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To Calculate the Alternate Formula for Production Rate When the When the Degree of Imbalance (D) in A Un-Paced Production Line

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Abstract – This study develop the formula for the production rate when the work station is more than 5-station in assembly line /production line From Alternate formula production rate are Known and standard deviation of Correction factor (error from the actual production rate "R" to the to the alternate formula production Rate "AFR" are known From 5- work station) are known. This formula is near about correct to calculate the higher (more than 5- work station) work station in production line/assembly line for calculating the production rate in un-paced production line.

Keywords – Un-paced production line, Correction Factor (CF), actual production rate (R), Alternate Formula Production rate (AFR), Correction Factor variation (Σ CF/n-CF$_i$) Standard deviation(σ), work station, work load(Time)distribution in work station μ$_i$.

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INTRODUCTION

In revaluation of Industrial development, All the Industries are Automatic System Plants. They utilize the CIM (Computer Integrated Manufacturing) or Flexible Manufacturing system for assembling the machine parts to make useful goods (Finished job). When we do the assembled the parts the time are not same for all work station because some component take more time some components take less time to Assemble it (e.g. when assemble a car steering system take more time rather than assembly of chassis or wheels).Due to variation in work load distribution (time) in each station are different the pacing agencies in production line are called un-paced production line. Calculating the production rate Up to 5-workstation is very difficult task even in computer programming (Jamali, et. al., 2015) therefore we develop an easy formula (Jamali) for production rate and say it alternate formula and also validate it from -3 σ to + 3 σ. Now we use all 60 outcomes (work load distribution" time" in work station) found in our study (Jamali, 2002) in production rate 5-workstation for un-paced production line and generate the near about exact Alternate formula (AFR) for production rate. And these formulas are easy to calculate higher (more than 5- work station) work station production rate.

THEORY

Here we Know the interval of time from previously we find out the actual production rate Stretegies (Jamali, 2015. Hiller and So, 1993. Jamali & Prof. Suhail, 2016. Jamali, Prof. Suhail, 2016. Jamali, 2002. Jamali, 2002) When we know we the Correction Factor, variance with mean value of Correction Factor (Σ CF$_i$/n-CF$_i$), standard deviation σ then we find the actual formula for production rate whose utilize in to calculating higher order workstation in production line. We define here each function.

Here D(degree of imbalance)= Highest work load (Time) distribution in work station – Lowest work load (time) distribution in work station

Correction Factor = Production Rate (R) - Alternate formula for Production Rate (AFR)

Alternate formula Rate = (μ1 + μ 5)/ total time in production line

Here μ1, μ2, μ3, μ4, μ5 is work load (time) distribution on work station 1,2,3,4,5

Mean value of Correction Factor = Σ CF/n

Variance with Mean vale Of Correction Factor (Σ CF/n-CF_i) here i indicate that S.NO. 1 to 60 (whose found from mathematical modeling of production rate) (Jamali, 2015, 2002).

For example, for S. No.1, 2, 3, ……..30,31…… 59, 60 means

Σ CF/n – CF1, Σ CF/n – CF2, Σ CF/n – CF5……., Σ CF/n – CF30, Σ CF/n – CF31…….. Σ CF/n – CF55, Σ CF/n – CF60

Where standard deviation σ = Sqrt (Σ (Σ CF/n-CFi)^2)/n Here i indicate that S. No. and n =total S.No.= 60

For example, for S. No.1, 2,…….30 ,31…… 59, 60 means

Sum (S) = (Σ CF/n- CF1)^2 + (Σ CF/n- CF3)^2 +……+(Σ CF/n-CF30)^2+(Σ CF/n-CF31)^2+……(Σ CF/n- CF59)^2+(Σ CF/n-CF60)^2

In the below tables we found the Production Rate (Jamali, 2015, 2002). AFR (Alternate Formula Rate), Correction Factor, Variance with Mean vale of Correction Factor (Σ CF/n-CF_i) and standard deviation σ = Sqrt (Σ (Σ CF/n- CFi)^2)/n in D= 1.2 and D=0.4 linear work load distribution. And then we found the corrected Alternate Formula for production Rate (AFPR)

Therefore we say(found) that AFPR = AFR ± (a +bi X i-1) σ Here we say that for work load distribution Means>1 we take -Ve sign upto Sr. No.(n/4) and some values up to mid Sr. no Because the we take only work load distribution (First and Last work station and ignore the other work load distribution in work station)and after words mid Sr. no we take +Ve Sign of σ the

If Workloads Distribution < 1 we take + Ve sign for all values of σ because the work load distribution on work station difference are not more.

