THE BEST MANUFACTURING PROCEDURE FOR THE COMMERCIAL PRODUCTION OF UREA: USING AHP BASED TOPSIS

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ABSTRACT

Nitrogen is one of the most significant nutrients needed for the proper growth and development of crops and other plants. In synthetic nitrogen fertilizers, solid urea is the largest source of nitrogen (N) as a nutrient. Prilling, granulation, and hybrid systems are the commercial processes used for the production of urea. One of the biggest challenges involved in the determination and implementation of those alternatives is rationalized decision making. The objective of this research study is to evaluate these processes by considering some of the significant attributes like profit, environmental friendliness, process flexibility and reliability to determine which process is the most optimal. The results show that the prilling process is the best technology for urea production. It is the most optimal process in terms of profitability and reliability, and is therefore widely used in the fertilizer industry. Prilling is not the best option when it comes to the environment when compared to granulation. The granulation process is not the best fit for the commercial production of urea because it is not a reliable process, especially for high agricultural demands and market competition. The results show that it would be very difficult to keep up with the rapid growth of the population using the granulation process.

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If the environmental and urea quality concerns are considered, the hybrid system is the highest priority and may be preferred.

Keywords: fertilizers; reliability; urea; prilling; granulation; MCDM; AHP; TOPSIS

1. Introduction

In the past few decades, there has been a big shift from the use of natural manure to synthetic fertilizers in agricultural activities. In the past, people used natural animal manure for better cultivation because animal manure possesses a considerable amount of nutrients for the growth of crops, especially nitrogen. On the other hand, animal manure contributes to land pollution as well (Galloway, 2003). Animal manure as a source of fertilizer could not keep up with the increasing demand for crops due to the increasing population of the world. Hence, there was a dire need for synthetic fertilizer that is readily available. Currently, the fertilizer industry is well-established and is the backbone of the agricultural industry. Nitrogenous fertilizers are commonly utilized for agricultural purposes. Nitrogen is produced from various resources that are listed in Table 1. (Rahmanian, 2011).

In synthetic nitrogen fertilizers, urea is the largest source of nitrogen, which is a nutrient that contributes to better growth of crops and other plants. Approximately 46wt% of urea consists of nitrogen, the highest when compared to other fertilizers. After applying urea to the soil, it is either absorbed directly via diffusion or first converted to ammonium nitrate by bacteria through a urease enzyme and then absorbed by plants as a nutrient. Furthermore, solid urea is produced in two different forms, namely prills and granules. The process involved for both forms is almost the same with the differentiation happening at the finishing point when either prilling, granulation, or the hybrid system occurs (Fertilizers Manual, 2015)[1]. Globally, all of these different processes are being practiced continuously in synthetic fertilizers like nitrogen phosphate (NP), calcium ammonium nitrate (CAN), & diammonium phosphate (DAP). The basic raw materials for the production of urea are natural gas and nitrogen. Nitrogen is always taken from the air while H_2 and CO_2 are taken mostly from natural gas. This is why countries that have natural gas in abundance are producing urea in huge quantities. In Pakistan, due to the shortage of natural gas, the production of urea and other fertilizers is highly affected. Most of the urea produced in Pakistan is through the prilling process, and the rest of the processes are not widely used because of the profitability of the prilling process.

In prilling, a tall tower with a rotating bucket at the top is used to spray the molten urea, and hot air is introduced from the bottom of the tower. While descending the tower, molten urea takes the form of small round grains (1mm-2mm in diameter) called prills. If the air is not dry, prills will be hollow and will break easily. However, the hot air carries dust, ammonia, CO_2 and other harmful gases which are released into the environment. These gases are dangerous to the environment and cause global warming, affecting millions of lives. On the other hand, the manufacturing capacity of the prilling tower is very high because there is no reverse loading. Due to this simplicity, the prilling process is very economically effective. Furthermore, in the granulation process, a large close rotary drum is used to mix molten urea with seeds of granules through some binding

[1] https://www.rothamsted.ac.uk/sites/default/files/rb209-fertiliser-manual-110412.pdf

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agents. The toxic gases produced during this process are scrubbed in the scrubbing section for environmental protection. The granulation process is environmentally friendly, but has a low capacity, and therefore possesses a high operating cost. The granulation process is very flexible and the quality of urea can easily be improved. The granules are strong and do not easily break as compared to prills. Furthermore, nitrogen loss is another drawback that is connected to prills (Rose et al., 2016). The combined form of the prilling and granulation processes is called the hybrid system. The hybrid system or combined process is more flexible and reliable than granulation or prilling alone. The only shortcoming of the hybrid process is that the technology has high initial and operating costs. It is also closely dependent on the needs of the market demand and varies accordingly.

