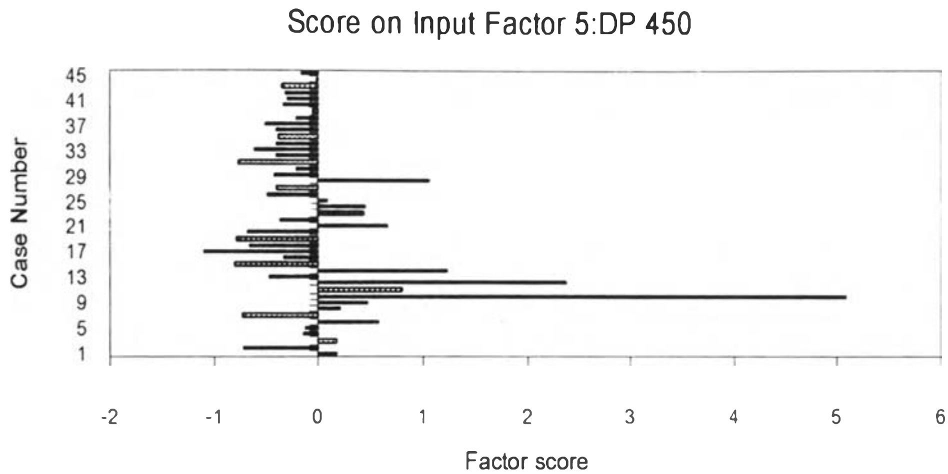


Figure 6.8 Factor Scores of DP 450 for F_5

Table 6.24 Cases of Highly Magnitude of Factor Score for F_5 of DP 450

Input Variables	Case Number	
	10	12
1. Water	-0.07	-0.07
2. Electricity	0.08	-0.07
3. A_6	0.33	0.33
4. A_7	-0.25	0.41
5. A_8	-0.85	3.32
6. A_9	1.06	0.63
7. A_1	-0.65	-0.35
8. A_5	-0.86	0.25
9.Clay	1.67	1.53
10.Emulsifier	1.15	1.06
11.Cato	0.20	0.55
12.Starch	-0.21	-0.84
13.Color	-0.00	-0.70
14.Latex	0.08	-0.66
15.Other	-0.30	-0.34
16.Alum	**4.92**	**2.71**
F_5	5.08	2.37

Based upon the cases of highly magnitude of F_5, it is found from Table 6.24 that these unusual cases were due to the large change of alum. While there was the large change of emulsifier, there were small changes of water and electricity.

It indicates that there was special requirement to treat product for paper information increase. Thus, it should be named F_5 as "special treatment of product for paper formation.

In conclusion, the significance factor scores for DP 450 production can be named as shown in Table 6.25.

Table 6.25 The Name of Significant Factors of DP 450

Significant Factor	Name
F_1	Variations of broke generation and usage and variations of coating chemicals
F_2	Inconsistent usage of wastepapers (A_1 and A_9)
F_3	Special treatment of product for binding property
F_4	Special treatment of product for coating
F_5	Special treatment of product for paper formation

Overall, the factor scores of DP 450 represented the combination of factors extracted and the events occurred indicated the production was so complex and all variables were somewhat independent.

6.1.3.2 Factor Scores of DP 400

For factor scores in F_1 of DP 400 (-2.37 to 3.17), it can be seen from Figure 6.9 that the variation of factor scores was quite balanced.

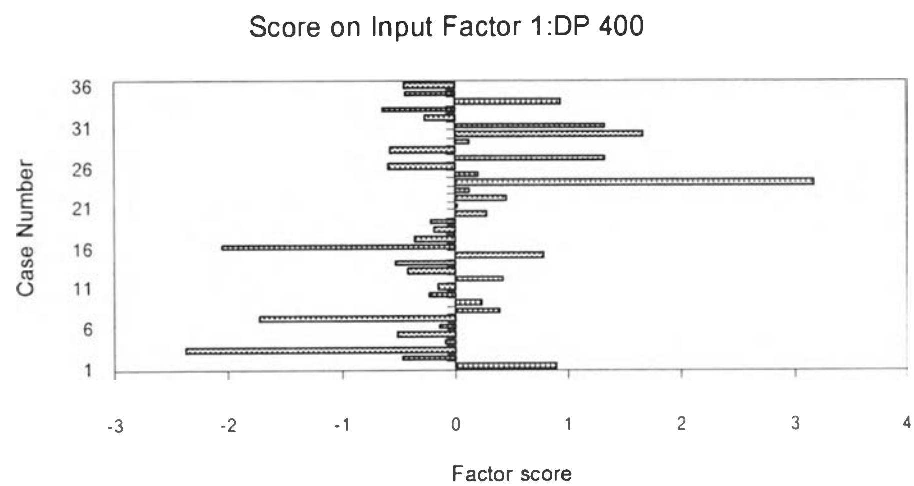


Figure 6.9 Factor Scores of DP 400 for F_1

Table 6.26 Cases of Highly Magnitude of Factor Score for F_1 of DP 400

Input Variables	Case Number			
	3	7	16	24
1. Water	0.76	-0.41	**1.99**	**4.39**
2. Electricity	-1.21	-0.29	**2.68**	**3.08**
3. A_6	-1.01	-0.05	0.11	**2.18**
4. A_7	**-0.55**	**0.36**	**-0.37**	**3.47**
5. A_8	-0.33	4.33	-0.63	0.77
6. A_9	-0.72	1.39	0.55	-0.56
7. A_1	-0.45	-0.61	-0.53	**2.69**
8. A_5	0.57	0.27	-0.76	**1.90**
9.Clay	-0.08	1.02	0.31	-0.53
10.Emulsifier	-0.06	-0.20	-0.20	-0.03
11.Cato	0.35	-0.62	0.66	**2.21**
12.Starch	-0.88	-0.21	-0.38	**2.46**
13.Color	**-1.96**	**-1.27**	**-1.09**	**3.94**
14.Latex	**-1.93**	**-1.24**	**-1.07**	**3.98**
15.Other	-0.50	-0.23	-0.16	0.18
16.Alum	1.04	-0.50	-0.50	1.62
F_1	-2.37	-1.72	-2.05	3.17

Based upon the cases of highly magnitude of F_1, it is found in Table 6.26 that these unusual cases were due to the large change of coating chemicals (color and latex) and some wastepaper (A_7). In addition, the large changes of water and electricity consumption were due to the use of broke more than usual resulting the large change of other chemicals in case # 16 and 24. While the other cases, brokes were used less than usual due to the small change of water and electricity. It indicated that there were variations of not only broke but also coating chemicals and some wastepaper from the broke usage. Therefore, it should be named F_1 of DP 400 as "variations of broke generation and usage and variations of coating chemicals".

For factor scores in F_2 of DP 400 (-1.15 to 3.57), the variation of the factor scores in F_2 was quite balanced with some trend of unusually positive cases as shown in Figure 6.10.

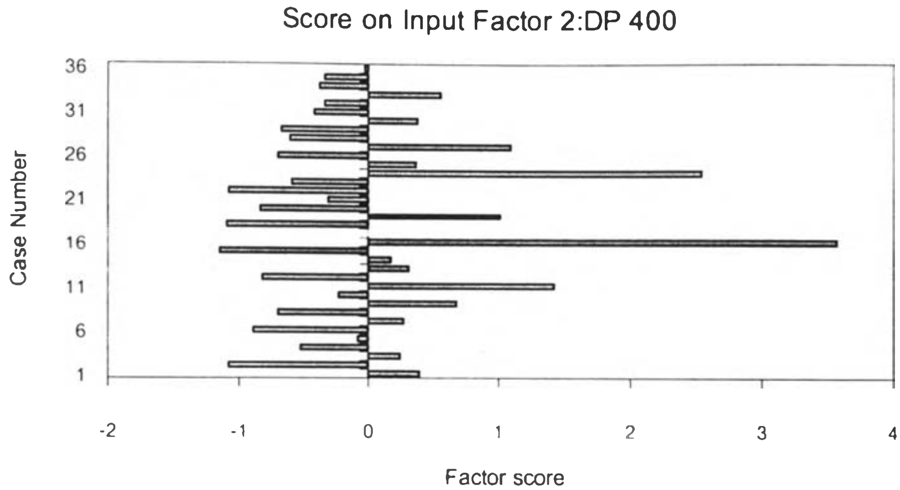


Figure 6.10 Factor Scores of DP 400 for F_2

Table 6.27 Cases of Highly Magnitude of Factor Score for F_2 of DP 400

Input Variables	Case Number	
	16	24
1. Water	**1.99**	**4.39**
2. Electricity	**2.68**	**3.08**
3. A_6	0.11	**2.18**
4. A_7	-0.37	**3.47**
5. A_8	-0.63	0.77
6. A_9	0.54	-0.56
7. A_1	-0.53	**2.69**
8. A_5	-0.76	1.90
9.Clay	0.31	-0.53
10.Emulsifier	-0.20	-0.03
11.Cato	0.66	**2.21**
12.Starch	-0.39	**2.46**
13.Color	-1.09	**3.94**
14.Latex	-1.07	**3.98**
15.Other	-0.16	0.18
16.Alum	-0.50	1.62
F_2	3.57	2.54

Based on the cases of highly magnitude of F_2, it is found from Table 6.27 that these unusual cases were due to both large and small changes of water and electricity resulting the change of other variables. It indicated that there were variations of water and electricity due to the broke usage more than usual (case # 24) and less than usual (case # 16). Thus, it can be named F_2 of DP 400 as "variations of broke generation and usage".

For factor scores in F_3 of DP 400 (5.51), it can be seen that the variation of factor scores in this factor was quite consistent, except in the usual case as shown in Figure 6.11.

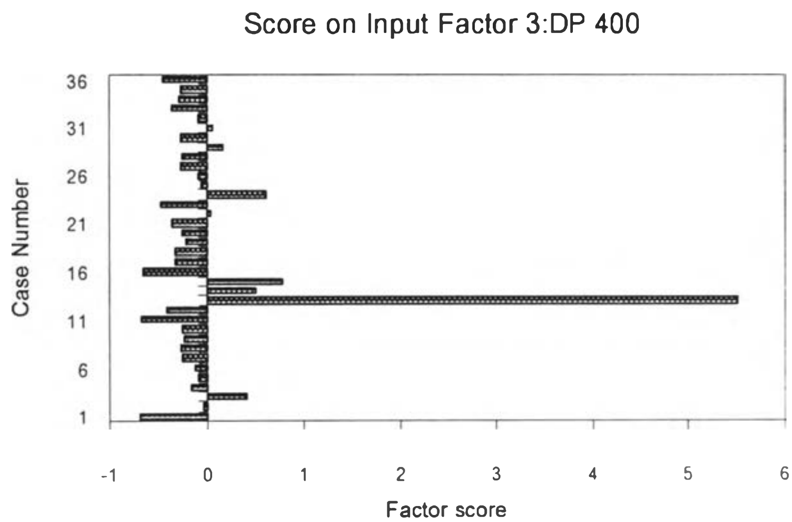


Figure 6.11 Factor Scores of DP 400 for F_3

Based on the cases of highly magnitude of F_3, it is found in Table 6.28 that this unusual case was due to the large changes of sizing agents (emulsifier and alum), particularly, alum. While there were no large changes of water and electricity due to the occurrence of broke and usage. It indicated that there was requirement to treat product for paper formation. Thus, it should then be named F_3 as "special treatment of product for paper formation".

Table 6.28 Cases of Highly Magnitude of Factor Score for F_3 of DP 400

Input Variables	Case Number
	13
1. Water	0.21
2. Electricity	0.95
3. A_6	0.26
4. A_7	-0.37
5. A_8	-0.41
6. A_9	-1.04
7. A_1	0.74
8. A_5	0.12
9.Clay	1.35
10.Emulsifier	**5.83**
11.Cato	-0.38
12.Starch	0.05
13.Color	-0.41
14.Latex	-0.39
15.Other	-0.40
16.Alum	**4.30**
F_3	5.51

For factor scores in F_4 of DP 400 (-2.26 to 1.50), the variation of factor scores in this factor was quite balanced as shown in Figure 6.12.

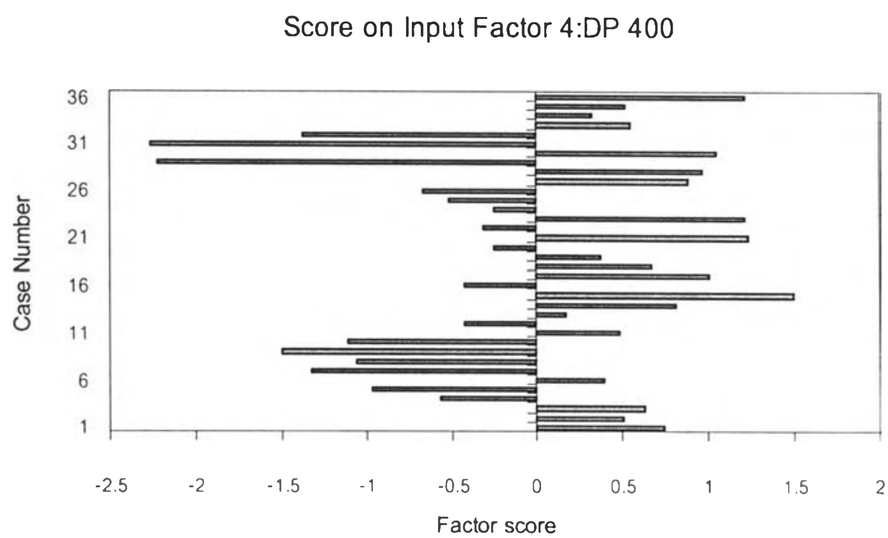


Figure 6.12 Factor Scores of DP 400 for F_4

Based on the cases of highly magnitude of F_4, it is found in Table 6.29 that these unusual cases were due to the large changes of some wastepaper (A_9) that were used in the middle and bottom layers of paper. While there were no large changes of other variables. This indicates that there was broke usage less than usual. Thus, it should be named F_4 as "Inconsistent usage of some wastepaper (A_9)".

Table 6.29 Cases of Highly Magnitude of Factor Score for F_4 of DP 400

Input Variables	Case Number	
	29	31
1. Water	-0.48	-0.06
2. Electricity	-0.62	-0.45
3. A_6	0.58	-1.65
4. A_7	0.18	1.46
5. A_8	0.11	-0.78
6. A_9	**1.87**	**2.03**
7. A_1	-1.13	-1.13
8. A_5	-0.32	0.12
9.Clay	0.42	-1.30
10.Emulsifier	-0.15	-0.20
11.Cato	-0.35	-1.34
12.Starch	-0.36	0.99
13.Color	-0.15	0.83
14.Latex	-0.18	0.64
15.Other	-0.30	-0.15
16.Alum	0.05	-0.50
F_4	- 2.23	-2.26

For factor scores in F_5 of DP 400 (-1.51 to 2.41), the variation of factor scores in this factor was also quite balanced as shown in Figure 6.13.

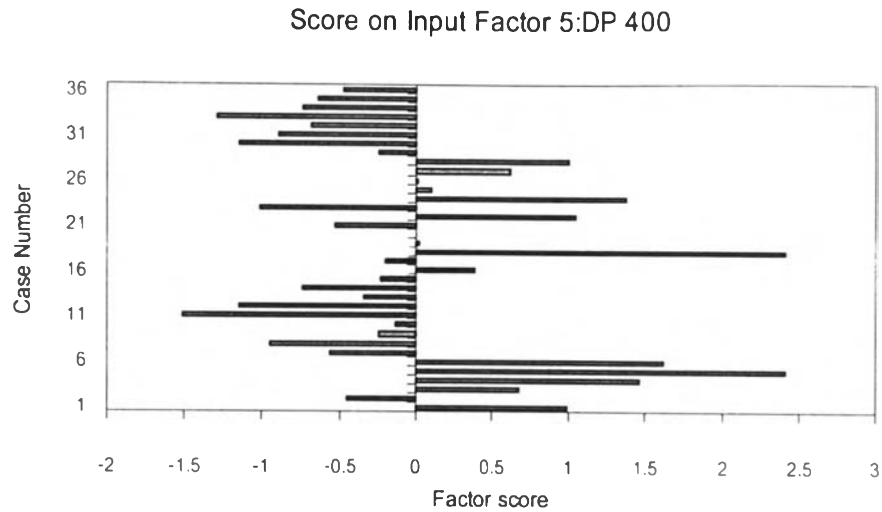


Figure 6.13 Factor Scores of DP 400 for F_5

Table 6.30 Cases of Highly Magnitude of Factor Score for F_5 of DP 400

Input Variables	Case Number					
	5	11	18	23	30	33
1. Water	-0.41	0.76	-0.61	-0.61	0.55	-0.13
2. Electricity	0.24	0.92	-0.96	-0.75	0.82	0.55
3. A_6	-0.05	-0.05	-0.05	-0.37	0.26	-0.37
4. A_7	-0.37	-0.55	-1.65	-0.55	0.73	1.09
5. A_8	-0.78	-0.19	-0.78	-0.26	1.14	-0.78
6. A_9	0.87	-0.19	-0.93	-0.88	-1.04	-0.35
7. A_1	-0.45	-0.02	1.22	0.42	1.38	-1.13
8. A_5	-0.76	-0.17	1.61	-0.62	0.12	0.12
9.Clay	0.42	0.81	0.74	0.21	-1.30	-1.30
10.Emulsifier	-0.14	-0.15	-0.12	-0.20	-0.20	-0.20
11.Cato	**1.78**	**-1.05**	**2.22**	**-0.85**	**-0.76**	**-1.29**
12.Starch	-0.48	-0.01	-0.77	-0.65	1.07	0.81
13.Color	-0.52	-0.05	-0.28	-0.23	1.73	-0.35
14.Latex	-0.49	-0.10	-0.31	-0.22	1.71	-0.35
15.Other	-0.24	-0.18	-0.19	-0.50	0.07	-0.20
16.Alum	-0.27	-0.50	-0.50	-0.37	-0.24	-0.50
F_5	2.41	-1.51	2.41	-1.02	-1.15	-1.29

Based on the cases of highly magnitude of F_5, it is found in Table 6.30 that these unusual cases were due to some large changes of cato. While there were small changes of water and electricity from usual operation. This indicates that there was inconsistent usage of cato. Thus, it should be named F_5 as "inconsistent usage of cato".

For factor scores in F_6 of DP 400 (-1.76 to 3.26), the variation of factor scores in this factor was quite consistent as shown in Figure 6.14.

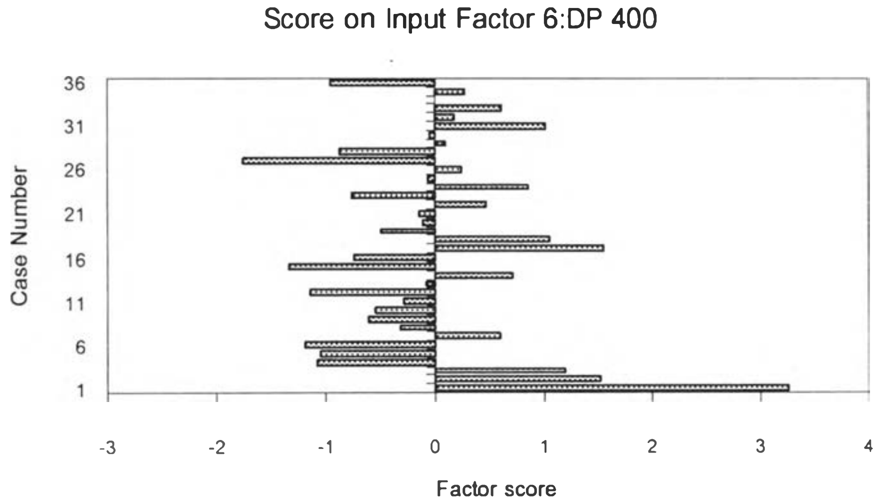


Figure 6.14 Factor Scores of DP 400 for F_6

Based on the cases of highly magnitude of F_6, it is found in Table 6.31 that these unusual cases were due to the large change of water and electricity consumption, some wastepapers (A_5 and A_8). This indicated that there were variations of broke generation and usage due to the increased use of related additives. In addition, there were variations of some wastepaper (A_5) from the use of broke both more (case #1 and 27) and less than usual (case # 12, 15, and 17). It should then be named F_6 as "variations of broke generation and usage and inconsistent usages of some wastepapers (A_5 and A_8)".

Table 6.31 Cases of Highly Magnitude of Factor Score for F_6 of DP 400

Input Variables	Case Number				
	1	12	15	17	27
1. Water	**1.24**	-0.61	-0.61	-0.13	**1.31**
2. Electricity	**0.92**	-0.76	-1.02	-0.21	**2.12**
3. A_6	**1.86**	-0.05	-0.05	-0.16	**2.50**
4. A_7	**2.01**	0.54	0.73	-0.37	**1.46**
5. A_8	**0.92**	-0.78	1.52	-0.78	**1.29**
6. A_9	-1.04	0.76	-1.04	-1.04	-1.04
7. A_1	**1.97**	-0.14	-1.13	-0.02	**1.81**
8. A_5	**4.13**	**-0.76**	**-0.76**	**1.16**	**-0.76**
9.Clay	**2.54** .	0.80	0.81	0.17	-1.30
10.Emulsifier	-0.09	-0.15	-0.13	-0.20	-0.20
11.Cato	**2.09**	-1.05	-0.38	0.08	1.00
12.Starch	**1.20**	-0.01	-0.89	-0.48	**1.23**
13.Color	**1.38**	-0.03	0.06	-0.33	**2.09**
14.Latex	**1.53**	-0.04	0.37	-0.35	**1.99**
15.Other	-0.16	-0.18	-0.15	-0.32	0.06
16.Alum	-0.50	-0.50	1.99	-0.15	-0.15
F_5	3.26	-1.15	-1.34	1.54	-1.76

Based upon these cases, the significant factor scores for DP 400 production can be named as in Table 6.32.

Table 6.32 The Name of Significant Factors of DP 400

Significant Factor	Name
F_1	Variations of broke generation and usage and variations of coating chemicals
F_2	Variations of broke generation and usage
F_3	Special treatment of product for paper formation
F_4	Inconsistent usage of some wastepaper (A_9)
F_5	Inconsistent usage of cato
F_6	Variations of broke generation and usage and inconsistent usages of some wastepaper (A_5 and A_8)

Based upon the factor scores for DP 400, the events occurred in the process indicate this production was so complex and all variables were somewhat independent.

6.1.3.3 Factor Scores of DP 350

For F_1 of DP 350 (-2.17 to 2.90), the variation of factor scores in this factor was quite balanced because of the changes of variables in both directions as shown in Figure 6.15.

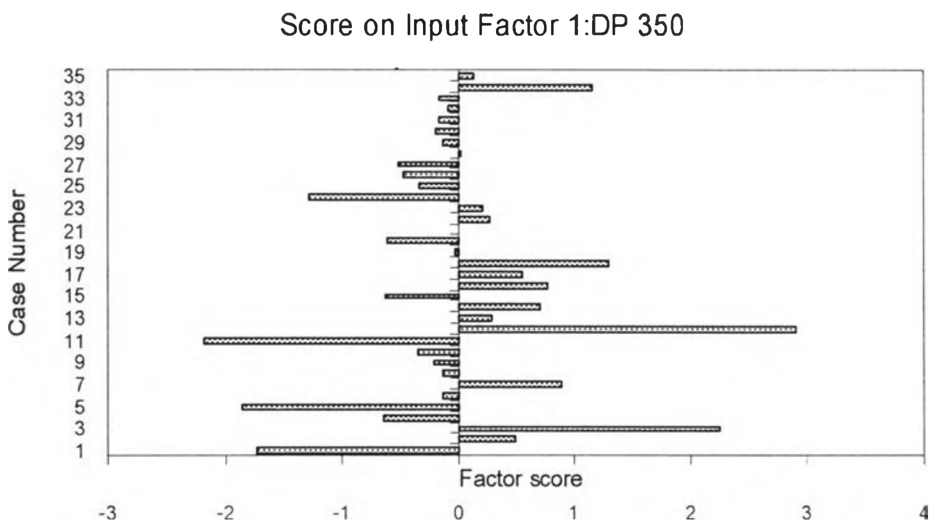


Figure 6.15 Factor Scores of DP 350 for F_1

Based upon the cases of highly magnitude of F_1, it is found in Table 6.33 that these unusual cases were due to the variation of coating chemicals (color and latex) as well as water and electricity consumption. In case # 12, the large changes of water and electricity were due to the broke usage more than usual resulting the highly consumption for other variables. While, the other cases, the changes of coating chemicals were due to the occurrence of broke. Thus, it should be named F_1 as "variations of broke generation and usage and variations of coating chemicals".

