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Highlights

- Carpal Tunnel Syndrome
- Tunnel Syndrome Symptoms
- Cost Minimization Model
- Gas Station: A Case Study

Discovering Thoughts, Inventing Future

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Contents of the Issue

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Carpal Tunnel Syndrome Symptoms and Associated Risk Factors for Assembly Line Workers Engaged in Shocker Manufacturing Industries: A Study

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Abstract- The Carpal Tunnel Syndrome (CTS) and associated risk factors for shocker manufacturing industries in Haryana were carried out. A comparison of CTS and other upper hand extremities amongst traditional and semi-ergonomic shocker manufacturing workers in actual industrial environment has been analysed through questionnaire and physical tests. Fisher's exact test and 't' test are used for statistical data analysis. From Fisher's exact test, it is observed that due to wrist/hand problems 80 % of traditional and 20 % of semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. The results reflect that the traditional shocker manufacturing workers are more CTS symptoms occurrence than the semi-ergonomic shocker manufacturing workers.

Keywords: musculoskeletal disorders, carpal tunnel syndrome, tinel's sign, phalen's sign, fisher's exact test, 't' test.

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Carpal Tunnel Syndrome Symptoms and Associated Risk Factors for Assembly Line Workers Engaged in Shocker Manufacturing Industries: A Study

Santosh Kumar [α], Manoj Kumar [σ] & M. Muralidhar [ρ]

Abstract- The Carpal Tunnel Syndrome (CTS) and associated risk factors for shocker manufacturing industries in Haryana were carried out. A comparison of CTS and other upper hand extremities amongst traditional and semi-ergonomic shocker manufacturing workers in actual industrial environment has been analysed through questionnaire and physical tests. Fisher's exact test and 't' test are used for statistical data analysis. From Fisher's exact test, it is observed that due to wrist/hand problems 80 % of traditional and 20 % of semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. The results reflect that the traditional shocker manufacturing workers are more CTS symptoms occurrence than the semi-ergonomic shocker manufacturing workers. From 't' test, it is found that there is significant difference in grip strength of dominant and non-dominant hand for high repetitive work as calculated t-ratio values 5.162 and 3.099 respectively are more than standard value 2.048.

Keywords: musculoskeletal disorders, carpal tunnel syndrome, tinel's sign, phalen's sign, fisher's exact test, 't' test.

I. Introduction

This paper presents analysis of Carpal Tunnel Syndrome (CTS) associated risk factors and exposure to repetition among assembly line workers engaged in traditional and semi-ergonomic shocker manufacturing industries in order to help reduce the work-related musculoskeletal disorders (WMSDs) in the upper-body extremities among assembly workers. An assembly line consists of a series of workstations, in which particular operations (set of assembly tasks) are executed repeatedly to increase line efficiency such as maximizing productivity (Carnahan et al., 2001, Xu et al., 2012). Musculoskeletal disorders (MSDs) refers to conditions where the workers have experienced discomfort in one or multiple body parts (neck, shoulder, back, elbow, hand, wrist, hip and knee), pain in the joints, tingling, and swelling. MSDs are common occupational diseases among assembly line workers due to repetitive motions or heavy workloads (Carayon et al., 1999). The assembly line workers of auto industry are one of several industries that have high incidence of MSDs (Ulin et al., 2004, Ferguson et al., 2011). One important risk factor might be the repetitive awkward posture of the worker relative to the work while trying to access different tasks in auto assembly line. Previous studies have shown that awkward postures increase the risk of MSDs [Silverstein et al., 1997, Punnet et al., 2004, Keyserling et al., 2005). Literature reviews of the evidence indicate that reducing workplace exposure to known risk factors including awkward posture results in reduced MSD risk [Bernard et al., 1997,Punnet et al., 2004).CTS is one of the type of MSDs brought on by over-worked, over-strained muscles of arms and hands, resulting in a loss of nerve conductivity and possibly leading to muscle strength problems (Jones et al., 2004). CTS results from the entrapment of the median nerve at the wrist. It is the most common entrapment syndrome causing frequent disability especially to working populations (Montgomery et al., 1995, Kostopoulos et al., 2004, Nordstrom et al., 1997, Nuckols et al., 2011). In the workplace, the risk of developing CTS is not confined to people in a single industry or job, but is especially common in those performing assembly line works such as manufacturing, sewing, finishing, cleaning, and packing etc. In fact, carpal tunnel syndrome is three times more common among assembly line workers than among data-entry personnel (U. S. Department of Health, 2012).

In the present study an attempt has been made to analyse CTS risk factors and symptoms in industrial activities of assembly profile section having manual operations such as case tube, cylinder and component cleaning, guide disk assembly, piston valve tightening, cylinder bottom pressing, piston rod circlipping, oil seal assembly etc. in two shocker manufacturing industries involving repetitiveness and over exertion. The Fisher's exact test and 't' test have been used for the analysis of

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Global Journal of Researches in Engineering (G) Volume XV Issue III Version I Year 2015 1

CTS risk factors and symptoms. Geometric distribution is applied to get probability values in Fisher's exact test. For the selected physical profiles of the workers, the mean and standard deviation have been evaluated.

II. Materials and Methods

This work was carried out at two shocker industries in Haryana State, India. 140 workers of two shocker manufacturing industries, one is based on traditional and other on semi-ergonomic standards, were included in the study. There are 70 workforce in traditional, with a mean age of 39.29 ± 7.76 years, range 25-56, and 70 in semi-ergonomic, with a mean age of 29.23 ±3.54 years, range 23-40. The number of employees at the studied line was 91 in traditional and 85 in semi-ergonomic. In the present study we excluded those who did not work at the line, those who were off work due to sick-leave, pregnancy, education, chronic illness or due to other reasons. The study included those 140 that were present at their workstation on the day of examination of those specific workstations.

a) *Shock Absorber Operations and Assembly Systems*

The ergonomics study has been conducted on total 140 workers of two shocker manufacturing industries. One is based on traditional and other on semi-ergonomic standards having manual operations such as Case tube cleaning, Cylinder cleaning, Component cleaning, Guide disk assembly, Piston valve tightening/riveting, Cylinder bottom valve assembly/tightening, Oil filling in cylinder, Cylinder bottom pressing, Piston rod Circlipping, Oil seal assembly, Oil seal pressing and Beading and Sealing. Flow diagram of shock absorber assembly operations are shown in Figure 1. The photographs of shock absorbers are shown in Figure 2. Brief description of each operation is given below.

i. *Case tube cleaning*

In this operation the outer tube is cleaned extensively so that the shocker can work properly. It is made up of mild steel and having weighs around 2 kg. The operation is performed in a cleaning chamber with a suitable brush in both the industries.

ii. *Cylinder cleaning*

To remove foreign particles properly from outer surface of cylinder the phosphate solution is used. In semi-ergonomic industry both case tube cleaning and cylinder cleaning operations are performed at same work station.

iii. *Component cleaning*

Small components like bush, washer and oil seal are cleaned in a tray by the air pressure to wipe out the dust and foreign particles properly. The number of operators engaged in traditional shocker assembly unit are five whereas in semi-ergonomic industry are four. In both the industries the operation was performed in cleaning chamber.

iv. *Guide disk assembly*

In this operation guide disk is used for piston and main spring support. The assembly is done by spanner and air nut runner. The four numbers of operators are engaged in traditional and semi-ergonomic industries. In traditional manufacturing unit, the operation is performed by a conventional spanner at guide disk assembly station whereas in semi-ergonomic industry, it is performed on a moving conveyor by air nut runner.

v. *Piston valve tightening/riveting*

In both the industries, the operation is performed by a riveting press at piston valve tightening station. The operation is performed on moving conveyor and piston valve is tightened by riveting machine. The number of operators engaged is five in both the industries.

vi. *Cylinder bottom valve assembly/tightening*

In both the industries, the operation is performed at cylinder bottom valve assembly station and cylinder bottom valve is tightened by riveting press. The operation is performed on a moving conveyor and piston valve is tightened by air nut runner. The number of operators engaged in traditional and semi-ergonomic industries is four and five respectively.

vii. *Oil filling in cylinder*

For friction control the lubricant oil is poured manually in the cylinder in traditional manufacturing unit whereas in semi-ergonomic industry, it is done by oil filing machine. Number of operators engaged in traditional and semi-ergonomic industry is five and three respectively.

viii. *Cylinder bottom pressing*

In this operation, after tightening the cylinder bottom valve, cylinder bottom is pressed by five tonnage presses. In traditional industry four operators are engaged whereas in semi-ergonomic industry three operators are engaged.

ix. *Piston rod circlipping*

In traditional industry the operation is performed with the help of conventional spanner whereas in semi-ergonomic industry the operation is performed by air nut runner. The operator engaged in this operation is four in both the industries.

x. *Oil seal assembly*

Oil seal prevents the oil leakage from cylinder during movement of piston in cylinder. In this operation oil seal is assembled to the top of cylinder. It contains rubber seal, valve inlet and a nut which is assembled manually with the help of spanner in both industries. The operators engaged in this operation are five in both the industries.

Global Journal of Researches in Engineering (G) Volume XV Issue III Version I Year 2015

xi. *Oil seal pressing*

In this operation, oil seal assembly is pushed with the help of a riveting machine in both the industries. The number of operators engaged in the operation is five in both the industries.

xii. *Beading and sealing*

In beading operation, the casing chamber of shocker is closed with special purpose machine called beading machine. In traditional manufacturing unit, five operators are engaged. The sealing operation is similar to beading operation but it is performed on a similar kind of special purpose machine, for the enforcement of beading joint to ensure the leakage of hydraulic oil and air in the casing tube chamber. In semi-ergonomic industry, the beading and sealing operation is performed on the same machine and total eleven operators are engaged in this combined task.

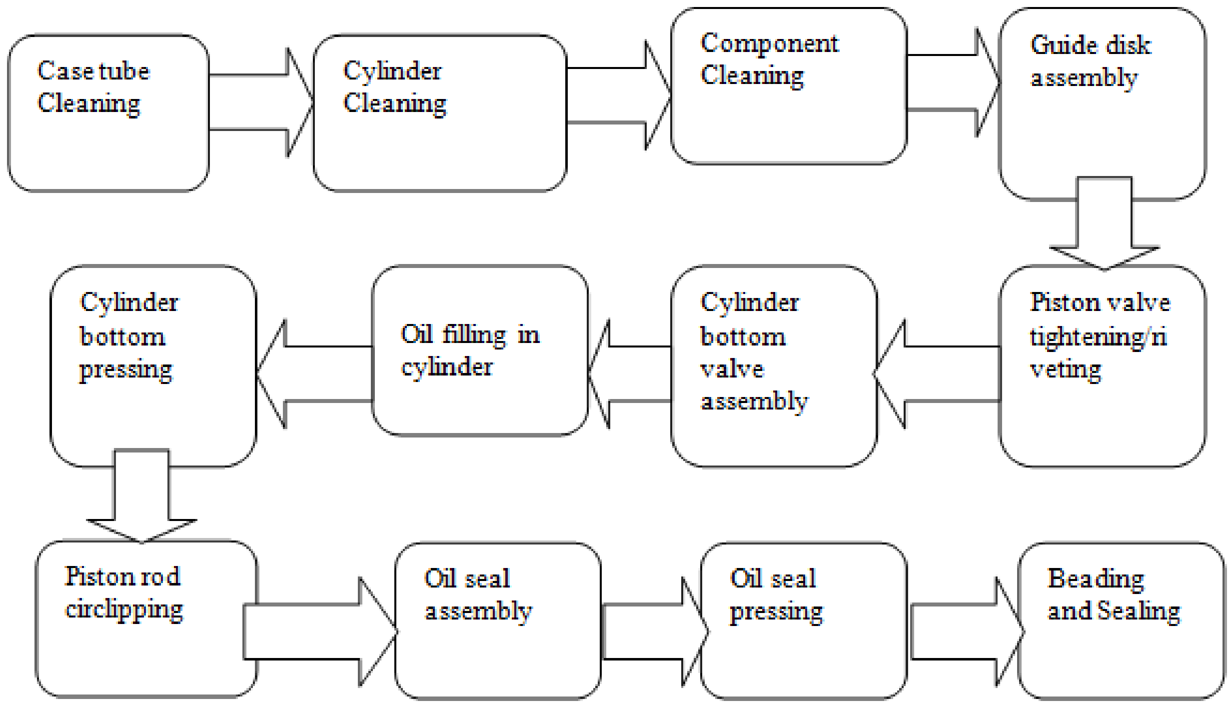

Figure 1 : Flow Diagram of Assembly Process of Shock Absorber

Figure 2 : Photographs of two and four wheeler shocker

b) Methods

The study was conducted at two shocker manufacturing plants. The companies provided a list of all jobs in the facility. The present study was conducted in traditional and semi- ergonomic assembly profile section. The workers were interviewed and examined at the work-site. The health questionnaire was designed andstatistical measurements were taken. Verbal consent of the workers was being taken and physical tests have been conducted. The health questionnaire included statistical description, investigation through physical examination, CTS symptom severity scale and on-job observation. Physical examination included height, weight, Body Mass Index (BMI), grip strength (dominant hand) and grip strength (non- dominant hand) measurement in assembly line as shown in Table 1. All physical examinations were being conducted through analog instruments. Readings were noted and tabulated. The descriptive statistics of the parameters with mean and standard deviation were computed and shown in the Table 1.

Hand grip strengths of dominant and non-dominant hands were taken so as to find out there relationships with potential CTS symptoms. CTS symptom severity scale is divided into four levels, namely 0, 1, 2 and 3. The level 0 for no, 1 for mild, 2 for moderate, and 3 is for severe CTS symptoms condition. No means zero pain, one means pain in APB muscle. Mild means pain in APB and FPB muscle, moderate means pain in fingers, thenar muscles and hands occasionally, severe means intolerable pain in fingers, thenar muscles, hands, elbow up to shoulder. CTS symptom severity scale has been applied upon potential CTS symptoms namely wrist pain, hand pain, numbness, tingling, difficulty in grasping and weakness to investigate the impact of CTS symptoms. Repetitiveness in the job has been categorized into two levels namely high and low based on cycle time. A ''high repetition'' job task was defined as one with a cycle time $\leq$15s and the job task classified as ''low repetition'' with a cycle time $\geq$15s and $\leq$3 0s. The physical examination included 4 items namely shoulders, hands, wrist and fingers. The work exposure evaluation was done in two ways; the workers own opinion in the questionnaire and an evaluation by the investigators including an ergonomic study. The whole examination took place in the supervisor's office, nearby the actual workstation. The results from these three sources were compared for each of the operations investigated. Workers at the same workstation did the same job, and there was job rotation every two hours. The standard values of weight of the job and magnitude of the force applied during operations by the workers was provided by the company.

Table 1 : Statistical ergonomic data of two shocker manufacturing assembly line workers

Factor of concern	Traditional Shocker Manufacturing workers (Mean ± S.D.)	Semi-ergonomic Shocker Manufacturing workers (Mean ± S.D.)
Number	70	70
Age (years)	39.29 ± 7.76	29.23 ±3.54
Weight (kg)	67.54 ± 7.91	64.33 ± 5.60
Height (Meter)	1.667 ± 0.072	1.664 ± 0.067
BMI (kg/m^2)	23.29± 0.65	23.18 ± 0.59
Grip strength (Dominant hand) (kg)	42.06 ± 16.57	50.67 ± 18.83
Grip strength (Non-Dominant hand) (kg)	39.27 ± 14.72	47.07 ± 18.07
Employment time at present site (years)	12.57 ± 7.40	4.57 ± 3.08

c) Statistical tools for CTS analysis

Following statistical tools have been used for CTS analysis.

i. Fisher's Exact Test

Fisher's exact test is used to check statistical significance of 2×2 contingency Tables [18]. In present study Fisher's exact test has been used to check all the symptoms of CTS in collected data of traditional and semi-ergonomic industries workers for comparison on the basis of response of workers for all the symptoms in yes or no. Notations a, b, c and d are assigned to cells for fisher's exact test and the grand total is assigned the notation n and are presented in Table 2.

Table 2 : A 2 × 2 contingency table set-up for Fisher's exact test

Description	Traditional shocker manufacturing worker	Semi-ergonomic shocker manufacturing worker	Total
Symptom Present (Test positive)	a	b	a + b
Symptom not Present (Test negative)	c	d	c + d
Total	a + c	b + d	n

The probability value p is computed by the hyper geometric distribution and expressed as

$$p = \frac{\binom{a+b}{a}!\binom{c+d}{c}!}{\binom{n}{a+c}!} = \frac{(a+b)!(c+d)!(a+c)!(b+d)!}{a!b!c!d!n!} \quad (1)$$

where the number of observations obtained for analysis is small (sample size ≤ 30) (Montgomery, 2005).

ii. 't' test

The t' test is used to determine the statistical significance of the difference between the means of two samples belonging to low and high repetitive work.Two independent samples of size n1 and n2 with means $\overline{X_1}$ and $\overline{X_2}$ and standard deviations S1 and S2 can be compared by testing the hypothesis that the samples come from the same normal population. To carry out the test, the statistic 't' can be calculated as follows:

$$t = \frac{\overline{X_1} - \overline{X_2}}{S_p} \times \sqrt{\frac{n_1 n_2}{n_1 + n_2}} \quad (2)$$

where

$\overline{X_1}$ = mean of the first sample,

$\overline{X_2}$ = mean of the second sample,

n_1 = number of observations in the first sample,

n_2 = number of observations in the second sample,

S_p = pooled or combined standard deviation,

Standard deviation 'S' for each sample can be calculated as

$$S = \sqrt{\frac{\sum(X - \overline{X})^2}{n - 1}} \quad (3)$$

where n is number of observations in each sample

From the number of observations and standard deviation of the two samples, the pooled estimate of standard deviation (S_p) can be obtained as follows:

$$S_p = \sqrt{\frac{(n_1 - 1){S_1}^2 + (n_2 - 1){S_2}^2}{n_1 + n_2 - 2}} \quad (4)$$

If the calculated value of t be greater than t0.05, the difference between the sample means is said to be significant at 5% level of significance otherwise data is consistent with the hypothesis (Gupta, 2001).Repetitiveness in the job has been categorized into two levels namely high and low based on cycle time.

III. Results and Discussions

a) Potential CTS symptoms based analysis by Fisher's exact test

The potential CTS symptoms like hand pain, wrist pain, numbness, tingling, difficulty in grasping, weakness, Tinel's sign, and Phenal's sign in traditional and semi-ergonomic shocker manufacturing workers with their percentage of presence are computed from the collected data and Eq. 1. The p-value so obtained is used to check the significance of the symptoms as shown in Table 3.

Table 3 : Test of difference between traditional and semi-ergonomic shocker manufacturing workers considering CTS related symptoms, and by applying Fisher's Exact Test

Symptoms	Traditional shocker manufacturing worker			Semi-ergonomic shocker manufacturing worker			p–value	Significance
	No. of workers	CTS symptoms Sufferer	% Percentage	No. of workers	CTS symptoms Sufferer	% percentage		
Hand pain	10	2	20	5	1	20	0.4945	Not Significant
Wrist pain	12	1	8.33	3	1	33.33	0.3428	Not Significant
Numbness	5	4	80	12	2	16.66	0.0266	Significant ($P < 0.05$)
Tingling	10	5	50	12	1	8.33	0.0405	Significant ($P < 0.05$)
Difficulty in grasping	5	4	80	10	2	20	0.0449	Significant ($P < 0.05$)
Weakness	7	1	14.2 8	3	1	33.33	0.4660	Not Significant
Tinel's sign	12	8	66.67	11	2	18.18	0.0237	Significant ($P < 0.05$)
Phenal's sign	9	5	55.55	14	2	14.28	0.0467	Significant ($P < 0.05$)

From the above Table 4 it is observed that due to wrist/hand problems 80 % of traditional and 20 % of Semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. The data analyzed from questionnaire also show that traditional shocker manufacturing workers have more percentage of CTS symptoms like numbness, tingling, Tinel's and Phalen's sign. Tinel's sign occurred in 66.67 % of the traditional and 18.18 % of the Semi-ergonomic shocker manufacturing workers ($p < 0.05$). Phalen's sign also show almost similar trend. Hand pain, wrist pain and feeling of weakness cannot correlate to CTS in the present study, as these are recognized as insignificant by Fisher's exact test. The results reflect that the traditional shocker manufacturing workers had more CTS symptoms occurrence than the Semi-ergonomic shocker manufacturing workers.

b) Physical profiles based comparison using 't' test

The collected data from questionnaire and physical tests is summarized based on age, height, weight, BMI, grip strength (dominant and non-dominant) in high and low repetitiveness work of traditional and Semi-ergonomic shocker manufacturing units as shown in Table 4 and Table 5 respectively. The descriptive statistics of the parameters with mean, standard deviation and range have also been mentioned in these Tables.

Table 4 : Ergonomic Statistical Analysis for High Repetitive Work

	Variable	Unit	Mean	Standard Deviation	Range
1.	Age	Years	44.87	7.22	56-34
2.	Height	Meter	1.646	0.073	1.78-1.6
3.	Weight	Kg	63.06	6.34	73-50
4.	BMI	kg/m2	23.21	0.77	21.40-24.10
5.	Grip strength (Dominant hand)	Kg	34.81	2.40	39-30
6.	Grip strength (Non-Dominant hand)	Kg	35.25	2.97	40-30
7.	Employment time at present site	Years	17.43	7.20	28-7

Table 5 : Ergonomic Statistical Analysis for Low Repetitive Work

	Variable	Unit	Mean	Standard Deviation	Range
1.	Age	Years	41.08	5.09	52-32
2.	Height	Meter	1.672	0.007	1.78-1.53
3.	Weight	Kg	65.14	8.02	75-50
4.	BMI	Kg/m^2	23.17	0.90	24-21.5
5.	Grip strength (Dominant hand)	Kg	38.85	1.79	41-35
6.	Grip strength (Non-Dominant hand)	Kg	38.07	1.77	41-36
7.	Employment time at present site	Years	15.35	6.47	29-3

In order to analyse the two sets (i.e. for high and low repetitive work) of data of physical profile given in Table 4 and Table 5, difference between means of each variable and corresponding 't' values are calculated and tabulated in Table 6.

Table 6 : Comparison between High and Low Repetitiveness Workers on Physical Variables

S. No.	Variable	Mean		Diff. Between means	't' ratio
		High Repetitive	Low Repetitive		
1.	Age	44.87	41.08	3.79	1.638
2.	Height	1.646	1.672	0.026	1.324
3.	Weight	63.06	65.14	2.08	0.792
4.	BMI	23.21	23.17	0.04	0.131
5.	Grip strength (Dominant hand)	34.81	38.85	4.04	5.162
6.	Grip strength (Non-Dominant hand)	35.25	38.07	2.82	3.099
7.	Employment time at present site	17.43	15.35	2.08	0.827

The Table 6 revealed that there were no significant differences in age, height, weight, BMI and employment time at present site of high and low repetitive work, as the obtained t-ratio values are 1.638, 1.324, 0.792, 0.131 and 0.827 respectively which are less than standard value 2.048 But there was significant difference in Grip strength (Dominant and non-dominant hand) of high repetitive work at the obtained t-ratio values are 5.162 and 3.099 respectively which are above the standard value 2.048 required for the t-ratio to be significant at 0.05 level of significance with 28 degree of freedom.

IV. Conclusion

From Fisher's exact test, it is observed that the traditional shocker manufacturing workers had more CTS symptoms occurrence than the Semi-ergonomic shocker manufacturing workers. The results elicit that due to wrist/hand problems 80 % of traditional and 20 % of Semi-ergonomic shocker manufacturing workers ($p < 0.05$), have been unable to perform the usual activities. Tinel's sign occurred in 66.67 % of the traditional and 18.18 % of the Semi-ergonomic shocker manufacturing workers ($p < 0.05$). Phalen's sign also show almost similar trend. Hand pain, wrist pain and feeling of weakness cannot correlate to CTS in the present study, as these are recognized as insignificant by Fisher's exact test. The 't' test result revealed that there were no significant differences in age, height, weight, BMI and employment time at present site of high and low repetitive work, as the obtained 't' ratio values are 1.638, 1.324, 0.792, 0.131 and 0.827 respectively which were

Global Journal of Researches in Engineering (G) Volume XV Issue III Version I Year 2015

less than standard value 2.048. But there was significant difference in grip strength (dominant and non-dominant hand) of high repetitive work at the computed 't' ratio values were 5.162 and 3.099 respectively which are above the standard value 2.048 required for the 't'-ratio to be significant at 0.05 level of significance with 28 degree of freedom. The study has good prospect in reducing the health hazards of CTS by keeping a continuous check on critical limits of risk factors. As a preventive measure for CTS well sound job rotation policy can be adopted and an employee wellness program can be implemented that include hand/wrist simple stretching exercises to be performed before the shift begins and/or during the first 5-20 minutes of each shift. However, research has not conclusively shown that these workplace changes prevent the occurrence of carpal tunnel syndrome.

