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# Productivity Improvement through Ergonomics Sub-System Concern Using MCDM with Goal Programing: A Case Study

**Seife Ebeyedengel Tekletsadik***

Department of Industrial Engineering, Institute of Technology, College of Engineering, Debre Berhan University, Debre Berhan, Ethiopia; seifnet.ebeye@gmail.com.

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## Abstract

Productivity improvement is important for the sustainability of the business. However, before improvement it is important to measure the existing system Productivity Index (PI). In this sense, the PI of the case company has been measured by using the PO-P approach. Using this approach, the overall productivity of the case company has become 0.652 [14]. By having the performance objectives of the KPAs under ergonomics sub-system and strategic goals of the case company with the given target values, GP model has been formulated to show by how much percent does the ergonomics subsystem alone will improve the overall PI. For this, optimal (suggested) solution of PV of the performance objectives of the KPAs under the ergonomics sub-system have been obtained using excel solver. Having these values, the PI of the ergonomics sub-system became 1.492, in effect increased the overall PI from 0.652 to 0.776.

**Keywords:** Excel solver, Goal programming, MCDM, Sewing thread and yarn manufacturing, Suggested performance value.

## 1 | Introduction



Various models of Operations Research (OR)/Goal Programming (GP) have been developed to solve multi-criteria industrial problems [1]. Different methods have been developed to solve Multi Criteria Decision Making (MCDM) industrial problems [2], [3]. The study conducted by [4] have applied three MCDM methods, TOPSIS, VIKOR and COPRAS, selecting the optimal industrial investment and prioritizing industrial investment. Now a days GP, common and popular, is an important class of Multi-Criteria Decision (MCD) models widely used in engineering, management, and social sciences to analyze and solve applied problems involving decision making for conflicting objectives [5]. This decision making is influenced by objective and subjective aspects and usually for each specific situation there are various criteria which must be taken into consideration. The MCDM models are helpful to the managers to solve various problems, such as to minimize the cost of production, increase the productivity and use the available resources carefully and for healthy industrial growth [6]. There are many possible criteria arising from different fields of application but some of the most commonly arising relate at the highest level to cost, profit, time, distance,

Corresponding Author: seifnet.ebeye@gmail.com

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performance of a system, company or organizational strategy, personal preferences of the decision makers, safety consideration.

Management of companies must provide decision making processes to ensure smooth running of the company. Widely used approach for solving multi criteria decision problems is GP. In this sense the unique GP model have created by [7] for the implementation of strategic goals of the company into the business plan. As well as GP method in combination with analytical hierarchy process have applied in forest management to estimate the optimal stock level of different tree species considering environmental, economic, and social issues [8]. The study conducted by [9] have developed a new system evaluation model of MCDM with GP for Airport Ground Handling Service (AGHS) Equipment Vendor Selection (EVS) by considering both qualitative and quantitative methods which have tested the proposed approach on an AGHS company in Taiwan. On the other hand the new decision rule called target decision rule have developed by [10] as a new application area of GP which is helpful when solving uncertain problems since it is especially designed for neutral criteria, which are not taken into account in existing procedures developed for 1-DMU. The study conducted by [11] have applied three MCDM methods on a facility location selection problem and their relative ranking performances are compared. Because of disagreement in the ranks obtained by the three different MCDM methods, a final ranking method based on REGIME is also proposed to facilitate the decision-making process. Finally, the results of this study are compared by the results of the same study.

The goals in MCDM are usually conflicting so the right solution is a good compromise between all goals which are set in the company, hence compromising solution is the main idea of MCDM by using variety of methods. One of these methods is GP which is the most promising, powerful, and flexible technique that can be applied to a variety of decision problems involving multiple objectives [12]. GP over other techniques is dealing with real-world decision problems that allows decision maker to incorporate environmental, organizational, and managerial consideration into model through goal levels and priorities [13]. If the decision maker can provide an ordinal ranking of goals in terms of their importance to the organization and if all relationships of the model are linear, the problem can be solved by GP. GP is used to perform three types of analysis:

I. Determine the required resources to achieve a desired set of objectives.
II. Determine the degree of attainment of the goals with the available resources.
III. Providing the best satisfying solution under a varying number of resources and priorities of the goals.