Tables and graph- These values are given below here

Table 1. Alternate formula rate, Production Rate when work load distribution linear are D=1.2

S. N0.	Mu 1	Mu 2	Mu 3	Mu 4	Mu 5	R	AFR	CF	Σ CF/n-CFi	(Σ CF/n-CF)2
1	1.6	0.4	1	0.7	1.3	0.469	0.58	-0.111	0.151695	0.02301
2	1.3	1	0.7	0.4	1.6	0.4677	0.58	-0.1123	0.153	0.0234
3	1.3	1	0.4	0.7	1.6	0.4662	0.58	-0.1138	0.1545	0.0237
4	1.6	0.7	1	0.4	1.3	0.4646	0.58	-0.1154	0.156	0.0244
5	1	1.3	0.7	0.4	1.6	0.4623	0.52	-0.0577	0.0984	0.009681
6	1	1.3	0.4	0.7	1.6	0.4616	0.52	-0.0584	0.0991	0.00982
7	1.6	1	0.4	0.7	1.3	0.4604	0.58	-0.1196	0.1603	0.0257
8	1.6	0.4	1.3	0.7	1	0.4592	0.52	-0.0608	0.1015	0.0103
9	1.6	1	0.7	0.4	1.3	0.458	0.58	-0.122	0.163	0.0265
10	0.7	1.3	1	0.4	1.6	0.4544	0.46	-0.0056	0.0463	0.0021
11	1	1.6	0.4	0.7	1.3	0.4539	0.46	-0.0061	0.0468	0.0022
12	0.7	1.6	0.4	1	1.3	0.4521	0.4	0.0521	-0.0114	0.0001
13	1	0.7	1.6	0.4	1.3	0.4519	0.46	-0.0081	0.0488	0.00238
14	1.6	0.7	1.3	0.4	1	0.4514	0.52	-0.0686	0.1093	0.0119
15	0.7	1	1.3	0.4	1.6	0.4508	0.46	-0.0092	0.0499	0.0025
16	0.7	1.3	0.4	1	1.6	0.4504	0.46	-0.0096	0.0503	0.0026
17	1.3	0.4	0.7	1.6	1	0.45	0.46	-0.01	0.0507	0.0026
18	1.3	0.7	1.6	0.4	1	0.4481	0.46	-0.0119	0.053	0.0028
19	1	1.3	0.4	1.6	0.7	0.4465	0.34	0.1065	-0.0651	0.00433
20	0.7	1.6	1	0.4	1.3	0.4451	0.4	0.0451	-0.0044	0.00002
21	1.6	0.7	1	1.3	0.4	0.4437	0.4	0.0437	-0.003	0.00001
22	1.3	1	0.7	1.6	0.4	0.4431	0.34	0.1031	-0.063	0.00389
23	1	1.6	0.4	1.3	0.7	0.4424	0.34	0.1024	-0.062	0.0038
24	1.3	0.4	1.6	1	0.7	0.4421	0.4	0.0421	-0.001	0.000002
25	0.4	1.3	0.7	1	1.6	0.4411	0.4	0.0411	-0.00041	0.0000002
26	1.6	1.3	0.4	0.7	1	0.441	0.52	-0.079	0.012	0.0143
27	0.4	1.6	1	0.7	1.3	0.4402	0.34	0.1002	-0.06	0.0035
28	1	0.7	0.4	1.6	1.3	0.4392	0.46	-0.0208	0.062	0.003781