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Mechanical Caracteristics of Fiber Palmyra

By Ngargueudedjim K., Allarabeye N., K. Charlet, J.-F. Destrebecq, R. Moutou Pitti & J.-L. Robert

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Abstract- We are interested in this work to the determination of the mechanical features of the fibre of a male Palmyra (Borassus aethiopum. Mart) aged around 40 years, taken in Houndouma, a village at the southern of Djaména in Chad. The paper presents results of an experimentation achieved on fiber's sapwood and heartwood's fiber. Sapwood and heartwood constitute the part useful of the log of the Palmyra as material of laths and frameworks in the traditional and semi-modern habitat construction in Chad.

Tests of traction achieved to the laboratory of institute French of the Advanced Mechanics permitted to determine the elastic modulus, rupture stress and rupture deformation of the fibers extracted from the heartwood and the sapwood.

The knowledge of the mechanical features of these fibers opens a perspective of the survey of their utilization as reinforcement in artificial composite materials.

Keywords: palmyra, mechanical characteristic, wood fiber, elastic modulus, rupture stress, cellulose, hemicellulose, lignin.

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Mechanical Caracteristics of Fiber Palmyra

Ngargueudedjim K. [α], Allarabeye N. [σ], K. Charlet [ρ], J.-F. Destrebecq [ω], R. Moutou Pitti [¥] & J.-L. Robert [§]

Abstract- We are interested in this work to the determination of the mechanical features of the fibre of a male Palmyra (Borassus aethiopum. Mart) aged around 40 years, taken in Houndouma, a village at the southern of Djaména in Chad. The paper presents results of an experimentation achieved on fiber's sapwood and heartwood's fiber. Sapwood and heartwood constitute the part useful of the log of the Palmyra as material of laths and frameworks in the traditional and semi-modern habitat construction in Chad.

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I. Introduction

Ligno fibers - Natural cellulose are biological structures composed of mainly cellulose microfibrile and an amorphous matrix consisting of lignin and hemicellulose, in relatively small proportion of non-extractable nitrogen, crude protein content, lipids and materials mineral [1] and [2]. The composition of the wood depends on the class of the tree (coniferous or deciduous), species, individuals of the same species and the diameter portion (heartwood, sapwood and heart) of the log of the individual.

Ligno fiber - celluloses wood are used extensively worldwide in the manufacture of paper pulp and dissolving pulp, in the manufacture of composite materials [3] and [4], in industries furniture [2].

The palmyra, wood in the class of palm trees, has a specific morphology. This is a very dense wood fibers (about 100 fibers per cm^2) and compact. Its fibers, brown in color, are very long, very large (area about 1 mm^2) and very rigid (Image.1). Its lignified structures are embedded in the main parenchyma which is also cellulose [5].

In Chad (Image.2), the palmyra is widely used as slats and beams in the construction of habitats, and as fence posts fields. The production of these building elements is hand-crafted without recovery of falls or its residues. Economically, this is a shortfall in earnings, and therefore an obstacle to sustainable development. The use of by-products has become a priority in applied research and key to sustainable development. The objective of this study is to popularize local materials on the one hand to participate in a recovering economy and secondly to gain autonomy by using local products that do not require large investments.

Determining the mechanical characteristics of tensile fibers allow to envisage its use as a reinforcement in the composite artificial. This is why the monotonous tensile tests are carried out on fibers extracted from the heartwood and sapwood of an individual palmyra aged around 40 years.

II. Material and Method

a) Material

The fibers tested are taken from the piece of tree 1.5m above the base. In this part, the heartwood which is very dense in old fibers is clearly distinguishable from the sapwood.

The average density is 124 fibers per cm^2 for the heartwood and 77 fibers per cm^2 for the sapwood (Image.1).

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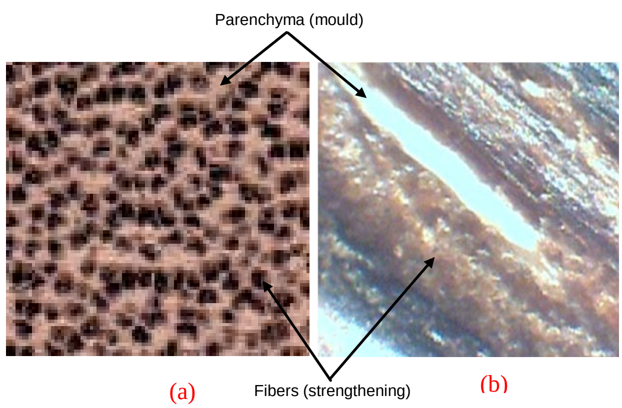

Image 1 : A photograph showing fibers and parenchyma:

(a): cross-sectional view, (b): longitudinal view of fibers [6].

This sample has an average chemical composition is as follows:

- Cellulose: 63.21% in the heartwood and 61.89% in sapwood;
- Hemicellulose: 09.60% in the heartwood and 11.32% in sapwood;
- Lignin: 19.36% in the heartwood and 19.68% in the sapwood.

Image 2 : Cartography of palmyra field in Houndouman

a) Experimental Procedure

The fibers are manually extracted from the heartwood and sapwood. After drying in the sun for 6 hours, the fibers are manually cleaned for reducing the presence of parenchyma that remained glued on them without. They were not subjected to chemical treatment.

The fiber dimensions were assessed caliper (0.01mm accuracy). Sections, calculated using the method of the circumscribed rectangle (Figure.1) are between 0.48 and 0.96 mm^2 for fibers of sapwood, and 0.46 and 1.03 mm^2 for the heartwood.

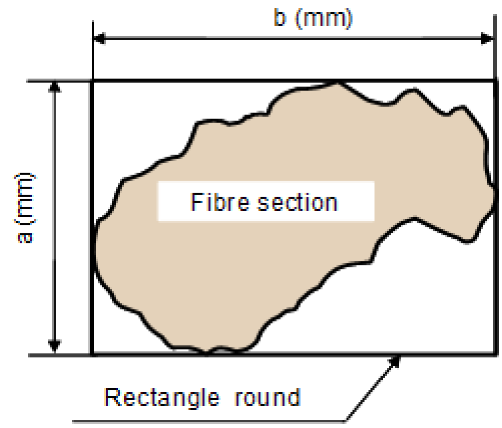

Figure 1 : Determination of the size of a fiber by the method of the circumscribed rectangle

For tensile tests, we used a UTS brand electric machine equipped with a 1.5kN capacity load cell and manual clamping jaws.

The fibers were clamped in the jaws and the test was started at 1 mm / min (as that typically found in the literature when testing plant fibers), up to rupture of the fiber. For each type of fiber, 8 specimens were tested, and those who had broken into the jaws were not taken into account in the calculation of averages.

The stresses are calculated using the formula $\sigma = F/S$, where F is the tensile force in Newton (N) and S the area of the cross section of the fiber in mm^2.

The deformations are calculated from the formula $A(\%) = 100(L - L_0)/L_0$, in which L_0 is the initial lengths and L the lengths after deformation.

The longitudinal elastic modulus of each fiber was obtained by using the linear regression method to the right of the stress - strain curve.

Then the average values of various characteristics were calculated.

III. Results and Discussions

The stress-strain curves are plotted for each of the eight sapwood fibers (Figure.2) and each of the eight heartwood fibers (Figure.3).

The Table.1 and 2 give the values of the calculated mechanical characteristics.

The table.3 presents the average values of the mechanical properties of sapwood and heartwood.

The average values of the mechanical characteristics of Table.3 show that:

- The modulus of elasticity of the fiber of the sapwood (17 GPa) is substantially the same as that of the fiber of the heartwood (16.8 GPa);
- The tensile strength of the fiber of the sapwood (184 MPa) is lower than the fiber heartwood (219 MPa);
- The break strains of the sapwood fiber and the heartwood fiber are substantially the same (a difference of 0.3%).

These differences between the mechanical characteristics are linked to the maturity of the fibers in the wood. Indeed, the fibers of the heartwood are very old, so mature enough to be more resistant than the fibers of the sapwood.

Compared with the fibers of the petiole of the palm doom, the palmyra fibers are very rigid and high-strength than the fibers of the palm petiole doom. However they have low strain at rupture. Note however that this comparison gave to the different aspects. Saw eye, the fiber of Palmyra is a macroscopic cluster of thin fiberboard.

Table 1 : Values of measurements and calculations for each fiber of the sapwood in traction

Sapwood								
N° Fiber	1	2	3	4	5	6	7	8
L_0 (mm)	30	30	31	31	32	30	30	30
S_0 (mm²)	0.80	0.58	0.80	0.74	0.96	0.59	0.48	0.58
E (GPa)	16.5	11.8	16.5	16.5	15.7	23.7	20.9	18.6
Rupture stress R_r (MPa)	163	109	118	299	284	157	75	154
Rupture Deformation (mm/mm)	1.2	0.8	0.9	1.8	2.2	0.9	0.4	1.0
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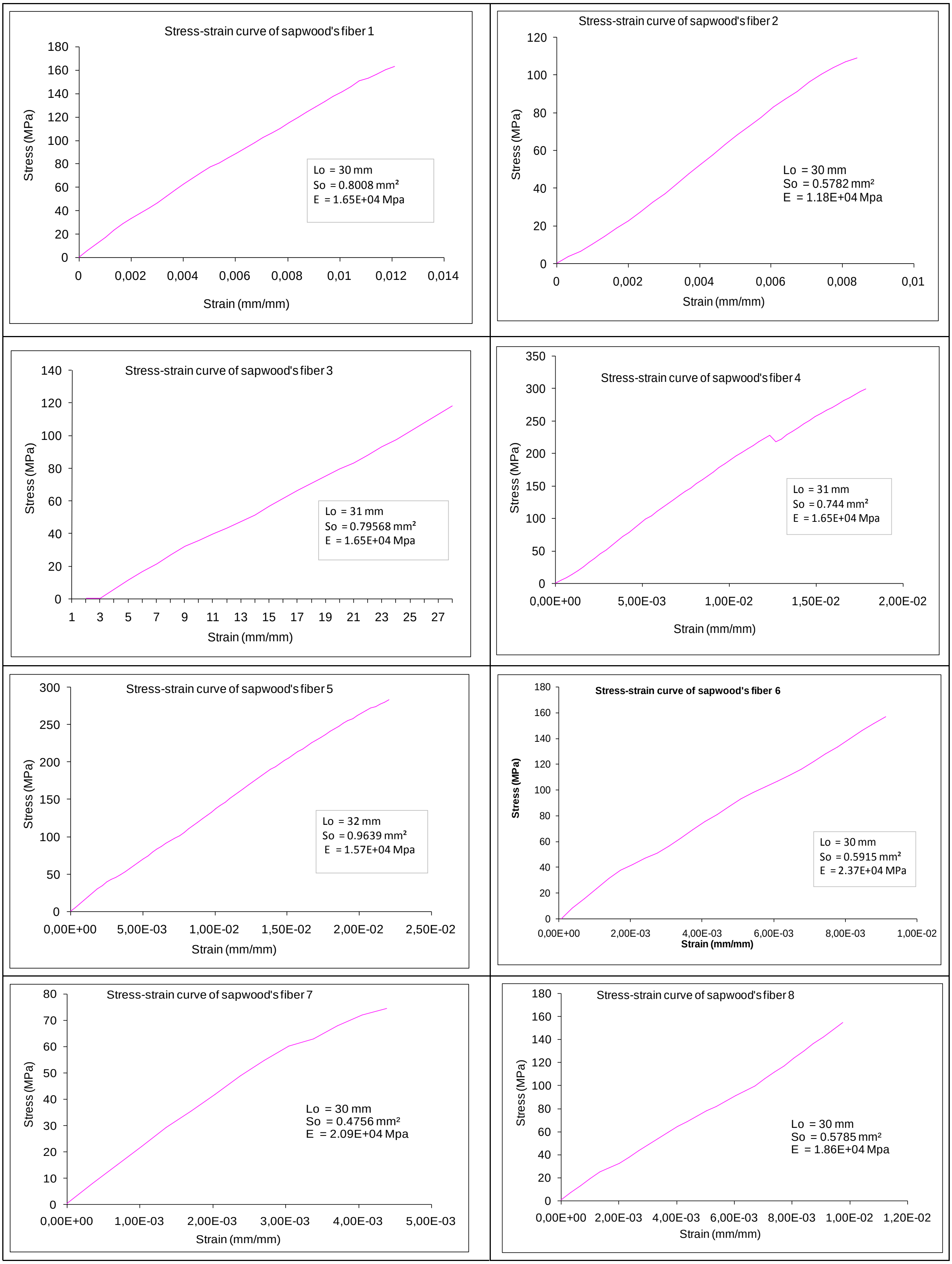

Figure 2 : stress-strain curves of each fiber of the sapwood in traction

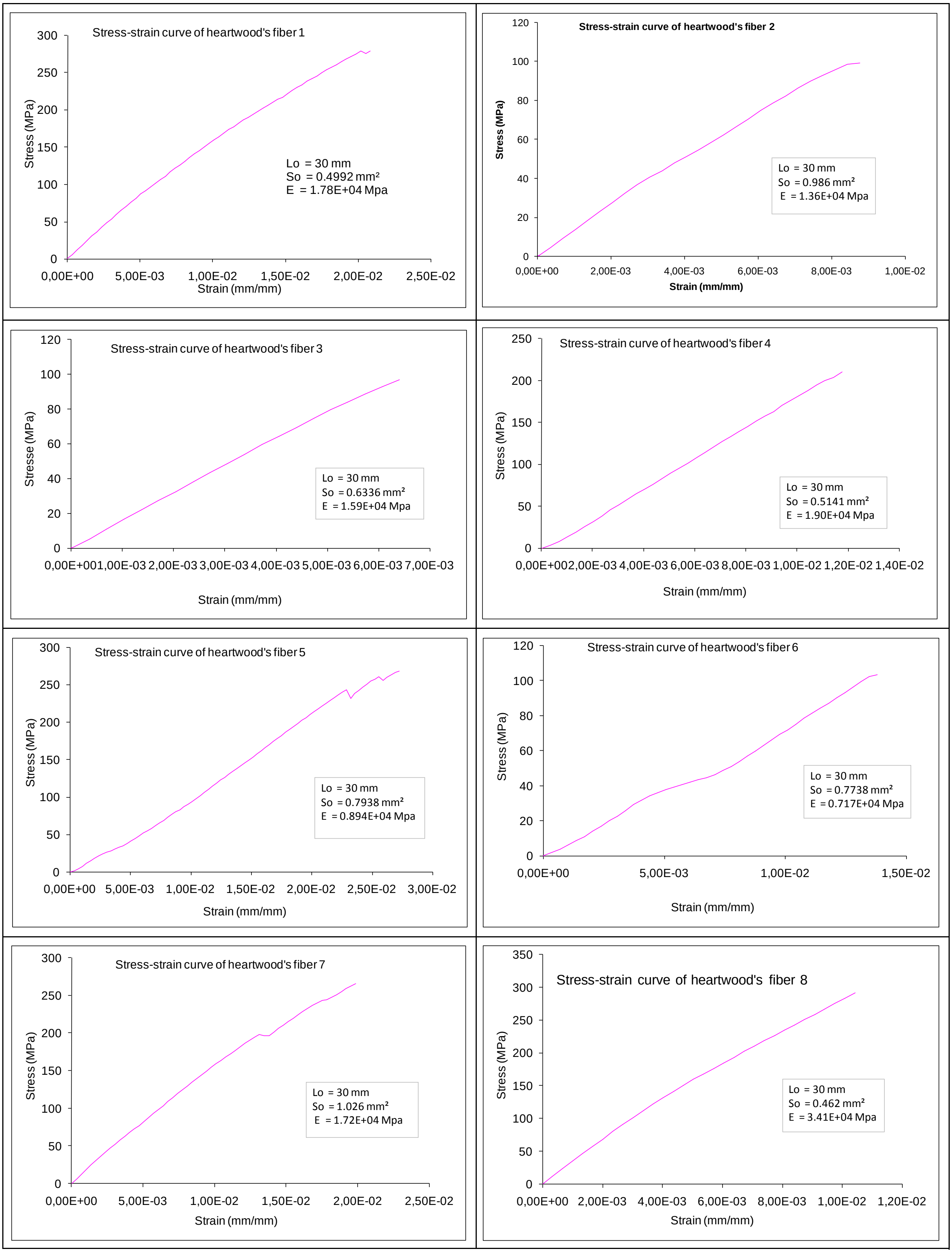

Figure 3 : stress-strain curves of each fiber of the heartwood in traction.

Table 2 : Values of measurements and calculations for each fiber of the heartwood in traction

Heartwood								
N° Fibre	1	2	3	4	5	6	7	8
L_0 (mm)	30	30	30	30	30	30	30	30
S_o (mm²)	0.50	0.99	0.63	0.51	0.79	0.77	1.03	0.46
E (GPa)	17.8	13.6	15.9	19.0	8.9	7.2	17.2	34.1
Rupture stress R_r (MPa)	279	99	97	210	268	104	284	291
Rupture deformation A (mm/mm)	2.1	0.9	0.6	1.2	2.7	1.4	2.1	1.0
RUPT. MORS								

Table.3: Mean values of calculated mechanical characteristics in traction.

Average value	Sapwood	Heartwood
Cross section So (mm²)	0.72 ± 0.15	0.72 ± 0.23
Young's modulus E (GPa)	17.0 ± 3.6	16.8 ± 8.8
Rupture stress R_r (MPa)	184 ± 77	219 ± 8.5
Rupture deformation (mm/mm)	1.3 ± 0.5	1.6 ± 0.7

Table.4: Mechanical characteristics of palm doom fibres [5].

Young's Modulus E (MPa)	Rupture strength R_r (MPa)	Rupture deformation A (%)
5760 ± 1,35	147,72 ± 34,25	3,19 ± 0,38

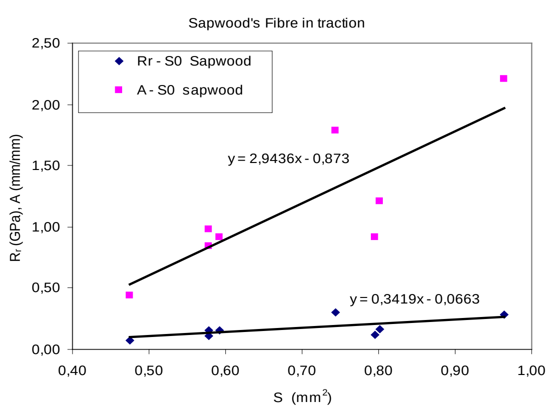

Figure 4 : Evolution curves of rupture strength and rupture deformation of sapwood and heartwood fibers of palmyra according to the cross section

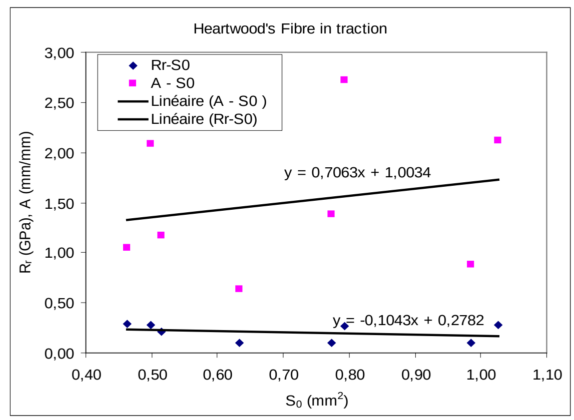

Figure 5 : Evolution curves of rupture strength and rupture deformation of fibers of heartwood palmyra versus the cross section

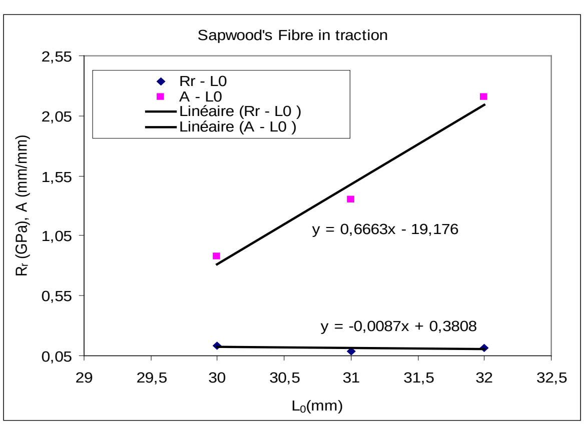

Figure 6 : Evolution curves of rupture strength and rupture deformation of sapwood fibers of palmyra versus the cross section

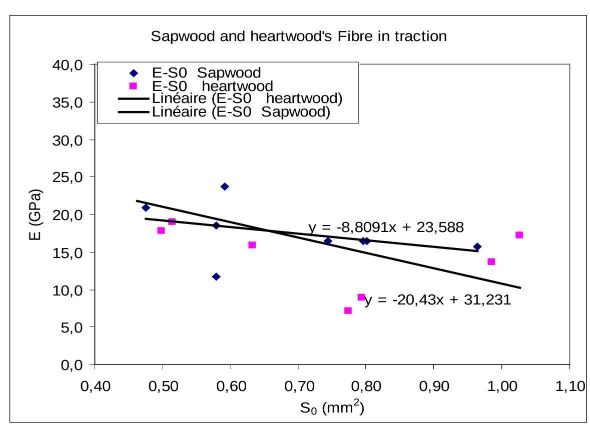

Figure 7 : Evolution curves of elastic modulus of heartwood and sapwood fibers of palmyra versus the cross section

Table.1, Table.2, Figure.4, Figure.5 and Figure.6 show that the percentage of the rupture elongation of the fibers sapwood and heartwood increases by their initial section and initial length. The effect of these two parameters on the tensile strength of a fiber is negligible.

Table.1, Tableau.2, Figure.7 and Figure.8 show that the modulus of longitudinal elasticity of the fibers decreases when their initial section and initial length increase.

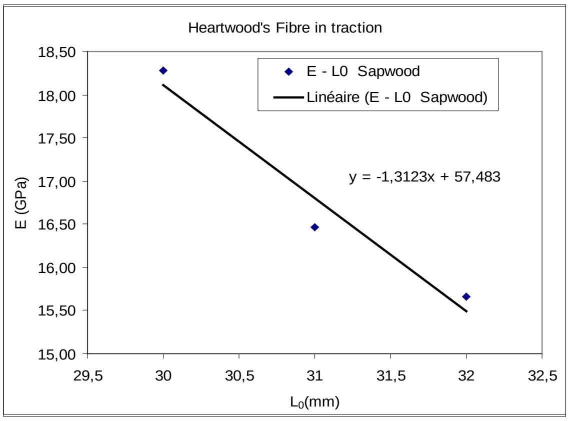

Figure 8 : Evolution curves of elastic modulus of sapwood fibers of palmyra versus the cross section

This behavior of the mechanical characteristics of the fibers is contrary to their intrinsic nature which is independent of their values in relation to the fiber dimensions. CHARLET and al. [7] LILLHOLT and al. [8] and Mott and al. [9] stated in their papers that vegetable fibers are characterized by a very high intraspecific and interspecific variability of their mechanical properties which depend on the species, the organ of origin fiber, the proportion cellulose-hemicellulose -lignin, the degree of polymerization and crystallization of the cellulose, the micro fibril angle (Figure.9) and the structural defects. Indeed, in native fibers, micro fibrils are arranged to describe with the fiber axis a micro fibril angle whose value varies from one plant species to another. The micro fibril angle partly determines the mechanical characteristics of elongation and stiffness of the fiber [8].

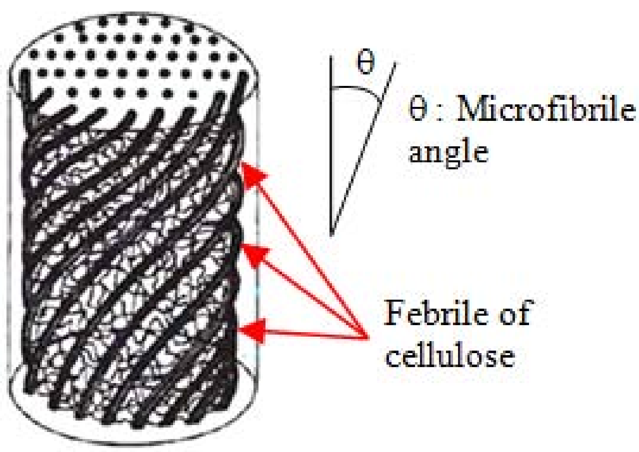

Figure 9 : Model description of the structure of a plant fiber [10]

The random evolution of these characteristics depending on the section and the length can be explained by variability along the fiber section.

In terms of the tensile strength, BOS et al. [11] also noted that its variation is related to the influence of structural defects in the fiber. NILSSON and GUSTAFSSON [12] explained the experimental results (modulus of elasticity) of BALEY [13] proposing a model that considers the dislocations and plastic behavior of hemicellulose as the main parameters governing the strength of the fiber. For them, the non-linearity of the Stress-strain curve (Figure.1 and Figure.2) is mainly dislocation movements.

