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Highlights

A Probabilistic Approach

Method in Apparel Industry

Discovering Thoughts, Inventing Future

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A Probabilistic Approach to Portfolio Optimization under Epistemic Uncertainty

By Rajan Kumar Saha & Montasir Mamun Mithu
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Abstract- Portfolio is an appropriate collection or list of investments held by an organization or an individual where Portfolio optimization means to calculate the optimal weights for the collection or list of investments that gives the highest return with least risk. In previous works on this topic did not consider correlation factor and epistemic uncertainty on returns. In our model both the factors are considered because correlation between the assets exists in real life and epistemic uncertainty may exist in different rate of return of different assets. In this work two models are developed to optimize a portfolio. Two models are Optimization model without EU and Optimization model with EU. By optimization we can decide the assets on which we can invest, how much to invest and can take divestment decisions.

Keywords: portfolio epistemic uncertainty (EU) covariance correlation.

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APROBABILISTICAPPROACHTOPORTFOLIOOPTIMIZATIONUNDEREPISTEMICUNCERTAINTY

A Probabilistic Approach to Portfolio Optimization under Epistemic Uncertainty

Rajan Kumar Saha [α] & Montasir Mamun Mithu [σ]

Abstract- Portfolio is an appropriate collection or list of investments held by an organization or an individual where Portfolio optimization means to calculate the optimal weights for the collection or list of investments that gives the highest return with least risk. In previous works on this topic did not consider correlation factor and epistemic uncertainty on returns. In our model both the factors are considered because correlation between the assets exists in real life and epistemic uncertainty may exist in different rate of return of different assets. In this work two models are developed to optimize a portfolio. Two models are Optimization model without EU and Optimization model with EU. By optimization we can decide the assets on which we can invest, how much to invest and can take divestment decisions.

Keywords: portfolio epistemic uncertainty (EU) covariance correlation.

I. Introduction

Portfolio is an appropriate collection or list of investments held by an organization or an individual. Portfolio optimization means to calculate the optimal weights for the collection or list of investments that gives the highest return with least risk. In this work we have used a probabilistic approach to optimize the portfolio. Existing models on this topic by other authors [e.g., 1] did not consider correlation factor and epistemic uncertainty on returns. In our model both the factors are considered. Epistemic uncertainty is the situation where we do not do things correctly. Epistemic uncertainty results in data because of not measuring a quantity with sufficient accuracy, or because of building a model by neglecting certain effects, or because of hidden data. Moreover in "portfolio optimization (2 Assets)" by Markowitz [1] proportion of investment was calculated with considering a riskless asset and two risky assets. In another paper [2] optimization of investments were calculated by the linear combination of the assets. This means in that model the co-variances of assets were not considered. Covariance measures the specified value by which two random variables change together. In our model co-variances between assets are considered. Kawas and Thiele [3] developed Log robust model for both the independent and correlated assets to optimize the portfolio. The continuous probability distribution of a random variable whose logarithm is normally distributed is called Log normal distribution [4]. They had considered the uncertainty on the rate of return. But Log robust model incorporates the randomness in the rate of returns of the assets. In our model no trends in the rate of return is required. Buckley et al [5] formulated the optimization of the investment where the rates of return of the assets have Gaussian mixture distribution. The continuous probability distribution that has a bell shaped probability density function is known as Gaussian distribution [6]. In our model we have considered that the rate of return or the range of rate of return will be known.

II. Epistemic Uncertainty (EU), Correlation and Covariance

a) Epistemic Uncertainty (EU)

Epistemic uncertainty is the situation where we do not do things correctly. Epistemic uncertainty results in data because of not measuring a quantity with sufficient accuracy, or because of building a model by neglecting certain effects, or because of hidden data [7]. In our model epistemic uncertainty exists in the rate of returns of assets. We do not know what will be the future rate of return of an asset. Moreover, we have used the rate of return on particular time interval where the rate of return is changing continuously. Therefore, by considering the epistemic uncertainty we will know the range of rate of return for an asset rather than the particular rate of return.

b) Correlation

One of the most commonly used statistics is correlation. It measures and describes the degree of relationship between two variables. To compute the correlation of two variables „Pearson's product-moment" method can be used. "Pearson's product-moment" correlation is computed by dividing the covariance with standard deviation [8].

$$\text{So, } corr(x,y) = \frac{\operatorname{cov}(x,y)}{\sigma_x * \sigma_y} = [\, n*\Sigma xy - (\Sigma x)(\Sigma y) / \sqrt{([n*\Sigma x^2 - (\Sigma x)^2][n*\Sigma y^2 - (\Sigma y)^2])}] \quad (1)$$

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Here,

corr(x,y) = Correlation between x and y

cov(x,y) = covariance of x and y

σ_x = standard deviation of x

σ_y = standard deviation of y

n = Number of values or elements

x = First Score

y = Second Score

Σxy = Sum of the product of first and Second Scores

Σx = Sum of First Scores

Σy = Sum of Second Scores

Σx^2 = Sum of square First Scores

Σy^2 = Sum of square Second Scores

Correlation is +1 in the case of a positive or increasing linear relationship, −1 in the case of a decreasing or negative linear relationship and some value between −1 and 1 in all other cases, indicating the degree of linear dependence between the variables. As it approaches zero, it implies that there is no relationship. The closer the coefficient is to either −1 or 1, the stronger the correlation between the variables.

c) Covariance

Covariance measures the specified value by which two random variables change together. If larger values of one variable correspond to the larger values of the other variable and the same holds for the smaller values, the covariance is positive. In the opposite case, when the larger values of one variable correspond to the smaller values of the other, the covariance is negative. Therefore, the sign of the covariance shows the trend in the linear relationship between the variables. Covariance can be calculated as follows [9]:

$$Cov(x,y) = E[(x-E[x])(y-E[y])] \quad (2)$$

$$Cov\,(x,y) = E[xy]-E[x]*E[y] \quad (3)$$

Here,

Cov(x,y) = Covariance of x and y

E[x] = Mean of x

E[y] = Mean of y

E[xy] = Mean of xy

III. Model Structure

Optimization refers to the selection of a best element from some set of available alternatives. Portfolio is an appropriate collection or list of investments held by an organization or an individual. Portfolio optimization means to calculate the optimal weights for the collection or list of investments that gives the highest return with least risk. We have developed two models for portfolio optimization:

1. Optimization Model without EU
2. Optimization Model with EU

a) Optimization Model without EU

Let us assume that a set of *n* assets and a sum of money are given, which to be invested to maximize the total return on investment. We have to find the investment proportions *xi* (*i* = 1, 2...*n*) to be invested in assets *i* = 1, 2 ...*n* so that the total return on investment over a period is maximized. It is not possible to determine with certainty because the actual returns of the assets are not known. However, if we assume that the expected returns of the assets and their variances and co-variances are known, we can calculate the investment proportions that results in high expected return with low variance. As the model does not consider epistemic uncertainty, we know the specified value of the returns. In this model we will maximize the total return while simultaneously minimizing the risk.

Let,

n = Number of available assets

r_i = Expected return of assets

x_i = Fraction of the capital invested in asset i

σ_{ij} = The covariance of the return for assets i and j

Therefore, the optimization formulation becomes,

$$Max\, f_1(x) = w*\sum x_i * r_i - v*\sum\sum \sigma_{ij} * x_i * x_j \quad (4)$$

Subject to,

$$f_2(x) = \sum\sum \sigma_{ij} * x_i * x_j \le \varepsilon \quad (5)$$

$$\sum x_i = 1 \quad (6)$$

$$x_i \ge 0 \quad (7)$$

where i and j = 1, 2 ……n

Here,

w and v are the weighting coefficients that represent the relative importance of the total return and the risk respectively, where $w+v = 1$

If $Smin$ and $Smax$ are the minimum and maximum attainable values of $f_2(x)$

then $\varepsilon \in [S_{min}, S_{max}]$

By using Equ. (3) we can calculate the co-variances of the assets.

b) Optimization Model with EU

In this model we have used multi objective functions. There are a number of method by which this optimization can be done like Deterministic design optimization, Robustness-based design optimization, Robustness-based design optimization under data uncertainty, Robustness-based design with sparse point data, Determination of optimal sample size for sparse point data, Robustness-based design with interval data [10]. We have used Robustness-based design optimization under data uncertainty. Let us assume a set of n assets and a sum of money are given, which are to be invested to maximize the total return on investment. As the model considers the epistemic uncertainty, we know the specified value of the returns of some assets and a range of the returns for the rest number of assets. Let a set of p assets whose specified return values are known and a set of q assets whose range of returns are known [where $p+q = n$]. We have to find the investment proportions xi to be invested in assets $i = 1, 2 ...n$ so that the total return on investment over a period is maximized. Therefore, we consider additional constraints in this model. The solution is obtained by simultaneously solving two objective functions. We have to find the proportion of investments in one function, the returns and co-variance of asset set q in another function. As for the asset set q, the ranges of returns are known; we can get the range of co-variances for asset set q.

Let,

n = Number of available assets

r_i = Expected return of assets

x_i = Fraction of the capital invested in asset i

σ_{ij} = The covariance of the returns of assets i and j

lb = lower bound of returns for asset set q

ub = upper bound of returns for asset set q

Therefore, the objective function 1 becomes,

$$\underset{x_i}{\arg Max} f_1(x) = w*\sum x_i * r_i - v*\sum\sum \sigma_{ij} * x_i * x_j \quad (8)$$

Subject to,

$$f_2(x) = \sum\sum \sigma_{ij} * x_i * x_j \le \varepsilon \quad (9)$$

$$\sum x_i = 1 \quad (10)$$

$$x_i \ge 0 \quad (11)$$

where i and $j = 1, 2 ......n$

And the objective function 2 becomes,

$$\underset{r_k, \sigma_{ij}}{\arg Max} f_3(x) = w*\sum x_i * r_i - v*\sum\sum \sigma_{ij} * x_i * x_j \quad (12)$$

Subject to,

$$f_2(x) = \sum\sum \sigma_{ij} * x_i * x_j \le \varepsilon \quad (13)$$

$$lb_k \le r_k \le ub \quad (14)$$

$$min\ \sigma_{ij} \le \sigma_{ij} \le max\ \sigma_{ij} \quad (15)$$

where k is the asset identity of asset set q.

For the asset set q described by epistemic uncertainty, the additional constraints in Eqs. (14) and (15) are incorporated in to the model.

Here,

w and v are the weighting coefficients that represent the relative importance of the total return and the risk respectively, where $w+v = 1$

If $Smin$ and $Smax$ are the minimum and maximum attainable values of $f_2(x)$ then $\varepsilon \in [S_{min}, S_{max}]$

We can calculate the co variances of the assets by Equ (3).

IV. Numerical Data Analysis

a) Model of Optimization without EU

Under this model we do not consider the epistemic uncertainty. That means we know the specified value of the returns for assets.

Example Problem 1

Let, we have two assets (mutual funds). We will use the EPS (Earning Per Share) values as the rate of return.

The earnings per share (EPS) values from year 1 to 10 (10 values) of two mutual funds named 2NDICB and 3RDICB are as follows:

Table 1 : EPS value of 2NDICB and 3RDICB

YEAR	2NDICB	3RDICB
1	89.32	45.01
2	70.75	54.04
3	41.06	53.41
4	48.86	42.74
5	78.77	41.21
6	80.75	52.31
7	66.06	66.10
8	76.15	69.11
9	107.14	92.86
10	135.55	121.40

In the following discussion, we solve the above problem using our proposed model that does not consider the epistemic uncertainty.

Average rate of return:

Here, $r_1 = 79.441$ and

$r_2 = 63.819$ (mean values)

Covariance:

As we know, $\sigma_{ij} = E(xy) - E(x)*E(y)$

Here, $E(x) = 79.441$; $E(y) = 63.819$ and $E(xy) = 5562.914$

So, $\sigma_{12} = \sigma_{21} = 493.07$; $\sigma_{11} = 2906.9$; $\sigma_{22} = 583.79$.

Optimized portfolio:

By using (4), (5), (6) and (7) the equations become:

$Max\ f_1(x) = w*(79.441*x_1+63.819*x_2) - v*(2906.9*x_1^2+986.14x_1x_2+583.79*x_2^2)$

Subject to,

$f_2(x) = 2906.9*x_1^2+986.14x_1x_2+583.79*x_2^2 \leq \varepsilon;$

Letting x_1 and $x_2 = .5$; ε becomes 1119.21.

$x_1+x_2 = 1;\quad x_1$ and $x_2 \geq 0$.

By using MATLAB code we get,

Table 2 : Value of x1 and x2 by MATLAB code

w	*v*	x_1	x_2	Optimized return
1	0	.5	.5	-71.63
.1	.9	.0366	.9634	516.0148
.2	.8	.0370	.9630	451.5250
.3	.7	.0376	.9624	387.0342
.4	.6	.0383	.9617	322.5419
.5	.5	.0393	.9607	258.0474
.6	.4	.0409	.9591	193.5487
.7	.3	.0435	.9565	129.0420
.8	.2	.0487	.9513	64.5149
.9	.1	.0643	.9359	-.0933
0	1	.0362	.9638	580.5039

b) Model of Optimization with EU

Under this model we will consider the epistemic uncertainty. So we know the specified value of the returns of some assets and a range of the returns for the rest number of assets.

Example Problem 2

Let, we have three assets (asset 1, asset 2 and asset 3). The rate of return of asset 1 and 2 are known. But we know the limit of the rate of return of asset 3.

Table 3 : The rates of returns of asset 1 and asset 2

Rate of return of asset 1	Rate of return of asset 2
89.32	45.01
70.75	54.05
41.06	53.41
48.86	42.74
78.77	41.21

Table 4 : The limits of asset 3

Lower limit	Upper limit
62	71
60	72
61	75
59	73
58	70

In the following discussion, we solve the above problem using our proposed model that considers the epistemic uncertainty.

Average rate of return:

Average rate of return of asset 1 (r_1) = 65.75

Average rate of return of asset 2 (r_2) = 47.28

But we will have a limit for the rate of return of asset 3.

Lower limit of the average rate of return of asset 3 *(lb)* = (62+60+61+59+58)/5 = 60

Upper limit of the average rate of return of asset 3 *(ub)* = (71+72+75+73+70)/5 = 72.2

Covariance

If we want to optimize the assets portfolio then we have to determine six co variances.

Table 5 : Co-variances for Example Problem 2

1	σ_{11}
2	$\sigma_{12} = \sigma_{21}$
3	$\sigma_{13} = \sigma_{31}$
4	σ_{22}
5	$\sigma_{23} = \sigma_{32}$
6	σ_{33}

We can easily calculate σ_{11}, σ_{22} and $\sigma_{12} = \sigma_{21}$ because we know the mean rate of return of asset 1 and 2. But we can know the lower (minimum value) and the upper (maximum value) limit of σ_{33}, $\sigma_{13} = \sigma_{31}$ and $\sigma_{23} = \sigma_{32}$ because we know the limit for asset 3.

$$\sigma_{ij} = E\,(xy) - E\,(x) * E\,(y).$$

So, $\sigma_{11} = 329.25;$

$\sigma_{22} = 29.58;$

$\sigma_{12} = \sigma_{21} = -34.31$

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Now we will calculate the limit for σ_{33}, $\sigma_{13} = \sigma_{31}$, $\sigma_{23} = \sigma_{32}$.

σ_{33} can easily calculated by using the MATLAB code.

By solving, the limit for σ_{33} = [4*e-10, 245.2];

To solve $\sigma_{13} = \sigma_{31}$ and $\sigma_{23} = \sigma_{32}$ we have to know the maximum and minimum value of *E(13)* and *E(23)*.

Solving by MATLAB we get *E(13)* = *E(31)* = [3947.8, 4719.2];

Similarly, *E(23)* = *E(32)* = [2840.7, 3419.6];

So we get, $\sigma_{13} = \sigma_{31}$ = [-799.39, 774.2] and $\sigma_{23} = \sigma_{32}$ = [-572.92, 582.8].

<u>Optimized portfolio:</u>

We will construct two objective functions to optimize the returns.

By using Eqs. (8), (9), (10) and (11) we get,

$$\max_{x_1, x_2, x_3} f_1(x) = w*(r_1*x_1+r_2*x_2+r_3*x_3) - v*(x_1^2*\sigma_{11}+x_2^2*\sigma_{22}+x_3^2*\sigma_{33}+2*x_1*x_2*\sigma_{12}+2*x_2*x_3*\sigma_{23}+2*x_3*x_1*\sigma_{31}) \quad (16)$$

Subject to,

$w*(r_1*x_1+r_2*x_2+r_3*x_3) -$

$v*(x_1^2*\sigma_{11}+x_2^2*\sigma_{22}+x_3^2*\sigma_{33}+2*x_1*x_2*\sigma_{12}+2*x_2*x_3*\sigma_{23}+2*x_3*x_1*\sigma_{31}) \leq 994.26;$

$x_1+x_2+x_3 = 1;$

$x_1, x_2, x_3 \geq 0.$

By using w =.5 and v =.5 with assumed value of x_1, x_2, x_3; we get ε = 994.26.

