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A Lean Manufacturing Model for Reducing Dead Time on A Labels Production Line

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***Abstract* - This article presents a lean manufacturing model for reducing dead time on production lines in a flexographic company. The model is constructed based on dead time indices; factors with the highest influence in dead times are determined by the principal components of the multivariate analysis. Risks under different dead time scenarios were calculated in order to compare results.**

***Mathematics Subject Classification* (2010):** 90B30, 90B70

***Keywords* - dead time, lean manufacturing, risk, principal components.**

I. Introduction

This research was developed at the ETIFLEX S.A. de C.V. Company. This company has a wide variety of clients, and supplies its products to companies dedicated to different lines of Business: food industries, pharmaceutical companies, cosmetics industries, industrial products manufacturers, plastic products manufacturers, cardboard factories, and others. Lately, this company has expanded its production capacity, because it has acquired printing presses that yield higher productivity; additionally the company has increased its necessity of:

- Process Design.
- Process Planning.
- Process Control.

Nowadays, it is necessary for the company to establish indicators in different process stages in order to be able to take better decisions during the business strategies that were previously planned.

In recent years, clients' specifications and requirements have increased and this is a primordial situation for every company. Costs reduction and service levels improvement must be considered as priority among company processes in order to get a competitive advantage in the industrial sector.

Furthermore, it is important to notice that failures related to quantity, shape, time and place of costumer requests are penalized in costs during the supply chain, observed as stoppages in production lines, reworks, delays, unscheduled storage, etc.

For that reason, and according to the parametres currently established, it is considered that stoppages on production lines is one of the most expensive and frequent causes in productive processes of a company. Quantifications have shown that an average of 17.7 dollars per minute is lost during a stoppage in production lines.

Costs of stoppages are considerable; because of this, ways to decrease them are always sought. However, firstly it is necessary to find the principal causes of stoppages on production lines and how to reduce them. It is also important to quantify reduction costs of stoppage causes.

This research aims to quantify stoppage times and the risk or loss caused by stoppage on production lines. Additionally stoppage indexes for each printing press are proposed, in order to compare them and be able to find a way to decrease stoppage times.

This research proposes a model based on Lean Manufacturing Philosophy to detect the principal causes of stoppage on production lines. The specific objectives are to build a model that will contribute to:

- Identify principal stoppage causes on production lines.
- Reduce dead times on production lines.
- Standardize stoppage measurements using indicators that lead to compare different production lines.
- Decrease loss caused by stoppages on production lines.
- Construct indexes to evaluate dead time.

II. Materials And Methods

The methods for describing the model used for decreasing production losses due to dead times on production lines in the company are described as follows.

2.1 Production Line

An experiment was performed in the printing press model FA-2500 trademark NILPETER, having five workstations.

2.2 Causes of stoppages on production line

There is a variety of causes of stoppages on production lines and they depend on the product characteristics manufactured in each company. Although most label and ticket production processes have similar stoppage causes, sometimes it is complicated to define a stoppage. For that reason, stoppage causes must be standardized for the whole company.

A diagnosis was made in two similar printing presses to find the most frequent stoppage causes and to define priorities and make an ABC classification or a Pareto study.

2.3 Performance of stoppage causes on production lines

The research team made a study to compare distribution models that best fit the data, Akaike 1974, AIC decision criteria was considered.

To make adjustments, a function that obtains the best parametres estimators of each proposed model was programed in the project R.

2.4 Risk and dead times scenarios

After the performance of each stoppage cause, Class A was determined. It was possible to define and calculate the risk of events or possible scenario during dead times in a company.

In a stoppage cause, the performance of its dead time can be defined as a random variable X with distribution function $F(x;\alpha,\lambda)$, then in a specific scenario with dead time T, risk will be defined as:

$$R(T) = F(T) \times C \times T \qquad (2.1)$$

Units used in this study case are:

- $R(T)$ risk of occurrence of scenario of dead time T in dollars,
- $F(T)$ - cumulative distribution function of the dead time T in minutes,
- C – cost of stoppage occurrence during one time unit (minute) in dollars,
- T- total time in minutes of the studied stoppage.

