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Choosing the best contemporary alliance strategy for the lowest R&D expenditure

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ABSTRACT: With so many advances in technology companies must achieve competitive advantage by taking cogent manoeuvres in R&D while facing greater competitive challenges. It is crucial for them to know how to maintain their advantage and achieve the highest profits. Particularly, the three essential relations are evaluated by 19 assessable sub-criteria of four measured criteria through the comparison of the Multiple Criteria Decision Making methodology, including four analytical approaches: factor analysis, Analytical Network Process, Fuzzy Analytical Network Process, and Grey Relation Analysis. Moreover, the specific feature of the four-model approach is to calculate the priority vector weights for each assessable characteristic, criteria and sub-criteria by a pair wise comparative matrix and, the content and the analytical hierarchical relations are expressed in four levels for each criteria. These enable enterprises to choose the best consolidated strategy for minimising R&D expenditure. The research concludes that the *partner relation* in consolidation is most beneficial in minimising R&D expenditures for the enterprises.

INTRODUCTION

In today's hypercompetitive era, traditional Research and Development (R&D) strategies, (Integrated Device Manufacturer (IDM), Original Design Manufacturer (ODM) and Original Equipment Manufacturer (OEM) are not enough to deal with the issues regarding various new competitive environment challenges. This has resulted in enterprises having the pressures of competing to positively adapt and to form a competitive global R&D strategy in order to satisfy three major demands. These are cost-down demand, advance-technology demand and market-share demand. Further, in terms of the R&D development phase, the initial R&D development in enterprises focuses on setting up domestic R&D footholds [1]. As enterprises grow, they then concentrate on establishing central R&D national centres. Most enterprises employ multiple-national off-shore R&D strategies to achieve the most beneficial R&D effect. However, many of these multi-national enterprises have reconsidered their worldwide R&D strategies by analysing the significant R&D cost of outsourcing, off-shoring and consolidation.

Further, in a hypercompetitive and lower profits environment, enterprises are faced with the decision to reduce their R&D expenditure through a consolidated strategy. Hence, enterprises are able to assess easily strategic performance through a recently innovative evaluation theory - Balanced-Scorecard (BSC) theory. Balanced-Scorecard theory not only creates the concretely and effectively evaluated unit, the Key Performance Indicator (KPI), but also integrates the assessable four aspects: learning and growth aspect, internal business process, customer and financial. However, what is the best contemporary consolidation for minimising R&D expenditures? It is an important issue for discussion of a consolidated relationship with the lowest R&D expenditure from a balanced-scorecard perspective in a global hypercompetitive era. In terms of the relationship between enterprises' development and R&D expenditure, enterprises are supposed to institute a complete and competitive global R&D that shares cross-industry knowledge and technologies to integrate R&D capacity for the benefits of achieving the lowest R&D expenditure.

According to the literature on consolidation, there are three principal relationships in a consolidated strategy: alliance (upstream/downstream vertical alliance, horizontal alliance and diversified alliance), takeover (merger/acquisition) and partner (light-handed). However, which relation will create the highest profits with the lowest R&D expenditure has become the most interesting issue in recent business research. Hence, this research attempted to discuss the consolidated relationship with the lowest R&D expenditure from a BSC perspective [2][3].

Up to the present, the innovation of a successful product in a global enterprise spreads wealth far beyond the lead enterprise who bears primary responsibility for conceiving, co-ordinating and marketing new products through effective and efficient global consolidation in order to create the most beneficial synergy. The enterprise positioned as the lead and its other beneficiaries including partners in the enterprise's consolidation and firms that offer complementary products or services may also benefit [4][5].

LITERATURE REVIEW

Three analytical theories were applied in this research: alliance theory, fuzzy set theory and balanced-scorecard theory, with Multiple Criteria Decision Making (MCDM), including four analytical approaches: factor analysis (FA), Analytical Network Process (ANP), Fuzzy Analytical Network Process (FANP) and Grey Relation Analysis (GRA). Research lectures are used to evaluate the three types of relationships in consolidations: alliance (upstream/downstream vertical, horizontal and diversified alliances), takeover (merger/acquisition) and partner (light-handed) for selecting the best strategy with the lowest R&D expenditures in a booming hypercompetitive business environment.

