ISSN:0975-542X
Selvamuthukumar.S / J Biomed Sci and Res., Vol 3 (1), 2011,368-377

Application of Fuzzy Analytic Hierarchy Process In Selecting A Suitable Granulation Process For The Formulation Of Aceclofenac Sustained Release Tablet

Selvamuthukumar.S
Department of Pharmacy, Faculty of Engineering and technology, Annamalai University, Annamalai Nagar, Tamil nadu, India 608002.

Abstract:
Granulation method selection as a decision process is the most important of all other decisions in the formulation of sustained release tablet. The importance of the subsequent outcome may bring a level of uncertainty to the judgment making process by the decision maker in the form of doubt, hesitancy, and procrastination. This study considers one such problem, namely the selection of the granulation method to be adopted in the formulation of Acelofenac SR tablets. With a number of criterias to consider, a fuzzy analytic hierarchy process (FAHP) analysis is undertaken to accommodate the inherent uncertainty.
Keywords:
Granulation method selection, degree of Fuzziness, FAHP, Uncertainty.

1. INTRODUCTION.

The last few decades have witnessed dramatic developments in pharmaceutical sciences. Much research effort in developing novel drug delivery systems has been focused on controlled release and sustained release dosage forms **[1-3].** The pharmaceutical formulations with novel drug delivery systems have been introduced with the course of optimizing the bioavailability through the modulation of the time course of the drug concentration in blood **[4, 5].** All sustained and controlled release products show the common goal of improving drug therapy over that achieved with their non sustained and controlled release counter parts **[6, 7].**

One of the more recent and interesting result of pharmaceutical research is the fact that absorption rate of a drug can be decreased by reducing its rate of release from the dosage form. The products so formulated are designed as sustained action, sustained release.

Prolonged action, depot, retarded release, delayed action and timed release medication **[8].** This has been due to various factors viz prohibitive cost of developing new drug entities, expiration of existing international patients, discovering of new polymeric materials suitable for prolonging the drug release, improvement in therapeutic efficacy and safety achieved by these delivery systems **[9,10].** Various approaches are available for achieving novel drug delivery dosage forms such as targeted delivery system, Sustained release tablets, nanoparticles, Prodrugs, transdermal system, ocular systems, intravaginal and intrauterine systems, injection and implants, microencapsulation, matrix devices, reservoir devices. One of the most effective approaches is Sustained release tablet **[11].**

Two of the major problems that encounter granulation process selection involve both the uncertainty and ambiguity surrounding the different criteria, including financial and non-financial. The problems of uncertainty and ambiguity assume even greater proportions because of the difficulty in estimating the impact of unexpected changes on cash flows.

Apart from uncertainty in quantitative (objective) data, the other problem of uncertainty in granulation method selection comes from the subjective opinions. These uncertainties involve incomplete information, inadequate understanding, and undifferentiated alternatives **[12-14].** . Here we focus on eliciting subjective opinions with the ultimate objective the selection of a best course of action from a set of available alternatives.

To operationalize this decision-making process, there exist a number of methods to elicit the subjective opinions **[15-18].** . Among the most well known is the analytic hierarchy process (AHP) in Saaty **[16].** Here, to accommodate the acknowledged possible uncertainty in the subjective judgments to be made, a Fuzzy AHP (FAHP) approach is adopted. The earliest work in the FAHP appeared **[19]** utilized triangular fuzzy numbers (TFNs) to model the pair wise comparisons made in order to elicit weights of preference of the decision alternatives considered. Since then, FAHP-related developments have been repeatedly reported in the concomitant literature; e.g., spatial allocation within FAHP **[20]**, the method of FAHP and fuzzy multiple-criteria decision-making **[21]**, deriving priorities from FAHP **[22]**, and revisiting the original FAHP **[23].**

The utilization of the FAHP presented in this paper brings together a number of advantageous aspects of group decision-making in a fuzzy environment. That is, while many of these aspects are present in other techniques, they are most salient in this FAHP method. Several studies have argued that the role of group decision making is increasingly important **[24, 25, 13].** The method used in this paper takes into account group decision making; see Equation (2). Each matrix can involve all the judgements.

A major consequence of the incorporation of decision-making in a fuzzy environment is the acknowledgement of and allowance for imprecision in the judgments made. Imprecision refers to the contents of the considered judgments and depends on the "granularity" of the language used in those judgments **[26].** The method in this paper allows judgments in the judgment matrices to be given a measure of imprecision by using the degree of fuzziness—δ—as the quantifiable allowance for a level of imprecision in the judgments made.