2.5 Dead time indexes construction

Dead time indexes were constructed for each printing press. The construction process is the following.

It is supposed that *m* causes exist with *n* observations per cause (days).

Step 1. To construct a daily indicator for each stoppage cause

Production lines are considered as independent, an indicator for each stoppage cause j is constructed standardizing each dead time per day, so the highest indicator corresponds to the lowest time

$$I_{ji} = \frac{M_j - x_{ji}}{M_j - m_j}.$$

Where, $i = 1,2,\ldots,n$ y $j = 1,2,\ldots,m$

- M_j is the longest dead time attributable to determined stoppage cause.
- m_j is the shortest dead time attributable to determined stoppage cause.
- x_{ji} is the dead time during the day i attributable to the stoppage cause j.
- I_{ji} is the index value in day i of stoppage cause j.

In the case of the studies printing press values are: $i = 1,2,\ldots,134$ y $j = 1,2,\ldots,7$.

Step 2. Calculate a dead time index per stoppage cause

The general dead time index of stoppage cause is defined as the average of daily dead time indexes of stoppage cause.

$$I_j = \frac{1}{n}\sum_{i=1}^{n} I_{ji}.$$

Step 3. Calculate dead time indexes in the printing press

To calculate the dead time index, it is necessary to propose a value for each stoppage cause. A good method for proposing values for constructing indexes is given by the principal components method, of the multivariate analysis.

For using the principal components method, calculations were made by the statistical software SAS.

III. Results

Methods proposed in the section above, were applied to measure dead times on production lines de 17 and 19.

3.1 Causes of stoppage on production lines 17 and 19

Dead times data from printing press 17, FA-2500 was collected from May to December 2010 for this study. Data was classified using ABC classification.

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Table 3.1 shows ABC classification of the stoppage causes in the printing press FA-2500. ABC classification was based on criteria related with dead times that statistically determine the most relevant stoppage causes according to minutes invested in each stoppage cause.

According to this analysis it can be said that stoppage causes grouped in Class A are the most important based on their frequency, see table 3.1.

In total 67704 dead minutes were identified during the observed period. Principal stoppage causes and respective costs are described in Table 3.2.

Similarly for printing press 19, see tables 3.3 and 3.4.

In total 70545 dead minutes were identified during the period from May to December 2010. Principal stoppage causes and respective costs are described in Table 3.4.

After analyzing both printing presses, results show that from May to December 2010 stoppage causes included in Pareto class A in printing press 17 represent 51897 dead minutes equivalent to $920,525.79 USD accumulated dead time cost. While in printing press 19, dead time is 56425 minutes that correspond to $1001284.2 USD accumulated dead time cost.

Causes	Min.	Accum.	%	Class
Machine cleaning	13356	13356	19.727	A
Lunch time	9738	23094	34.111	
Load change	7926	31021	45.818	
Quality approval	6687	37708	55.694	
Tape change (raw material)	6349	44057	65.072	
Not defined	4618	48675	71.894	
Engravings cleaning	3312	51987	76.785	
Frame was broken	3241	55228	81.572	B
Personnel	2740	57968	85.619	
Waiting for coiling	1909	59877	88.439	
Cutting mold does not cut	1464	61341	90.601	
Shade adjustment	922	62263	91.963	
Engravings change	770	63033	93.101	
Anilox cleaning	684	63717	94.111	
OP Information failure	574	64291	94.959	
Defective plates	519	64810	95.725	C
Corrective mechanical mant.	487	65297	96.445	
Lack of personnel	456	65753	97.118	
Turn changing	382	66135	97.682	
Corrective electrical mant.	375	66510	98.236	
Lack of tools	323	66833	98.713	
Lack of raw materials	310	67143	99.171	
Lack of technical or approval documents	173	67316	99.427	
Electrical failure	124	67440	99.610	
Failures in raw materials	102	67542	99.761	
Logistic failure	89	67631	99.892	
Laminate changing	63	67694	99.985	
Weekend	9	67703	99.999	
Folio failure	1	67704	100	
TOTAL	**67704**			

Table 3.1 Pareto diagram of dead times causes in FA-2500 printing press.