29	1.6	0.7	1.3	1	0.4	0.4376	0.4	0.0376	0.0031	0.00001
30	1.6	1.3	0.4	1	0.7	0.4367	0.46	-0.0233	0.064	0.0041
31	0.4	1.6	0.7	1.3	1	0.4367	0.28	0.1567	-0.116	0.0134
32	1.6	1.3	0.7	0.4	1	0.4359	0.52	0.0841	-0.0434	0.00188
33	0.7	1	0.4	1.6	1.3	0.4345	0.4	0.0345	0.0062	0.00004
34	1.3	1.6	0.7	0.4	1	0.4334	0.46	-0.0266	0.0673	0.0045
35	1.3	0.7	1.6	1	0.4	0.4314	0.34	0.0914	-0.051	0.0026
36	0.4	1.3	0.7	1.6	1	0.4313	0.28	0.1513	-0.111	0.01223
37	1.6	1	1.3	0.4	0.7	0.4304	0.46	-0.0296	0.07	0.0049
38	0.7	0.4	1.6	1	1.3	0.4293	0.4	0.0293	0.0114	0.00013
39	0.7	1.3	1.6	0.4	1	0.4288	0.34	0.0888	-0.0481	0.00231
40	0.7	1.6	1.3	0.4	1	0.4287	0.34	0.0887	-0.04774	0.00228
41	0.4	1	0.7	1.3	1.6	0.4275	0.4	0.0275	0.0132	0.000174
42	1	0.7	1.3	1.6	0.4	0.4262	0.28	0.1462	-0.1055	0.0111
43	1.6	1	1.3	0.7	0.4	0.426	0.4	0.026	0.015	0.00022
44	0.7	1.3	1	1.6	0.4	0.4247	0.22	0.2047	-0.164	0.027
45	0.4	1	0.7	1.6	1.3	0.4243	0.34	0.0843	-0.0436	0.0019
46	1.3	1	1.6	0.7	0.4	0.4236	0.34	0.0836	-0.043	0.0018
47	0.4	1.3	1.6	0.7	1	0.4235	0.28	0.1435	-0.1028	0.0106
48	0.7	1.6	1	1.3	0.4	0.423	0.22	0.203	-0.1623	0.2634
49	1.6	1.3	1	0.4	0.7	0.4227	0.46	-0.0373	0.078	0.0061
50	1	1.3	1.6	0.4	0.7	0.4208	0.34	0.0808	-0.0401	0.00161
51	1.6	1.3	1	0.7	0.4	0.4193	0.4	0.0193	0.0214	0.000458
52	1.3	1.6	1	0.4	0.7	0.419	0.4	0.019	0.022	0.00047
53	1	1.6	1.3	0.4	0.7	0.4181	0.34	0.0781	-0.0374	0.0014
54	0.7	1	1.3	1.6	0.4	0.418	0.22	0.198	-0.157	0.0247
55	1.3	1.6	1	0.7	0.4	0.4155	0.34	0.0755	-0.0348	0.00121
56	0.4	0.7	1.6	1.3	1	0.4152	0.28	0.1352	-0.0945	0.0089
57	0.4	1	1.3	1.6	0.7	0.4149	0.22	0.1949	-0.154	0.238
58	0.7	1	1.6	1.3	0.4	0.4146	0.22	0.2135	-0.173	0.297
59	0.4	0.7	1.3	1.6	1	0.4135	0.28	0.1335	-0.093	0.00861
60	0.7	1.3	1.6	1	0.4	0.4131	0.22	0.1931	-0.15241	0.02323
								Σ CF/n = 0.040695		**S=1.2156**