One aspect of the FAHP method in this paper is the prevalence of and allowance for incompleteness in the judgments made. For example, if a DM is unwilling or unable to specify preference judgments in the detailed way required by the method, then a DM is able to not make a judgment in the form of a pair wise comparison between two decision alternatives (DAs). The problem of DMs being unable to provide complete information in the above circumstances is addressed by the allowance for incompleteness in the FAHP.

In this study, an attempt is made to further the understanding of the FAHP method introduced and developed **[27, 28]** which includes the utilization of the Extent Analysis method and the use of group decision making in the FAHP. A redefining of the measure of the degree of fuzziness in the pair wise comparison judgments is made which removes the restriction on the scale values able to be utilized in future studies.

The structure of the rest of the paper is as follows. In Section 2, the details of the granulation method selection problems are described. In Section 3, the synthetic extent method of the FAHP is presented. In Section 4, the results of the FAHP analysis of the granulation method selection problem are illustrated. In Section 5, Results and discussions are given and finally in section 6, conclusions are given as well as directions for future research.

2. IDENTIFICATION OF GRANULATION PROCESS SELECTION:

This section presents the details of the granulation process investigated throughout this study. This concerns sustained release tablet formulation and selection of the type of granulation process to be adopted. A number of techniques are available for the preparation of sustained release tablet, among which Dry granulation and Wet granulation process are the most commonly used. The choice of an appropriate granulation technique mainly depend on the nature of the polymer used, the drug intended use of the products, processing conditions involved in the manufacturing product and the duration of the therapy.

The method of preparation and its choice are equivocally determined by technique related factors like the knowledge and experience, requirement, reproducibility of the release profile and method. It was decided to restrict the number of criteria to five areas: safety, efficacy, formulation technique, cost, formulation information. (Hereafter $C_{1,}$ C2, C3, $C4_{,}$ and C_5)

The initial interview also identified two granulation processes. This is because the most commonly used granulation process is wet granulation and dry granulation. Preference between pairs of criteria and then pairs of alternatives over the different criteria through the structured interview was indicated.

Apart from the five criteria, the initial analysis identified two granulation processes. This is because initial discussions indicated that two granulation processes are the most commonly used for the formulation of tablets. The two types of granulation process are dry granulation and wet granulation (hereafter *A*1 and *A*2). These are the decision alternatives (DAs) in this case study. Given the necessary details of the criteria and DAs, preferences between pairs of criteria and then between pairs of alternatives over the different criteria were indicated.

The linguistic variables used to make the pair wise comparisons were those associated with the standard 9-unit scale **[16, 29, and 30]**; see Table 1. The results of the pair wise comparisons made by the DM are illustrated in Tables 2 for the five criteria and Table 3 for the five DAs.

Table 1. Scale of relative preference based on Saaty

Intensity of preference(Numerical)	Definition (Verbal Scale)	Explanation
1	Equally preferred ; equal preference	Two elements contribute equally to the objective
3	Moderately preferred ;weak preference of one over other	Experience and judgment slightly favor one element over another.
5	Strongly preferred; essential or strong preference	Experience and judgment favor one element over another.
7	Very strongly preferred; demonstrate preferred; demonstrate	An element is very strongly favored and its dominance is demonstrated in practice
9	Extremely preferred ; absolute preference	The evidence favoring one element over another is of the highest possible ordered of affirmation
2,4,6,8	Intermediate values between the adjacent judgments	When compromise is needed
Reciprocal of above non zero	If element I has one of the above numbers assigned to it when compared with element j , then j has the reciprocal value when compared with i	
Rations	Rations arising from the scale	If consistency were to be forced by obtaining a numerical values to span the matrix.

Table 2. Pair wise comparisons between criteria

	C_1	C_2	C_3	C_4	C_5
C_1	1	3	-	3	1/5
C_2	1/3	1	1/9	-	½
C_3	-	9	1	-	1
C_4	1/3	-	1/7	1	1/5
C_5	5	2	1	5	1

Table 3.Pairwise comparisons between alternatives over the different criteria

i)

Safety	A_1	A_2
A_1	1	5
A_2	1/5	1

ii)

Efficacy	A_1	A_2
A_1	1	5
A_2	1/5	1

iii)

Formulation Technique	A_1	A_2
A_1	1	3
A_2	1/3	1

iv)

Cost	A_1	A_2
A_1	1	6
A_2	1/6	1

v)

Formulation information	A_1	A_2
A_1	1	1/9
A_2	9	1

3. Presentation of the synthetic extent FAHP method

In this study the modified synthetic extent FAHP is utilized, which was originally introduced **[27, 28]** developed, and recently applied to the selection of computer integrated manufacturing systems **[31]**. One reason for its employment is that it allows for incompleteness of the pair wise judgments made, though it is not the only FAHP approach to allow this **[32]**. This feature reflects its suitability in decision problems where uncertainty exists in the judgment-making process. A brief exposition of triangular fuzzy numbers and the FAHP method are given next.

