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A Review on Multi Objective Optimization in Turning Using Goal Programming and Taguchi Technique on CNC Lathe

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Abstract: The Call Of Recent Time Is To Make Precise And Dimensionally Accurate Product To Sustain In Competitive Market. In Machining Process, Surface Finish Is One Of The Most Significant Technical Requirements Of The Customer [1].So, Quality Of The Product Is In Direct Relation To The Surface Finish And Ultimately Life Of Product. Surface Finish Is Very Difficult To Control By Just Experience Or Gambling Due To Lots Of Factors Involvement (Eg. Feed, Depth Of Cut, Speed, Tool Wear, Temp.Etc). There Are Various Disciplines Available To Us Like Taguchi, Full Factorial Design, Surface Response Method, Genetic Algorithm, Min-Max Method, Fuzzy Logic, Scatter Search Technique, Particle Swarm Optimization (PSO), Goal Programming, Etc. In Modern Manufacturing Trades The Quality Of Product, Cost Of Process And Less Marching Time Are Main Factor Of The Industries. Taguchi Techniques And Goal Programming Are Developed To Make Product Least Sensitive To The Noise Factors And Achieve Optimal Response For Given Set Of Input Parameters. Complexity In Cutting Processes Increased Substantially, Researchers And Practitioners Have Focused On Mathematical Modelling Techniques To Determine Optimal Or Near-Optimal Cutting Condition [2]. Thus, Taguchi Technique Will Help Us To Optimize The Parameters Using Matrix Design And ANOVA And Goal Programming Will Give Us Mathematical Model Of The Experiments. This Review Paper Is Attempt To Evaluate Importance Of Different Optimization Techniques To Acquire Controlled Surface Finish, High MRR And Optimal Tool Life Using CNC Lathe.
Key Words: Taguchi, Goal Programming, MRR, Surface Roughness, ANOVA, Optimization

I. INTRODUCTION

Today, CNC Machine Replaced The Conventional Lathes Which Provides Extreme Level Of Accuracy And Precision. But, In Spite Of Accuracy There is Room Of Error. CNC Machine is Purely Mercy Of Workers Experience And Decision Making To Get Desire Output. The Challenge Of Modern Machining Industries Is Mainly Focused On The Achievement Of High Quality, In Terms Of Work Piece Dimensional Accuracy, Surface Finish, High Production Rate, Less Wear On The Cutting Tools, Economy Of Machining In Terms Of Cost Saving And Increase The Performance Of The Product With Reduced Environmental Impact [3]. Groover (1996) Depicted The Impact Of Three Factors, Namely The Feed, Nose Radius And Cutting-Edge Angles, On Surface Roughness. Modelling Of Input–Output And In-Process Parameter Relationship Is Considered As An Abstract Representation Of A Process Linking Causes And Effects Or Transforming Process Inputs Into Outputs [4]. Numbers Of Precise Engineering Components Such As Shaft, Transmission Rods, Rivets, Screw-Nuts Etc Which Need Highly Accuracy Along With Excellent Surface Finish For Serving Their Definite Purpose. The Irregularities In Surface Finishing Leads To The Misalignment, Wear And Tear, Additional Stresses Gets Developed To Element Which Leads To Less Life Of System With Highly Possible Damages Although It Gives Shabby Look To The Product. Selection Of Optimal Machining Condition(S) Is A Key Factor In Achieving This Condition [5]. In Any Multi-Stage Metal Cutting Operation, The Manufacturer Seeks To Set The Process-Related Controllable Variable(S) At Their Optimal Operating Conditions With Minimum Effect Of Uncontrollable Or Noise Variables On The Levels And Variability In The Output(S)[6] It Incorporates The Use Of One Or More Of The Existing Modelling And Optimization Techniques, Making The Framework A Unified And Effective Means [6]. Also Optimization Techniques Also Have Certain Constraints, Assumptions And Limitations For Implementation In Real-Life Cutting Process Problems. Some Of These Limitations And Assumptions Are Discussed In The Literature. [7], [8], [9]. It Is Estimated That 36% Of All Machine Hours (40% Of CNC) Are Spent Performing Drilling Operations, As Opposed To 25% For Turning And 26% For Milling, Producing 60% Of The Resultant Chips [10].