σ = Sqrt (sum)/n=0.14234

Table 1 Alternate formula rate, Production Rate when work load distribution linear are D= 0.4

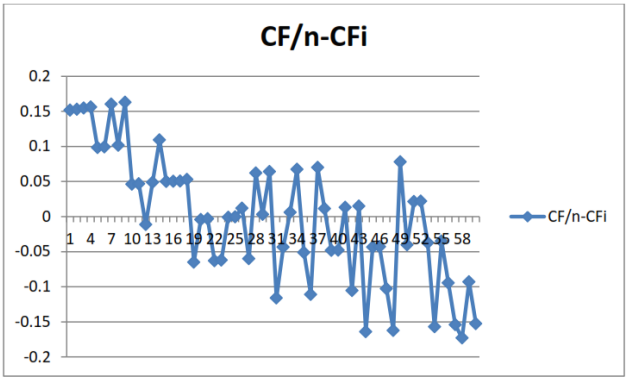
S. N0.	Mu 1	Mu 2	Mu 3	Mu 4	Mu 5	R	AFR	CF	ΣCF/n-CFi	(CF/n-CF)2
1	1.2	0.9	0.8	1	1.1	0.4907	0.46	0.0307	0.04866	0.00237
2	1.1	1	0.9	0.8	1.2	0.4902	0.46	0.0302	0.04916	0.00242
3	1.2	1	0.8	0.9	1.1	0.4899	0.46	0.0299	0.04946	0.00245
4	1.1	0.9	1	0.8	1.2	0.4898	0.46	0.0298	0.04956	0.00246
5	1.1	0.8	1	0.9	1.2	0.4892	0.46	0.0292	0.05016	0.00252
6	1.1	0.8	0.9	1	1.2	0.4889	0.46	0.0289	0.05046	0.00255
7	1.2	0.9	0.8	1.1	1	0.4881	0.44	0.0481	0.03126	0.00098
8	1	1.1	0.9	0.8	1.2	0.4875	0.44	0.0475	0.03186	0.00102
9	1	0.9	1.1	0.8	1.2	0.486	0.44	0.046	0.0336	0.001113
10	1.2	1.1	0.8	0.9	1	0.4854	0.44	0.0454	0.03396	0.01153
11	1.1	0.9	0.8	1.2	1	0.485	0.42	0.065	0.01436	0.00021
12	1	0.8	1.1	0.9	1.2	0.4848	0.44	0.0448	0.03456	0.0012
13	0.9	1.1	0.8	1	1.2	0.4846	0.42	0.0646	0.01476	0.00022
14	0.9	1.1	1	0.8	1.2	0.4839	0.42	0.0639	0.01546	0.00024
15	1.1	0.8	0.9	1.2	1	0.4837	0.42	0.0637	0.01566	0.00025
16	1	0.8	0.9	1.1	1.2	0.4836	0.44	0.0436	0.03576	0.00128
17	1.1	1.2	0.8	0.9	1	0.4831	0.42	0.0631	0.01626	0.00027
18	0.9	1	1.1	0.8	1.2	0.483	0.42	0.063	0.01636	0.00027
19	0.9	1.2	0.8	1	1.1	0.4829	0.4	0.0829	-0.00354	0.00013
20	0.9	1	0.8	1.1	1.2	0.4827	0.42	0.0627	0.01666	0.00028
21	1	0.9	1.2	0.8	1.1	0.4824	0.42	0.0624	0.01696	0.00029
22	1.1	0.9	1.2	0.8	1	0.4819	0.42	0.0619	0.01746	0.00031
23	1	0.8	0.9	1.2	1.1	0.4812	0.42	0.0612	0.01816	0.00033
24	0.9	1.2	1	0.8	1.1	0.4806	0.4	0.0806	-0.00124	0.000001
25	0.9	1	0.8	1.2	1.1	0.4805	0.4	0.0805	-0.00114	0.0000013

26	1.2	1	0.9	1.1	0.8	0.4804	0.4	0.0804	-0.00104	0.0000011
27	0.8	1.1	1	0.9	1.2	0.4803	0.4	0.0803	-0.00094	0.0000009
28	0.9	1.2	0.8	1.1	1	0.4802	0.38	0.1002	-0.02084	0.00434
29	0.9	1.1	0.8	1.2	1	0.4796	0.38	0.0996	-0.02024	0.00041
30	0.9	0.8	1.1	1	1.2	0.4794	0.42	0.0594	0.01996	0.0004
31	0.9	1	1.2	0.8	1.1	0.4791	0.4	0.0791	0.00026	0.00000007
32	0.8	1.2	0.9	1	1.1	0.4789	0.38	0.0989	-0.1954	0.000382
33	0.9	0.8	1	1.1	1.2	0.4786	0.42	0.0586	0.02076	0.000431
34	0.8	1	1.1	0.9	1.2	0.4785	0.4	0.0785	0.00086	0.0000007
35	0.8	1	0.9	1.1	1.2	0.4781	0.4	0.0781	0.00126	0.000002
36	1.1	0.9	1	1.2	0.8	0.478	0.38	0.098	-0.01864	0.00035
37	0.9	0.8	1.2	1	1.1	0.4769	0.4	0.0769	0.00246	0.0000061

