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Inspection Assignment Form for Product Quality Control Using Neutrosophic Logic

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Abstract: During the production process, production companies need to monitor the finished products and ensure their quality, which imposes on them the appointment of inspectors for auditing, and this appointment costs the company amounts that affect the general profit, so it strives to make this cost as low as possible and that the audit process is carried out with high accuracy because in case that the finished products do not conform to the basic specifications of the product, the company is required to pay a fine. In this research, we will formulate the text of the problem appropriately for such a case and then we will build the appropriate mathematical model through which we can obtain the lowest possible cost of inspection, and we will present the study using classical values and neutrosophic values, and we will demonstrate them through an example that shows us the difference between them.

Keywords: Mathematical models; Neutrosophic science; Inspection issue; Product quality control.

1. Introduction

Since the genesis of the science of operations research, it has been providing solutions to the problems faced by companies through studies presented by scientists and researchers in all fields using the methods of this science, in this research we will use the method of linear programming to build a mathematical model that enables us to ensure the quality of products using inspectors and at the lowest possible cost where we will formulate the appropriate issue for that and build the mathematical model that by finding the optimal solution to it and using the methods of solution provided by the science of operations research we get on the lowest cost of inspection and high-quality products, where the matter will be displayed

First : Using classical values based on references [1,2,3]

Second: Neutrosophic values based on what researchers and those interested in this science have presented and developed through studies and research that have been published in references [4, 16]

Discussion:

1- Studying using classical values:

Formulating the problem and building the mathematical model:

Text of the issue: Through the available information about the functioning of companies, we can develop the following text:

The company has a rank for inspectors and wants to assign the task of quality control to them, and a piece of product should be audited daily during an hour of work per day, in the following table we explain the full information about the inspectors and for all mattresses nKS.

Table 1. Information on inspectors using classical values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	M_1	D_1	G_1	A_1	R
2	M_2	D_2	G_2	A_2	R
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n	M_n	D_n	G_n	A_n	R

Required: Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible.

Building the Mathematical Model:

To build the mathematical model, we impose the number of inspectors of each rank on the order assigned to the inspection task, then the following inequality must be met:

$x_1, x_2, - - - - x_n$

$$x_j \leq A_j \quad ; \quad j = 1,2, --, n$$

Since the company needs to audit K piece daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} SM_j x_j \geq K$$

To obtain the target follower we note that the company bears two types of costs during the inspection process, the inspector's wage and the fine corresponding to the error committed by the inspector to write the target follower note the following:

The cost of the inspector from rank j hourly salary is calculated through the following relationship

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \quad ; \quad j = 1,2, - - -, n$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

The target function is then written as follows:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

From the above, we can develop the following mathematical model:
We want to find the smallest possible value for the function:

$$Z = S\sum_{j=1}^{n}\left[G_j + M_j R_j\left(\frac{100 - D_j}{100}\right)\right]x_j \rightarrow Min$$

Within Restrictions

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

$$\sum_{j=1}^{n} SM_j x_j \geq K$$

$$x_j \geq 0 \; ; \; j = 1,2,----n$$

Example:

The company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500piece should be audited daily during 8working hours per day, in the following table we explain the full information about the inspectors and for all mattresses.

Table 2. Information on inspectors using classical values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	15	95	4	10	2
2	10	90	3	6	2
3	25	98	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible

To build the mathematical model, we impose the number of inspectors from the three ranks in the order assigned to the inspection task, then the following in equations must be fulfilled. x_1, x_2, x_3

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$

Since the company needs to audit 1500 pieces daily during 8working hours a day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_j x_j \geq 1500$$

That is

$$8(M_1 x_1 + M_2 x_2 + M_3 x_3) \geq 1500$$

From it we get the following restriction:

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target function will be written as follows:

Then the cost of the inspector's hourly salary from rank j is calculated through the following relationship :

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \;\; ; \;\; j = 1,2,---,n$$

From them we get

$$C_1 = 4 + 15 \times 2 \times \left(\frac{100 - 95}{100}\right) = 5.5$$

$$C_2 = 3 + 10 \times 2 \times \left(\frac{100 - 90}{100}\right) = 5$$

$$C_3 = 5 + 25 \times 2 \times \left(\frac{100 - 98}{100}\right) = 6$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We substitute the values available to us and we get:

$$TC_j = 5.5x_1 + 5x_2 + 6x_3$$

substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We get:

$$Z = 44x_1 + 40x_2 + 48x_3$$

From the above, we can develop the following mathematical model:

We want to find :

$$MinZ = 44x_1 + 40x_2 + 48x_3$$

Within Restrictions

$$x_1 \leq 10$$

$$x_2 \leq 6$$

$$x_3 \leq 8$$

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

$$x_j \geq 0 \;\; ; \;\; j = 1,2,3$$

To obtain the optimal solution, we use the simplex method, which is sufficiently explained in the references [1,2,3]

2- Formulation of the problem and the construction of mathematical model according to neutrosophic values:

The study concluded in the research [12] shows us how to construct neutrosophic linear models, (the linear model is a neutrosophic model if at least one of the likes of variables in the target function or neutrosophic value constraints)

The text of the issue:

The company has n rank for inspectors and wants to assign the task of quality control to them, and K pieces should be audited daily during an S hour of work per day, in the following table we explain the full information about the inspectors and for all ranks:

Table 3. Information on inspectors using neutrosophic values

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	NM_1	ND_1	G_1	A_1	R
2	NM_2	ND_2	G_2	A_2	R
-----	--		-		-----
n	NM_n	ND_n	G_n	A_n	R

The number of pieces is a neutrosophic value$NM_j = M_j + \varepsilon_j$ where ε_j is the indeterminacy on the number of pieces, it can take one of the shapes $[\lambda_{j1}, \lambda_{j2}]\ or\ \{\lambda_{j1}, \lambda_{j2}\}$or any value close to M_j as well as the precision, neutrosophic values $ND_j = D_j + \delta_j$ where δ_j is the indeterminacy on the precision that can take one of the shapes $[\mu_{j1}, \mu_{j2}]$ or $\{\mu_{j1}, \mu_{j2}\}$ or any value close to D_j.

Required: Formulate the appropriate mathematical model through which we can assign the optimal support to the inspectors so that the cost of inspection is as low as possible

Building the neutrosophic mathematical model:

To build the mathematical model, we impose $x_{1,}x_2, - - --, x_n$ the number of inspectors of each rank on the order assigned to the inspection task, then the following inequality must be met:

$$x_j \leq A_j \quad ; \quad j = 1,2, --, n$$

Since the company needs to audit K piece daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} S(NM_j)x_j \geq K$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:

$$Z = S\sum_{j=1}^{n} G_j + NM_j R_j \left[\frac{100 - ND_j}{100}\right] x_j$$

Then the mathematical model is written as follows:

$$Z = S\sum_{j=1}^{n} G_j + NM_j R_j \left[\frac{100 - ND_j}{100}\right] x_j \ \rightarrow Min$$

Within Restrictions

$$x_j \leq A_j \quad ; \quad j = 1,2,--,n$$

$$\sum_{j=1}^{n} S(NM_j)x_j \geq K$$

$$x_j \geq 0 \ ; \ j = 1,2,----n$$

Example 1:

A company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500 pieces should be audited daily during 8 working hours per day, in the following table we explain the full information about the inspectors and for all ranks, in this example we will take the number of pieces checked by the inspectors from each rank as neutrosophic values

Table 4. Information on inspectors using neutrosophic values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (Monetary Unit per Hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	{15,16}	95	4	10	2
2	{10,11}	90	3	6	2
3	{25,26}	98	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible

To build the mathematical model, we impose $x_{1,}x_2, x_3$ as the number of inspectors from the three ranks in the order assigned to the inspection task, then the following inequality must be met:

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$

Since the company needs to audit K pieces daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_j x_j \geq 1500$$

That is

$$8(M_1x_1 + M_2x_2 + M_3x_3) \geq 1500$$

From it we get the following restriction:

$$8\{15,16\}x_1 + 8\{10,11\}x_2 + 8\{25,26\}x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:

Then the cost of the inspector is calculated from j the hourly rank through the following relationship:

$$C_j = G_j + M_j R_j \left(\frac{100 - D_j}{100}\right) \;\; ; \;\; j = 1,2, - - -, n$$

From that we get

$$C_1 = 4 + \{15,16\} \times 2 \times \left(\frac{100 - 95}{100}\right) = \{5.5,5.6\}$$

$$C_2 = 3 + \{10,11\} \times 2 \times \left(\frac{100 - 90}{100}\right) = \{5,5.2\}$$

$$C_3 = 5 + \{25,26\} \times 2 \times \left(\frac{100 - 98}{100}\right) = \{6,6.04\}$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

$$TC_j = \{5.5,5.6\}x_1 + \{5,5.2\}x_2 + \{6,6.04\}x_3$$

substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - D_j}{100}\right)\right] x_j$$