3.1. Triangular fuzzy numbers (TFN s)

In applications it is often convenient to work with TFNs because of their computational simplicity **[33, 34]**, and they are useful in promoting representation and information processing in a fuzzy environment **[35]**. In addition, TFNs are the most utilized in FAHP studies **[27, 28, 36, and 37]**. This paper adopts TFNs in the FAHP and describes their algebraic operations in the following subsection. A TFN can be defined by a triplet (*l*, *m*, *u*) and the membership function can be defined by Equation (1) **[27, 38]**.

$$\mu_A(x) = \begin{Bmatrix} 0 & x < k \\ \dfrac{x-l}{m-l} & l \le x \le m; \\ \dfrac{m-x}{n-m} & m \le x \le u; \\ 0 & x > u. \end{Bmatrix}$$

3.1.1. Algebraic Operation on TFN s

There are various operation on TFNs **[38]**, in this subsection, three important operation used in this paper are illustrated. Define two TFN s *A* and *B* by the triplets *A*= *(l 1, m1, u1)* and *B*= (l2, m2, u2*)*.Then

(i) Addition :

A(+) *B* = *(l1,m1,u1)(+)(l2,m2,u2)=(l1+l2,m1+m2,u1+u2),*

(ii) Multiplication:

A. B =(l1,m1,u1).(l2,m2,u2)=(l1 l2,m1 m2,u1 u2)

B.

(iii) Inverse:

(*L1, m1, u1)*$^{-1}$ ≈ *(1/u1, 1/m1, 1/l1)*, where ≈ represents approximately equal to.

3.2. Construction of FAHP comparison matrices

The aim of any FAHP method is to elucidate an order of preference on a number of alternatives, i.e., a prioritized ranking of alternatives. Central to this method is a series of pair wise comparisons , indicating the relative preference between pairs of alternatives in the same hierarchy .Using triangular fuzzy numbers with the pair wise comparisons made, fuzzy comparison matrix *X=(xij)n ×m* is constructed. The pair wise comparison are described by values taken from a pre-defined set of ratio scale values as presented in table 1.The ratio comparison between the relative preference of elements indexed *i* and *j* on a criterion can be modeled through a fuzzy scale value associated with a degree of fuzziness. Then an element of *X, xij* is a fuzzy number defined as *xij=(lij, mij,uij),* where *mij, uij,* and *lij* are the modal, upper bound, and lower boud values for *xij,* respectively.

3.3. Value of fuzzy synthetic extent

Let C= {C1, C2,…….C_n} be a criteria set, where *n* is the number of criteria and *A = {A1,A2,……Am }* is a alternative set with *m* the number of alternatives. Let 1 Ci M, Ci M…….., *m* Ci M be values of exent analysis of the *i*th criteria for *m* alternatives . Here *i*=1, 2,……*n* and all the *j Ci M (j=1,2,…..m)* are triangular fuzzy numbers (TFNs). To make use of algebraic operation on TFNs as described in subsection 3.1.1, the values of fuzzy synthetic extent *Si* with respect to the *i*th criteria is defined as:

$$S_i = \sum_{j=1}^{m} M_{C_j}^{j} \left[\sum_{j=1}^{n} \prod_{j=1}^{m} M_{C_j}^{J} \right]^{-1}$$

Where represents fuzzy multiplication and the superscript -1 represents the fuzzy inverse.