Most of the urea fertilizer industries are focusing on innovative research where consideration of different alternatives and developmental improvements are the key to successful businesses. One of the biggest challenges involved in the determination and implementation of those alternatives is rationalized decision making (Chen, 1992). This research project aims to resolve the complexity of the rationalized decision scenario of determining the best finishing technology for the production of urea fertilizer (Hodgett, 2013). The selection of the best manufacturing procedure for the production of urea must not be based only on profit, but also on other factors like environment, flexibility, and reliability. The main purpose of this research is to carry out a comparative study of the prilling process, granulation and the hybrid system. The research study will help industrialists and managers decide the best alternative from among the different procedures of urea production based on the same criteria or factors. An approved questionnaire was distributed among experts such as professors of chemical engineering and working engineers in the urea fertilizer field. The collected data were analyzed by MCDM techniques like AHP and then TOPSIS to determine the rank of the alternatives. The article is organized as follows: introduction, literature review, methodology, results and discussions, and finally the conclusion.

Table 1
Sources of nitrogen

Forms of Nitrogen	**Source**
Organic nitrogen	Animal manure, plants residue
Urea	Commercial fertilizer plant
Nitrogen phosphate (NP)	Commercial fertilizer plant
Ammonium nitrate (NH_4NO_3)	Commercial fertilizer plant

2. Literature review

There would be no life without nitrogen because nitrogen is one of the most significant nutrients for plants along with phosphorous (P) and potassium (K). The combination of these three nutrients forms an NPK-value of a fertilizer in which the NPK-value of urea is 1-0-0 (Fertilizers Manual, 2015). Solid urea is the largest source of nitrogen produced in the two forms of prills and granules. Nitrogen is released from the earth in the form of gas into the atmosphere which results in a deficiency of nitrogen in the soil. As a nitrogen

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fertilizer, urea has wide applications in the agriculture sector covering a wide range of areas (Rehmanian, 2015).

The chemical and fertilizer industries are facing critical problems like increased manufacturing time, environmental regulations, and costs. Most of the urea plants incorporate the prilling technology because of its high capacity and low cost. There are other technologies, like granulation and the hybrid system (prilling with granulation) that can also be used, not only based on costs but also the flexibility of the process, environmental friendliness, sustainability, and effectiveness (Aber, 1997). The different physical and mechanical properties of prills and granules are distinguishable and make them suitable as a fertilizer or intermediate material for other chemical industries. The granulation process is very flexible for improving the quality of urea as well as reducing the overall cost. Similarly, the prilling process requires a prilling tower with a height range of 40m. In the prilling process, the perforated rotating bucket is fed with urea melt which rotates at a high speed and sprays urea melt in the form of droplets. These droplets are solidified by falling against blown air. This process is not very flexible and produces off-gases while in granulation. The urea melt is sprayed on the recycled seeds of urea along with some other agglomerating agents to form granules of high strength and normal size (2mm-4mm) in a granulation drum (Day et al., 1984). The granulation process is very flexible and produces good quality urea with less emission of toxic gases (Fertilizer Manual, 1998). In the combined or hybrid system, prills from the prilling tower are sometimes introduced to the granulation loop to produce granules with some specific properties, but often the granulation and prilling processes work independently. This process is flexible, but still produces a sufficient amount of greenhouse gases.

According to Rehmanian, N. et al. (2015), the granulation process is preferred over prilling because of the flexibility of the process and the product quality. The chemical properties of both types of urea are the same, but the physical properties of prilled and granulated urea are different. Urea granules are strong and do not cake easily, while prilled urea is weak and formulates into cake easily. However, the strength distribution and size of prilled urea are more uniform than granulated urea. On the other hand, the flexibility of the prilling process and the product quality can be sufficiently improved by installing dispersants RVG with a vibration unit. This will help improve the safety of the prilling process and product quality, and reduce emissions of harmful gases to the environment.