Printing press 17			
Cause	**Cost USD**	**Min**	**Total cost**
Machine cleaning	**$ 18.10**	**13356**	$ 241,743.60
Lunch time	**$ 16.50**	**9738**	$ 160,683.11
Load change	**$ 15.30**	**7926**	$ 121,270.10
Quality approval	**$ 22.20**	**6687**	$ 148,451.40
Tape change (raw material)	**$ 15.90**	**6349**	$ 100,953.39
Not defined	**$ 19.30**	**4618**	$ 89,133.00
Engravings cleaning	**$ 17.60**	**3312**	$ 58,291.20
		51987	**$920,525.79**

Table 3.2 Principal stoppage causes and respective costs in printing press 17.

Causes	Min.	Accum.	%	Class
Machine cleaning	**16139**	**16139**	**22.878**	**A**
Tape change (raw material)	**9550**	**25689**	**36.415**	
Load change	**8527**	**34216**	**48.502**	
Not defined	**7936**	**42152**	**59.752**	
Quality approval	**6356**	**48508**	**68.762**	
Frame was broken	**4498**	**53006**	**75.138**	
Engravings cleaning	**3419**	**56425**	**79.984**	
Lunch time	**2306**	**58731**	**83.253**	**B**
Personnel	**1421**	**60152**	**85.268**	
Turn changing	**1370**	**61522**	**87.210**	
Anilox cleaning	**1253**	**62775**	**88.986**	
Cutting mold does not cut	**1147**	**63922**	**90.612**	
Engravings change	**988**	**64910**	**92.012**	
Shade adjustment	**977**	**65887**	**93.397**	
Waiting for coiling	**726**	**66613**	**94.426**	
Lack of raw materials	**616**	**67229**	**95.299**	**C**
Defective plates	**580**	**67809**	**96.122**	
Corrective mechanical mant	**510**	**68319**	**96.845**	
Raw material failure	**461**	**68780**	**97.498**	
Training	**421**	**69201**	**98.095**	
Corrective electrical mant	**353**	**69554**	**98.595**	
Logistic failure	**189**	**69743**	**98.863**	
Lack of tools	**165**	**69908**	**99.097**	
Laminate changing	**134**	**70042**	**99.287**	
Lack of standard	**131**	**70173**	**99.473**	
Preventive maintenance	**103**	**70276**	**99.619**	
Electrical failure	**101**	**70377**	**99.762**	
Printing press without work assigned	**88**	**70465**	**99.887**	
Lack of technical or approval documents	**48**	**70513**	**99.955**	
OP information failure	**13**	**70526**	**99.973**	
Lack of personnel	**10**	**70536**	**99.987**	
Weekend	**9**	**70545**	**100**	
	70545			

Table 3.3 Pareto diagram of dead time causes in printing press19.

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Printing press 19			
Cause	Cost USD	Min	Total cost
Machine cleaning	$ 18.10	16139	$ 292,115.90
Tape change (raw material)	$ 15.90	9550	$ 151,845.00
Load change	$ 15.30	8527	$ 130,463.10
Not defined	$ 19.30	7936	$ 153,164.80
Quality approval	$ 22.20	6356	$ 141,103.20
Frame was broken	$ 16.10	4498	$72,417.80
Engravings cleaning	$ 17.60	3419	$ 60,174.40
		56425	$ 1,001,284.20

Table 3.4 Principal stoppage causes and respective costs in printing press 19.