3.4. Calculation of the sets of weight values of FAHP

To obtain the estimates for the sets of weight values under each criterion, it is necessary to consider a principle of comparison for fuzzy numbers **[27]**. For example, for fuzzy numbers *M1* and *M2,* the degree of possibility of *M1≥M2* is defined as

$V(M_1 \geq M_2)=x \quad \geq[min\ (\mu\ M_1(x),\ \mu\ M_2(y))],$

Where sup represent supremum (i.e., the least upper bound of set) and when pair (x.y) exists such that x≥ y and $\mu_{M1}(x)\ \mu\ M_2\ (Y)$ =1, it follows that V $(M_2 \geq M_2) =1$ and V $(M_2 \geq M_1)$ = 0. Since M_1 and M_2 are convex fuzzy where sup represents supreme (i.e., the least upper bound of a set) and when a pair (x, y) exists such that x ≥ y and μ M_2 (y) = 1, if follows that

$V (M_1 \geq M_2) =1 \qquad \text{iff } M_1 \geq M_2;$

$V (M_2 \geq M_1) = hgt\ (M_1 \cap M_2) = \mu_M (x_d)$

$V (M_1 \geq M_2)1$ and $V (M_2 \geq M_1) = 0$. Since M_1 and M_2 numbers defined by the TFNs (l_1, m_1, u_1) and (l_2, m_2, u_2) respectively, it follows that Where iff represents “if and only if” and *d* is the ordinate of the highest intersection point between the M_1 μ and M_2 μ TFNs **(See Figure 1)** and x_d is the point on the domain of M_1 μ and M_2 μ where the ordinate *d* is found. The term hgt is the height of fuzzy numbers on the intersection of M_1 and M_2. For $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the possible ordinate of their intersection is given by Equation (3). The degree of possibility for a convex fuzzy number can be obtained from the use of Equation (4):

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \frac{l_1 - n_2}{(m_2 - n_2) - (m_1 - l_1)} = d$$

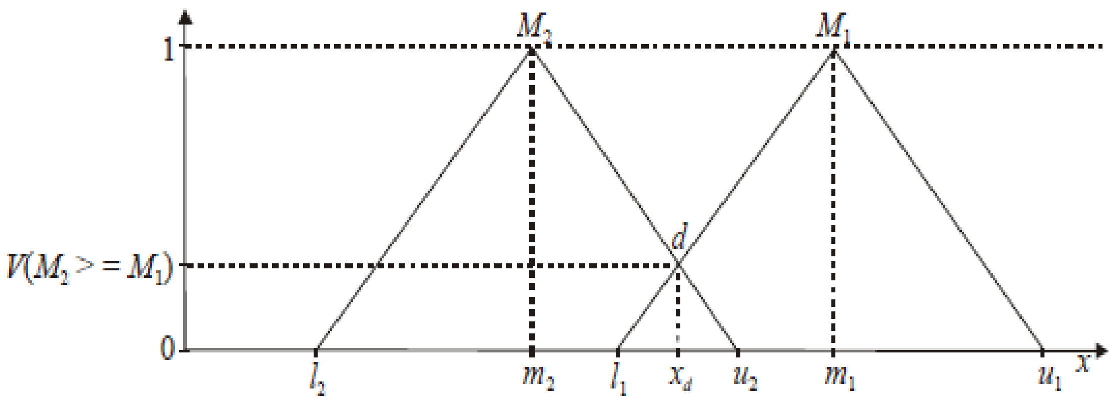

Figure 1: The comparison of two fuzzy numbers M_1 and M_2

The degree of possibility for a convex fuzzy number *M* to be greater than the number of *k* convex fuzzy numbers M_i (i = 1, 2,…, k) can be given by the use of the operations max and min **(23)** and can be defined by:

$V(M \geq M_1, M_2, \ldots, M_k) =$

$V[(M \geq M_1)$ and $(M \geq M_2)$ and … and $(M \geq M_k)]$

$= \min V(M \geq M_i), i = 1, 2, \ldots, k.$

Assume that $d(Ai) = \min V(Si \geq Sk)$, where k = 1, 2, …, n, $k \neq i$, and n is the number of criteria as described previously. Then a weight vector is given by:

$W = (d(A_1), d(A_2), \ldots, d(Am))$,

Where A_i (i = 1, 2, …, m) are the m alternatives. Hence each d' (Ai) value represents the relative preference of each alternative. To allow the values in the vector to be analogous to weights defined from the AHP type methods, the vector W' is normalized and denoted:

$W = (d(A_1), d(A_2), \ldots, d(A_m))$

One point of concern, highlighted in this paper, is when two elements (fuzzy numbers, say $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ in a fuzzy comparison matrix satisfy $l_1 - u_2 > 0$ then $V(M_2 \geq M_1) = \mathrm{hgt}(M_1 \cap M_2) = \mu M_2 (X_d)$ given **[28]**.

$$\mu_{M_2}(X_d) = \begin{cases} \frac{l_1 - n_2}{(m_2 - n_2) - (m_1 - l_1)} l_1 \leq n; \\ 0 \quad \textit{otherwise} \end{cases}$$