By using Eqs. (12), (13), (14) and (15) we get,

$$\min_{r_3, \sigma_{33}, \sigma_{23}, \sigma_{31}} f_1(x) = w*(r_1*x_1+r_2*x_2+r_3*x_3) - v*(x_1^2*\sigma_{11}+x_2^2*\sigma_{22}+x_3^2*\sigma_{33}+2*x_1*x_2*\sigma_{12}+2*x_2*x_3*\sigma_{23}+2*x_3*x_1*\sigma_{31}) \quad (17)$$

Subjected to,

$60 \leq r_3 \leq 72.2;$

$-572.92 \leq \sigma_{23} \leq 582.8;$

$-799.39 \leq \sigma_{31} \leq 774.2;$

$4*e\text{-}10 \leq \sigma_{33} \leq 245.2;$

$w*(r_1*x_1+r_2*x_2+r_3*x_3) -$

$v*(x_1^2*\sigma_{11}+x_2^2*\sigma_{22}+x_3^2*\sigma_{33}+2*x_1*x_2*\sigma_{12}+2*x_2*x_3*\sigma_{23}+2*x_3*x_1*\sigma_{31}) \leq 994.26;$

By using MATLAB code we can calculate the value of x_1, x_2, x_3 from Equ. (16) to use them in Equ. (17) and simultaneously calculating the value of $r_3, \sigma_{33}, \sigma_{23}, \sigma_{31}$ to use them in Equ. (16). Thus we can calculate the optimum return.

V. Findings

To calculate the optimal weights for the collection or list of investments that gives the highest return with least risk is called portfolio optimization. In this work we have used a probabilistic approach to optimize the portfolio. We have developed two models to optimize the asset portfolio. The two models optimize the portfolio in different approach. One considers the epistemic uncertainty and the other does not consider the epistemic uncertainty. By using these models we can optimize the portfolio of different investments, different shares. If we look through the results then we can see how the results define how much to invest in which asset.

Firstly, the two models optimize the portfolio by considering not only the rate of returns but also the risks. We have considered the risk portion in the constraint area from where we can minimize it and simultaneously we have considered it in the objective function also.

Secondly, we have not only calculated the range of co variances but also optimized the values of the co variances. The risks become less while the co variances become less.

Thirdly, we have shown the examples of the models by using two or three assets. However, the models can optimize as many assets as are there. But in that case we have to calculate the co variances with proper situation. That means we have to calculate the co variances by considering whether there exists epistemic uncertainty or not.

Fourthly, in the second model "Optimization Model with EU" we have considered the epistemic uncertainty. We have optimized the proportions of investments with simultaneously optimizing the co variances and the rate of returns for the assets under uncertain returns. We could optimize the co variances and rate of returns for the assets under uncertain returns by considering a separate objective functions and not considering the proportions of assets. In that case the calculation will be simpler than the present calculation but we will not have a properly optimized solution.

Finally, in optimizing the portfolio we have considered two notations w and v, where they are weighting coefficients that represent the relative importance of the objective functions. That means w and v represent the relative importance of the total return and the risk respectively. If we have a portfolio where the risk part has less importance then we can use a lower v value than the w value. And if we have a portfolio where the risk part has a greater importance then we can use a v value with comparison to the w value.

So the models optimize a portfolio regardless the number of assets by both considering and not considering the epistemic uncertainty, giving relative importance factor to the total return part and the risk part.

VI. Conclusion

Optimization refers to the selection of a best element from some set of available alternatives. Portfolio is an appropriate collection or list of investments held by an organization or an individual. Portfolio optimization means to calculate the optimal weights for the collection or list of investments that gives the highest return with least risk. In this work we have developed two models using probabilistic approach to optimize the portfolio. As we have stated earlier the findings of my thesis that the models optimize a portfolio regardless of the number of assets by both considering and not considering the epistemic uncertainty, giving importance factor to the total return part and the risk part. By using these models we can optimize the portfolio of investments, shares etc. We can know the proportions of investment on particular assets in efficient way that minimizes the risk on profitability. However, the models use discrete time interval values of the rate of returns. Moreover, the code used for the model "Optimization Model with EU" is not more flexible. Further research can be done by developing the model for the continuous values of the rate of return and developing the code for the model "Optimization Model with EU" by incorporating more flexibility.

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Improving Quality and Productivity in Manufacturing Process by using Quality Control Chart and Statistical Process Control Including Sampling and Six Sigma

By Ghazi Abu Taher & Md. Jahangir Alam
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Keywords: statistical process control, control chart, tqm, 6-sigma, sampling, histogram, pareto diagram, cause and effect diagram, AQL, LTPD, process performance index, process potential index, process centering index.

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Ghazi Abu Taher [α] & Md. Jahangir Alam [σ]

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Keywords: statistical process control, control chart, tqm, 6-sigma, sampling, histogram, pareto diagram, cause and effect diagram, AQL, LTPD, process performance index, process potential index, process centering index.

I. Introduction

The art of meeting customers' specification, which today is termed "quality". Quality is the symbol of human civilization, and with the progress of human civilization, quality control will play an incomparable role in the business. It can be said that if there is no quality control, there is no economic benefit. In the current world of continually increasing global competition it is imperative for all manufacturing and service organizations to improve the quality of their products. Construction projects are an extremely complex process, involving a wide range. There are plenty of factors affecting the quality of construction, such as design, materials, machinery, construction technology, methods of operation, technical measures, management systems, and so on. Because of the fixed project location, large volume and differen t location of different projects, the poor control of these factors may produce quality problems. During controlling the whole process of construction, only accord with the required quality standards and user promising requirements, fulfilling quality, time, cost, etc., construction companies could get the best economic effects. Construction companies must adhere to the principle of quality first, and insist on quality standards, with the core of artificial control and prevention, to provide more high quality, safe, suitable, and economic composite products.

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II. Objectives

The main purposes in accomplishing this study are shown below:

- To implement industrial engineering tools in selected manufacturing company.
- To identify the highest frequency of defects occurs at the workstations.
- To propose new methods to the selected manufacturing company.
- To improve the productivity of the company.

III. Quality Control

Because of the negative consequences of poor quality, organizations try to prevent and correct such problems through various approaches to quality control. Broadly speaking, quality control refers to an organization's efforts to prevent or correct defects in its goods or services or to improve them in some way. Some organizations use the term quality control to refer only to error detection, whereas quality assurance refers to both the prevention and the detection of quality problems. Organizations must have a department or employee devoted to identifying defects and promoting high quality. In these cases, the supervisor can benefit from the expertise of quality-control personnel. Ultimately, however, the organization expects its supervisors to take responsibility for the quality of work in their departments. In general, when supervisors look for high-quality performance to reinforce or improvements to make, they can focus on two areas: the product itself or the process of making and delivering the product.

a) Product Quality Control

An organization that focuses on ways to improve the product itself is using product quality control. Computer technology can greatly improve product quality control.

b) Process Control

An organization might also consider how to do things in a way that leads to better quality. This focus is called process control. The spur gear manufacturing company might conduct periodic checks to make sure its employees understand good techniques for setting up the machines. A broad approach to process control involves creating an organizational climate that encourages quality.

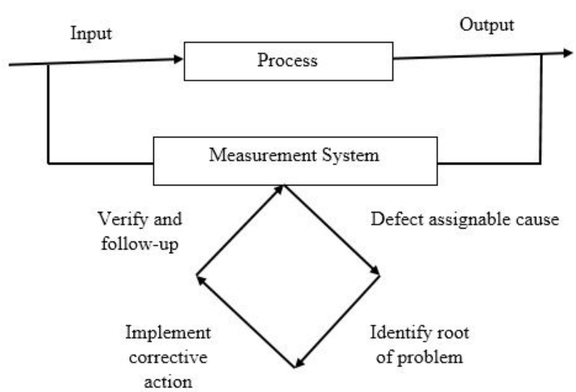


Figure 1 : Process improvement using the control chart

Process control techniques can be very effective. At Accurate Gauge and Manufacturing, process control is an important part of the company's efforts to plan for quality and correct the causes of defects in the precision parts it manufactures for heavy equipment and commercial and automotive vehicles. Quality teams meet weekly to prevent problems, but some process improvements are responses to problems. Even when a failure occurred in a product line the company was preparing to phase out, engineering manager led efforts to correct the process by setting up procedures for operators to check the parts were being produced. In addition to impressing the customer with this extreme commitment to quality, the effort established a process that became the standard procedure for making other defect-free parts.

IV. Consequences of Poor Quality

The consequences of poor quality are grave and of many folds in business term. Some are worth explaining [1]:

- Lower productivity.
- Loss of productive time.
- Loss of material.
- Loss of business.
- Liability.

V. Quality Improvement Methods

Within this broad framework, managers, researchers, and consultants have identified several methods for ensuring and improving quality. Today most organizations apply some or all of these methods, including statistical quality control, the zero-defects approach, employee involvement teams, Six Sigma, and total quality management.

a) Statistical Quality Control

It rarely makes economic sense to examine every part, finished good, or service to ensure it meets quality standards. For one thing, that approach to quality control is expensive. In addition, examining some products can destroy them. As a result, unless the costs of poor quality are so great that every product must be examined, most organizations inspect only a sample. Looking for defects in parts, finished goods, or other outcomes selected through a sampling technique is known as statistical quality control. The most accurate way to apply statistical quality control is to use a random sample. This means selecting outcomes (such as parts or customer contacts) in a way that each has an equal chance of being selected. The assumption is that the quality of the sample describes the quality of the entire lot [2].

b) Zero defect approach

A broad view of process quality control is that everyone in the organization should work toward the goal of delivering such high quality that all aspects of the organization's goods and services are free of problems. The quality-control technique based on this view is known as the zero-defects approach. An organization that uses the zero-defects approach provides products of excellent quality not only because the people who produce them are seeking ways to avoid defects but also because the purchasing department is ensuring a timely supply of well-crafted parts or supplies, the accounting department is seeing that bills get paid on time, the human resources department is helping find and train highly qualified personnel, and so on [2].

c) Employee Involvement Teams

Recognizing that the people who perform a process have knowledge based on their experiences, many organizations directly involve employees in planning how to improve quality. Many companies set up employee involvement teams such as quality circles, problem-solving teams, process improvement teams, or self-managed work groups. The typical employee involvement team consists of up to 10 employees and their supervisor, who serves as the team leader. In this role, the supervisor schedules meetings, prepares agendas, and promotes the participation and cooperation of team members.

d) Six Sigma

Applying the terminology and methods of statistical quality control and the strong commitment of the zero-defects approach, manufacturers and other companies have used a quality-control method they call Six Sigma. This is a process oriented quality-control method designed to reduce errors to 3.4 defects per 1 million operations, which can be defined as any unit of work, such as an hour of labor, completion of a circuit board, a sales transaction, or a keystroke. (Sigma is a statistical term defining how much variation there is in a product. In the context of quality control, to achieve a level of six sigma, the output of operations would be 99.9997 percent perfect.) Along with the basic goal of reducing variation from the standard to almost nothing, Six Sigma programs typically include a rigorous analytical process for anticipating and solving problems to reduce defects, improve the yield of acceptable products, increase customer satisfaction, and deliver best-in-class organizational performance [1].

e) Total Quality Management

Bringing together aspects of other quality-control techniques, many organizations have embraced the practice of total quality management (TQM), an organization- wide focus on satisfying customers by continuously improving every business process for delivering goods or services. Thus, it is not a final outcome but an ongoing commitment by everyone in the organization. Today most companies accept the basic idea of TQM that everyone in the organization should focus on quality [1].

VI. Quality Control Plans

As with the other responsibilities of supervisors, success in quality control requires more than just picking the right technique. The supervisor needs a general approach that leads everyone involved to support the effort to improve quality.

a) Prevention versus Detection

It is almost always cheaper to prevent problems from occurring than it is to solve them after they happen; designing and building quality into a product is more efficient than trying to improve the product later. Therefore, quality-control programs should not be limited to the detection of defects. Quality control also should include a prevention program to keep defects from occurring. One way to prevent problems is to pay special attention to the production of new goods and services. In a manufacturing setting, the supervisor should see that the first piece of a new product is tested with special care, rather than wait for problems to occur down the line. Also, when prevention efforts show that employees are doing good work, the supervisor should praise their performance. Employees who are confident and satisfied are less likely to allow defects in goods or services.

b) Standard Setting and Enforcement

If employees and others are to support the quality-control effort, they must know exactly what is expected of them. This calls for quality standards. In many cases, the supervisor is responsible for setting quality standards as well as for communicating and enforcing them. These standards should have the characteristics of effective objectives: They should be written, measurable, clear, specific, and challenging but achievable. Furthermore, those standards should reflect what is important to the client.

c) Using Control Chart

Control chart is the most populated quality tool. The main reasons of their popularity are [2]:

i. A proven technique for improving productivity.
ii. Effective in defect prevention.
iii. Prevent unnecessary process adjustment.
iv. Provide diagnostic information.
v. Provide information about process capability.
vi. Problem Statement

A spur gear manufacturing company in Khulna wants to test their quality and productivity and wants to find the most effective way of their quality testing.

Figure 2 : A spur gear

The following procedure of quality testing and improving productivity is given below:

VII. Seven basic Tools of tqm used in Industry

If a product is to meet customer requirements, generally it should be produced by a process that is stable or repeatable. More precisely, the process must be capable of operating with little variability around the target or nominal dimensions of the product’s quality characteristics. Statistical process control (SPC) is a powerful collection of problem solving tools useful in achieving process stability and improving capability through the reduction of variability.

SPC can be applied to any process. Its seven major tools are [2]:

1) Histogram.
2) Check sheet.
3) Pareto chart.
4) Cause and effect diagram.
5) Defect concentration diagram.
6) Scatter diagram.
7) Control chart.

These tools are called "the magnificent seven". SPC builds an environment in which it is the desire of all individuals in an organization for continuous improve-ement in quality and productivity. This environment is best developed when management becomes involved in an ongoing quality improvement process. Once this environment is established, routine application of the magnificent seven becomes part of the usual manner of doing business, and the organization is well on its way to achieving its quality improvement objectives.
The mostly used quality tools are described below for spur gear manufacturing industry:

a) Cause and Effect Diagram

Cause-Effect (CE) analysis is a tool for analyzing and illustrating a process by showing the main cause and sub-causes leading to an effect (symptom). It is sometimes referred to as the "fishbone diagram" because the complete diagram resembles a fish skeleton. The fishbone is easy to construct and interactive participation [1].

Once a defect, error, or problem has been identified and isolated for further study, we must begin to analyze potential causes of this undesirable effect. In situation where causes are not obvious, the cause and effect diagram is a formal tool frequently useful in unlayering potential causes.

The cause and effect diagram constructed to identify potential problem areas in the spur gear manufacturing process mentioned in the following figure:

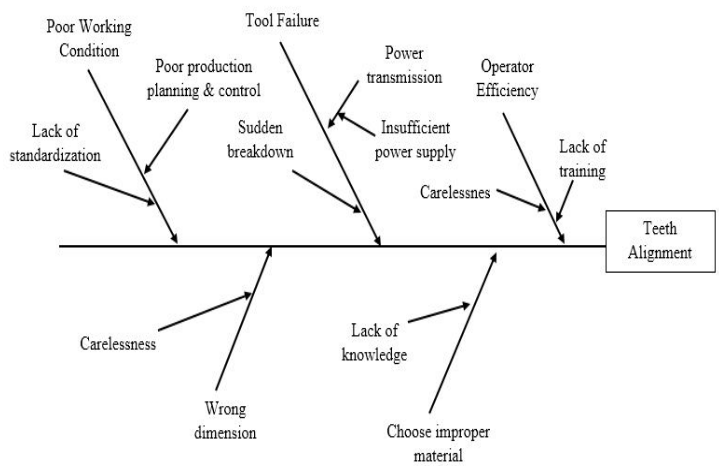


Figure 3 : Cause and effect diagram of spur gear defect problem for teeth alignment

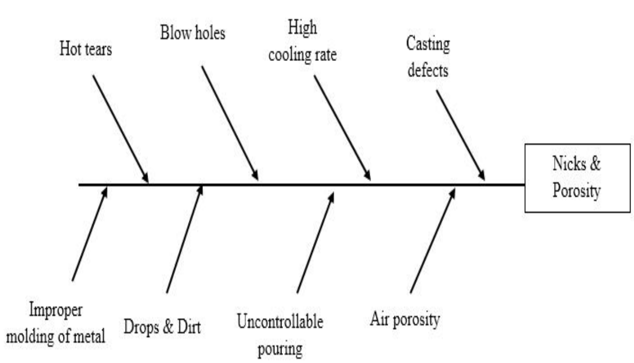


Figure 4 : Cause and effect diagram of spur gear defect problem for nicks and porosity.

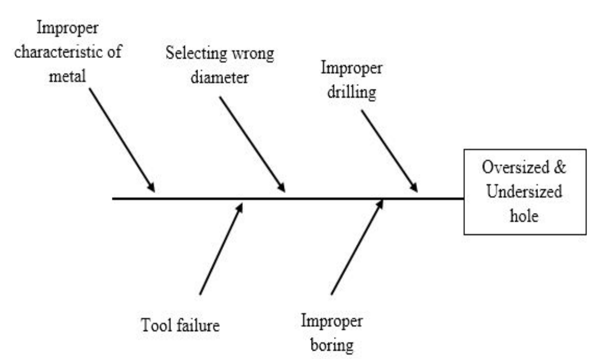


Figure 5 : Cause and effect diagram of spur gear defect problem for oversized and undersized hole.

In analyzing the spur gear defect problem, we elected to lay out the major categories of spur gear defects as man, machine, material, methods, measurement and environment. We got some effect such as teeth alignment, nicks and porosity, undersized and oversized hole and their causes. A brainstorming session ensured to identify the various sub-causes in each of these major categories and to prepare the diagram in Figure 3, Figure 4 and Figure 5. Then through discussion and the process elimination, we decided that materials and methods contained the most likely cause categories.

Cause and effect diagram analysis is an extremely powerful tool. A highly detailed cause and effect diagram can serve as an effective trouble-shooting aid. Furthermore, the construction of a cause and effect diagram as a team experience tends to get people involved in attacking a problem rather than in affixing blame.

b) Pareto Chart

The Pareto principle states that it is possible for many performance measure, such as scarp, machine failure, vendor's problems, and inventory cost and product development time, to separate the vital few causes resulting in unacceptable performance from the trivial many causes. Historically, this concept has also known as the 80/20 rule, which states that the performance measure can be improved 80% by eliminating only 20% of the causes of unacceptable performance [1].