According to Quin et al. (2017), the prilling process can also be improved by increasing the fall height along with improving the process design. Alamdari (2000) used a mathematical model to study the urea finishing processes. The mathematical model was based on the design equations of the prilling tower. The experimental data obtained from the model were compared with the actual tower to bring the model closer to the practical one. Similarly, in the granulation drum, a liquid binder is used to bind the liquid urea onto the surface of the seeds. Therefore, in granulation, the scaling of the drum with the materials is also unavoidable. Furthermore, the combined system of granulation and prilling also faces the same problems as the individual processes. Since the granulation process is very flexible, any desired material can be added to it to produce the desired quality of urea (Emady et al., 2016).

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The nitrogen loss of urea is not only economically inefficient, but also creates an environmental burden. The nitrogen that is released moves from the soil down to the water aquifers and pollutes the natural underground water. It has been determined that if a certain amount of coal is mixed with the raw materials it will reduce the loss of nitrogen from the urea. The treated urea that is produced is known as brown coal-urea and shows a high capability of more efficient use of nitrogen in the long term because of reduced nitrogen loss and the environmental benefits of retaining more nitrogen in the soil (Emady et al., 2016). Considering the work done in previous studies, the research topic of this study revolves around the evaluation of urea producing processes i.e. prilling, granulation and hybrid (prilling plus granulation). These three alternatives are being considered after a vigorous literature review. The alternatives will be analyzed based on four distinct criteria i.e. profit, environmentally-friendly, flexibility, and reliability. The alternatives along with their distinct criteria are shown in Figure 1. Until now, most of the research that has been conducted on this topic has only considered a specific characteristic of the process or product, and then decided which of the finishing processes is optimal for the commercial manufacturing of urea (Jahanmiri, A. et al. 2013). Hence, this study addresses the research gap by considering all of the sustainable factors involved in the manufacturing processes of urea along with an in-depth evaluation of these processes.

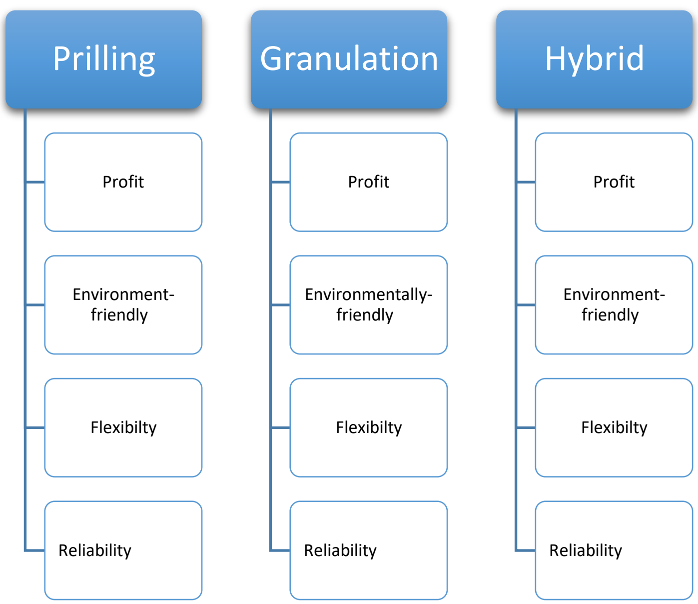

Figure 1 Hierarchy diagram of alternatives and criteria

The current research is mostly concerned with all of the major multiple factors that must be considered when deciding which finishing process is best for the commercial production of urea. The problem must be addressed by considering all of the important and relevant factors which may affect the decision. These decisions involve complex situations that have many criteria factors to be considered for multiple alternatives. These situations display a need for multi-criteria decision-making (MCDM) techniques such as DEMATEL, TOPSIS, VIKOR, AHP, and ANP, to name a few. For this study, the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are incorporated. The AHP technique was developed by