3.5. The modified synthetic extent FAHP: Redefinition of the proportional distance

Referring back to fuzzy numbers, for example an element x_{ij} in a fuzzy comparison matrix, if alternative i is preferred to alternative j then m_{ij} takes an integer value from two to nine (from the 1-9 scale). It follows that the values l_{ij} and u_{ij} directly describe the fuzziness of the judgment given in x_{ij}. . This fuzziness is influenced by δ (the degree of fuzziness), where $m_{ij} – l_{ij} = u_{ij} – m_{ij} = \delta$ **[28]**. That is, δ is a constant and is considered an absolute distance from the lower bound value (l_{ij}) to the modal value (m_{ij}) or the modal value (m_{ij}) to the upper bound value (u_{ij}).

Given the modal value (scale value) m_{ij}, the fuzzy number representing the fuzzy judgment made is defined by ($m_{ij} - \delta$, m_{ij}, $m_{ij} + \delta$), with its associated inverse fuzzy number subsequently described by ($1/m_{ij}+\delta$, $1/m_{ij}$, $1/m$, $-\delta$). In the case of m_{ij} given a value of one ($m_{ij} = 1$) off the leading diagonal ($i \neq j$), the general form of its associated fuzzy scale value is defined as ($1/(1 + \delta)$, 1, $1 + \delta$). One restriction of the method described [**28]** is that it assumes equal unit distances between successive scale values. However with respect to the traditional AHP there has been a growing debate on the actual appropriateness of the Application and Development of a Fuzzy Analytic Hierarchy Process within a granulation process selection

Study Saaty 1-9 scale, with a number of alternative sets of scales being proposed. Here the effect of the δ value on a fuzzy number (l_{ij}, m_{ij}, u_{ij}) will be elucidated. For example, around this scale value 1, the domain of the fuzzy scale value measured is between 0 and ∞. In the case of fuzzy scale values, there is still a need for the strict partition of the scale value domain. That is, the support of any fuzzy scale value should be in either the 0 to 1 or the 1 to ∞ sub-domains of δ

To illustrate, using the fuzzy scale value $m_{ij} = v_k = 2$, following [**28**] if δ = 1.5 the associated fuzzy number is (0.5, 2, 3.5). (More formally, given the entry m_{ij} in the fuzzy comparison matrix has the k^{th} scale value v_k, then l_{ij} and u_{ij} have values either side of the v_k scale value.) It follows that $l_{ij} = 0.5 < 1$ and implies that a sub-domain of the support (0.5, 1) is meaningless with the fuzzy scale value $m_{ij} = 2$.

Table 4. The fuzzy comparison matrix over different criteria when δ = 0.5

	C_1	C_2	C_3	C_4	C_5
C_1	1, 1, 1	1,3,5	-	1,3,5,	(1/7,1/5,1/3)
C_2	(1/5,1/3,1/1)	1,1,1	(1/11,1/9,1/7)	-	(1/4,1/2,1/1)
C_3	-	7,9,11	1,1,1	5,7,9	1,1,1
C_4	(1/5,1/3,1/1)	-	(1/9,1/8,1/6)	1,1,1	(1/7,1/5,1/3)
C_5	3,5,7	1,2,4	1,1,1	3,5,7	1,1,1

4. Results of the FAHP analysis in granulation method selection

In this section, the concepts presented above are applied to the data from the granulation method selection. The redefinition of the proportional distance between lower bound and upper bound values associated with fuzzy numbers in the FAHP is now applied in a practical environment to reach a decision on granulation process selection. The application of the FAHP to the data from the granulation method selection is described as follows.

4.1. The process of weight evaluation

The modified FAHP extent analysis method to the data on granulation method selection was described above. The following stages demonstrate how to obtain the weight values for alternatives. In this demonstration, the degree of fuzziness is set at 2. (The degree of fuzziness is not necessarily 2; it can be any number as explained later.)

4.1.1. Weights evaluation for criteria

In this granulation method selection, only the judgments between criteria obtained are demonstrated. Subsequently, the judgments between alternatives over different criteria are dealt with in an identical manner. The first stage of the weight evaluation process is the aggregation of l_{ij}, m_{ij}, and u_{ij} values present in the pair wise comparison matrix for the judgments between criteria. Following the fuzzy synthetic extent concept shown in Equation (2), the evaluation with respect to the five criteria in terms of the 1-9 scale from Saaty **[16]** based on δ = 0.5 can be illustrated as shown in Table 1.