In the literature review, most of the studies on MCDM with GP solution have given little consideration for the potential sub-systems within the system (case company). The studies conducted on this issue in developing countries' manufacturing sector are not enough like Ethiopia. Since Ethiopia is a developing country still the research in MCDM with GP solution is in the infant stage which is not enough to make management decision for the area which needs improvement.

In this research, the GP model has been applied in company management for calculation of target value of selected strategic goals in related with potential sub systems which have been identified during productivity assessment of the researcher's previous work: technology, marketing, production, and ergonomics [14]. The model has made especially for the implementation of calculated achievable value of strategic goals into the business plans through which company´s management can provide day to day activities of the company. There were set general strategic goals of the case company called Edget Yarn and Sewing thread S.C. entering the model: sales growth, profit maximization, and cost minimization.

The researcher has believed that the strategic goals of the case company are related with potential sub systems, defined as technology, marketing, production, and ergonomics. To maximize sales (marketing sub-system) requires increasing production volume (production sub-system). To maximize profit (marketing sub system) requires minimizing cost and volume of waste, machine, and labor cost, (technology and production sub-system), and maximizing sales (marketing sub-system). These all have been achieved if we are trying to provide a critical concern for ergonomic sub-system through workers health and safety issues. It requires maximizing the performance levels for each performance objectives under levels of personal fitness to the work, workplace environment and other issues key performance areas of the ergonomic sub system.

In general, by considering the system level overall productivity of the case company that have been measured, during the study of overall productivity assessment using PO-P approach in the researchers' priviuos study, mathematical GP model have been developed to improve the overall productivity. The model has been developed using the combinations of the strategic goals of the case company with their planned target values and the Performance Value (PV) of the KPAs under the ergonomics sub-system. This has finally depicted how much percent does the ergonomics sub-system alone will improve overall Productivity Index (PI) from 0.652 to crtain levels.

## 2 | Materials and Methods

### 2.1 | Linear Programming Versus GP Model

The formulation of GP problem is like that of Linear Programming (LP) problems. The major differences are an explicit consideration of goals and the various priorities associated with the different goals. In GP, instead of attempting to maximize or minimize the objective criterion directly, as in LP, the deviations between goals and what can be achieved within the given set of constraints are minimized.

The slack variables (deviations) in simplex algorithm of LP, take on a new significance in GP called deviational variable. This is represented in two dimensions, both positive and negative deviations from each sub goal or goal. Then the objective function becomes the minimization of these deviations based on the relative importance or priority assigned to them. The decision maker can determine the priority of the desired attainment of each goal or sub goal and rank the priorities in an ordinal sequence. Obviously, it is not possible to achieve every goal to the extent desired. The true value of GP, therefore, is its contribution to the solution of decision problems involving multiple and conflicting goals according to the decision maker's structure.

### 2.2 | General Goal Programming Model

#### 2.2.1 | Objective function

Unlike in the basic model of LP, in GP approach are not used constraints, but system of goals which represents and behaves as constraints. If we want to define the basic theoretical framework of GP firstly, we must determine goals while each one has assigned the target value. Charnes and Cooper [17] presented the general GP model which can be expressed mathematically as

$$\text{Minimize } Z = \sum_{i=1}^{m} d_i^+ + d_i^-)n. \quad (1)$$

#### 2.2.2 | General constraints

The objective function of the goal progrmaing model have been subjected to the following general constraints:

$$\text{Goal Constraints:} \quad \sum_{j=1}^{n} a_{ij}x_j - d_i^+ + d_i^- = b_i \text{ , for } i = 1 \ldots m, \quad (2)$$

$$\text{System Constraints:} \quad \sum_{j=1}^{n} a_{ij}x_j \begin{bmatrix} \le \\ \ge \\ = \end{bmatrix} b_i \text{ , for } i = m+1 \ldots m+p, \quad (3)$$

with $d_i^+, d_i^-, x_j \ge 0$, for i=1…, m; for j=1…, n.