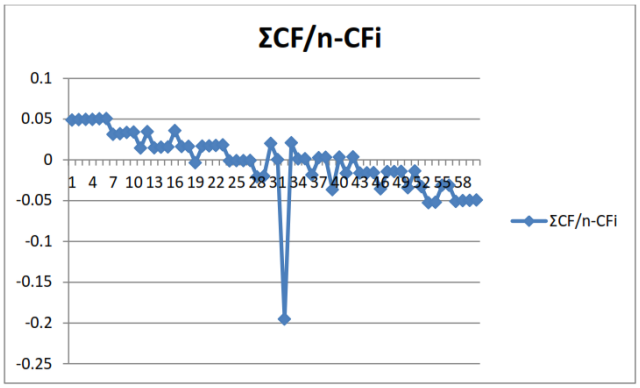
38	0.8	0.9	1.1	1	1.2	0.4763	0.4	0.0763	0.00306	0.0000094
39	0.8	1.2	0.9	1.1	1	0.4761	0.36	0.1161	-0.03674	0.0014
40	1.1	1.2	1	0.8	0.9	0.476	0.4	0.076	0.00336	0.0000113
41	1	0.8	1.1	1.2	0.9	0.4758	0.38	0.0958	-0.01644	0.00027
42	1.2	1.1	1	0.9	0.8	0.4757	0.4	0.0757	0.00366	0.0000134
43	1.1	1.2	0.9	1	0.8	0.4756	0.38	0.0956	-0.01624	0.000264
44	0.9	1.1	1.2	0.8	1	0.4753	0.38	0.0953	-0.01594	0.000254
45	1.1	0.9	1.2	1	0.8	0.4752	0.38	0.0952	-0.01584	0.000251
46	1	1.2	0.9	1.1	0.8	0.4751	0.36	0.1151	-0.03574	0.00128
47	0.9	0.8	1.2	1.1	1	0.4738	0.38	0.0938	-0.01444	0.00021
48	0.9	0.8	1.1	1.2	1	0.47373	0.38	0.09373	-0.01437	0.00021
49	0.8	0.9	1.2	1	1.1	0.47369	0.38	0.09369	-0.01433	0.00021
50	1	0.9	1.1	1.2	0.8	0.47365	0.36	0.11365	-0.03429	0.00118
51	1.1	1.2	1	0.9	0.8	0.4732	0.38	0.0932	-0.01384	0.00019

52	0.8	1.1	1.2	0.9	1	0.4725	0.36	0.1125	-0.03314	0.0011
53	0.9	1.1	1	1.2	0.8	0.472	0.34	0.132	-0.05264	0.00277
54	0.8	1.1	1	1.2	0.9	0.4715	0.34	0.1315	-0.05214	0.00272
55	1	1.2	1.1	0.9	0.8	0.4706	0.36	0.1106	-0.03124	0.00098
56	0.8	0.9	1.2	1.1	1	0.4705	0.36	0.1105	-0.03114	0.00097
57	0.9	1	1.1	1.2	0.8	0.4704	0.34	0.1304	-0.05104	0.002605
58	0.8	1	1.1	1.2	0.9	0.4695	0.34	0.1295	-0.05014	0.00251
59	0.8	1.1	1.2	1	0.9	0.4691	0.34	0.1291	-0.04974	0.00247
60	0.8	1	1.2	1.1	0.9	0.4687	0.34	0.1287	-0.04934	0.00243
								ΣCF/n = 0.07936		**S=0.06532 727**

σ = Sqrt (sum)/n=0.033



Variance with Mean vale Of Correction Factor(Σ CF/n-CFi) VS S.No WhenD= 1.2linear



Variance with Mean vale Of Correction Factor (Σ CF/n-CFi) VS S. No. When D= 0.4 linear