II. VERVIEW OF OPTIMIZATION TECHNIQUES

Increase in complexity of machining, lots of parameters involvement and introduction to new composite material forced researcher to develop a different optimization method which can easily leads us to conclusion in different condition. Aggarwal & Singh proposed TAGUCHI technique to review the literature on optimizing machining parameters in turning processes. Various conventional techniques employed for machining optimization include geometric programming, geometric plus linear programming, goal programming, sequential unconstrained minimization technique, dynamic programming etc[11]. Derringer and Suich describe a multiple response method called desirability. It is an attractive method for industry for optimization of multiple quality characteristic problems [12]. Zuperl & Crus proposed a neural network based approach to complex optimization of cutting parameters, and described the multi-objective technique of optimization of cutting conditions by means of the neural networks taking into consideration the technological, economic and organisational limitations [13]. Oktem et al utilized response surface methodology to create an effi cient analytical model for surface roughness in terms of cutting parameters: feed, cutting speed, axial DOC, radial DOC and machining tolerance [14]. Al-Ahmari developed empirical models for tool life, surface roughness and cutting force for turning operations. Two important data mining techniques used were response surface methodology and neural networks [15]. Hossain et al developed an ANN algorithm for predicting the surface roughness in end milling of Inconel 718 alloy [16]. Ojha and Das [14] also carried out a research on Multi-Objective Geometric Programming Problem Being Cost Coefficients as Continuous Function with Weighted Mean Method [17]. Tong and Su presented a procedure to optimize multi-response problems using fuzzy multiple attribute decision-making process. The use of fuzzy attribute decision-making assisted in taking into account multiple decision goals and constraints simultaneously. However, this methodology requires rather complicated computation and involves difficulty in implementation of expert's knowledge into the formulae [18]. Suresh et al. developed a surface roughness prediction model for turning mild steel using a response surface methodology. Surface roughness prediction model has also been optimized by using genetic algorithms [19]. To overcome the drawbacks of penalty function strategy for considering the constraints, Chi Zhou et al (2006) presented Particle Swarm Optimization (PSO) algorithm, involving simultaneous assignment of both design and machining tolerance. The objective function considered was optimal total machining cost. The efficiency and effectiveness were improved by using PSO [20]. Taguchi based utility concept is a multi-objective optimization has been employed for optimization of machining parameters in turning operation of AISI202 austenitic stainless steel with CVD coated carbide tool [21]. Taguchi based utility concept coupled with and Principal Component Analysis (PCA) has been employed to estimate the optimum combination of cutting speed, feed and depth of cut for simultaneous minimization of surface roughness, cutting force and maximization of material removal rate where found that coated tool is the most significant parameter followed by cutting Speed [22]. El Baradie developed of a surface roughness model while using tipped carbide tools for turning grey cast iron under dry conditions and with constant depth of cut. The mathematical model is utilizing the response surface methodology was developed in terms of cutting speed, feed rate and nose radius of the cutting tool. These variables were investigated using design of experiments and utilization of the response surface methodology Using of goal programming technique in for single pass turning operation **[23].**