Table 6.33 Cases of Highly Magnitude of Factor Score for F_1 of DP 350

Input Variables	Case Number				
	1	3	5	11	12
1. Water	-0.56	0.05	0.15	-0.36	**2.08**
2. Electricity	-0.34	**0.94**	0.62	-0.58	**3.16**
3. A_6	0.22	1.46	0.63	0.22	**3.58**
4. A_7	-0.60	0.88	-0.35	-0.60	**2.11**
5. A_8	-0.82	-0.82	-0.25	-0.82	-0.82
6. A_9	-0.06	0.11	0.89	0.61	**1.56**
7. A_1	0.47	0.82	-0.89	-0.64	**1.22**
8. A_5	2.03	2.03	-0.77	-0.77	**2.03**
9. Alum	-0.51	0.53	-0.51	1.66	**2.74**
10.Clay	0.75	2.42	0.82	1.42	**1.94**
11.Emulsifier	-0.14	0.19	0.15	-0.14	-0.14
12.Cato	0.50	0.82	-0.02	0.48	**4.42**
13.Starch	-0.59	0.78	-0.82	-0.31	**1.14**
14.Color	**-0.32**	**0.65**	**-0.31**	**-0.39**	**1.07**
15.Latex	**-0.32**	**0.68**	**-0.33**	**-0.40**	**1.08**
16.Other	-0.16	-0.07	-0.18	-0.16	0.08
F_1	-1.74	2.25	-1.85	-2.17	2.90

For factor scores in F_2 of DP 350 (-2.01 to 2.01), the variation of factor scores in this factor was quite balanced as shown in Figure 6.16.

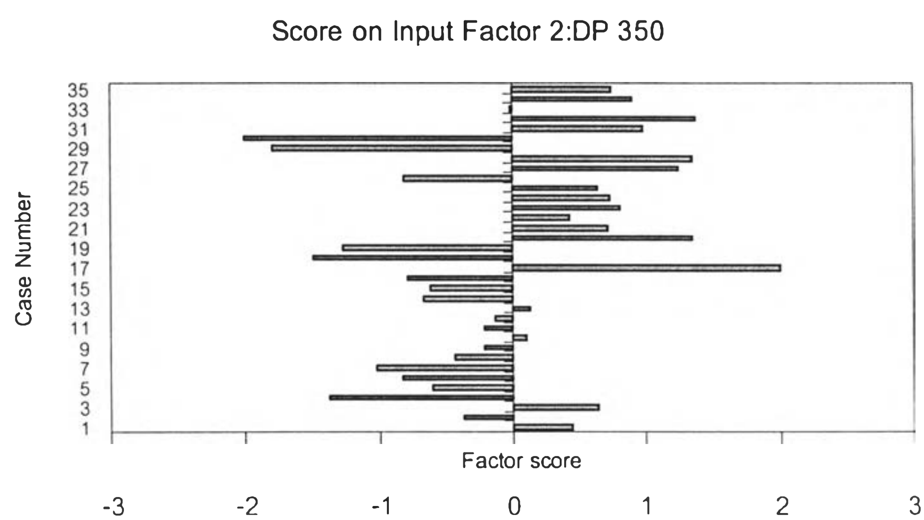


Figure 6.16 Factor Scores of DP 350 for F_2

Table 6.34 Cases of Highly Magnitude of Factor Score for F_2 of DP 350

Input Variables	Case Number		
	17	18	19
1. Water	-0.76	-0.66	-0.25
2. Electricity	-0.83	-0.76	-0.31
3. A_6	-0.20	-0.61	0.22
4. A_7	-0.11	-0.35	-0.35
5. A_8	0.65	0.20	0.87
6. A_9	**-1.07**	**1.28**	**1.79**
7. A_1	**1.82**	**-1.05**	**-0.49**
8. A_5	0.23	-0.17	0.83
9. Alum	-0.09	-0.51	0.92
10.Clay	0.22	0.16	0.42
11.Emulsifier	-0.14	- 0.14	-0.14
12.Cato	0.43	0.47	0.38
13.Starch	-0.93	-0.82	-0.13
14.Color	0.06	0.08	0.01
15.Latex	0.06	0.11	0.02
16.Other	-0.14	-0.15	-0.30
F_2	2.01	-1.49	-1.27

Based upon the cases of highly magnitude of F_2, it is found in Table 6.34 that these unusual cases were due to the large changes of some wastepapers (A_9 and A_1). As there were no large changes of water and electricity, it seems to indicate that there was inconsistent usage of these wastepapers. Thus, it should be named F_2 as "inconsistent usage of some wastepapers (A_9 and A_1)".

For factor scores in F_3 of DP 350 (-1.18 to 3.66), the variation of factor scores in this factor was inconsistent due to the presence of some unusual cases as shown in Figure 6.17.

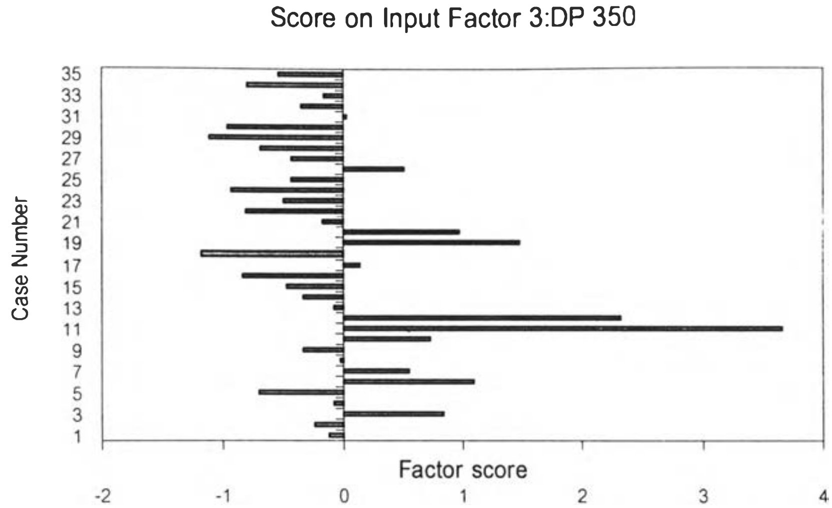


Figure 6.17 Factor Scores of DP 350 for F_3

Table 6.35 Cases of Highly Magnitude of Factor Score for F_3 of DP 350

Input Variables	Case Number	
	11	12
1. Water	-0.36	**2.08**
2. Electricity	-0.58	**3.16**
3. A_6	0.22	**3.58**
4. A_7	-0.60	**2.11**
5. A_8	-0.82	-0.82
6. A_9	0.61	**1.56**
7. A_1	-0.64	**1.22**
8. A_5	-0.77	**2.03**
9. Alum	**1.66**	**2.74**
10.Clay	**1.42**	**1.94**
11.Emulsifier	-0.14	-0.14
12.Cato	0.48	**4.42**
13.Starch	-0.31	**1.14**
14.Color	-0.39	**1.07**
15.Latex	-0.40	**1.08**
16.Other	-0.16	0.08
F_3	3.66	2.32

Based upon the cases of highly magnitude of F_3, it is found in Table 6.35 that these unusual cases were due to the large changes of not only clay and alum but also water and electricity from the occurrence of broke. While the large changes of clay and alum were due to the use of broke less than usual. Thus, it should be named F_3 as "variations of broke generation and usage"

For factor scores in F_4 of DP 350 (-1.31 to 3.13), the variation of factor scores in this factor fluctuates in the first part and was consistent in the last part as shown in Figure 6.18.

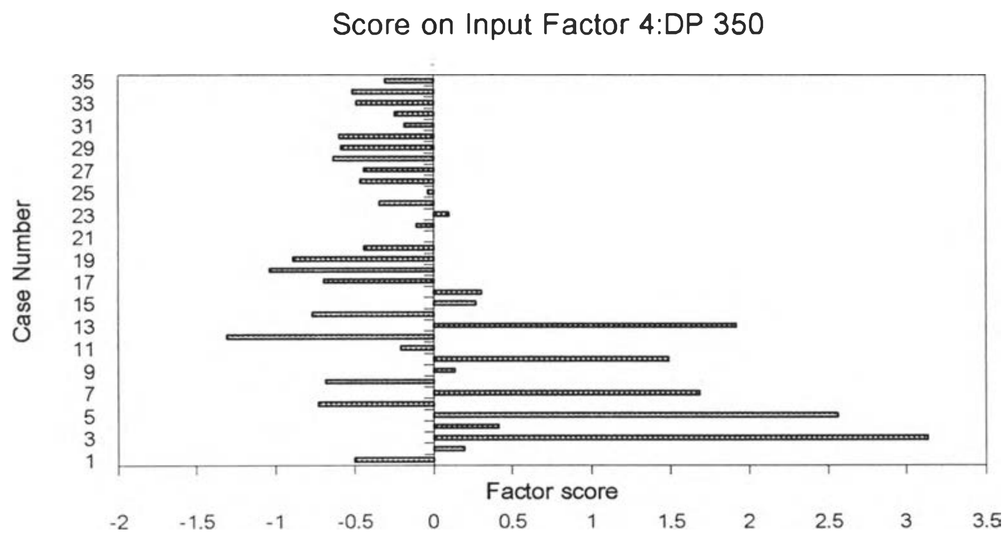


Figure 6.18 Factor Scores of DP 350 for F_4

Based upon the cases of highly magnitude of F_4, it is found in Table 6.36 that these unusual cases were due to the large changes of emulsifier (one of sizing agents that are used for paper formation) in all cases. There were no large changes of water and electricity in these cases. It seems to indicate that there is requirement to treat product more for paper formation. Thus, it should be named F_4 as "special treatment of product for paper formation".

Table 6.36 Cases of Highly Magnitude of Factor Score for F_4 of DP 350

Input Variables	Case Number				
	3	5	7	10	13
1. Water	0.05	0.15	-0.46	-0.15	0.56
2. Electricity	0.94	0.62	-0.77	-0.18	0.43
3. A_6	1.46	0.63	-0.20	0.22	-0.26
4. A_7	0.88	-0.35	0.39	-0.35	0.14
5. A_8	-0.82	-0.25	-0.25	2.34	-0.59
6. A_9	0.11	0.89	0.95	0.05	0.39
7. A_1	0.82	-0.89	-1.35	-0.39	0.01
8. A_5	2.03	-0.77	-0.77	-0.77	0.03
9. Alum	0.53	-0.51	0.34	0.41	-0.04
10.Clay	2.42	0.82	0.43	0.58	1.09
11.Emulsifier	**0.19**	**0.15**	**0.06**	**0.08**	**0.09**
12.Cato	0.82	-0.02	0.43	-0.46	0.74
13.Starch	0.78	-0.82	-0.77	-0.85	-0.48
14.Color	0.65	-0.31	0.14	-0.04	0.12
15.Latex	0.68	-0.33	0.14	-0.03	0.14
16.Other	-0.07	-0.18	-0.14	-0.18	-0.15
F_4	3.13	2.57	1.68	1.49	1.91

For factor scores in F_5 of DP 350 (-1.41 to 4.10), the variation of factor scores in this factor was small as shown in Figure 6.19.

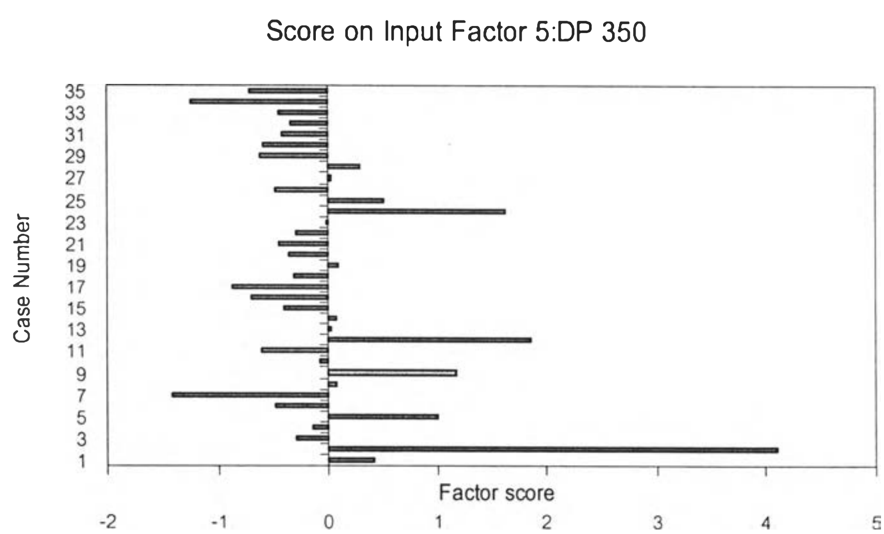


Figure 6.19 Factor Scores of DP 350 for F_5

Table 6.37 Cases of Highly Magnitude of Factor Score for F_5 of DP 350

Input Variables	Case Number				
	2	5	9	12	24
1. Water	-0.86	0.15	0.05	**2.08**	0.35
2. Electricity	**2.30**	**0.62**	**0.52**	**3.16**	**1.16**
3. A_6	-0.61	0.63	-0.20	**3.58**	**0.63**
4. A_7	-0.11	-0.35	0.39	**2.11**	**0.63**
5. A_8	-0.37	-0.25	-0.14	-0.82	-0.59
6. A_9	-0.91	0.89	0.39	**1.56**	-1.07
7. A_1	-1.25	-0.89	-0.54	**1.22**	0.77
8. A_5	-0.57	-0.77	-0.77	**2.03**	0.43
9. Alum	-0.05	-0.51	-0.14	**2.74**	-0.51
10.Clay	-0.08	0.82	1.05	**1.94**	-1.18
11.Emulsifier	-0.03	0.15	-0.04	-0.14	-0.14
12.Cato	0.47	-0.02	-0.59	**4.42**	**1.82**
13.Starch	-0.69	-0.82	-1.07	**1.14**	**1.91**
14.Color	0.06	-0.31	-0.03	**1.07**	-0.12
15.Latex	0.08	-0.33	-0.02	**1.08**	-0.11
16.Other	-0.14	-0.18	-0.15	0.08	-0.12
F_5	4.10	1.01	-1.41	1.18	1.86

Based upon the cases of highly magnitude of F_5, it is found in Table 6.37 that these unusual cases were due to the variation of electricity from the use of broke both more (case # 12) and less than usual (case # 2, 5, 9, and 24). Thus, it should be named F_5 as "inconsistent consumption of electricity".

Based on the cases of highly magnitude of factors (Appendix A13), the significance factor scores for DP 350 production can be named as shown in Table 6.38.

Table 6.38 The Name of Significant Factors of DP 350

Significant Factor	Name
F_1	Variations of broke generation and usage and variations of coating chemicals
F_2	Inconsistent usage of some wastepapers (A_9 and A_1)
F_3	Variations of broke generation and usage
F_4	Special treatment of product for paper formation
F_5	Inconsistent consumption of electricity

Overall, the factor scores of DP 350 represented the combination of factors extracted. The events occurred in the process indicated this production was so complex and all variables were somewhat independent.

6.1.3.4 Factor Scores of DP 310

For factor scores in F_1 of DP 310 (-0.51 to 7.4), the variation of factor scores in this factor was quite consistent, except in the case # 4 as shown in Figure 6.20.

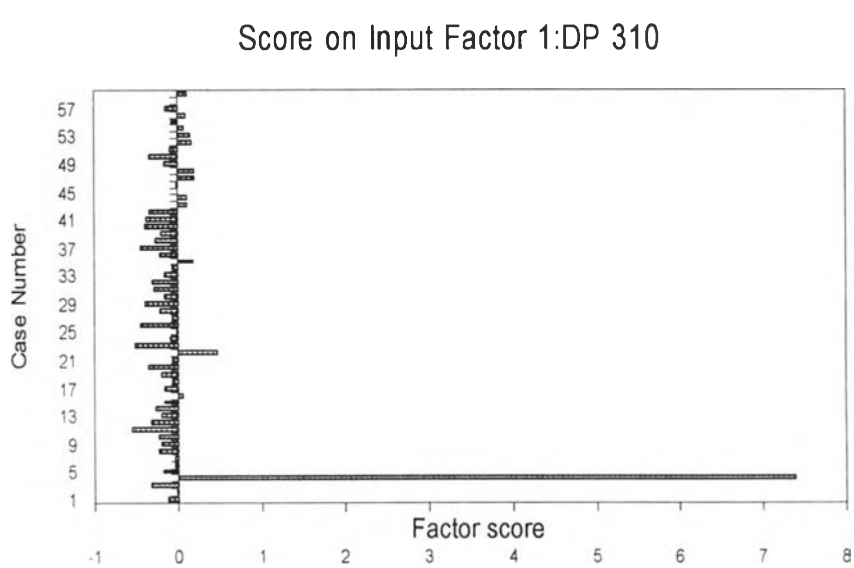


Figure 6.20 Factor Scores of DP 310 for F_1

Table 6.39 Cases of Highly Magnitude of Factor Score for F_1 of DP 310

Input Variables	Case Number
	4
1. Water	-0.56
2. Electricity	-0.42
3. A_6	1.05
4. A_7	-0.60
5. A_8	-0.82
6. A_9	-0.51
7. A_1	0.67
8. A_5	-0.77
9. Alum	-0.04
10.Clay	0.63
11.Emulsifier	-0.03
12.Cato	0.74
13.Starch	-0.83
14.Color	**12.74**
15.Latex	**12.58**
16.Other	0.92
F_1	7.40

Based upon the cases of highly magnitude of F_1, it is found in Table 6.39 that the variation of this factor was due to only the large change of coating chemicals. It indicates that there was requirement to treat product more for coating due to the use of broke less than usual. Thus, it should be named F_1 as "special treatment of product for coating".

For factor scores in F_2 of DP 310 (-1.07 to 5.51), the variation of factor scores in this factor was mostly consistent. Although there are some unusual cases (case # 18 and 41) as shown in Figure 6.21.

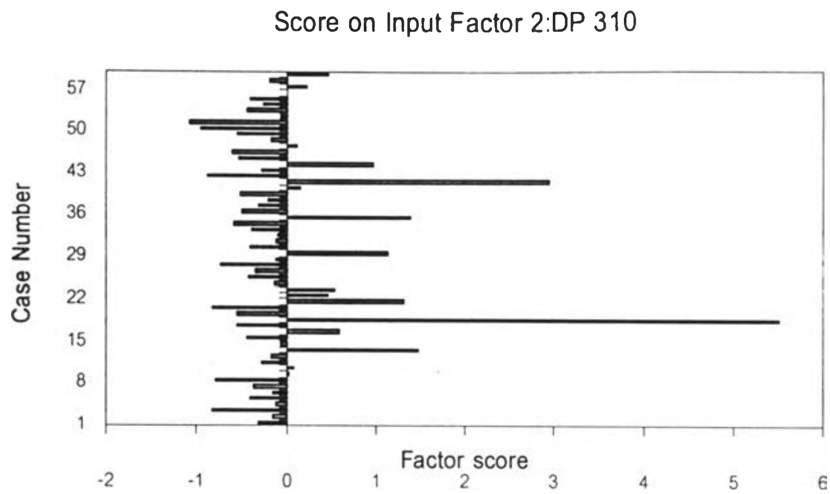


Figure 6.21 Factor Scores of DP 310 for F_2

Table 6.40 Cases of Highly Magnitude of Factor Score for F_2 of DP 310

Input Variables	Case Number	
	18	41
1. Water	**1.47**	**1.06**
2. Electricity	**3.72**	**0.86**
3. A_6	-0.20	-1.44
4. A_7	0.14	-1.09
5. A_8	0.31	0.20
6. A_9	-0.39	-0.45
7. A_1	0.01	-1.35
8. A_5	-0.77	0.03
9. Alum	-0.51	-0.51
10.Clay	0.74	-0.07
11.Emulsifier	-0.04	-0.14
12.Cato	-0.50	-0.55
13.Starch	-1.10	2.08
14.Color	-0.03	-0.67
15.Latex	-0.01	-0.69
16.Other	-0.16	-0.28
F_2	5.51	2.93

Based upon the cases of highly magnitude of F_2, it is found in Table 6.40 that the large magnitudes of this factor were due to the large changes of water and electricity due to the use of broke more than usual, as well as the overflow of white water. It should then be named F_2 as "variations of broke usage and balancing of white water".

For factor scores in F_3 of DP 310 (-2.60 to 2.39), the variation of factor scores in this factor was quite balanced as shown in Figure 6.22.

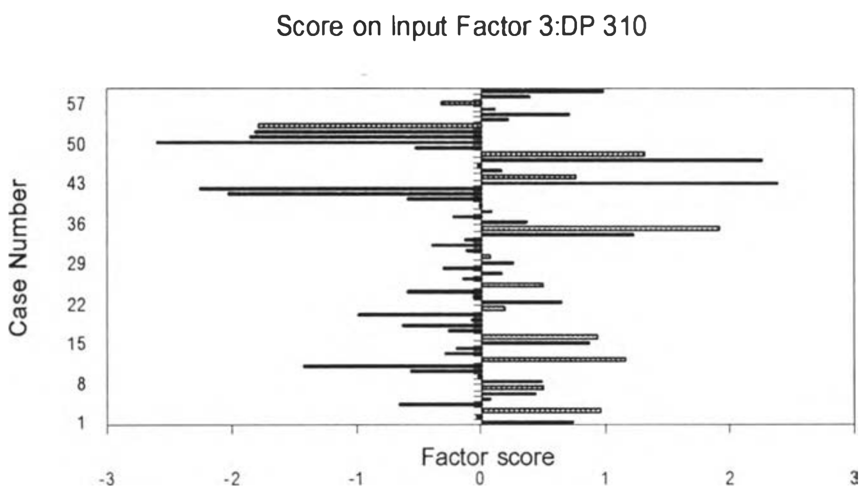


Figure 6.22 Factor Scores of DP 310 for F_3

Based upon the cases of highly magnitude of F_3, it is found in Table 6.41 that the variation of this factor was due to the large change of some wastepaper (A_7). While there were the large changes of water and electricity consumption due to the occurrence of broke in some case (case # 41), there were the small changes of theses variables in other cases (case # 35, 42-43, 47, and 50) due to the broke usage less than usual. Thus, it should be named F_3 as "variations of broke generation and usage".

Table 6.41 Cases of Highly Magnitude of Factor Score for F_3 of DP 310

Input Variables	Case Number					
	35	41	42	43	47	50
1. Water	0.05	**1.06**	-0.66	-0.36	-0.15	-0.66
2. Electricity	1.16	**0.86**	-1.06	-0.54	-0.82	-1.31
3. A_6	-0.20	-1.44	-0.20	0.22	-0.20	-1.86
4. A_7	**1.37**	**-1.09**	**-0.85**	**1.62**	**1.37**	**-1.58**
5. A_8	1.89	0.20	0.20	0.20	-0.82	0.31
6. A_9	-1.07	-0.45	-1.07	-1.07	1.23	-0.67
7. A_1	1.32	-1.35	0.67	0.87	-1.35	-0.34
8. A_5	-0.77	0.03	-0.77	-0.77	-0.37	-0.17
9. Alum	-0.51	-0.51	-0.51	-0.51	-0.51	-0.51
10.Clay	-1.18	-0.07	-1.18	-1.18	-1.18	-1.18
11.Emulsifier	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
12.Cato	0.48	-0.55	-1.05	-0.89	-1.01	-1.15
13.Starch	0.24	2.08	0.23	0.35	0.43	0.06
14.Color	0.03	-0.67	0.12	0.13	0.06	-0.08
15.Latex	0.03	-0.69	0.12	0.13	0.06	-0.69
16.Other	-0.07	-0.28	-0.17	-0.17	-0.13	-0.17
F_3	1.92	-2.03	-2.26	2.39	2.27	-2.60

For factor score in F_4 of DP 310 (-1.68 to 2.08), the variation of factor scores in this factor was quite balanced as shown in Figure 6.24.

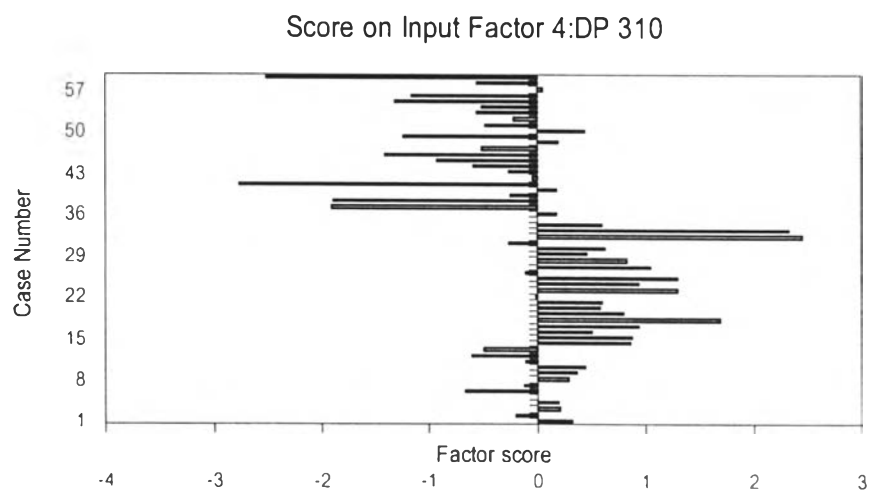


Figure 6.24 Factor Scores of DP 310 for F_4

Table 6.42 Cases of Highly Magnitude of Factor Score for F_4 of DP 310

Input Variables	Case Number						
	18	32	33	37	38	41	59
1. Water	**1.47**	-0.56	-0.66	-0.56	-0.25	**1.06**	-0.15
2. Electricity	**3.72**	-0.35	-0.68	-0.29	-0.72	**0.86**	0.11
3. A_6	-0.20	-0.20	-0.20	0.22	-0.20	-1.44	0.22
4. A_7	0.14	0.39	0.39	0.63	0.39	-1.09	1.12
5. A_8	0.31	-0.82	-0.82	-0.48	-0.70	0.20	-0.03
6. A_9	-0.39	-0.28	0.73	-1.07	1.12	-0.45	-1.07
7. A_1	0.01	0.97	-0.19	-0.44	-0.74	-1.35	1.42
8. A_5	-0.77	-0.48	-0.24	-0.17	0.03	0.03	-0.17
9. Alum	-0.51	-0.51	-0.51	-0.51	-0.51	-0.51	-0.27
10.Clay	0.74	-1.18	-1.18	-1.18	0.72	-0.07	-1.18
11.Emulsifier	-0.04	-0.10	-0.08	-0.14	-0.04	-0.14	-0.14
12.Cato	-0.50	-0.53	-0.43	1.67	-0.19	-0.55	-0.38
13.Starch	**-1.10**	**-1.68**	**-1.68**	**1.36**	**0.75**	**2.08**	**1.65**
14.Color	-0.03	0.07	0.20	-0.02	-0.15	-0.67	0.35
15.Latex	-0.01	0.10	0.20	-0.02	-0.14	-0.69	0.38
16.Other	-0.16	2.12	2.04	-0.18	-0.15	-0.28	-0.06
F_4	1.69	2.46	2.33	-1.91	-1.89	-2.77	-2.51

Based upon the cases of highly magnitude of F_4, it is found in Table 6.42 that the variation of this factor was due to the large change of starch. It occurs from the use of broke both more (case #18 and 41) and less than usual (case # 32-33, 37-38, and 59) due to the different changes of water and electricity. Thus, it should be named F_4 as "inconsistent usage of starch".