IV. Conclusion

The study on the mechanical properties of the fiber palmyra shows that:

- The longitudinal elastic modulus (Young's modulus) and the failure strains of heartwood of fibers and fiber sapwood are of the same order of magnitude as those of sapwood;
- The tensile strength of the fiber heartwood is very higher than that of the fiber of sapwood;
- The values of its mechanical properties are strongly dependent on the cross-sectional area (diameter) of the fiber;

This modest contribution to the understanding of the mechanical properties of the fiber palmyra will undertake the study of its use as reinforcement in artificial composite materials.

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Environmental Impacts Management of a Brazilian Gas Station: A Case Study

By Thales Botelho De Sousa
University of São Paulo, Brazil

Abstract- The relative questions to the impacts of human activities in the environment are becoming increasingly present inworld population's life, by receiving great attention from various segments of society in recent years. All industrialsectors are pressured to achieveits activities in harmony with the environment. The gasstations, exercising potentially polluting activities, because ofstored and sold products, as well as effluents, emissions and generated residues, must conduct its activities according to standards and laws to ensure the minimization of risks to the environment, safety and health of employees and neighboring community. In this sense, the focus of this paper is to present, based on a case study, what the environmental management measures adopted at a gas station located in the São Paulo State, Brazilto control environmental impacts generated by its activities, as well as adapt to environmental regulations. It was chosen only a single case study because of the possibility of obtaining more detailed information of the subject and studied organization.

Keywords: superalloys, phase reactions, differential thermal analysis, latent heat of solidification.

GJRE-G Classification: FOR Code: 290502p

ENVIRONMENTALIMPACTSMANAGEMENTOFABRAZILIANGASSTATIONACASESTUDY

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Keywords: environmental impacts, environmental management, gas station, environmental legislation, case study.

I. Introduction

The concern with environmental conservation and sustainable development of human activities is a topic of great relevance. In recent times, it is possible to feel with great intensity the negative effects of human activities developed over the centuries without worrying about the quality of the environment.

In view of the various environmental disasters occurring today, it is great desire of society for sustainability, which requires of organizations (especially those that pollute or that have the potential to pollute the environment) a more harmonious coexistence and balanced environmental development of its activities. According to Cavalcanti (2010) the efforts carried out to promote the improvement of pollution levels, both associated with air, water, soil and other environmental compartments are essential, especially due to growing concern of combining economic development and sustainability.

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The gas stations represent a business activity branch which basically sell alcohol and fossil fuels. These fuels, although high in energy density, are known to cause high levels of air pollution and are blamed for contributing to climate change and global warming (SHUKLA, PEKNY and VENKATASUBRAMANIAN, 2011).These fuels also are important sources of contamination of the soil and the water, and have been the subject of numerous studies due to the complexity of the phenomena of interaction of these pollutants with the soil and the large number of contaminated areas (FREIRE, TRANNIN and SIMÕES, 2014). Additionally, the environment where gas stations are localized exposes gas station attendants to several risks and health hazards, which should be considered harmful to the health status of these workers (ROCHA et al., 2014). Among the risks are the contact with fuels and other chemical products, remaining close to fuel pumps, noise, etc. (ROCHA et al., 2014).

According to Freire, Trannin andSimões (2014) there are approximately 36 730 gas stations in Brazil.Gas stations in Brazil are commonly located in residential and commercial areas, which canlead to the degradation of health quality for people who live and work in the neighborhood (CORRÊA et al., 2012).Bearing in mind that all installation and oil and other fuels' storage systems are characterized as enterprises partially or potentially polluting and generators of environmental accidents, due to the large potential of pollution severe and environmental impacts that can generate, the environmental licensing of gas stations became mandatory in all Brazil after publication of CONAMA Resolution No. 273/2000. In the São Paulo State, became mandatory after the publication of SMA Resolution No. 05/2001.

Gas stations as emission sources of pollutants in the atmospheric air, contaminants in the soil and groundwater have been the subject of considerable study, a particular interest being those related to the design and evaluation of control systems in an attempt to diminish environmental impacts (TERRÉS et al., 2010). Based on statements highlighted, this paper has as purpose to present through a case study how the management of environmental impacts of a gas station localized in São Paulo Stateis carried out. For this the research seeked to answer the following questions:

1) What are the main environmental impacts generated by the gas station?

2) How does the compliance with current environmental legislation impact the effective management of environmental impacts generated by the gas station?

II. Methodological Procedures

According to its goals, this papercan be classified as an exploratory research. The exploratory research was chosen in order to provide greater familiarity with the problem, in order to make it more explicit or form hypotheses, and their schedule is quite flexible, so it allows the consideration of various aspects related to the fact studied (GIL, 2010).In most cases, these studies involve literature review, interviews with people who had practical experience with analyzed problem and researched examples that encourage understanding (GIL, 2010).

Regarding the technical procedures used to carry out this paper, it was designed by a case study and bibliographical researches. For Gil (2010), the case study is the detailed and exhaustive study of one or a few objects, in a way that allows its broad and thorough knowledge. Despite the limitations, the case study is the most appropriate method to know in depth the characteristics of a particular organizational phenomenon (YIN, 2010). Although Eisenhardt (1989) and Miguel (2007) recommend the use of multiple case studies for obtaining more concret results, Yin (2010) states to conduct single case studies it is justifiedif the case constitute a rare event or unique or serve as a revealing way. In this paper, a single case study was carried out because of the possibility of obtaining more detailed information on environmental impacts of a gas station.

For achieve this case study were done researches on the main aspects and environmental impacts of sector, prepared questionnaires that were sent to the person in charge and were made technical visits in the gas station. In the technical visits, it was possible to get a better structured description of facilities, environmental licenses and the development of the post activities. The gas station object of the case study, as a restriction for collaboration in the research, requested confidentiality regarding their identity, so in this paperwill be cited as Gas Station A.

The bibliographical researches on environmental impacts of gas stations were especially conducted on SCIELO, SCOPUS and Web of Science databases because of its broad access and impact in the international academic community, and papers published in journals indexed in them being considered as the research of the highest scientific level (CARNEVALLI and MIGUEL, 2008; NGAI et al., 2008). Some information from papers published in other databases and laws were obtained, because although they have less relevance for impact researches, certainly can have important issues (BORTOLLOSSI and SAMPAIO, 2012).

III. Literature Review

a) Environmental impacts caused by gas stations

Gas stations represent a business activity branch that works primarily with the retail sale of fossil fuels and bi-fuels (LORENZETT and ROSSATO, 2010).These endeavors store various types of fuel tanks that in most cases are underground, also possessing a set of lines and pumps that are part of the storage system and commercialization of products(CATUNDA et al., 2011).Because of the fuels that store and activities that develop these endeavors have great potential for degrading the environment where theyare localized.

The contamination of the soil and consequently of groundwater is one of the major environmental impacts caused by the activities of gas stations, since this is related to health problems, environmental damage and adverse social impacts. There are several sources of groundwater contamination. However, one of the most hazardous is contamination through leaks in underground storage tanks of fuel, the severity of which increases due to the characteristics of the fuels being rich in toxic substances of a mutagenic and carcinogenic character, and to the great likelihood of movement in the soil, and the fact that a leak is not always detected immediately (ROCHA, SOARES and MEDEIROS, 2011). Over time these tanks may leak due to corrosion, cracks, defective piping, and spills during refilling and maintenance activities. Petroleum and other fuels pollution from leaking underground storage tanks leaches into the surrounding soil and groundwater and can damage nearby water bodies and ecological systems (ZABEL and GUIGNET, 2012).

The increase in groundwater use has raised concerns related to the main sources of pollution, among which are included those caused by leaks in fuel storage tanks such as petrol, diesel and alcohol. Contamination of soil and groundwater by fuel storage facilities carry risks to human health directly and indirectly. In direct contact, it can highlight inhalation, ingestion, skin and eyes contact; in indirect contact, there is the ingestion of food and water contaminated with compounds present in fuels, which in most cases are carcinogenic(FREIRE, TRANNIN and SIMÕES, 2014).

Petroleum by-products are harmful to human health.By filling the tank, e.g., with petrol, there is an exchange of saturated vapor inside the tank of the vehicle by the corresponding liquid fuel coming from the underground tank. This underground tank also makes this exchange of saturated vapor by liquid fuel to be supplied by the tanker truck (CORRÊA et al., 2012). Vapors can travel upwards through the soil into nearby homes and buildings. These vapors, known as volatile organic compounds (VOCs) poses acute health risks caused by inhalation such as headaches, asthma, fatigue, throat, eye irritation nausea, mucosal symptoms and even risks of explosion (EMARA et al., 2010; PEREZ-RIAL et al., 2009; TERRÉS et al., 2010). Exposure to petroleum by-products such as gasoline and diesel oil over long periods of time increases the riskof several chronic diseases, including cancer, and can affect the kidneys, liver, and nervous system (CORRÊA et al., 2012; YANG et al., 2014; ZABEL and GUIGNET, 2012).

Gasoline is a petroleum-derived liquid mixture consisting primarily of hydrocarbons and enhanced with additives to increase octane ratings, and improve performance in internal combustionengines (KINAWY, EZZAT and AL-SUWAIGH, 2014). According to Haest et al. (2010) it is a light non-aqueous phase liquid that typically comprise C6-C8 mono-aromatics (benzene, toluene, ethylbenzene and xylenes, broadly known as BTEX) and other additional constituents such as methyl tertiary butyl ether (MTBE). Gasoline spills are among the most frequent causes of groundwater pollution. If released into the subsurface, it migrates through the vadose zone until it reaches the water table (HAEST et al., 2010). Furthermore, gasoline vapour emissions constitute one of the main sources of air pollutants in gas stations. There is a wide range of volatile aromatic hydrocarbons (VAHs) present in the atmosphere of gas stations as a result of emissions of vapours during dispensing, loading, unloading and transportation of gasoline (EDOKPOLO, YU and CONNELL, 2014).

Diesel oil leakages from underground storage tanks, distribution facilities and various industrial operations represent an important source of soil and aquifer contamination (MARIANO et al., 2007). Diesel oil contains 2000 to 4000 hydrocarbons, a complex mixture of normal, branched and cyclic alkanes, and aromatic compounds obtained from the middle-distillate fraction during petroleum separation (MARIANO et al., 2008).Some of the polycyclic aromatic hydrocarbons (PAHs) - compounds of diesel oil are among the least affected by weathering, and these semi-volatile compounds with a low solubility and recalcitrant characteristic may persist for a long time in the environment (MARIANO et al., 2008), being listed as priority pollutants by international environmental protection agencies due to their carcinogenic, mutagenic, and toxic effects (GARCIA et al., 2010).

Another fuel broadly stored and sold in gas stations currently is the ethanol. In Brazil, ethanol produced by sugar cane juice fermentation is the most used (TANO and BUZATO, 2003). Ethanol is expected to degrade rapidly and without any acclimation period under most redox conditions unless present at very high concentrations, such as might occur adjacent to fresh spills (POWERS et al., 2001; MACKAY et al., 2006). Ethanol nonetheless is expected to impact in situ biodegradation of other fuel components due to its rapid preferential degradation causing depletion of ready available electron acceptors and/or alterations in the fraction of the native microbial community able to degrade the various contaminants (MACKAY et al., 2006; MACKAY et al., 2007; POWERS et al., 2001; RUIZ-AGUILAR et al., 2002; SILVA and ALVAREZ, 2002).In case of the BTEX compounds (benzene, toluene, ethylbenzene and xylene isomers), it has been shown that ethanol can slow or stop their biodegradation in situ and in microcosms (MACKAY et al., 2006; MACKAY et al., 2007; SILVA and ALVAREZ, 2002).

Another relevant environmental impacts caused by the activities of gas stations are the effects caused by fires, which, when they occur, are very harmful to employees, customers, owners, and the neighborhood and may cause fatalities; and the impacts caused by their respective wastes from auxiliary services provided (ROCHA, SOARES and MEDEIROS, 2011).

According to Lorenzett et al. (2011) environmental management at gas stations can be understood as the measures carried out by the establishment that contribute to the protection, preservation and environmental recovery, measures ranging from deploying more secure facilities to the maintenance of green areas of environmental preservation, taking into account that in the absence of environmental management measures entities may incur in environmental impacts, affecting not only the environment but also all forms of life, especially humans. The activity of gas stations is becoming increasingly complex, since the cost of environmental accidents is high, and therefore, these endeavors must carry out their activities in accordance with the standards and environmental laws in order to ensure the minimization of risks to the environment, safety, employees and surrounding community health (CATUNDA et al., 2011). Given these dangers and severe environmental impacts, some pre cautions must be taken in the handling of petroleum products in order to prevent fire, diseases and risks to people, soil, air and water. In view of this, it is important to know environmental legislation applied to this sector.

b) *Environmental licensing of gas stations in São Paulo State, Brazil*

According to CONAMA Resolution No. 01/1986 environmental impact is defined as any change in physical, chemical and biological environment, caused by any form of matter or energy resulting from human activities that directly or indirectly affect health, safety and welfare's population, social and economical activities, the biota, the aesthetic and sanitary conditions of the environment and the quality of environmental resources.

CONAMA Resolution No. 237/1997 defines environmental licensing as an administrative procedure whereby the competent environmental agency licenses the location, installation, expansion and operation of projects and activities that are considered effectively or potentially pollutant and that use environmental resources, or those who, under any form, can cause environmental degradation, considering the laws and regulations and technical standards applicable to the case.

As a tool for pollution prevention, the licensing is essential to ensure the environmental quality of organizations, including public health, economic development and biodiversity conservation. Obtaining environmental licenses, coupled with the fulfillment of technical requirements, forms the basis for environmental compliance, adapting the organization to the competitive market. Environmental licensing is divided into three stages, the end of which are subsequently issued the preview, installation and operation licenses.

The environmental licensing of gas stations became mandatory in all Brazil after the publication of CONAMA Resolution No. 273/2000. According Lorenzett and Rossato (2010), this resolution aims to stabilize the enterprises that have fuel storage tanks and how management measures and environmental licensing of activities.

In the São Paulo State, the environmental licensing of gas stations fuel became mandatory after the publication of SMA Resolution No. 05/2001. According to this Resolution, the CETESB - Companhia de Tecnologia de SaneamentoAmbiental (now CompanhiaAmbiental do Estado de São Paulo) is responsible by the application of the provisions of CONAMA Resolution No. 273/2000, and the related monitoring and environmental licensing of pollution sources referred to.

According to CONAMA Resolution No. 273/2000, the competent environmental agency will demand the preview, installation and operation environmental licenses. The activities which are object of licensing understand fuels storage and supply, and other relatedprocesses such as car washing, oil change, vehicles lubrication and related administrative services. Should not be included in the licensing other activities usually associated with gas stations, such as convenience stores (unless they harbor activities related to the supply fuels), shops, restaurants, snack bars, parking, garage and other commercial activities (CETESB, n. d.).

IV. Case Study in the gas Station A

a) *Gas station A's operational history*

According to information obtained from the responsible person of the gas station' administration during the interviews, the endeavor began its activities in 1995, selling alcohol, gasoline and diesel oil, making the lubricating oils' change,and selling other products in an annex convenience store.

In 2001, the gas station Awas summoned by CETESB to obtain the necessary environmental licenses, in compliance with SMA Resolution No. 05/2001. It was summonedin the time by CETESB to license up adapting to the operation minimum conditions, because according to the classification of the environmental agency, it was classified into the category of enterprises subject to adjustment to the minimum operation conditions, because their tanks and underground pipes had less than 15 years.

In compliance with the necessary procedures for environmental licensing, it was conducted a technical assessment of environmental liabilities in the Gas Station A's area, to verify if it was contaminated by chemicals present in fuels derived from petroleum, which are parameters BTEX (benzene, toluene, styrene, ethylbenzene and xylenes); parameters PAH (polycyclic aromatic hydrocarbons), which include substances as anthracene, benzo (a) anthracene, benzo (k) fluoranthene, benzo (g, h, i) perylene, benzo (a) pyrene, chrysene, dibenzo (a, h) anthracene, phenanthrene, indeno (1,2,3-c, d) pyrene and naphthalene, and due to oil change's activities development, the parameters TPH (total petroleum hydrocarbons). The technical assessment report testified that the area was not contaminated by any of the compounds,because all parameters were below the limits set by the CETESB' Decision of the Board No. 014-2001-E, which in the time defined limits allowed for each compound in soil and groundwater. It was also carried out an inspection by the Fire Department in order to certify the conformity of the facilities on the risk of fires and explosions, being issued the AVCB (Auto de Vistoria do Corpo de Bombeirosor Fire Department's Inspection Certificate), which should be renewed every three years because its expiration date.

The gas station received the operation license in 2001, with an expiration date of 5 years because the value of it w (activity complexity factor) is equal to 1.5, according to the classification established by State Decree No. 8,468/1976. In compliance with the technical requirements and aiming to avoid the occurrence of environmental liabilities, the gas station made annually sealing of tanks, gas pumps and equipments, as well as its underground pipes. In 2006, the operation license' renewal was obtained.

In 2011, with the operation license validity end, and how it could not renew due to the fact that the tanks and pipes had completed 15 years, the gas station requested the environmental licensing in adaption to the category subject to complete renovation of their facilities, obtaining preview and installation licenses, and later, the operation license. To obtain these environmental licenses the following activitieswere carried out:

1) New technical assessment of environmental liabilities in the Gas Station A's area (to verify if all parameters were below the limits set by the CETESB Decision of the Board No. 195-2005-E), being analyzes of soil samples and groundwater conducted by laboratory duly accredited by INMETRO (InstitutoNacional de Metrologia, Qualidade e Tecnologia), in compliance with SMA Resolution No 37/2006.
2) Evaluation of environmental liabilities in the installation areas of old tanks, following the same technical evaluation requirements previously mentioned. The two technical assessments carried out confirmed that the gas station A's area was not contaminated.
3) Removal of old tanks, pumps and pipes, with its subsequent adequate disposal.
4) Acquisition of modernand reliable tanks, pipes, pumps and equipments, and that also meet the requirements of the CETESB and ABNT (AssociaçãoBrasileira de NormasTécnicas).
5) Sealing technical analysis of installed tanks, pumps and equipments.

b) Activities developed in gas station A currently

According to data from the questionnaires and the observations made during visits techniques, the following activities in the gas station A are developed:

1) Fuel storage: for the development of this activity the gas station has two underground tanks, located in their vicinity. These tanks have a capacity of 30 000 liters of fuel each, totaling 60000 liters of fuel stored. One of the tanks is two-compartmented and stores gasoline and ethanol, the another is tri-compartmented and store gasoline, ethanol and diesel oil.
2) Vehicles supply: this activity is carried out by attendants and occurs on the supply track through the use of five supply pumps.
3) Lubricating oil change: this activity is developed in a location away from the administration, which has a ramp built to provide greater security in the operation of the activity, and where the burned oil is stored in drums to be collected by a reprocessor company.
4) Convenience store: in this place are sold snacks, drinks and other food products.
5) Administration office: in this local are developed activities of administration and management of the activities of the gas station.

c) Main environmental impacts of the gas station A

The main environmental impacts generated by the development of the gas station A's activities can be viewed in Table 1.

Table 1 : Main environmental impacts of gas station A

Activities	Mainenvironmentalimpacts	Sourceofimpacts	Environmentimpacted
Fuelsreceipt	Emission of VOCs	Fuelsdischarge	Air
	Fuelsspill	Possible products spills in the discharge operation	Groundwater and surface water, soil and air
	Explosionsandfires	Ignitionsourceshandling	People, gas station facilities, residential and commercial establishments adjacent to the gas station
Fuelsstorage	Emission of VOCs	Underground tanks breather	Air
	Fuelsspill	Possible holes in tanks and pipes	Groundwater and surface water, soil and air
Vehiclessupply	Emission of VOCs	Fuelssupplyoperation	Air
	Fuelsspill	Possible products spills in vehicles supply operation, coming from the diesel oil filters, pumps and absorbent materials	Groundwater and surface water, soil and air
	Residues release	Improper disposal of absorbent materials	Groundwater and surface water, soil
	Explosionsandfires	Ignitionsourceshandling	People, gas station facilities, residential and commercial establishments adjacent to the gas station
Gas station equipment and facilities cleaning	Oilywaters	Inadequate operation and/or inefficient control of these impacts	Groundwater and surface water, soil
Lubricatingoilexchange	Productsspill	Possible products spills in oil change operation	Groundwater and surface water, soil and air
	Residues release	Improper disposal of product empty packages	Groundwater and surface water, soil
Conveniencestore	Residues release	Improper disposal of household garbage	Soil
Administration office	Residues release	Improper disposal of office garbage	Soil

d) Main measures to manage the environmental impacts of the gas station A

Through of the observations obtained duringvisits,from questionnaires answers, environmental licensesanalysis and technical analyzes results of environmental liabilities carried out, it was observed that the gas station A is managing adequately the main environmental impacts caused by the development of its activities. The total fulfillment of essential technical requirements defined by environmental agency to develop the fuel resale and other related activities strongly helps the gas station in successful reach of the environmental resources preservation. It was also observed that the impacts management began in the period of first operation license obtaining, increasing effectiveness in preview and installation licenses obtaining, in compliance with the technical requirements demanded for obtaining the operation license of the year 2011. The relation of the main actions taken to contain or mitigate the gas station A's environmental impacts today, can be seen in Table 2.

Table 2 : Actions taken to contain or mitigate the environmental impacts generated in gas station A

Activities	Mainenvironmentalimpacts	Actions to contain or mitigate the environmental impacts
Fuelsreceipt	Emission of VOCs	- Independent breather for each underground tank. The breather is positioned in such a way that it not causes discomfort and allow the vapors dispersion.
	Fuelsspill	- Installation of double-walled tanks, constructed according to NBR 13785 and equipped with interstitial monitoring linked to continuous monitoring system; - Installation of anti-overflow valves in the tanks discharge pipe; - Acquisition of flexible and non-metallic underground pipes, in compliance with NBR 14722; - Installation of discharge pipe with waterproof sidewalk chamber and sealed for spills containment; - Sealed discharge installation (adapter nozzle for sealed discharge); - Installation of watertight and waterproof access chambers to the tanks entrance; - Fuels discharge area constructed in reinforced concrete and provided with drainage directed to the effluent treatment system (oil and water separation box); - Performing of technical report about fuels storage and distribution systems watertight, issued by a company or a qualified professional, accompanied by appropriate ART (Technical Responsibility), carried out every operation license renewal.
	Explosionsandfires	- Compliance of establishment's operation and maintenance plan, which contains guidelines for verifying the integrity and maintenance of equipments and systems, operational procedures, response plan to the emergencies considering the occurrence reporting to the Fire Department and CETESB, personnel training program covering operational practices, maintenance program of equipment and systems and response to incidents and accidents.
Fuelsstorage	Emission of VOCs	Independent breather for each underground tank. The breather is positioned in such a way that it not causes discomfort and allow the vapors dispersion.
	Fuelsspill	- Installation of double-walled tanks, constructed according to NBR 13785 and equipped with interstitial monitoring linked to continuous monitoring system; - Installation of anti-overflow valves in the tanks discharge pipe; - Acquisition of flexible and non-metallic underground pipes, in compliance with NBR 14722.
Vehiclessupply	Emission of VOCs	-
	Fuelsspill	- Check valve installation in the diesel oil filtration system; - Check valves installation in the supply pumps; - Watertight and waterproof containment chamber installation in supply pumps, which contains liquids detection sensor connected to the monitoring system.
	Residues release	- Residues dispatch to landfills, correctly licensed.
	Explosionsandfires	- Compliance of establishment's operation and maintenance plan, which contains guidelines for verifying the integrity and maintenance of equipments and systems, operational procedures, response plan to the emergencies considering the occurrence reporting to the Fire Department and CETESB, personnel training program covering operational practices, maintenance program of equipment and systems and response to incidents and accidents.
Gas station equipment and facilities cleaning	Oilywaters	- Waters drainage system construction, internally positioned to 55 centimeters from the covering projection of the supply track; - Drainage system installation and sewage treatment system constituted of the sandbox and water-oil separator with coalescing plates, for effluents generated in the supply track; - Sending of sandbox toxic mud and water-oil separator for a treatment company correctly licensed.

Lubricatingoilexchange	Productsspill	- Installation of effluent treatment system constituted of the sandbox and water-oil separator with coalescing plates for the effluents produced in the oil exchange and area cleaning operations; - Oil change area built in waterproof floor; - Used oil storage in drums located in area with containment basin and cover; - Used oil dispatch for refinery company correctly licensed.
	Residues release	- Packages dispatch to specializing companies in contaminated packages cleaning, with its subsequent proper disposal.
Conveniencestore	Residues release	- Final disposal in municipal landfill.
Administration office	Residues release	- Final disposal in municipal landfill.