III. OVERVIEW OF TAGUCHI TECHNIQUES

Taguchi Methods are Statistical Methods, Or Sometimes Called Robust Design Methods, Developed By Genichi Taguchi To Improve the Quality of Manufactured Goods. According to Phillip Rose, Taguchi Philosophy provides two tenets : (1) Reduction in Variation of Product or process shows a lower loss to society (2) the Proper development strategy can intentionally reduce variation. Taguchi has two main areas off-line and on-line Quality Control. Taguchi approach has a wide variety of applications in the different fields because of its easiness and optimized results [24].Taguchi's introduction of the method to several major American industries, including AT&T, Ford Motor. and Xerox, resulted in some significant quality improvement in product and manufacturing process design [25]. Taguchi technique is a powerful tool for identification of affect of various process parameters based on orthogonal array (OA) experiments which provides much reduced variance for the experiments with an optimum setting of process control parameters [30, 31]. In turning process parameters such as cutting tool geometry and materials, the depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the material removal rates and the machining qualities like the surface roughness, the roundness of circular and dimensional deviations of the product [26]. The Taguchi method emphasizes over the selection of the most optimal solution (i.e. MRR, Surface Roughness) over the set of given inputs (i.e. cutting speed, feed rate and depth of cut) with a reduced cost and increased quality. The optimal solution so obtained is least affected by any outside disturbances like the noise or any other environmental conditions [27]. Agarwal et al. carried out theoretical and experimental studies to investigate the influence of wear parameters like applied load, sliding speed, percentage of reinforcement content and sliding distance on the dry sliding wear of the composites. A plan of experiments, based on the techniques of Taguchi, was performed to acquire data in controlled way. An orthogonal array and the analysis of variance were employed to investigate the wear behaviour [28]. Selvara and Chandramohan presented the influence of cutting parameters like cutting speed, feed rate and depth of cut on the surface roughness of austenitic stainless steel during dry turning. A plan of experiments based on Taguchi's technique has been used to acquire the data [29]. The Taguchi approach has a wide variety of applications in the different fields because of its easiness and optimized results [32].

A. P-Diagram

P-Diagram is used to classify the variables associated with the product into noise, control, signal (input), and response (output) factors. In this Step Identify the input signal and output response associated with design. The factor which is not in under control is called Noise Factor.

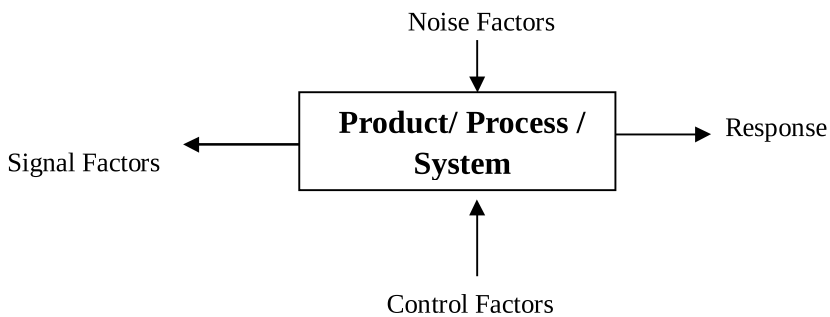

Fig.1 P-Diagram **[67]**

B. Quality Measurement

1) The Taguchi loss function is graphical depiction of loss developed by the Japanese business statistician Genichi Taguchi to describe a phenomenon affecting the value of products produced by a company. Praised by Dr. W. Edwards Deming (the business guru of the 1980s American quality movement) [33]. In Quality measurement, the primary consideration is that the product should not deviate from the mean targeted value which means product should have less specification but better Quality.

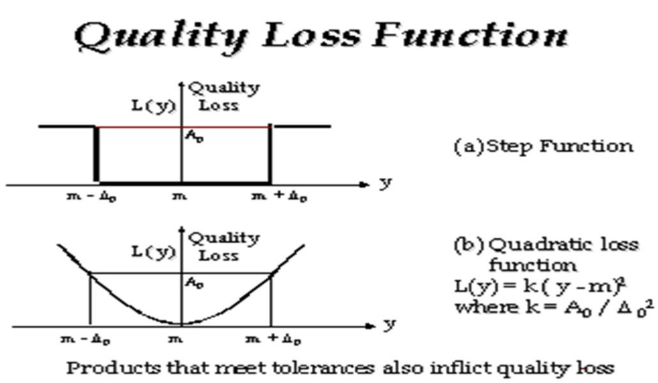

Fig.2. Taguchi Loss Function [67]

The Taguchi loss function is important for a number of reasons—primarily, to help engineers better understand the importance of designing for variation. Quadratic loss function is very useful to evaluate impact of decision variables on consumers or high-level system. Taguchi *loss* function, more nearly describes actual situation.

C. Signal-to-Noise Ratio (S/N ratio)

Taguchi recommend signal to noise (SN) ratio which is the logarithmic function of desired response act as the objective function for optimization. The level at which the highest SN ratio is the level of optimal combination of machining parameters **[34]**. The experimental condition that has the maximum S/N ratio is considered as the optimal condition because the variability of the

Volume 5 Issue V, May 2017
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characteristics is inversely proportional to S/N ratio **[35].** In this ratio the Signal is Controlled Parameters(eg. Feed, Speed, Depth of cut etc.) and Noise is Uncontrolled factors(eg. Coolant, Temperature etc.). Control Factor Easily Set By Designer Which Brings Maximize Quality Of Product Whereas Noise Factor are Difficult To Control Or Expensive.