For factor scores in F_5 of DP 310 (-1.52 to 3.49), the variation of factor scores in this factor was quite unbalanced due to the inconsistent changes of the variables as shown in Figure 6.24.

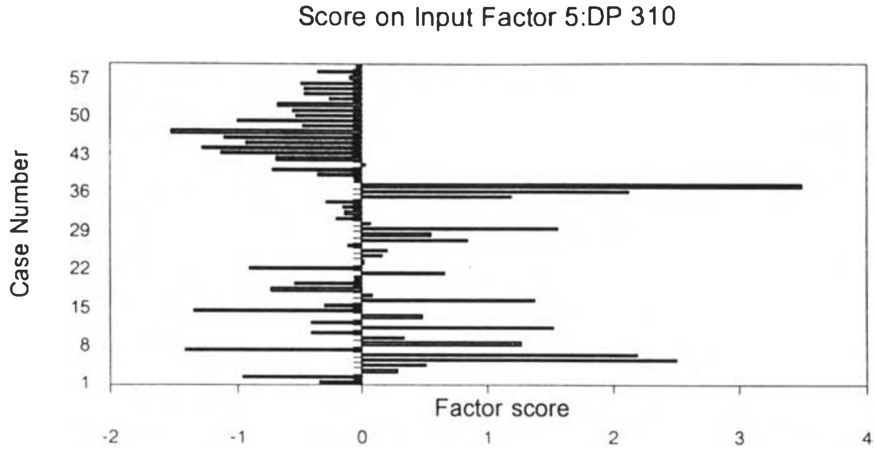


Figure 6.24 Factor Scores of DP 310 for F_5

Table 6.43 Cases of Highly Magnitude of Factor Score for F_5 of DP 310

Input Variables	Case Number						
	5	6	7	14	29	36	37
1. Water	-0.56	-0.56	-0.36	-0.36	0.05	-0.56	-0.56
2. Electricity	-0.39	-0.03	-0.76	-0.36	0.92	-0.60	-0.29
3. A_6	-0.61	-0.61	-0.20	-0.20	0.22	-0.20	0.22
4. A_7	0.39	0.39	0.39	0.14	1.12	0.63	0.63
5. A_8	0.31	0.76	-0.03	-0.82	-0.82	-0.14	-0.48
6. A_9	0.61	1.96	0.56	-0.28	-1.07	-0.90	-1.07
7. A_1	-0.24	-1.35	-0.44	-0.24	2.88	-0.44	-0.44
8. A_5	-0.77	-0.77	-0.77	-0.77	-0.37	-0.37	-0.17
9. Alum	0.05	-0.02	-0.05	0.20	0.77	-0.51	-0.51
10.Clay	0.16	0.46	0.59	0.94	0.97	-1.18	-1.18
11.Emulsifier	-0.00	-0.02	-0.03	-0.04	-0.14	-0.14	-0.14
12.Cato	**1.47**	**1.43**	**-0.84**	**-0.82**	**0.91**	**0.90**	**1.67**
13.Starch	-0.47	-0.09	-0.35	-0.95	-0.76	0.11	1.36
14.Color	0.08	0.02	0.10	-0.00	0.01	0.05	-0.02
15.Latex	0.09	0.01	0.10	0.00	0.05	0.05	-0.02
16.Other	-0.17	-0.15	-0.18	-0.13	-0.15	-0.13	-0.18
F_5	2.50	2.19	-1.41	-1.34	1.56	2.12	3.49

Based upon the cases of highly magnitude of F_5, it is found in Table 6.43 that the variation of this factor, particularly cato was due to the use of broke less than usual because of large changes of water and electricity consumption. It should then be named F_5 as "inconsistent usage of cato".

For factor scores in F_6 of DP 310 (-1.34 to 3.79), the variation of factor scores in this factor was quite unbalanced as in Figure 6.25.

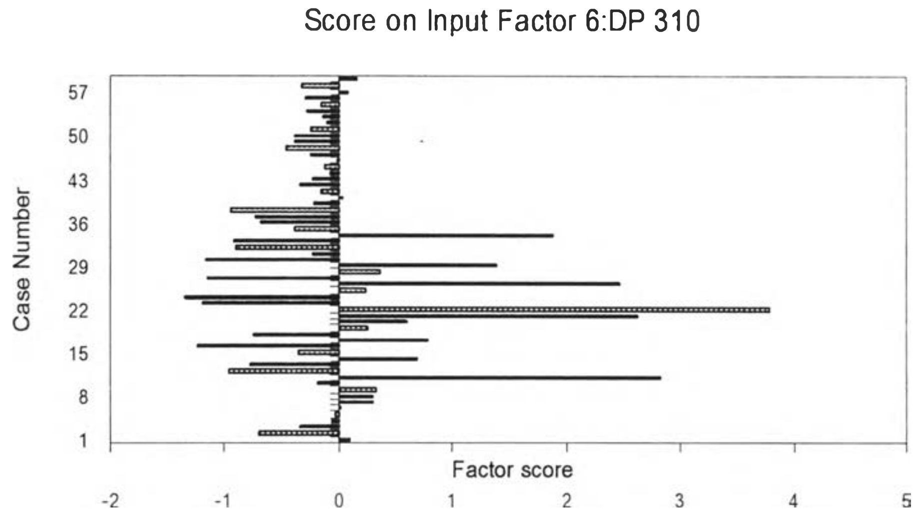


Figure 6.25 Factor Scores of DP 310 for F_6

Based upon the cases of highly magnitude of F_6, it is found in Table 6.44 that the variation of this factor, in particular alum was due to the use of broke less than usual because of small changes of water and electricity. It seems to indicate that there was requirement to treat product for paper formation. Thus, it should be named F_6 as "special treatment of product for paper formation".

Table 6.44 Cases of Highly Magnitude of Factor Score for F_6 of DP 310

Input Variables	Case Number				
	11	21	22	26	34
1. Water	-0.46	0.25	-0.15	-0.46	-0.66
2. Electricity	-0.66	0.39	-0.11	-0.44	-0.71
3. A_6	-0.20	0.22	-0.16	-0.20	-0.20
4. A_7	-0.35	0.63	0.63	0.39	0.88
5. A_8	0.09	-0.82	-0.82	-0.82	-0.37
6. A_9	2.40	-1.07	0.89	-1.07	-0.56
7. A_1	-1.20	-0.24	-0.29	0.77	-0.64
8. A_5	-0.77	1.63	3.83	-0.37	-0.69
9. Alum	**1.42**	**1.34**	**2.00**	**1.12**	**0.55**
10.Clay	0.84	0.68	0.50	0.60	-1.18
11.Emulsifier	0.03	-0.02	-0.02	-0.03	-0.09
12.Cato	1.20	0.40	-0.53	-0.07	-0.23
13.Starch	-0.92	-0.98	-0.96	-0.51	-0.51
14.Color	-0.29	0.25	0.19	-0.17	0.05
15.Latex	-0.29	0.27	0.99	-0.18	0.04
16.Other	-0.16	-0.15	-0.15	-0.18	1.06
F_6	2.82	2.62	3.79	2.46	1.87

Based upon the cases of highly magnitude of factors, the significance factor scores for DP 310 production can be named as shown in Table 6.45.

Table 6.45 The Name of Significant Factors of DP 310

Significant Factor	Name
F_1	Special treatment of product for coating
F_2	Variations of broke usage and balancing of white water
F_3	Variations of broke generation and usage
F_4	Inconsistent usage of starch
F_5	Inconsistent usage of cato
F_6	Special treatment of product for paper formation

Based upon the factor scores for DP 310, the events occurred in the process indicate this production was also so complex and all variables were somewhat independent.

6.1.3.5 Factor Scores of DP 270

For factor scores in F_1 of DP 270 (-3.41 to 1.13), the variation of scores in this factor was quite balanced, except for the unusual case in case # 2 as shown in Figure 6.26.

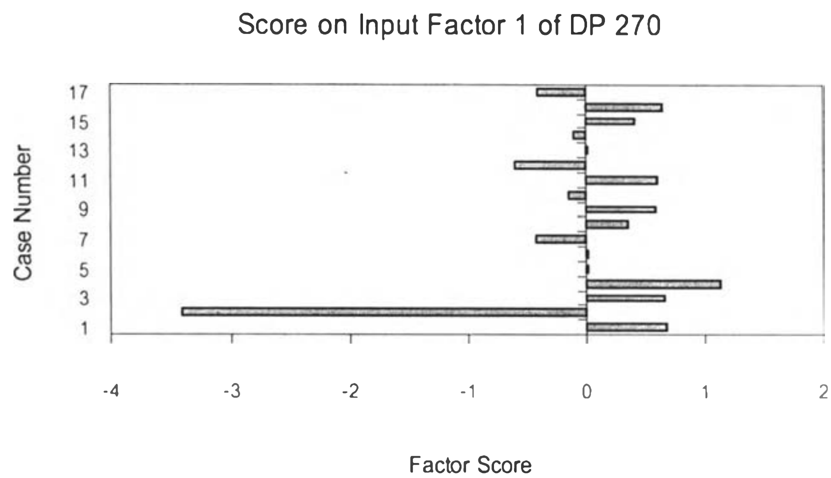


Figure 6.26 Factor Scores of DP 270 for F_1

Based upon the cases of highly magnitude of F_1, it is found in Table 6.46 that the variation of this factor occurs from the use of broke more than usual. There were the large change of water, electricity, some wastepaper (F_1) and coating chemicals. Thus, it should be named F_1 as “variations of broke generation and usage”.

Table 6.46 Cases of Highly Magnitude of Factor Score for F_1 of DP 270

Input Variables	Case Number
	2
1. Water	**2.68**
2. Electricity	**2.25**
3. A_6	2.30
4. A_7	0.63
5. A_8	-0.14
6. A_9	0.33
7. A_1	-0.44
8. A_5	-0.77
9. Alum	-0.11
10.Clay	0.76
11.Emulsifier	0.06
12.Cato	0.51
13.Starch	-0.37
14.Color	**-0.98**
15.Latex	**-1.00**
16.Other	**-0.29**
F_1	-3.41

For factor scores in F_2 of DP 270 (-2.50 to 1.68), the variation of factor scores in this factor was quite balanced as shown in Figure 6.27

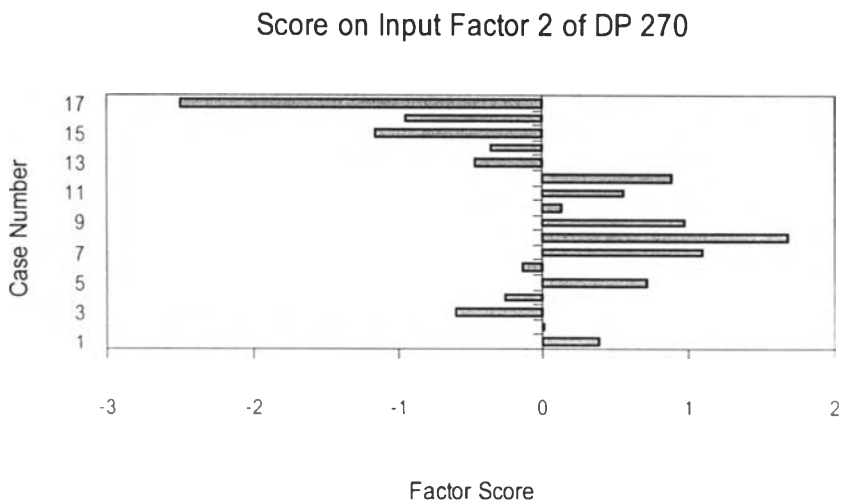


Figure 6.27 Factor Scores of DP 270 for F_2

Table 6.47 Cases of Highly Magnitude of Factor Score for F_2 of DP 270

Input Variables	Case Number	
	8	17
1. Water	-0.25	0.45
2. Electricity	-0.86	0.44
3. A_6	0.27	-0.20
4. A_7	1.12	0.14
5. A_8	-0.70	-0.82
6. A_9	0.17	-1.07
7. A_1	1.32	1.12
8. A_5	-0.77	0.03
9. Alum	-0.08	-0.51
10.Clay	0.05	-1.18
11.Emulsifier	**0.07**	**-0.14**
12.Cato	0.48	-0.16
13.Starch	**-0.76**	**1.74**
14.Color	0.19	0.13
15.Latex	0.21	0.13
16.Other	-0.14	-0.07
F_2	1.68	-2.50

Based upon the cases of highly magnitude of F_2, it is found in Table 6.47 that the large magnitudes of this factor occurred due to some large changes of emulsifier and starch without the large changes of water and electricity. It seems to indicate that there were inconsistent usages of emulsifier and starch in the process. Thus, it should then be named F_2 as "inconsistent usages of emulsifier and starch".

For factor scores in F_3 of DP 270 (-2.90 to 1.18), it is shown that the variation of factor scores in this factor was quite balanced, except for the unusual case in case # 3 as shown in Figure 6.28.

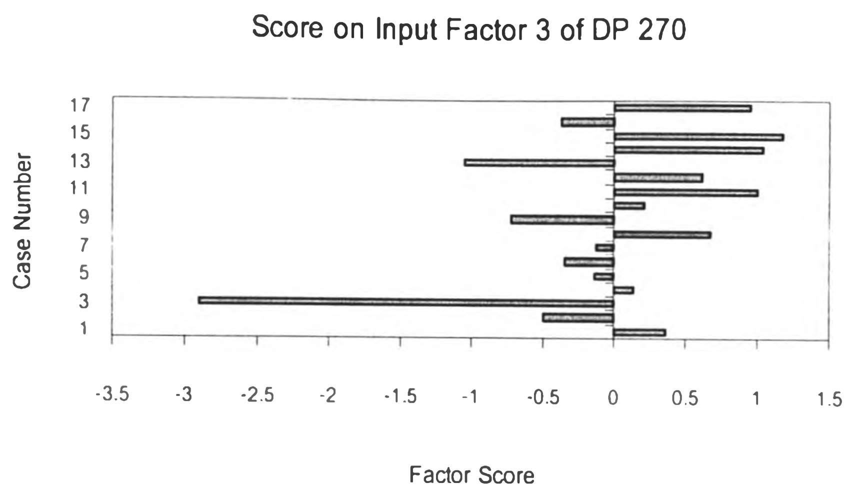


Figure 6.28 Factor Scores of DP 270 for F_3

Table 6.48 Cases of Highly Magnitude of Factor Score for F_3 of DP 270

Input Variables	Case Number
	3
1. Water	-0.76
2. Electricity	-0.65
3. A_6	-0.20
4. A_7	0.63
5. A_8	0.20
6. A_9	**2.18**
7. A_1	**-1.35**
8. A_5	-0.77
9. Alum	-0.20
10.Clay	0.40
11.Emulsifier	-0.14
12.Cato	0.34
13.Starch	-0.66
14.Color	0.22
15.Latex	0.22
16.Other	-0.15
F_3	-2.90

Based upon the cases of highly magnitude of F_3, it is found in Table 6.48 that the unusual case was due to the large changes of some wastepapers (A_9 and A_1) with the small change of water and electricity. It indicated that there was broke usage less than usual. Thus, it should be named F_3 as "inconsistent usage of some wastepapers (A_9 and A_1)".

For factor scores in F_4 of DP 270 (-2.13 to 1.23), the variation of factor scores in this factor was unbalanced as shown in Figure 6.29.

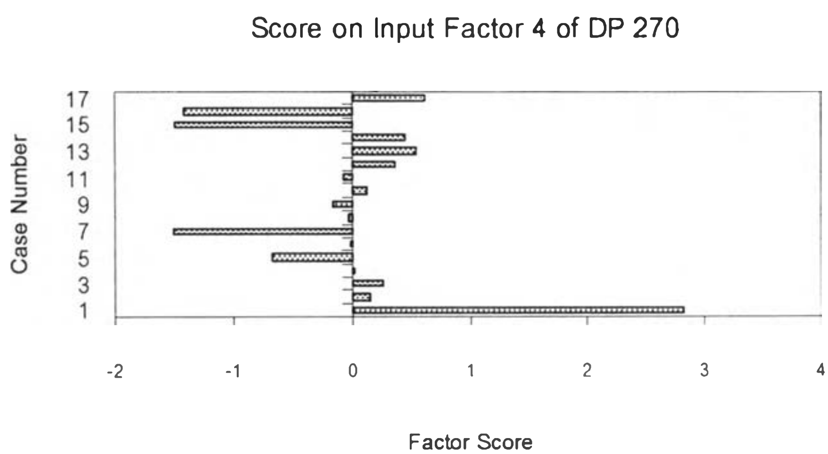


Figure 6.29 Factor Scores of DP 270 for F_4

Based upon the cases of highly magnitude of F_4, it is found in Table 6.49 that the large magnitudes of this factor occur due to the large change of cato. While there were no large changes of water and electricity. It indicated that there was inconsistent usage of cato in the process. Thus, it should be named F_4 as "inconsistent usage of cato".

Table 6.49 Cases of Highly Magnitude of Factor Score for F_4 of DP 270

Input Variables	Case Number			
	1	7	15	16
1. Water	-0.66	0.05	-0.46	-0.66
2. Electricity	-0.15	0.22	-0.74	-0.63
3. A_6	-0.20	-0.65	-0.20	-0.20
4. A_7	0.39	-0.35	0.63	0.63
5. A_8	0.87	0.31	0.42	-0.82
6. A_9	-0.45	-0.17	-1.07	-0.28
7. A_1	0.41	0.01	1.22	0.11
8. A_5	-0.77	1.03	-0.77	0.23
9. Alum	-0.05	-0.51	-0.51	-0.51
10.Clay	0.58	0.32	-1.18	-1.18
11.Emulsifier	0.08	0.05	-0.14	-0.14
12.Cato	**1.78**	**-0.85**	**-0.98**	**-1.11**
13.Starch	-0.52	-0.84	0.67	0.60
14.Color	0.31	-0.15	0.22	0.31
15.Latex	0.30	-0.14	0.23	0.33
16.Other	-0.12	-0.17	-0.11	-0.12
F_4	2.81	-1.50	-1.50	-1.42

For factor scores in F_5 of DP 270 (-1.38 to 2.73), the variation of factor scores in this factor was quite small, except some unusual cases (case # 6 and 11) as shown in Figure 6.30.

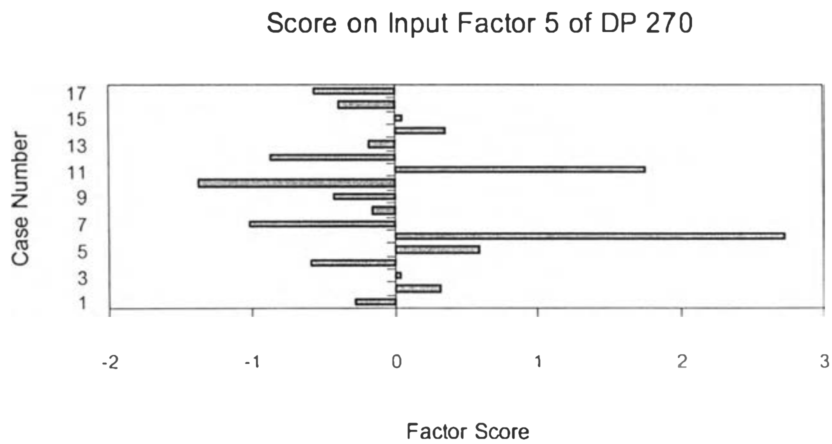


Figure 6.30 Factor Scores of DP 270 for F_5

Table 6.50 Cases of Highly Magnitude of Factor Score for F_5 of DP 270

Input Variables	Case Number	
	6	11
1. Water	-0.05	-0.46
2. Electricity	-0.21	-0.39
3. A_6	-0.36	-0.20
4. A_7	0.39	0.63
5. A_8	-0.82	-0.82
6. A_9	0.50	-0.56
7. A_1	0.26	1.27
8. A_5	2.23	0.03
9. Alum	**2.57**	**1.29**
10.Clay	1.24	0.55
11.Emulsifier	-0.00	-0.03
12.Cato	0.09	0.42
13.Starch	-0.47	-0.54
14.Color	0.08	0.33
15.Latex	0.10	0.39
16.Other	-0.11	-0.09
F_5	2.73	1.76

Based upon the cases of highly magnitude of F_5, it is found in Table 6.50 that there was large change of alum. While there are no large changes of water and electricity due to the use of broke less than usual. It indicated that there was requirement to treat product more for paper formation. Thus, it should be named F_5 as "special treatment of product for paper formation".

Based upon the cases of highly magnitude of factors, the significance factor scores for DP 270 production can be named as shown in Table 6.51.

Table 6.51 The Name of Significant Factors of DP 270

Significant Factor	Name
F_1	Variations of broke generation and usage
F_2	Inconsistent usages of emulsifier and starch
F_3	Inconsistent usage of some wastepapers (A_9 and A_1)
F_4	Inconsistent usage of cato
F_5	Special treatment of product for paper formation

Based upon the factor scores for DP 270, the events occurred in the process indicate this production was also so complex and all variables are somewhat independent. Application of all factor scores for each variety of DPs as the predictor variables may be affected the predictive environmental model for the wastewater loads due to the changes of variables and several events occurred in these factors.

6.1.4 Validation of FA Input Model

Validation of the FA Model was performed using a time-average approach. From a separate set of data collected in a different time period at the same site, one case at a time was used with the original data to rebuild the FA Model. When a new case (or set of observations) was added, the oldest case was removed from the original data set. The results of the second model were compared with those of the first. The process was repeated until all of the new cases are added, and the oldest data sets from the original data collection have been removed. The final model that was used was determined from the average of all of the individual models that were generated in this way (Table 6.52 and 6.53). Based on the available data for 7 months, the data for validation of DPs were 11, 9, 9, 34, and 17 cases for DP 450, DP 400, DP 350, and DP 270, respectively.

Table 6.52 Validation Results of FA Input Model of DP for F_1- F_5

Common Factors (F)	DP 450		DP 400		DP 350		DP 310		DP 270	
	MB	MV	MB	MV	MB	MV	MB	MV	MB	MV
1. F_1										
Color	X	X	X	X	X	X	X	X	X	X
Latex	X	X	X	X	X	X	X	X	X	X
Water									X	
Electricity									X	
Other									X	
A_7			X	X						
Cato										8
Emulsifier										8
2. F_2										
Water			X	X			X			
Electricity			X	X		7	X			
A_1	X	X			X	X				
A_9	X	X			X	X				
Emulsifier									X	
Starch									X	X
Clay						5				
Alum						6				
A_7								4		
3. F_3										
A_1						6			X	X
A_7						X				
A_9						6			X	X
Water								4		
Cato	X	X								
Clay					X					
Alum					X					
Emulsifier			X	X						
4. F_4										
Emulsifier					X					
Cato								13	X	
Alum										
A_9			X	X						
Water						6				6
Starch							X	X		
Electricity										6
Other	X	X								
5. F_5										
Emulsifier						X				
Cato			X				X			
Clay						X(4)				
Water					X					
Electricity					X					
A_5				8						6
A_9										
A_1										
Alum	X	X							X	

Note: X: the presence of variable in factor, MB: Model Building, MV: Model Validation.
Number: the number of new added case that causes the change of variables in the factor.

Table 6.53 Validation Result of FA Input Model of DP for F_6 - F_{10}

Common Factors (F)	DP 450		DP 400		DP 350		DP 310		DP 270	
	MB	MV	MB	MV	MB	MV	MB	MV	MB	MV
6. F_6										
Starch	X	X								
Alum							X	X		3
Cato				4						
A_9										
A_7									X	
A_6										
A_5			X		X	X				
7. F_7										
Water										
Electricity										
A_8			X	X		6			X	X
A_5							X			
Emulsifier	X	X								
A_9								5		
Clay										
A_6										7
A_7										9
Other					X					
8. F_8										
A_5								3		
A_9							X			
A_6									X	
Cato										
Clay	X	X								X(2)
Alum										
Emulsifier										
Other			X	X		6				
Starch					X					
9. F_9										
Clay			X							
Electricity								15		
A_9										
A_1										
A_8	X	X			X					
Starch				X(2)		6				
A_5									X	
Other							X	X		3
10. F_{10}										
Starch										
Other										10
A_6										
A_7										
A_8							X	X		
Clay				7						

Note: X: the presence of variable in factor, MB: Model Building, MV: Model Validation.
Number: the number of new added case that causes the change of variables in the factor.