Table 5. Sum of rows and columns based on different criteria

	Row sums	**Column sums**
C_1	3.1428,7.2,11.3333	4.4,6.666, 10
C_2	1.5409, 1.9444, 3.1428	10, 15, 21
C_3	14, 18, 22	2.202, 2.2159, 2.3094
C_4	1.4337, 16583, 2.4999	10, 15, 22
C_5	9, 14, 20	2.5356, 2.9, 3.6666
	Sum of column sums	58.976, 41, 7825, 29.1376

The associated S_i values can be found as follows:

$$S_1 = (3.1428, 7.20, 11.333) \times \left(\frac{1}{58.976}, \frac{1}{41.7825}, \frac{1}{29.1376}\right) = (0.0532.0.1723, 0.3889)$$

$$S_2 = (1.5409, 1.9444, 3.1428) \times \left(\frac{1}{58.976}, \frac{1}{41.7825}, \frac{1}{29.1376}\right) = (0.0261, 0.0465, 0.1078)$$

$$S_3 = (14,18,22) \times \left(\frac{1}{58.976}, \frac{1}{47.7825}, \frac{1}{29.1376} \right) = (0.2376.0, 0.4308, 0.7550)$$

$$S_4 = (1.4337, 1.6583, 2.4999) \times \left(\frac{1}{58.976}, \frac{1}{47.7825}, \frac{1}{29.1376} \right) = (0.02430, 0.0396, 0.0857)$$

$$C_5 = (9,14,20) \times \left(\frac{1}{58.976}, \frac{1}{47.7825}, \frac{1}{29.1376} \right) = (0.1526, 0.3350, 0.6863)$$

Using Equations (3) and (4) described in Section 3, one obtains:

$V(S_1 \geq S_2) = 1$; $V(S_1 \geq S_3) = 1$; $V(S_1 \geq S_4) = 1$, $V(S_1 \geq S_5) = 0$

$V(S_2 \geq S_1) = 0$; $V(S_3 \geq S_2) = 0$; $V(S_3 \geq S_4) = 1$, $V(S_2 \geq S_5) = 0$

$V(S_3 \geq S_1) = 1$; $V(S_3 \geq S_2) = 1$; $V(S_3 \geq S_4) = 1$, $V(S_3 \geq S_5) = 1$

$V(S_4 \geq S_1) = 0$; $V(S_4 \geq S_2) = 0.8962$; $V(S_4 \geq S_3) = 0$, $V(S_4 \geq S_5) = 0$

$V(S_5 \geq S_1) = 1$; $V(S_5 \geq S_2) = 1$; $V(S_5 \geq S_3) = 0.8240$, $V(S_5 \geq S_4) = 1$

Finally, using Equation (5) in Section 3, it follows that:

$d'(C_1) = V(S_1 \geq S_2, S_3, S_4, S_5) = \min(1, 0, 1, 0) = 0$,

$d'(C_2) = V(S_2 \geq S_1, S_3, S_4, S_5) = \min(0, 0, 1, 0) = 0$,

$d'(C_3) = V(S_3 \geq S_1, S_2, S_4, S_5) = \min(1, 1, 1, 1) = 1$,

$d'(C_4) = V(S_4 \geq S_1, S_2, S_3, S_5) = \min(0, 0.5655, 0, 0) = 0$,

$d'(C_5) = V(S_5 \geq S_1, S_2, S_3, S_4) = \min(1, 1, 0.4039, 1) = 0.4039$.

Therefore, $W' = (0, 0, 1, 0, 0.4039)$. Through normalization, the weight vectors are obtained with respect to the decision criteria C_1, C_2, C_3, C_4 and C_5 to yield $W = (0, 0, 0.7123, 0, 0.2876)$.

Similarly, the transformation procedures for comparisons between criteria based on other alternative scales can be found, and the final results based on $\delta = 2$ and final results are shown below.

5. RESULTS AND DISCUSSIONS:

Table 6. The sets of weight values for all fuzzy comparison matrices and the final results obtained when $\delta = 2$

Alternatives	A1 (Wet - Granulation)	A2 (Dry-Granulation)	Weight values of criteria
C_1	1	0	0
C_2	1	0	0
C_3	0.700	0.2999	0.7123
C_4	1	0	0
C_5	1	0	0.2876

This table shows that wet granulation is better than dry granulation process.