This rules has been applied to a wide range of performance measures:

- Customer complaints
- Warranty repair and cost
- Quality defects
- Rework
- Machine downtime
- Material utilization
- Time utilization
- Energy use
- Product development time

i. *Choosing Pareto chart*

- When analyzing data about the frequency of problems or causes in a process is required.
- When there are many problems or causes and the quality analyst wants to focus on the most significant.
- When analyzing broad causes by looking at their specific components.
- When analyzing the characteristics of the shop or production process.

ii. *Data collection for Pareto chart:*

Identification of the vital few items from the Pareto principle is most easily conveyed using a Pareto diagram. We consider following defects for a spur gear machined part:

Table 1 : Data for Pareto analysis

Defect	Quantity
Undersized hole	224
Nicks	149
Teeth alignment	58
Porosity	52
Diameter	46
Oversized hole	5
Other	23
TOTAL	557

It is apparent that from this short list that under sized a holes are the main problem. However, real applications typically have many defects categories and many parts, all of which monitored over time. It is convenient to represent these data graphically as in (Figure 6). This graph has been prepared using the work sheet in (Table 2). The defects are arranged in rank order in column-1. The number of defects appears in column-2. The percentages that each defects represents of the total number of defects appears in column-3. The cumulative percentage of column-3 appear in column-4. One difficulty in collecting data by such categories as under size, nicks and oversize is that a particular part or item being evaluated may fit into several categories. In this case the preferred approach is to mark each defects. In (Figure 6) all defects are shown graphically to find out a most effective defect over these defects.

Table 2 : Example Pareto analysis worksheet

Column-1	Column-2	Column-3	Column-4
Defect	No of defects	% Composition	Cumulative %
Undersized hole	224	224/557 = 40	40
Nicks	149	149/557 = 27	67
Teeth alignment	58	58/557 = 11	78
Porosity	52	52/557 = 9	87
Diameter	46	46/557 = 8	95
Oversized hole	5	5/557 = 1	96
Other	23	23/557 = 4	100
TOTAL	557		100

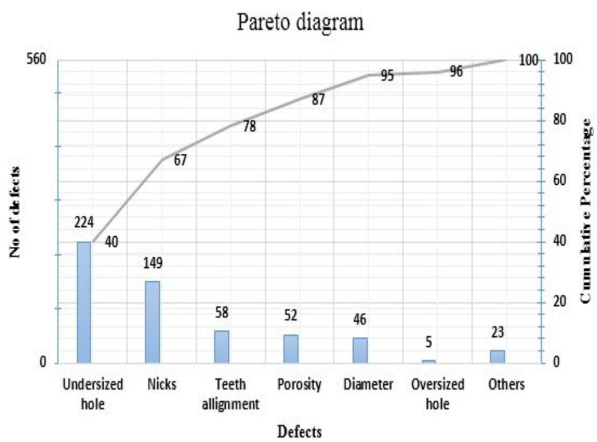


Figure 6 : Typical Pareto diagram for spur gear

c) *Histogram*

A histogram is the most commonly used graph to show frequency distributions and its pattern and shape. The shape determines its statistical nature of the collected data sets. It looks very much like a bar chart, but there are important differences between them.

Table 3 : Observation data of spur gear diameter

Sample No	Observations			
	1	2	3	4
1	4.9	4.8	5.1	5.4
2	5.0	5.8	5.3	5.3
3	4.4	4.7	4.8	4.6
4	4.6	5.8	5.4	4.9
5	5.2	5.3	6.1	5.2
6	5.0	5.9	5.8	4.8
7	4.3	4.6	4.7	4.5
8	4.9	4.9	5.5	5.7
9	5.9	6.4	6.1	6.5
10	5.3	5.9	6.1	4.8
11	4.6	4.6	5.3	5.0
12	5.3	5.8	5.4	5.1
13	4.9	5.3	5.2	5.7
14	5.2	5.4	4.6	5.5
15	5.4	4.8	4.4	5.1
16	4.6	4.4	4.9	5.1
17	5.7	5.4	5.0	4.8
18	5.1	4.3	5.7	5.8
19	5.9	6.4	6.2	6.1
20	5.0	5.1	4.5	4.8
21	4.9	5.9	5.3	5.2
22	5.4	5.9	4.4	5.0
23	5.2	4.7	5.7	5.8
24	4.0	4.8	5.1	5.8
25	5.3	5.8	6.0	6.3

Table 3 represents 100 observations on the diameter of spur gear used in lathe machine. The data were collected in 25 samples of four observations each. Notice that there is some variability in spur gear diameter. However, it is very difficult to see any pattern in the variability or structure in the data, with the observations arranged as they are in Table 3.

Table 4 : Frequency distribution for spur gear diameter

Diameter range, x (inch)	Tally	Frequency	Cumulative Frequency	Relative Frequency	Cumulative Relative frequency
3.75-4.25	I	1	1	0.01	0.01
4.25-4.75	IIII IIII IIII IIII II	18	19	0.18	0.19
4.75-5.25	IIII IIII IIII IIII IIII IIII IIII IIII II	34	53	0.34	0.53
5.25-5.75	IIII IIII IIII IIII IIII III	23	76	0.23	0.76
5.75-6.25	IIII IIII IIII IIII IIII	20	96	0.20	0.96
6.25-6.75	IIII	4	100	0.04	1.00
TOTAL		100		1.00	

A frequency distribution is an arrangement of the data by magnitude. It is a more compact summary of data than a stem-and-leaf display. For example, a frequency distribution of the spur gear data is shown in Table 4. From this table we note that there was one gear that had a diameter between 3.75 inch and 4.25 inch, eighteen gears having diameters between 4.25 inch and 4.75 inch, and so forth.

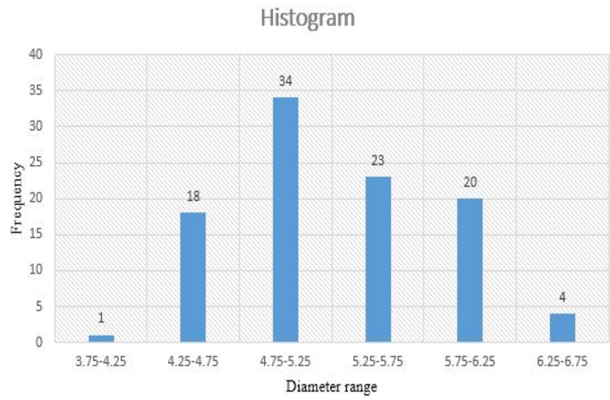


Figure 7 : Histogram for spur gear diameter data

A graph of the observed frequencies versus the spur gear diameter is shown in Figure 7. This display is called histogram. The height of each bar in Figure 7 is equal to the frequency of occurrence of spur gear diameter. The histogram represents a visual display of the data in which one may more easily see three properties [2]:

i. Shape.
ii. Location, or central tendency.
iii. Scatter, or spread.

In the spur gear diameter data, the distribution of gear diameter is roughly symmetric with skewed distribution tendency very close to 5.25 inch. The variability in gear diameter is apparently relatively high, as some gears are as small as 4.00 inch, while others are as large as 6.50 inch. Thus, the histogram give some insight into the process that inspection of the raw data in Table 3 does not.

d) Control Chart

Control chart is the seventh and most effective tool of Total Quality Management (TQM). This chart displays of a quality characteristic that has been measured or computed from a sample versus the sample number or time. The chart contains a center line that represents the average value of the quality characteristic corresponding to the in-control state (That is, only chance causes are present). Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL). These control limits are chosen so that if the process is in control, nearly all the sample points will fall between them. As long as the points plot within the control limits, the process is assumed to be in control and no action is necessary. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to find and eliminate the assignable cause or causes responsible for this behavior. It is customary to connect the sample points on the control chart with straight-line segments so that it is easier to visualize how the sequence of points has evolved over time.

Different types of control charts can be used depending upon the type of data. The two broadest groupings are:

i. Variable chart.
ii. Attribute chart.

i. *Variable Chart:*

Variable data are measured on a continuous scale in variable chart. For example: time, weight, distance or temperature can be measured in fraction or decimals. The possibility of measuring to greater precision defines variable data [1].

Based on mean (μ) and deviation (σ), commonly used variable charts are:

a. $\bar{X}-R$ Chart.
b. $\bar{X}-S$ Chart.
c. Moving Range (MR) Chart.
d. Cumulative Sum (CUSUM) Chart.
e. Exponentially Weighted Moving Average (EWMA) Chart.

$\bar{X}-R$ Chart is applicable when the sample size (n) is between 2 to 10 and $\bar{X}-s$ chart is applicable when the sample size is more than 10. For spur gear problem the sample size is 4. So, here $\bar{X}-R$ chart is used to obtain the quality limit of spur gear diameter.

a. *The $\bar{X}-R$ Chart*

A quality characteristic is normally distributed with mean μ and standard deviation σ, where both μ and σ are known. If $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n$ is a sample of size n, then the average of this sample is [1],

$$\bar{x}=\frac{x_1+x_2+\cdots\ldots\ldots\ldots.+x_n}{n}$$

and we know that $\bar{x}$ is normally distributed with μ and standard deviation $\sigma_{\bar{x}}=\frac{\sigma}{\sqrt{n}}$. Furthermore, the probability is 1-α that any sample mean will fall between

$$\mu+Z_{\alpha/2}\sigma_{\bar{x}}=\mu+Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$$

and $\mu-Z_{\frac{\alpha}{2}}\sigma_{\bar{x}}=\mu-Z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$

If $x_1, x_2, x_3, \ldots\ldots\ldots\ldots x_n$ is a sample of size n, then the range of this sample is the difference between the largest and the smallest observations and that is, R $= x_{max}-x_{min}$

Let R_1, R_2,……..R_m be the ranges of the m samples. The average range is [1],

$$\bar{R}=\frac{R_1+R_2+\cdots\ldots\ldots\ldots.+R_m}{m}$$

- Control limits for the $\bar{x}$ chart
- Upper Control Limit, UCL $=\bar{\bar{x}}+A_2\bar{R}$
- Center Line, CL $=\bar{\bar{x}}$
- Lower Control Limit, LCL $=\bar{\bar{x}}-A_2\bar{R}$
- Control limit for R chart

- Upper Control Limit, UCL = $D_4\bar{R}$
- Center Line, CL = $\bar{R}$
- Lower Control Limit, LCL = $D_3\bar{R}$

- *Data collection for $\bar{X} - R$ chart*

The diameter of the gear of a spur gear manufacturing company was monitored. During the base period 25 samples are observed the sample size is 4. The measurements of individual diameters are as follows:

Table 5 : Data for $\bar{X} - R$ chart of spur gear diameter

Sample No	Sample Size				$\bar{x}$	R
	1	2	3	4		$(x_{max} - x_{min})$
1	4.9	4.8	5.1	5.4	5.05	0.6
2	5.0	5.8	5.3	5.3	5.35	0.8
3	4.4	4.7	4.8	4.6	4.63	0.4
4	4.6	5.8	5.4	4.9	5.18	1.2
5	5.2	5.3	6.1	5.2	5.45	0.9
6	5.0	5.9	5.8	4.8	5.38	1.1
7	4.3	4.6	4.7	4.5	4.53	0.4
8	4.9	4.9	5.5	5.7	5.25	0.8
9	5.9	6.4	6.1	6.5	6.22	0.6
10	5.3	5.9	6.1	4.8	5.53	1.3
11	4.6	4.6	5.3	5.0	4.88	0.7
12	5.3	5.8	5.4	5.1	5.40	0.7
13	4.9	5.3	5.2	5.7	5.23	0.8
14	5.2	5.4	4.6	5.5	5.18	0.9
15	5.4	4.8	4.4	5.1	4.93	1.0
16	4.6	4.4	4.9	5.1	4.75	0.7
17	5.7	5.4	5.0	4.8	5.23	0.9
18	5.1	4.3	5.7	5.8	5.23	1.5
19	5.9	6.4	6.2	6.1	6.15	0.5
20	5.0	5.1	4.5	4.8	4.85	0.6
21	4.9	5.9	5.3	5.2	5.33	1.0
22	5.4	5.9	4.4	5.0	5.12	1.5
23	5.2	4.7	5.7	5.8	5.35	1.1
24	4.0	4.8	5.1	5.8	4.93	1.8
25	5.3	5.8	6.0	6.3	5.85	1.0
					$\bar{\bar{x}} = 5.241$	$\bar{R} = 0.912$

After observing and calculating the following data we found that,

- *Control limits for the $\bar{x}$ chart*

Upper Control Limit, UCL = $\bar{\bar{x}} + A_2\bar{R}$

= 5.241 + 0.483 × 0.912 = 5.682

Center Line, CL = $\bar{\bar{x}}$ = 5.241

Lower Control Limit, LCL = $\bar{\bar{x}} - A_2\bar{R}$

= 5.241 - 0.483 × 0.912 = 4.800

- *Control limit for R chart*

Upper Control Limit, UCL = $D_4\bar{R}$

= 2.004 × 0.912 = 1.828

Center Line, CL = $\bar{R}$ = 0.912

Lower Control Limit, LCL = $D_3\bar{R}$ = 0 × 0.912 = 0

Where, (for sample size 4)

A_2 = 0.483

D_3 = 0

D_4 = 2.004

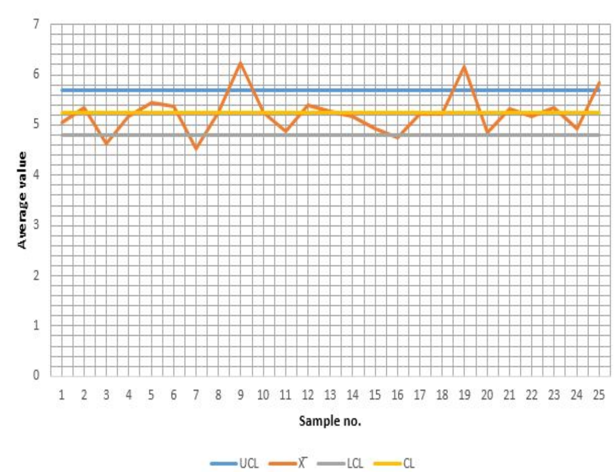


Figure 8 : Average-Control chart for spur gear diameter

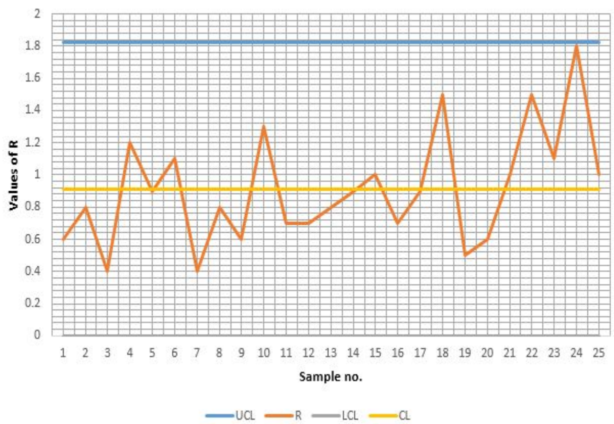


Figure 9 : Range-Control chart for spur gear diameter.

ii. *Attribute Chart*

This type of control chart is applicable equally to manufacturing and service organizations. In a manufacturing organization, manufacturing time and quality may be accepted as good or bad. Attributed data are counted and cannot have fractions or decimals. Attributed data arise when to determine only the presence or absence of something, success or failure, accept or reject, correct or not correct.

There are many types of attribute control charts. The most commonly used ones are-

a. P chart (proportion non-conforming)
b. np chart (number non-conforming)
c. c chart (count chart)
d. u chart.
e. *P Chart*

P chart is the most commonly used attribute control chart. There are companies which use hundreds of such P charts to measure hundreds of quality characteristics of attribute type.

- *Control limit for p chart*

Upper Control Limit, UCL $= \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

Center Line, CL $= \bar{p}$

Lower Control Limit, LCL $= \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

Where,

$\bar{p}$ = fraction non-conforming

1- $\bar{p}$ = fraction conforming

Table 6 : Number and fraction defective (non-conforming)

Sample No.	No. of failures, (d_i)	Fraction nonconforming
1	2	0.05
2	0	0
3	4	0.10
4	2	0.05
5	0	0
6	1	0.025
7	4	0.10
8	2	0.05
9	3	0.075
10	2	0.05
11	2	0.05
12	0	0
13	1	0.025
14	1	0.025
15	2	0.05
16	3	0.075
17	1	0.025
18	1	0.025
19	3	0.075
20	2	0.05
21	1	0.025
22	1	0.025
23	1	0.025
24	2	0.05
25	1	0.025
TOTAL	42	1.05

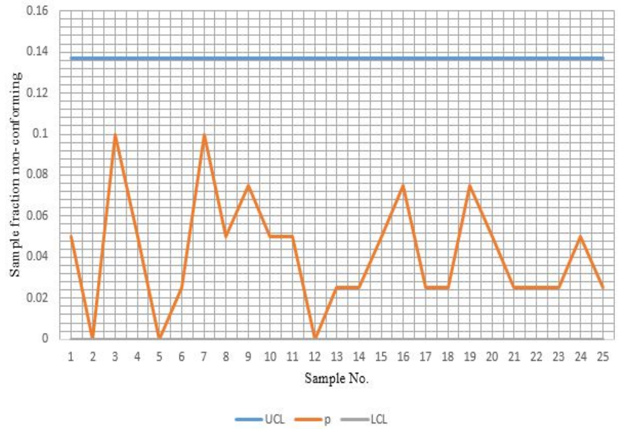


Figure 10 : Control chart (p-type) for the data set of Table 6

VIII. Process Capability Analysis

a) *Measurement of process capability analysis*

Measurement of process capability analysis basically means quantification of the capability of a stable process to produce parts within the specification limits.