For DP 450, the pattern of the factor structure or FA model resulting from validation was the same as the pattern of the original factor model building. Therefore, the physical meaning of its model and its factors is valid for current operation.

For DP 400, the pattern of the factor model resulting from validation was almost the same as the pattern of the factor model resulting from model building. Although some variables are shifted from one factor to another factor, namely, the shift of A_5 from F_6 to F_5, cato from F_5 to F_6, and the shift of clay from F_9 to F_{10}, the physical meaning of these significance factors was not changed. The reason was that each factor has the same importance, even its position was changed. Hence, their physical meaning was somewhat valid for process operation.

For DP 350, the pattern of the factor solution or FA model resulting from validating was quite different from that obtained from the original model building. Some variables were shifted from one factor to another factor, namely, the shifts of alum and clay from F_3 to F_2, starch from F_8 to F_9, emulsifier from F_4 to F_5, A_8 from F_9 to F_7, and the shift of electricity from F_5 to F_2. Thus, there were some changes in physical meaning of the FA model for DP 350 affecting the explanation of its production.

For DP 310, the pattern of the factor model resulting from model validation was quite different from that obtained from the original model building as well. Some variables were shifted from one factor to another factor, namely, the shifts of electricity from F_2 to F_9, A_7 from F_3 to F_2, A_9 from F_8 to F_5, A_5 from F_7 to F_8, and cato from F_5 to F_4. These changes provide un-valid description for process operation.

For DP 270, the pattern of the factor model resulting from model validation was also quite different than that obtained from model building. Some variables are shifted from one factor to another factor, namely, the shifts of water and electricity from F_1 to F_4, A_6 from F_8 to F_7, A_7 from F_6 to F_7, emulsifier from F_2 to F_1, cato from F_4 to F_1, and alum from F_5 to F_6. The difference of factors that occurred in validation of FA model of DP 270 mainly was dependent on the pattern of variation of the newdata set. Thus, these models were not valid for process operation.

Overall, based upon the results of the FA model validation for the various types of DP production, it is found that FA model of DPs were generally valid for DP 450 and DP 400 in describing the physical meaning of material input and utility consumption. While these models were not valid for DP 350, DP 310, and DP 270 due to unclearly relationship between input variables. The factors for some groups of input variables were changed resulting the reduction of representative ability of these DPs. Therefore, FA was not successfully used for DP 350, DP 310, and DP 270.

6.2 Model II: MRA Predictive Environmental Model for DP

6.2.1 Data preparation and reduction of predictor variables

This step was performed through FA. The predictor variables (x) were obtained as significant factor scores. All significant factor scores for all DPs were used to determine their relationships with the response variables (y); wastewater load of DPs. In the step of model building, some cases of DPs that were considered as outlier were excluded in the models as shown in Table 6.54.

Table 6.54 The Outlier of Error between Wastewater Load and Factor Occurred in Model Building for all DPs

Model	Case Number				
	DP 450	DP 400	DP 350	DP 310	DP 270
SS	5, 6, 12, 16, 34, 35, 37, 38, 40	7, 9, 16, 18, 28	3, 7, 9, 11, 14, 16, 18, 28, 33	4, 16, 24, 27, 31, 35-38, 41, 55-59	3, 11, 13
TDS	5, 13, 14, 16, 28, 30, 40, 41	2, 3, 14, 15, 18, 24, 27, 32, 35, 36	3, 7, 12, 19, 21, 30	2, 5, 8, 18, 22, 28, 35, 44, 47	2, 3, 7
COD	5, 13, 14, 16, 28, 41, 42	3, 11, 13, 16, 22, 23, 26, 27, 34	7, 10, 21, 33	5, 8, 29, 31, 32, 34, 44, 47	4, 6, 10, 12
BOD	5, 13, 14, 16, 28, 41, 42	3, 11, 13, 16, 22, 23, 26, 27, 34	7, 10, 21, 33	5, 8, 29, 31, 32, 34, 44, 47	4, 6, 8, 11, 13, 16, 17

From Table 6.54, the number of cases that were considered as outlier of error for each type of wastewater load are 9, 8, 7, and 7 for SS, TDS, COD and BOD of DP 450, respectively. Also 5, 10, 9, and 9 for SS, TDS, COD and BOD of DP 400 were not included in these models. 9, 6, 4, and 4 for SS, TDS, COD and BOD of DP 350 were also excluded in these models. 15, 9, 8, and 8 for SS, TDS, COD and BOD of DP 310 were excluded in these models as well. 3, 3, 4, and 7 for SS, TDS, COD and BOD of DP 270 were not included in these models.

For DP 450, the outlier for the final predictive model occurred from wastewater loads (6 cases) more than related factors (2 cases). The outliers were 132 kg/ton for SS load and 33 to 43 kg/ton for TDS load. The ranges of outliers were 41 to 42 kg/ton and 41 to 98 kg/ton for COD and BOD loads, respectively.

For DP 400, the outlier for the final predictive model also occurred from wastewater loads (7 cases) more than related factors (3 cases). The range of outliers are 125 to 204 kg/ton for SS load and 42 to 65 kg/ton for TDS load. The ranges of outliers were 118 to 147 kg/ton and 84 to 103 kg/ton for COD and BOD loads, respectively.

For DP 350, the outlier for the final predictive model occurred from wastewater loads (8 cases) more than related factors (5 cases) as well. The outliers were in the range of 78 to 90 kg/ton for SS load and 22 to 84 kg/ton for TDS load. The ranges of outliers were 11 to 99 kg/ton and 7 to 96 kg/ton for COD and BOD loads, respectively.

For DP 310, the outlier for the final predictive model occurred from wastewater loads (7 cases) more than related factors (5 cases). The outliers were 99 to 220 kg/ton for SS load and 33 to 43 kg/ton for TDS load. The ranges of outliers were 41 to 42, kg/ton and 41 to 98 kg/ton for COD and BOD loads, respectively.

For DP 270, the outlier for the final predictive model occurred only from related factors (1 case). As there was no outlier of wastewater loads for SS, COD and BOD loads, except the outlier of TDS load (2 cases) not occurred for this model.

6.2.2 Model Investigation

It is found that the statistical significance of the proposed models met the assumption in the study for all DPs although they had different values. The result showed that the wastewater loads of all of the types of DPs were in different equation forms. The exact form for each wastewater load and paper grade was illustrated in Table 6.55, and 6.56. These models were used for model testing in a later step.

Table 6.55 Result of Model Investigation for Basic Equation of DP 450, 400, and 350

Model	Predictor Variable	F-test	Sig	R^2	SE	n	Basic Equation
1. DP450							
SS	F_2	0.04	0	0.12	0.31	36	$-0.07+0.03/F_2$
	F_4	0.04	0	0.23	0.30	36	$-0.15-0.11F_4-0.04F_4^2+0.01F_4^3$
TDS	F_1	5.02	0	0.31	0.49	32	$-0.24+0.02F_1+0.13F_1^2+0.01F_1^3$
COD	F_5	35.47	0	0.76	0.45	32	$-0.43+0.36F_5+1.29F_5^2-0.27F_5^3$
BOD	F_2	37.08	0	0.77	0.51	32	$-0.46+0.42F_5+1.49F_5^2-0.31F_5^3$
2.DP 400							
SS	F_3	28.55	0	0.76	0.35	27	$-0.40-0.05F_1+0.36F_1^2-0.08F_1^3$
TDS	F_2	5.80	0	0.34	0.58	27	$-0.52-0.04F_6+0.13F_6^2$
COD	F_2	6.90	0	0.47	0.28	27	$-0.23+0.51F_2+0.44F_2^2-0.21F_2^3$
	F_6	4.90	0	0.29	0.32	27	$-0.15+0.15F_6+0.03F_6^2$
BOD	F_2	6.37	0	0.47	0.31	27	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
	F_6	5.10	0	0.30	0.35	27	$-0.15+0.16F_6+0.03F_6^2$
3. DP 350							
SS	F_3	14.86	0	0.50	0.19	26	$-0.40-0.05F_1+0.36F_1^2-0.08F_1^3$
	F_2	15.79	0	0.64	0.16	26	$-0.52-0.04F_6+0.13F_6^2$
	F_2	12.83	0	0.59	0.17	26	$-0.23+0.51F_2+0.44F_2^2-0.21F_2^3$
TDS	F_6	5.79	0	0.26	0.22	28	$-0.15+0.15F_6+0.03F_6^2$
	F_2	5.24	0	0.25	0.25	28	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
	F_6	6.10	0	0.16	0.24	28	$-0.15+0.16F_6+0.03F_6^2$
	F_6	3.89	0	0.18	0.24	28	$-0.15+0.15F_6+0.03F_6^2$
COD	F_2	12.64	0	0.55	0.29	30	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
BOD	F_6	13.05	0	0.55	0.32	30	$-0.15+0.16F_6+0.03F_6^2$

Table 6.56 Result of Model Investigation for Basic Equation of DP 310 and 270

Model	Predictor Variable	F-test	Sig	R^2	SE	n	Basic Equation
4. DP 310							
SS	F_1	13.43	0	0.12	0.31	36	$-0.31+0.29F_1+1.09F_4^2$
	F_2	3.39	0	0.23	0.30	36	$-0.35+1.13F_2-0.03F_2^2$
	F_3	3.90	0	0.31	0.49	32	$-0.35+0.14F_3+0F_3^2-0.02F_3^3$
TDS	F_5	9.46	0	0.76	0.45	32	$-0.48+0.04F_5+0.08F_5^2+0.06F_5^3$
	F_6	9.09	0	0.77	0.51	32	$-0.44+0.008/F_6$
COD	F_2	8.67	0	0.76	0.35	27	$-0.24+0.47F_2+0.23F_2^2-0.06F_2^3$
	F_4	11.82	0	0.34	0.58	27	$-0.37+0.24F_4-0.04F_4^2-0.14F_4^3$
BOD	F_2	14.49	0	0.47	0.28	27	$-0.36+0.49F_2+0.32F_2^2-0.07F_2^3$
	F_4	13.88	0	0.29	0.32	27	$-0.39+0.3F_4-0.04F_4^2-0.16F_4^3$
5.DP 270							
SS	F_1	28.02	0	0.89	0.25	14	$-0.28-0.04F_1-0.04F_1^2-0.07F_1^3$
	F_2	98.94	0	0.89	0.23	14	$-0.30+0.005/F_2$
TDS	F_1	48.68	0	0.84	0.51	11	$-0.41+0.04/F_1$
	F_2	14.50	0	0.62	0.80	11	$0.06-0.26/F_2$
	F_4	61.52	0	0.87	0.46	11	$-0.32-0.03/F_4$
	F_5	57.77	0	0.94	0.35	11	$-0.14+0.74F_5+0.21F_5^2$
COD	F_1	26.94	0	0.93	0.13	10	$-0.30-0.09F_1+0.31F_1^2+0.06F_1^3$
BOD	F_1	29.30	0	0.94	0.15	10	$-0.35-0.13F_1+0.57F_1^2+0.14F_1^3$

6.2.3 Model Testing

Through a statistical test (Table 6.57, and 6.58), the proposed models that meet the MRA assumptions were developed The results of the appropriateness properties of the model were as discussed in the following section.

Means of the error of the proposed models were zero with low standard errors. Moreover, the Kolmogorov-Smirnov and Shapiro-Wilk tests and Levene's test have higher significance values than the values at a significance level of 0.05. Furthermore, there were no outlier due to the error values of the proposed model less than 1.5 inter-quantile range (1.5IQR). This meant that the error distributions of the model were normal distribution for all types of wastewater loads: SS, TDS, COD, and BOD loads for all varieties of DP. The model testing was also run through several iterations until the models meet the assumption. Then, the models for all predictor variables were obtained for estimating the model parameters.

Table 6.57 Result of Model Testing for Basic Equation of DP 450, 400, and 350

Model	Kolmogorov-Smirnov	Sig.	Shapiro-Wilk	Sig	Mean of error & SE	Basic Equation
1. DP 450						
SS	0.10	0.2	0.98	0.72	0	$-0.07+0.03/F_2$
	0.09	0.2	0.97	0.50	0	$-0.15-0.11F_4-0.04F_4^2+0.01F_4^3$
TDS	0.09	0.2	0.96	0.38	0	$-0.24+0.02F_1+0.13F_1^2+0.01F_1^3$
COD	0.09	0.2	0.97	0.48	0	$-0.43+0.36F_5+1.29F_5^2-0.27F_5^3$
BOD	0.09	0.2	0.97	0.43	0	$-0.46+0.42F_5+1.49F_5^2-0.31F_5^3$
2.DP 400						
SS	0.15	0.2	0.96	0.38	0	$-0.40-0.05F_1+0.36F_1^2-0.08F_1^3$
TDS	0.13	0.2	0.95	0.32	0	$-0.52-0.04F_6+0.13F_6^2$
COD	0.09	0.2	0.98	0.74	0	$-0.23+0.51F_2+0.44F_2^2-0.21F_2^3$
	0.11	0.2	0.97	0.66	0	$-0.15+0.15F_6+0.03F_6^2$
BOD	0.12	0.2	0.74	0.71	0	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
	0.12	0.2	0.66	0.44	0	$-0.15+0.16F_6+0.03F_6^2$
3.DP 350						
SS	0.10	0.2	0.82	0.82	0	$-0.40-0.05F_1+0.36F_1^2-0.08F_1^3$
	0.12	0.2	0.45	0.49	0	$-0.52-0.04F_6+0.13F_6^2$
	0.13	0.2	0.36	0.36	0	$-0.23+0.51F_2+0.44F_2^2-0.21F_2^3$
TDS	0.14	0.2	0.99	0.99	0	$-0.15+0.15F_6+0.03F_6^2$
	0.10	0.2	0.97	0.66	0	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
	0.09	0.2	0.98	0.75	0	$-0.15+0.16F_6+0.03F_6^2$
	0.12	0.2	0.98	0.38	0	$-0.15+0.15F_6+0.03F_6^2$
COD	0.10	0.2	0.98	0.75	0	$-0.22+0.61F_2+0.50F_2^2-0.25F_2^3$
BOD	0.10	0.2	0.98	0.80	0	$-0.15+0.16F_6+0.03F_6^2$

Note: Values of Levene's test for DP 450 are 0.55 for SS, 0.65 and 0.65 for TDS, and COD & BOD
For DP 400, they are 0.55 for SS, 0.45 for TDS, 0.7 to 0.95 for COD and BOD, respectively
For DP 350, they are 0.55 for SS, 0.5, 0.7, and 0.95 for TDS, and 0.55 for COD and BOD

Table 6.58 Result of Model Testing for Basic Equation of DP 310, and 270

Model	Kolmogorov-Smirnov	Sig.	Shapiro-Wilk	Sig	Mean of error & SE	Basic Equation
4. DP 310 SS	0.08	0.2	0.98	0.72	0	$-0.31+0.29F_1+1.09F_4^2$
	0.12	0.2	0.97	0.50	0	$-0.35+1.13F_2-0.03F_2^2$
	0.09	0.2	0.96	0.38	0	$-0.35+0.14F_3+0F_3^2-0.02F_3^3$
TDS	0.09	0.2	0.97	0.48	0	$-0.48+0.04F_5+0.08F_5^2+0.06F_5^3$
	0.05	0.2	0.97	0.43	0	$-0.44+0.008/F_6$
COD	0.10	0.2	0.96	0.38	0	$-0.24+0.47F_2+0.23F_2^2-0.06F_2^3$
	0.11	0.2	0.95	0.32	0	$-0.37+0.24F_4-0.04F_4^2-0.14F_4^3$
BOD	0.08	0.2	0.98	0.74	0	$-0.36+0.49F_2+0.32F_2^2-0.07F_2^3$
	0.11	0.2	0.97	0.66	0	$-0.39+0.3F_4-0.04F_4^2-0.16F_4^3$
5.DP 270 SS	0.12	0.2	0.74	0.77	0	$-0.28-0.04F_1-0.04F_1^2-0.07F_1^3$
	0.12	0.2	0.66	0.58	0	$-0.30+0.005/F_2$
TDS	0.16	0.2	0.96	0.74	0	$-0.41+0.04/F_1$
	0.18	0.2	0.94	0.48	0	$0.06-0.26/F_2$
	0.15	0.2	0.95	0.54	0	$-0.32-0.03/F_4$
	0.15	0.2	0.97	0.82	0	$-0.14+0.74F_5+0.21F_5^2$
COD	0.16	0.2	0.98	0.94	0	$-0.30-0.09F_1+0.31F_1^2+0.06F_1^3$
BOD	0.16	0.2	0.97	0.79	0	$-0.35-0.13F_1+0.57F_1^2+0.14F_1^3$

Note: Values of Levene's test for DP 310 are 0.55 to 0.65 for SS, 0.35 for TDS, and 0.75 to 0.95 for COD &BOD
For DP 270, they are 0.98 for SS, 1.25 to 1.85 for TDS, and 1.85 for COD and BOD

6.2.4 Estimation of Model Parameters

The estimated model parameters that had low standard error were used as the model parameters of the predictive equation (Table 6.59). Based on these parameters, the relationships between factors and wastewater loads can be determined. These predictive wastewater models were then evaluated and the results were interpreted in the next step.

Table 6.59 Result of Estimation of Model Parameters in Predictive Equation of DPs

Model	R^2x100	SE	n	Estimated Model Parameters in Composite Predictive Equation
1. DP 450				
SS	29.22	<0.5	36	$-0.16 + 0.2/F_2 - 0.14 F_4 - 0.01 F_4^2 + 0.004 F_4^3$
TDS	31.33	<0.5	37	$-0.24 + 0.02 F_1 + 0.13 F_1^2 + 0.01 F_1^3$
COD	75.78	<0.5	38	$-0.43 + 0.36 F_5 + 1.29 F_5^2 - 0.27 F_5^3$
BOD	76.59	<0.5	38	$-0.46 + 0.42 F_5 + 1.49 F_5^2 - 0.31 F_5^3$
2. DP 400				
SS	76.03	<0.5	31	$-0.40 - 0.05 F_1 + 0.37 F_1^2 - 0.08 F_1^3$
TDS	33.53	<0.5	26	$-0.52 - 0.04 F_6 + 0.13 F_6^2$
COD	65.76	<0.5	27	$-0.26 + 0.44 F_2 + 0.42 F_2^2 - 0.19 F_2^3 + 0.12 F_6 + 0.03 F_6^2$
BOD	66.16	<0.5	27	$-0.27 + 0.53 F_2 + 0.48 F_2^2 - 0.23 F_2^3 + 0.13 F_6 + 0.03 F_6^2$
3. DP 350				
SS	76.77	<0.5	26	$- 0.39 + 0.11 F_1 + 1.02 F_1^2 + 0.08 F_2 - 0.01F_2^2 + 0.16 F_3 + 0.002 F_3^2 - 0.02 F_4$
TDS	72.39	<0.5	28	$- 0.48 - 0.1 F_1 + 0.05 F_1^2 - 0.01 F_2 - 0.08 F_2^2 -0.02/F_4 + 0.1 F_5 - 0.01 F_5^2$
COD	60.09	<0.5	30	$- 0.51 + 0.42 F_4 + 0.63 F_4^2 - 0.24 F_4^3$
BOD	60.25	<0.5	30	$- 0.49 + 0.36 F_4 + 0.55 F_4^2 - 0.21 F_4^3$
4. DP 310				
SS	42.52	<0.5	44	$- 0.39 + 0.11 F_1 + 1.02 F_1^2 + 0.08 F_2 - 0.01F_2^2 + 0.16 F_3 + 0.002 F_3^2 - 0.02 F_4$
TDS	41.40	<0.5	45	$- 0.48 + 0.04 F_5 + 0.08 F_5^2 + 0.05 F_5^3 + 0.02/F_6$
COD	59.96	<0.5	51	$- 0.32 + 0.33 F_2 + 0.08 F_2^2 - 0.02 F_2^3 + 0.15 F_4 - 0.08F_4^2 - 0.11 F_4^3$
BOD	60.25	<0.5	51	$- 0.33 + 0.36 F_2 + 0.09 F_2^2 - 0.03 F_2^3 + 0.21 F_4 - 0.09F_4^2 - 0.13 F_4^2$
5. DP 270				
SS	90.15	<0.5	14	$- 0.33 - 0.15 F_1 + 0.03 F_1^2 + 0.14 F_1^3 + 0.16/F_2$
TDS	96.60	<0.5	11	$- 0.34 + 0.02/F_1 - 0.12/F_2 + 0.02/F_4 + 0.18 F_5 + 0.26F_5^2$
COD	92.71	<0.5	10	$- 0.29 + 0.13 F_1 + 0.09 F_1^2 - 0.04 F_1^3$
BOD	91.87	<0.5	10	$- 0.32 + 0.15 F_1 + 0.14 F_1^2 - 0.05 F_1^3$

6.2.5 Evaluation and Interpretation of the Model

Through the statistical test of the MRA model, the results showed that all of the proposed models met the statistical significance and MRA assumptions as demonstrated in Table 6.60. In addition, there were zero mean of residuals and standard error (*SE*) for these models. Furthermore, the statistical values of Kolmogorov-Smirnov and Shapiro-Wilk and Levene's test were higher than the significance values at the 0.05 level. This indicated that the residual distribution is a normal distribution. Therefore, all of the predictive models obtained were used for model validation in a further step.

Table 6.60 Result of Evaluation of Model for Predictive Equation of DPs

Model	Kolmo gorov-Smirnov	Sig.	Shapiro -Wilk	Sig	Predictive Equation
1. DP 450					
SS	0.10	0.2	0.97	0.72	$-0.16 + 0.2/F_2 - 0.14 F_4 - 0.01 F_4^2 + 0.004F_4^3$
TDS	0.09	0.2	0.96	0.50	$-0.24 + 0.02 F_1 + 0.13 F_1^2 + 0.01 F_1^3$
COD	0.09	0.2	0.97	0.38	$-0.43 + 0.36 F_5 + 1.29 F_5^2 - 0.27 F_5^3$
BOD	0.09	0.2	0.97	0.48	$-0.46 + 0.42 F_5 + 1.49 F_5^2 - 0.31 F_5^3$
2. DP 400					
SS	0.15	0.2	0.96	0.43	$-0.40 - 0.05 F_1 + 0.37 F_1^2 - 0.08 F_1^3$
TDS	0.13	0.2	0.95	0.38	$-0.52 - 0.04 F_6 + 0.13 F_6^2$
COD	0.10	0.2	0.99	0.32	$-0.26 + 0.44 F_2 + 0.42 F_2^2 - 0.19 F_2^3 + 0.12 F_6 + 0.03 F_6^2$
BOD	0.09	0.2	0.99	0.74	$-0.27 + 0.53 F_2 + 0.48 F_2^2 - 0.23 F_2^3 + 0.13 F_6 + 0.03 F_6^2$
3. DP 350					
SS	0.09	0.2	0.98	0.90	$- 0.39 + 0.11 F_1 + 1.02 F_1^2 + 0.08 F_2 - 0.01F_2^2 + 0.16 F_3 + 0.002 F_3^2 - 0.02 F_4$
TDS	0.14	0.2	0.95	0.30	$- 0.48 - 0.1 F_1 + 0.05 F_1^2 - 0.01 F_2 - 0.08 F_2^2 - 0.02/F_4 + 0.1 F_5 - 0.01 F_5^2$
COD	0.10	0.2	0.98	0.80	$- 0.51 + 0.42 F_4 + 0.63 F_4^2 - 0.24 F_4^3$
BOD	0.10	0.2	0.98	0.80	$- 0.49 + 0.36 F_4 + 0.55 F_4^2 - 0.21 F_4^3$
4. DP 310					
SS	0.15	0.2	0.91	0.10	$- 0.39 + 0.11 F_1 + 1.02 F_1^2 + 0.08 F_2 - 0.01F_2^2 + 0.16 F_3 + 0.002 F_3^2 - 0.02 F_4$
TDS	0.08	0.2	0.97	0.48	$- 0.48 + 0.04 F_5 + 0.08 F_5^2 + 0.05 F_5^3 + 0.02/F_6$
COD	0.13	0.2	-	-	$- 0.32 + 0.33 F_2 + 0.08 F_2^2 - 0.02 F_2^3 + 0.15 F_4 - 0.08F_4^2 - 0.11 F_4^3$
BOD	0.11	0.2	-	-	$- 0.33 + 0.36 F_2 + 0.09 F_2^2 - 0.03 F_2^3 + 0.21 F_4 - 0.09F_4^2 - 0.13 F_4^2$
5. DP 270					
SS	0.14	0.2	0.98	0.98	$- 0.33 - 0.15 F_1 + 0.03 F_1^2 + 0.14 F_1^3 + 0.16/F_2$
TDS	0.13	0.2	0.95	0.95	$- 0.34 + 0.02/F_1 - 0.12/F_2 + 0.02/F_4 + 0.18F_5 + 0.26F_5^2$
COD	0.14	0.2	0.98	0.98	$- 0.29 + 0.13 F_1 + 0.09 F_1^2 - 0.04 F_1^3$
BOD	0.11	0.2	0.99	0.99	$- 0.32 + 0.15 F_1 + 0.14 F_1^2 - 0.05 F_1^3$

Note: Values of Levene's test are 0.45 to 0.55 for DP 450, and 0.85 to 1.98 for DP 400, 350, 310, and 270

6.2.6 Predictive Equation for Wastewater Loads of DPs and its Validation

The results of predicted model for all DPs were shown in Table 6.61.