The results from Table 6 cannot fully represent the preferences for alternatives. That is, since pair wise comparisons are made between criteria (or Alternatives), it is expected that all weights should have positive values. This aspect was discussed within the traditional AHP, suggesting not favouring one criterion (or Alternative) and ignores all others but rather places the criteria (or Alternatives) at various levels. Furthermore, it is suggested the 1-9 scale forces the concentration of the weight values, whereas only with an unbounded scale range would it be possible for the weights to overwhelmingly prefer one criterion.

Among the criteria in granulation selection problem was cost; from its definition this has an associated value with each alternative and hence it is a tangible criterion. Within AHP and subsequently FAHP, an ongoing question is how to effectively incorporate the tangible with the intangible criteria. Specifically to FAHP, whether the change in the degree of fuzziness may aid in this appropriateness is again, left for future research. An important development in this study is to evaluate the workable degree of fuzziness, possibly specific to the synthetic extent FAHP and it needs adoption in future studies to strengthen its appropriateness.

6. CONCLUSION

The aim of this study is to investigate the application of the Fuzzy Analytic Hierarchy Process (FAHP) method of multi-criteria decision-making within granulation method selection problem. The application problem in question is the selection of the type of granulation methods available in formulation of Aceclofenac SR tablet. The important consequences of the choice outcome may confer a level of uncertainty on the decision maker, in the form of doubt, procrastination etc. This is one reason for the utilization of FAHP, with its allowance for imprecision in the judgments made. The issue of imprecision is reformulated in this study which further allows a sensitivity analysis on the preferences weights evaluated to changes in the levels of imprecision.

This works is a structural approach that considers both qualitative & quantitative factors. It must be mentioned that the criteria's, decision alternatives may vary from case to case. Similar approaches can be extended to other situation for selection of alternatives such as, tablet machines, liquid or semi solid preparations, site selection for pharmaceutical plants, assay techniques, choice of excipients etc.

REFERENCES:

[1] Patrick B Deasy. Microencapsulation and related drug processes. Marcel Dekker, New York, Vol. 20, 1984, pp. 01-159

[2] Mine Qrlu, Erdal Cevher and Ahmet Araman. *Int J Pharm*.318: 103-117 (2006).

[3] Frederic Lagarce, Pascal Renaud, Nathalie Faisant, Guillaume Nicolas, Annie Cailleux, Joel Richard, Philipp Menei and Jean-Pierre Benoit. *Eur J Pharm Biopharm*. 59:449-459 (2004).

[4] A.Khawla, Abu – izza, Lucila Garcia- Contreras and D.Robert Lu. *J Pharm Sci*. 85:144-149 (1996).

[5] A.Khawla, Abu – izza, Lucila Garcia- Contreras and D.Robert Lu. *J Pharm Sci*. 85:572-575 (1996).

[6] Jian You, Fu-de Cui, Xu Han, yongsheng Wang, Lei Yang, Ying-Wei Yu and Qing-po LI. *B: Biointerfaces*. 48:35-41 (2006).

[7] Mirzaagha Babazadeh. *Int J Pharm*. 316:68-73 (2006).

[8] G.S.Banker and C.T.Rhodes (4thed), Modern pharmaceutics, Marcel Dekker, New York, Vol.121, 2002, pp. 501-527

[9] M.C.Gohel and A.F.Amin. *J Controlled Rel*. 51,115-122(1998).

[10] Sunil K.Jain, P.Govind Agarwa and K.Narendra Jain. *J Controlled Rel*. 28:111-116 (2006)

[11] Yan Gao, Fu-deCui, Ying Guan, Lei Yang, Yong-Sheng Wang and Li-na Zhang. *Int J Pharm*. 318: 62-69 (2006).

[12] Lipshitz, R. and O. Strauss, (1997), "Coping with Uncertainty: A Naturalistic Decision-Making Analysis," *Organizational Behavior and Human Decision Processes*, 69, 149-163.

[13] Ahn, B. S., K. S. Park, C. H. Han and J. K. Kim, (2000), "Multi-Attribute Decision Aid under Incomplete Information and Hierarchical Structure," *European Journal of Operational Research*, 125, 431-439.

[14] Ahn, B. S., (2000), "The Analytic Hierarchy Process in an Uncertain Environment: A Simulation Approach by Hauser and Tadikamalla (1996)," *European Journal of Operational Research*, 124, 217-218.

[15] Wang, W., (1997), "Subjective Estimation of the Delay Time Distribution in Maintenance Modeling," *European Journal of Operational Research*, 99, 516- 529.

[16] Saaty, T. L., (1980), *The Analytical Hierarchy Process*, New York: McGraw Hill.