We get:

$$Z = \{44,44.8\}x_1 + \{40,41,6\}x_2 + \{48,48.32\}x_3$$

From the above, we can develop the following mathematical model:

We want to find:

$$MinZ = \{44,44.8\}x_1 + \{40,41,6\}x_2 + \{48,48.32\}x_3$$

Within Restrictions

$$x_1 \leq 10$$

$$x_2 \leq 6$$

$$x_3 \leq 8$$

$$8\{15,16\}x_1 + 8\{10,11\}x_2 + 8\{25,26\}x_3 \geq 1500$$

$$x_j \geq 0 \;\; ; \;\; j = 1,2,3$$

Example 2:

A company has three ranks for inspectors and wants to assign the task of quality control to them, and 1500 pieces should be checked daily during 8working hours per day, in the following table we explain the full information about inspectors and for all ranks, in this example we will take the accuracy of inspection for each inspector as neutrosophic values in the form of areas whose minimum range is less accurate and the highest range is the highest accuracy that the inspector reaches by rank.

Table 5. Information on inspectors using neutrosophic values.

About the Inspector Inspector rank	Number of pieces checked (hour)	Accuracy (percent)	Inspector's remuneration (monetary unit per hour)	Number of inspectors	The fine paid by the company for each fault to the inspector
1	15	[95,97]	4	10	2
2	10	[90,92]	3	6	2
3	25	[98,99.5]	5	8	2

Required : Formulate the appropriate mathematical model through which we can assign the optimal assignment to the inspectors so that the cost of inspection is as low as possible.

To build the mathematical model, we impose $x_{1,}x_2, x_3$ the number of inspectors from the three ranks in the order assigned to the inspection task, then the following inequality must be met:

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$

Since the company needs to audit K pieces daily within S working hour per day, the following set of restrictions must be met:

$$\sum_{j=1}^{n} 8M_j x_j \geq 1500$$

That is

$$8(M_1x_1 + M_2x_2 + M_3x_3) \geq 1500$$

From it, we get the following entry:

$$120x_1 + 80x_2 + 200x_3 \geq 1500$$

To obtain the target function, we note that the company bears two types of costs during the inspection process, the inspector's fee and the fine corresponding to the error committed by the inspector for each piece then the target follower writes as follows:

Then the cost of the inspector is calculated from j the hourly rank through the following relationship:

$$C_j = G_j + M_j R_j \left(\frac{100 - ND_j}{100}\right) \;\; ; \;\; j = 1,2, - - -, n$$

From that we get

$$C_1 = 4 + 15 \times 2 \times \left(\frac{100 - [95,97]}{100}\right) = [4.9,5.5]$$

$$C_2 = 3 + 10 \times 2 \times \left(\frac{100 - [90,92]}{100}\right) = [4.6,5]$$

$$C_3 = 5 + 25 \times 2 \times \left(\frac{100 - [98,99.5]}{100}\right) = [5.25,6]$$

The total costs for all inspectors assigned to the task of quality control per hour shall be given by the following relationship:

$$TC_j = \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - ND_j}{100} \right) \right] x_j$$

$$TC_j = [4.9,5.5]x_1 + [4.6,5]x_2 + [5.25,6]x_3$$

Substituting the following target phrase:

$$Z = S \sum_{j=1}^{n} \left[G_j + M_j R_j \left(\frac{100 - ND_j}{100} \right) \right] x_j$$

We get:

$$Z = [39.2,44]x_1 + [36.8,40]x_2 + [42,48]x_3$$

From the above, we can develop the following mathematical model:

We want to find:

$$MinZ = [39.2,44]x_1 + [36.8,40]x_2 + [42,48]x_3$$

Within Restrictions

$$x_1 \leq 10$$
$$x_2 \leq 6$$
$$x_3 \leq 8$$
$$120x_1 + 80x_2 + 200x_3 \geq 1500$$
$$x_j \geq 0 \ ; \ j = 1,2,3$$

In the two examples, and two for the optimal solution we use the neutrosophic simplex method sufficiently explained in the reference [13].

2. Conclusion and Results

Through the previous study, we note that by using the linear programming method, we can provide the optimal solution to most of the problems that can face the production companies by formulating the situation under treatment with an issue that can be converted into a linear model by solving it using the ideal solution for it, the company achieves the highest profit, and in order to obtain solutions that enjoy a margin of freedom, the concepts of neutrosophic science can be used because the indeterminacy enjoyed by the neutrosophic values can be responsible for managing the company and developing alternative plans that suit all working conditions.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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