Table 6.61 Predictive Environmental Model for Wastewater of Duplex Coated Board

DPs	Predictive Environmental Model	% Relation (R^2 x 100)	
		MB	MV
1.DP 450	1. ZSS load = $-0.16 + 0.2/F_2 - 0.14 F_4 - 0.01 F_4^2 + 0.004 F_4^3$	29.22	20.17
	2. ZTDS load = $-0.24 + 0.02 F_1 + 0.13 F_1^2 + 0.01 F_1^3$	31.33	13.33
	3. ZCOD load = $-0.43 + 0.36 F_5 + 1.29 F_5^2 - 0.27 F_5^3$	75.78	5.96
	4. ZBOD load = $-0.46 + 0.42 F_5 + 1.49 F_5^2 - 0.31 F_5^3$	76.59	5.75
2.DP 400	1. ZSS load = $-0.40 - 0.05 F_1 + 0.37 F_1^2 - 0.08 F_1^3$	76.03	29.71
	2. ZTDS load = $-0.52 - 0.04 F_6 + 0.13 F_6^2$	33.53	7.50
	3. ZCOD load = $-0.26 + 0.44 F_2 + 0.42 F_2^2 - 0.19 F_2^3 + 0.12 F_6 + 0.03 F_6^2$	65.76	16.77
	4. ZBOD load = $-0.27 + 0.53 F_2 + 0.48 F_2^2 - 0.23 F_2^3 + 0.13 F_6 + 0.03 F_6^2$	66.16	15.73
3.DP 350	1. ZSS load = $-0.52 - 0.02 F_1 - 0.04 F_1^2 - 0.15 F_3 + 0.08 F_3^2 + 0.09 F_3^3 - 0.13 F_4 + 0.13 F_4^2 - 0.01 F_4^3$	76.77	_
	2. ZTDS load = $-0.48 - 0.1 F_1 + 0.05 F_1^2 - 0.01 F_2 - 0.08 F_2^2 - 0.02/F_4 + 0.1 F_5 - 0.01 F_5^2$	72.39	_
	3. ZCOD load = $-0.51 + 0.42 F_4 + 0.63 F_4^2 - 0.24 F_4^3$	60.09	_
	4. ZBOD load = $-0.49 + 0.36 F_4 + 0.55 F_4^2 - 0.21 F_4^3$	59.32	_
4.DP 310	1. ZSS load = $-0.39 + 0.11 F_1 + 1.02 F_1^2 + 0.08 F_2 - 0.01F_2^2 + 0.16 F_3 + 0.002 F_3^2 - 0.02 F_4$	42.52	_
	2. ZTDS load = $-0.48 + 0.04 F_5 + 0.08 F_5^2 + 0.05 F_5^3 + 0.02/F_6$	41.40	_
	3. ZCOD load = $-0.32 + 0.33 F_2 + 0.08 F_2^2 - 0.02 F_2^3 + 0.15 F_4 - 0.08 F_4^2 - 0.11 F_4^3$	59.96	_
	4. ZBOD load = $-0.33 + 0.36 F_2 + 0.09 F_2^2 - 0.03 F_2^3 + 0.21 F_4 - 0.09F_4^2 - 0.13 F_4^2$	60.25	_
5.DP 270	1. ZSS load = $-0.33 - 0.15 F_1 + 0.03 F_1^2 + 0.14 F_1^3 + 0.16/F_2$	90.15	_
	2. ZTDS load = $-0.34 + 0.02/F_1 - 0.12/F_2 + 0.02/F_4 + 0.18 F_5 + 0.26F_5^2$	96.60	_
	3. ZCOD load = $-0.29 + 0.13 F_1 + 0.09 F_1^2 - 0.04 F_1^3$	92.71	_
	4. ZBOD load = $-0.32 + 0.15 F_1 + 0.14 F_1^2 - 0.05 F_1^3$	91.87	_

Note: % relation calculation for MB Model building excluding outliers, and for MV Model validation including outliers, _ % relation can not determined for all real cases

From Table 6.61, the relationship between each wastewater load and significant factors of DP production were discussed through each type of DP as the following sections.

6.2.6.1. Predictive model of Wastewater load for DP 450 :

1) SS load :

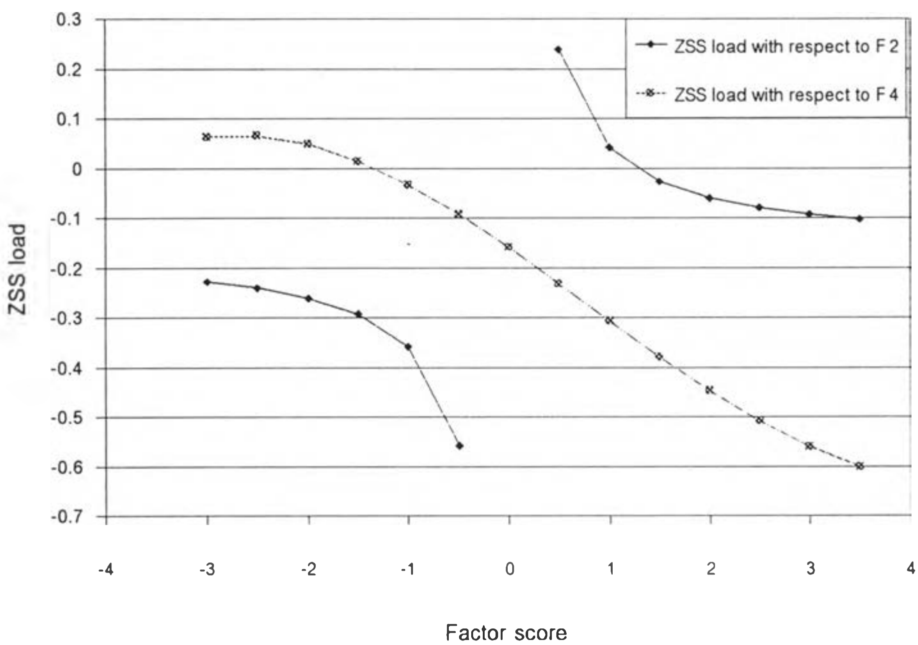


Figure 6.31 The Relationship between ZSS Load of DP 450 and F_2 and F_4

From Figure 6.31, in terms of increasing of ZSS load, it is found that ZSS load was more sensitive to F_2 than F_4 at magnitude of factor score 0 to <1.5. In practical situation, the highest magnitude is < 4.

Through the unusual cases (case # 15, 23-25, 30, 33, 35-37, 38-39, and 43-44) for the magnitude of dominant factor, F_2 (0 to < 1) in the model and its name, it indicated that the root cause for ZSS load increase was due to the overflow of white water from the change of paper grade. The white water from the previous operation was drained off. The loss of this water that contains fine (fibers) and dispersed materials can affect the increase of SS load and leads to the highly consumption of some wastepapers. In addition, the use of broke more than usual can affect the increase of ZSS load due to the loss of chemical additives as dispersed materials that needs to be added.

2) TDS load :

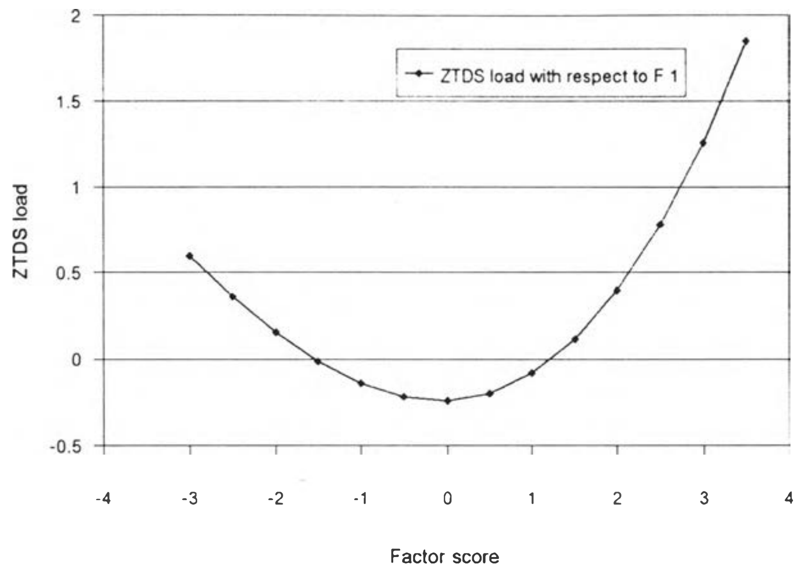


Figure 6.32 The Relationship between ZTDS Load of DP 450 and F_1

From Figure 6.32, in terms of increasing of ZTDS load, it is found that ZTDS load was sensitive to F_1 at magnitude of factor score >|1.5|. In practical situation, the highest magnitude is < 4.

Through the highly cases (case # 8, 22, 34, 42, and 45) for the magnitude of dominant factor, F_1 (> |1|) in the model and its name, it indicated that the root cause for ZTDS load increase was due to the overflow of white water from the change of paper grade. The loss of this water that contained dissolved materials affected ZTDS load increase and can lead to the highly consumption of dissolved chemicals such as starch.

3) COD load :

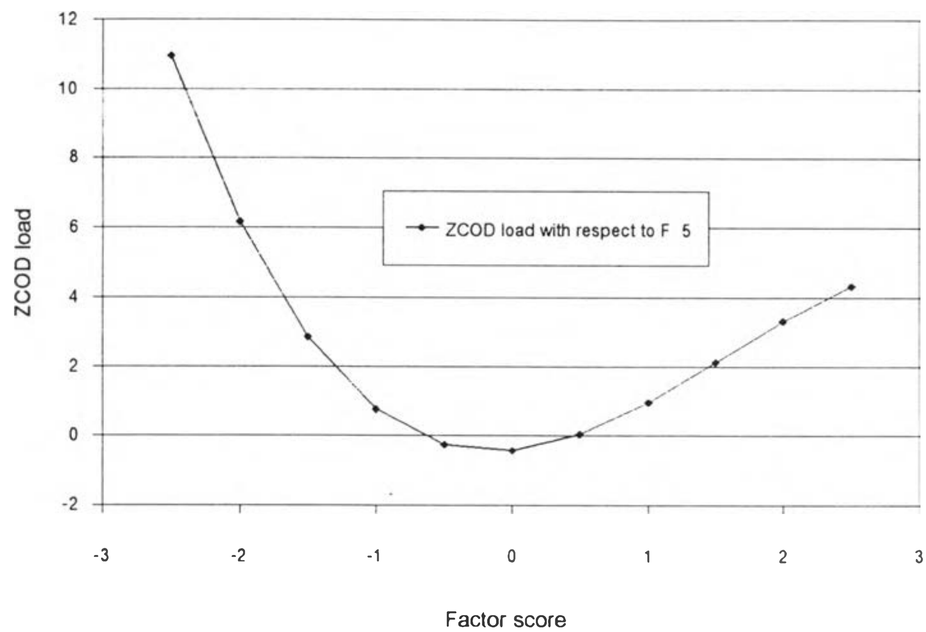


Figure 6.33 The Relationship between ZCOD Load of DP 450 and F_5

From Figure 6.33, in terms of increasing of ZCOD load, it is found that within the range of actual ZCOD load (±3), ZCOD load was sensitive to F_5 at magnitude of factor score in between |1| to |3|.

Through the highly cases (case # 12, 14, and 28) for the magnitude of dominant factor, F_5 (> |1|) in the model and its name, it indicated that the root cause for ZCOD load increase was due to the use of broke less than usual. The highly consumptions of not only wastepapers but also other chemicals were needed. These materials supplied contributed to the ZCOD and ZBOD loads increase.

4) BOD load :

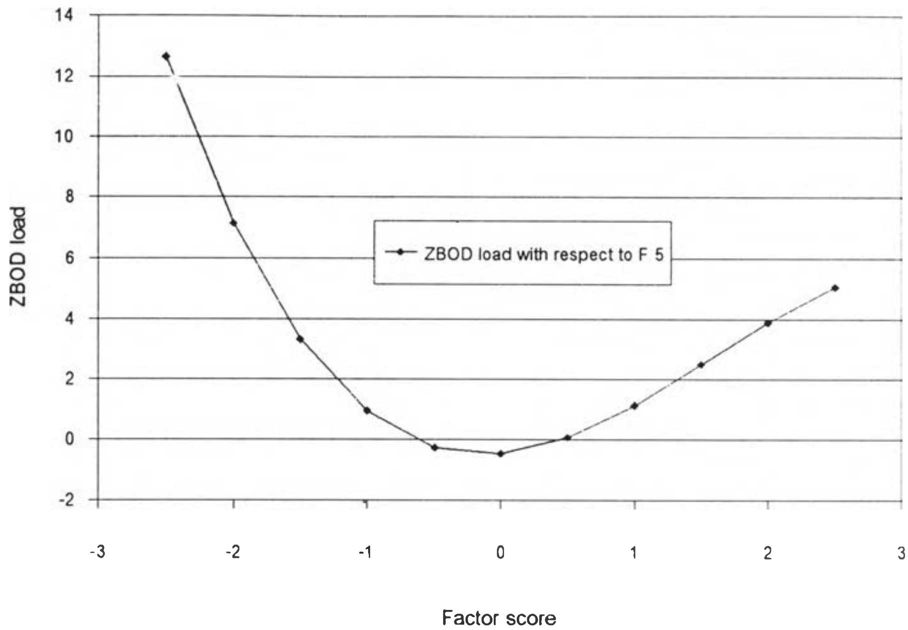


Figure 6.34 The Relationship between ZBOD Load of DP 450 and F_5

From Figure 6.34, in terms of increasing of ZBOD load, it is found that within the range of actual ZBOD load (±3), ZBOD load was also sensitive to F_5 at magnitude of factor score in between |1| to |3|.

Through the highly cases (case # 12, 14, and 28) for the magnitude of dominant factor, F_5 (> |1|) in the model and its name, it indicated that the root cause for ZBOD load increase was due to the use of broke less than usual as mentioned in ZCOD load.

6.2.6.2. Predictive model of Wastewater load for DP 400 :

1) SS load :

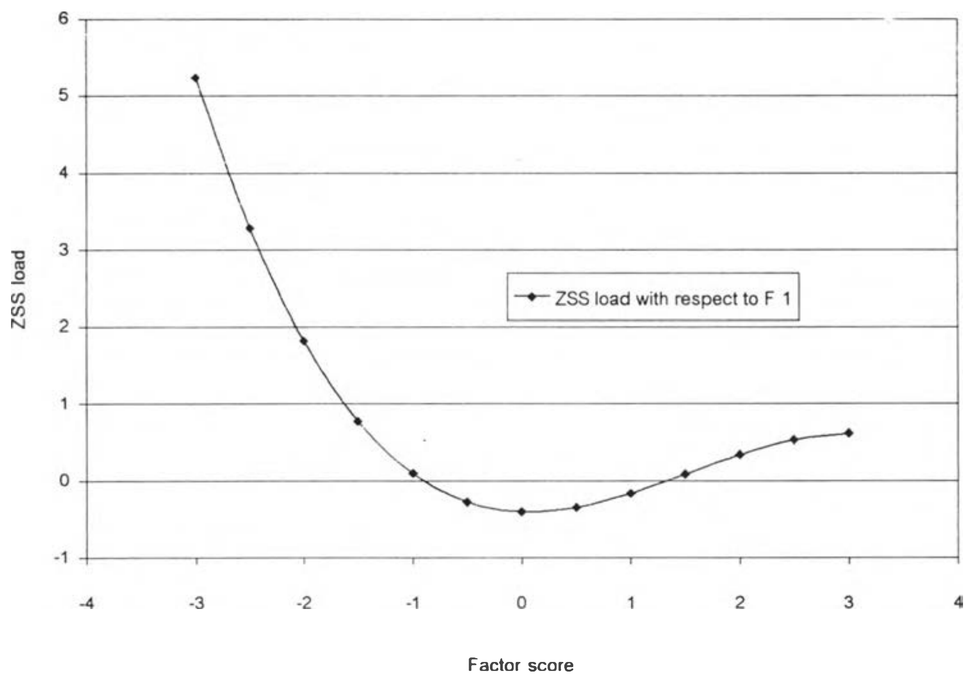


Figure 6.35 The Relationship between ZSS Load of DP 400 and F_1

From Figure 6.35, in terms of increasing of ZSS load, it is found that within the range of actual ZSS load (±3), ZSS load was also sensitive to F_1 at magnitude of factor score > |1|.

Through the highly cases (case # 3, 7, 16, 24, and 30) for the magnitude of dominant factor, F_1 (> |1|) in the model and its name, it indicated that the root cause for ZSS load increase was due to the overflow of white water from the change of paper grade. The loss of fibers that contained in this water affected the increasing of SS load.

2) TDS load :

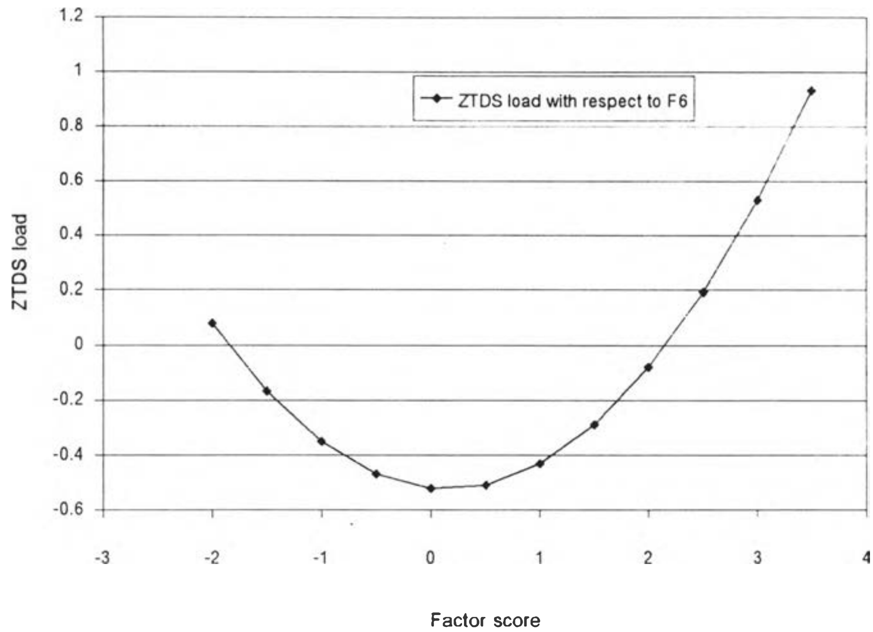


Figure 6.36 The Relationship between ZTDS load of DP 400 and F_6

From Figure 6.36, in terms of increasing of ZTDS load, it is found that, within the range of actual ZTDS load (-2 to 3.3), ZTDS load was also sensitive to F_6 at magnitude of factor score > |1|.

Through the highly cases (case # 1-6, 11, 15, 17-18, 27, and 31) for the magnitude of dominant factor, F_6 (> |1|) in the model and its name, it indicated that the root cause for ZTDS load increase was due to the overflow of white water from the change of paper grade. The loss of this water that contained dissolved materials affected the ZTDS load increase.

3) COD load :

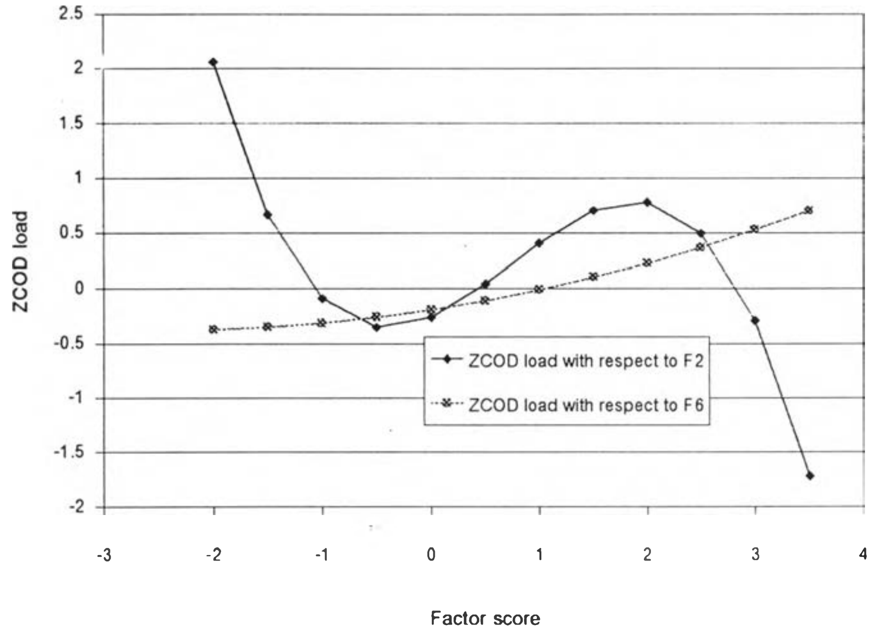


Figure 6.37 The Relationship between ZCOD load of DP 400 and F_2 and F_6

From Figure 6.37, in terms of increasing of ZCOD load, it is found that ZCOD load was more sensitive to F_2 than F_6 at magnitude of factor score in between |1| to |2|.

Through the highly cases (case # 11, 19, and 27) for the magnitude of dominant factor, F_2 (in between |1| to 3) in the model and its name, it indicated that the root cause for ZCOD load increase was due to the use of broke more than usual. In this case, the use of broke contributes to not only ZBOD load but also ZCOD load due to the highly chemical additives that need to be added.

4) BOD load :

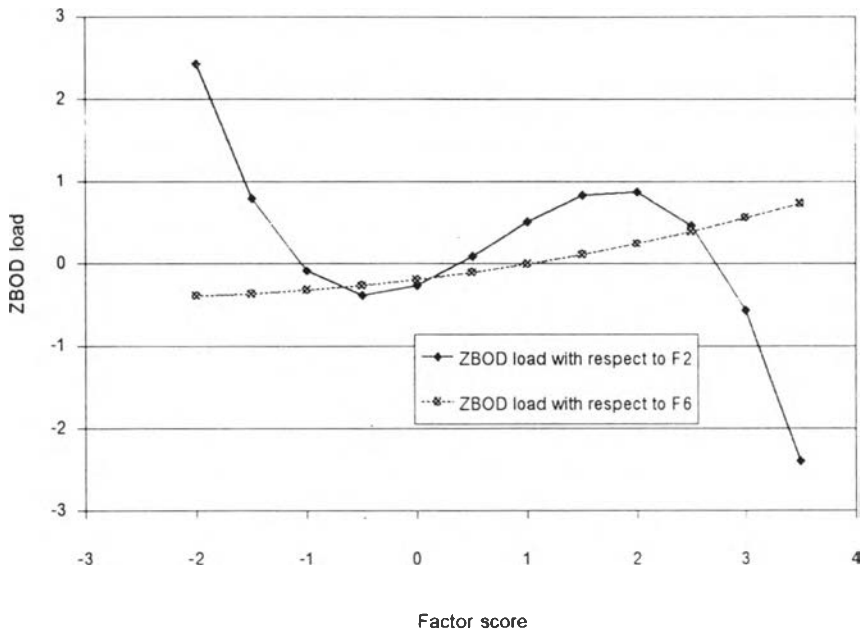


Figure 6.38 The Relationship between ZBOD Load of DP 400 and F_2 and F_6

From Figure 6.38, in terms of increasing of ZBOD load, it is found that ZBOD load is also more sensitive to F_2 than F_6 at magnitude of factor score in between |1| to |2|.

Through the highly cases (case # 11, 19, and 27) for the magnitude of dominant factor, F_2 in the model and its name, it indicated that the root cause for ZBOD load increase was due to the use of broke more than usual with the same reason as mentioned in ZCOD load.

6.2.6.3. Predictive model of Wastewater load for DP 350 :

1) SS load :

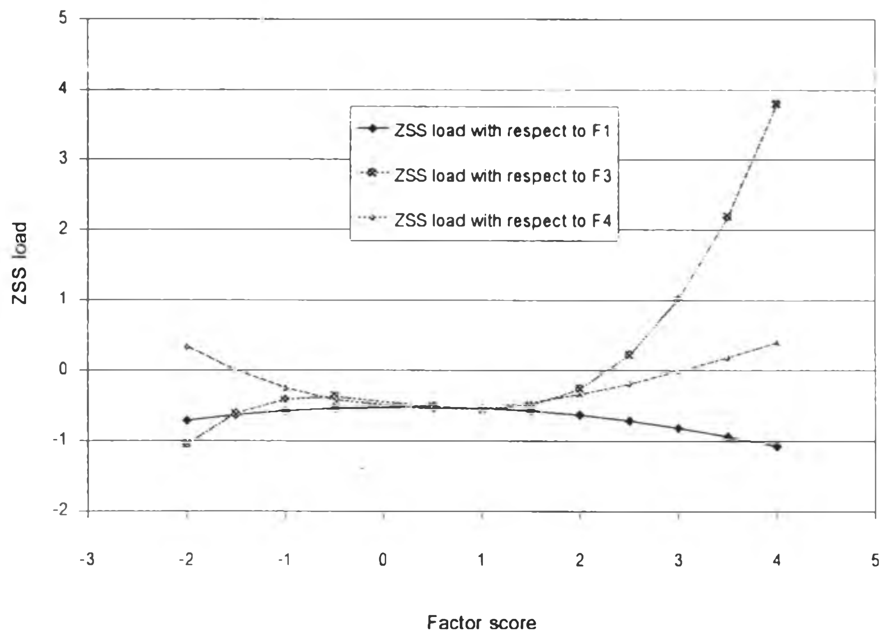


Figure 6.39 The Relationship between ZSS Load of DP 350 and F_1, F_3 and F_4

From Figure 6.39, in terms of increasing of ZSS load, it is found that, within the range of actual ZSS load (in between –2 to 3.7), ZSS load was more sensitive to F_3 than F_1 and F_4 at magnitude of factor score > 2.5. Although, at magnitude of factor score < -1.5, ZSS load was more sensitive to F_4 than F_1 and F_3. In practical, there were no factor scores < -1.5 for F_4 and F_3, except F_1.