RESEARCH METHODOLOGY

Spearman first developed FA, which evaluates correlation coefficients among analytical variables to determine the communality between factors [6]. Further, Sheppard addressed the issue of analytical dimensions of FA consisting of two principal factors: common factor (or latent factor) and the unique factor to validly construct or categorise FA into two typical factors: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) [7]. In addition, Sheppard mentioned the sequence of FA and cluster analysis through differentiating segmentation and dimensionality of assessable variables by factor scores [7]. In 2001, Driva, Pawar and Menon expressed component analysis and common FA, which are two principal structures and analyses to prompt two similarities to problems in FA because of the analytical data format. First, the variable is the same for the two groups, for example: *the same set of measures might be taken on men and women, or on treatment and control groups and then, the question arises whether the two factor structures are the same* [8]. Another is two conditions or sets of variable in the one group, for example: *two test batteries might be given to a single group of subjects, and questions asked about how the two sets of scores differ. Or the same battery might be given under two different conditions* [8].

Additionally, Darlington, Weinberg and Walberg addressed the issue of four research problem examples which can be measured by FA: *how many different factors are needed to explain the pattern of relationships among these variables; what is the nature of those factors; how well do the hypothesised factors explain the observed data;* and *how much purely random or unique variance does each observed variable include* [9].

Factor analysis, which originated from mental philosophical researches of the 1900s, and in statistics, is inductively created to handle complex analysis with complex factors because there are many indirectly observed potentially influencing factors in mental philosophical research. Specifically, these potential factors are supposed to be organised into common influencing factors (oblique factors) or uncommon influencing factors (orthogonal factors). Based on the pattern of linear combinations of these organised common factors; the multilateral analyses is undertaken around the research problems, e.g. the linear Equation (1) is able to represent that *K* numbers of common potential factors are organised from the *L* numbers of general influenced factors (the *M* numbers are more than the *K* numbers). The directly observed influenced factors are presented as $y_1, y_2, \ldots, y_k$, directly unobserved influenced factors are presented as $x_1, x_2, \ldots, x_k$ and the constants are shown as w_{ij} which represented the factor loading in FA and the weights of the influenced factors under a linear combination equation:

$$y_k = w_{k1}x_1 + w_{k2}x_2 + \ldots + w_{kL} + n_k \tag{1}$$

After the FA, the ANP approach is utilised to assess patterns, criteria (factors) and sub-criteria. The initiation of ANP, expressed in a journal paper by Saaty, a Professor at the University of Pittsburgh, is utilised for handling the more complex research questions not solved by the Analytical Hierarchy Process (AHP) [10]. Because the original decision hypothesis principal (variable) of AHP is defined as *independent*, AHP is reconsidered by some scholars and leaders because the relationships between patterns, criteria, sub-criteria and selected candidates are not certainly *independent*. In 1980, Saaty delivered a new research methodology, positive reciprocal matrix and super-matrix to develop this limited hypothesis to carry out more complex hierarchical analysis by collecting experts' opinions through the Delphi method and brainstorming approach under the comprehensive, limited-resource and in a difficult decision making environment [11].

Hence, the initial purpose of AHP is to analyse complex problems with an hierarchical research approach, which integrates the influenced analytical factors refine the patterns, criteria, sub-criteria and candidates and then, to evaluate the influenced weights by calculating the assessable *A* matrix of pair wise comparison to decide on the best decision-making. The initial concept of an *A* matrix of pair wise comparisons is expressed by Equation (2):

$$A = \begin{pmatrix} 1 & . & a_{1j} & . & a_{1n} \\ . & . & . & . & . \\ a_{i1} & . & a_{ij} & . & a_{in} \\ . & . & . & . & . \\ a_{n1} & . & a_{nj} & . & 1 \end{pmatrix}_{n\times n} = \begin{pmatrix} W_1/W_1 & . & W_1/W_j & . & W_1/W_n \\ . & . & . & . & . \\ W_i/W_1 & . & W_i/W_j & . & W_i/W_n \\ . & . & . & . & . \\ W_n/W_1 & . & W_n/W_j & . & W_n/W_n \end{pmatrix}_{n\times n} \tag{2}$$

- The calculated weight of W_j and the pair wise ratio of W_i / W_j are described and determined by the decision-making persons in the *A* matrix of pair wise comparisons.
- Specifically, there are three kinds of characteristics in this *A* matrix: 1) $a_{ij} = W_i / W_j$; 2) $a_{ij} = 1$, for i = j, $a_{ij} \times a_{ji} = 1$.
- Therefore, *W* = 【 $W_1,...,W_j,...,W_n$ 】 is the relative pair wise weights and the calculated consequence of *W* is represented by vector quantities (*AW* = *nW*), which is based on the inductive principle (*AW*= $\lambda_{\max}$).
- Eventually, the priority vector and maximised eigenvalue are measured by examination of the *A.* matrix.