[17] Zhu, X. and A. P. Dale, (2001), "Java AHP: A Web-Based Decision Analysis Tool for Natural Resource and Environmental Management," *Environmental Modelling & Software*, 16, 251-262.

[18] Tenekedjiev, K., S. Kamenova and N. Nikolova, (2004), "Formalized Procedure for Ranking Alternatives in Developing Environmental Programs," *Journal of Cleaner Production*, 12, 353-360.

[19] Laarhoven, P. J. M. and W. Pedrycz, (1983), "A Fuzzy Extension of Saaty's Priority Theory," *Fuzzy Sets and Systems*, 11, 229-241.

[20] Wu, F. G., Y. J. Lee and M. C. Lin, (2004), "Using the Fuzzy Analytic Hierarchy Process on Optimum Spatial Allocation," *International Journal of Industrial Ergonomics*, 33, 553-569.

[21] Hsieh, T. Y., S. T. Lu and G. H. Tzeng, (2004), "Fuzzy MCDM Approach for Planning and Design Tenders Selection in Public Office

Buildings,*International Journal of Project Management*, 22, 573-584.

[22] Mikhailov, L., (2003), "Deriving Priorities from Fuzzy Pairwise Comparison Judgements," *Fuzzy Sets and Systems*, 134, 365-385.

[23] Buckley, J. J., T. Feuring and Y. Hayashi, (2001), "Fuzzy Hierarchical Analysis Revisited," *European Journal of Operational Research*, 129, 48-64.

[24] Belton, V. and J. Pictet, (1997), "A Framework for Group Decision Using a MCDM Model: Sharing, Aggregating or Comparing Individual Information?" *Journal of Decision Systems*, 6, 283-303.

[25] Armacost, R. L., J. D. Hosseini and J. Pet-Edwards, (1999), "Using the Analytic Hierarchy Process as a Two-Phase Integrated Decision Approach for Large Nominal Groups," *Group Decision and Negotiation*, 8, 535-555.

[26] Smets, P., (1991), "Varieties of Ignorance and the Need for Well-Founded Theories," *Information Sciences*, 57-58, 135-144.

[27] Chang, D. Y., (1996), "Applications of the Extent Analysis Method on Fuzzy AHP,"*European Journal of Operational Research*, 95, 649-655.

[28] Zhu, K. J., Y. Jing and D. Y. Chang, (1999), "A Discussion on Extent Analysis Method and Applications of Fuzzy AHP," *European Journal of Operational Research*, 116, 450-456.

[29] Saaty, T. L., (1986), "Axiomatic Foundation of the Analytic Hierarchy Process,"*Management Science*, 32, 841-855.

[30] Saaty, T. L., (1988), *The Analytic Hierarchy Process*, Pittsburgh: RWS Publications.

[31] Bozdağ, C. E., C. Kahraman and D. Ruan, (2003), "Fuzzy Group Decision Making for Selection among Computer Integrated Manufacturing Systems," *Computers in Industry*, 51, 13-29.

[32] Davis, J. P. and J. W. Hall, (2003), "A Software-Supported Process for Assembling Evidence and Handling Uncertainty in Decision-Making," *Decision Support Systems*, 35, 415-433.

[33] Giachetti, R. and R. E. Young, (1997), "A Parametric Representation of Fuzzy Numbers and Their Arithmetic Operators," *Fuzzy Sets and Systems*, 91, 185-202.

[34] Moon, J. H. and C. S. Kang, (2001), "Application of Fuzzy Decision Making Method to the Evaluation of Spent Fuel Storage Options," *Progress in Nuclear Energy*, 39, 345-351.

[35] Liang, G. S. and M. J. J. Wang, (1993), "A Fuzzy Multi-Criteria Decision-Making Approach for Robot Selection," *Robotics & Computer-Integrated Manufacturing*, 10, 267-274.

[36] Kuo, R. J., S. C. Chi and S. S. Kao, (2002), "A Decision Support System for Selecting Convenience Store Location through Integration of Fuzzy AHP and Artificial Neural Network," *Computers in Industry*, 47, 199-214.

[37] Chiou, H. K. and G. H. Tzeng, (2001), "Fuzzy Hierarchical Evaluation with Grey Relation Model of Green Engineering for Industry," *International of Fuzzy System*, 3, 466-475.

[38] Kaufmann, A. and M. M. Gupta, (1988), *Fuzzy Mathematical Models in Engineering and Management Science*, North-Holland.