Through the highly cases (case # 11 and 12) for the magnitude of dominant factor, F_3 (> 2.3) in the model and its name, it indicated that the root cause for ZSS load increase was due to the overflow of white water during the change of paper grade. The loss of fibers in this water contributed to the increase of ZSS load.

2) TDS load :

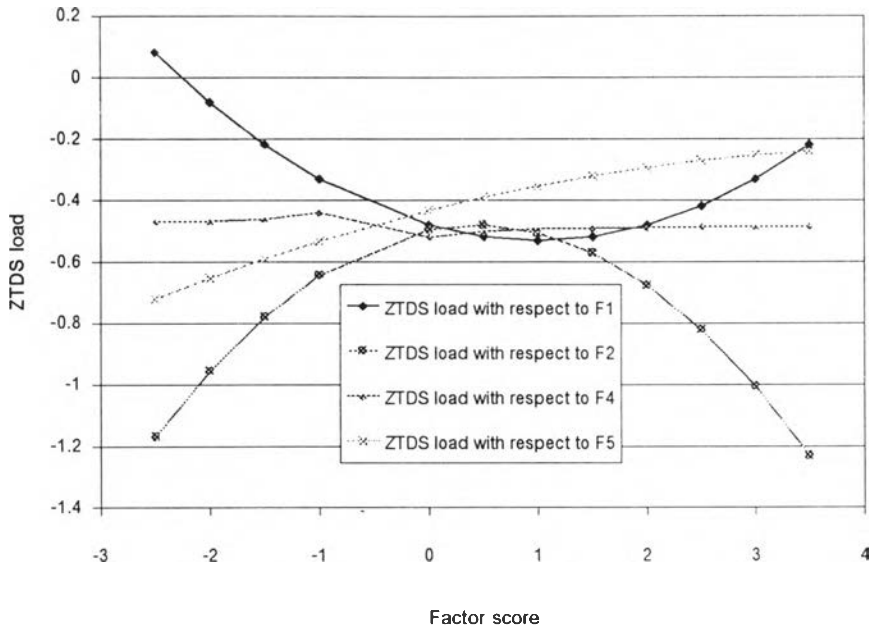


Figure 6.40 The Relationship between ZTDS Load of DP 350 and F_1, F_2, F_4, and F5

From Figure 6.40, in terms of increasing of ZTDS load, it is found that ZTDS load was more sensitive to F_1 than other factors at magnitude of factor score $> |1|$. Except F_5 at magnitude of factor score in between 0 to 3.4, ZTDS load was more sensitive to F_5 than other factors. In practical situation, there was no case that all of other factors were in the same range of F_5.

Through the highly cases (case # 1, 3, 5, 11-12, 18, 24, and 34) for the magnitude of dominant factor, F_1 in the model and its name, this indicates that the root cause for ZTDS load increase was due to the increased use of broke. The loss of dissolved chemicals in broke also contributed to the increase of ZTDS load.

3) COD load :

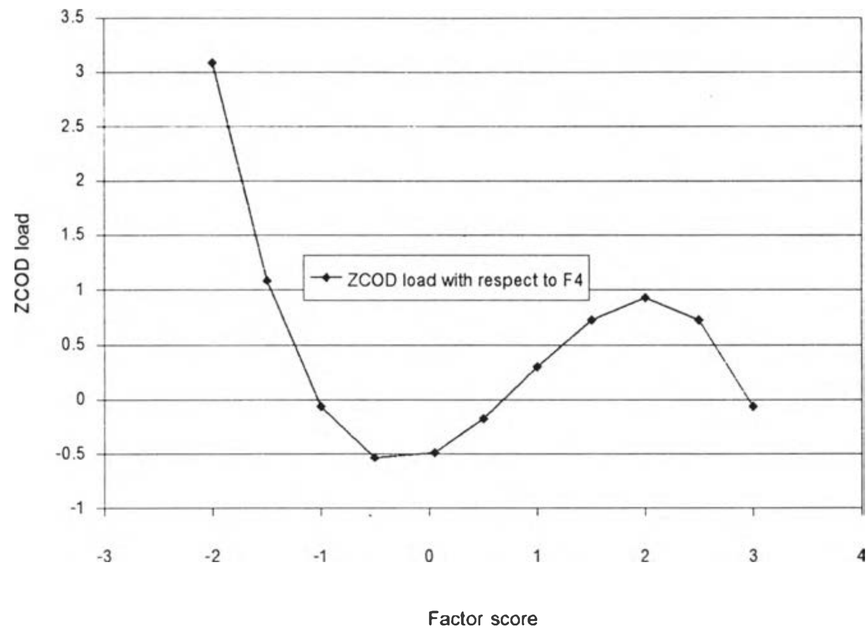


Figure 6.41 The Relationship between ZCOD Load of DP 350 and F_4

From Figure 6.41, in terms of increasing of ZCOD load, it is found that, within the range of actual ZCOD load (-1.5 to 3), ZCOD load was sensitive to F_4 at magnitude of factor score > |0.5|.

Through the highly cases (case # 3, 5, 7, 10, 12-13, and 18) for the change of magnitude of dominant factor, F_4 (>|1|) in the model and its name, it indicated that the root cause for ZCOD load increase was due to the use of broke less than usual The increase of fiber materials from the consumption of wastepapers contributed to the increase of both ZCOD and ZBOD loads.

4) BOD load :

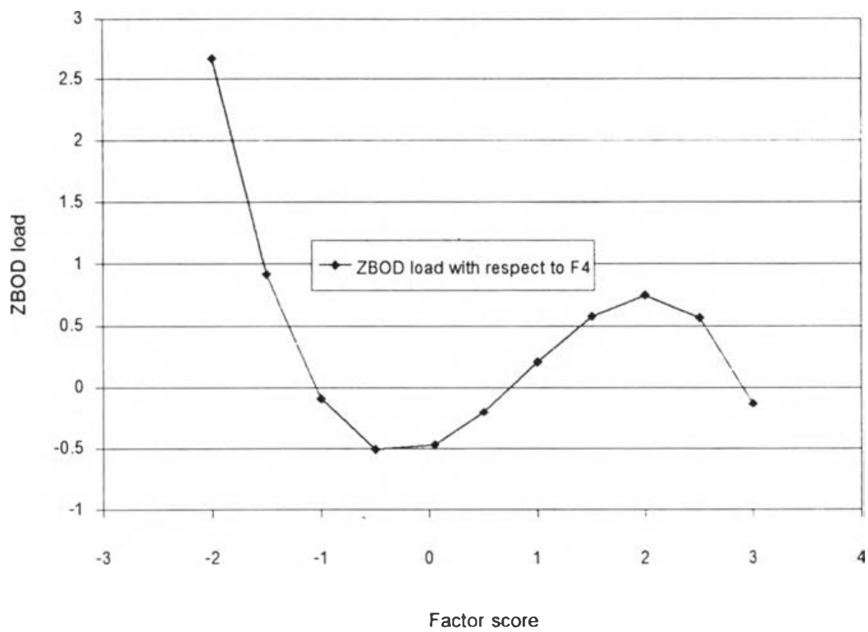


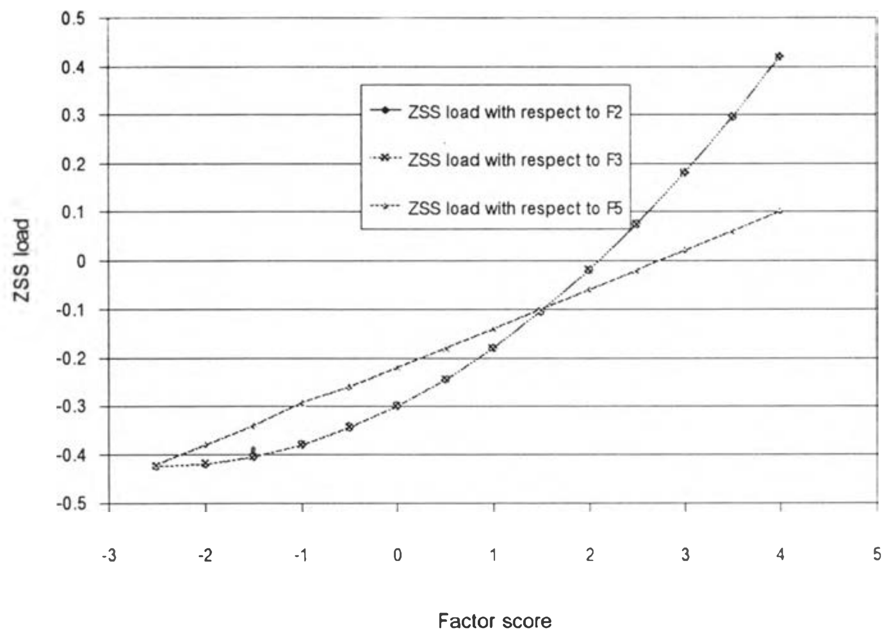
Figure 6.42 The Relationship between ZBOD Load of DP 350 and F_4

From Figure 6.42, in terms of increasing of ZBOD load, it is found that, within the range of actual ZBOD load (-1.5 to 3), ZBOD load was also sensitive to F_4 at magnitude of factor score > |0.5|.

Through the highly cases (case # 3, 5, 7, 10, 12-13, and 18) for the magnitude of dominant factor, F_4 (>|1|) in the model and its name, it indicated that the root cause for ZBOD load increase was due to the same events occurred for ZCOD load.

6.2.6.4. Predictive model of Wastewater load for DP 310 :

1) SS load :



Note : Based on the same equation, ZSS loads with respect to F2 and F3 are in the same line

Figure 6.43 The Relationship between ZSS Load of DP 310 and F_2, F_3 and F_5

From Figure 6.43, in terms of increasing of ZSS load, it is found that ZSS load is more sensitive to F_2 and F_3 than F_5 at magnitude of factor score >2.5.

Through the unusual cases (case # 13, 18, 21, 29, 35, 41, and 47) for the change of magnitude of dominant factor, F_2 and F_3 in the model and their names, this indicated that the root cause for ZSS load increase was due to the overflow of white water during the change of paper grade, and the increased use of broke. The loss of fibers in this water, and deteriorated fibers in broke contributed to the increase of ZSS load.

2) TDS load :

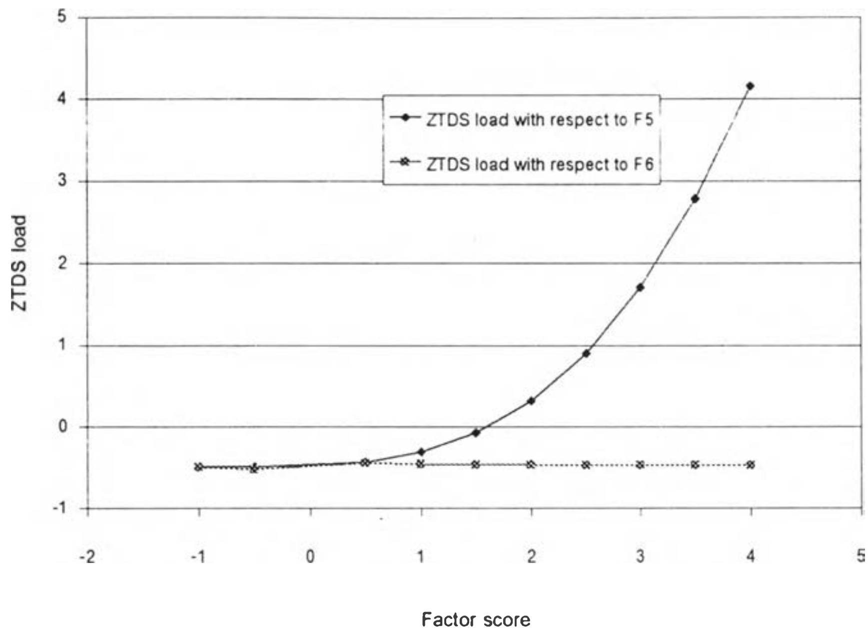


Figure 6.44 The Relationship between ZTDS Load of DP 310 and F_5 and F_6

From Figure 6.44, in terms of increasing of ZTDS load, it is found that, within the range of actual ZTDS load (-1.5 to 3.8), ZTDS load was more sensitive to F_5 than F_6 at magnitude of factor score > 1.5.

Through the highly cases (case # 5-6, 8, 11, 16, 29, 35-24, 28, and 35-37) for the change of magnitude of dominant factor, F_5 (-1.3 to 3.5) in the model and its name, it indicated that the root cause for ZTDS load increase was due to the use of broke less than usual. The additions of more dissolved chemicals that need to be added contributed to the increase of ZTDS load.

3) COD load :

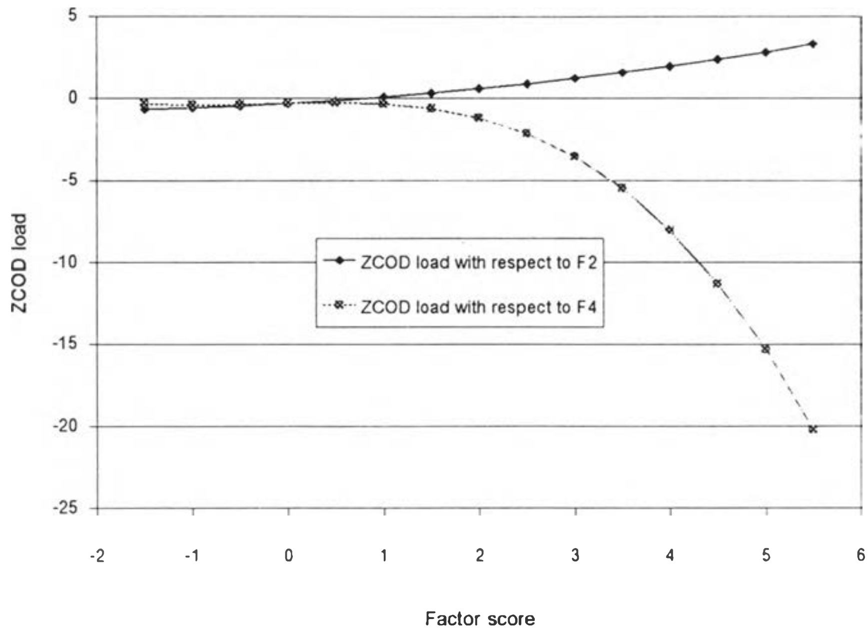


Figure 6.45 The Relationship between ZCOD Load of DP 310 and F_2 and F_4

From Figure 6.45, in terms of increasing of ZCOD load, it is found that, within the range of ZCOD load (-1.1 to 5.51), ZCOD load was more sensitive to F_2 than F_4 at magnitude of factor score > 2.

Through the highly cases (case # 13, 18, 21, 29, 35, and 41) for the change of magnitude of dominant factor, F_2 (1.13 to 5.51) in the model and its name, this indicates that the root cause for ZCOD load increase was due to the overflow of white water during the change of paper grade, and the increased use of broke. The loss of fibers and chemical additives in this water, including the loss of deteriorated fibers from broke contributed to the increase of ZCOD and ZBOD loads.

4) BOD load :

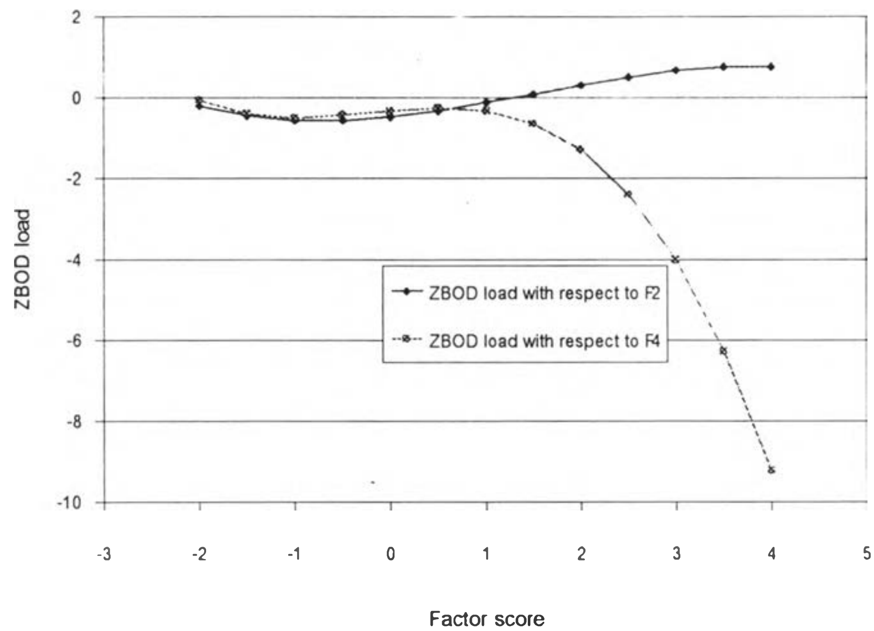


Figure 6.46 The Relationship between ZBOD Load of DP 310 and F_2 and F_4

From Figure 6.46, in terms of increasing of ZBOD load, it is found that ZBOD load was more sensitive to F_2 than F_4 at magnitude of factor score > 1.5 to 4.5. In practical situation, the highest magnitude of F_2 was < 6.

Through the unusual cases (case # 13, 18, 21, 29, 35, and 41) for the change of magnitude of dominant factor, F_2 (1.13 to 5.51) in the model and its name, this indicated that the root cause for ZBOD load increase was due to the same events occurred for ZCOD load.

6.2.6.5. Predictive model of Wastewater load for DP 270 :

1) SS load :

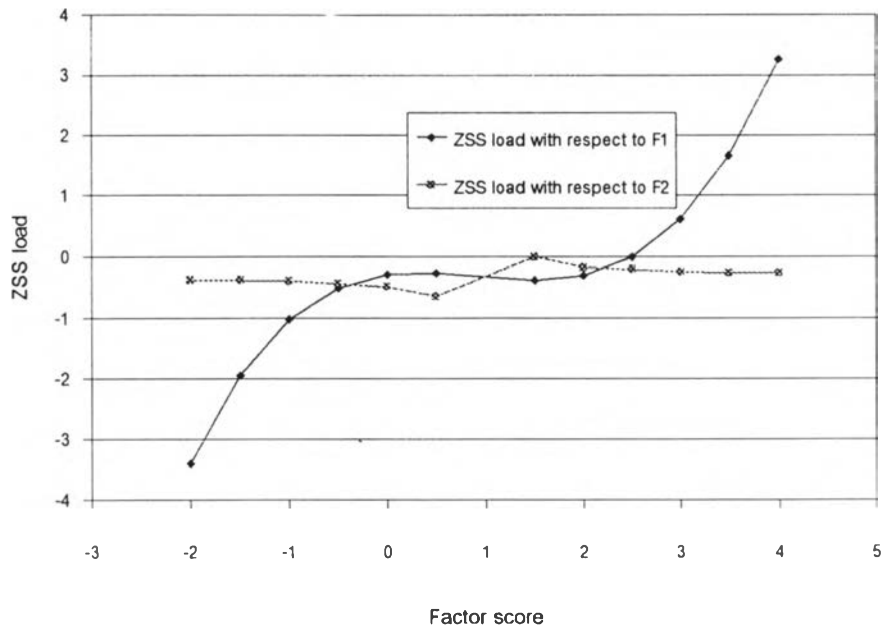


Figure 6.47 The Relationship between ZSS Load of DP 270 and F_1 and F_2

From Figure 6.47, in terms of increasing of ZSS load, it is found that, within the range of actual ZSS load (-3.41 to 1.13), ZSS load was more sensitive to F_1 than F_2 at magnitude of factor score > 2.5.

Through the highly cases (case # 4) for the change of magnitude of dominant factor, F_1 (1.13) in the model and its name, this indicated that the root cause for ZSS load increase was due to the overflow of white water during the change of paper grade. The loss of fibers as deteriorated fibers from broke contributed to the increase of ZSS load.

2) TDS load :

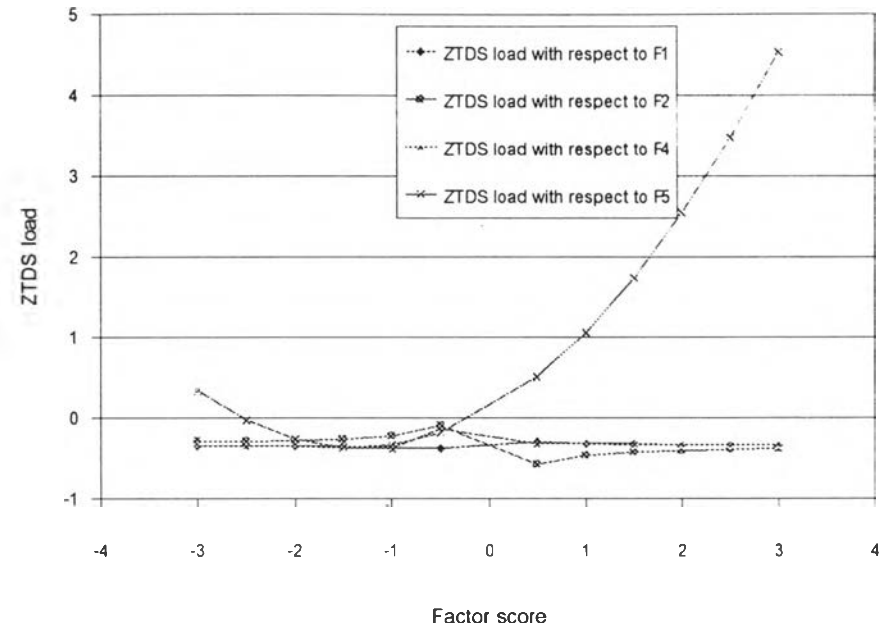


Figure 6.48 The Relationship between ZTDS Load of DP 270 and F_1, F_2, F_4, and F_5

From Figure 6.48, in terms of increasing of ZTDS load, it is found that, within the range of actual ZTDS load (-1.37 to 2.73), ZTDS load was more sensitive to F_5 than other factors at magnitude of factor score > 0.

Through the highly cases (case # 6 and 11) for the change of magnitude of dominant factor, F_5 in the model and its name, this indicated that the root cause for ZTDS load increase was due to the use of broke less than usual causing the highly consumption of dissolved chemicals and affecting the increase of ZTDS load.

3) COD load :

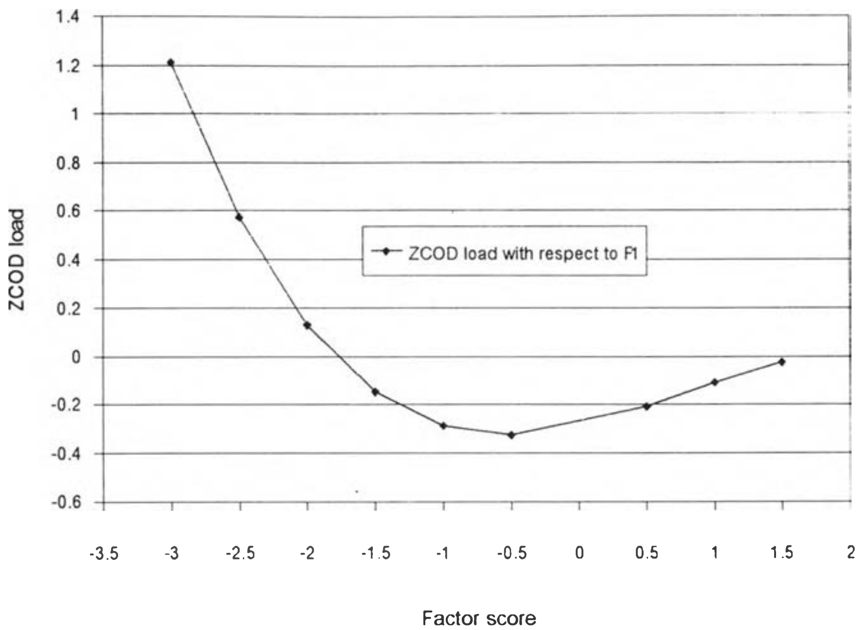


Figure 6.49 The Relationship between ZCOD Load of DP 270 and F_1

From Figure 6.49, in terms of increasing of ZCOD load, it is found that, within the range of actual ZCOD load (-3.41 to 1.13), ZCOD load was sensitive to F_1 at magnitude of factor score > |0.5|.

Through the highly cases (case # 4) for the change of magnitude of dominant factor, F_1 (1.13) in the model and its name, this indicates that the root cause for ZCOD load increase was due to the use of broke more than usual. The loss of fibers as deteriorated fibers and chemical additives in broke contributed to the increase of ZCOD and ZBOD loads.