These are:

- C_P = Process Potential Index
- C_{PK} = Process Performance Index
- CPU = Upper Process Performance Index
- CPL = Lower Process Performance Index
- K = Process Centering Index

b) *Basic concepts of process capability*

Process capability is a statistical analysis tool. It requires collecting data from the process, constructing a histogram, drawing a curve that fits in the histogram, and then finally finding out what percentages of data goes outside the upper specification limit (USL) and lower specification limit (LSL). For any part, upper specification limit, lower specification limit and allowable process spread are of two important concern. Traditionally, a process is called "capable" if the process spread 6σ is equal to the width of the specification limit (Figure 11).

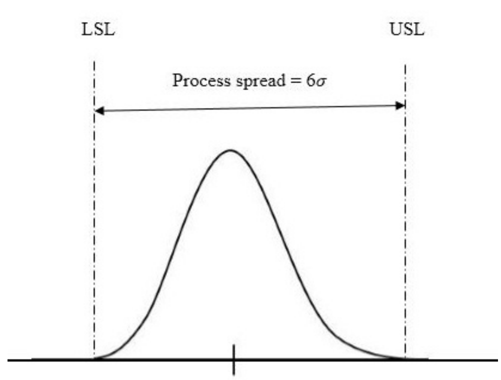


Figure 11 : Concept of process capability

There are three ways in which a process can be judge not capable:-

- The process is not stable
- The process is centered too close to a specification limit (Figure 12)
- The process variability is excessive (Figure 13)

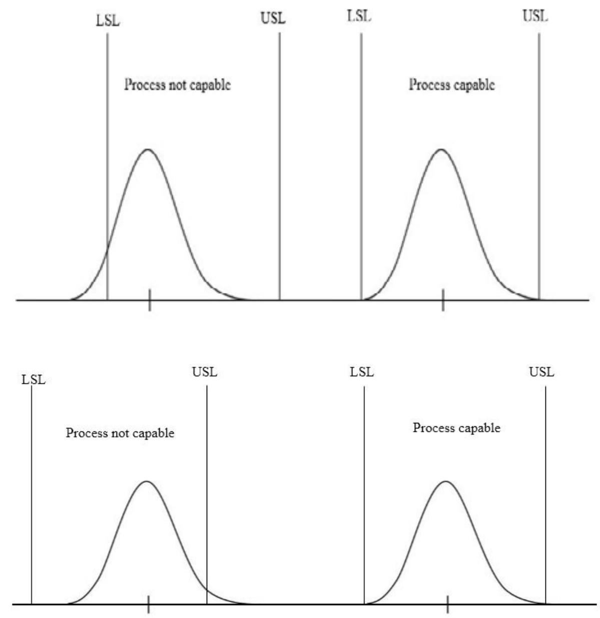


Figure 12 : Influence of location on process capability

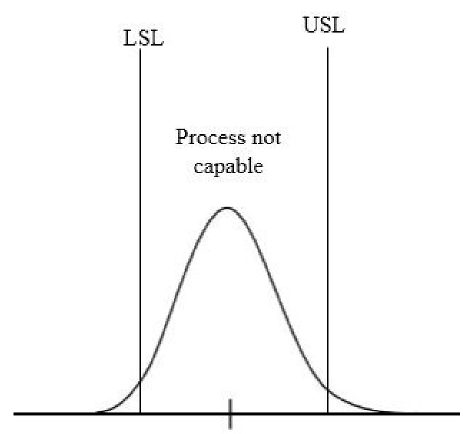


Figure 13 : Influence of variability on process capability

c) *Process Potential Index, C_P*

The potential of a stable process to be capable depends only on the variability of the process. A simple method of evaluating this potential is to relate the actual process spread (6σ) to the allowable process spread (USL- LSL).

C_P = allowable process spread / actual process spread = (USL-LSL) / 6σ

Values of C_P greater than 1 imply a desirable process in which the actual spread is less than the allowable spread (Fig-4). It is generally believed that a minimum C_P of 1.33 is required for most manufacturing process.

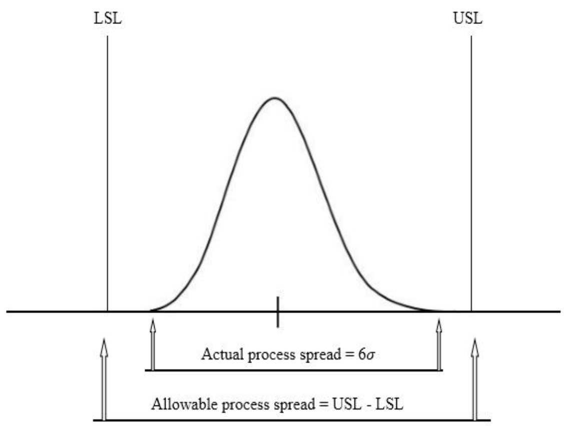


Figure 14 : Relationship of C_p parameters

- The values of C_P with respect to (σ) which is shown below (Table 7):

Table 7 : Value of Cp

	2σ	3σ	4σ	5σ	6σ
C_p	0.67	1.0	1.33	1.67	2.0

- Typical process spread diagram with respect to C_P value which is shown below (Figure 15):

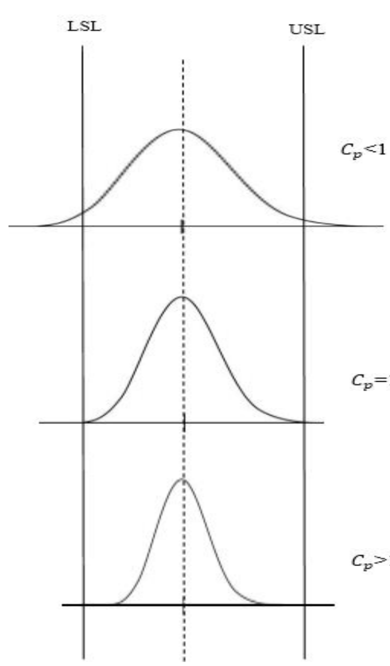


Figure 15 : Typical process spread diagram with respect to C_P

d) Process Performance Index

The performance of a process must relate the process potential to the location, measured by $\bar{X}$. We can relate the actual process spread to the allowable spread for a process with only an upper specification limit.

Actual upper process spread = 1/2 * actual process spread = 1/2 * 6σ = 3σ

Allowable upper process spread = USL- $\bar{X}$

Upper process performance index (CPU) = (USL-$\bar{X}$) / 3σ

Lower process performance index (CPL) = ($\bar{X}$-LSL) / 3σ

Hence process performance index (C_{PK}) = minimum (CPL, CPU)

- The values of C_{PK} with respect to (σ) which is shown in Table 8.

Table 8 : Value of Cpk

	2σ	3σ	4σ	5σ	6σ
C_{pk}	-0.17	0.5	0.83	1.17	1.5

- Typical process spread diagram with respect to C_{PK} value which is shown in Figure 16:

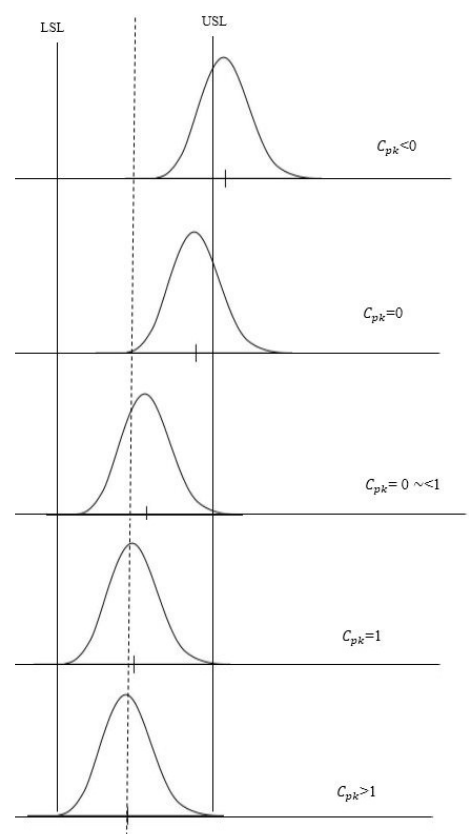


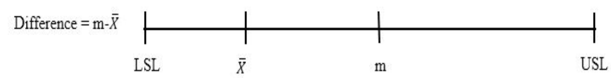
Figure 16 : Typical process spread diagram with respect to C_{PK}

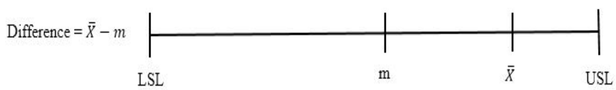
e) Process Centering Index

Another equivalent approach for obtaining C_{PK} allows relating the process potential C_P to the process performance index C_{PK}. Consider the midpoint of the specification limit,

$$m = (USL+LSL) / 2$$

If the process is exactly centered, $\bar{X} = m$ and there are the possible parts beyond the specification limits. The distance between the m and $\bar{X}$ can be computed by the difference.





This difference can be related to one half the allowable spread, as with CPU, CPL, to form a centering index (Process Centering Index):

$$K = \frac{\text{Distance of process mean from midpoint of the specification limit}}{\frac{1}{2} * \text{allowable process spread}}$$

$$= \frac{2|m - \bar{X}|}{USL - LSL}$$

The values of C_{PK} and C_P are related: $C_{PK} = C_P (1\text{-}K)$.

For stable process, if the process spread is sufficiently narrow ($C_P > 1.33$) and process mean sufficiently Close to the nominal value ($C_{PK} > 1.33$), process is capable, though possibility and scope For further improvement may be investigated and if not, the process through common causes should be improved. If the process is not stable then special causes should be eliminated.

- *Data collection for process capability analysis*

A manufacturing company wants to monitor the diameter of the spur gear. During the base period 25 samples are observed the sample sizes is 4. If USL = 6.5 inch and LSL= 3.5 inch and the measurements of individual diameter are as follows:
From Table-5,

$$\text{Range value } \bar{R} = 0.912$$

$$\text{Now } \sigma = \frac{R}{d_2} = \frac{0.912}{2.059} = 0.4429$$

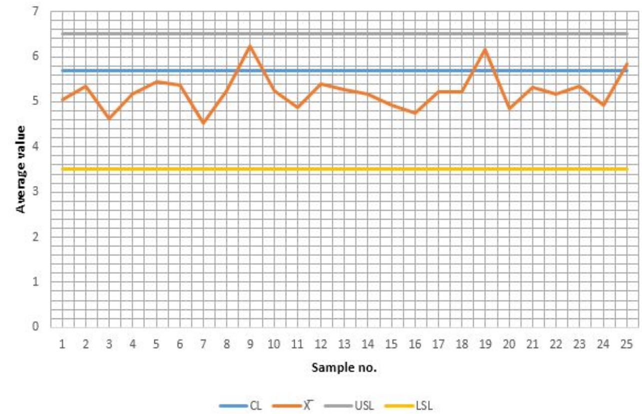


Figure 17 : Average-Control chart for spur gear diameter

- *Calculating C_P and C_{PK}*

$$m = \frac{USL + LSL}{2} = 5$$

$$K = \frac{2|m - \bar{X}|}{USL - LSL} = 0.16$$

$$C_P = \frac{USL - LSL}{6\sigma} = 1.13$$

$$C_{PK} = C_P (1\text{-}K) = 0.94$$

Since the process is within the specification limit and $C_P > 1$, hence the process is capable. And C_P may not be equal to zero and C_{PK} is always less than or equal to C_P.

f) Variation in process

Two types of causes are responsible for variation in a process. These are:

i. Chance cause or common cause:

Variation because of this type of causes are quite natural and very difficult to control fully. Temperature, environment, noise, vibration are some examples of common causes [1].

ii. Assignable cause:

Variation from this type of causes are identifiable and may be significant for product or service quality. Assignable causes occur due to machines, tools and operator and for ineffective operation [1].

The above tables and figures shown that the random variation occurred due to only chance cause or common causes.

g) Errors in control chart

Two types of error occur in quality control chart. Type-I error occurs when a sample value falls outside the control limit when the process is still in control. The type-II error occurs when a sample value falls within the control limits while the process is actually out of control. This type of wrong signaling happens because of sampling errors [1].

Table 9 : Summary of errors in sampling for control chart

	God's view (Process reality)		
		Process in control	Process out of control
Results from sample	Process in control	Right signal	Type-II error (Failure to detect)
	Process out of control	Type-I error (False signal)	Right signal

IX. Acceptance Sampling

Acceptance sampling is concerned with inspection and decision making regarding products one of the oldest aspects of quality assurance. It is represented by operating characteristic curve. It is related to sampling plan such as AQL (Acceptable Quality Level) and LTPD (Lot Tolerance Percent Defective). AQL can be considered as a person defective that is the base line requirement for the quality of the producer product whereas LTPD is a designated defect level for a lot beyond which the lot is unacceptable to the consumer. An attribute sampling is done for spur gear manufacturing company.

- *Data collection for acceptance sampling*

A batch of 1000 products are manufactured by a spur gear manufacturing company. An agreement between the producer and the customer specified by the following:

Batch size, N = 1000 where sample size, n = 40. Acceptance number, c = 2 (from Nomo-graph).

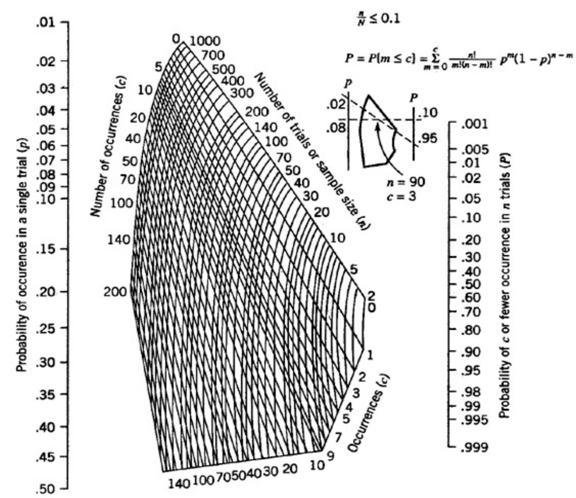


Figure 13-9 Binomial nomograph.

Figure 18 : Nomo graph

From Nomo-graph,

n = 40 and c=2 with respect to $P_1 = 0.05$, $P_2 = 0.15$, $\alpha = 0.05$, $1-\alpha = 0.95$, $\beta = 0.20$.

Table 10 : Probability of acceptance value

Fraction nonconforming, p	Probability of acceptance, p_a
0.01	0.9925
0.03	0.8821
0.05	0.6767
0.07	0.4625
0.09	0.2894
0.10	0.2281
0.11	0.1688
0.13	0.0929
0.15	0.0485

a) *Operating Characteristics curve*

It shows the characteristics of a production process in terms of statistical reasoning. Typical example of OC curve is shown (Figure 19). From OC curve, only type-I error is present.

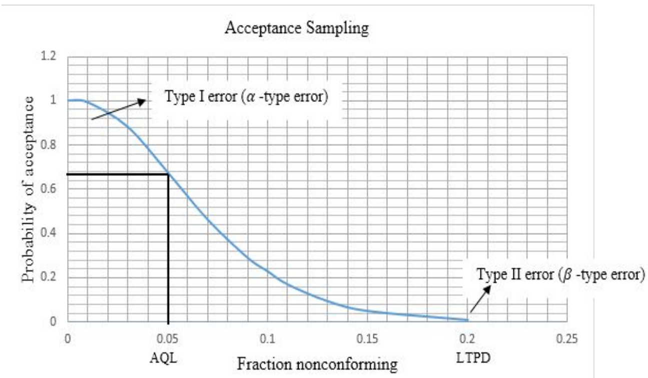


Figure 19 : Operating characteristic (OC) curve for acceptance sampling of spur gear diameter

b) *Hypothesis testing*

- *Basic concept of hypothesis testing*

This test is used to test whether a target value is achieved or not. The two sided hypothesis testing are

$$H_0 = \mu$$

$$H_1 = \mu$$

Since the hypothesis testing is based on sample data, there is always a chance of committing an error. Two types of error may be committed while testing hypothesis are:

1. If the null hypothesis is rejected (erroneously because of sampling limitations) when it is actually true, then a type-I error occurs. It is also called producer risk and α type error.
2. If the null hypothesis is not rejected, when it is false then a type-II error occurs. It is also called consumer risk and β type error. Type-II error is more serious than type-I error.