3.2 Random performance of stoppage causes on production lines FA-2500 and FB-2500

At this stage of the research, dead time performances were analyzed. For each stoppage cause in Class A the best dead time distribution was determined and its parametres were estimated using the AIC decision criteria. Calculations were made using the statistical package R. The graphic in figure 3.1 shows the distribution of dead times for the "engravings cleaning" stoppage cause. Similar calculations were made for each stoppage cause. In the graphic 3.1 axis *X* represents dead time in minutes and axis *Y* is relative stoppage frequency. Results of the best adjustments are show in tables 3.5 and 3.6.

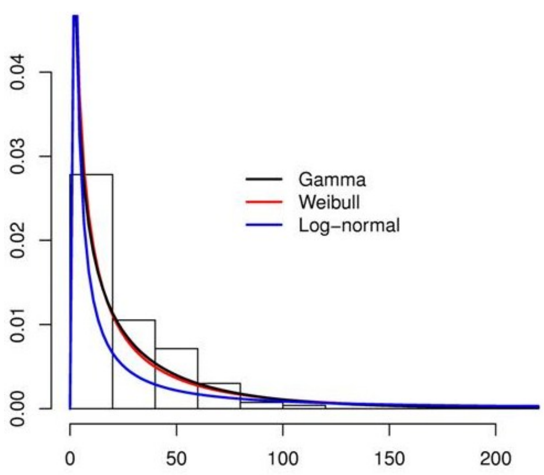

Figure 3.1 Histogram and graphic of engravings cleaning in P17.

3.3 Risk and dead time scenarios for printing pressers 17 and 19

Considering the results obtained above about the performance of each stoppage cause and best adjustments, it is possible to calculate the risk for each scenario of 50, 100, 150, 200, 250, 300, 350 y 400 minutes for each stoppage cause in each printing press.

Results of printing press 17 are show in tables 3.7 – 3.9 where stoppage causes are:

LM- Machine cleaning

R- Lunch time

CC- Load changing

AC- Quality approval

CCMP- Tape change (raw material)

ND- not defined

LG- Engravings cleaning

			Estimators	
Cause	Distr.	AIC	V1	V2
Machine cleaning. LM	Weibull	8948.9	1.0907	102.3756
	Gamma	8953.0	0.8237	0.0082
	Lognormal	9770.4	3.9539	2.1095
Lunch time R	Weibull	8429.1	1.1781	75.0885
	Gamma	8442.4	0.8760	0.0120
	Lognormal	9377.1	3.6220	2.2978
	Normal	7970.0	73.2197	35.5976
Load change CC	Weibull	8116.1	1.0856	61.1012
	Gamma	8123.6	0.9805	0.0165
	Lognormal	8738.0	3.4967	1.7450
Quality approval AC	Weibull	7852.0	1.0198	50.5800
	Gamma	7842.5	0.8743	0.0174
	Lognormal	8487.3	3.2461	1.9162
Tape change (raw material) COMP	Weibull	7632.9	1.4328	52.0562
	Gamma	7678.7	1.5922	0.0334
	Lognormal	8183.3	3.5196	1.2048
Not defined ND	Weibull	7203.4	1.2467	37.1615
	Gamma	7214.4	1.3849	0.0399
	Lognormal	7593.9	3.1446	1.2118
Engravings cleaning LG	Weibull	6399.2	0.6045	19.2345
	Gamma	6279.2	0.4602	0.0185
	Lognormal	6786.0	1.8159	2.7582

Table 3.5 Models for adjustments of dead times in printing press 17.