Where, there are m goals, p system constraints and n decision variables:

Z = objective function = Summation of all deviations.

$a_{ij}$ = the coefficient associated with variable j in the ith goal.

$x_j$ = the jth decision variable.

$b_i$ = the associated right hand side value.

$d_i^-$ = negative deviational variable from the ith goal (underachievement).

$d_i^+$ = positive deviational variable from the ith goal (overachievement).

Both overachievement and underachievement of a goal cannot occur simultaneously. Hence, either one or both variables must have a zero value; that is, $d_i^+ * d_i^- = 0$.

## 2.3 | Identified Constriants

The case company has produced two prodcuts namely: yarn count 10 and count 21 and has strategic goals related with sales growth, profit maximization and cost minimizations. To be effective in attaining these goals they also planned the target value of profit, targe value of cost, target value of sales, target value of total hour of production, target value of total materials for production, target value of production capacity. By considering the starategic goal of the case company with its detail target values and the ergonomics sub-system, general constraint model has been developed in this study for the purpose of improving the productivity of the company. Under the ergonomics sub-system there are three KPAs (workplace environment, levels of personal fitness to the work, and other issues) with respective PI. Again, under each KPA there are different performance objectives having Objectivated Output (OO)/Objectivated Value (OV) with respective weights.

Let

$g_1$_target value of profit.

$g_2$_target value of costs.

$g_3$_target value of sales.

$g_4$_target value of total hour of production.

$g_5$_target value of total materials for production.

$g_6$_target value production capacity.

$p_{1-n}$_profit from one product.

$c_{1-n}$– cost of production of one product.

$s_{1-n}$– Sales price of one product.

$x_{1-n}$– Individual products of the company.

$x_{3-I}$- Performance objective I.

$pv(x_{3-I})$– PV for each performance objective I.

$PIKPA_i$ - PI of KPA i.

u-the component/subsystem.

v-the KPA.

y-the performance objectives.

W-the weightage factor.

Oyvu-the PV of POy in KPAv in component/subsystem u.

O'yvu-the OO of PO-y in KPAv in component/subsystem u.

**Profit constraint:** the profit from one product multiplied by production volume of that product. These results are summed, and then the sum is equal to or greater than the target value of the profit:

$$\sum_{i=1}^{n} p_i x_i \geq g_i. \tag{4}$$

**Cost constraint:** the cost for one product multiplied by production volume of that product. These results are summed, and then the sum is equal to or less than the target value of cost:

$$\sum_{i=1}^{n} c_i x_i \leq g_2. \tag{5}$$

**Sales constraint:** the sales revenue from one product multiplied by production volume of that product. These results are summed, and then the sum is equal to or greater than the target value

$$\sum_{i=1}^{n} s_i x_i \geq g_3. \tag{6}$$

**Time capacity constraint:** the time required to produce one product multiplied by the production volume of that product. These results are summed, and then the sum is equal to or less than the target value of total hours of production.

$$\sum_{i=1}^{n} t_i x_i \leq g_4 \tag{7}$$

**Material capacity constraint:** the material required to produce one product multiplied by the production volume of that product. These results are summed, and then the sum is equal to or less than the target value of total materials for production

$$\sum_{i=1}^{n} m_i x_i \leq g_5. \tag{8}$$

**Production capacity constraint:** the sum of the capacity to produce each product is specified to maximum value

$$\sum_{i=1}^{n} x_i \leq g_6. \tag{9}$$

**Ergonomics constraint:** because to satisfy product demand from the customers, sales revenue, and profit target of the company, the working environment should be safe and comfortable to every position worker.

$$x_{3\ldots I} \geq pv(x_{3\ldots I}) \tag{10}$$

Hence the company must achieve not fewer than the OV/OO of each performance objective. Therefore, each performance objective is set to equal to or greater than the respective OV, where, I=11.