Thus, α = p {type-1 error} = p {reject H_0 | H_0 is true}

β = p {type-2 error} = p {accept H_0 | H_0 is false}

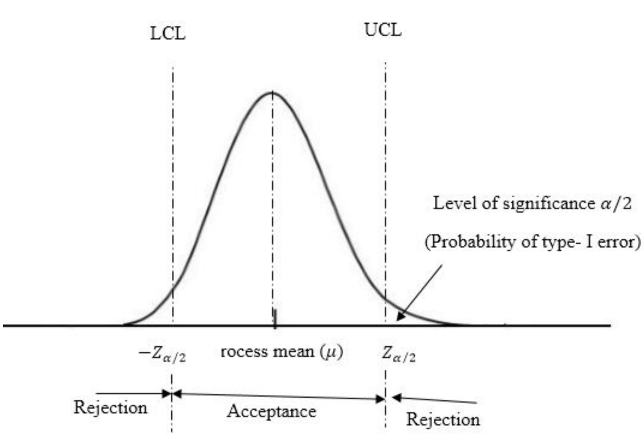


Figure 20 : Probability of type-I error [1]

c) *Case study*

A manufacturing company producing spur gear with mean diameter of the spur gear are 4.9 inch. The standard deviation of diameter of spur gear are 0.4429 inch. As a part of statistical quality control, a sample sizes 4 are taken and the mean diameter is obtained as 5.241 inch. Probability of type-I error is 0.05. Test was performed if the process is producing spur gear as per target mean diameter and also measured type-II error.

$$H_0: \mu = 5$$

$$H_1: \mu \neq 5$$

This is a two tail test, thus level of significance on both sides is $\frac{\alpha}{2}$

$$\frac{\alpha}{2} = 0.05/2 = 0.025$$

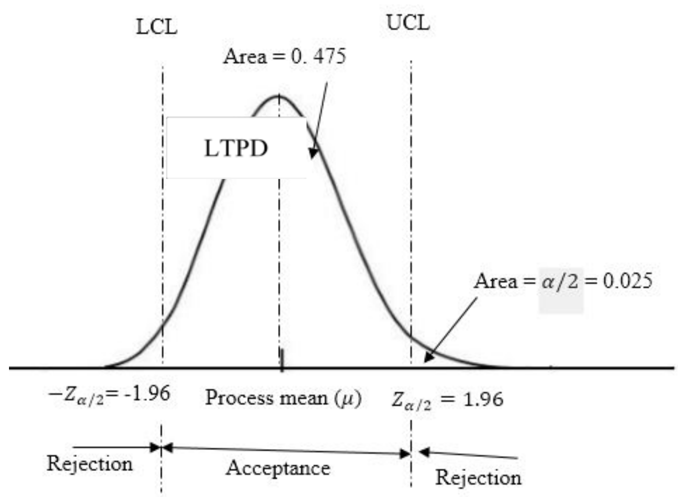


Figure 21 : Probability of type-I error for spur gear manufacturing

$$\text{Here, } Z = \frac{\bar{X}-\mu}{\frac{\sigma}{\sqrt{n}}} = 2 > Z_{Critical}\ (1.96)$$

Since Z = 2 is greater than $Z_{Critical}$ =1.96 (From standard normal distribution chart), the null hypothesis is rejected. That means the process mean has really shifted. However a sample size of 4 should not be enough to justify a normal distribution. So sample size should be increased in all future estimation.

Now, for type-II error,

$$Z_{\alpha/2} = 1.96, \mu_0 = 4.8, \mu_1 = 5.241, \sigma = 0.4429, n = 4$$

So, probability of type II error,

$$\beta = \emptyset\left(Z_{\frac{\alpha}{2}} - \frac{\delta\sqrt{n}}{\sigma}\right) - \emptyset\left(-Z_{\frac{\alpha}{2}} - \frac{\delta\sqrt{n}}{\sigma}\right)$$

$$= \emptyset\left(1.96 - \frac{0.4429\sqrt{4}}{0.4429}\right) - \emptyset\left(-1.96 - \frac{0.4429\sqrt{4}}{0.4429}\right)$$

$$= \emptyset(-0.04) - \emptyset(-3.96)$$

$$= 0.0054$$

Here, $\emptyset(-3.96)$ denotes the area on the left side of LCL under the left tail of sample distribution which is very small and thus negligible.

So, probability of detecting the shift of process mean or probability of not accepting the bad lot,
$= 1-\beta$ = 1- 0.0054 = 0.9946 = 99.46%.

X. Sigma

Sigma (σ) means standard deviation. It indicates the quality limit of control chart. Increase or decrease of sigma maintain the characteristics of products or services. Two sets of limits on control chart, such as those shown in Figure 22. The outer limit called 3-sigma, are the usual action limit; that is, when a point plots outside of this limit, a search for an assignable cause is made and corrective action is taken if necessary. The inner limits, usually at 2-sigma are called warning limit. In Figure 22, we have shown the 3-sigma upper and lower control limits and 2-sigma upper and lower warning limits for $\bar{x}$ chart for the spur gear diameter.

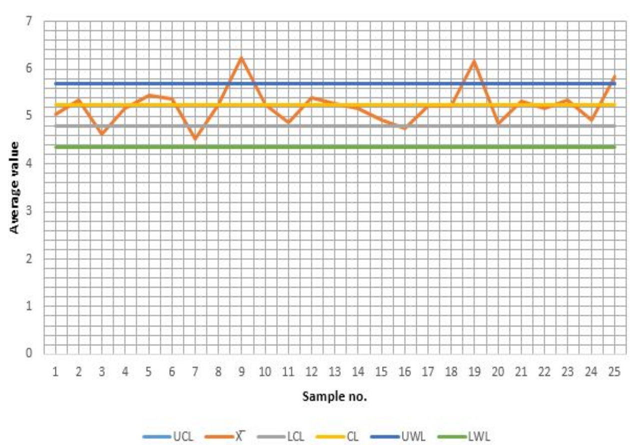


Figure 22 : Average-Control chart with 2 sigma and 3 sigma for spur gear diameter

UCL= 5.682
LCL= 4.800
UWL= 5.6839
LWL= 4.3552

XI. Improving Productivity

Productivity is the ratio of output and input.

$$\text{Productivity} = \frac{Output}{Input}$$

When supervisors and other managers look for ways to boost productivity, they often start by looking at their costs per unit of output. Productivity improves when the department or organization can do as much work at a lower cost and when output rises without a cost increase. Another way to improve productivity is to improve process quality so that employees work more efficiently and do not have to spend time correcting mistakes or defects. Mistakes, errors, and rework are a drag on productivity. Poor quality can slow the output of both individuals and the firm as a whole. For that reason, one of the supervisor's most important tasks is to think of and implement ways to get the job done right the first time.

a) Use Budgets

Before a supervisor can make intelligent decisions about how to trim costs, he or she has to know where the money is going. The most important source of such information is budget reports. By reviewing budget reports regularly, a supervisor can see which categories of expenses are largest and identify where the department is spending more than it budgeted. Then a supervisor should spend time with workers, observing how they use the department's resources, including their time. The process of gathering information about costs and working with employees to identify needed improvements is part of a supervisor's control function.

b) Increase Output

The numerator in the productivity equation (output/input) represents what the department or organization is producing. The greater the output at a given cost, the greater the productivity. Thus, a logical way to increase productivity is to increase output without boosting costs. Sometimes, by applying themselves, people can work faster or harder. A supervisor must also communicate the new goals carefully, emphasizing any positive aspects of the change. Some companies use technology to ensure productivity. Software programs that monitor e-mail and Internet usage have many uses, including applications that identify computer use that is not work related or that violates company rules. Electronic monitoring can also provide basic productivity measures such as how long order takers spend processing each customer order.

c) Improve Methods

Process control techniques for improving quality also can improve productivity. A process called *kaizen*, in which teams map the details of each work process, looking for ways to eliminate waste. Like managers at all levels, supervisors should be constantly on the lookout for ways to improve methods. Some ideas will come from supervisors themselves. Employees often have excellent ideas for doing the work better because they see the problems and pitfalls of their jobs. Supervisors should keep communication channels open and actively ask for ideas.

d) Reduce Overhead

Many departments spend more than is necessary for overhead, which includes rent, utilities, staff support, company cafeteria, janitorial services, and other expenses not related directly to producing goods and services. Typically, an organization allocates a share of the total overhead to each department based on the department's overhead expenses. However, a supervisor can periodically look for sources of needless expenses, such as lights left on in unoccupied areas or messy work areas that mean extra work for the janitorial staff. By reducing these costs to the company, a supervisor ultimately reduces the amount of overhead charged to his or her department.

e) Minimize Waste

Waste occurs in all kinds of operations. A factory may handle materials in a way that produces a lot of scrap. A costly form of waste is idle time, or downtime—time during which employees or machines are not producing goods or services. This term is used most often in manufacturing operations, but it applies to other situations as well. In a factory, idle time occurs while a machine is shut down for repairs or workers are waiting for parts. Idle time may occur because jobs and work processes are poorly designed. Detour behavior is a tactic for postponing or avoiding work. Wasted time may be an even more important measure of lost productivity than wasted costs. They can set a good example for effective time management and make detecting waste part of the control process. Often, employees are good sources of information on how to minimize waste. The supervisor might consider holding a contest to find the best ideas.

f) Regulate or Level the Work Flow

A supervisor can take several steps to regulate departmental work flow:

1) A supervisor should first make sure that adequate planning has been done for the work required.
2) A supervisor may also find it helpful to work with his or her manager and peers or form teams of employees to examine and solve work-flow problems. Cooperation can help make the work flow more evenly or at least more predictably.
3) If the work flow must remain uneven, a supervisor may find that the best course is to use temporary employees during peak periods, an approach that can work if the temporary employees have the right skills.

g) Install Modern Equipment

Work may be slowed because employees are using worn or outdated equipment. If that is the case, a supervisor may find it worthwhile to obtain modern equipment. Although the value of installing modern equipment is obvious for manufacturing departments, many other workplaces can benefit from using modern equipment, including up-to-date computer technology. In deciding to buy new equipment or recommending its purchase, a supervisor needs to determine whether the expense will be worthwhile. One way to do this is to figure out how much money per year the new equipment will save in terms of, for example, lower repair costs, less downtime, and more goods produced.

h) Train and Motivate Employees

To work efficiently, employees need a good understanding of how to do their jobs. Thus, a basic way to improve productivity is to train employees. Training alone does not lead to superior performance; employees also must be motivated to do good work. In other words, employees must want to do a good job. Motivation is a key tactic for improving productivity because employees carry out most changes and are often in the best position to think of ways to achieve their objectives more efficiently.

i) Minimize Tardiness, Absenteeism, and Turnover

When employees dislike their jobs or find them boring, they tend to use excuses to arrive late or not at all. Lost time is costly; in most cases, the organization is paying for someone who is not actually working. In addition, other employees may be unable to work efficiently without the support of the missing person. As a result, minimizing Absenteeism and Tardiness is an important part of the supervisor's job. Recent research indicates that the degree to which employees feel supported by their organization and supervisor can play an important role in whether they choose to leave their current job. In general, when an employee is feeling unsupported by his or her organization or supervisor, that employee is more likely to look for a new employment opportunity. Therefore, as a supervisor, it is important to be aware of how supported his or her employees feel about their relationship with him or her and the company as a whole. Supervisors can also minimize turnover by applying the principles of motivation.

XII. Result

For spur gear manufacturing problem, after observing all the data and analysis we find that its production quality is very close to the six sigma limits. Some variation occurs due to natural causes which can be eliminated. Type-I error occurred. So, if the spur gear manufacturing company continuing their quality research, it will help them to acquire a best product quality and make a highest position in the market.

XIII. Discussion

In this paper, the most effective way of quality control and productivity improvement has tried to find by experimenting on a manufacturing company. Using all quality tools and sampling plan is an expensive procedure. For any industry, using the control chart is the best way for quality testing. Cause and effect diagram, histogram are used to determine the causes and effects of production process. Acceptance sampling is used to determine the errors in control chart.

Statistical process control is a powerful tool to achieve sig sigma level. The following improved tools used in spur gear manufacturing can be used in any industry to achieve their desired level of quality and productivity.

XIV. Conclusion

There are several approaches to choose from when the goal is to increase the quality and productivity of a spur gear manufacturing company. The techniques used in this paper have been limited due to insufficient time and resources. In this paper only the quality tools have been used and tried to find the most effective way of quality testing and improving productivity. These have given a better solution. But if any one uses other technique of industrial engineering then he will get more benefit than this paper. If it is decided to use the data in future studies it would be interesting .By this way it may be possible to specify high quality and productivity. The quest for higher quality and productivity will never stop and the project extreme spur gear manufacturing will proceed. An important suggestion for future work is to test if the findings are applicable to other products and machines within the factory. A deeper understanding could possibly make the conclusions from this study more understandable and easier to apply to other products.

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Development of a Hybrid Metamodel based Simulation Optimization Algorithm

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Abstract- In this paper, a metamodel based hybrid algorithm was developed for optimization of digital computer simulation models. The simulation models are considered to be computationally expensive. It is also considered to have a single stochastic and unconstrained response function. The hybrid algorithm is developed by modification and integration of several concepts and routines. We employed the nested portioning and the particle swarm optimization algori-thms to develop an efficient search mechanism for the hybrid algorithm. Then we integrated the modified Kriging metamodel to the search mechanism for facilitating the function fitting processes of the simulation's output. The efficiency of the developed hybrid algorithm was then evaluated through computational experiments. Ten complex test problems were selected from the literatures and the efficiency of the developed hybrid algorithm was evaluated by comparing its performances against three known algorithm which are cited in the literature. The result of these computational experiments revealed that the developed hybrid algorithm can provide very robust solutions with a very low computational effort.

Keywords: simulation, optimization, nested partitioning, stochastic kriging, particle swarm optimization.

GJRE-G Classification : FOR Code: 290502p

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Development of a Hybrid Metamodel based Simulation Optimization Algorithm

Farhad Ghassemi Tari α & Zohreh Omranpour σ

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Keywords: simulation, optimization, nested partitioning, stochastic kriging, particle swarm optimization.

I. Introduction

Digital computer simulation models have been very successful approach for analyzing the complex systems. In simulation models the analytical expression for input/output relationship is generally unavailable and hence conducting its output performance analysis is a cumbersome task. Based on Barton and Meckesheimer [2] simulation optimization is defined as a repeated analysis of simulation models with different values of design parameters, in an attempt to identify best simulated system performance. Since 1950when simulation optimization has been introduced as a new area for research, many practical problems are modeled as simulation optimization problems and successful results have been achieved. Some recent achievements are the works of Liu and Maghsoodloo, [17] and Kleijnen et al.[14]. Also a number of software packages have been developed with the ability of simulation optimization and have been added to some well-known simulation software's. However, the related literatures are still waiting for developments of more new robust methods with the high results efficiency. For recent surveys in this field, we acknowledge the research studies conducted by Fuand Glover [7], Tekin and Sabuncuoglu [28], Henderson and Nelson [8] and Kleijnen [13].

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Since simulation models have stochastic response they potentially require extensive runtime. When an optimization routine is incorporated to the simulation models, this problem will intense dramatically. Due to the stochastic nature of the simulation models, the output must be estimated by averaging of the outputs values over reasonable number of replications [10]. In addition the simulation models are usually considered as the black-box models in which, the output function is not usually expressed explicitly. Therefore determining the best combination of controllable variables which provide the best output value can be done either by fitting an explicit function to the output values or by one of the algorithmic input-output optimization routines.

One of the approaches is the use of metamodel-based methods. Metamodels provide deterministic objectives, which surrogate simulation models, and generally need fewer computational efforts. One of the powerful metamodel, addressed in the literatures, is Kriging method. Kriging is an interpolation method which initially developed for using in spatial statistics. Thismethod which is initially proposed by Krige [15]was applied by Cressie [5] in geology. Later it was applied in areas like economic and modeling black box computer experiments [9].

The efficiency of this method in deterministic simulation models has proven [11,20, 26]. Based on the good results obtained in deterministic simulation, Beer and Klijnen [3] applied this method to the random simulation models. With considering successful application of Kriging methodology in design and analysis of deterministic computer experiments Ankenman et al [1]. Introduced stochastic Kriging (SK) metamodel inspired by Kriging methodology. Actually they extend Kriging methodology which applied successfully in deterministic simulation as a global metamodel, to the stochastic simulation. Despite of high accuracy and successful results, SK has not been use as metamodel in numerous papers and has not been use to any of the commercial simulation software package.

A powerful population based metaheuristics which can be employed for solving large-scale optimization problems efficiently is nested partition (NP) method. This method introduced by Shi and Ólafsson

[21] inspired by adaptive partitioned random search (APRS) [27] and branch and bound algorithm. Concentrating search effort in some regions which are most likely to have global optimum has been the key idea in developing NP method and this goal can be achieved by partitioning.

NP method has been used in both deterministic [21] and stochastic [22] optimization problems and also has been successfully applied in many areas, such as planning and scheduling, logistics and transportation, supply chain design, data mining and health care and task assignment. This method also is used for solving some difficult optimization problems like traveling sales man problem [23] and production scheduling problems [21]. More details about these applications are provided in [4, 11]. Based on Shi and Ólafsson [25] the NP results significantly depend on the method of sampling and low quality samples can affect the final result. In the young literature of NP, using other heuristics in order to improve samples quality is common.

Using heuristic search method for optimizing simulation models has been very successful approaches. The majority of researches in this area focus on some well-known algorithms like genetic algorithm (GA), simulated annealing (SA), and particle swarm optimization (PSO). PSO method is a global population-based metaheuristic which developed by Kennedy [12] and Eberhart [6] in 1995for optimizing nonlinear programming problems. The key idea of this algorithm was derived from movement of flying birds. There is a population (swarm) which consists of some particles. These particles are representative of solutions in feasible region. Each particle position and velocity updated based on the best performance of the particle achieving so far (its own previous best position) and the best performance obtained by any other particles.

In this paper we developed a metamodel-base simulation optimization hybrid algorithm. The developed algorithm is hybrid by the fact that it is constructed by modification and combination of several optimization routines. We used stochastic Kriging (SK) metamodel for fitting a functional relation to the input output of our simulation models. SK actually is a global metamodel, since it is fitted on the whole feasible space. We then incorporated the NP method into our hybrid algorithm. Through the NP method, the developed hybrid algorithm will concentrate its search effort in the regions which are most likely contained the global optimum. And finally we integrated the PSO method as the searching mechanism for improving the searching process of the proposed hybrid algorithm. Through these integrations a hybrid algorithm for optimization of the digital simulation models is developed, which is described in the next sections of this manuscript in more detailed.