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Cause	Distr.	AIC	V1	V2
		Estimators		
Machine cleaning **LM**	Weibull	9433.0	1.2666	123.912
	Gamma	9483.4	1.1177	0.0095
	Lognormal	10277.1	4.2521	1.7821
	Normal	9350.2	117.8037	71.2421
Tape change (raw material) **CCMP**	Weibull	8561.1	1.2833	74.0276
	Gamma	8609.6	1.2004	0.0172
	Lognormal	9284.9	3.7727	1.5741
Load change **CC**	Weibull	8421.8	0.8911	59.4223
	Gamma	8397.4	0.7692	0.0124
	Lognormal	8970.0	3.3533	1.9770
Not defined **ND**	Weibull	8321.3	1.0103	58.1494
	Gamma	8321.6	0.9183	0.0159
	Lognormal	8824.5	3.4560	1.6328
Quality approval **AC**	Weibull	7690.0	0.6282	38.0219
	Gamma	7533.9	0.4752	0.0103
	Lognormal	8182.4	2.4873	2.9107
Frame was broken **RE**	Weibull	7364.0	0.8742	31.0076
	Gamma	7342.0	0.7593	0.0231
	Lognormal	7814.6	2.7038	1.8743
Engravings cleaning **LG**	Weibull	6674.4	0.6398	19.9346
	Gamma	6569.1	0.4951	0.0199
	Lognormal	7069.7	1.9317	2.5787

Table 3.6 Models for adjustments of dead times in printing press 19.

Cause	Distr.	T	Risk	T	Risk	T	Risk
LM	**Weibull**	50	332.3458	100	1127.089	150	2119.332
R	**Normal**	50	212.1154	100	1277.210	150	2436.62
CC	**Weibull**	50	422.7691	100	1252.476	150	2133.034
AC	**Gamma**	50	709.5512	100	1902.768	150	3137.992
CCMP	**Weibull**	50	485.6575	100	1465.620	150	2359.931
ND	**Weibull**	50	738.1174	100	1867.834	150	2885.269
LG	**Gamma**	50	741.482	100	1674.855	150	2597.118

Table 3.7 Risks of scenarios 50, 100 and 150 dead minutes in printing press 17.

Cause	Distr.	T	Risk	T	Risk	T	Risk
LM	**Weibull**	200	3165.926	250	4204.674	300	5215.341
R	**Normal**	200	3299.392	250	4124.999	300	2909.762
CC	**Weibull**	200	2978.284	250	3787.161	300	4573.467
AC	**Gamma**	200	4335.758	250	5496.653	300	6633.695
CCMP	**Weibull**	200	3176.727	250	3974.694	300	4769.978
ND	**Weibull**	200	3858.888	250	4824.898	300	5789.992
LG	**Gamma**	200	3499.987	250	4391.025	300	5276.072

Table 3.8 Risks of scenarios 200, 250 and 300 dead minutes in printing press 17.

Cause	Distr.	T	Risk	T	Risk
LM	**Weibull**	350	6196.388	400	7152.997
R	**Normal**	350	3201.852	400	3605.357
CC	**Weibull**	350	5348.079	400	6117.197
AC	**Gamma**	350	7757.356	400	8874.034
CCMP	**Weibull**	350	5564.999	400	6360.000
ND	**Weibull**	350	6754.999	400	7720.000
LG	**Gamma**	350	6158.309	400	7039.281

Table 3.9 Risks of scenarios 350 and 400 dead minutes in printing press 17.

Similarly results for printing press 19 were calculated and a stoppage cause has been added:

RE- Frame was broken

A stoppage cause was eliminated:

R- Lunch time

Results are shown in tables 3.10 – 3.12.

Cause	Distr.	T	Risk	T	Risk	T	Risk
LM	**Normal**	50	154.4069	100	726.409	150	1830.833
CCMP	**Weibull**	50	360.5937	100	1224.776	150	2184.28
CC	**Weibull**	50	440.4377	100	1218.046	150	2060.788
ND	**Weibull**	50	556.0419	100	1587.619	150	2681.029
AC	**Gamma**	50	782.3879	100	1903.390	150	3083.859
RE	**Gamma**	50	627.3374	100	1510.617	150	2371.588
LG	**Gamma**	50	741.8924	100	1679.672	150	2601.886

Table 3.10 Risks of scenarios 50, 100 and 150 dead minutes in printing press 19.