Taguchi suggest the response variables mainly into three different classes, e.g. smaller-the-best (STB), larger-the-best (LTB) and nominal-the-best (NTB) **[36].**

Bigger the better: $\frac{S}{N} = -10log\frac{\left(\Sigma^{1}/_{y^2}\right)}{n}$

Smaller the better: $\frac{S}{N} = -10log\frac{(\Sigma y^2)}{n}$

Nominal is Better: $\frac{S}{N} = 10\log\left(\frac{\overline{Y^2}}{s^2}\right)$

Where, $\begin{cases} n = nos.of\ observation \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \\ y = characteristics\ to\ resp.Observation \\ s = Standard\ deviation \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \end{cases}$

D. Analysis of variance (ANOVA)

Analysis Of variance (ANOVA) is the statistical tool which segregates the total variability of the response into individual contributions of each of the factors and the error.ANOVA formally helps us to identifying factor interaction to Response parameters by mean square against estimate of experimental error at specific confidence level. Kirby *et al*. found that Analysis of Variance (ANOVA) has a strong linear relationship among the Input Parameters and the response (surface roughness, MRR etc.) was found. if the "Model P Value" is very small (less than 0.05) then the terms in the model have a significant effect on the response [38].

The squared deviation SS_T from total means S/N ratio can be evaluated by following formula:

$$SS_T = \sum_{i=1}^{n}(n_i - n_m)^2$$

Where

$$n_m = \text{total nos. of experiments in array}$$
$$n_m = \text{mean}\frac{s}{n}\text{ratio for } i^{th} \text{ experiment} \ldots$$

Whereas, Percentage Contribution of parameters to the response (output) can be formulated as:

$$P = \frac{SS_d}{SS_T}$$

Where,

$SS_d = sum\ of\ squared\ deviation\ldots$

IV. OVERVIEW OF GOAL PROGRAMMING

Most of the real-world problems are multi objective in nature and the objectives conflict to each other. According to Arua *et al* Modeling is very important in operations research. Though model has different shades of meaning. The fundamental problem of optimization is to arrive at the best possible decision in any given set of circumstance." [39]. To resolve the conflict, Goal Programming was first introduced by Charnes et al. in 1955 [47], more explicitly defined by the same authors in 1961 [48], and further developed by Ijiri [49] during the 1960's..Goal Programming is a branch of multi-criteria decision analysis and it has been successfully applied in many areas of management as an aid to decision making applications in accounting [41], finance [42], marketing [43], and the management sciences attest to its effectiveness in dealing with optimization Goal programming has been widely applied to financial management problems during the past 15 to 20 years. [44]. Questions were raised as to the effectiveness of GP as an application tool by Zeleny [50] and Harrald [51] during the late 1970's and early 1980's, but GP still grew in popularity judging by the increase of papers applying GP during that period. Several classes of goal programming can be obtained, depending on the nature of the goal functions. decision variables. and coefficients[45]. Recently, papers have been published dealing with some

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

of the perceived "errors" in GP [52, 53, 54], and explaining how these can be avoided by the correct setting of weights, goals, priority levels, etc.

There is mainly two way to evaluate the goal programming problem which we are reviewing as part of our study.

A. *Lexicographic Goal Programming*

Romero **[52]**, 226 use the concept of Lexicographic GP (LGP), which requires the pre-emptive ordering of priority levels. The first algorithm for solving a lexicographic GP was presented by Charnes and Cooper in their 1961 book **[55]**. This used a modified version of the two-phase simplex method. The first recorded computer code to implement this method was produced **[56]** in 1969. This code was, however, inefficient and could only deal with small problems (fewer than 50 variables). The next stage of LGP algorithms treated each priority level as a separate LP and solved accordingly. Extra constraints were added, to make sure the higher priority level optimal solutions were not denegrated, at each priority level. These were known as sequential simplex algorithms and allowed the solution of medium-scale models.