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Thomas L. Saaty in the 1980s (Wind & Saaty, 1980). The AHP technique helps derive ratio scales from pairwise comparisons. Furthermore, the AHP also extends its usefulness into complex decision-making situations and helps decision-makers make a conclusive decision. In this way, the experts can reach a strong agreement while deciding on any situation (Saaty, 1989). Various studies have incorporated the AHP for decision making, and clearly shown the authenticity of this method in many situations. One such study employed the AHP with grey relational analysis (GRA) for integrated supplier selection (Wang et al., 2017). This study also showed that the AHP can work in combination with other techniques, thus improving their analytical capacity. Furthermore, another study by Dweiri et al. (2016) incorporated AHP for supplier selection in the automotive industry. Similarly, Karim and Karmaker (2016) employed AHP in combination with TOPSIS for the most suitable machine for the current industrial era. These studies show that AHP can fulfill the purpose of decision making in a complex situation with utter efficiency.

The TOPSIS technique was first developed by Hwang and Yoon (1981). It offers an efficient decision-making opportunity for researchers in every field. TOPSIS is based on the concept of distance from the ideal solution. An alternative whose distance is closer to the positive ideal solution is considered the best option. Comparatively, the alternative that is near the negative ideal solution is considered the worst case scenario. Many studies have incorporated the TOPSIS technique, clearly showing that this method is worthy of consideration. Jain et al. (2018) carried out a study to make a selection in the Indian automotive industry. The study employed a fuzzy AHP and fuzzy TOPSIS technique for decision making. Another study by Gupta and Barua (2017) incorporated fuzzy TOPSIS and BWM for supplier selection among SMEs. Similarly, another study by Mavi et al. (2016) also used fuzzy TOPSIS for supplier selection in supply chain risk management. Based on the above-mentioned studies, there is enough literature suggesting that AHP and TOPSIS can both prove to be efficient options for decision-making scenarios.

3. Methodology

The complex problem is to determine and implement the most optimal finishing process for the commercial production of urea with rationalized decision making. This research project uses the AHP and TOPSIS techniques to solve this complex problem.

3.1 Data collection

An approved questionnaire was used to collect data from experts in the fertilizer industry such as professors, engineers, and industrial managers. There were a total of ten respondents whose breakdown is given in Table 2. The AHP technique was used to rate all of the supposed criteria with relative weights. In the second phase, these weights were used as input for the TOPSIS technique to evaluate the designated alternatives of the present research study.

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Table 2
Respondents of the questionnaire-based survey

Qualification	**No of Respondents**
Professors	3
Engineers	4
Managers	3

3.2 AHP

AHP was first developed by Thomas L. Saaty in 1980, and is currently used extensively when there are multi-criteria that significantly affect a single decision (Saaty, 1990; Ali et al, 2017a&b). The AHP has been shown to be the best option of an effective tool in decision-making. It helps researchers and decision-makers make the best decision by setting priorities. All of the alternatives are simultaneously compared to each criterion in the form of a pairwise comparison matrix. A pairwise comparison matrix is established to cross-compare the alternatives as well as criteria. Pairwise matrices are formed when the AHP reduces complex situations. The AHP will rank or categorize all of the alternatives from the most to the least optimal. This is why the method is known as the Analytic Hierarchy Process. The AHP can effectively help answer the question 'which one' among different alternatives. It helps capture the subjective and objective characteristics of a decision, and assists in evaluating the consistency of a decision that a researcher has made after the analysis. In this way, the inconsistent factors can be ruled out. The AHP is a linear procedure and should be used in problems where the alternatives are distinctive rather than very fuzzy. The steps involved in the AHP process are shown in Figure 2.The problem is to determine the most optimal finishing process for the commercial production of urea, and this research study will help managers and industrialist select the best procedure.

1. The finishing procedures for the production of urea that have been designed and developed are prilling, granulation, and the hybrid system. The most relevant and distinguishable factors for these processes are profits, environmentally-friendly, flexibility, and reliability.
2.
3. The linguistic scale used in this research study is a nine-point scale.
4. First, the data for the pairwise comparison matrices are collected with the help of a survey questionnaire. The pairwise comparison matrices are created using this data. The criteria of the pairwise matrix are equally represented as:

$$A=[aij];i,j=1,2,3,4\ldots\ldots\ldots n \quad (1)$$

The entries of the comparison matrices follow three simple rules as:

$$Aij>0, \quad aji = 1/aij \; ; \quad ajj = aii = 1$$

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Normalized matrices result from the pairwise comparison matrices being made stochastic. Then, the equation below is used to calculate the maximum eigenvalue for the normalized matrix;

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{i^{th}\ entry\ in\ AW}{i^{th}\ entry\ in\ W}\right) \tag{2}$$

To check whether the matrices are consistent or not; we

$$CI = {(\lambda_{max} - n)}/{(n-1)} \tag{3}$$

n is the number of alternatives. To calculate CI, Random index (RI) values are required which are given in Table 3.