Cause	Distr.	T	Risk	T	Risk	T	Risk
LM	**Normal**	200	3170.038	250	4381.305	300	5401.37
CCMP	**Weibull**	200	3091.379	250	3941.202	300	4758.458
CC	**Weibull**	200	2899.711	250	3720.28	300	4523.39
ND	**Weibull**	200	3741.501	250	4763.617	300	5759.531
AC	**Gamma**	200	4264.047	250	5429.646	300	6579.869
RE	**Gamma**	200	3202.818	250	4018.552	300	4827.659
LG	**Gamma**	200	3503.277	250	4392.959	300	5277.109

Table 3.11 Risks of scenarios 200, 250 and 300 dead minutes in printing press 19.

Cause	Distr.	T	Risk	T	Risk
LM	**Normal**	350	6331.462	400	7239.730
CCMP	**Weibull**	350	5561.395	400	6358.955
CC	**Weibull**	350	5313.333	400	6094.220
ND	**Weibull**	350	6740.319	400	7713.079
AC	**Gamma**	350	7717.608	400	8846.187
RE	**Gamma**	350	5634.169	400	6439.710
LG	**Gamma**	350	6158.833	400	7039.535

Table 3.12 Risks of scenarios 350 and 400 dead minutes in printing press 19.

3.4 Dead time indexes construction for printing pressers 17 and 19

Daily indicators for each stoppage cause and their averages were calculated. Thereafter, principal components (C.P.) were calculated using a multi-varied analysis. Based on that, results stoppage causes can be weighed for each printing press. Summarized results are shown in tables 3.13 and 3.14.

Cause	Index	C.P.	Value
LM	0.7451	0.886	**0.4802**
R	0.6497	0.175	**0.0949**
CC	0.7635	0.259	**0.1404**
AC	0.7077	0.312	**0.1691**
CCMP	0.6959	0.110	**0.0596**
ND	0.7605	0.018	**0.0098**
LG	0.8797	0.085	**0.0461**
	sum	1.845	

Table 3.13 Values for each stoppage cause of printing press 17

Cause	Indicator	C.P.	Value
LM	0.6034	0.717	**0.3344**
CCMP	0.7083	0.137	**0.0639**
CC	0.8894	0.558	**0.2603**
ND	0.8604	0.204	**0.0951**
AC	0.8307	0.292	**0.1362**
RE	0.8383	0.141	**0.0658**
LG	0.8050	0.095	**0.0443**
	sum	2.144	

Table 3.14 Values for each stoppage cause of printing press 19

Finally, dead times in each printing press are compared using weighed indexes that were calculated considering their respective indicators and values.

For printing press 17: **0.7357**
For printing press 17: **0.7643**

It can be concluded that the dead time index of printing press 19 considering 7 stoppage causes in class A is 0.7643 higher than the one calculated for printing press 17, 0.7357.

IV. Conclusions And Future Work

Throughout this research a lean manufacturing model was used to quantify and detect printing presses with the highest risk of presenting dead times.

The model is designed for production lines in a flexographic company. The model was tested in two printing presses using data from May to December 2010. Similar results for stoppage causes were obtained.

For results interpretation, dead time indexes are considered to take values between 0 and 1. They were constructed considering that the higher the value of an indicator in a printing press, the lower the dead times in that production line.

It can be concluded that in general, dead times in printing press 19 are slightly lower than the ones in printing press P17. This fact is observed similarly in a calculation of risks. Lower risks are present in printing press 19 compared with the risks presented in printing press 17. This can be observed in tables 3.7 to 3.12.

Finally, it can be concluded that in order to compare dead times in any printing press, it is necessary to calculate and compare risks and dead time.

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