The Standard LPG Model can be algebraically represent as:[66]

$$\text{Lex min } a = (g_1(n,p),\ g_2(n,p), \ldots, g_k(n,p))$$

$$\text{Subjected as } f_i(x) + n_i - p_i = b_i \qquad i=1,\ldots,m$$

A textbook description of the theory of the sequential simplex method is given in Ignizio [57]. The next attempts to exploit the lexicographic structure were made by Arthur and Ravindran [58], who suggested considering only the constraints relevant to each priority level at that level. Schniederjans and Kwak then produced a dual simplex based method which can eliminate up to half of the deviational variables [59]. A good comparison of these methods as compared with the sequential simplex (conventional and revised) method of solving is found in Olson [60]. Ignizio then introduced a sophisticated primal-dual method of solution based on his work on the development of the multi-dimensional dual [61]. Markland and Vickery [62] have developed an integer GP model capable of handling large-scale problems.

B. *Weighted Goal Programming*

Weighted (or non-pre-emptive) GP (WGP) requires no pre-emptive ordering of the objective functions. Instead, all the different deviations are placed in a single priority level objective with different weights to represent their importance.

Algebraically, a WGP has the following structure [66]

$$\text{minimize} \quad a = \sum_{i=1}^{k} (\alpha i n i + \beta i p i)$$

$$\text{subjected to} \quad f_i(x) + n_i - p_i = b_i, \quad i=1,\ldots m \qquad x \in Cs$$

where, Cs = Optional Constraints Sets

One of the major disadvantages of using weighted GP in the past has been the problem of incommensurability (i.e. elements in objective functions being measured in different units). Hence the need for a normalisation procedure. Several normalization procedures have been suggested by various authors. The most popular are presented below.

1) *Euclidean normalization:* First suggested by De Kluyver [63] in 1979, this method divides each objective by the Euclidean (L2) norm of its coefficients,

$$3x_1 + 4x_2 + n - p = 16 \quad \longrightarrow \quad 3/5x_1 + 4/5x_2 + n^e - p^e = 16/5$$

As noted by Romero [64], this approach alleviates some of the problems caused by incommensurability but since its critical factor is the coefficients, it can still leave distortions when the values taken by the technical coefficients are small compared with the goal target values.

2) *Percentage normalization:* This method is clearly illustrated in Romero [64]. Each objective is first divided through by its right-hand side and then multiplied by 100. The new deviations (n% and p%) then represent percentage deviations away from the goals.

$\longrightarrow$

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$3x_1 + 4x_2 + n - p = 16$ $300/16x_1 + 400/16x_2 + n\% - p\% = 100$

The critical factor in this method is the goal target value *(bi)*. Thus, this method works well except in the case where the target value is very small.