The primarily critical points are the Consistency Ratio (CR) by calculating the Consistent Index (CI) and the Random Index (RI). The acceptable result is for both the evaluated numbers CR and CI that both are necessarily smaller than 0.1. Further, the assumption of the AHP approach is based on the fact that the criteria and sub-criteria are independent of each other but other researchers discovered a situation where, there are two kinds of relationships between criteria and sub-criteria: internal/external dependency and feedback, when dealing with the more complicated research problems. For the above reason, there is another new approach - the Analytical Network Process (ANP) created to deal with more complicated research problems. According to the characteristics of the ANP approach, the AHP method can be utilised to undertake the 12 main steps of assessable research, including setting priority, generating a set of alternatives, choosing a best policy alternative, determining requirements, allocating resources, predicting outcomes - risk assessment, measuring performance, system design, ensuring system stability, optimisation, planning and conflict resolution. Ultimately, more scholars have combined the AHP model into a more analytical approach to develop inductively the Analytical Network Process (ANP).

In 1965, Zadeh first developed fuzzy set theory. This outlined fuzzy sets and membership of fuzzy sets in order to substitute for the crisp sets of traditional mathematics, which can be used for uncertain and fuzzy research problems. In traditional mathematics, there is a two-value (true or false) logic [12]. However, in uncertain and fuzzy research problems, Zadeh induced fuzzy set theory, which is based on the two characteristics of membership degree and membership function, to solve these research problems, and uses the membership function, u_A to represent the fuzzy set in Equation (3) [13]. Further, the fuzzy set is also shown as a fuzzy function by utilising trigonometric function since the characteristics of the fuzzy set are represented by three points, *L*, *M* and *U* ($X = [L, M, U]$), as in Equation (4):

$$u_A : X \longrightarrow [0,1] \text{ and } 0 \le u_A \le 1,\ x \in X \tag{3}$$

$$u(x) = \begin{cases} (x-L)/(M-L), & L \le x \le M \\ (x-U)/(M-U), & M \le x \le U, \\ 0, & \text{otherwise} \end{cases}$$

through defuzzification processes,

$$F_i = \frac{[(U_i - L_i) + (M_i - L_i)]}{n} + L_i \tag{4}$$

Based on the doctrine of Zadeh's fuzzy theory, Deng Julong further expressed the more complete and innovative theory - Grey System Theory (GST). He applied the associated approach, structure measure and model-making method to induce a grey system located between a black system and white system, to integrate the indefinite research data into useful research data. This allows research into managerial control, decision-making and foreseeing [14]. The main goal of GST is to calculate the level of relation between each influenced factor to handle the patterns of uncertain research problems or circumstances. The most creative idea of GST, with traditional measuring statistics, is to use the trend-level among uncertain and incomplete information of each influenced factor, to quantify the level of relation to assess the dependence or independence between each influenced factor. Further, there are four specific advantages to GST: 1) it can be used with uncertain research data; 2) it can be used without a linear relation or statistical distribution among the impacted factors; 3) the measured processes are easier; and 4) FA often can be employed in GST. There are two kinds of grey relations in GST (partial grey and whole grey), which affect the functions of the grey system theory. The assessed grey relation is expressed by the following Equations (5),(6),(7) and (8) [15].

Function for partial grey:

$$\gamma(x_0(k)_r x_j(k)) = \frac{\Delta \min + \delta * \Delta \max}{\Delta_{oj}(k) + \delta * \Delta \max} \tag{5}$$

Function for whole grey:

$$\gamma(x_i(k)_r x_j(k)) = \frac{\Delta \min + \delta * \Delta \max}{\Delta_{ij}(k) + \delta * \Delta \max} \tag{6}$$

where $x_i(k) = (x_i(1), x_i(2), ..., x_i(k)) \in X$, $\Delta ij = x_i(k) - x_j(k)$, $\Delta \min = \min_{\forall j \in i} \min_{\forall k} x_i(k) - x_j(k)$, $\Delta \max = \max_{\forall j \in i} \max_{\forall k} x_i(k) - x_j(k)$

δ (Zeta) expresses the identified coefficient, $\delta \in [0,1]$

$r(x_i(k)_r x_j(k))$ are coefficients, between $x_i(k)$ and $x_j(k)$, $i = 0,...,m$, $j = 1,...,m$, $k = 1,...,n$, $\in X, j \in i$

The grey relation function for equal weights among analytical factors:

$$\gamma(x_i, x_j) = \frac{1}{n}(\sum_{k=1}^{n} \gamma(X_i(k), x_j(K)) \tag{7}$$

The grey relation function for unequal weights among analytical factors:

$$\gamma(x_i, x_j) = \sum_{k=1}^{n} \beta_k \gamma(X_i(k), x_j(K)) \tag{8}$$

Recently, the fuzzy set theory and grey system theory were used to assess performance in managerial and strategic research fields. The literature review of this research concentrated on three theories (alliance, BSC and fuzzy) and four methodological methods by combining these measurements to determine the sub-criteria in order to select the best potential relationship in alliance (upstream/downstream vertical, horizontal and diversified), takeover (merger/acquisition) and partner (light-handed) in the booming business environment. Hence, both crisp sets and fuzzy sets are considered and measured in this research, according to the characteristics of the MCDM approach.