II. Problem Statements

In this article we focus on the simplest optimization problem which is an unconstrained simulation model with the continuous variables and a single output. We aim to minimize the expected value of this univariant output. Despite the simplicity, these kinds of problems have many applications in practice. Examples are(*s, Q*)inventory management simulation, inventory production simulation models in logistics and operation management and queuing simulation models [13].

This problem is formulated as follow:

$$\min_x E(w(x)) \quad (1)$$

$$l_j \le x_j \le u_j \quad j = 1,2,\dots,d \quad (2)$$

Where $x = [x_1, x_2, \dots, x_d]^T$ denotes a *d*-dimensional input vector and w indicates the output value. The expected value in the objective function is estimated by simulation and we consider only box constraints where l_j and u_j are the lower and upper bounds of the input variables x_j respectively.

III. Development of the Hybrid Algorithm

The developed hybrid algorithm is a metamodel-based optimization process. We used the stochastic Kriging (SK) metamodel and employed a sequential experiment design for validating its results. In optimization part we used the hybrid metaheuristic algorithm of nested partition (NP) method, which benefits of quick convergence for large scale problems with high computational efforts and we also used the advantages of Particle swarm optimization (PSO) algorithm for its simplicity and good local search ability.

During the process of developing the hybrid algorithm, we first developed an algorithm with the integration of the NP and the PSO algorithm, and we called it PSPO algorithm [19]. The efficiency of the PSPO algorithm was then tested through a computation experiment. As the result, we found that although the solution obtained by this algorithm was either optimal or closed to the optimal, but the computational efforts to obtain the solution were extensive. Due to this problem we directed the path of our research to the metamodel based algorithm and we developed the hybrid algorithm.

Fig.1 represents a flow diagram of the developed hybrid algorithm. According to Fig.1, the first part of the hybrid algorithm includes initial sampling (step 1) and simulating this sample points with a number of specified iteration (step2). The second stage is an iterative process for fitting metamodel using the input output data (step3) and then validating metamodel by the method developed by Liu, Nelson, and Staum [18]. Their method is actually based on cross-validation method and developed for stochastic Kriging metamodels (step4). Finally the last stage, algorithm starts with primary partitioning of feasible space (step 5) and then sampling and improving these sample points in each partition (step6). By using the validated metamodel and improved samples we computed the fitness value of each partition and then determine the best partition (the most promising partition) and consequently the best point (step7). Actually this point was used for re-partitioning the solution space and adds it to the experiment design process, which can be used for updating the metamodel (step8). After this step, the algorithm checks the existence of any significant improvement. If a significant improvement is not achieved, the hybrid algorithm performs a pre-specified number of simulation runs, denoted by $I^{\max}$, and then stops and accepts the best obtained point. Otherwise it loops back to step 6.

For presenting a detailed description of the algorithm steps, let us show the whole feasible space by Θ, the number of algorithmic iteration by k and the most promising partition by $\sigma(k)$. Now, the following sections provide more details for each step.

Step 1 : Performing the initial experiment design

The first step of the hybrid algorithm includes generating some initial simulation observations, based on a statistical sampling. Selecting an efficient experiment design is an important step in the process of developing a metamodel and can affect the hybrid algorithm performances.

Since we intend to use stochastic Kriging metamodel and based on the assumption that there is no former information about output values, we employed the max-min Latin Hyper Cube sampling [13] while checking the box constraints. Considering a d-dimensional space, we used the sample size suggested by Kleijnen [14]. Therefore the sample size was designated as $5+2d$ of the initial sample points. In step 5 we will explain more detail regarding the sequential experiment design.

Step 2 : Simulating the initial design points

Stochastic simulation models have stochastic output values, so we should obtain an average of simulation outputs over the number of replications. If we denote n_i as the number of simulation runs in a design point x_i, the average will be obtained by:

$$\overline{w}(x_i)=\frac{\sum_{l=1}^{n_i} w_l(x_i)}{n_i} \qquad (3)$$

Where $w_l(x_i)$ represent simulation output in the l^{th} iteration. Fordetermining the number of simulation run (replication) in each design point, we used the method of Liu et al. [18] through which the output variance is reduced. At first we performed n_0 replications for every design point x_i. Then we calculated mean $\overline{w}(x_i)$ and the variance $S^2(x_i)$ of these replications. We targeted a relative precision for simulation output γ and then determined the total replication size n_i in each design point. The relative precision for n_i replication in design point x_i was calculated by $l(x_i,n_i;\alpha)\big/\left|\overline{w}(x_i)\right|$ which we required it to be less than γ. Where $l(x_i,n_i;\alpha)$ is a half-width of the $(1-\alpha)$ confidence interval for output $w(x_i)$. We then used the following condition, proposed by Law [16], for obtaining n_i:

$$\frac{l(x_i,n_i;\alpha)}{\left|\overline{W}(x_i)\right|}\leq\frac{\gamma}{1+\gamma} \qquad (4)$$

And therefore n_i is obtained as:

$$n_i=\max\left\{n_0,\left\lceil\left(\frac{(1+\gamma)t_{n_{0-1,1-\alpha/2}}S(x_i)}{\gamma\overline{W}(x_i)}\right)^2\right\rceil\right\} \qquad (5)$$

As the result, n_i-n_0 more replication runs in the design point x_i should be executed. After determining design points and number of replication in each design point, simulation of all the design points can be executed.

Step 3 : Fitting stochastic Kriging metamodel

By using initial design points and simulation model output (I/O data) we fit stochastic Kriging motamodel, and used it for estimation of the simulation output. Considering m initial design points, the stochastic Kriging predictorwhich optimizes mean square error (MSE) has the form of:

$$\hat{w}(x_c) = \hat{\beta}_0 + \hat{\tau}^2 R_M(x_c,.;\hat{\theta})^T \left[\hat{\tau}^2 R_M(\hat{\theta}) + \hat{\Sigma}_\varepsilon\right]^{-1} \times \left(\overline{w} - \hat{\beta}_0 1_m\right) \tag{6}$$

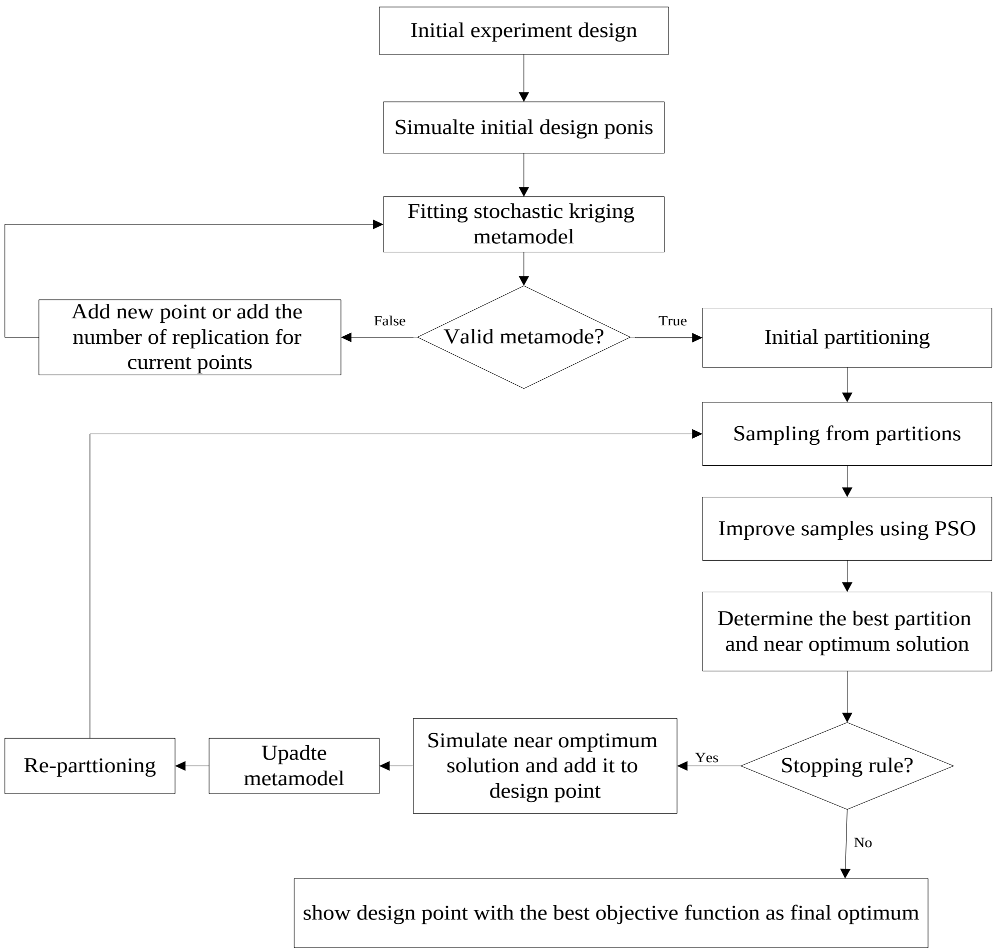

Figure 1 : The flow diagram of the hybrid algorithm

Where x_c is a point to be predicted, R_M is the correlation between two points which depends on the distance between points and a function of $\hat{\theta}$, $\hat{\Sigma}_\varepsilon$ is an $m \times m$ matrix and is calculated by the following formula:

$$\hat{\Sigma}_\varepsilon = Diag\left\{ \hat{V}(x_1)\big/ n_1, \hat{V}(x_2)\big/ n_2, \ldots, \hat{V}(x_m)\big/ n_m \right\}$$

where

$$\hat{V}(x_i) = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} \left(w_j(x_i) - \overline{w}(x_i)\right)^2,$$

$\hat{\tau}^2$, $\hat{\theta}$, $\hat{\beta}_0$ are estimated by solving the following likelihood equation:

$$l\left(\beta_0, \tau^2, \theta\right) = -\ln\left[(2\pi)^{m/2}\right] - \frac{1}{2}\ln\left[\left|\tau^2 R_M(\theta) + \Sigma_\varepsilon\right|\right] - \frac{1}{2}\left(\overline{w} - \beta_0 1_m\right)^T \left[\tau^2 R_M(\theta) + \Sigma_\varepsilon\right]^{-1} \left(\overline{w} - \beta_0 1_k\right), \tag{7}$$

and $\overline{w} = (\overline{w}(x_1), \overline{w}(x_2), ..., \overline{w}(x_m))^T$, where $\overline{w}(x_i)$ calculated by equation (3) and 1_m is avector of ones with a compatible dimension.

For more details, we refer the reader to Ankenman, Nelson, and Staum [1].

Step 4 : Validating of the metamodel

For checking the validity of metamodel we used the leave-one-out cross-validation method. The main goal of this method is to decrease the difference between real simulation output in a specific design point, $w(x_i)$, and the metamodel prediction for the same design point, after eliminating the point designated by $\hat{w}^{(-i)}(x_i)$. In other words, the key idea is to control the relative leave-one-out prediction error at each design point which is calculated as follow:

$$\frac{\left|\hat{w}^{(-i)}(x_i) - w(x_i)\right|}{\left|w(x_i)\right|} \quad (8)$$

Liu and coworkers (2010) demonstrated achieving this goal need to control E_i value which is calculated as follow:

$$E_i = \frac{l(x_i, n_i; \alpha)}{\left|\overline{w}(x_i)\right| - l(x_i, n_i; \alpha)} + \frac{\left|w^{(-i)}(x_i) - \overline{w}(x_i)\right|}{\left|\overline{w}(x_i)\right| - l(x_i, n_i; \alpha)} \quad (9)$$

Where the half-width is a measure of uncertainty in $\overline{w}(x_i)$.

Before cross-validation we should separate design points which are not on the edges, i.e. for design point $x_i = (x_1, x_2, \cdots, x_d)$ in the *d* dimensions, we select point which none of the factors contains the extreme value. This subset of designing points is showed by set *II* and E_i is calculated for this subset.

Based on equation (9) the lack of credibility of E_i originated from two sources:

- Relative difference between simulation output and true value (relative precision of simulation output) which need to add more replication.
- Relative difference between true value and leave-one-out prediction which need to add more design point.

In each iteration, if $E_i > \beta$, even just for one design point, we should add some more design points or add more replication to existing design points. If the first term of E_i is less than $\lambda\beta$, we select a new design point and we add it to the experimental design points. Otherwise, we add more simulation replications for the point with maximum value of E_i. This selection is based on covering complex areas, when λ is a predefined parameter which aims to control the effect of Mont Carlo variability during cross-validation [17}for $\lambda \in (0,1)$. We selected $\lambda = 1/4$ in our experiments;

The procedure for the validation process can be summarized by the following steps:

1. Separate design points which are not on the edges and show this subset by *II*.
2. Determine number of simulation replication n_i in each design points as in equation (5) and set $N_i \leftarrow n_i$.
3. Calculate $\overline{w}(x_i)$, and $S^2(x_i)$ for all design points in set *II*.
4. Calculate E_i as in equation (9) for all design point in set *II*.
5. $i^* \leftarrow \arg\max_{i \in II} E_i$.
6. If $E_{i^*} > \beta$,

6.1. If $\frac{l(x_{i^*}, n_{i^*}; \alpha)}{\left|\overline{w}(x_{i^*})\right| - l(x_{i^*}, n_{i^*}; \alpha)} > \lambda\beta$

a) Run simulation model at x_{i^*}, N_{i^*} more replication and set $N_{i^*} \leftarrow 2N_{i^*}$.

b) Calculate $\overline{w}(x_{i^*})$, and $S^2(x_{i^*})$ again.

c) Go to step 4.

6.2. Else

a) Add a new design point in the middle of distance between x_{i^*} and the nearest design point.

b) Calculate the number of simulation replication in new design point and then calculate $\overline{w}(x_{k+1})$, and $S^2(x_{k+1})$.

c) $k \leftarrow k+1$.

d) Go to step 4.

The main advantage of this validation method is considering the possibility of adding simulation replications in some points which has high error.

Step 5 : Initial partitioning

In optimization process first we should partition experimental area. Different methods have been developed for partitioning in the NP algorithm. In this article for initial partitioning we divided the range of each variable, which is defined by the box constraint, into two halves. Through this way each variable's dimension is divided into two equal parts. Then we use the SK algorithm for determining the potential areas.

Step 6 : Sampling and improving samples

After defining partition boundaries, a uniform random sampling procedure was used for each partition. In this article the PSO algorithm is used to improve the quality of initial samples and generate feasible solutions which improve the effectiveness and efficiency of the NP algorithm. Suppose we have *N* initial random samples in the j^{th} partition denoted by $D_I^j = \{x_I^{j1}, x_I^{J2}, \cdots x_I^{jN}\}$. Using PSO algorithm, the hybrid algorithm generates a sequence of improving solutions until no further improvement is possible. The final solutions which are more likely to be near optimal solution is shown by $D_F^j = \{x_F^{j1}, x_F^{J2}, \cdots x_F^{jN}\}$.

By using high quality samples we increase the probability of selecting correct partition and making correct moves. Assuming simulation runs are computationally very time consuming, in the process of running the PSO, we used the metamodel for estimating outputs instead of using the simulation run outputs.

It should be noted that in the next iterations (except first iteration) we will have five partitions for sampling. More details provide in step8.

Step 7 : Determining winner partition and near optimal solution

Final population is used for estimating promising index and finally determining the winner partition (next most promising region). To achieve this goal we use the validated metamodel to estimate the output for all the final samples which are shown by $Y(x_F^{Ji})$ for i^{th} sample in j^{th} partition.

The best answer for each partition shows fitness coefficient for that partition. For example in minimization problems it is calculated as follow:

$$Y(\sigma_j) = \min_{i\in\{1,2,\cdots N\}} Y(x_F^{ji}) \qquad j = 1,2,\cdots,5 \tag{10}$$

And the partition with the best overall fitness coefficient is chosen as the next most promising partition, with the index as follow:

$$\hat{J}_k \leftarrow \arg Y(\sigma_j) \qquad j = 1,2,\cdots,5 \tag{11}$$

If this index corresponds to a sub region of $\sigma(k), \hat{J}_k \leq 4,$ we let this to be the next most promising partition, ie:

$$\sigma(k+1) = \sigma_{\hat{J}_k}(k) \tag{12}$$

But if it belongs to complementary region we backtrack to previous iteration, ie:

$$\sigma(k+1) = \sigma(k-1) \tag{13}$$

All partitions features in different iterations are saved.Also the backtrack-flag is set on. This flag is used for counting the number of back tracking simulation runs.

We also record the best point which is obtained. The index of the best point in j^{th} partition is as follow:

$$\hat{J}_i = \arg \min_{i\in\{1,2,\cdots N\}} x_F^{ji} \qquad j = 1,2,\cdots,5 \tag{14}$$

So the best overall point will be denoted by $x_k^{opt} = x_F^{\hat{J}_k \hat{i}_{\hat{j}_k}}$ which will be used in next partitioning (step 8). We also compare this point with the best answer which is obtained so far (x^{opt}) and we record the point which has the better performance measure.

Step 8 : Updating the metamodel and re-partitioning solution space

In this step the near-optimal point which is obtained from previous step, (x_k^{opt}), is simulated and then it will be added to the experimental design. With this new experimental design we re-fit and re-validate the metamodel. This new metamodel which may be

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more likely to have better prediction is used in the next iteration.

As we explained before, if the current near-optimal point belongs to the complementary region we back track and we use previous partitioning, but if this point belongs to the promising region, the algorithm partitions the promising region into four new partitions (four rectangles) somehow that the obtained best point becomes one of the corner of these rectangular while the other corners are kept as the corners of the promising region. It is clear that these regions may not have equal area. All the remaining parts of the region except these four partitions are aggregated together and will be formed as the complementary partition. Having these five partitions, the algorithm checks the stopping rule and if the stopping rule is not satisfied returns back to step 6 for the new sampling.