V. Conclusions

Nowadays, due to the intense problems related to environmental degradation, the world lives a period where the environmental issue is gaining momentum, environmental agencies are increasingly active and environmental legislation increasingly rigorous. Due to intense environmental impacts that the development of its activities can generate, the environmental legislation applied to gas stations are increasingly severe, requiring effective preventive and corrective actions with respect to the generation of environmental accidents.

Environmental licensing shows up as an important instrument for the environment preservation by the gas stations, because the fulfillment of their demands provides an efficient control of various environmental impacts generated by the activities developed by the sector.

The fuels resale activities are becoming increasingly complex, given that the environmental accidents and incidents costs, as well as costs for its remediation are high, requiring thatgas stations to carry out their activities in accordance with the existing environmental laws and regulations as well as compliance with good work practices, in order to ensure the minimization of risks to the environment, safety and health of employees and neighboring community.

This study aimed to analyze through a case study, what the environmental management measures adopted in a Brazilian gas station, which aim to meet the principles of sustainable development, and at the same time, the guidelines of environmental legislation applied to the sector.

During this study it was observed that the activities developed by the gas station A are fuel storage, vehicles supply, lube oil change, convenience store and administration office. Such activities maintain direct and intense relationships with the environment, through of contact with soil, groundwater and air, which can cause direct and indirect impacts on them, on the facilities of the station, adjacent facilities and human health.

During the study achievement, analyzing the environmental licenses of gas station it was possible to observe that the legislation has a focus on possible accidents involving fires and leaks into the soil and groundwater, but it is necessary to give more attentionto emissions into the atmosphere, which was also stated by Corrêa et al. (2012).

This paper presented how the environmental management in a gas station which is not contaminated for fuels derived from oil is carried out. Future papers must be conducted in gas stations contaminated to check the main measures adopted for decontaminate the soil and/or groundwater and to prevent health human of gas station workers and neighborhood.

With the development of the paper it could be concluded that compliance with the technical requirements required by environmental legislation and the environmental agency as requisite for carried out the fuels resale and other related activities, allows to the gas station A an effective management of environmental impacts of their activities, avoiding the generation of environmental liabilities, which, besides requiring high costs for remediation, can bring severe negative effects to the environment.

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Simulation Et Régulation Par Logique Floue D'une Colonne d'Absorption Industrielle

By M. Selatnia, I. Zidane, H. Zebiri, R. Illoul & Et M.S. Boucherit

Résumé- Ce travail consiste en la modélisation, la simulation dynamique et enfin la régulation d'une colonne d'absorption industrielle destinée à extraire le CO2, du gaz naturel en utilisant une solution aqueuse de methydiéthanolamine (MDEA). Nous présentons d'abord le modèle mathématique estimant la concentration du CO2 et comparons la réponse du modèle aveccelle du système en réponse à une variation échelon sur l'entrée. Nous simulons la colonne d'absorption industrielle en boucle ouverte, puis nous étudions sa réponse à un échelon de perturbation en boucle fermée avec une régulation classique PID.

Enfin, nous appliquons à notre colonne deux types de commande floues avec respectivement des fonctions d'appartenance triangulaires et gaussiennes. Les résultats obtenus pour les différentes simulations sont satisfaisants.

Motsclés: colonne d'absorption; modélisation; methydiéthanolamine (MDEA); régulation pid; logique floue; commande floue.

GJRE-G Classification: FOR Code: 290502

Simulation Et Régulation Par Logique Floue D'une Colonne d'Absorption Industrielle

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Résumé- Ce travail consiste en la modélisation, la simulation dynamique et enfin la régulation d'une colonne d'absorption industrielle destinée à extraire le CO2, du gaz naturel en utilisant une solution aqueuse de methydiéthanolamine (MDEA). Nous présentons d'abord le modèle mathématique estimant la concentration du CO2 et comparons la réponse du modèle aveccelle du système en réponse à une variation échelon sur l'entrée. Nous simulons la colonne d'absorption industrielle en boucle ouverte, puis nous étudions sa réponse à un échelon de perturbation en boucle fermée avec une régulation classique PID.

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Motsclés : colonne d'absorption ; modélisation ; methydiéthanolamine (MDEA) ; régulation pid ; logique floue ; commande floue.

I. Introduction

La colonne d'absorption est une unité de separation physico-chimique largement utilisée en chimie et en biologie. Il s'agit en général d'un tube dans lequel on passe un ou plusieurs mélanges gazeux et qui permet de séparer un ou plusieurs composés du mélange principal. Elle est largement utilisée pour la séparation des gaz acides (CO_2, H_2S) du gaz naturel.

Le modèle de la colonne d'absorption industrielle présenté dans ce papier est un modèle dynamique qui consiste en un ensemble d'équations non linéaires aux dérivées partielles obtenu à partir de considérations sur les bilans de matière du CO_2 et du MDEA dans les phases gazeuse et liquide [1,2], il prend en compte le gradient thermique le long de la colonne d'absorption. Le bilan énergétique de la colonne industrielle est également posé.

Quelques études ont été publiées sur la modélisation et la commande de la colonne d'absorption. Crosby and Durbin [3] étudient les performances d'un régulateur d'état. Roffel [4] développe un régulateur sous optimal avec contraintes d'état. Darwish and Fantin [5] utilisent la commande décentralisée avec placement de pôles. Petrovsky [6] développe un régulateur PI multivariable. Najim [7,8] développe un régulateur auto-ajustable dans le cas de l'absorption du CO_2 par une solution de diéthanolamine. Il reprendra le problem par la suite avec une commande prédictive [9].

Peu d'études ont par contre été publiées concernant la modélisation et la simulation de l'absorption du CO_2 par une solution aqueuses de MDEA ou de MEA en milieu industriel [10-12]. Pour le modèle développé dans notre étude, il nous a semblé intéressant de considérer la logique floue pour la commande de la colonne car elle permet d'obtenir de bonnes performances pour des processus à dynamique complexe. Nous développerons en première étape une régulation PID pour comparer les performances des techniques de regulation classiques avec celles de la commande par logique floue.

II. Modelisation et Simulation en Boucle Ouverte de la Colonne Industrielle

La colonne d'absorption présentée ici se situe à Khrechba et fait partie du projet In Salah Gaz, elle permet de prélever du CO_2 du gaz naturel en utilisant une solution aqueuse de methydiéthanolamine (MDEA) comme liquide de lavage. Elle est du type colonne à garnissage mesurant 8 mètre de hauteur et 4 m de diamètre. Le garnissage disposé en vrac est du type anneaux de Pall et est destiné à améliorer la surface de contact entre phases. Pour une meilleure élimination du CO_2 du mélange gazeux, le liquide de lavage (eau+ MDEA) circule à contre courant du flux de gaz. La pression et la température de travail sont respectivement de 71.5 bar et 55°C [2].

Lors du contact entre phase liquide et gazeuse sur la surface des anneaux de Pall, le CO_2 passe de la phase gazeuse vers la phase liquide. Cette diffusion est accélérée par reaction chimique du CO_2 avec la MDEA dans la phase liquide. Le débit de MDEA et la concentration du CO_2 en sortie dans le gaz naturel sont respectivement sélectionnés comme variables de commande et de sortie.

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Figure 1 : La colonne d'absorption de In Salah Gas (ISG)

a) Equations du modèle

Dans le but de simplifier le modèle, nous avons adopté les hypothèses suivantes [2,13]:

- Il n'y a pas de résistance en phase gazeuse
- La réaction entre le CO_2 et le MDEA est rapide (Ha>5)
- La dispersion axiale est négligeable dans la phase gazeuse et dans la phase liquid
- La MDEA ne passe pas en phase gazeuse Le bilan de matière sur une tranche élémentaire dz de la colonne pour le CO_2 dans la phase gazeuse s'écrit [2,13,14]:

Quantité de soluté à l'entrée z = quantité de soluté à la sortie (z+dz) + quantité de soluté transféré de la phase liquide à la phase gazeuse + accumulation. Ce qui donne :

$$(GC_{Ag})_z = (GC_{Ag})_{z+dz} + \varphi S\,dz + S\frac{dC_{Ag}}{dt}dz \qquad (1)$$

où G (m^3/s) est le débit volumique du gaz, φ le flux de CO_2 transféré de la phase gazeuse vers la phase liquide, S la section de la colonne et C_{Ag}(mol/m^3) la concentration du CO_2 dans le gaz. Soit U_G=G/S (m/s) la vitesse moyenne d'écoulement du gaz, on obtient alors :

$$U_g\frac{dC_{Ag}}{dz} + \varphi = -\frac{dC_{Ag}}{dt} \qquad (2)$$

La réaction chimique entre le CO_2 et le MDEA est [10-12]:

$$CO_2 + R_1R_2NCH_3 + H_2O \rightarrow R_1R_2NCH_4^{+} + HCO_3^{-} \qquad (3)$$

La vitesse de réaction r_A a la forme suivante [14,15]:

$$r_A = k\,C_{AL}\,C_{BL} \qquad (4)$$

Où k est la constante de la vitesse de réaction [14,15]:

$$k = 2{,}9610^5\exp\left(-\frac{5332.8}{T}\right) \qquad (5)$$

C_{AL} est la concentration du CO_2 dans la phase liquide et C_{BL} la concentration du MEA dans la phase liquide. Le bilan de matière pour le CO_2 dans la phase liquide donne finalement:

$$\varphi = [kC_{AL}C_{BL}] \qquad (6)$$

Ce qui signifie que la totalité du CO_2 transféré dans la phase liquide réagit avec le MDEA.

Le bilan de matière pour le MDEA dans la phase liquid donne :

$$(LC_{Bl})_z = (LC_{Bl})_{z+dz} - [k\,C_{Al}\,C_{Bl}]\,S\,dz - S\frac{dC_{Bl}}{dt}dz \qquad (7)$$

où L est le débit volumique du liquide. En tenant compte de (5) et en notant par *UL* = L/S (m/s) la vitesse moyenne d'écoulement du flux liquide on obtient :

$$U_l\frac{dC_{Bl}}{dz} - \varphi = \frac{dC_{Bl}}{dt} \qquad (8)$$

Notre colonne d'absorption est finalement décrite par le système d'équations aux dérivées partielles suivantes:

$$\begin{cases} U_g\dfrac{\partial C_{Ag}}{\partial z} + \varphi = -\dfrac{\partial C_{Ag}}{\partial t} \\ U_L\dfrac{\partial C_{BL}}{\partial z} - \varphi = \dfrac{\partial C_{BL}}{\partial t} \end{cases} \qquad (9)$$

La procédure pour calculer le flux φ est donnée en [2] d'après [14-16].

En dernier lieu, nous considérons les conditions aux limites qui sont pour la phase gazeuse la concentration du CO_2 en bas de la colonne C_{Age} et pour la phase liquide la concentration du MDEA en haut de la colonne C_{BLe}.

$$\begin{cases} C_{Ag}\big|_{z=0} = C_{Age} \\ C_{BL}\big|_{z=h} = C_{BLe} \end{cases} \qquad (10)$$

La réaction au sein de la colonne industrielle induit un fort dégagement de chaleur et l'apparition d'un gradient de température tout au long de la colonne ; la variation de température est d'environ 5°C entre l'entrée et la sortie de la colonne, ce qui nous amène à établir un bilan énergétique permettant de décrire l'évolution de la température et son effet sur les différentes concentrations le long de la colonne [16] :

$$\begin{cases} U_g\dfrac{\partial T_g}{\partial z} + \dfrac{a.h_{g|l}(T_l - T_g)}{\left[\sum_i cp^g{}_i C^g{}_i\right]} = \dfrac{\partial T_g}{\partial t} \\ -U_L\dfrac{\partial T_l}{\partial z} + \dfrac{1}{\sum_i cp^l{}_i C^l{}_i}\left[\Delta H_r r_A - a.h_{g|l}(T_l - T_g)\right] = \dfrac{\partial T_l}{\partial t} \end{cases} \qquad (11)$$

Avec :

C_i^g : la concentration en phase gazeuse à l'interface (mol/m^3)

C_i^l : la concentration en phase liquide à l'interface (mol/m^3)

cp_i^g : Chaleur spécifique dans la phase gazeuse à l'interface (J/mol.K)

$h_{g/l}$: coefficient de transfert de chaleur (convection) ($J/m^2.K.s$)

T_l : température du liquide (K)

T_g : températu re du gaz (K)

ΔH_r : l'enthalpie de la réaction (J/mol)

cp_i^l : la chaleur spécifique dans la phase liquide à l'interface (J/mol.K)

On prend finalement en compte les conditions aux limites pour la température qui sont les températures respectives du gaz et du liquide en entrée de la colonne.

$$\begin{cases} T_g \Big|_{z=0} = T_{ge} \ , \ \dfrac{\partial T_l}{\partial z}\Big|_{z=0} = 0 \\ T_l \Big|_{z=h} = T_{le} \ , \ \dfrac{\partial T_g}{\partial z}\Big|_{z=h} = 0 \end{cases} \qquad (12)$$

b) Validation Du Modèle

Un test a pu être effectué sur notre colonne d'absorption industrielle pour comparer la concentration du CO_2 en sortie donnée par le modèle avec celle du système et ce pour une variation de l'entrée du type échelon de 10 t/h. Les données ont pu être recueillies sur un horizon de temps de 6800 secondes. Les résultats sont groupés dans la figure 2 où on représente respectivement, les débits de MDEA, de gaz et les concentrations du CO_2 en sortie de la colonne et celles données par le modèle [2].

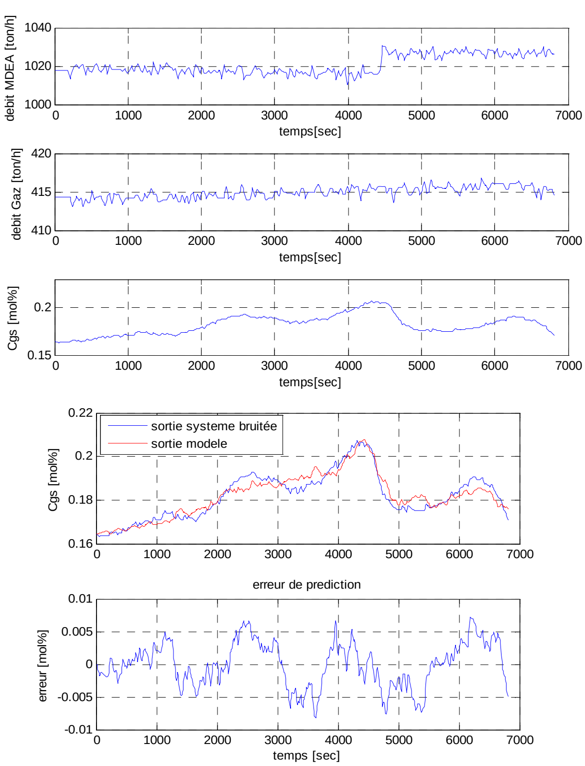

Figure 2 : Concentration du CO_2 en sortie du système et du modèle

On note que la dynamique des concentrations de CO_2 en sortie de la colonne obtenue théoriquement agrée avec les résultats expérimentaux.

c) *Simulation en boucle ouverte de la colonne industrielle*

En considérant les équations (2) et (8), le modèle dynamique de la colonne d'absorption est un système aux paramètres répartis non linéaires. Les résultants de la simulation en boucle ouverte sont présentés en figures 3 et 4.

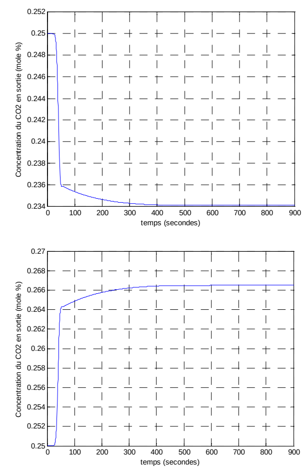

Figure 3 : Concentration du CO_2 en sortie de la colonne pour un échelon de perturbation de +/- 5% sur la concentration en entrée du gaz

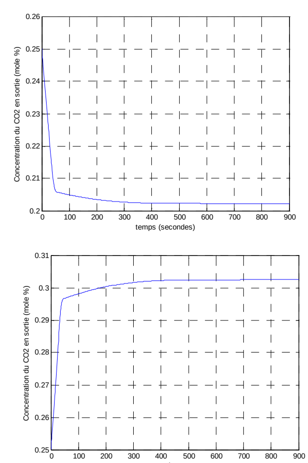

Figure 4 : Concentration du CO_2 en sortie de la colonne pour un échelon de perturbation de +/- 10% sur le débit du gaz

La simulation montre que le système est stable. Il présente un temps mort en réponse à un échelon de perturbation sur la concentration en entrée du CO_2 dû à la propagation du gaz le long de la colonne d'absorption.

III. Regulation PID de la Colonne d'absorption Industrielle

Nous appliquons une régulation PID au modèle dynamique de notre colonne d'absorption. Une commande échantillonnée est choisie pour faciliter la simulation avec une période de 10 secondes. La référence pour la concentration de CO_2 en sortie est choisie égale à 0.25mole %, ce qui correspond à une concentration de 7.05 mole CO_2/m^3 Les paramètres du régulateur PID ont été optimisés par essai/erreur.

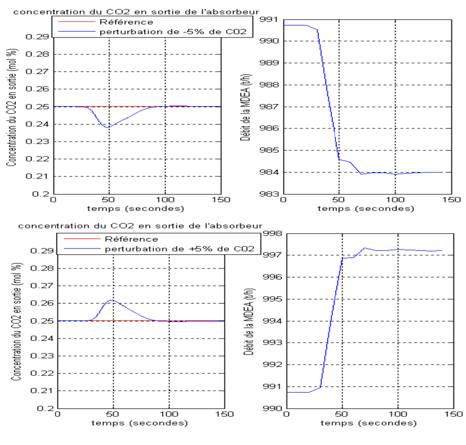

Figure 5 : Concentration du CO_2 en sortie et débit du liquide de lavage pour un échelon de perturbation de ± 5 % sur la concentration de gaz

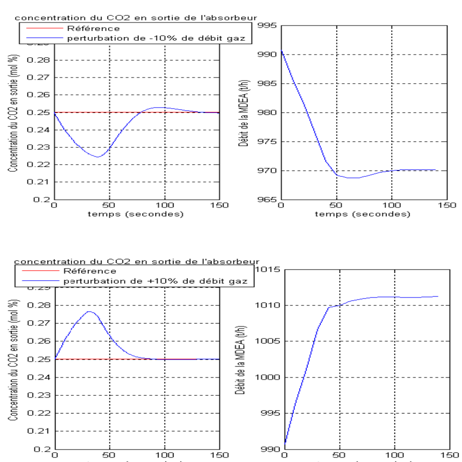

Figure 6 : Concentration du CO2 en sortie et débit du liquide de lavage pour un échelon de perturbation de ±10 % sur le débit du gaz

Les résultats obtenus en simulation sont satisfaisants, le régulateur PID annule l'erreur en régime permanent et assure une réponse rapide grâce à l'action dérivée. Le système présente en régulation un certain comportement asymétrique dû a la forte non linéarité de la sortie par rapport à la commande choisie qui est le débit du liquide de lavage.

IV. Commande par Logique Floue de la Colonne d'absorption Industrielle

Le concept de logique floue a été introduit par Zadeh [17] en 1965.Ce concept s'est avéré très utile pour des procédés non linéaires difficiles à modéliser et diverses applications ont été développées pour des processus industriels dans le domaine de la supervision ou de la commande du procédé [18].

a) Structure de la commande de la colonne d'absorption

Un système flou est un système de prise de décisions à base de connaissance particulières composé de quatre modules principaux, à savoir : la base de règles, la fuzzification, le moteur d'inférence et la défuzzification. Le régulateur flou [19,20] n'est qu'un cas particulier de système flou destiné à calculer la commande

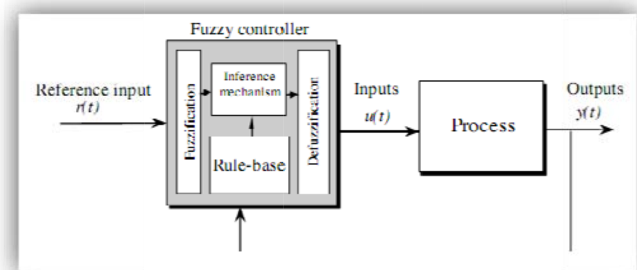

Figure 7 : Structure d'un contrôleur flou

On distingue deux types de systèmes flous :

- Le modèle de Mandani où les conclusions sont des règles floues
- Le modèle de Takagi-Sugeno-Kang (TSK) où les conclusions sont directement numériques.

Le contrôleur flou choisi ici possède deux entrées *e* $\Delta e = e(k)-e(k-1)$ et la sortie est Δu, il est ainsi est du type PI. Pour simplifier la synthèse, nous avons choisi le modèle TSK où les conclusions sont directement numériques [21].

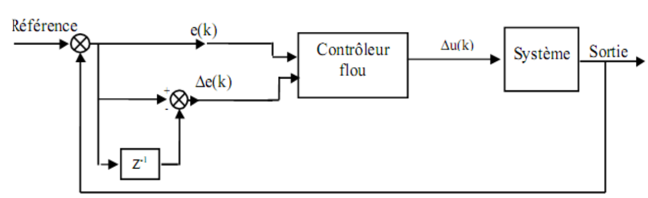

Figure 8 : Structure de la boucle de régulation floue

Pour notre problème, nous avons choisi pour les deux entrées d'abord des fonctions d'appartenances triangulaires, puis des fonctions gaussiennes et ce afin de faire une comparaison entre ces deux approches [2]. On a choisi dans les deux cas 5 fonctions d'appartenance en entrée couvrant tout l'univers du discours : PG (Positif Grand), PP (Positif Petit), Z (Zéro), NP (Négatif Petit), NG (Négatif Grand)

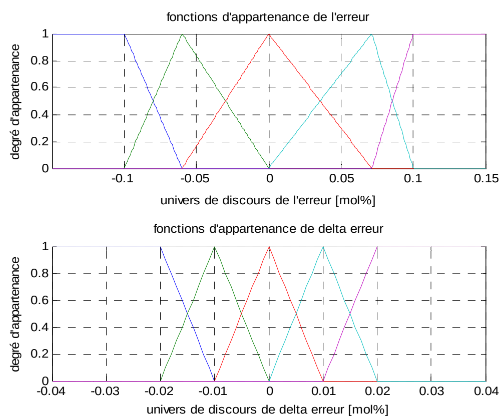

Figure 9 : Fonctions d'appartenance triangulaires

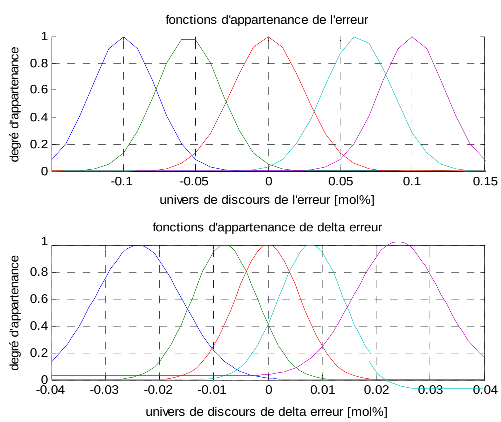

Figure 10 : Fonctions d'appartenance gaussiennes

La table des règles a été synthétisée en collaboration avec les opérateurs de l'installation afin de profiter de leur expérience, il y a eu un ajustement pour aboutir aux performances désirées. En termes d'agrégation des règles cette table a une forme antisymétrique [22,23].