4) BOD load :

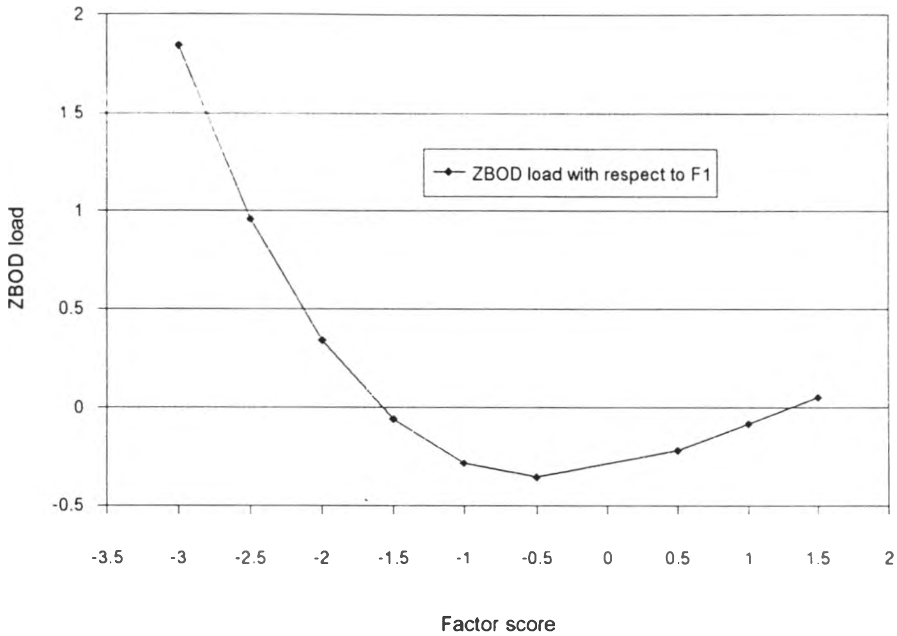


Figure 6.50 The Relationship between ZBOD Load of DP 270 and F_1

From Figure 6.50, in terms of increasing of ZBOD load, it is found that, within the range of actual ZBOD load (-3.41 to 1.13), ZBOD load was sensitive to F_1 at magnitude of factor score > |0.5|. Through the highly case (case # 4) for the change of magnitude of dominant factor, F_1 in the model and its name, this indicated that the root cause for ZBOD load increase was the same events occurred for ZCOD load.

Through the highly cases of wastewater load for all DPs, the root cause of the wastewater generated from DP production can be concluded as in Table 6.62 to 6.64.

However, the real root causes of wastewater generation can be found from all cases through the events occurred in FA model. Because the predictive MRA models are excluded the outliers due to the limitation of the MRA model building. Therefore, the real root causes of wastewater load for DP were the increased use of broke due to the contaminants and deteriorated fibers causing web breaks, the overflow of white water due to the change over of paper grade, including the scheduling of machine operation between paper machine and wastepapers plant; and the excess chemicals in the white water due to poor control over the addition of chemicals and poor retention of fines and filler. The presence of excess chemicals can be easily identified through the special product treatments for the desired property.

Table 6.62 Root cause and effect relating wastewater generated of DP 450 and 400

Effect on Wastewater Load	Root Event & Cause	Indicator
1. DP 450		
1.1 Increasing SS load	-Overflow of white water due to the change over of paper grade -Increased use of broke	- High water & electricity consumption - High some fibers consumption - High sizing agents (emulsifier and alum) consumption
1.2 Increasing TDS load	-Overflow of white water due to the change over of paper grade	same
1.3 Increasing COD load	-Decreased use of broke	- High sizing agents (alum) consumption
1.4 Increasing BOD load	Same as COD load	same
2. DP 400		
2.1 Increasing SS load	-Overflow of white water due to the change over of paper grade -Increased use of broke	- Same as SS load of DP 450, and high coating chemicals consumption
2.2 Increasing TDS load	-Overflow of white water due to the change over of paper grade	- Same as SS load of DP 450, and high dry strength agents (cato)
2.3 Increasing COD load	-Increased use of broke	- Same as SS load of DP 450
2.4 Increasing BOD load	same	same

Table 6.63 Root cause and effect relating wastewater generated of DP 350 and 310

Effect on Wastewater Load	Root Event & Cause	Indicator
3. DP 350		
3.1 Increasing SS load	-Overflow of white water due to the change of paper grade	- High water & electricity consumption - High some fibers consumption - High sizing agents (emulsifier and alum), and dry strength agents consumption
3.2 Increasing TDS load	-Increased use of broke	- High water consumption - High some fibers usage
3.3 Increasing COD load	-Decreased use of broke	- High chemicals additives
3.4 Increasing BOD load	same	same
4. DP 310		
4.1 Increasing SS load	-Overflow of white water due to the change of paper grade -Increased use of broke	- High water & electricity consumption - High filler and some sizing agents (alum) consumption
4.2 Increasing TDS load	-Decreased use of broke	- High chemicals additives
4.3 Increasing COD load	-Overflow of white water due to the change of paper grade -Increased use of broke	- Same as SS load of DP 350
4.4 Increasing BOD load	same	same

Table 6.64 Root cause and effect relating wastewater generated of DP 270

Effect on Wastewater Load	Root cause	Indicator
5. DP 270		
5.1 Increasing SS load	-Overflow of white water due to the change of paper grade	-High water & electricity consumption -High some fibers (A_5 and A_8) consumption -High dry strength agents, consumption
5.2 Increasing TDS load	-Decreased use of broke	-High chemicals additives usage
5.3 Increasing COD load	-Increased use of broke	-High water consumption -High some fibers consumption
5.4 Increasing BOD load	same	same

6.2.7 Validation of the Predictive Model

The predictive environmental models for wastewater loads and input factors from all of the varieties of duplex coated board (DPs) were validated based on all real cases.

Based upon the prediction accuracy, (% of relation for all cases of the predictive model from model validation (MV) x 100)/ (% of relation of the predictive model from model building (MB)for all DPs), the predictive ability of these models is quite low (<40%) by average as shown in Table 6.65.

Based upon the prediction accuracy, (% of relation for all cases of the predictive model from model validation (MV) x 100)/ (% of relation of the predictive model from model building (MB)for all DPs), the predictive ability of these models is quite low (<40%) by average as shown in Table 6.65.

Table 6.65 Validity of predictive model for wastewater from Duplex coated board

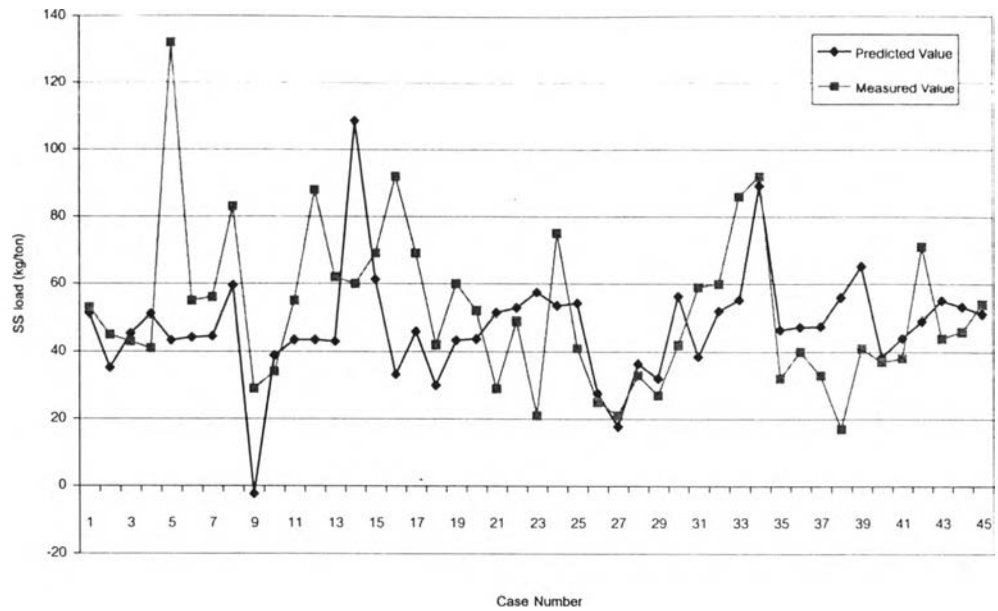
Wastewater load	Prediction accuracy (%) (% relation of MV x 100) / % relation of MB				
	DP 450	DP 400	DP 350	DP 310	DP 270
1. SS load	69.03	39.08	-	-	-
2. TDS load	42.55	22.37	-	-	-
3. COD load	7.86	25.50	-	-	-
4. BOD load	7.51	23.78	-	-	-

It is found that the predictive models were applicable for SS and TDS load of DP 450. While these models were not applicable for COD and BOD load of DP 450 due to their low prediction accuracy. In addition, the uses of predictive models for DP 400 were in error. Moreover, applications of the predictive models for DP 350, DP 310, and DP 270 were impossible due to undetermined of their prediction accuracy.

The calculation results of these models for all real cases of DPs in comparison with all measured value of each wastewater load were graphically displayed in the form of original variables in Figures 6.51 to 6.60. It is found that the outliers of error between wastewater load and factors have more affected to the fluctuation of the predictive models than the outliers from each type of wastewater load and each related factors. Moreover, the numbers of the error outliers were more than the numbers of other outliers for all DPs. Therefore, when all outliers were included in the predictive models for all real cases, these models were low valid.

Overall the predictive models for DPs were applicable only for SS and TDS load of the thickest basis weight (DP 450). In addition, this implies that additional material input issues concerned with the load of other basis weight product of DP.

a) Calculated Result for SS Load of Total DP 450



b) Calculated Result for TDS Load of Total DP 450

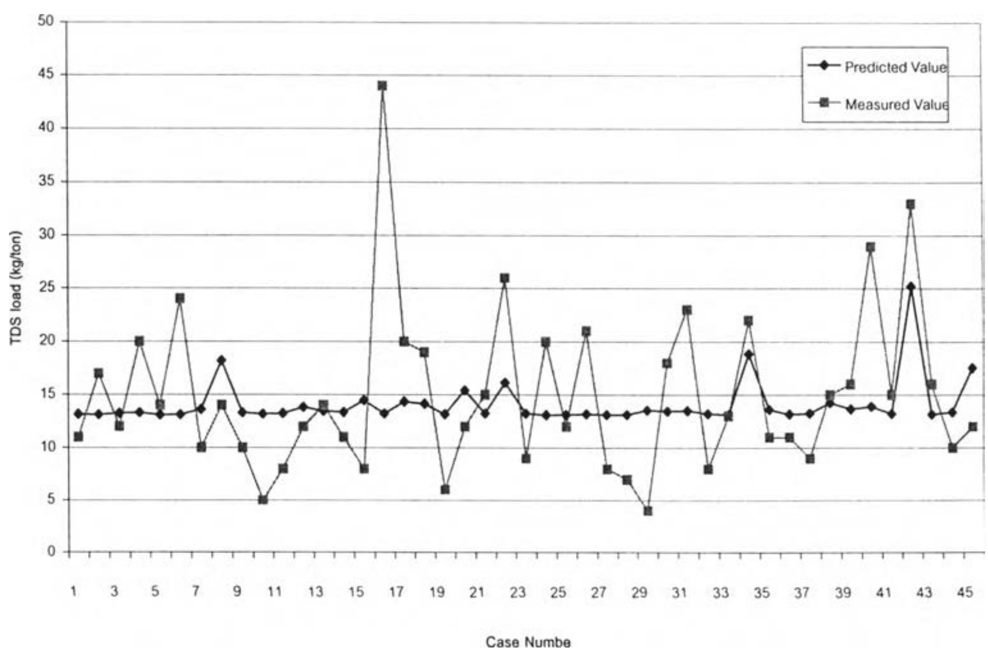
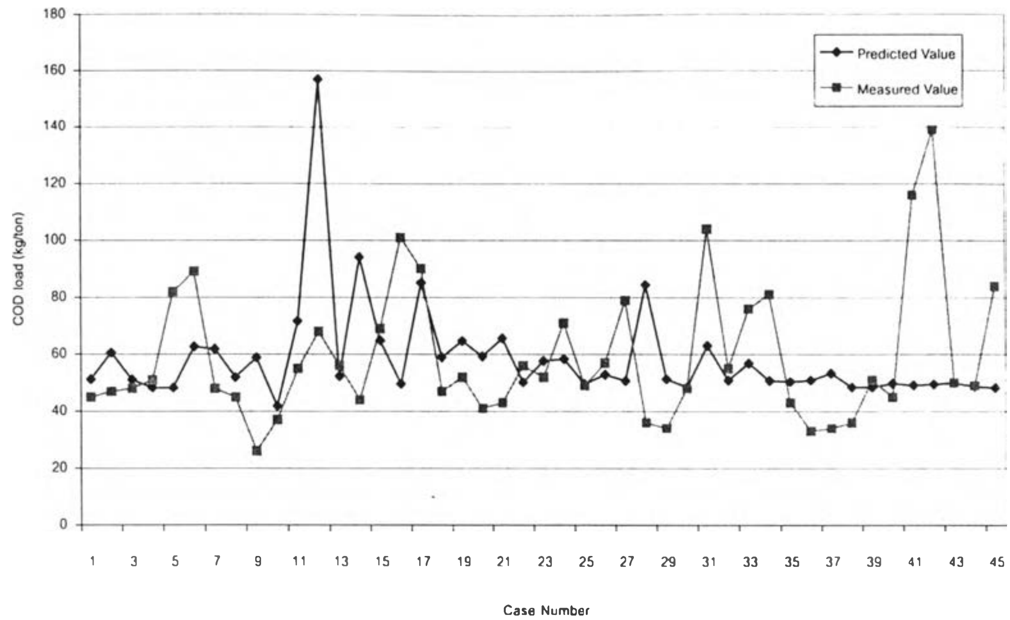


Figure 6.51 Result of Calculation for SS and TDS Loads of Total DP 450

c) Calculated Result for COD Load of Total DP 450



d) Calculated Result for BOD Load of Total DP 450

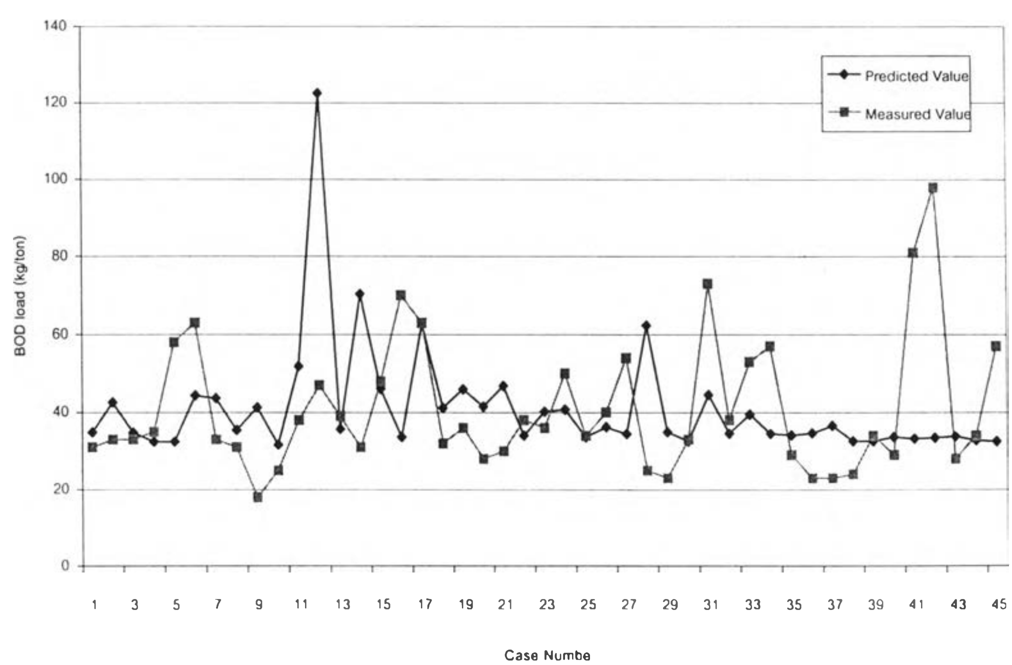
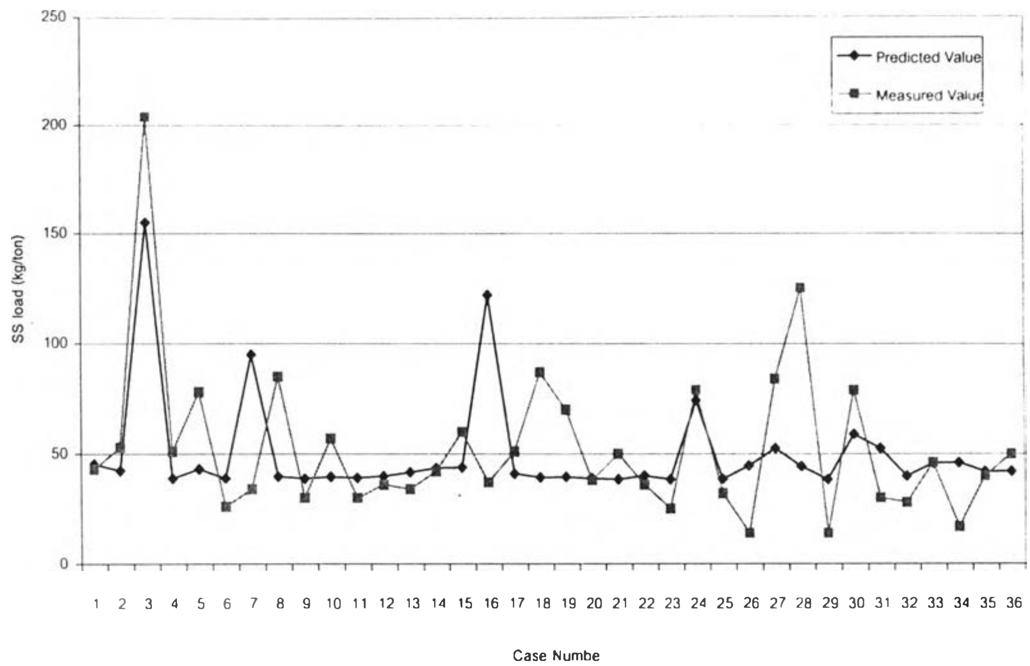


Figure 6.52 Result of Calculation for COD and BOD Loads of Total DP 450

a) Calculated Result for SS Load of Total DP 400



b) Calculated Result for TDS Load of Total DP 400

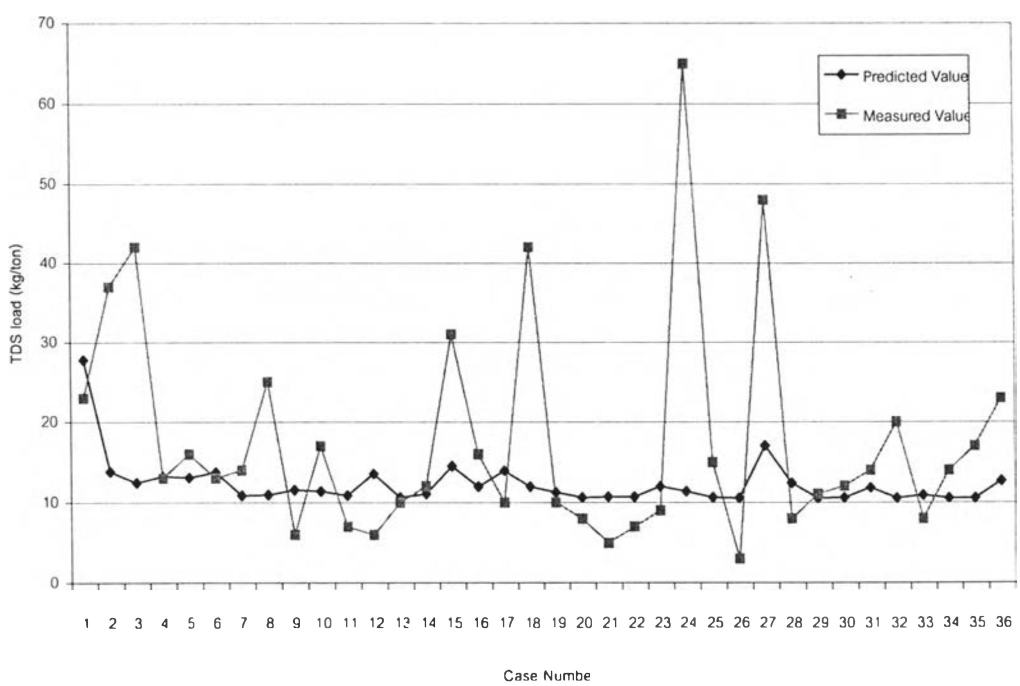
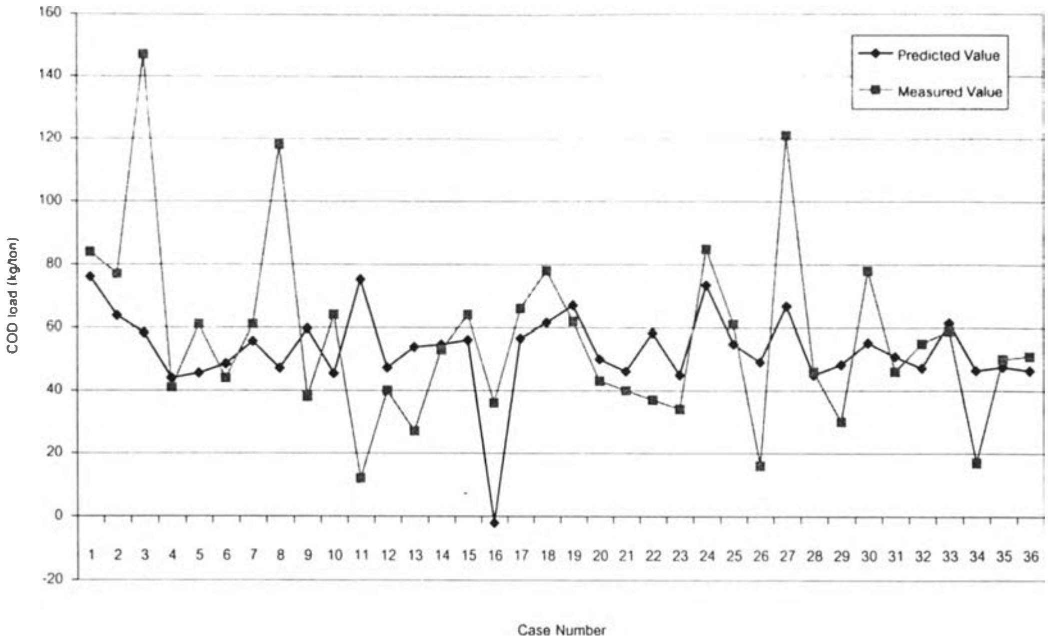


Figure 6.53 Result of Calculation for SS and TDS Loads of Total DP 400

c) Calculated Result for COD Load of Total DP 400



d) Calculated Result for BOD Load of Total DP 400

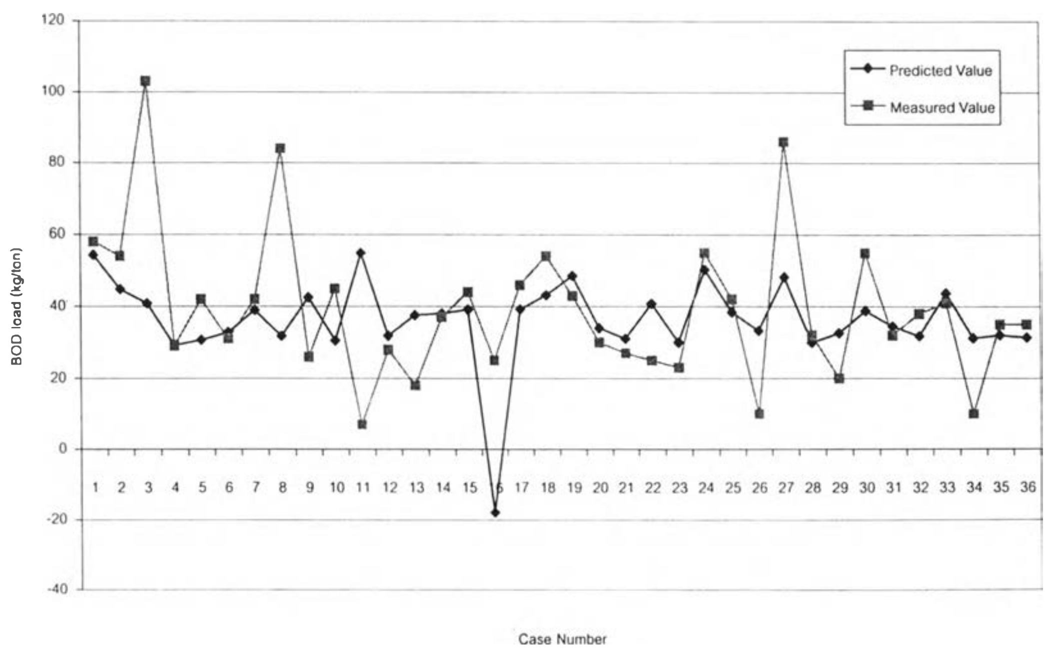
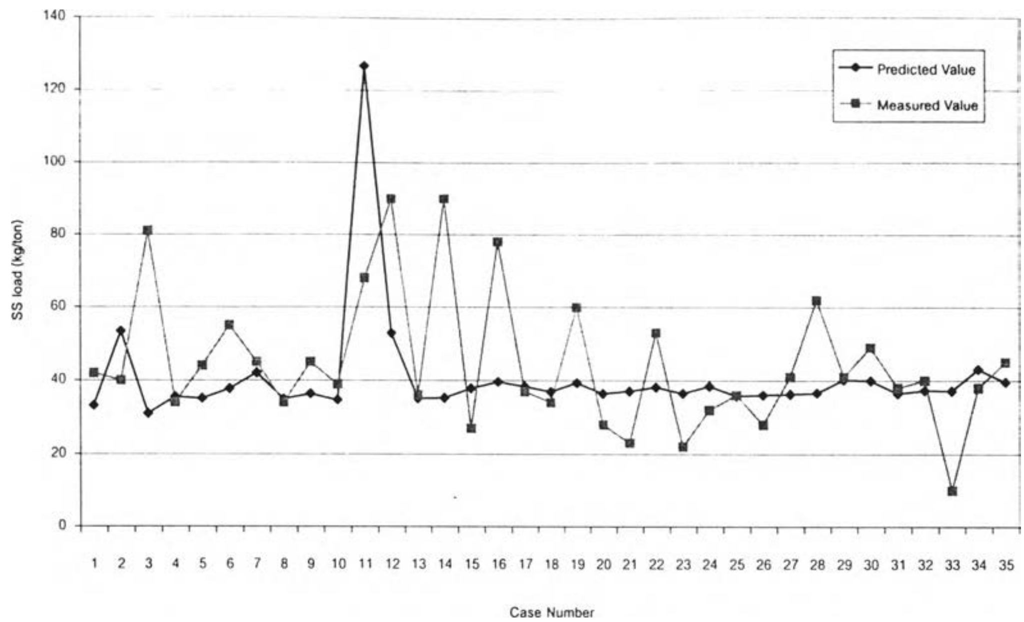