Table 3
Random index (RI) for different values of n

N	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

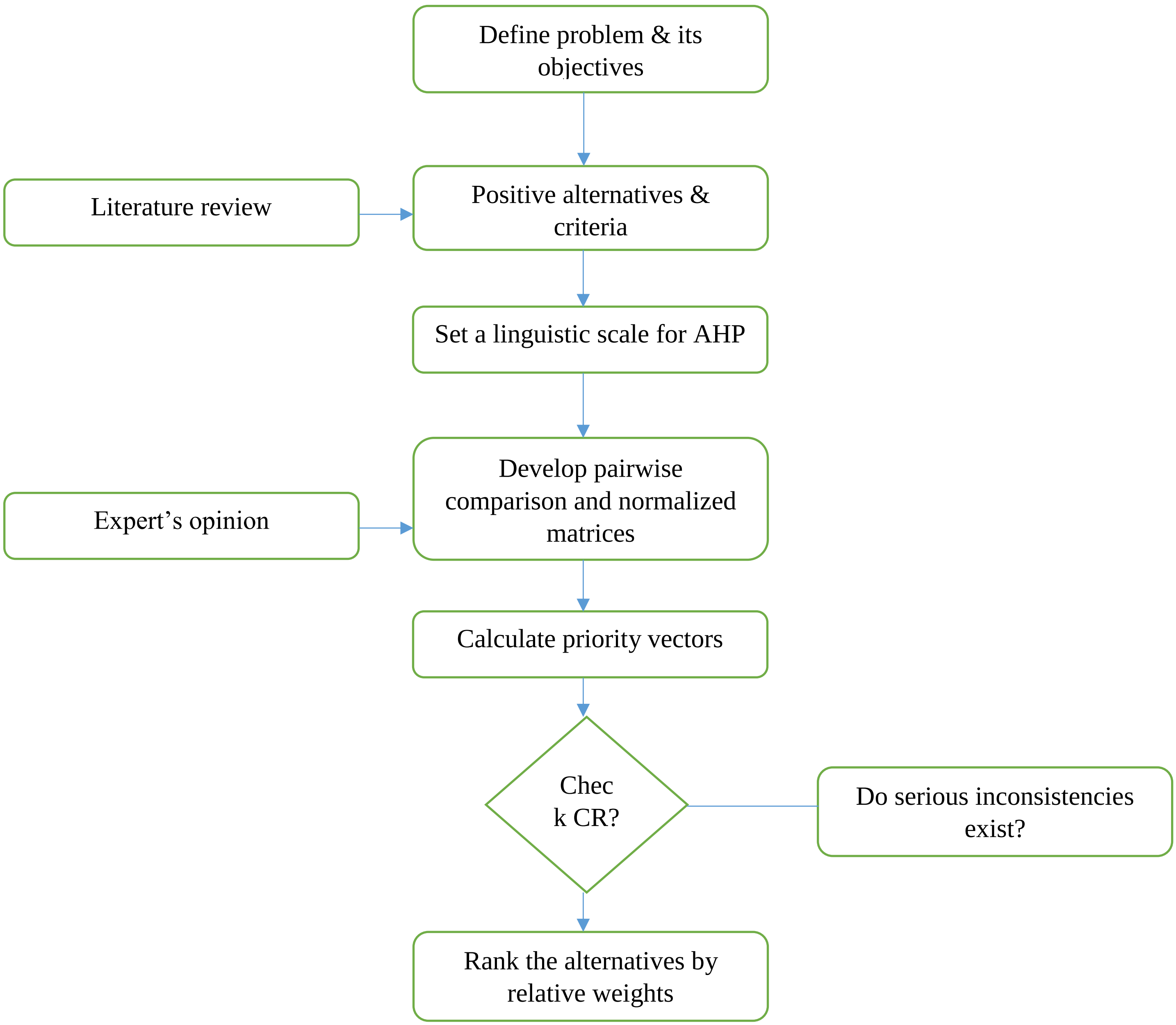

Figure 2 Flow diagram for AHP based model

If CR = CI/RI < 0.10, then the degree of consistency is satisfactory. If CR>0.10, serious inconsistencies may exist.