TABLEAU 1 : TABLE DES REGLES

Δu [ton/h]		e(k)				
		NG	NP	Z	PP	PG
$\Delta e(k)$	NG	+25	+20	+3	-5	-16
	NP	+22	+18	+2	-8	-18
	Z	+20	+12	0	-12	-20
	PP	+18	+8	-2	-18	-22
	PG	+16	+5	-3	-20	-25

Les resultants pour les deux types de fonction d'appartenance sont présentés ci-dessous.

b) *Résultats de simulations pour des fonctions d'appartenance triangulaires*

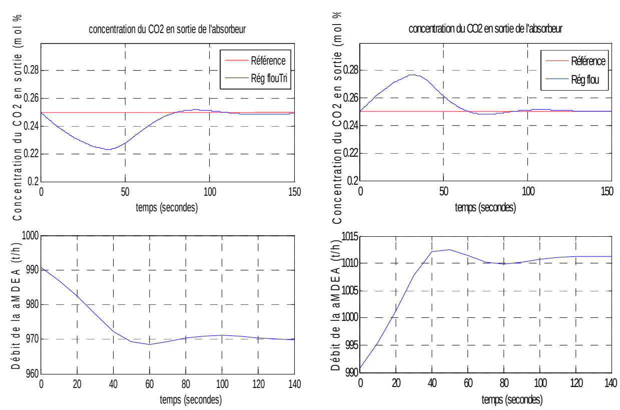

Figure 11 : Concentration du CO_2 en sortie et débit du liquide pour un échelon de perturbation de +/-10% sur le débit du Gaz

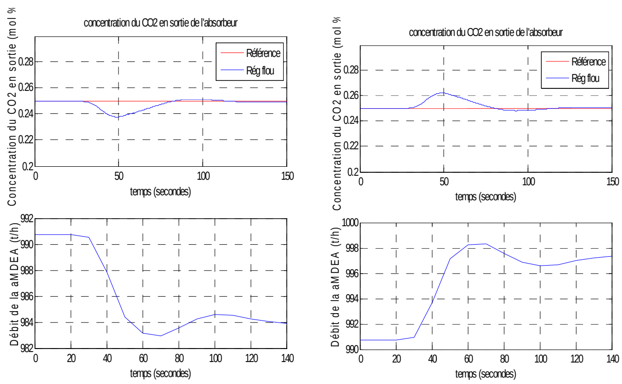

Figure 12 : Concentration du CO_2 en sortie et débit du liquide pour un échelon de perturbation de+/-5% sur la concentration du CO_2 en entrée

c) Résultats de simulations pour des fonctions d'appartenance gaussiennes

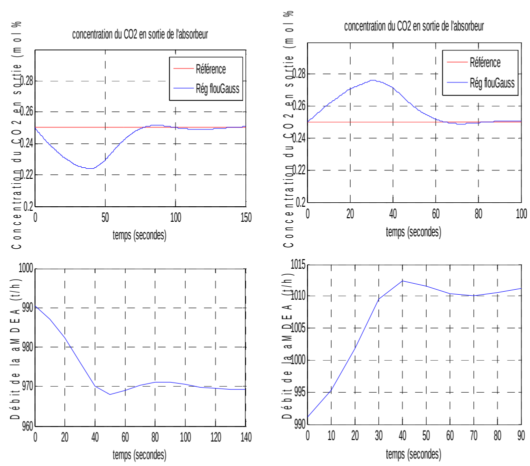

Figure 13 : Concentration du CO_2 en sortie et débit du liquide pour un échelon de perturbation de +/-10% sur le débit du Gaz

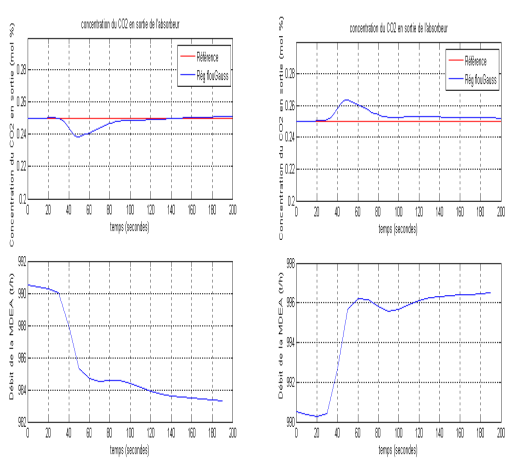

Figure 14 Concentration du CO_2 en sortie et débit du liquide pour un échelon de perturbation de +/-5% sur la concentration du CO_2 en entrée

d) Comparaison Des Régulateurs Flou

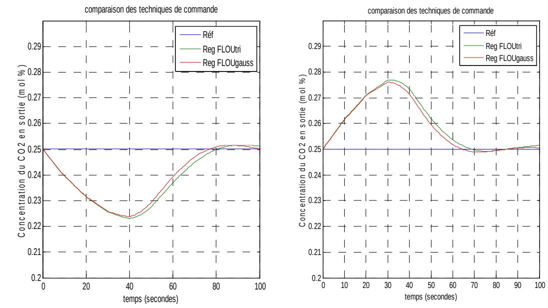

Figure 15 : Comparaison entre les régulateurs flous pour des perturbations de +/-10 sur le débit du Gaz

e) Comparaison du régulateur flou gaussien et PID

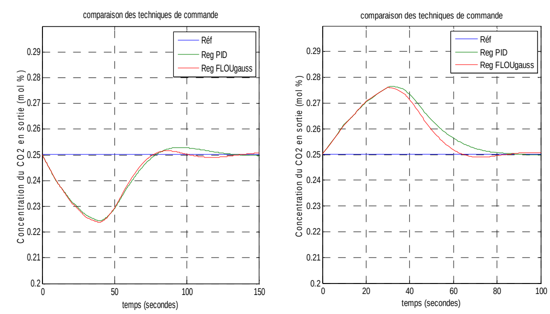

Figure 16 : Comparaison entre le régulateur flou et PID pour des perturbations de +/-10% sur le débit du gaz

f) discussion des résultats

Les figures 11 à 14 montrent que le régulateur flou présente de bonnes performances pour les deux types de fonction d'appartenance.. La figure 15 montre que le régulateur flou à fonctions d'appartenance gaussiennes donne une réponse plus rapide que celui à fonctions triangulaires. La figure 16 montre que le régulateur flou gaussien présente également de meilleures performances que le régulateur PID.

V. Conclusion

Les simulations effectuées montrent que nous obtenons des performances satisfaisantes avec les trois techniques de réglage que ce soit pour les échelons de perturbation sur la concentration de CO_2 ou le débit de gaz. Il faut noter que la régulation floue donne de meilleurs temps de réponse que la régulation classique PID. Nous envisageons d'appliquer des commandes neuronales dans un proche avenir à notre modèle de colonne industrielle.

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Simulation Et Régulation Par Réseaux De Neurones D'une Colonne d'Absorption Industrielle

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Motsclés: colonned'absorption; modélisation; methydiéthanolamine (MDEA); régulation pid; réseaux de neurones, commande non linéaire prédictive neuronale (nnpc).

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I. Introduction

La colonne d'absorption est une unité de séparation physico-chimique largement utilisée en chimie et en biologie. Il s'agit en général d'un tube dans lequel on passe un ou plusieurs mélanges gazeux et qui permet de séparer un ou plusieurs composés du mélange principal. Elle est largement utilisée pour la séparation des gaz acides (CO_2, H_2S) du gaz naturel.

Le modèle de la colonne d'absorption industrielle présenté dans ce papier est un modèle dynamique qui consiste en un ensemble d'équations non linéaires aux dérivées partielles obtenu à partir de considérations sur les bilans de matière du CO_2 et du MDEA dans les phases gazeuse et liquide [1,2], il prend en compte le gradient thermique le long de la colonne d'absorption. Le bilan énergétique de la colonne industrielle est également posé.

Quelques études ont été publiées sur la modélisation et la commande de la colonne d'absorption. Crosby and Durbin [3] étudient les performances d'un régulateur d'état. Roffel [4] développe un régulateur sous optimal avec contraintes d'état. Darwish and Fantin [5] utilisent la commande décentralisée avec placement de pôles. Petrovsky [6] développe un régulateur PI multivariable. Najim [7,8] développe un régulateur auto-ajustable dans le cas de l'absorption du CO_2 par une solution de diéthanolamine. Il reprendra le problème par la suite avec une commande prédictive [9].

Peu d'études ont par contre été publiées concernant la modélisation et la simulation de l'absorption du CO_2 par une solution aqueuses de MDEA ou de MEA en milieu industriel [10-12]. Pour le modèle développé dans notre étude, il nous a semblé intéressant de considérer les réseaux de neurones pour la commande de la colonne car elle permet d'obtenir de bonnes performances pour des processus à dynamique complexe. Nous développerons en première étape une régulation PID pour comparer les performances des techniques de régulation classiques avec celles de la commande par réseaux de neurones.

II. Modelisation et Simulation en Boucle Ouverte de la Colonne Industrielle

La colonne d'absorption présentée ici se situe à Khrechba et fait partie du projet In Salah Gaz, elle permet de prélever du CO_2 du gaz naturel en utilisant une solution aqueuse de methydiéthanolamine (MDEA) comme liquide de lavage. Elle est du type colonne à garnissage mesurant 8 mètre de hauteur et 4 m de diamètre. Le garnissage disposé en vrac est du type anneaux de Pall et est destiné à améliorer la surface de contact entre phases. Pour une meilleure élimination du CO_2 du mélange gazeux, le liquide de lavage (eau+ MDEA) circule à contre courant du flux de gaz. La pression et la température de travail sont respectivement de 71.5 bar et 55°C [2].

Lors du contact entre phase liquide et gazeuse sur la surface des anneaux de Pall, le CO_2 passe de la phase gazeuse vers la phase liquide. Cette diffusion est accélérée par réaction chimique du CO_2 avec la MDEA dans la phase liquide. Le débit de MDEA et la concentration du CO_2 en sortie dans le gaz naturel sont respectivement sélectionnés comme variables de commande et de sortie.

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Figure 1 : La colonne d'absorption de In Salah Gas (ISG)

a) *Equations Du Modèle*

Dans le but de simplifier le modèle, nous avons adopté les hypothèses suivantes [2,13]:

- Il n'y a pas de résistance en phase gazeuse
- La réaction entre le CO_2 et le MDEA est rapide (Ha>5)
- La dispersion axiale est négligeable dans la phase gazeuse et dans la phase liquide
- La MDEA ne passe pas en phase gazeuse Le bilan de matière sur une tranche élémentaire dz de la colonne pour le CO_2 dans la phase gazeuse s'écrit [2,13,14]:

Quantité de soluté à l'entrée z = quantité de soluté à la sortie (z+dz) + quantité de soluté transféré de la phase liquide à la phase gazeuse + accumulation.

Ce qui donne :

$$(GC_{Ag})_z = (GC_{Ag})_{z+dz} + \varphi S\,dz + S\frac{dC_{Ag}}{dt}dz \qquad (1)$$

où G (m^3/s) est le débit vol umique du gaz, φ le flux de CO_2 transféré de la phase gazeuse vers la phase liquide, S la section de la colonne et C_{Ag}(mol/m^3) la concentration du CO_2 dans le gaz. Soit UG=G/S (m/s) la vitesse moyenne d'écoulement du gaz, on obtient alors :

$$U_g\frac{dC_{Ag}}{dz} + \varphi = -\frac{dC_{Ag}}{dt} \qquad (2)$$

La réaction chimique entre le CO_2 et le MDEA est [10-12]:

$$CO_2 + R_1R_2NCH_3 + H_2O \rightarrow R_1R_2NCH_4^{\,+} + HCO_3^{\,-} \qquad (3)$$

La vitesse de réaction r_A a la forme suivante [14,15]:

$$r_A = k\,C_{AL}\,C_{BL} \qquad (4)$$

Où k est la constante de la vitesse de réaction [14,15]:

$$k = 2{,}9610^5\exp(-\frac{5332.8}{T}) \qquad (5)$$

C_{AL} est la concentration du CO_2 dans la phase liquide et C_{BL} la concentration du MEA dans la phase liquide. Le bilan de matière pour le CO_2 dans la phase liquide donne finalement:

$$\varphi = [kC_{AL}C_{BL}] \qquad (6)$$

Ce qui signifie que la totalité du CO_2 transféré dans la phase liquide réagit avec le MDEA.

Le bilan de matière pour le MDEA dans la phase liquide donne :

$$(LC_{Bl})_z = (LC_{Bl})_{z+dz} - [k\,C_{Al}\,C_{Bl}]\,S\,dz - S\frac{dC_{Bl}}{dt}dz \qquad (7)$$

où L est le débit volumique du liquide. En tenant compte de (5) et en notant par U_L = L/S (m/s) la vitesse moyenne d'écoulement du flux liquide on obtient :

$$U_l\frac{dC_{Bl}}{dz} - \varphi = \frac{dC_{Bl}}{dt} \qquad (8)$$

Notre colonne d'absorption est finalement décrite par le système d'équations aux dérivées partielles suivantes:

$$\begin{cases} U_g\dfrac{\partial C_{Ag}}{\partial z} + \varphi = -\dfrac{\partial C_{Ag}}{\partial t} \\ U_L\dfrac{\partial C_{BL}}{\partial z} - \varphi = \dfrac{\partial C_{BL}}{\partial t} \end{cases} \qquad (9)$$

La procédure pour calculer le flux ϕ est donnée en [2] d'après [14-16].

En dernier lieu, nous considérons les conditions aux limites qui sont pour la phase gazeuse la concentration du CO_2 en bas de la colonne C_{Age} et pour la phase liquide la concentration du MDEA en haut de la colonne C_{BLe}.

$$\begin{cases} C_{Ag}\big|_{z=0} = C_{Age} \\ C_{BL}\big|_{z=h} = C_{BLe} \end{cases} \qquad (10)$$

La réaction au sein de la colonne industrielle induit un fort dégagement de chaleur et l'apparition d'un gradient de température tout au long de la colonne ; la variation de température est d'environ 5°C entre l'entrée et la sortie de la colonne, ce qui nous amène à établir un bilan énergétique permettant de décrire l'évolution de la température et son effet sur les différentes concentrations le long de la colonne [16] :

$$\begin{cases} U_g \dfrac{\partial T_g}{\partial z} + \dfrac{a.h_{g|l}\left(T_l - T_g\right)}{\left[\sum_i cp^g{}_i C^g{}_i\right]} = \dfrac{\partial T_g}{\partial t} \\ -U_L \dfrac{\partial T_l}{\partial z} + \dfrac{1}{\sum_i cp^l{}_i C^l{}_i}\left[\Delta H_r r_A - a.h_{g|l}\left(T_l - T_g\right)\right] = \dfrac{\partial T}{\partial t} \end{cases} \quad (11)$$

Avec :

C_i^g : la concentration en phase gazeuse à l'interface (mol/m^3)

C_i^l : la concentration en phase liquide à l'interface (mol/m^3)

cp_i^g : Chaleur spécifique dans la phase gazeuse à l'interface (J/mol.K)

$h_{g/l}$: coefficient de transfert de chaleur (convection)(J/m^2.K.s)

T_l : température du liquide (K)

T_g : température du gaz (K)

ΔH_r : l'enthalpie de la réaction (J/mol)

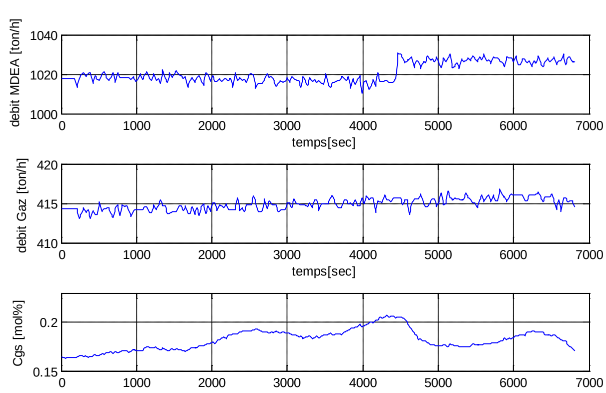
cp_i^l : la chaleur spécifique dans la phase liquide à l'interface (J/mol.K)

On prend finalement en compte les conditions aux limites pour la température qui sont les températures respectives du gaz et du liquide en entrée de la colonne.

$$\begin{cases} T_g\Big|_{z=0} = T_{ge}\ , \dfrac{\partial T_l}{\partial z}\Big|_{z=0} = 0 \\ T_l\Big|_{z=h} = T_{le}\ , \dfrac{\partial T_g}{\partial z}\Big|_{z=h} = 0 \end{cases} \quad (12)$$

b) Validation du modèle

Un test a pu être effectué sur notre colonne d'absorption industrielle pour comparer la concentration du CO_2 en sortie donnée par le modèle avec celle du système et ce pour une variation de l'entrée du type échelon de 10 t/h. Les données ont pu être recueillies sur un horizon de temps de 6800 secondes. Les résultats sont groupés dans la figure 2 où on représente respectivement, les débits de MDEA, de gaz et les concentrations du CO_2 en sortie de la colonne et celles données par le modèle [2].



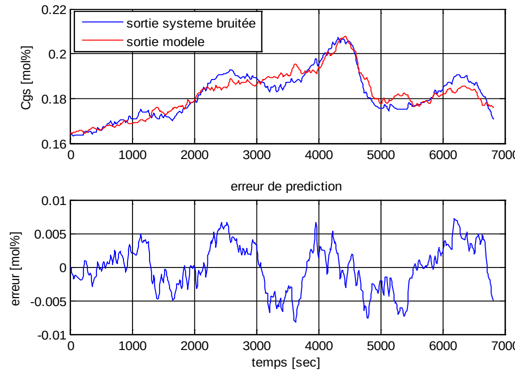


Figure 2 : Concentration du CO_2 en sortie du système et du modèle

On note que la dynamique des concentrations de CO_2 en sortie de la colonne obtenue théoriquement agrée avec les résultats expérimentaux.

c) *Simulation en boucle ouverte de la colonne industrielle*

En considérant les équations (2) et (8), le modèle dynamique de la colonne d'absorption est un système aux paramètres répartis non linéaires. Les résultants de la simulation en boucle ouverte sont présentés en figures 3 et 4.

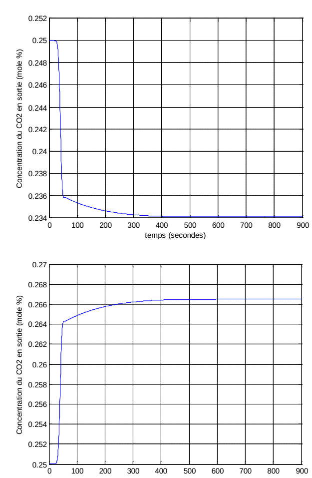


Figure 3 : Concentration du CO_2 en sortie de la colonne pour un échelon de perturbation de +/- 5% sur la concentration en entrée du gaz

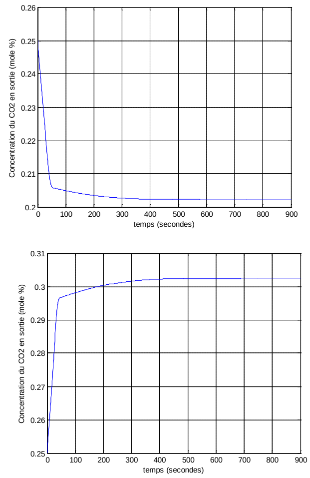


Figure 4 : Concentration du CO_2 en sortie de la colonne pour un échelon de perturbation de +/- 10% sur le débit du gaz

La simulation montre que le système est stable. Il présente un temps mort en réponse à un échelon de perturbation sur la concentration en entrée du CO_2 dû à la propagation du gaz le long de la colonne d'absorption.

III. Regulation pid de la Colonne D'absorption Industrielle

Nous appliquons une régulation PID au modèle dynamique de notre colonne d'absorption. Une commande échantillonnée est choisie pour faciliter la simulation avec une période de 10 secondes. La référence pour la concentration de CO_2 en sortie est choisie égale à 0.25mole %, ce qui correspond à une concentration de 7.05 mole CO_2/m^3 Les paramètres du régulateur PID ont été optimisés par essai/erreur.

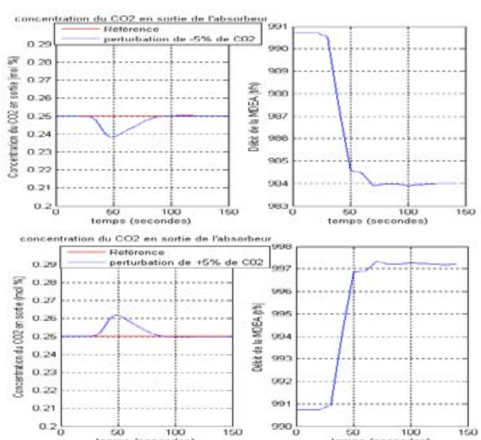


Figure 5 : Concentration du CO_2 en sortie et débit du liquide de lavage pour un échelon de perturbation de ± 5% sur la concentration de gaz

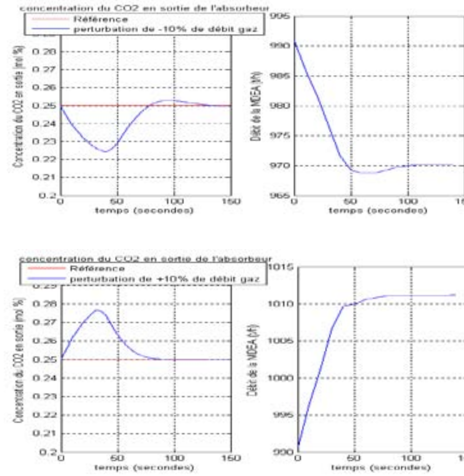


Figure 6 : Concentration du CO2 en sortie et débit du liquide de lavage pour un échelon de perturbation de ±10 % sur le débit du gaz

Les résultats obtenus en simulation sont satisfaisants, le régulateur PID annule l'erreur en régime permanent et assure une réponse rapide grâce à l'action dérivée. Le système présente en régulation un certain comportement asymétrique dû a la forte non linéarité de la sortie par rapport à la commande choisie qui est le débit du liquide de lavage.

IV. Commande par Reseaux de Neurones de la Colonne D'absorption Industrielle

Les réseaux de neurones artificiels (RNA) sont des approximateurs universels de fonctions et permettent ainsi d'approcher n'importe quelle fonction non linéaire. Cette propriété motive leur utilisation pour la réalisation de commandes non linéaires par identification d'un modèle donné. . Nous envisageons dans notre étude un modèle général pour la synthèse de la commande non linéaire prédictive neuronale (NNPC) [18]-[19].

a) *Commande non linéaire prédictive neuronale (NNPC)*

Nous prenons pour la commande NNPC une structure d'identification simple série-parallèle. Le réseau de neurones est choisi en essayant de minimiser l'erreur de rétropropagation du gradient. Après plusieurs essais, notre choix s'est arrêté sur un réseau à quatre entrées u(k),u(k-1),y(k), y(k-1) et une seule couche cachée à 15 neurones. L'apprentissage de notre réseau de neurones et le test de validation du modèle neuronal sont présentés dans les figures 7 et 8.

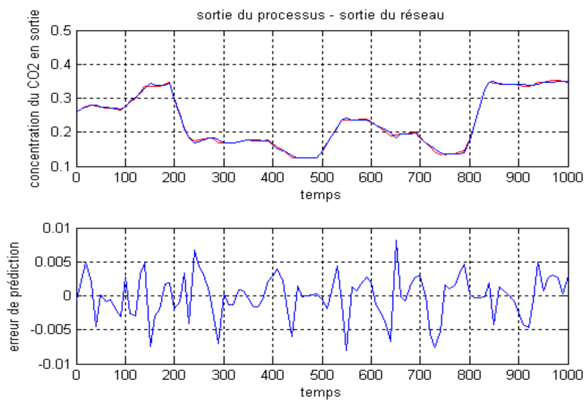


Figure 7 : Identification neuronale de la colonne industrielle

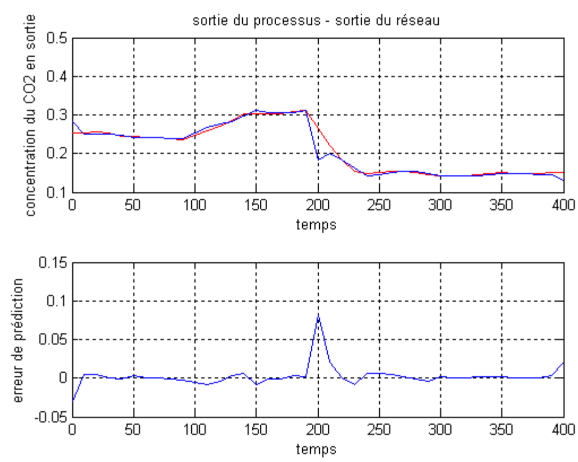


Figure 8 : Validation de l'identification neuronale de la colonne

La stratégie de commande prédictive est basée sur un horizon de prédiction [22]. Le réseau de neurones prédit la réponse du processus sur l'intervalle de temps spécifié. La prédiction est ensuite utilisée par un programme d'optimisation pour déterminer la commande minimisant le critère de performance *J* ci-dessous sur l'horizon de prédiction considéré :

$$J = \sum_{j=N_1}^{N_2} \left(y_d(t+j) - \hat{y}(t+j)\right)^2 + \rho \sum_{j=1}^{N_u} \left(u'(t+j-1) - u'(t+j-2)\right)^2 \qquad (13)$$

Où *U'*(t) est le vecteur de commandes tests :

$$U'(t) = \left[u'(t) .... u'(t+N_u-1)\right]^T \qquad (14)$$

N_1 et N_2 définissent l'horizon de prédiction, N_u est l'horizon de commande. Y_d est la réponse désirée et $\hat{y}$ est la sortie estimée du modèle. La valeur de ρ détermine la contribution des commandes tests dans le critère de performance. Le critère J est minimisé en utilisant un algorithme d'optimisation itératif en général l'algorithme BFGS qui est une méthode quasi Newton [18,22]. Le schéma de la figure 9 illustre le principe de la commande prédictive neuronale. Le contrôleur est composé d'un réseau de neurones pour estimer $\hat{y}$ et d'un bloc d'optimisation pour déterminer *U'*(t).