Step 9 : Checking stopping rule

The hybrid algorithm is iteratively proceeds until no significant improvement is realized. In order to check this condition the algorithm compares the objective function value of the current best point, $\overline{w}(x_k^{opt})$, with the best point obtained among all the previous iterations, $\overline{w}(x^{opt})$. To conduct this it first calculate the*t* -student prediction error as follow:

$$t_0 = \frac{\overline{w}(x_k^{opt}) - \overline{w}(x^{opt})}{\sqrt{\hat{v}(\overline{w}(x_k^{opt})) + \hat{v}(\overline{w}(x^{opt}))}} \qquad (15)$$

The current best point is accepted as the best solution point until now, only if $t_0 < t_{1-\alpha,df}$, otherwise, we conclude that there was not any improvement, where is the degree of freedomand is calculated as follow:

$$df = \min(n_k, n_{opt}) \qquad (16)$$

In our experiments we set α=0.1. We also set a threshold for maximum number of unimproved replications equal to 30, i.e. I^{max}= 30.

Whenever this threshold is reached, the iterations are terminated. The algorithm is stopped and the best solution point is acknowledged as the final solution point (x^{opt}).

IV. Computational Experiments

For evaluating the performances of the developed algorithm, it is common to employ some known response surface functions, which are presented in the optimization literatures. We selected 10 complex test problems as the bench mark. Due to deterministic nature of these problems, we add a noise to their objective function relations. The main advantage of using these test problems was their complexity of obtaining their optimal solutions.

In this section the developed hybrid algorithm is evaluated against three known algorithms cited in the literatures. Ten unconstrained hard test problems with the following mathematical structures were selected from the literatures.

1. P1; which has just one global minimum, with the following mathematical form:

$$P_1 = \frac{x_1}{\left(1 + x_1^2 + x_2^2\right)} - 2 \le x_j \le 2 \quad j = 1,2 \qquad (17)$$

2. P2; which has one local minimum and one global minimum with the following mathematical form:

$$P_2 = 3\left(1 - x_1^2\right)\exp\left(-x_1^2 - (x_2+1)^2\right) - 10\left(\left(x_1/5\right) - x_1^3 - x_2^5\right)\exp\left(-x_1^2 - x_2^2\right) - \left(1/3\right)$$
$$-\exp\left(-(x_1+1)^2 - x_2^2\right) \qquad -3 \le x_j \le 3 \quad \text{for } j = 1,2 \qquad (18)$$

3. P3; which has two local minimum and one global minimum, with the following mathematical form:

$$P_3 = -\left(10\left(1 - x_1^2\right)\right)\exp\left(-x_1^2 - (x_2+1)^2\right) - 15\left(\left(x_1/5\right) - x_1^3 - x_2^5\right)\exp\left(-x_1^2 - x_2^2\right) - \left(1/3\right)$$
$$-\exp\left(-(x_1+1)^2 - x_2^2\right) \qquad -3 \le x_j \le 3 \quad \text{for } j = 1,2 \qquad (19)$$

4. P4; which is called Six Hump Camel back (SHC) has six local minimum and two global minimum, with the following mathematical form:

$$P_4 = \left(4 - 2.1x_1^2 + {x_1^4}/{3}\right)x_1^2 + x_1x_2 + \left(-4 + 4x_2^2\right)x_2^2 \qquad -3 \le x_j \le 3 \text{ for } j = 1,2 \tag{20}$$

5. P5; which called Himmelblau function (Hmb) and has several local minimum and one global minimum with the following mathematical form:

$$P_5 = \left(x_1^2 + x_2 - 11\right)^2 + \left(x_1 + x_2^2 - 7\right)^2 + 0.1\left(\left(x_1 - 3\right)^2 + \left(x_2 - 2\right)^2\right)$$
$$-6 \le x_j \le 6 \text{ for } j = 1,2 \tag{21}$$

6. P6; which has several local minimum and one global minimum, with the following mathematical form
7. :

$$P_6 = x_1^2 + 2x_2^2 - 0.3\cos\left(3\pi x_2\right) + 0.7 \qquad -100 \le x_j \le 100 \quad \text{for } j = 1,2 \tag{22}$$

7. P7; which called Booth function and has several local minimum and one global minimum with the following mathematical form:

$$P_7 = \left(x_1 + 2x_2 - 7\right)^2 + \left(2x_1 + x_2 - 5\right)^2 \qquad -100 \le x_j \le 100 \quad \text{for } j = 1,2 \tag{23}$$

8. P8; which called Michalewics function and has several local minimum and one global minimum with the following mathematical form:

$$P_8 = -\sin\left(x_1\right)\sin^{20}\left({x_1^2}/{\pi}\right) - \sin\left(x_2\right)\sin^{20}\left({\left(2x_2^2\right)}/{\pi}\right)$$
$$-100 \le x_j \le 100 \quad \text{for } j = 1,2 \tag{24}$$

9. P9; which called Sphere function and has no local minimum except the global one with the following mathematical form:

$$P_9 = x_1^2 + x_2^2 - 5.12 \le x_j \le 5.12 \quad \text{for} \quad j = 1,2 \tag{25}$$

10. P10; which called Brownian function and has three global minimum with the following mathematical form:

$$P_{10} = \left(x_2 - \left({5}/{\left(4\pi^2\right)}\right)x_1^2 + \left({5}/{\pi}\right)x_1 - 6\right)^2 + 10\left(1 - \left({1}/{8\pi}\right)\right)\cos\left(x_1\right) + 10$$
$$-5.12 \le x_j \le 5.12 \text{ for } j = 1,2 \tag{26}$$

Each test problem was solved using the developed algorithm and three above mentioned algorithms. To overcome the problem of stochastic output of the simulation models, twenty replication of simulation model was considered and the test problems are solved by each method. The performance criteria were selected as the number of simulated points and the quality of final results.

Table (1) summarizes the computational results over 20 replications for the four considered algorithms in term of the best result. As it is seen in eight out of ten test problems the developed hybrid algorithm provided the optimal solutions. For two other problems, problems #4 and #5, the objective function values are very closed to the optimal, less than 0.1 and 0.3 percents.

Table (2) summarizes the computational results over 20 replications for the four considered algorithms in term of the average best result. As it is seen in four out of ten test problems the developed hybrid algorithm provided the average solutions equal to the optimal solutions. For the other problems, except problem #3 and #5 the average solutions have the deviations less than 1.1 percent from the optimal solutions. For problem #3 the dilation is 4.06 per cent from the optimal solution. Only for problem #5 we obtained a solution point which is far away from the optimum which is caused to have an average solution with unacceptable deviation from the optimal solution.

Table (3) summarizes the number of simulated points for obtaining the final solution. As we emphasized earlier, it is assumed that the simulation runs are expensive or from computation points of view they are assumed to be very time consuming. Therefore the number simulation points for obtaining the optimal solution is very critical performance measure in evaluation of the optimization algorithm. As it is seen considering this performance measure, the developed hybrid algorithm outperforms the other thee algorithms. Actually in most of the ten test problems, the developed algorithm provided more than 80 percent saving in the number of simulated points comparing with the average number of points simulated by the other three algorithms.

Table 1 : Best objective function value obtained comparing to other methods

Problem No.	Optimum	Best objective function value			
		NP	PSO	PSPO	Hybrid A.
P1	-0.500	-0.493	-0.500	-0.500	-0.500
P2	-6.081	-6.079	-6.081	-6.081	-6.081
P3	-19.935	-19.934	-19.934	-19.935	-19.935
P4	-1.032	-1.032	-1.032	-1.032	-1.031
P5	0.000	0.006	0.001	0.000	0.003
P6	0.000	0.008	0.000	0.000	0.000
P7	0.000	0.000	0.000	0.000	0.000
P8	-1.801	-1.780	-1.801	-1.801	-1.801
P9	0.000	0.000	0.000	0.000	0.000
P10	0.398	0.398	0.398	0.398	0.398

Table 2 : Average objective function value obtained comparing to other methods

Problem No.	Optimum	Average objective function over replications			
		NP	PSO	PSPO	Hybrid A.
P1	-0.500	-0.344	0.498	-0.500	-0.496
P2	-6.081	-6.080	-5.670	-6.080	-6.080
P3	-19.935	-19.916	-19.935	-19.935	-19.126
P4	-1.032	-1.031	-1.031	-1.031	-1.032
P5	0.000	1.350	1.506	0.002	3.830
P6	0.000	0.000	0.488	0.000	0.011
P7	0.000	0.080	0.000	0.000	0.000
P8	-1.801	-1.733	-1.681	-1.800	-1.821
P9	0.000	0.000	0.000	0.000	0.000
P10	0.398	0.498	0.399	0.398	0.398

Table 3 : Number of simulated points to obtain the final solution

Problem No.	Number of simulation points			
	NP	PSO	PSPO	Hybrid A.
P1	490	220	900	102
P2	570	300	1400	126
P3	520	800	1275	134
P4	810	300	3275	114
P5	530	550	1730	93
P6	610	600	2035	99
P7	290	436	1555	123
P8	390	328	2490	140
P9	240	264	305	112
P10	340	500	1150	137

V. Conclusions and Remarks

In this paper, a metamodel based hybrid algorithm was developed for optimization of the digital computer simulations models. It is assumed that the considered simulation models are computationally expensive, and have a single output function which is nonlinear continuous unconstrained function. By the computationally expensive we mean that, each simulation run is required an extensive computational time.

The hybrid algorithm is developed by modifying and integrating of several concepts and routines. We incorporated NP and PSO algorithms to develop an efficient search mechanism and we modified K metamodel to be applied in stochastic simulation-optimization model (SK), and is integrated to the search mechanism as a metamodel for facilitating the function fitting processes of the simulation's output. As the result a hybrid algorithm is developed.

The efficiency of the developed hybrid algorithm was then evaluated through computational experiments. Six complex test problems were selected from the literatures and the efficiency of the developed hybrid algorithm was evaluated by comparing its performances against three other algorithms. Two algorithms were selected from the existing literatures, and one algorithm was a preliminary developed algorithm by the authors. The result of these computational experiments revealed that the developed hybrid algorithm can provide very robust solutions with a very low computational effort.

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Assembly Line Balancing to Improve Productivity using Work Sharing Method in Apparel Industry

By Md. Niaz Morshed & Kazi Saifujjaman Palash
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Abstract- Line balancing is an effective tool to improve the throughput of assembly line while reducing non-value-added activities, cycle time. Line balancing is the problem of assigning operation to workstation along an assembly line, in such a way that assignment is optimal in some sense. This project mainly focuses on improving overall efficiency of single model assembly line by reducing the non-value added activities, cycle time and distribution of work load at each work station by line balancing. The methodology adopted includes calculation of cycle time of process, identifying the non –value-added activities, calculating total work load on station and distribution of work load on each workstation by line balancing, in order to improve the efficiency of line and increase overall productivity.

Keywords: line balancing (lb), assembly line balancing (alb), line efficiency (le), labor productivity.

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Strictly as per the compliance and regulations of:

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Md. Niaz Morshed [α] & Kazi Saifujjaman Palash [σ]

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I. Introduction

Textile industry is one of the world's major industries and the garment industry is a substantial one within the supply chain of textile industry. The production process of garments is separated into four main phases: designing or clothing pattern generation, fabric cutting, sewing, and ironing or packing. The most critical phase is the sewing phase, as it generally involves a great number of operations.

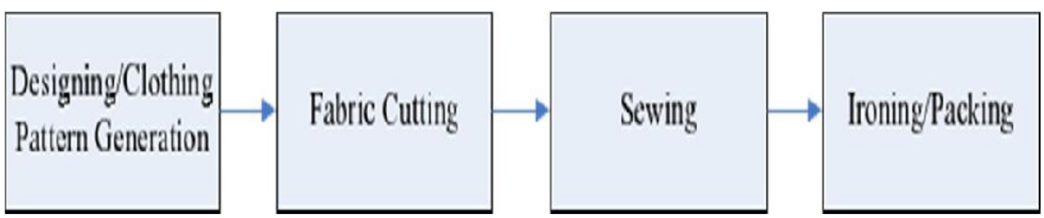
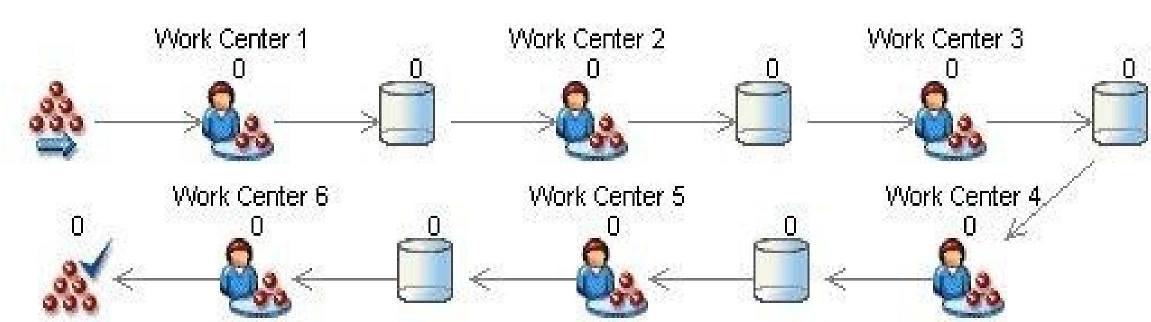


Figure 1 : Garment manufacturing processes

The sewing line consists of a set of workstations in which a specific task in a predefined sequence is processed. In general, one to several tasks is grouped into one workstation. Tasks are assigned to operators depending on the constraints of different labor skill levels. Finally, several workstations in sequence are formed as a sewing line. Shop floor managers are concerned with the balance of the lines by assigning the tasks to workstations as equally as possible. Unequal workload among workstations of a sewing line will lead to the increase of both WIP and waiting time, indicating the increase of both production cycle time and cost. In practice, the sewing line managers or production controllers use their experience to assign tasks to workstations based on the task sequence, labor skill levels and the standard time required to complete each task. As a result, the line balance performance cannot be guaranteed from one manager to another with different assignment preference and/or work experience.



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In garment industry a product is manufactured through a series of operations. Each operation must be performed on a machine (sewing machine) with a specific machine setting, i.e. yarn color, machine attachment. Manufacturing a product always requires different types of sewing machines and different yarn colors, making it difficult to assign a worker to perform operations on just a single machine. There is a maximum number of machines that each worker can use for a particular product. Figure 1, for example, denotes the line configuration of the problem considered in this research of which each worker can use at most three different machines. For the ease of working, identical machines of different settings will be treated as different machines. The worker therefore needs not to adjust the setting every time he/she performs an operation.

The optimization model takes into account workers' skill levels as well as the constraint on the number of machines at each station (worker). Each operation can be classified as a skill type. Each worker in the team is evaluated for all these skills on standardized tests. The ratings based on time required to perform such skill to meet acceptable quality level is given to each worker for each skill. This rating system allows for incompetent workers who cannot perform certain skills as well. The solution approach is divided into two phases. In the first phase, a multi-stage integer programming model is developed to assign operations, corresponding machines and their settings to stations considering standard operation times, station by station. Parallel stations are allowed so as to improve overall line cycle to as well as to use the required number of workers. Then in the second phase, another integer programming model is used to assign workers to stations based on their aptitudes to minimize the overall line cycle time.

II. Literature Review

Assembly line balancing is the problem of assigning various tasks to workstations, while opt-imizing one or more objectives without violating any restrictions imposed on the line. ALBP has been an active field of research over the past decades due to its relevancy to diversified industries such as garment, footwear and electronics. The assembly line balancing problem has received considerable attention in the literature, and many studies have been made on this subject since 1954. The assembly line balancing problem was first introduced by Bryton in his graduate thesis. In his study, he accepted the amount of workstations as constant, the workstation times as equal for all stations and work tasks as moving among the workstations. The first article was published in 1955 by Salveson. He developed a 0-1 integer programming model to solve the problem. COMSOAL (Computer Method of Sequencing Operations for Assembly Lines) was first used by Arcus in 1966 as a solution approach to the assembly line balancing problem. Helgeson ve Birnie [11] developed the "Ranked Positional Weight Technique". In this method, the "Ranked Positional Weight Value" is determined. It is the sum of a specified operation time and the working times of the other operations that can't be assembled without considering the operation finished. While taking into consideration the cycle time and technological precedence matrix, the operation having the largest ranged weight is assigned to the first workstation, and other operations are assigned to workstations in accordance with their ranked positional weight value.

Configurations of assembly lines for single and multiple products could be divided by three line types, single-model, mixed-model and multi-model.

Single-model assembles only one product, and mixed-model assembles multiple products, whereas a multi-model produces a sequence of batches with intermediate setup operations. A single-model line balancing problem with real application was solved in this project.

ALBP with various objectives are classified into three types

- ALBP-I: Minimizes the number of workstations, for a given cycle time.
- ALBP-II: Minimizes the cycle time, for a given number of workstations.
- ALBP-III: Maximizes the workload smoothness, for a given number of workstations.

In type I problems, the ALBP of assigning tasks to workstations is formulated with the objective of minimizing the number of workstations used to meet a target cycle time. It can result in low labor costs and reduced space requirements. Type II problems maximize the production rate of an assembly line. Since this objective requires a predetermined number of workstations, it can be seen as the counterpart of the previous one. In general, shop managers are concerned with the workload equity among all workers. The issue of workload smoothing in assembly lines allocates tasks among a given number of workstations, so that the workload is distributed as evenly as possible. This problem is known as Type III problem. Our project was focused on type-1 line balancing problem. Relevant data obtained from an apparel industry was used to formulate the solution. The objective of the project was to balance the cycle time for various operations and minimization of workstations.

III. Methodology

In order to balance a production line in sewing floor a line was chosen and necessary data was accumulated from the line.