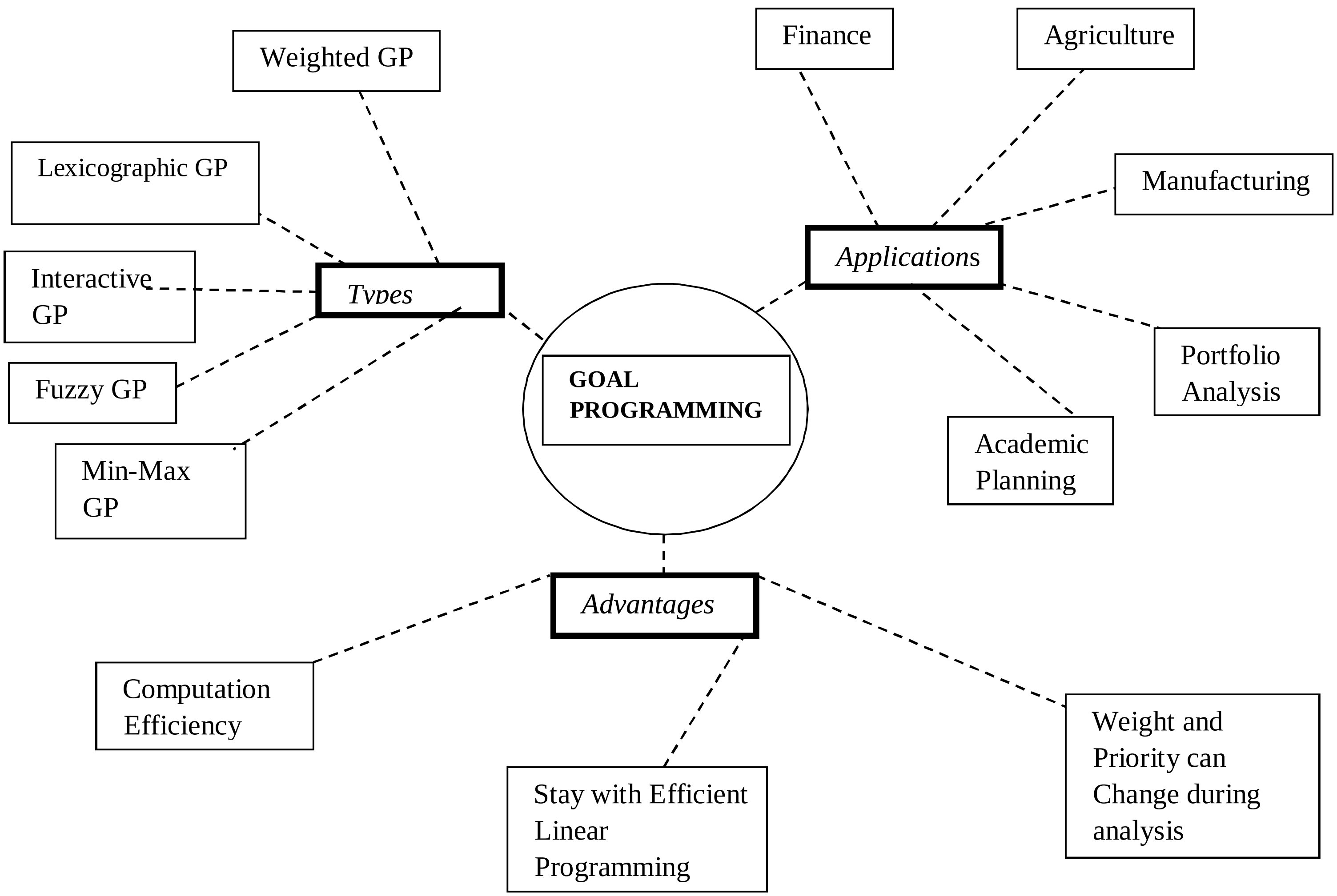
3) *Scaling between ideal and nadir points:* In this method, we find the minimum (ideal) deviation from the goal for each objective within Cs and label this value g_{ib}. Likewise, the maximum (nadir) deviation from the goal within Cs is also calculated and labelled g_{iw}.

The following scaling function is then applied[66]

$$[g_{iw} - g_i\,(ni, pi)] \,/\, [g_{iw} - g_{ib}]$$

This method appears both robust and theoretically sound. Problems do occur, however, when the
feasible region defined by the constraint set C_s contains some undesirable alternatives, since these alternatives have an effect on the maximal deviation and thus distort the weights for some objectives. C_s are should therefore be taken on defining C_s. if this method is used. A second problem that may occur is the degenerate case in which an objective has a constant deviation over C_s, i.e. $g_{iw} = g_{ib}$. The normalization process is, however, computationally expensive. An application of this method to an interactive GP framework is given by Masud and Hwang [65].

C. Graphic Presentation of influencing area of Goal Programming



International Journal for Research in Applied Science & Engineering Technology (IJRASET)

D. Concluding Remarks

This Review Paper Was Sincere Effort To Emphasizes On The Basic Overview And Recent Advances In The Field Of Optimization As Well As Different Optimization Techniques Uses In Manufacturing To Get Extremely Accurate Results Without Any Vague Decision.

Our Work Was To Illustrate The Pros And Cons Of The Taguchi Techniques And Goal Programming, As Well As Its Application In Various Fields Including In Science And Commerce Filed As Well. This Will Helps Reader To Fetch Out The Exact Method Of Optimization Which Is Flexibility And Accurate To Get Desired Results In Quick Span Without Investing Much Time And Energy.

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