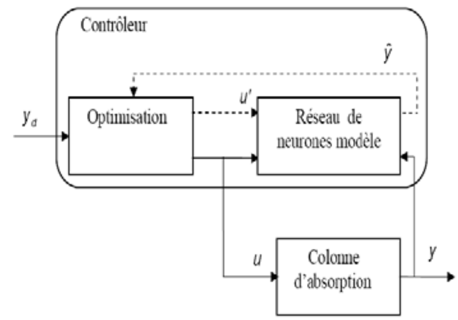


Figure 9 : Commande NNPC de la colonne d'absorption Industrielle

a) Résultats de simulation de la commande NNPC

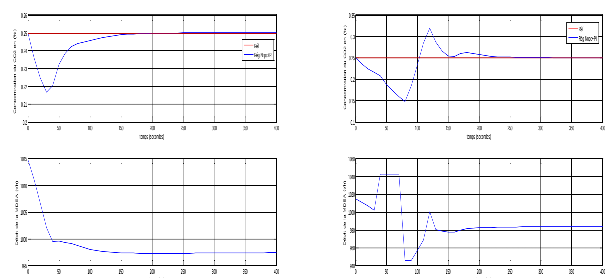


Figure 10 : Concentration de CO_2 en sortie et débit du liquide de lavage pour un échelon de perturbation de+/-5% sur la concentration de CO_2

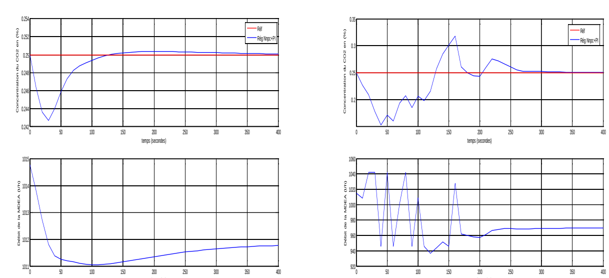


Figure 11 : Concentration du CO_2 en sortie et débit du liquide de lavage pour un échelon de perturbation de +/-10% sur le débit de gaz

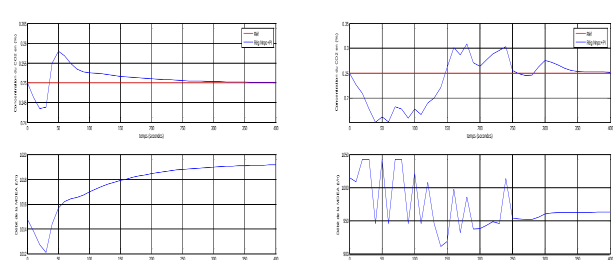


Figure 12 : Concentration du CO_2 en sortie et débit du liquide de lavage pour un échelon de perturbation de +/-5% sur la concentration de CO_2 et +/-10% sur le débit de gaz

A cause des erreurs de modélisation on a normalement une erreur en régime permanent. Pour remédier à ce problème, on a introduit un régulateur PI sur lequel on commute dès que la sortie approche le voisinage de la consigne (10%) (figure 13). Toutes fois la réponse du système présente un comportement asymétrique pour les perturbations sur le débit gaz.

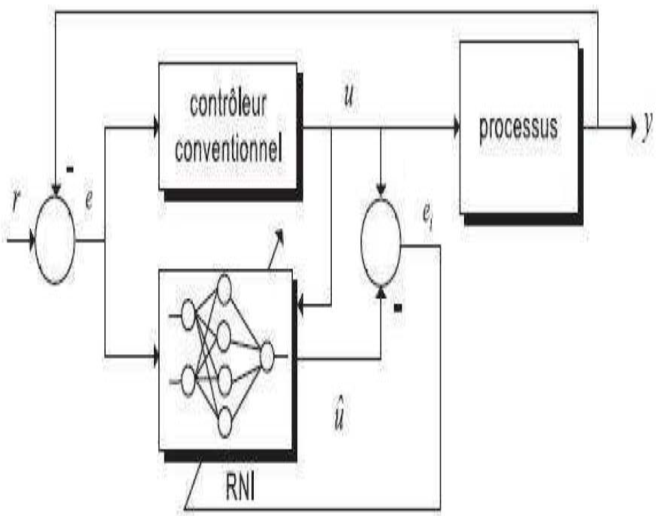


Figure 13 : Commande NNPC avec PI de la colonne d'absorption Industrielle

b) Comparaison de la technique de réglage neuronale et classique

cause de l'algorithme d'optimisation, ce qui donne un temps de réponse relativement long par rapport à une simple régulation PID qui atteint le régime établi pour moins de 100 secondes. la réponse de la commande NNPC est peu oscillatoire du fait du réseau de neurones qui se sature de par et d'autre. Néanmoins, les résultats obtenus sont satisfaisants.

V. Conclusion

Les simulations montrent que nous obtenons des performances satisfaisantes avec les deux techniques de réglage que ce soit pour les échelons de perturbation sur la concentration du CO_2 ou sur le débit de gaz. Il faut noter que la régulation PID donne de meilleurs temps de réponse que la commande neuronale du fait de sa simplicité.

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An Application of a Cost Minimization Model in Determining Safety Stock Level and Location

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ANAPPLICATIONOFACOSTMINIMIZATIONMODELINDETERMININGSAFETYSTOCKLEVELANDLOCATION

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An Application of a Cost Minimization Model in Determining Safety Stock Level and Location

Bahareh Amirjabbari α & Nadia Bhuiyan σ

Abstract- In recent decades, the lean methodology and the development of its principles and concepts have widely been applied in supply chain management. One of the most important strategies of being lean is having efficient inventory within the whole supply chain. Managing inventory efficiently requires appropriate management of safety stock in order to compensate the weakness of the supply chain for product availability.A nonlinear cost minimizationsafety stock model with the objective of minimizing the total logistics cost is developed in this paper. This modelis also applied to a real-world case company which is a manufacturer.The model results in optimum levels and locations of safety stock within the company's supply chain in order to minimize total logistics costs.

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I. Introduction

Intoday's competitive environment, applying the lean paradigm has been extended to the field of supply chain management.Taylor (1999), Adamides et al. (2008), Kainuma&Tawara (2006), Lamming (1996), Crino et al. (2007), Wu & Wee (2009) researched on lean supply chain. Naylor (1999), Qi et al. (2007), Mason-Jones et al. (2000) compared lean paradigm with other methodologies in supply chain management. Contributors of a supply chain, no matter to which industry they belong, aim to follow a lean philosophy to make their business processes more and more efficient in order to survive on the market. Manufacturers are one of these contributors and inventory plays a paramount role in their efforts to become lean.Chun Wu (2003), Wu (2009), McCullen&Towill (2001) studied on the application of lean manufacturing. There are different inventory drivers such as level of supply chain collaboration and visibility, forecast accuracy, order pattern, and safety stock policy, among others. Therefore, proper management of inventory and consequently safety stock as one of its drivers has become critical objective towards achieving leanness. In this paper, we propose a safety stock cost minimization model in a manufacturing case company thatis attemptingto become lean by managingthe inventory across its supply chain efficiently, and towards this goal, efficient levels and locations of safety stock becomes more and more significantas a prerequisitecondition.

An optimization model of safety stock can be built on different objectives. Minimizingcost, maximizingservice level, and aggregate considerations are examples of such objectives (Silver, 1998). Optimal determination approaches based on cost and service level objectives are more appropriate for practical applications (Inderfurth, 1991). One of the vital goals of the enterprise is to maximize earnings under certain investment conditions (Long et al., 2009). On the other hand, as reducing costs of materials, equipment, and labor is difficult at best in today's competitive market, enterprises are more interested in targeting logistics costs in this regard (Long et al., 2009). In this paper, minimization of logistics costs is selected as the basis of the determination of optimum safety stock.Logistics costs are mainly related to procurement and supply, manufacturing process, and after sales service. Thus, holding and shortage costs are selected as representations of logistics costs in the optimization model. Indeed, product availability is a critical measure for the performance of logistics and supply chain (Coyle et al., 2009). Any obstacles at any node and level of supply chain can result in unavailability of products to their customers. There are different issues that cause disruptions and unavailability of products in the supply chain, as for example variability, whether in demand or lead time; quality issues; or internal and external issues such as low delivery performances, improper scheduling, inadequate product capacity, poor maintenance, among others. Figure. 1 is a schematic of a supply chain with its nodes such as different tiers of suppliers, producer, assembly, distributors, and customer. Any actions taken by any member of the chain can affect the profitability of the others. Therefore, companies have great interest in having better coordination among the contributors of their supply chain (Silver, 1998). Safety stock is essential to compensate for the weakness of the supply chain for part availability and this factor has been considered in the selected optimization model.

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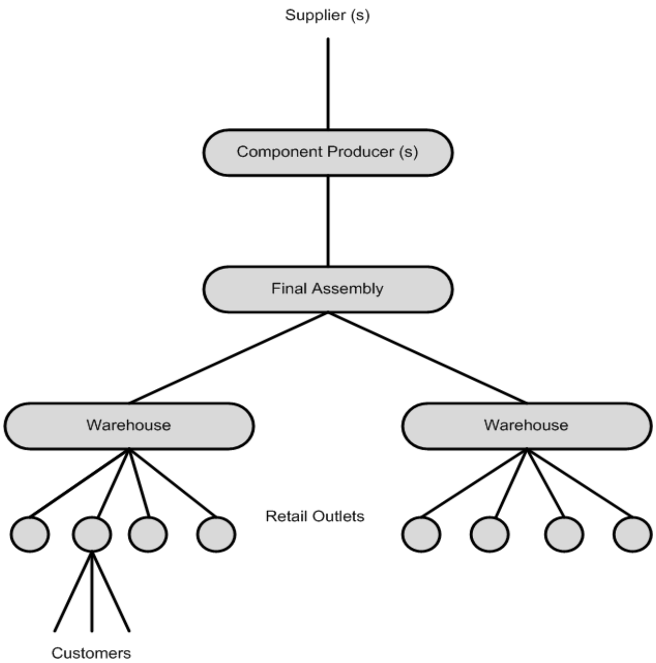

Figure 1 : A schematic of a supply chain

In this paper, we apply a safety stock cost minimization model in a case company which is a manufacturer. In the next section, we provide a review of the literature. In Section 3, we describe the case company. In Section 4, we introduce the model, followed by the model formulation in Section 5. Results are then presented in the next section, followed by validation. We then provide a discussion of the results and their implication, and then conclude with some suggestions for avenues of future research.

II. Literature Review

According to the literature, there are different approaches and methods for determining safety stock under different situations. Some different methods for computing safety stock in the Just In Time (JIT) environments are presented by Natarajan &Goyal (1994). These methods deal with objectives related to service level, expected number of stock outs, tradeoff between stocking out and carrying extra buffer, minimization of total cost comprises of set-up, holding, and shortage costs. Efficient level of inventory in creases the inventory turnover in companies. Reducing the level of inventory helps to increase the turns according to its definition. One of the approaches towards reduction of inventory especially in Just In Time (JIT) environments is reducing lot sizes. On the other hand, smaller lot sizes will lead to uncertainties and consequently stock outs (Natarajan &Goyal, 1994). Therefore, safety stock is really needed to protect against these kinds of uncertainties.

Minner (1997) uses dynamic programming algorithms to find the optimal combinations of coverage times with the target of minimizing the average holding costs in serial, divergent, and convergent inventory systems. In this paper, it is assumed that customer demand is normally distributed and correlations between demands are permitted. One of the outcomes of this paper is that concentrating safety stocks at the first and final stages would be optimal for a serial system with a high enough service level.

A linear programming model with the objective of establishing a trade-off among plan changes, carrying, and shortage costs under resource constraints for a multi-item production system is presented by Kanyalkar & Adil (2009). Plan changes cost is related to the instabilities occur under rolling schedule. These instabilities in the chain affect costs such as setup and expediting costs and they also affect material plans like shortage or excess of components (Kanyalkar & Adil, 2009).

Jung et al. (2008) present a linear programming formulation which includes the control variables of safety stock with the purpose of minimization of the total supply chain's inventory while meeting the target of the service level. This model incorporates the nonlinear performance functions, the interdependence between the service level at upstream and downstream stages of supply chain and also the safety capacity constraint. A section also provided for linearization of the nonlinear functions of the model. Some of the assumptions applied in this model are normally distributed demand, zero lead time at the warehouse, and constant production capacity. In addition, it is assumed that raw material and transportation means in any size are always available.

A dynamic model of the safety stock by assuming a Vendor Managed Inventory (VMI) system is presented by Yuan Li &Jian Li (2009). Under VMI system, the uncertainties related to the efficiency of the supplier disappear and the model considers only the variability sourced by demand.

Patel & Rodrigues (2010) present the dynamics of the model of optimizing safety stock for small-scale aluminum utensil manufacturing industry. This model takes into account factors of demand, production rate, delay, and waste time. Indeed, this paper concentrates on the bullwhip effect in a manufacturing supply chain and tries to reduce it by increasing safety stock.

Zhao et al. (2001) use a simulation approach to evaluate alternative methods of determining the level of safety stock based on historical forecasting errors in multilevel MRP systems. In addition, the relation between the safety stock multiplier and different system performance measures such as total cost, service level, and schedule instability in different methods analyzed and results also provided.

Badinelli (1986) is about combining stock out cost and holding costs functions towards determining the optimal safety tock. It also presents a technique for estimating the stock out with a decision maker's disvalue function.

An approximation model for safety stock in a two echelon distribution system is provided by Desmet et al. (2010). This model tries to incorporate the variance of the retailers and the central warehouse in the replenishment lead time. It also takes into account the variance of the service time of orders at the warehouse as it has significant effect on the system's lead time variance.

Inderfurth (1991)represents a safety stock optimization model in multi-stage problems with divergent structure and provides a dynamic programming algorithm for solving that. The analysis for the impact of the correlation of demands on safety stock allocation has also provided in this paper. This model does not include inter-stage shortage costs by assuming of having a certain capacity of slack resources for operating flexibility.

Inderfurth (1995) is the continuation of hisprevious work in 1991.He extended his study to a case that demand is not only cross-product but also cross-time correlated. Cross-time correlation of demand yields a tendency to keep safety stock at the end-item level, while cross product correlation provides a tendency for holding buffer more in upstream stages. One of the results of this study is that increasing the correlation in both products and time makes the safety stock policy to be more expensive. This research also shows that not taking into account demand correlation may result in incorrect sizing and positioning of safety stock in multi-stage manufacturing systems. Neglecting this may also lead to missed cost reduction opportunities.

A nonlinear integer optimization model with the objective of minimization of the total setup and inventory holding costs by considering service level constraint has been provided by Carlson & Yano (1986). The only variability that is incorporated into the model isrelated to demand. In addition, it is assumed that there are no capacity constraints. The model suggests having safety stock at those stages with high setup or disruption costs.

An optimization model with the purpose of minimizing the total holding and shortage costs is presented by Aleotti Maia & Qassim (1998). Then, an analytical solution provided for finding the preferable case by comparing inventory and opportunity costs. It is concluded that holding inventory at the intermediate levels is not economical if it is solely using for reduction of the frequency of stock out. The model from this paper is expanded for this study and applied in a real-world case company. The reason for this selection is that the objective of this model is the same as the objective of the case company which is minimization of the cost. Determination of the optimal level and location of safety stock in a supply chain with different stages and stochastic environment is a very complex task; therefore, most of the models and approaches provided in this regard have applied certain assumptions in their own cases to make it simpler. Some of these approaches are applicable for only a specific inventory system, some of them limit the distribution of demand, and some of them exclude the suppliers' variability. In this paper, we present a general model with the objective of logistics costs minimization by considering both internal and external variability and taking into account of part availability factor which is very important in the chain.

III. Case Study

The company under study, which we will hereinafter refer to as ABC for the purpose of confidentiality, is a manufacturer in the aerospace industry. The company is characterized by high demand variability and long lead time, among others. ABC is a multi-stage manufacturer. Tiers of suppliers, procurement, manufacturing, final assembly, and customers (internal and external) are different nodes of the ABC's supply chain. The downstream nodes are the upstream nodes' customers, and the replenishmentlead time of customer nodes is the order waiting time provided by their upstream nodes. In addition, ABC has a generally structured multi-stage system and there is no restriction with respect to the number of predecessors and successors of any node. Such multi-stage systems focus considerable attention on setting and positioning safety stock. ABC has two different manufacturing plants (MFs). The procurement department of the company is responsible for procuring the raw materials or semi- finished parts through suppliers to manufacturing plants or even supplying parts from one manufacturing plant to another (inter plants transfers). Indeed, the word "supplier" in the model could be the representative of the external supplier or internal manufacturing entity. It should be noted that procurement's location can be different from manufacturing ones. Finished parts from manufacturing entities have two internal customers that pull their outputs; they are Assembly (ASSY) and Aftermarket(AFM). These two latter entities are the last stages of the internal chain of the company just before the end customer. There are also some external supplied finished parts required for Assembly and Aftermarket that the procurement department is again in charge of supplying them. The Assembly entity has different finished product families with their own specifications.Therefore, if availability of parts (right parts at right time) can be assured for the internal customers, on-time delivery performance to the end customer will be assured as well. This availability should be guaranteed through safety stock, but the optimum

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safety stock level and location should also minimize logistics costs.

IV. Model Description

The optimization model is presented through different possible value streams of each finished product family of the company and developed using lingo optimization software to result in the optimum level of safety stock with its optimum location in the stream. Value stream is the aggregation of all actions needed to bring a specific product through problem-solving task, information management task, and physical transformation task (Womack and Jones, 2003). Value stream mapping as a tool of lean is a method to depict material and information flow throughout whole the chain for both value added and non-value added processes.Value stream is used to give the visibility of the whole supply chain form end to end for each specific part. By applying the model through different value streams, it will not only result in the optimal level of the safety stock but also in the optimal location of it in the supply chain (raw material safety stock, semi-finished part safety stock, or finished part safety stock). Each of the possible value streams of the case company can have different combinations of the chain's contributors before the end customer. In order to limit the number of stages and for simplification, only the last two stages of those value streams that have more than two nodes before the internal customer stage are selected. Therefore, all the previous stages and their connections are being excluded and their performances are being captured only through the input of the latest second stage. The other reason for this limitation is the difficulty in defining the shortage costs in upstream stages of the chain due to lack of visibility and control. Furthermore, the objective of the model is cost minimization, and the upstream stages' contributions towards cost are significantly less than the downstream stages, thus this simplifying assumption should have a negligible effect on overall results. Although, there is a sample (Value Stream 4) presented in "Computational Results" section that goes beyond this limitation just to show the applicability of the model for the whole chain from end to end point.

Shortage cost, overage cost, and delivery performances (percentage of product availability) are the inputs of the model. Different combinations of raw material (semi-finished part) and finished part are considered as indices in the model based on the selected value streams.

V. Model Formulation

For all value streams, the notations of the model are as follows:

a. Sets and Indices

i Raw material/ semi-finished part

p Finished part

u Customer (ASSY, AFM)

b. Variables

K_i Delivery performance of procurement to manufacturing

K_p Delivery performance of manufacturing orprocurement to customers

c. Parameters[1]

P_i Supplierdelivery performance to procurement (If supplier is a manufacturing plant, thenP_i wouldbe manufacturing performance for semi-finishedpart)

P_p Manufacturing performance for finished part (Ratiobetween on time manufactured and plannedmanufacture of finished part)

C_s Cost of shortage

C_o Cost of overage

x_i Raw material/semi-finished part safety stock

x_p Finished part safety stock

q_i Raw material/semi-finished part quantity ordered

q_p Finished part quantity ordered

q^* On-time delivered quantity of raw material/ semi-finished part or finished part

Figures.2 to 4present variables and parameters in possible value streams for procuring a part to the customer in the case company.

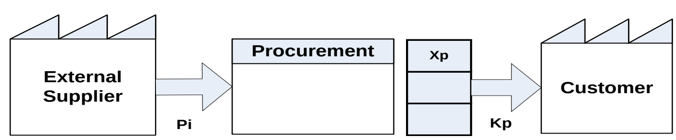

Figure 2 : Variables and parameters in value stream

[1] It should be noted that index of "p" is used for only those finished parts that are manufactured in ABC. Indeed, for those finished parts that are supplied through suppliers, index of "i" is used.

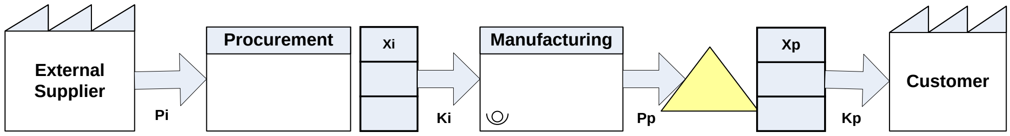

Figure 3 : Variables and parameters in value stream

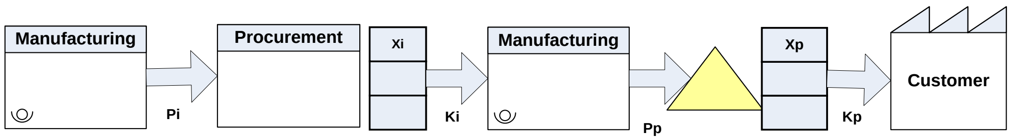

Figure 4 : Variables and parameters in value stream

K_i is the summation of the availability percentage of raw material/semi-finished part for manufacturing through procurement based on the absolute suppliers' performances (P_i) and the availability percentage of procurement's safety stock for that part (x_i/q_i). Indeed, procurement can deliver whatever quantities they received on time through suppliers plus their safety stock to the manufacturing. K_p is the summation of the availability percentage of the finished part which is dependent on the manufacturing performance (P_p) and also their previous stages' performances (K_i) and the availability percentage of manufacturing's safety stock for that part (x_p/q_p). Likewise, manufacturing can deliver what everquantities of finished parts they can produce on time which is also dependent on the deliveries of their previous stages in the chain plus their own safety stock quantities to their customers (ASSY and AFM).

The related formulas of K_i and K_p are as (1) and (2):

$$K_i = P_i + x_i/q_i \quad (1)$$

$$K_p = P_p \times K_i + x_p/q_p \quad (2)$$

In the cases that the finished part is directly procured through the external supplier for the customers, K_p formula will be equal to (1).

P_i and P_p are calculated as average numbers based on historical data from the last year. A report called the First Filled Rate (FFR) is used for calculation of these parameters. This report is used top resent the availability of the right part at the time that is required. The FFR result takes into account the total on hand stock in its calculation which does include safety stock as well. It should be noted that P_i and P_p should be the absolute delivery performance of supplier and manufacturing without the contribution of the safety stock that may be used during last year. Therefore, the safety stock has been excluded from the FFR report for this purpose. In addition, when there are two stages in the selected value stream, the FFR report also includes the contribution of the last second stage's performance in its results for calculating the last stage's performance which is manufacturing. Therefore, this must also be excluded. Indeed, P_p is the manufacturing performance without taking into account the stock out of raw materials (Aleotti Maia & Qassim, 1998). Hence, to calculate the required absolute value of P_p from FFR, three other parameters should be defined. First one is K'_p which is the exact number extracted through FFR, the other one is P'_p which is the FFR's result excluding safety stock contribution. And the third one is K'_i which is the historical previous stage's delivery performance; by dividing this by P'_p the absolute manufacturing performance is measured ($P_p = P'_p/K'_i$). Indeed, there is no direct report for tracking absolute manufacturing performance in the case company. Table1 is a snapshot of a sample FFR and presents the formulas used to eliminate the safety stock from its calculation. As shown through the table, in the 12th week of 2010, the FFR report gives 100% (K'_p=100%) as the delivery performance of manufacturing to its customer because it takes into account the 300 pieces of safety stock for meeting the past and current requirements; however, safety stock must be excluded through this calculation and P'_p becomes 18%. The next step for calculating the absolute manufacturing performance would be the elimination of the effect of the previous stage's performance (K'_i).

About the calculation of P_i in FFR, it should be noted that if the supplier delivers a part on time with the right quality, but defects occurs during transportation from procurement to manufacturing or customer, although the delivery performance of the supplier is 100%, P_i will be 0% since the part is not available for use. Therefore, P_i can also be called "part availability" instead of supplier delivery performance.