As well as, the PV of each performance objective is divided by the OO of that performance objective, then this value is multiplied by the respective weight. These results are summed, and then the sum is set to equal to or less than the calculated PV in *Table 1*

$$\sum_{I=11} w_{3-I}\left(\frac{X_{3-I}}{OV_{3-I}}\right) \leq PIKPA_{i}, \tag{11}$$

where I = 1, 2, 3.

Once, the optimal (suggested) PV of each performance objective has been obtained using the excel solver, the PI (the revised form) of each KPA has been calculated using *Eq. (12)*, the PI of the ergonomics sub-system has been calculated using *Eq. (13)* and finally the PI of the case company has been calculated using *Eq. (14)* to show the improvement in the overall system [14]:

$$(PI)_{vu} = \sum_{y=1} W_{yvu}\left(\frac{O_{yvu}}{O'_{yvu}}\right). \tag{12}$$

$$(PI)_{u} = \sum_{v=1} W_{vu}\,(PI)_{vu}. \tag{13}$$

$$PI = \sum_{u=1} W_{u}\,(PI)_{u}. \tag{14}$$

## 2.4 | GP Solution Methodology

There are GP computer software/computers required the availability of GP algorithms used to generate the primary GP problem solutions and to permit a post- solution analysis through supporting algorithms obtained in the primary solution. Collectively, these primary and secondary algorithms can be called GP solution methodologies. The primary GP algorithms and methodology are categorized and used to generate linear GP, integer GP and nonlinear GP solutions. Secondary GP methodologies: includes duality and sensitivity analysis used to obtain post-solution information. According to [15] there are seven types of changes that can be implemented as a part of sensitivity analysis in GP:

I. Changes in the right-hand-side values.
II. Changes in the weighting at a priority level.
III. Changes in the weighting of deviation variables within a priority level.
IV. Changes in technologies coefficients.
V. Changes in the number of goals.
VI. Changes in the number of decision variables.
VII. Reordering preemptive priorities.

## 2.5 | Computer Software Supporting GP Solution Analysis

For the calculation of defined GP model and obtaining solutions can be used various software programs. These include the most popular optimization software CPLEX Solver of GAMS software [16], Excel Solver, Multi Objective Programming (MOP) package. Excel solvers are most used in GP models and have been applied for this research. Solving a GP problem by using Excel is like solving a LP model, although not quite as straightforward. When using an excel spreadsheet to solve a GP problem, it must be solved sequentially. In this procedure, a new problem is formulated and solved for each priority goal in the objective function, beginning with the highest priority. In other words, the minimization of the deviational variable at the highest priority is the initial objective. Once a solution for this formulation is achieved, the value of the deviational variable that is the objective is added to the model as a constraint, and the second-priority deviational variable becomes the new objective. A new solution is achieved for each new objective sequentially until all the priorities are exhausted or a better solution cannot be reached. For our purposes, this means editing Excel's Solver for each new solution. The optimal solution from excel solver have been discussed by using answer report, sensitivity report. The results of data analysis have been discussed to draw vital conclusions and recommendations that are very useful for the success of the company.



## 3 | Result and Discussion

During productivity assessment one can understand that the PI of the other issues KPA with weight of 20% got better in productivity achievement among the three KPA under the ergonomic sub-system. Assume that by taking this value as reference, the maximum possible value of the productivity of the rest two KPAs is calculated proportionally and have been shown in *Table 1*.

**Table 1. Calculated PI of the KPAs under ergonomics sub-system.**

| KPAs | Actual Prodcuctivity Index | Calculated/Expected Prodcutivity Index |
|---|---|---|
| Workplace environment (50%) | 0.7931 | 1.9 |
| Levels of personal fitness to the work (30%) | 0.5568 | 1.14 |
| Other isuues (20%) | 0.76 | 0.76 |

*Source: Own calculation of expected PI from actual PI.