5. Finally, the optimum alternative is the one that has the greatest value in the following expression:

$$AHP_i = \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \times w_j \qquad (4)$$

Through an AHP analysis, the relative weights of the criteria and the optimal solution of the present problem were calculated. These results are used as an input for the TOPSIS technique to determine the most optimal finishing procedure for the production of urea.

3.3 TOPSIS

TOPSIS (Technique of Order Preference by Similarity to Ideal Solution) is one of the classical MCDM techniques developed by Hwang and Yoon (Markovic, 2010). It evaluates alternatives with respect to the ideal solution. The alternative that is closer to the ideal solution is preferred by TOPSIS (Ali et al, 2018). Therefore, it develops a space for each criterion in which the alternative (A_i) is represented by a point. The decision matrix assigns criterion values to the coordinates of those points. Next, the ideal and negative ideal solutions are hypothesized, which represents the most optimal points in that defined space. TOPSIS decides the best alternative, the one that has the shortest Euclidean distance from the ideal solution, and is simultaneously furthest from the negative ideal solution (Ishfaq et al., 2018). The ideal alternative can be defined in terms of the best attribute values i.e. maximum benefit criteria and minimum cost criteria. Similarly, the negative ideal solution can be defined in terms of having the worst attributes such as the minimum benefit attributes and the maximum cost attributes (Cheng et al., 2018).

Suppose that *m* represents the number of alternatives and n the number of criteria. Similarly, X_{ij} is the score of the i^{th} alternative with respect to the j^{th} criterions. J is assumed to be the set of positive attributes, while J' is a set of negative attributes.

STEP 1. Develop a decision matrix

Let, A = [X_{ij}] be a decision matrix and W = [w_1, w_2, …., w_n] be a weight vector of the criteria determined from the AHP analysis in the previous section, where X_{ij} & w_{ij} are real numbers.

STEP 2. Determine the normalized decision matrix

Decision matrices have criteria values that must be normalized into non-dimensional numbers. There are different methods for normalizing decision matrices. The most frequently used formula for normalization is:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{5}$$

For i = 1, 2, 3, …., m and j = 1, 2, 3, …., n

STEP 3. Calculate the weighted normalized matrix

Relative importance weights w_{ij} are multiplied with the corresponding entries of the normalized matrix;

$$S_{ij} = w_{ij} \times n_{ij} \tag{6}$$

STEP 4. Determine the positive and negative ideal solution

The positive ideal solution has the largest values of positive attributes and the lowest values for negative (cost) attributes. It maximizes the positive criteria while minimizing the negative criteria. The negative ideal solution is the reverse of the positive ideal solution. A^+ is the set of positive ideal alternatives:

$$A^+ = (S1, S2, \ldots\ldots, Sn) = [(\max S_{ij} \mid j \in J), (\min S_{ij} \mid j \in J')] \quad (7)$$

A- is representing a negative ideal solution in the form of:
B-

$$A^- = (S1, S2, \ldots\ldots, Sn) = [(\min S_{ij} \mid j \in J), (\max S_{ij} \mid j \in J')] \quad (8)$$

STEP 5. Calculate the Euclidean distance (separation) from the positive and negative ideal solution

TOPSIS evaluates each alternative on the basis of its Euclidean distance or separation from the ideal solution. The Euclidean distance from the positive ideal solution is given as;

$$d^+ = \sqrt{\sum_{j=1}^{n} (S_{ij} - S_j^+)^2} \quad , \quad i = 1, 2, \ldots\ldots, m. \quad (9)$$

The Euclidean distance of each of alternative from the negative ideal solution is

$$d^- = \sqrt{\sum_{j=1}^{n} (S_{ij} - S_j^-)^2} \quad , \quad i = 1, 2, \ldots\ldots, m. \quad (10)$$

STEP 6. Calculate the relative closeness to the positive ideal solution

The relative closeness of an alternative A_i with respect to A^+ is;

$$RC_i = \frac{d_i-}{d_i^- + d_i^+} \quad , \quad 0 \leq RC_i \leq 1 \, , \quad i = 1, 2, \ldots\ldots, m. \quad (11)$$

STEP 7. Rank the alternatives

Finally, each alternative has a certain value of RC. The alternative which has an RC value more close to 1 is the most optimal alternative for the given problem.