RESULTS

From Graph and table we see that the values of D=1.2 linear, the values of CF_i(-0.111$_1$, -0.1123$_2$ … -0.0056 $_{10}$… -0.0092$_{15}$ …… 0.0451$_{20}$, ….. 0.0421$_{25}$ …….. -0.0233$_{30}$ …… 0.0914$_{35}$, ……. 0.0887$_{40}$ …… 0.0843$_{45}$ …. 0.0808$_{50}$, …… 0.1325$_{55}$ …… 0.1931$_{60}$) σ = 0.14234

values of D=0.4 linear, the values of CF_i (0.0307$_1$, 0.0302$_2$ …… 0.0292$_5$ ……. 0.0454$_{10}$ …….. 0.0627$_{20}$ ……. 0.0594$_{30}$ …… 0.076$_{40}$ …… 0.1136$_{50}$ ….. 0.1287$_{60}$) σ = 0.00425

Here we know that the formula of production rate are

AFPR = AFR ± (a +b) σ

Where for D= 1.2 linear

a = CF/ σ = -0.111/ 0.14234= -0.7798 for S.No.1 that's be nearly equal to a= D/2 + (D-1) = (1.2 /2) + (1.2-1) = 0.6+0.2= 0.8 for b = (CF_1 - CF_2)/ σ = (-0.111- (-0.1123))/0.14234 = -0.009133 ≈ 0.01 for S. NO. 2 and onwards upto 30 because Upto 30 values are –ve Sign, for S. No. 1 the value of b= 0 then we calculate the + Ve values are b= (CF_{20}-CF_{21})/ σ = (0.0451-0.0437)/0.14234 =0.00983 ≈ 0.1 therefore we say that the value of b = 0.1 X S. No. (i-1) where i= 1 to 60 we calculate the last value (Worst production Rate) the formula is AFPR = AFR ± (a + b) σ

For Example S. No.60 the production Rate is(here S. No. is higher than 30 then we take +Ve) hence AFPR= (AFR_{60} + (a + b_{i-1}) σ) = 0.22 +(0.8+59 X0.01) X0.14234 = 0.4178 ≈ 0.4131 (R_{60})

For Example S. No 2 AFPR = AFR_{60} + (a + b_{i-1}) σ = 0.58 – (0.8 - 0.01 x1)x 0.14234=0.4675 ≈ 0.4677 (R_2) Therefore our formula is correct when we know the D (degree of Imbalance) for higher values of work load distribution in production rate in production line

Similarly for Where for D=0.4 linear. All the values are + Ve here in formula therefore we calculate a and b

a= CF_1/ σ = 0.0307/ 0.033 = 0.93 = (3D/2+3D/4) = ((3x0.4/2) + (3x0.4/4)) = 0.9

here b1 = 0

and b_2= (CF_1 – CF_2)/ σ =(0.0307 -0.0302)/0.033 ≈ 0.015

b20 = (CF_{20} – CF_{21})/ σ = (0.0627-0.0624)/ 0.033 ≈ 0.0091

b60 = $(CF_{59} – CF_{60})/ \sigma$ = (0.1291 -0.1287)/ 0.033 ≈ 0.0121

therefore we take $b_{i-1} = 0.01$ for each S.NO. (i-1)

where $\sigma = D_{0.4}/10 = 0.04$

CONCLUSION

Therefore we conclude that our formula

1. AFPR = $AFR_{60} + (a + b_{i-1}) \sigma$ is applicable when we Know that when (a= 3D/2+3D/4)) where $D_{0.4}$ =0.4, b_{i-1}= 0.1X S.NO. (i-1) and $\sigma = D_{0.4}/10$ for each lower values of degree of imbalance (D<1) in a production line

2. AFPR = AFR ± (a +b) σ is applicable when we Know that When (a= D/10+(D-1)/10) where D=D , b_{i-1}= 0.1X S.NO. (i-1) and σ = D /10 X 0.15 for each higher values of degree of imbalance (D>1) in a production line

3. Formula is valid because in both graph we say that the Variance with Mean vale Of Correction Factor (-0.15 to +0.15 for D=1.2 and -0.05 to -0.05for D= 0.4) is near about -3 σ to +3 σ when the Correction factor is not included.

4. These strategies (formula) are very useful when we calculate production rate the workload distribution higher than 5-work station (like 7- 9-11 –or more work station) in production line

FUTURE SCOPE

We make a Simple program in C to calculate the production rate of 7-and analyze the results and also calculate the production rate when the Setup time on work station and work load distribution known in batch type production rate in Flexible manufacturing system or Computer Integrated Manufacturing.

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