**Table 2. Performance objectives of the ergonomics sub system.**

| KPAs and Weight | Designation of Performance Objectives | Weight | OV | PV | PI |
|---|---|---|---|---|---|
| Levels of personal fitness to the work (30%) | X3: Does the mgt consider work-experience for the job? | 40% | 0.6 | 0.4 | 07931 |
| | X4: Do the recruited staffs trained before using the available machines? | 45% | 0.82 | 0.53 | |
| Workplace environment (50%) | X5: Do the supporting-facilities timely delivered to workers to aid the staffs in doing the job? | 25% | 0.7 | 0.56 | 0.5568 |
| | X6: Do working-tools advanced? | 25% | 0.8 | 0.65 | |
| | X7: Doe the workplace- environment at satisfying level? | 25% | 0.6 | 0.4 | |
| | X8: Doe work-load distribution is balanced throughout the workers? | 25% | 0.75 | 0.67 | |
| Other issues (20%) | X9: Are there rules, regulations, and policies to shape the work culture? | 75% | 0.8 | 0.6 | 0.76 |
| | X10: Is work-schedule & rotation fairly implemented? | 15% | 0.5 | 0.45 | |
| | X11: Is there any staffs cased in unusual environmental stress? | 10% | 0.4 | 0.25 | |

* Source: [14].

To get the required results of GP in improving the productivity of the case company, necessary data have been obtained from the management staffs of the company. Data with target values of defined strategic goals have been gathered from production, technology, marketing department of the case company. The gathered data have been associated with the two main products of the case company namely count 10 and count 21, and each product is characterized by costs connected with its production, sales price and profit. The company also specified maximum and minimum possible amount for profit, cost, sales, production, material and production time. These input data have been shown in *Table 3*.

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**Table 3. Input data from the companys' strategic goal to the GP model.**

| Products Variable | Count 10 | Count 21 |
|---|---|---|
| Unit cost (ETB)/kg | 51.00 | 60.40 |
| Unit price (ETB)/kg | 57.83 | 66.96 |
| Profit (ETB)/unit/kg | 6.83 | 6.56 |
| Production time(hour) for unit | 2.01 sec=000558 hour | 4.41 sec=001225 hour |
| Material(kg) for unit | 1.25 | 1.25 |

*Source: the case company management staffs.

For each product group there is a maximum possible capacity or required minimum value

I. Target value of profit: 7, 680, 828 birr/year.
II. Target value of costs: 61, 548, 600 birr/year.
III. Sales (minimum): 69, 229, 428 birr/ year.
IV. Production amount (maximum): 1, 139, 100 kg (products)/year.
V. Total amount of material (cotton) for production (maximum): 1, 423, 875 kg/year.
VI. Total production time (maximum): 4500 hours/year.

By considering the strategic goal of the company; defined input data, target values, capacities, variables obtained from production, marketing, technology and ergonomics sub-systems, the following main priorities to goals and the objective function have been developed.

P1: achieving that capacity utilization will not violet the upper limit.

P2: maximization of sales price and profit. Product $x_1$ will satisfy the maximum demand.

P3: product $x_2$ will satisfy the maximum demand.

P4: to minimize cost the company would like to minimize time and material to produce unit product.

P5: because to satisfy product demand from the customers, sales revenue, and profit target of the company: the working environment should be safe and comfortable to every position worker and the productivity of each KPAs must be met. But this has been done on three stages which have been listed as: levels of personal fitness to the work (50%), workplace environment (30%), other issues (20%).

## 3.1 | The Goal Programing Model: Case Study

Minimize: $P_1d_6^+, P_2d_1^-, P_2d_3^-, P_2d_7^-, P_3d_8^-, P_4d_2^+, P_4d_4^+, P_4d_5^+, 0.4P_5d_7^+ + 0.45P_5d_8^+,\ 0.25P_6d_9^+ + 0.25P_5d_{10}^+ + 0.25P_6d_{11}^+ + 0.25P_6d_{12}^+, 0.75P_7d_{13}^+ + 0.15P_7d_{14}^+ + 0.1P_7d_{15}^+, 0.5P_8d_{16}^+ + 0.3P_8d_{17}^+ + 0.2P_8d_{18}^+.$

Subject to

$6.83 * x_1 + 6.56 * x_2 + d_1^- - d_1^+ = 7{,}680{,}828.$ (Profit constraint)