4. Results and discussion

The present research study is related to the evaluation of different finishing procedures for the commercial production of urea. The AHP technique with TOPSIS was used to evaluate prilling, granulation, and the hybrid system which are the best current technologies for urea production. According to the AHP analysis, the hybrid or combined system has the top ranking among the other alternatives (Table 4.). This is because the hybrid system is a combination of the prilling and granulation processes. Therefore, the beneficial properties of both systems combine to give an optimal solution. In this study, we assumed a 50% contribution from both the prilling and granulation process in the hybrid system. If the percentage is skewed more towards prilling or granulation, the results would also change. The hybrid system also closely depends on market demand, and that is why its application varies based on the needs of the market.

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Table 4
Ranking of alternatives in AHP analysis

Alternative	**Relative weights**	**Ranks**
Hybrid System	0.54	1
Granulation	0.24	2
Prilling	0.22	3

The main processes are prilling and granulation, which are also mostly applied in the fertilizer industry (Shrev, 1998). The granulation and prilling processes are almost equally preferred. Environmentally, granulation is ranked first based on the relative weights of the AHP, which is the same result that Shrev (1998) obtained. The flexibility of the granulation process is also greater than that of the prilling process as shown in Table 5. Since the quality of urea is strongly dependent on the process flexibility, the quality of the granulated urea will be higher than the prilled urea according to Rahmanian (2015). The reliability of granulation is a bit less than prilling because of the high loop loading of the granulation process. Due to this problem, granulation is not recommended for higher capacity requirements.

Table 5
Relative importance weights of each alternative

Alternatives	**Profit**	**Environment-friendly**	**Flexibility**	**Reliability**
Prilling process	0.1212	0.020	0.0080	0.0634
Granulation process	0.040	0.1400	0.02811	0.0310
Hybrid System	0.2400	0.0456	0.0587	0.20607

As mentioned above, the relative weights of criteria were used as an input for TOPSIS in order to evaluate the prescribed alternatives. The relative importance weights from the AHP analysis are given in Figure 3.