It is worth mentioning here that ABC has three different strategies for managing its inventory. It applies a two-bin kanban system for the parts with low costs. The company is moving towards excellence and applying a pull system for managing the inventory of those parts that have high cost with high volume; but this system is not applicable for all parts due to the complexity and lack of required conditions such as having suppliers with delivery performance of higher than 80% and with a supermarket of finished goods, having parts with a robust process and steady volume, among others. Therefore, its inventory strategy for the rest of the parts with high cost and low volume is MRP system. Based on this, a safety stock strategy is really required for this latter category of parts.For calculating q_i and q_p, we need to understand the *risk period*. Risk period consists of a review period and replenishment lead time (Tempelmeier, 2006). The review period is the basis on which the company updates its data. As a result, if a company reviews its data once a week, its review period would be one week. Of course this review period has an effect on the duration that the company should wait to receive its order through the supplier.In the case company of this paper the data are updated daily; therefore, there is no need fordefining the review period.Consequently for parts managed by the MRP system, quantities within the replenishment lead time have found as the most appropriate definition for q_i and $q_p$to result in the proper level of safety stock for the company through the model.In essence, if changes happen in demand within this period (replenishment lead time), we cannot count on the suppliers' support 100% of the time. Safety stock is required for coverage of this variability. The first step for their calculation would be identifying the planned order quantity of each specific part (raw/semi or finished part) per week according to its planning parameters which it itself is related to ordering policies. Some of the examples of planning parameters in this regard are Lot for Lot, Weekly Batch, 2 Weeks Batch, and Fixed Order Quantity, among others. The second step would be the calculation of the average weekly forecast demand of that specific part for the next year. After that, the division of the planned order quantity and average weekly demand would result in the replenishment lead time in weeks. When changes happen in the supply chain such as changes in the demand or capacity ration, entrance of new competitors, introduction of a new product, or retirement of a matured one, the safety stock required for the supply chain must be re-evaluated (Jung et al., 2008).ABC has decided to run the model and update it every quarter, therefore, the weekly demand of the next quarter would be merged based on the calculated replenishment lead time. And finally, the maximum quantity of this combination will be selected as q_i/q_p in order to allow the safety stock strategy to support the *worst case*.

Table 1 : First fill rate report sample

Part Code	Entity	Calendar Week	Stock	Required Past	Required Current	% Met Global (K'p)	Theoretical Safety Stock	Safety Stock On-Hand	q*	P'p
AF1	MF	11.2010	2100	500	500	100	0	0	500	100%
AF1	MF	12.2010	1100	700	560	100	300	300	100	17.85%

* Shaded sections are used to make the FFR report applicable.
* Theoretical safety stock based on historical data.
* Safety Stock On-Hand = Max (0, Min (Stock - Required Past, Theoretical Safety Stock))
* q* = Max(0 ,Min (Stock - Required Past - Safety Stock On Hand, Required Current))
* P'_p = (q*/Required Current)×100

One of the advantages of this method of calculating q_i and q_p is making the market variability involved by taking into account of the forecast demand. It should be mentioned that the planned order quantity for a manufacturing part should always be calculated through its demand only in the plant in which it is being manufactured because the part will be replenished based on the ordering policy in that plant. On the other hand, in the case that a raw material has more than one customer (MF and AFM), calculation of q_i required by manufacturing through weekly demand seen in procurement (entity that receives part through supplier)is not correct because procurement sees the demand of both customers mix. Therefore, the respective q_i must be calculated through the part's parameters (planned order and weekly demand) all in the manufacturing plant that it is going to be used.

Shortage costs (costs of safety stock violation) have different definitions for raw materials (semi-finished parts) and finished parts as they are located in different stages within the chain and their shortages have different effects on the system. The shortage cost of the raw material (semi-finished part) is the summation of the expediting cost on the supplier, expediting cost on transportation, and overtime of the manufacturing section. On the other hand, shortage of the finished part which is required by Assembly, causes disruptions and stock not pulled for all the other parts related to that finished part and also its finished product in different locations of the supply chain. In addition, shortage of the finished part causes the finished assembled product to be held up unreleased. Therefore, the shortage cost is defined as follows:

C_{sp} = (Standard cost of the finished assembled product* average days of holding finished assembled product due to the shortage of the specific finished part during last year*0.1)/365

Coefficient of 10% in the above formula is the annual interest rate that company could receive by putting this amount of money in the bank, although the company has this as inventory buckets instead of cash right now.

The cost of shortage of the finished part required by Aftermarket is defined as the profit that the company will lose by not having the part ready to deliver ontime to the customer, which is the direct cost. Besides that, there are many intangible effects of this shortage that are called indirect costs and are difficult to gauge accurately (Graves et al., 1993). One of them is loss of customers' goodwill that may turn them to other competitors in the future. On the other hand, at the time of shortage of a specific part, the Aftermarket department may rent out another more expensive part instead of the required one to the customer until it arrives. Therefore, the shortage cost of these parts is defined as four times of the standard cost (Stnd.Cost) of the finished part.

The cost of overage is defined as the interest that the company is losing by holding inventory instead of having it in cash. Hence, it is the multiplication of standard cost of the part and the annual interest rate (10%).

As can be seen through the formulas and definitions, a period of one year has been selected for historical data collection. As the factors (such as shortage cost and delivery performances) that are gathered within this time frame are critical to make an appropriate decision about the level and location of safety stock, one year has been selected in order to have a sufficient window view.

Some samples of value streams associated with their models' formulas are presented below.

Value stream 1 shown in Figure.5consists of one raw material/semi-finished part used to make one finished part which has two customers, ASSY and AFM. The corresponding objective function and constraints are presented by (3).

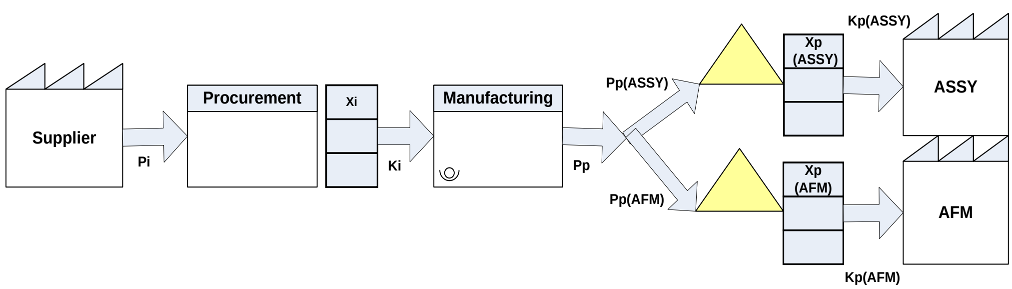

Figure 5 : Value stream 1

$$MinC = C_{si}q_i(1-P_i) + C_{oi}q_i(K_i - P_i) + \sum_{u=1}^{2} C_{spu}q_{pu}(1-K_{pu})$$

$$+ \sum_{u=1}^{2} C_{opu}q_{pu}(K_{pu} - (P_{pu} \times K_i))$$

$$\begin{aligned} &SubjectTo: \\ &K_i \le 1 \\ &K_i \ge P_i \\ &K_{pu} \le 1, \qquad u = 1,2 \\ &K_{pu} \ge P_{pu} \times K_i, \qquad u = 1,2 \end{aligned} \tag{3}$$

If for this case, there were two different kinds of finished parts but again in demand with both customers, then there should be a summation on both indices of finished part (p) and customer (u) in the objective function:

$$MinC = C_{si}q_i(1-P_i)+C_{oi}q_i(K_i-P_i)$$
$$+\sum_{p=1}^{2}\sum_{u=1}^{2} C_{spu}q_{pu}(1-K_{pu})$$
$$+\sum_{p=1}^{2}\sum_{u=1}^{2} C_{opu}q_{pu}(K_{pu}-(P_{pu}\times K_i)) \tag{4}$$

$$SubjectTo:$$
$$K_i \le 1$$
$$K_i \ge P_i$$
$$K_{pu} \le 1, \quad u,p=1,2$$
$$K_{pu} \ge P_{pu}\times K_i, \quad u,p=1,2$$

In value stream 2 which is shown in Figure. 6, two raw materials/semi-finished parts are used to make one finished part which has two customers, ASSY and AFM. The corresponding model is also presented by (5).

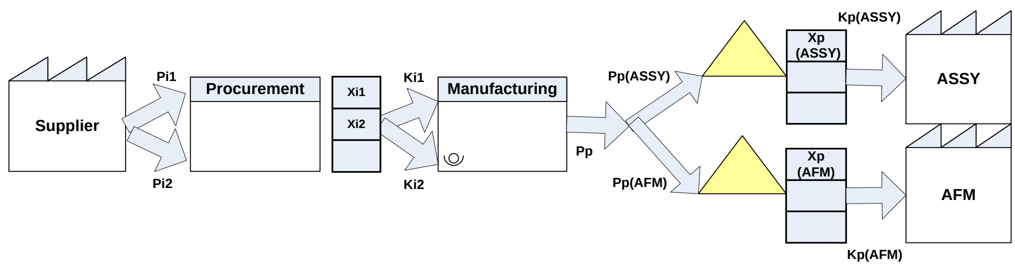

Figure 6 : Value stream 2

$$MinC = \sum_{i=1}^{2} C_{si}q_i(1-P_i)+\sum_{i=1}^{2} C_{oi}q_i(K_i-P_i)$$
$$+\sum_{u=1}^{2} C_{spu}q_{pu}(1-K_{pu})$$
$$+\sum_{u=1}^{2} C_{opu}q_{pu}(K_{pu}-(P_{pu}\prod_{i=1}^{2}K_i)) \tag{5}$$

$$SubjectTo:$$
$$K_i \le 1, \quad i=1,2$$
$$K_i \ge P_i, \quad i=1,2$$
$$K_{pu} \le 1, \quad u=1,2$$
$$K_{pu} \ge P_{pu}\prod_{i=1}^{2}K_i, \quad u=1,2$$

As before, if there were two different finished parts for the same situation, the model would be changed as (6):

$$MinC = \sum_{i=1}^{2} C_{si}q_i(1-P_i) + \sum_{i=1}^{2} C_{oi}q_i(K_i - P_i)$$
$$+ \sum_{p=1}^{2}\sum_{u=1}^{2} C_{spu}q_{pu}(1-K_{pu})$$
$$+ \sum_{p=1}^{2}\sum_{u=1}^{2} C_{opu}q_{pu}(K_{pu} - (P_{pu}\prod_{i=1}^{2} k_i))$$

$$SubjectTo:$$
$$K_i \le 1, \qquad i = 1,2$$
$$K_i \ge P_i, \qquad i=1,2 \tag{6}$$

$$K_{pu} \le 1, \qquad p,u = 1,2$$
$$K_{pu} \ge P_{pu}\prod_{i=1}^{2} K_i, \qquad p,u = 1,2$$

As can be seen through the constraints of the model, the company's objective is to have 100% delivery performances. Therefore, the upper boundaries of both stages are assigned to 1 in order to not to allow the model to impose a shortage to the system. Of course, these upper bounds could be less than 1 based on the service level goals in different cases.

By this definition of the model, costs factors would be the indicators for the location of the safety stock and its level would be identified based on the boundaries of the delivery performances.

This optimization model will be linear if there is only one raw material/semi-finished part and optimum point with minimum cost will happen only in one of the four boundaries. Based on this, we assume the optimization model as (7) with only one customer for finished part:

$$MinC = C_{si}q_i(1-P_i) + C_{oi}q_i(K_i - P_i) +$$
$$C_{spu}q_{pu}(1-K_{pu}) + C_{opu}q_{pu}(K_{pu} - (P_{pu}\times K_i))$$

$$SubjectTo:$$
$$K_i \le 1$$
$$K_i \ge P_i$$
$$K_{pu} \le 1$$
$$K_{pu} \ge P_{pu}\times K_i \tag{7}$$

Varying the location of the safety stock based on the optimum point in two sample cases of the linear model in (7) are shown with the following feasible regions in Figures.7and8. In addition, Table 2 presents the comparison between the costs in each of the cases and also the recommended location of the model for the safety stock. In this comparison, it is assumed that q_i and q_p are equal.

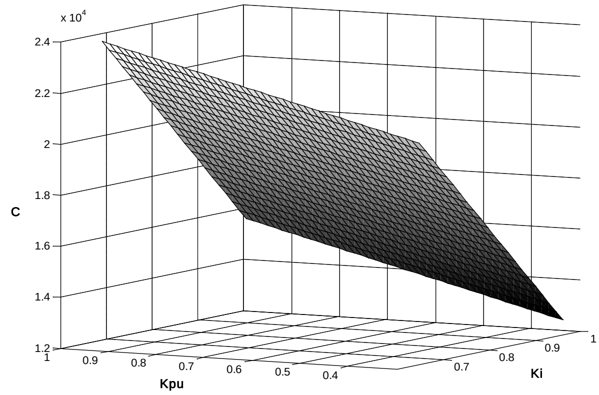

Figure 7 : Location of safety stock-Case 1

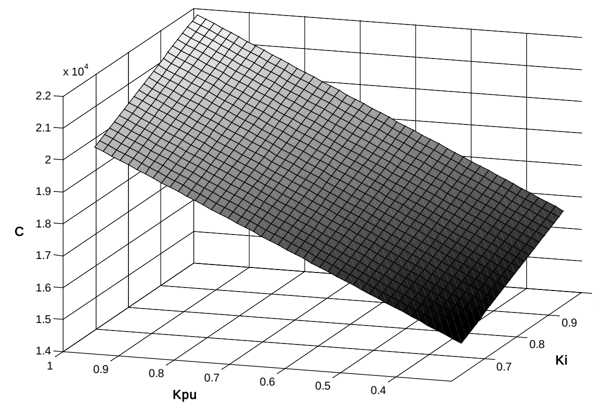

Figure 8 : Location of safety stock-Case 2

Table 2 : Costs Comparison and safety stock locations

Case	Costs Comparison	Safety Stock for Raw Material	Safety Stock for Finished Part
1	Cop>Csp>Csi>Cos	Yes	No
2	Cop>Coi>Csp>Csi	No	No

In order to make the results of the model more effective for the company, one of the most problematic finished product families of the Assembly was selected, and value streams of its finished parts that are going to be assembled were reviewed with the model. As each of the selected final product families could have 100 different value streams in the case company, it was decided to apply the optimization model only for those value streams that end with finished parts that were consistently in shortage report during last year in order to limit samples. Value streams of these pacer parts vary. Some of them could have only the supplier stage before the assembly and some others could be very long. As discussed before, these long value streams were limited by taking into account only parts of level 1 and 2 of its finished product's bill of materials (BOM).

VI. Computational Results

Results of the model applied to some value stream samples of one finished product family in the company are presented in Table 3. This table includes input factors to the model such as delivery performances (P_i,P_p), parts quantities (q_i, q_p), costs (C_s, C_o) along with parameters required to calculate them (K'_i, P'_p, K'_p, standard cost) for each value stream. This table also presents the old and new safety stock levels and total costs (for those cases that all required data were available)to compare previous situation with new one. All historical data presented in this table, as mentioned before in "Model Formulation" section,are based on last year records. In addition, recommendations of the model based on the analysis of the real cases are explained. Lingo 11.0 was used to solve the non-linear optimization model. It should be mentioned that due to confidentiality, masked data are used in this paper.

Table 3 : Computational Results

Value Stream	Part Code	Entity	K'i	Pi	qi	P'p	Pp	qp	K'p	Stnd Cost	Cs	Co	Old xi	New xi	Old xp	New xp	Total Old Cost	Total New Cost
VS1	B	MF	0.65	0.57	1400					$40	$2	$4	0 & 500	602			$497,732	$15,116
VS1	AB	ASSY				0.40	0.62	1100	0.53	$120	$500	$12			1 & 8	429		
VS1	AB	AFM				0.20	0.30	900	0.46	$120	$480	$12			300	630		
VS2	C	MF	0.22	0.22	5					$2,000	$25	$200	0	0			$28,257	$10,757
VS2	D	MF	0.24	0.24	7					$8,000	$30	$800	0	0				
VS2	ACD	ASSY				0	0	7	0	$15,000	$4,000	$1,500			1&2	7		
VS3	E	MF	0.55	0.31	200					$250	$10	$25	&160&34	138			$75,200	$3,450
VS3	AE	ASSY				0.57	1	170	0.57	$400	$1,000	$40			0	0		
VS4	F	MF	0.58	0.37	25					$500	$150	$50	5&9	16			$4,457.5	$913
VS4	AF	ASSY				0.59	1	12	0.58	$1,000	$450	$100			0	0		
VS4	AF	AFM				0.48	0.82	7	1	$1,000	$4,000	$100			24	2		
VS5	G	MF	0.30	0.30	12					$3,000	$45	$300	0	0			$150,378	$6,378
VS5	AG	ASSY				0	0	10	0	$6,000	$15,000	$600			0	10		
VS5	AG	AFM				0	0	0	0	$6,000	$24,000	$600			0	0		
VS6	H	MF	0.15	0.15	10					$4,000	$80	$400	0	9				$3,400
VS6	AH	ASSY				0.25	1	6		$10,000	$800	$1,000			1	0		
VS6	AH	AFM				0.38	1	5		$10,000	$40,000	$1,000			1	0		
VS7	I	MF	0.18	0.18	8					$3,500	$36	$350	0	7				$13,246
VS7	AI	ASSY				0.05	0.27	6		$25,000	$8,000	$2,500			1	5		
VS8	M	MF	0	0	12					$8,000	$15	$800	0	0				$19,980
VS8	AM	ASSY				0.09	0.09	11		$18,000	$6,000	$1,800			3&0&1	11		
VS9	T	MF	0.70	0.59	25					$2,000	$15	$20	6	10			$1,249	$468.96
VS9	L	MF				0.30	0.43	12	0.50	$300	$25	$30			4&3	7		
VS9	N	MF	0.70	0.53	12					$90	$2	$9	14&0&5	6				
VS9	S	MF	0.95	0.95	10					$160	$8	$16	0	1				
VS9	ALNS	ASSY				0.59	1	5	0.85	$3,500	$500	$350			6&3	0		

a) *Value Stream 1*

Shortage costs of ASSY and AFM (customers) are the first two highest costs; therefore, the model has targeted them at first and recommended that the delivery performances in those entities be increased to 100% by keeping safety stock for the finished parts. ASSY and AFM can count on receiving their required demand on time for 0.61% and 0.30% respectively; thus, they need to compensate the 0.39% and 0.70 % of *unavailability* of partsby asking manufacturing to keep safety stock.

Then, the third and fourth highest costs are the overage costs of the same entities. Hence, the model suggests keeping some level of safety stock in the raw material (semi-finished part) level as well to lower the level of finished parts' safety stocks. It is shown that procurement can count on on-time delivery performance of supplier(s) for 0.57% and they have to reimburse the remaining 0.43% by having safety stock. As in this case, safety stock has been increased in both levels of supplier and manufacturing, of course before applying the recommendations, the capacity of both should be checked in order to be aligned with the new level of demand and input respectively.

b) *Value Stream 2*

According to the priority of the costs, shortage should be removed for the Assembly entity by keeping safety stock for its required finished part. In this case, the manufacturing performance is zero; therefore, having safety stock for the rawmaterials' level in case of improving the input ration to this entity will not make any changes. Consequently, there is no choice but to pay for the holding cost for the finished part, although this holding cost is the second highest cost. On the other hand, as soon as manufacturing performance increases even slightly, the level of safety stock required for the finished part will decrease by recommending holding some safety stock for raw materials.

c) *Value Stream 3*

Again the highest cost is the shortage cost of the finished part and an action required to reduce this cost by making K_p(delivery performance) 100%. As the manufacturing performance is 100% (P_p=1) and based on the formula of $K_p = P_p \times K_i$, the only way to make K_p equal to 1 is by making K_i equal to 1. Therefore, having safety stock for raw material is recommended by the model for this purpose. In sum, in this case, the manufacturing entity has produced whatever they received from procurement; therefore, to improve their delivery performance, the input amount should be improved. Of course, for this kind of change, the capacity of manufacturing should be checked in order to be aligned with its input.

d) Value Stream 4

In this case, the highest cost is related to the shortage of finished part required for Aftermarket; hence, safety stock should be kept for this customer. Then, the biggest loss would happen if the company cannot deliver the required demand of ASSY; As manufacturing's performance in response to Assembly's demand is 100% and it can produce whatever it receives from procurement, delivery performance to ASSY will be improved only by increasing input of the raw material to manufacturing. To make a decision about the value of K_i, the model will hit the third highest cost which is the raw material's shortage cost. The selected value for K_i will also affect the level of required safety stock for Aftermarket.

e) Value Stream 5

Apparently, it is understood that there is no need for safety stock for Aftermarket as its demand for the next quarter is zero. But, it should be noted that as the manufacturing performance for this customer is zero, safety stock should be considered as soon as demand occurs. On the other hand, for the purpose of cost reduction, delivery performance to Assembly should become 100%. As the manufacturing performance in response to this customer is also zero, the full quantity of the finished part within the replenishment lead time should be kept as safety stock. By improving manufacturing's performance up to 50%, the level of safety stock required to be kept in finished part will be lowered but still there would not be any recommendation for keeping safety stock for raw material. But, as soon as manufacturing's performance increases by more than 50%, the model will suggest starting keeping safety stock in the raw material stage as well and balancing it to minimize the total cost.

f) Value Stream 6

Based on the investigation done for this case, it is known that raw material has quality problems most of the times. With this background, the result of the model does make sense: to keep safety stock in that level of the chain.

g) Value Stream 7

The model suggests balancing the level of safety stock by keeping it in both raw material and finished part levels and ensuring the on-time delivery to the customer, Assembly.

h) Value Stream 8

This value stream includes one raw material and one finished part with only one customer, Assembly, just as in Value Stream 7. As shown previously, safety stock was kept at both levels; but now the model is suggesting keeping safety stock for the finished part only. The reason is that manufacturing performance is almost zero and improving its input will never help to provide on time delivery to Assembly. On the other hand, holding cost of the raw material is really greater than its shortage cost; so, it is not beneficial even for lowering the level of finished part's safety stock.

i) Value Stream 9

This sample shows one of the class A finished parts required for Assembly for the selected product family. This finished part has three semi-finished parts (level 2 in finished product's BOM which are L, N, and S in Table 3). "L" is an in-house part and is manufactured in ABC. Furthermore, the manufacturing plant requires raw material (T) to produce this part which is procured through the supplier.Part T is in level 3 in the BOM. Therefore, this sample goes far beyond the limitation of levels 1 and 2, andshows that the model is applicable for all stagesof the value streams as long as the input data of the model are provided.

Manufacturing, receives the two other semi-finished parts (N and S) required forproducing the finished part directly through suppliers. Figures.9and 10present the respective value stream and BOM.

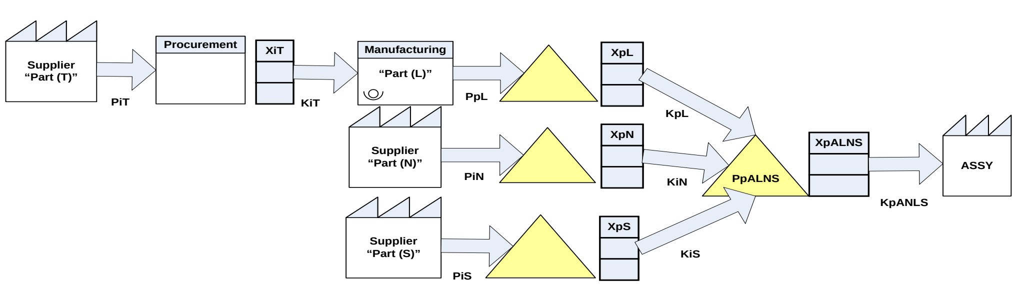

Figure 9 : Value stream

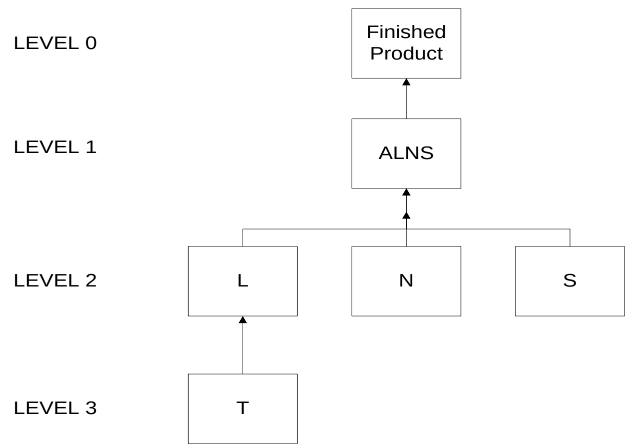

Figure 10 : Bom

Assume that there is a bottleneck in the first value stream in Figure. 9as the manufacturer does not have the capacity for the requested new level of demand. Then the other two value streams can make their delivery performances 100% by keeping safety stock, although the finished product cannot be cleared yet due to the pacer part of the first value stream (if there is no safety stock kept for the finished product). In this situation, there may be some complaints that safety stock must not be kept in the other value streams either since in the end, the company will pay for the holding costs while the finished product cannot be released. The response to this complaint is that if the first value stream comes out of the pacer situation, then another one will become the pacer due to not having safety stock. In essence, bottleneck always moves. Therefore, for this case, it makes sense to keep safety stock only for two of the value streams although the delivery performance of the finished part will not be 100% due to the low performance of the value stream with the bottleneck. On the other hand, by improving the delivery performances even only for two value streams out of three, holding cost of the finished part based on its formula ($C_{op}\times K_p$-($P_p\times K_1\times K_2\times K_3$)) will be decreased.