$51 * x_1 + 60.4 * x_2 + d_2^- - d_2^+ = 61{,}548{,}600.$ (cost constraint)

$57.83 * x_1 + 66.96 * x_2 + d_3^- - d_3^+ = 69{,}229{,}428.$ (sales constraint)

$0.000558 * x_1 + 0.001225 * x_2 + d_4^- - d_4^+ = 4{,}500.$ (time constraint)

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$$1.25 * x_1 + 1.25 * x_2 + d_5^- - d_5^+ = 1{,}423{,}875. \qquad \text{(material constraint)}$$

$$x_1 + x_2 + d_6^- - d_6^+ = 1{,}139{,}100. \qquad \text{(production capacity constraint)}$$

$$\left.\begin{array}{r} x_3 - d_7^+ = 0.6 \\ x_4 - d_8^+ = 0.82 \\ x_5 - d_9^+ = 0.7 \\ x_6 - d_{10}^+ = 0.8 \\ x_7 - d_{11}^+ = 0.6 \\ x_8 - d_{12}^+ = 0.75 \\ x_9 - d_{13}^+ = 0.8 \\ x_{10} - d_{14}^+ = 0.5 \\ x_{11} - d_{15}^+ = 0.4 \\ 0.4 * \frac{x_3}{0.6} + 0.45\frac{x_4}{0.82} - d_{16}^+ = 1.14 \\ 0.25 * \frac{x_5}{0.7} + 0.45\frac{x_6}{0.8} + 0.4 * \frac{x_7}{0.6} + 0.45\frac{x_8}{0.75} - d_{17}^+ = 1.9 \\ 0.75 * \frac{x_9}{0.8} + 0.15\frac{x_{10}}{0.5} + 0.45\frac{x_{11}}{0.4} - d_{18}^+ = 0.76 \end{array}\right\}. \qquad \text{(Ergonomics constraint)}$$

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, d_1^-, d_1^+, d_2^-, d_2^+, d_3^-, d_3^+, d_4^-, d_4^+, d_5^-, d_5^+, d_6^-, d_6^+,$$
$$d_7^+, d_8^+, d_9^+, d_{10}^+, d_{11}^+, d_{12}^+, d_{13}^+, d_{14}^+, d_{15}^+, d_{16}^+, d_{17}^+, d_{18}^+ \geq 0.$$

By considering strategic goals of the case company with the given/planned target values and the priorities of goals, the PI of the KPAs' of the ergonomics sub-system, the performance objectives of each KPAs with its respective weight, OV, and each performance objectives with their respective PV; the objective function and constriants has been developed as follows so as to improve the productivity of the case company.