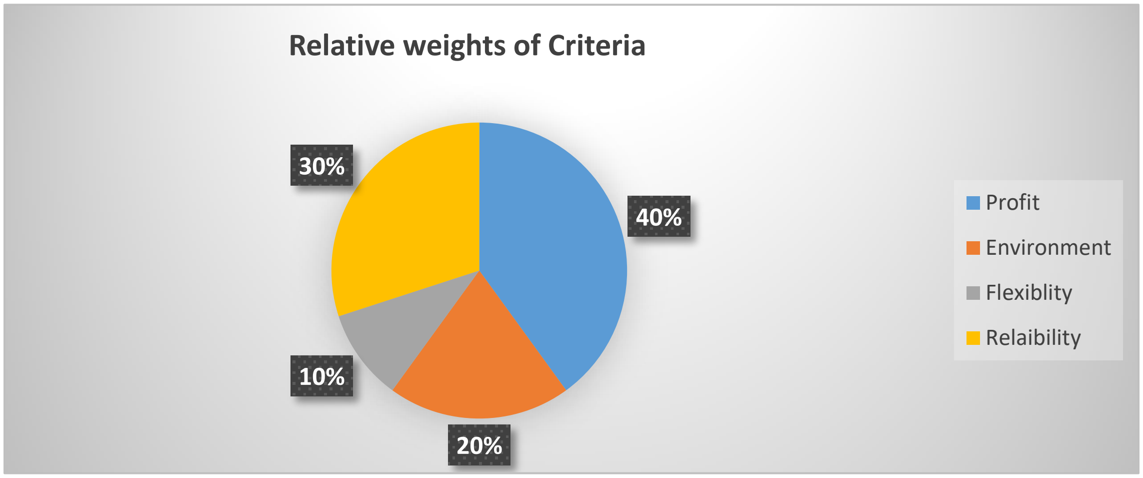

Figure 3 Relative weights of each criterion from the AHP analysis

According to the TOPSIS analysis, prilling is the most optimal finishing process for the commercial production of urea. The hybrid system ranked second followed by granulation which ranked third (Table 6.). The rankings were formulated based on the relative closeness of each alternative. In a positive ideal solution, prilling is selected as the ideal with respect to profit and reliability. This means that the prilling process is the most profitable and reliable for the production of urea (K.M. Constant, 1992).

Table 6
Ranking of alternatives in TOPSIS analysis

Alternative	Relative Closeness	Ranks
Prilling	0.76	1
Hybrid system	0.48	2
Granulation	0.40	3

Granulation is an ideal process for the commercial production of urea with respect to the environment and process flexibility. Since granulation is not as profitable and reliable as the prilling process, it ranked the lowest in the TOPSIS analysis. Due to these reasons, the granulation process is rarely used in industry when compared to the prilling process (Baba, 2012). The rankings are depicted in Table 6.

Table 7
Positive ideal solution

Criteria	Prilling	Granulation	Hybrid System
Profit	0.31	0.1833	0.174
Environmental	0.164	0.0356	0.096
Flexibility	0.03714	0.0711	0.05975
Reliability	0.1455	0.1102	0.2381

Table 8
Negative ideal solution

Criteria	Prilling	Granulation	Hybrid System
Profit	0.31	0.1833	0.174
Environmental	0.164	0.0356	0.096
Flexibility	0.03714	0.0711	0.05975
Reliability	0.1455	0.1102	0.2381

From Tables 7 and 8, it is clear that prilling is close to the positive ideal solution in profit and reliability, but closer to the negative ideal solution in environment and flexibility as shown by the colored boxes. The reason for creating two tables was to identify the values for the positive and negative ideal solutions, respectively. The question is, why was prilling still ranked first? The reason is because the AHP analysis gave higher weights to profit and reliability and lower weights to environment and process flexibility. In Table 9 the separation of each alternative from the positive (S_i) and negative ideal solutions (S_i') are listed.

Table 9
Euclidean distance from positive & negative ideal solutions

Alternative	S_i	S_i'	Result
Prilling	0.162	0.53	0.76
Hybrid system	0.18	0.116	0.48
Granulation	0.149	0.139	0.40

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This research study used MCDM techniques (AHP and TOPSIS) to determine the most optimal process for the production of urea. The results and methodology of the present study only focus on urea, but almost the same results would be obtained if we focused on other types of production facilities. Other methods, such as experimentation and forecasting with historical data may also be used to determine the best process for urea production

5. Conclusions

Urea is most widely used as a nitrogen fertilizer in agricultural activities. Factors like profit/cost, environment, process flexibility, and reliability are the most significant decision attributes for determining the optimal technological finishing process (prilling, granulation, and hybrid system) for the commercial production of urea. The AHP and TOPSIS results confirm that prilling is the best finishing process for urea production as a whole. Prilling is an ideal process with respect to profitability as well as reliability. Furthermore, it has some greater environmental concerns when compared to granulation. Granulation is not the best fit for commercial production of urea because of its low profitability and reliability when compared to others. If only the granulation process was used, it would not meet the market demand and therefore may not be able to cope with the rapid growth of the population. One of the positive attributes of this process is that it is the most environmentally safe process when compared to the others. Since process flexibility is almost analogous to product quality, the present analysis also confirms that the quality of granulated urea is higher than that of prilled urea. This analysis also demonstrates that granulation is not capable of being widely used as a commercial process, especially for high agricultural demands. If the concerns about environment and process flexibility are high, then the hybrid system may be preferred. Although this research study only focused on urea production, the same results may be obtained for other fertilizers because the processes are the same in all cases. However, since only fertilizer (urea) was used as a case study these results might not be exactly in accordance with other fertilizer or chemical facilities. Therefore, it can be concluded that the prilling process has been shown to be more reliable for the market demand, and the government should focus on sustainable urea production processes to avoid risk to the general population and environment.

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