Figure 6.54 Result of Calculation for COD and BOD Loads of Total DP 400

a) Calculated Result for SS Load of Total DP 350



b) Calculated Result for TDS Load of Total DP 350

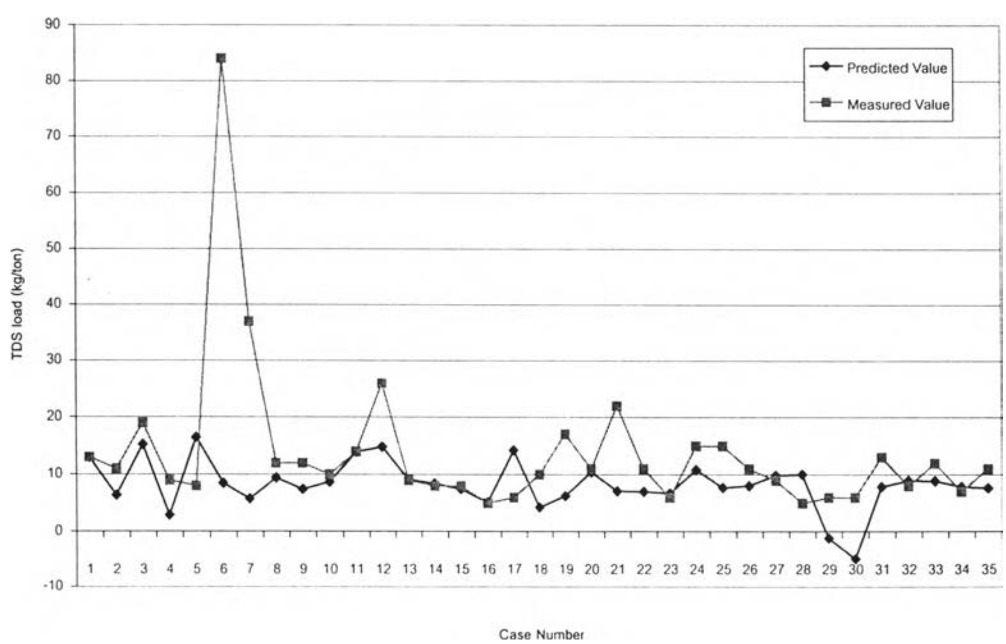
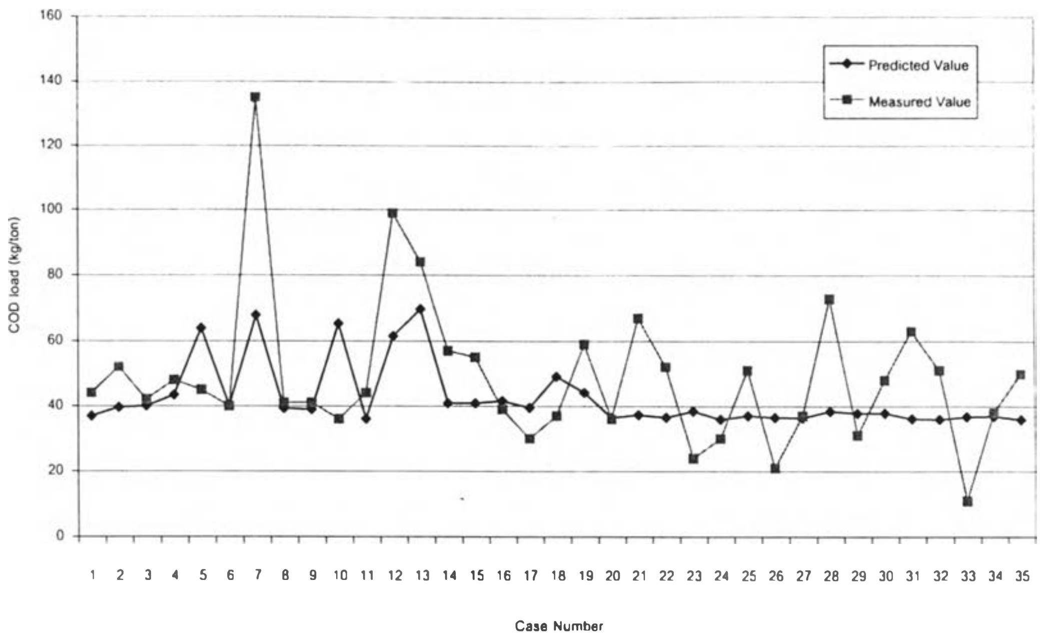


Figure 6.55 Result of Calculation for SS and TDS Loads of Total DP 350

c) Calculated Result for COD Load of Total DP 350



d) Calculated Result for BOD Load of Total DP 350

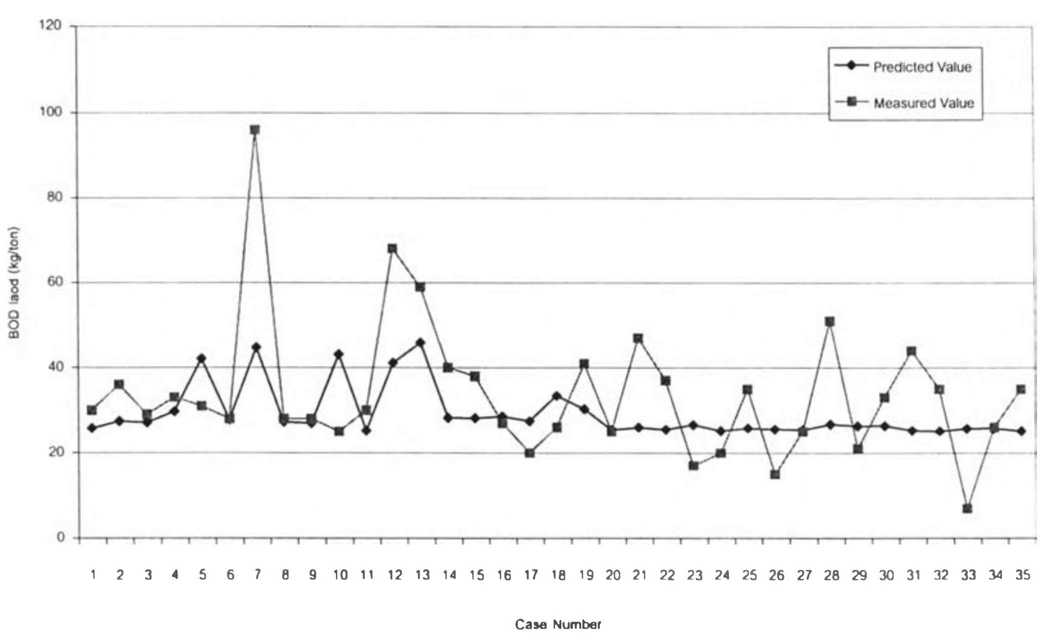
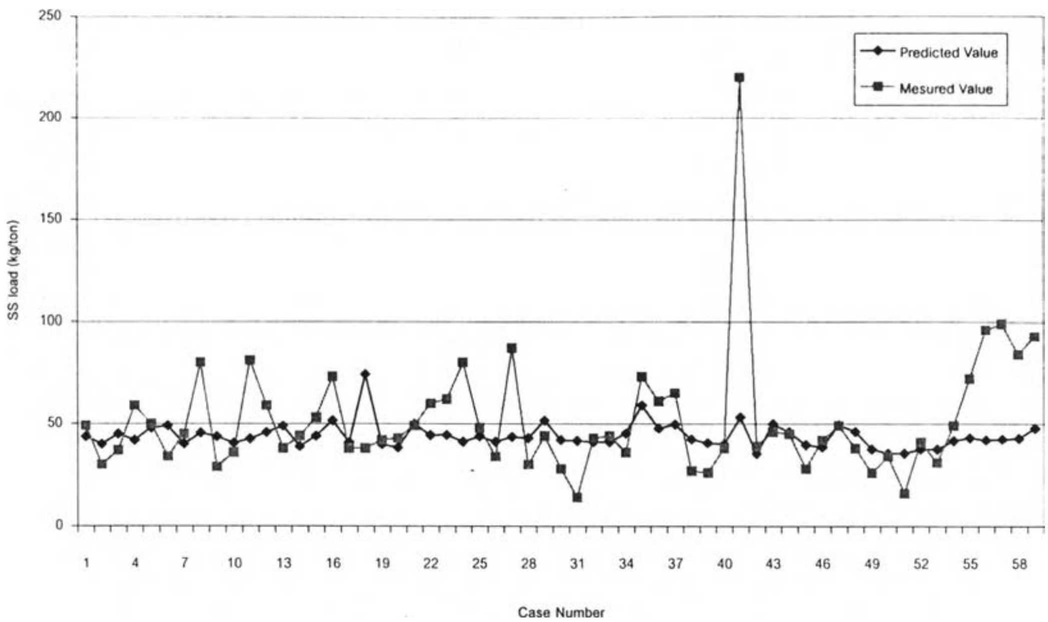


Figure 6.56 Result of Calculation for COD and BOD Loads of Total DP 350

a) Calculated Result for SS Load of Total DP 310



b) Calculated Result for TDS Load of Total DP 310

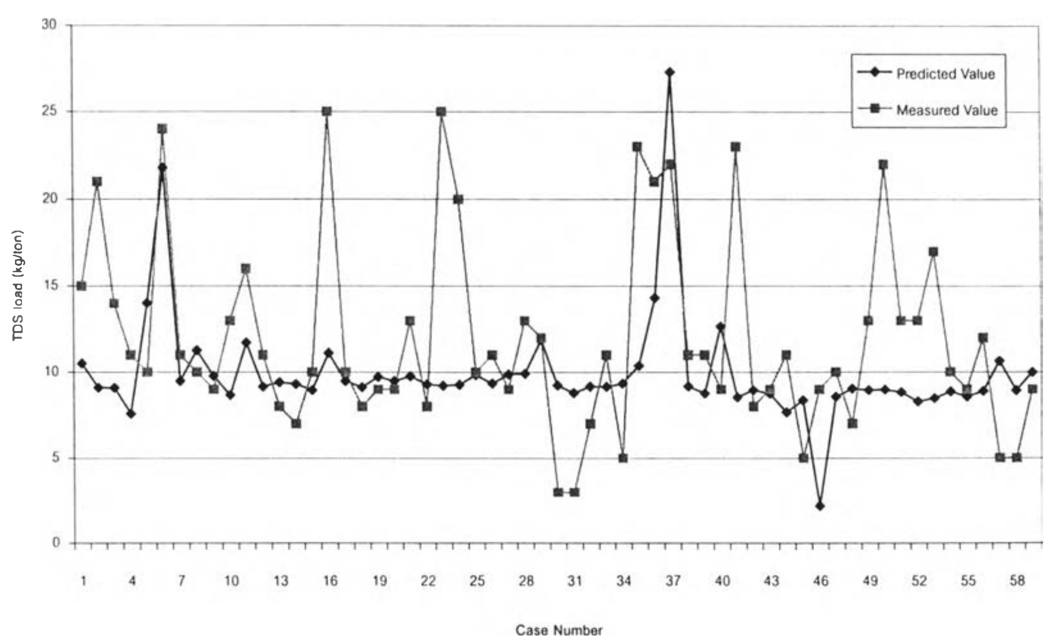
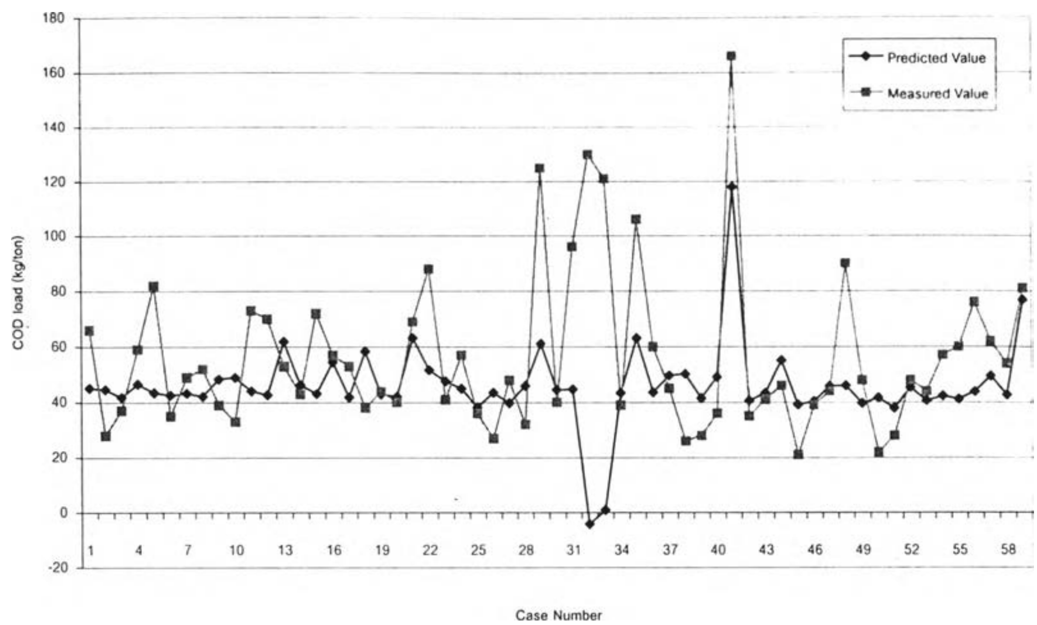


Figure 6.57 Result of Calculation for SS and TDS Loads of Total DP 310

c) Calculated Result for COD Load of Total DP 310



d) Calculated Result for BOD Load of Total DP 310

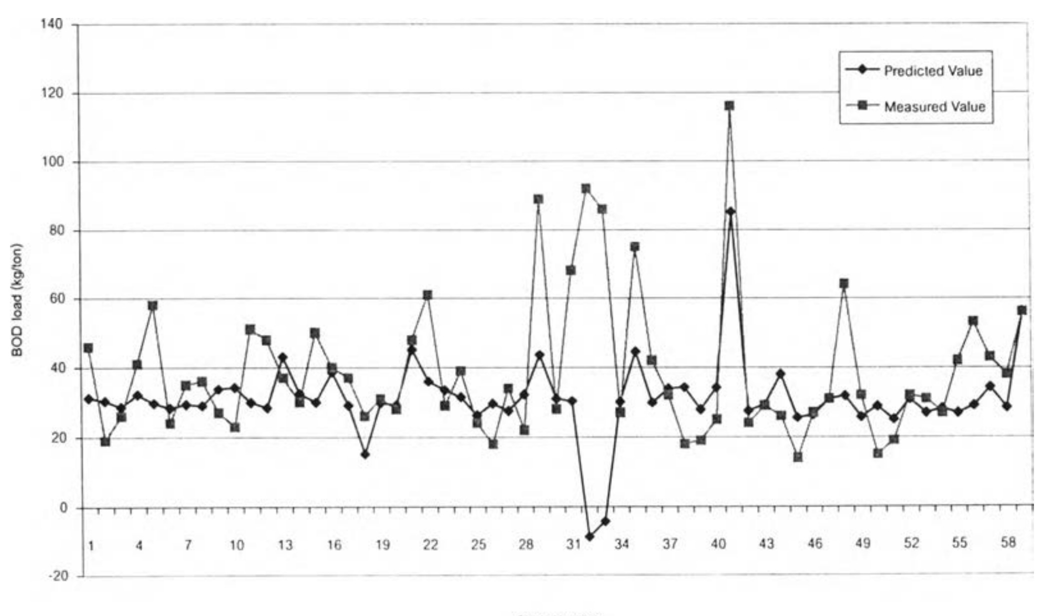
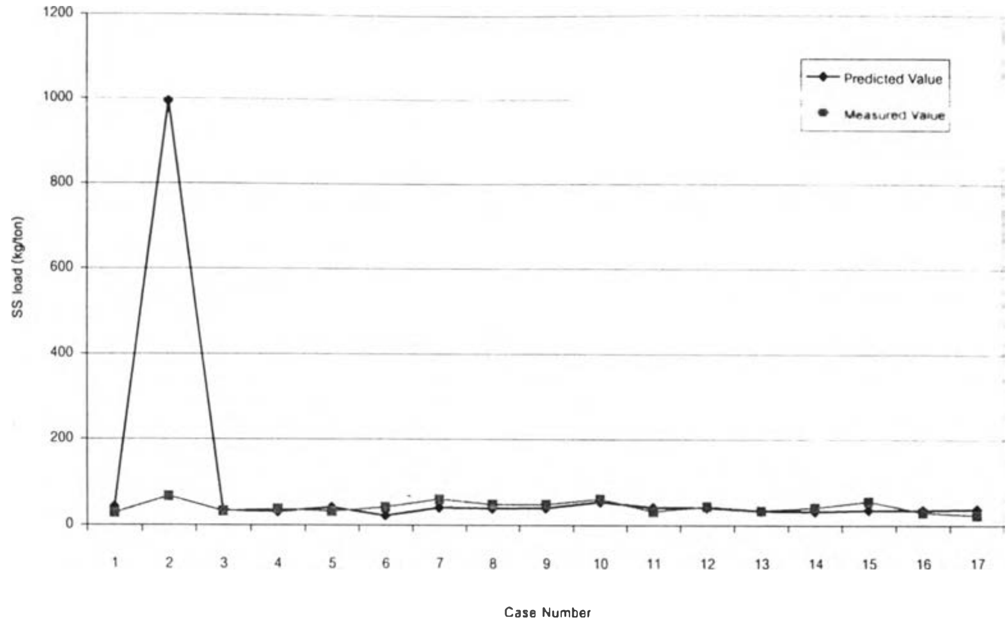


Figure 6.58 Result of Calculation for COD and BOD Loads of Total DP 310

a) Calculated Result for SS Load of Total DP 270



b) Calculated Result for TDS Load of Total DP 270

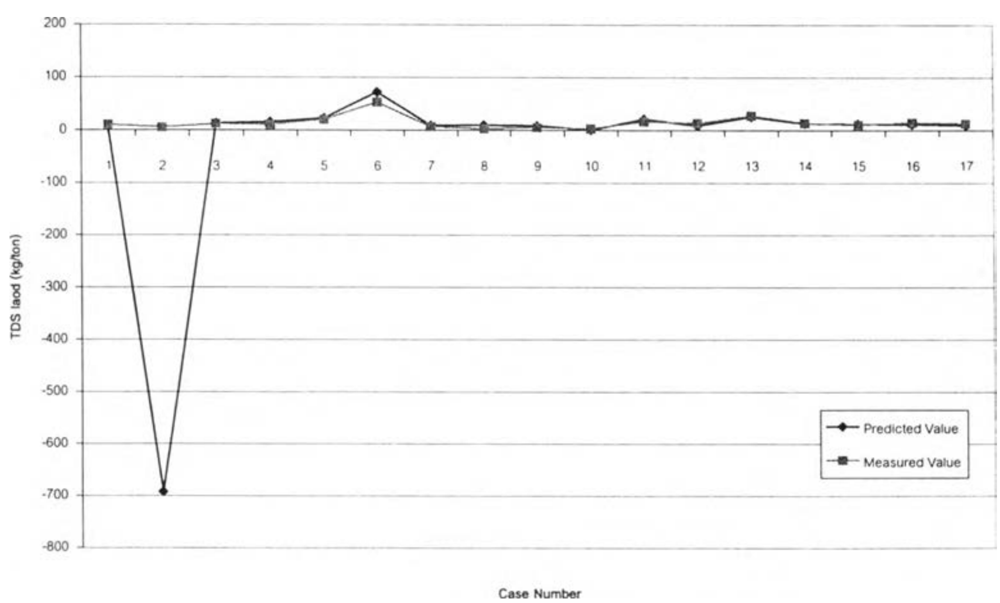
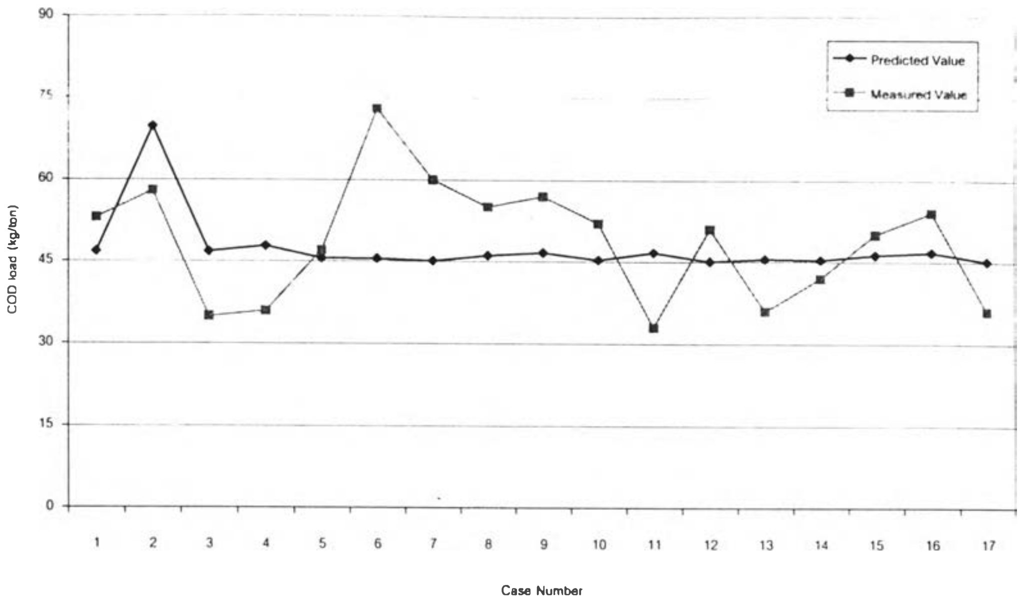


Figure 6.59 Result of Calculation for SS and TDS Loads of Total DP 270

c) Calculated Result for COD Load of Total DP 270



d) Calculated Result for BOD Load of Total DP 270

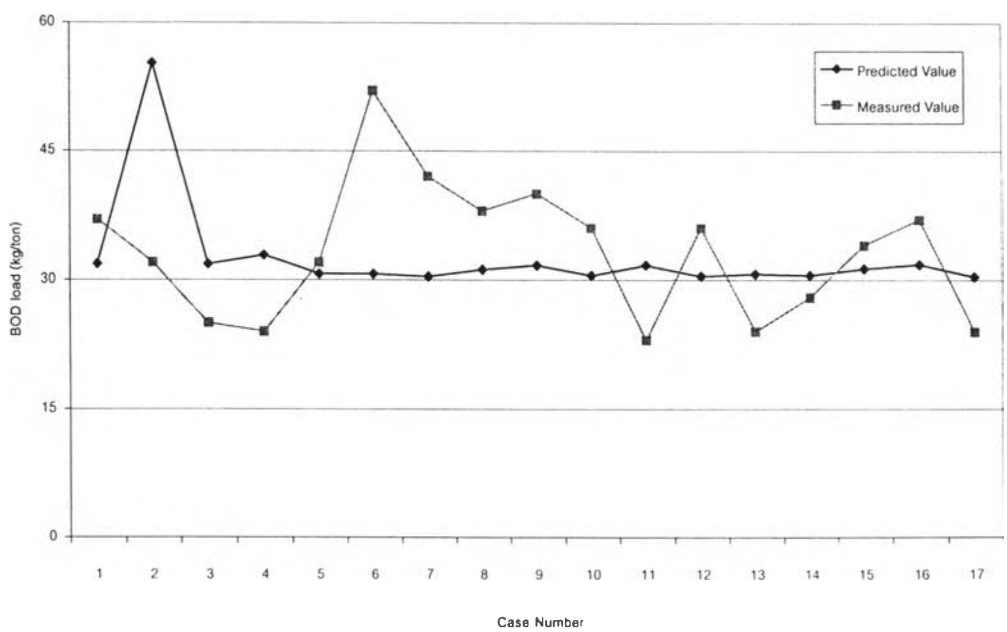


Figure 6.60 Result of Calculation for COD and BOD Loads of Total DP 270