## 3.2 | Result Analysis

Q2

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | GOAL PROGRAMING:EDGET YARN AND SEWING THREAD SHARE COMPANY | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | |
| 3 | | | COUNT 10 | COUNT 21 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | d- | d+ | | | |
| 4 | | | 771600 | 367500 | 1.04 | 0.82 | 0.7 | 0.8 | 2.76 | 0.75 | 0.8 | 0.5 | 0.4 | | | | | |
| 5 | | | | | | | | | | | | | | | | CONSTRAINT | | |
| 6 | | | | | | | | | | | | | | | | TOTAL | | |
| 7 | GOAL CONSTRAINTS | | | | | | | | | | | | | | | LHS | CONSTRA | RHS |
| 8 | PROFIT | | 6.83 | 6.56 | | | | | | | | | | 0 | 0 | 7680828 | | 7680828 |
| 9 | SALES | | 57.83 | 66.96 | | | | | | | | | | 3.027E-09 | 0 | 69229428 | | 69229428 |
| 10 | COST | | 51 | 60.4 | | | | | | | | | | 0 | 0 | 61548600 | | 61548600 |
| 11 | TIME | | 0.000558 | 0.001225 | | | | | | | | | | 3619.2597 | 0 | 4500 | | 4500 |
| 12 | MATERIAL | | 1.25 | 1.25 | | | | | | | | | | 0 | 8.77E-11 | 1423875 | | 1423875 |
| 13 | CAPACITY | | 1 | 1 | | | | | | | | | | 1.714E-11 | 0 | 1139100 | | 1139100 |
| 14 | ERGONON | x3 | | | 1 | | | | | | | | | 0 | 0.435 | 0.6 | | 0.6 |
| 15 | | x4 | | | | 1 | | | | | | | | 0 | 0 | 0.82 | | 0.82 |
| 16 | | x5 | | | | | 1 | | | | | | | 0 | 0 | 0.7 | | 0.7 |
| 17 | | x6 | | | | | | 1 | | | | | | 0 | 0 | 0.8 | | 0.8 |
| 18 | | x7 | | | | | | | 1 | | | | | 0 | 2.16 | 0.6 | | 0.6 |
| 19 | | x8 | | | | | | | | 1 | | | | 0 | 0 | 0.75 | | 0.75 |
| 20 | | x9 | | | | | | | | | 1 | | | 0 | 0 | 0.8 | | 0.8 |
| 21 | | x10 | | | | | | | | | | 1 | | 0 | 0 | 0.5 | | 0.5 |
| 22 | | x11 | | | | | | | | | | | 1 | 0 | 0 | 0.4 | | 0.4 |
| 23 | ERGONOMICS KPAs | | PERSONAL CAPABILITY | | | | | | | | | | | 0 | 0 | 1.14 | | 1.14 |
| 24 | | | WORKING CONDITION | | | | | | | | | | | 0 | 0 | 1.9 | | 1.9 |
| 25 | | | OHERS | | | | | | | | | | | 0 | 0.24 | 0.76 | | 0.76 |
| 26 | | | | | | | | | | | | | | | | | | |

**Fig. 1. Excel solver optimal solution sheet.**

The answer report of the excel solver have given details of the optimal solutions with cell value of $x_1 =$ 771600 kg of yarn with count 10, $x_2 = 367500$ kg of yarn with count 21. These values are the maximum amount to be produced for each product. To get the optimal PV of the performance objectives in KPAs of the ergonomics sub-system sequential approach to attempt to obtain a better solution have been accomplished. For instance, by having cell O14 as the target cell and *N8* = 0, *N10* = 0, *O9* = 0, *O11* = 0, *O13* = 0 and *O15* = 0 as a constraint again solve for the third time but the answer became the same with the first and second solution. That means the solution did not provide a better optimal result without sacrificing the goal achievement at the higher priority levels. Thus, $x_1 = 771600$, $x_2 = 367500$, $x_3 = 1.035$, $x_4 = 0.82$, $x_5 = 0.7$, $x_6 = 0.8$, $x_7 = 2.76$, $x_8 = 0.75$, $x_9 = 0.8$, $x_{10} = 0.5$, and $x_{11} = 0.4$ are better solutions with deviational values of $d_2^- = 3.027\text{E-}09$, $d_4^- = 3619.2597$, $d_6^- = 1.714\text{E-}11$, $d_5^+ = 8.77\text{E-}11$, $d_7^+ = 0.435$, $d_{11}^+ =$

2.16, $d_{18}^{+} = 0.24$. The report also indicates that all constraints are binding, so all are utilized in the final solution because all constraints have been adjusted to equality signs.

The sensitivity report of the excel solver have shown the GP model is good, for example, the shadow price for profit goal constraint is zero (0), and if the value of $x_1$ is increased by 1 (from 771600 to771601), the corresponding value at the optimal solution of profit will not be increased. Similarly, if the $x_1$ is decreased by 1 (from 771600 to 771599), the respective profit value at the optimal solution will not be decrease. In addition to this, the sensitivity report details shown how changes in the coefficients of the objective function affect the solution. For instance, if the coefficient on x3 is raised to 1+1 = 2, or decreased to 1-1 = 0, the optimal solution remains unchanged. Similarly, if the coefficient on $d_3^{+}$ is raised to 1+1 = 2, or decreased to 1-1 = 0, the optimal solution remains unchanged.