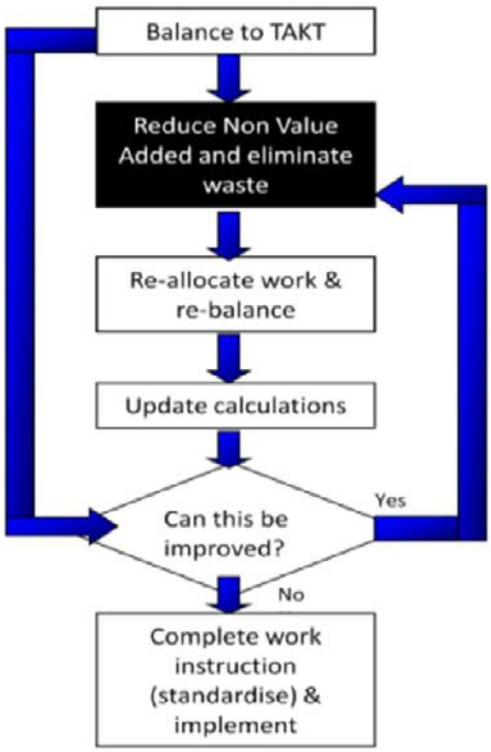

Figure 2 : flowchart for line balancing

A garment order is chosen which was started in that line, knowing total amount of order, style description, fabric type and color. Two important attributes have been considered, one is possible standard method for each process and another is considerable time in between the input has been fed to the time study took to record the actual individual capacity of each worker. We have recorded the time to make each process for each and every worker to find out the number of operator and helper, type of machines and individual capacity. To find out the(standard minute value) S.M.V , process wise capacity has been calculated, in addition to that we have calculated the target, benchmark capacity, actual capacity line graph, labor productivity and line efficiency. After taking necessary data from the line we proposed a suitable line balancing technique for the line. At first we highlighted the bottleneck processes which were our prime concern and then seek solution to minimize the problem. In this project we proposed a method to balance the line by sharing workload among equally adept workers who has experience in both the bottleneck process and balancing process. Line has been balanced considering the bottleneck and balancing process where the balancing process has shared the excess time after the benchmark production in the bottleneck process. After balancing, new manpower has been proposed and final capacity of each worker has been reallocated. We have compared the line graph after balancing the line, labor productivity and line efficiency. Finally a proposed production layout has been modeled with balanced capacity.

IV. Equations

Standard minute value (S.M.V) = (average cycle time * allowance) in minute

$$\text{Takt time}=\frac{\text{Total S.M.V}}{\text{no. of operators}}$$

$$\text{Target}=\frac{\text{Total manpower per line}*\text{total working minutes per day}}{\text{S.M.V}}*100\%$$

$$\text{Theoretical manpower}=\frac{\text{Benchmark target per hour}}{\text{process capacity per hour}}$$

$$\text{Labor productivity}=\frac{\text{Total number of output per day per line}}{\text{number of workers worked}}$$

$$\text{Line efficiency}=\frac{\text{Total output per day per lines}*\text{S.M.V}}{\text{Total manpower per line}*\text{total working minutes per day}}*100\%$$

V. Data Analysis and Calculations

a) *Before balancing the line*

The first step of line balancing is to breakdown the operation into sequential logical order.

The breakdown is done to better understand and implement the sequential order of product processing steps.

Taking cycle time for each operation is done manually and S.M.V is calculated from the average time with suitable allowance. Adding total S.M.V we can obtain target/hour. In this case 80% efficiency is the desired output level per hour.

Before line balancing production scenario is illustrated in table -1

Table 1 : Bench mark Target, Labor productivity and Line Efficiency before balancing line

Total output per day Total manpower Working time S.M.V	= = = =	1100 27 600 6.42
Takt time (min)	=	.238
Target/hour	=	252 (efficiency 100%)
Target/hour	=	201 (efficiency 80%)
	=	151 (efficiency 60%)
Labor productivity		40
Line efficiency		44

Process wise capacity of each work station has been shown in Annexure 1 where Standard minute value (S.M.V) has been calculated by taking average cycle time for each process and considering allowances. Table: 1 shows the target per hour for the line calculating total 27 manpower worked on that line for 6oo minutes with a S.M.V value of 6.42. We have standardized the Bench mark target of 201 pieces of garment at 80% efficiency. Observation before balancing the line has been reflected as labor productivity is 40, line efficiency is 44%.

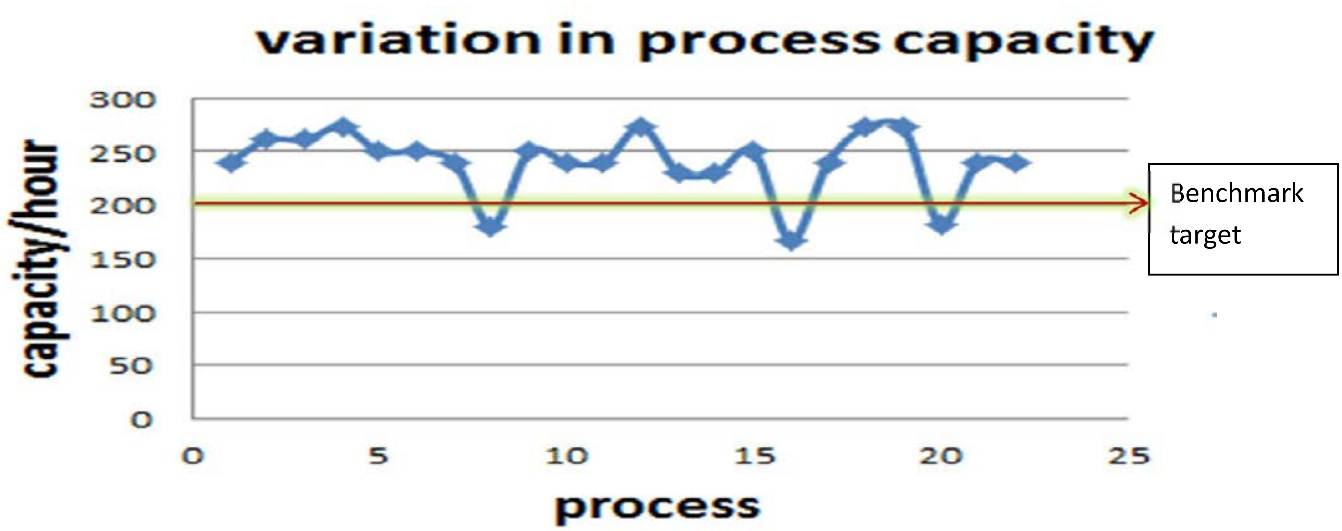

Figure 1 : Variation in each process capacity per hour compare to bench mark target per hour

Plotting process wise capacity in a line graph shows the variation of each process from the bench mark target as the upper capacity is 273 pieces per hour where the lower capacity is only 167 pieces per hour compare to the bench mark target of 201 pieces. This shows the imbalance situation in the line and bottleneck condition throughout the process of the whole garment making as lots of WIP stations in the line.

Table 2 : Balancing Processes to equalize the bottleneck process

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
1.	Main label attach position mark	8	180	200	Thread cut & fold	7	240	212
	Remarks	Process # 7 can work for 50 min. and share work with process # 8 for last 10 min.						

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
2.	Side seam	16	167	195	Sleeve join with body	13	230	192
	Remarks	Process # 13 can work for 50 min. and share work with process # 16 for last 10 min.						

Sl no		Bottleneck process				Balancing process		
	Process name	Process no	Capacity /hour	Balanced capacity	Process name	Process no	Capacity /hour	Balanced capacity
3.	Body heam	20	182	212	Sleeve heam	18	273	227
	Remarks	Process # 18 can work for 50 min. and share work with process # 20 for last 10 min.						

b) Bottleneck processes

From Figure 1: we have identified some variations in process capacity from the bench mark target and the lower capacity from the bench mark target is the bottleneck process as production flow would stuck on the bottleneck point. Comparing total capacity of each process to the 80% bench mark target, we have identified the bottleneck processes named Main label attach position mark, Side seam with care label attaching, Body heam . Total production has been blocked in these seven work stations and large work in process (WIP) has been stuck in these bottleneck processes.

c) Balancing Processes

Balancing method is very essential to make the production flow almost smoother compare to the previous layout. Considering working distance, type of machines and efficiency, workers who have extra time to work after completing their works, have been shared their work to complete the bottleneck processes. Previously identified three bottleneck processes have been plotted in the left side of the Table 2. Side seam and Sleeve join with body both have been made by overlock machine and these have been shared by two overlock machine processes.

Operator who work in Process no. 13 Sleeve join with body, have been worked for 50 minutes per hour in her first process, capacity 192 pieces and then have been worked in the process no. 16 Side seam for last 10 minutes to make additional 28 pieces for overall capacity of 195 pieces on process no. 16.

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d) Proposed Layout

Balanced Capacity/hr	Previous capacity	S.M.V	Process name	Process No.	M/C		M/C	Process No.	Process name	S.M.V	Previous capacity	Balanced Capacity/hr
120	120	.25	Back and Front matching	1. a	ML		ML	1. b	Back and Front matching	.25	120	120
261	261	.23	Shoulder join	2	O/L		ML	4	Neck rib measure & cut	.22	273	273
261	261	.23	Thread cut & fold	3	ML		SN	5	Neck rib make	.24	250	250
250	250	.24	Neck rib join with body	6	o/L							
212	240	.25	Trim & fold	7	ML		ML	8	Main label attach positioning mark	.33	180	200
240	240	.25	Back tape	10	F/L		SN	9	Main label attach with body	.24	250	250
240	240	.25	Thread cut & fold	11	ML							
273	273	.22	Sleeve match with body	12	ML		O/L	13	Sleeve join with body	.26	230	192
						WIP	ML	14	Thread cut & fold	.26	230	230
250	250	.24	Care label make	15	SN		O/L	16	Side seam with care label	.36	167	195
							ML	17	Thread cut & fold	.25	240	240
227	273	.22	Sleeve heam	18	F/L		F/L	20	Body heam	.33	182	212
273	273	.22	Thread cut & fold	19	ML		ML	21	Thread cut & fold	.25	240	240
120	120	.5	Quality inspection	22. a	ML		ML	22.b	Quality inspection	.5	120	120

Figure 2 : Work in Process in different table in a sewing section in a garments industry

First column on both side of center table shows the machine type and then followed by process no. process name, S.M.V value, previous capacity and after balance capacity. After first process front and back match, bundle of garments have been come to process no. 2 shoulder joint, then the bundle have been passed to process no. 6 Neck rib join with body and in between the processes, 3 helper has been worked in process no. 3,4,5. The working bundle then has been passed to process no. 7 and so on. In the proposed balancing process machines of the same type are used for line balancing. Process no 7 and 8 are both manual operations, process 13 and 16 are done by overlock machine, process 18 and 20 are done by flatlock machine .So workers operating on the same machines are accustomed to the various operations done by the same machine. As a result they can share their work.

VI. Result and Findings

Changing from traditional layout to balanced layout model, there are considerable improvements have moved toward us. Among the three operators who were replaced to another line, have been used in the overlock and flatlock machines and the total worker of 24 instead of 27, labor productivity has been increased from 40 to 50.

In a day we have boost up the production up to 1190 and with manpower of 24, line efficiency has been improved from 43% to 53% which is shown in Table 3. In an improved layout, target has been decreased at each efficiency level. At 80% efficiency, target is now 180 pieces per hour which has been considered as new bench mark target.

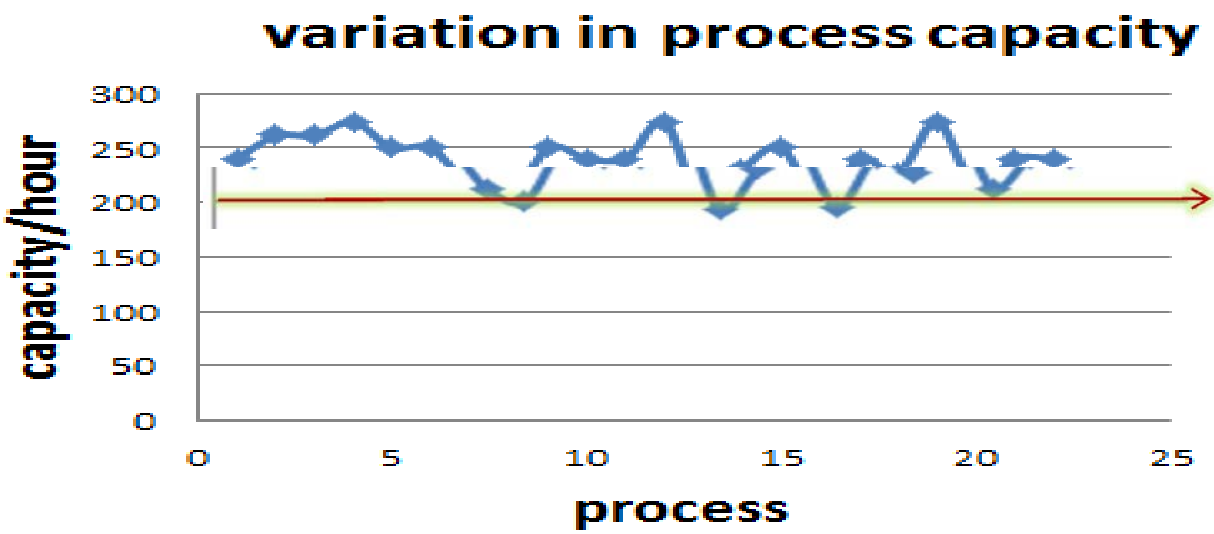

Figure 3 : Variation in each process capacity per hour compare to bench mark target per hour

Figure 3: Variation in each process capacity per hour compare to bench mark target per hour Figure -3 illustrates the distribution of target capacity after implementing proposed balancing method. Here we can see all the target capacity for each operations are above or very close to the benchmark capacity/hour .So the effect of bottleneck operation has been minimized by this balancing method.

Table 3 : Process wise revised capacity and optimized manpower distribution

Serial no	process	S.M.V	Total capacity	Total capacity (revised)	Target (80%)	Actual manpower	Proposed manpower
1	Back and Front matching	.25	240	240	201	2	2
2	Shoulder join	.23	261	261	201	1	1
3	Thread cut & fold	.23	261	261	201	1	1
4	Neck rib measure & cut	.22	273	273	201	1	1
5	Neck rib make	.24	250	250	201	1	1
6	Neck rib join with body	.24	240	240	201	1	1
7	Trim & fold	.25	240	212	201	1	1
8	Main label attach positioning	.33	180	200	201	2	1
9	Main label attach with body	.24	250	250	201	1	1
10	Back tape	.25	240	240	201	1	1
11	Thread cut & fold	.25	240	240	201	1	1

12	Sleeve match with body	.22	273	273	201	1	1
13	Sleeve join with body	.26	230	192	201	1	1
14	Thread cut & fold	.26	230	230	201	1	1
15	Care label make	.24	250	250	201	1	1
16	Side seam with care label	.36	167	195	201	2	1
17	Thread cut & fold	.25	240	240	201	1	1
18	Sleeve heam	.22	273	227	201	1	1
19	Thread cut & fold	.22	273	273	201	1	1
20	Body heam	.33	182	212	201	2	1
21	Thread cut & fold	.25	240	240	201	1	1
22	Quality inspection	.50	240	240	201	2	2
					total	27	24

(Blue cells signifies capacity changing cells and orange cells shows change of manpower)

As a result of the balancing process total output per day has been increased and manpower requirement has been reduced which ultimately leads to increased labor productivity and line efficiency. Revised takt time is estimated to be .2675.

Table 3 : Bench mark Target, Labor and machine productivity and Line Efficiency after line balancing

Total output per day	=	1190	
Total manpower	=	24	
Working time	=	600	
S.M.V	=	6.42	
Takt time (min)		.2675	
Target/hour	=	224	(efficiency 100%)
Target/hour	=	180	(efficiency 80%)
	=	134	(efficiency 60%)
Labor productivity		50	
Line efficiency		53	

VII. Improvement

Further improvements in the productivity can be achieved by considering large amount of order minimum 10000pieces. Table 2 shows the new bench mark target which can be the further chance of improvements to balance the line with this new bench mark target. Proposed layout model has been followed the logic of modular system (one worker works more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training and supervision is essential to achieve the optimum improvements on productivity and efficiency.

Maximum outputs have been increased to 1190 pieces a day which was previously recorded to 1100 pieces a day. Before balancing the line 7700 pieces of garments have been produced for 7 days where 7140 pieces have been produced for 6 days after balancing the line. We have saved one day lead time for that style of 9000 pieces and almost 600 minutes of labor work value time. We have replaced 2 operators and 1 helpers into different lines and relatively saved 3 workers work time of 1800 minutes from that line.

VIII. Conclusion

Result would have been more effective if we would have taken some large quantity order and balancing the process is highly related to the type of machines as machine utilized in bottleneck and balancing process should be similar. Further improvements in the productivity can be achieved by considering large amount of order minimum. Proposed layout model has been followed the logic of modular system (one worker works more than two processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production) and traditional system (one worker works in one process and all the workers who may be skilled or not finish their work in bundle flow production) both together where only modular production system can be applicable with a series of skilled workers to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training and supervision is essential to achieve the optimum improvements on productivity and efficiency.

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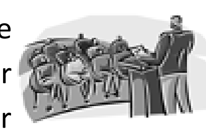

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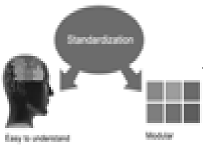

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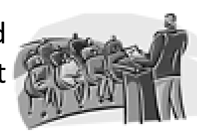

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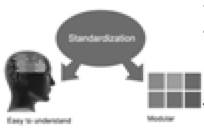

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated 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.

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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

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