This last value stream (value stream 4), can be a representative case to illustrate the error and especially in this case, the overestimating of safety stock result in the analysis of parts in isolation and not within the chain. If, ALNS was being considered separately and apart of its chain, system may allocate some level of safety stock for that due to the K'_pwhich is 85%. But, when this part is analyzed within its chain, it is understood that the reason for no availability of the finished part is not due to the last stage performance but it is due to the low delivery performances of the semi-finished parts. Therefore, keeping safety stock in the last stage only increases the holding cost of the system.

VII. Validation

In this section, historical data on a raw material part will be used for analysis and compared to the results of the model.

As illustrated in Figure. 11, there were periods in the last 5 months during which the company was in shortage and had negative stock. There was no safety stock assigned to the part during these periods. On the other hand, the stock situation became better starting in week 14 by allocating 600 units of safety stock. Thus the theoretical safety stock was 0 and 600for this part during the last five months. The same analysis in the same period has been done for P_i and K'_i as shown in Figures.12and 13.

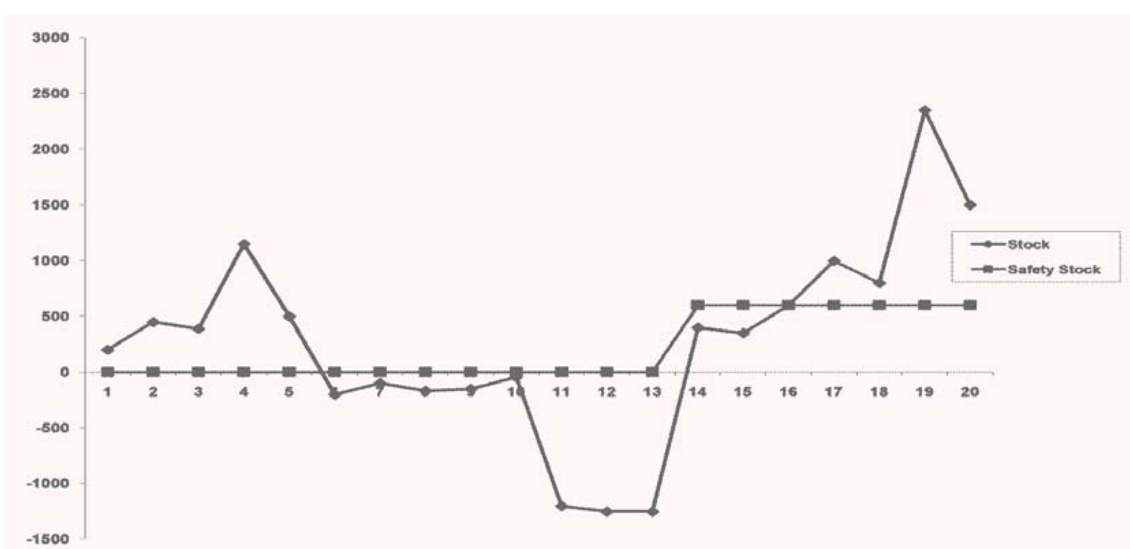

Figure 11 : Past stock situation and safety stock level

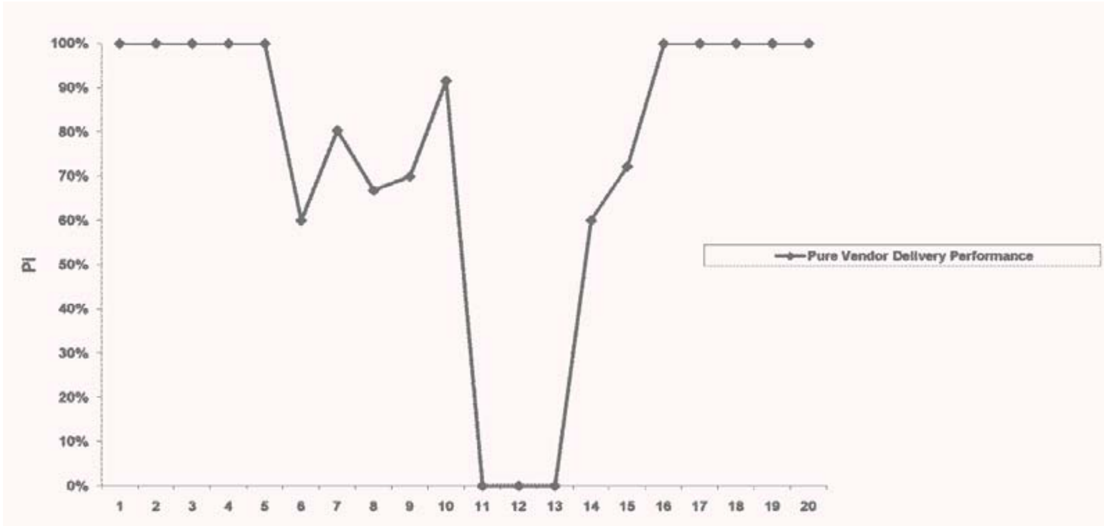

Figure 12 : Absolute part availability percentage without safety stock

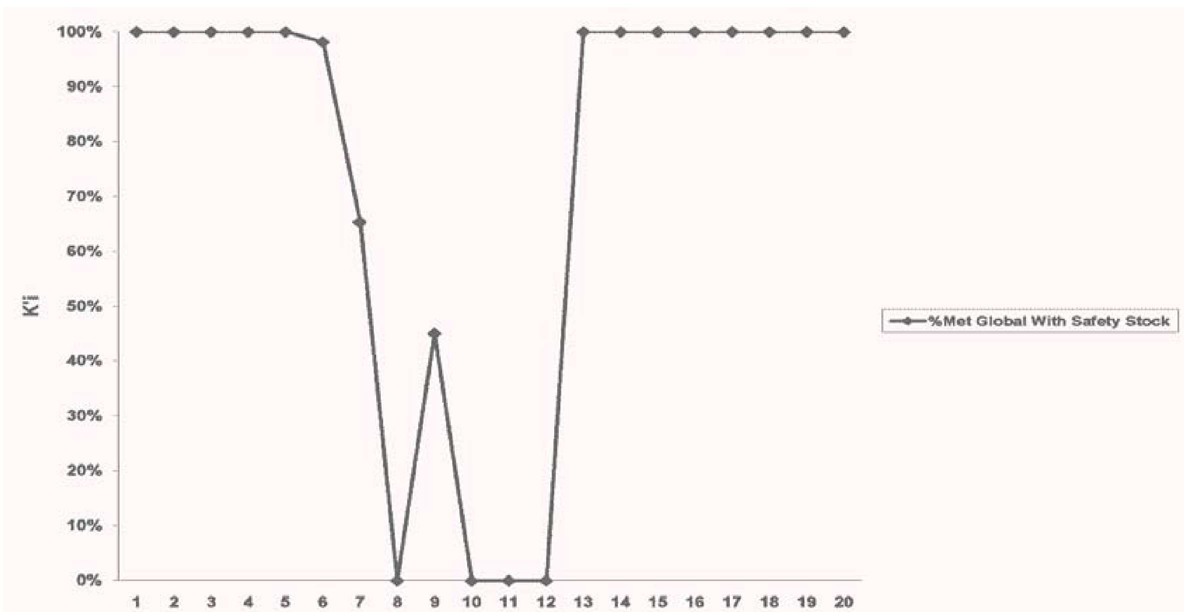

Figure 13 : Procurement delivery performance with safety stock

It can be seen that the weakness of part availability in weeks 13, 14, and 15 had been compensated by safety stock; although this weakness could not be remunerated previously as there was no safety stock. Therefore, it is concluded that by this amount of availability for this part, safety stock is essential to guarantee on-time delivery to manufacturing.

The optimization model was then run for the raw material's value stream. The result of the model was 394 pieces for the raw material's safety stock; but of course this level is based on the next quarter ratio of demand. Indeed, the lower level of safety stock recommended through the model is related to the maximum quantity of this part that will be required in the next three months based on the forecast. And this maximum number is being considered in the model to decide the level of safety stock to guarantee the worst case. On the other hand, it is shown through Figure. 13that by keeping 600 pieces of safety stock, the level of stock is going to be increased and this is not a desired case as holding cost is associated with this increase; therefore, lowering the level of safety stock does make sense.

Figures.14and 15show the historical data of three factors, FFR (%), safety stock fulfill rate (SS FR%), and number of parts with quality issues (QN in pieces) for three different parts. The messages of these charts are provided as well. These messages were aligned with the safety stock model's results obtained for the respective parts.

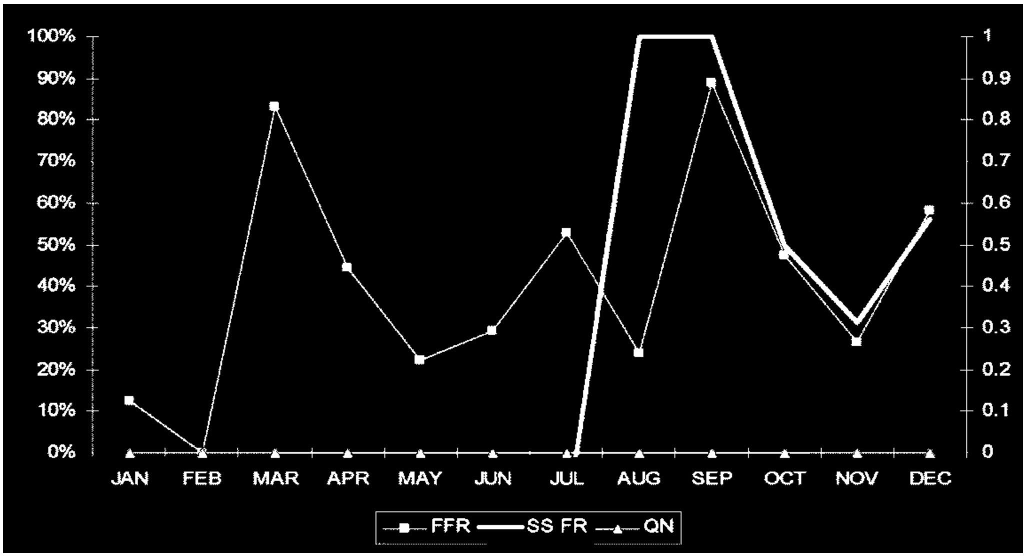

Figure 14 : FFR,SS FR, QN

*There is no quality issue.

*Buffer strategy is required to compensate the low delivery performance.

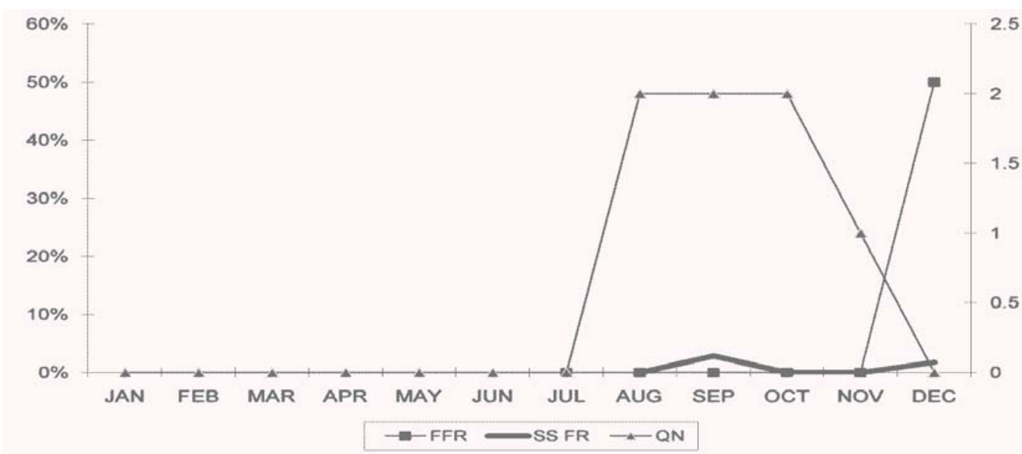

Figure 15 : FFR,SS FR, QN

* Low FFR can be improved by 50% if quality issues solved.

*Additional buffer may be required to increase FFR by 50% and make it 100%.

VIII. Discussion and Implications

The recommendations of the model are according to the current situation of the system. Of course as soon as the company takes action towards improving its system for parts availability within the chain, the results of the model for level and location of required safety stock will be adjusted accordingly.The managerial guidelines that are provided in this section can be used in any kind of manufacturing systems.

Re-sourcing of the suppliers would be a solution for their low delivery performances and quality problems. Increasing the capacity of manufacturing and improving its quality would be a solution for low availability percentage at semi-finished and finished parts level.

On the other hand, in the cases that the company requires keeping some level of safety stock due to the bad performance of vendors (low delivery performance, low quality), it is recommended that a VMI system be applied to have safety stock at the vendors' place.

The existing FFR report in the case company for the Aftermarket entity is based on their forecast demand instead of their firm orders; therefore, the model is not capturing the accurate delivery performance record for them. By deciding the level of safety stock based on the forecast demand, we will put safety stock on top of the safety stock because forecast demand is itself a kind of buffer stock. To solve this problem, it is recommended that ABC design an FFR report specifically for Aftermarket in order to capture the performances in response to only firm orders.

There may be some parts that are dual sourced and there is a quota arrangement between different suppliers, but the FFR report being used in the case company does not include the vendor field in its results. Therefore, it is recommended that the supplier field in the FFR report be considered as well to allow the company to recognize their delivery performances separately and consequently be able to make decisions about re-sourcing more accurately.

One of the other factors other than delivery performance or service level of the suppliers in making decisions in the dual source cases is the *waiting time*for receiving the late parts. Indeed, the company as a customer will select the supplier with the lower waiting time among the ones with the same service level. One way of tracking the waiting time of the supplier is through the calculation of the period within the replenishment lead time in that the company had negative stocks; but it is subject to keeping stock of each supplier separately to be able to relate its negative period to the corresponding supplier. Now consider a case that the supplier of a specific required raw material has the delivery performance of 50%, demand is one piece per week, its replenishment lead time is 10 weeks, and its waiting time is 2 weeks. Assume that the worst case for its q_i for the next quarter is 10 pieces. And again assume that itis the case that the model suggests keeping safety stock for the remaining 50% of the time that the supplier is late, which is equal to 5 pieces. This level of safety stock is equivalent to 5 weeks of demand, although the company will receive its late demand after 2 weeks according to the waiting time of the supplier. Therefore, the company does really need safety stock of 2 weeks instead of 5 weeks. Hence, no matter if it is a dual source case or not, it can be concluded that waiting time is also an important factor for determining the optimum safety stock.

If there is safety stock for the finished assembled product or it is scheduled for build ahead, sizing the required safety stock within the chain should be done by taking into account of these factors as well. One way to get them involved is by converting them to the weeks of demand for each stage and comparing them with the suggested amount of safety stock (like the method suggested for waiting time). But the time lag between the time that we put safety stock for the finished product (or build ahead) and the time that we will have it should also be considered; otherwise, reducing the safety stock within this period by will put the system in a shortage situation.

For some cases where unavailability of a part is solely related to the low delivery performances and not to quality issues, safety lead time can be applied instead of safety stock.

Delivery performances of some parts in their last stage are very low due to different engineering issues such as changing the layout and design consistently. Therefore, recommendation of the model to have safety stock for these parts will make sense only if the cost of reverse engineering of these parts is less than their shortage cost.

If the model suggests increasing the level of safety stock for a specific stage, the company will receive it by the end of the *total lead time* of the chain related to that part. Therefore, if the company adds the extra pieces of safety stock to its demand, it will allow all purchase orders to be expedited although this extra amount is not theactual demand and it is required for safety stock. Hence, the company must inform the suppliers that it needs this portion of demand for their next lead time. On the other hand, it is really important to take into account the lead time of the whole chain, otherwise, it will put them in a shortage situation. As a result, knowing the existence of this time lag makes the selection of the periods for calculating q_i and q_p more accurate. It should be noted that after selecting this appropriate period, standard cost of the parts should also be updated accordingly.

The q_i for those parts that are strategic ones should be validated with the responsible value stream managers. Indeed, quantities of this kind of parts could be really greater than the number which is result in through the mentioned definition for them. There are different indicators that make a part strategic such as the critical parts that are single sourced, or the parts that have limited suppliers or the parts with the resourcing strategy. For example, there could be a single sourced critical part which is received in a batch and based on the experience it is known that if one part of this batch has a quality issue, there is a high possibility that the entire batch needs to be scrapped. Therefore, by having correct level of safety stock for this part, the company can survive and save the supplier's lead time.

IX. Conclusions

This research extends the work of Aleotti Maia and Qassim (1998). They proposed a nonlinear safety stock optimization model for a system with n suppliers, one manufacturer and one customer with the objective of total inventory cost minimization. In this study we extended the model to be applicable to the whole supply chain of a generally structured multi-stage manufacturing system. Proper required index, parameters, and variables have been introduced and added more flexibility to the model implementation. In addition, the possibility of stock out for all materials at any stage of supply chain (raw material, semi-finished part or finished part) has been taken into account in the model of this study; although it was assumed previously that the material (raw material or semi-finished part) required by manufacturing is always available. This consideration makes the model more realistic. In this research, the safety stock optimization model is provided with the objective function of total logistic costs minimization to result in the optimal level and location of it across the supply chain. The constraints of the model provided for the boundaries of the delivery performances of each stage of the supply chain. Then, we applied the optimization model in a practical real-world problem with different possible value streams. We accurately defined the inputs of the model such as shortage and overage costs and also quantities of the parts. Lingo 11.0 was used to solve the non-linear optimization model.

The weakness of the supply chain must be compensated with safety stock, while it is optimized to meet the desired objective of the business. It has been shown in this paper that in optimizing the safety stock based on a cost minimization objective, not only its level but also its location in the supply chain is important. Indeed, by keeping safety stock in upstream stages, the company will save in holding costs. On the other hand, by keeping safety stock in downstream stages, it will save lead time. Therefore, these two options must be traded off towards optimizing safety stock location for minimizing the total logistics costs. Through this procedure, the company can improve its profitability and also become a superior competitor with its chain.

The first contribution of this paper is developing a nonlinear optimization safety stock model applicable for the whole supply chain. Thus, the applications are not limited to specific stages or levels of the chain. The second contribution of this study is applying the proposed safety stock optimization model to a real-world case company. Through this contribution, it has been shown that analysis of any part in isolation and not within the chain will result in errors (overestimating or underestimating) in safety stock calculation. It also proved that in optimizing the safety stock, not only its level but also its location within the supply chain is really critical.

The optimization model developed in this paper can be adjusted according to the requirements of different value streams of any supply chain. Therefore, it is applicable
to any kind of manufacturing system with the goal of creating flow in their supply chain and reducing logistic costs by applying lean principles.

If a part is procured through more than one supplier, the current model tracks their performance with only one average number representative of all of them. In future work, the model may be extended simultaneously by increasing the accessibility of the other required input data to decide on the level of safety stock foreach of these suppliers separately.

Due to the inaccessibility of the required data, the model is currently limited to the last two stages before the customer in the chain. Again, by enhancing the visibility and control of the upstream stages in the chain, the model can be applied for each specific part from its starting point until the end of the chain. Furthermore, by increasing the accessibility of the data, the cost of shortage of raw material/semi-finished part can be more accurate by adding the re-sequencing cost of manufacturing.

The cost of shortage of the finished part required by Assembly can be more precise by making the average days of shortage weighted based on the frequency of its occurrence (increasing or decreasing trend of shortage).

One of the avenues for future work for this research would be taking into account the factors of waiting time for receiving the late parts, safety stock for the finished assembled product, and build ahead in making the decision for the safety stock.

Sensitivity analysis would be helpful for this model. This kind of analysis will support the system for taking appropriate action towards improving the system. For example, it will help to find out that improving delivery performance even with a slight amount will make a big difference in the level of required safety stock and consequently saving costs for the system.

In order to have a high level view of safety stock kept across the chain, this model can be applied to the aggregate level of stages and entities involved in the chain instead of applying it to the part level. Indeed, q_i and q_p will be the total demand of the downstream stage in a specific period seen by its upstream stage (kits of parts instead of one part). Delivery performances will be delivery performance of each stage to its downstream stage in respond to its whole demand. The parts that were historically pacers with the maximum number of shortages within the total demand of each stage will be selected as the representatives for calculating the shortage and overage costs of the stages for determining the location of safety stock.

X. Appendix

Now, assume a case that there are two different finished parts manufactured in the same plant and they require a common raw material. Model formulation and value stream for this case would be as (8) and Figure. 16:

$$MinC = C_{si}q_i(1-P_i) + C_{oi}q_i(K_i - P_i) + \sum_{p=1}^{2} C_{spu}q_{pu}(1-K_{pu}) + \sum_{p=1}^{2} C_{opu}q_{pu}(K_{pu} - (P_{pu} \times K_i)) \quad (8)$$

$$SubjectTo:$$
$$K_i \le 1$$
$$K_i \ge P_i$$
$$K_{pu} \le 1, \qquad p = 1,2$$
$$K_{pu} \ge P_{pu} \times K_i, \qquad p = 1,2$$

Procurement sees the summation of demands for both finished parts through manufacturing at once and not separately. Therefore, mathematical proof of (9) is provided to make sure that the used formulation is accurate. Indeed, it is shown that manufacturing plant absorbs the input ration of the raw material based on its performance for each finished part:

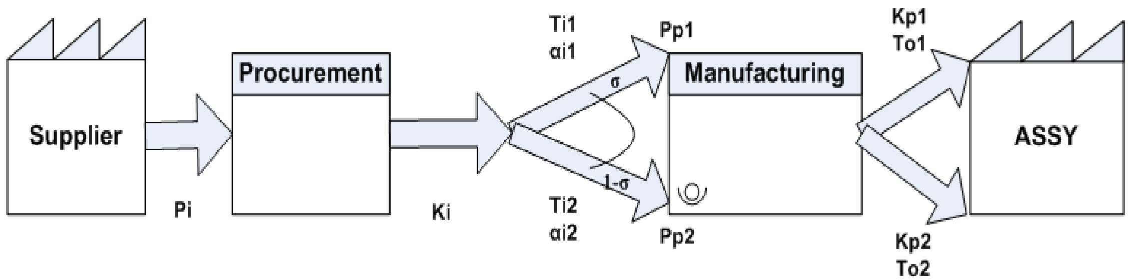

Figure 16 : Value Stream

$$T_i = Total\ Input$$
$$\alpha_i = Input\ On\ Time$$

$$T_{o_1} = Total\ Output\ 1$$
$$\alpha_{o_1} = Output\ On\ Time$$

$$T_{o_2} = Total\ Output\ 2$$
$$\alpha_{o_2} = Output\ On\ Time$$

$$K_i = \frac{\alpha_i}{T_i}, \quad K_{p_1} = \frac{\alpha_{o_1}}{T_{o_1}}, \quad K_{p_2} = \frac{\alpha_{o_2}}{T_{o_2}}$$
$$T_{o_1} + T_{o_2} = T_i \qquad (Input = Output)$$
$$\alpha_{o_1} \ge \alpha_{i_1} \times P_{p_1} \qquad Because\ of\ Safety\ Stock$$
$$\alpha_{o_2} \ge \alpha_{i_2} \times P_{p_2} \qquad Because\ of\ Safety\ Stock$$
$$\alpha_{i_1} = \sigma \times \alpha 1$$
$$\alpha_{i_2} = (1-\sigma) \times \alpha_i$$

$$T_{i_1} = \sigma \times T_i = T_{o_1}$$
$$T_{i_2} = (1-\sigma) \times T_i = T_{o_2}$$

$$K_{p_1} = \frac{\alpha_{o_1}}{T_{o_1}} = \frac{\alpha_{o_1}}{\sigma \times T_i} \geq \frac{\alpha_{i_1}}{\sigma} \times \frac{P_{p_1}}{T_i}$$
$$= \frac{\sigma}{\sigma} \times \frac{\alpha_{i_1}}{T_i} \times P_{p_1} = P_{p_1} \times K_i$$

$$K_{p_1} \geq P_{p_1} \times K_i$$

$$K_{p_2} = \frac{\alpha_{o_2}}{T_{o_2}} = \frac{\alpha_{o_2}}{\sigma \times T_i} \geq \frac{\alpha_{i_2}}{\sigma} \times \frac{P_{p_2}}{T_i}$$
$$= \frac{\sigma}{\sigma} \times \frac{\alpha_{i_2}}{T_i} \times P_{p_2} = P_{p_2} \times K_i \qquad (9)$$

$$K_{p_2} \geq P_{p_2} \times K_i$$

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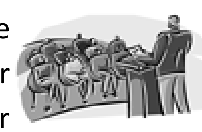

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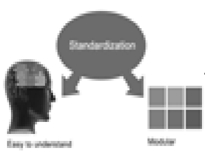

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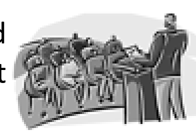

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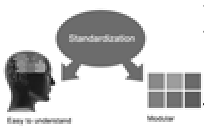

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All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

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- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.

- Do not give permission to anyone else to "PROOFREAD" your manuscript.

- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

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