According to the interpretation of the answer report, sensitivity report as well as the optimal solution sheet of the excel solver in *Fig.1* the results of the optimal (suggested) PV of each performance objectives those should attain to provide comfortable and safe work environment to works are summarized.

**Table 4. Suggested solutions of PV of performance objectives.**

| | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 |
|---|---|---|---|---|---|---|---|---|---|
| OV | 0.6 | 0.82 | 0.7 | 0.8 | 0.6 | 0.75 | 0.8 | 0.5 | 0.4 |
| PV | 0.4 | 0.53 | 0.56 | 0.65 | 0.4 | 0.67 | 0.6 | 0.45 | 0.25 |
| Optimal (Suggested) value | 1.035 | 0.82 | 0.7 | 0.8 | 2.76 | 0.75 | 0.8 | 0.5 | 0.4 |

* Source: OV and PV from Table 2. and suggested value from Fig.1.

Using the optimal (suggested) PV of the performance objectives the PI of KPAS under ergonomics sub-system using *Eq. (12)* became:

I. For levels of personal fitness to the work, $(PI)_{vu} = 0.4*(1.035 \div 0.6) + 0.45*(0.8 \div 0.82) = 1$.
II. For workplace environment, $(PI)_{vu} = 0.25*(0.7 \div 0.7) + 0.25*(0.8 \div 0.8) + 0.25*(0.2.76 \div 0.6) + 0.25*(0.75 \div 0.75) = 1.9$.
III. For other issues, $(PI)_{vu} = 0.75*(0.8 \div 0.8) + 0.15*(0.5 \div 0.5) + 0.1*(0.4 \div 0.4) = 1$ Then, using *Eq. (13)* the PI of the ergonomics sub-system has been improved and became; $(PI)_u = 0.3*1 + 0.5*1.9 + 0.2*1 = 1.492$.

Finally, using the three sub systems' (production, marketing, and technology) PI and their respective weight as they are during the productivity assessment, and the recalculated/improved PI of the ergonomics sub-system with its weight as it is, the improved PI of the system have been determined.

**Table 5. PI of the sub-systems.**

| System-Sub | Relative Weight | PI |
|---|---|---|
| Production | 12% | 0.7379 |
| Technology | 40% | 0.7882 |
| Marketing | 20% | 0.661 |
| Ergonomics | 6% | Existing durinng assessment = 0.7156<br>Improvd after optimal (suggested) pvof the performance objectivesof the ergonomics sub-system = 1.492 |

*Source: [14] and the recalculated PI of ergonomics sub-system using Eq. (13).

Therefore, using *Eq. (14)* and the information in *Table 5* productivity of the system became;

$$PI = 0.12*0.7379 + 0.4*0.7882 + 0.2*0.6661 + 0.16*1.492 = 0.776$$

## 4 | Conclusion

Productivity of the system, Edget Yarn and Sewing Thread Share Company, have been measured by using the PO-P approach. Hence, the existing system productivity level is determined from the productivity of potential subsystems and is 0.652 [14]. By having these potential sub system and strategic goal of the case company GP have been formulated to show by how much percent does the ergonomics subsystem alone improves the overall PI. For this it is required to have optimal solution of PV of the performance objectives of KPAs under the ergonomics sub-system. This optimal solution brings the PV values of the performance objectives x3 = 1.035, x4 = 0.82, x5 = 0.7, x6 = 0.8, x7 = 2.76, x8 = 0.75, x9 = 0.8, x10 = 0.5, and x11 = 0.4. Having these optimal (suggested) PVs of performance objectives, the PI of the ergonomics sub-system has been recalculated and became 1.492, in effect increases the overall PI of the system (case company) from 0.652 to 0.776.



The following suggestions can be drawn from the results of this paper. The workplace environment design should be carried out using ergonomic guidelines, acts and recommendations and environment must be given adequate consideration. Strategies should be formulated and implemented to introduce ergonomics systematically through ergonomic programs in the company to improve productivity, safety and health and environment. The decision maker in ergonomics sub system of the company should implement GP technique to set out the planned output of performance objectives of the ergonomic subsystems. This should be done by integrating ergonomic sub system with potential subsystems.

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