Ultimately, Yeh inductively delivered the innovative similarity measure by applying the extension principle to estimate the fuzzy number of two sharp triangles and the similarity measure (*S*【*A*,*B*】) [16], as expressed in Equation (9):

A= (c_1, a_1, b_1) and *B*= (c_2, a_2, b_2), and then,

$$S【A,B】 = \begin{cases} 1 & \text{, if A=B} \\ \text{Exp}\left(-\frac{d_{LR}^2[A,B]}{\sigma}\right) & \text{, if A} \neq \text{B} \end{cases}$$

$$d_{LR}^2[A,B] = (a_1 - a_2)^2 + \frac{[(c_1 + a_1) - (c_2 + a_2)]^2}{4} + \frac{[(b_1 + a_1) - (b_2 + a_2)]^2}{4}$$

where $\sigma = \frac{(D^* + D_*)}{2} + \frac{[|c_1 - c_2| + |b_1 - b_2|)}{8}$; $D^* = \frac{|(a_1 + b_1) - (a_2 + b_2)|}{2}$; $D_* = \frac{|(a_1 + c_1) - (a_2 + c_2)|}{2}$ (9)

RESEARCH MEASUREMENT MODEL

Linden, Kraemer and Dedrick, addressed the typical measurement statistics process of FA [17] as:

$$\underset{\sim}{X}' = (X_1, X_2, \cdots, X_k) \to (PC_1, PC_2, \cdots PC_k) \equiv (Y_1, Y_2, \cdots, Y_k) = \underset{\sim}{Y}' \tag{10}$$

After FA, the related-impacted factors are categorised as the four groups, which match the four perspectives of BSC and, then, according to the patterns of the ANP approach. These related-impacted factor-groups are decomposed as a third hierarchy of criteria of assessment according to the second hierarchy of the three patterns of a corporation's demand. The related-impacted factors are also decomposed as a fourth hierarchy of sub-criteria for each criterion. The framework of best potential relationship in consolidation with the lowest R&D expenditure in a hypercompetitive environment is described in Figure 1.

Further, in terms of the ANP model, *once the pair wise comparison is conducted and completed, the local priority vector w (eigenvector) is computed as the unique solution* and w is represented by the priority vector *w* (relative weights). Additionally, in 2005, Saaty developed the two-stage algorithm as represented in Equation (11) [18].

$$Rw = \lambda_{\max} w \quad \text{and} \quad w_i = \frac{\sum_{j=1}^{m} \left(\frac{Rij}{\sum_{i=1}^{m} Rij} \right)}{m} \tag{11}$$

In each pair wise comparison, the consistency of compared factors will match transitivity in order to accomplish the representativeness of the experts' opinion. The Consistency Index (CI), which is considered in each pair wise comparison matrix and the Consistency Ratio (CR), which is estimated with CI and the Random Index (RI) obtained from the statistics table of random index figures, are expressed in the following Equation (12):

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \quad \text{and} \quad C.R. = \frac{C.I.}{R.I.} \tag{12}$$

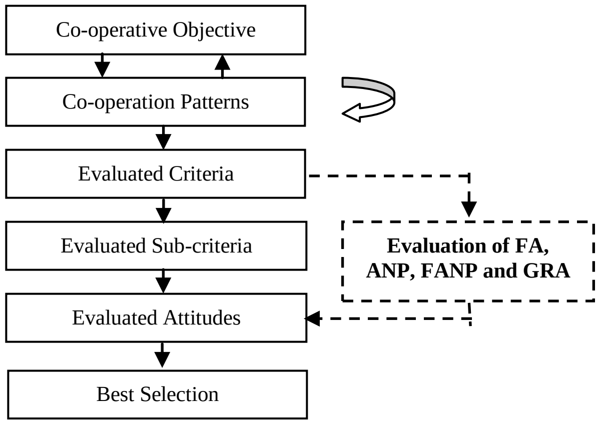

Figure 1: The framework of best relationships in consolidation.

Further, this research also applies the weights of each attitude, criteria, sub-criteria and attitude of second survey questionnaires to calculate the grey relation coefficient in order to select the best based on the Equations (13),(14) and (15) of the grey relation system's approach:

The analytical goal belongs to the efficient goal and satisfies the maximised analytical goal:

$$x_i^* = \frac{x_i^{(0)}(k) - \min x_i^{(0)}(k)}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)} \tag{13}$$

The analytical goal belongs to the cost goal and satisfies the minimised analytical goal:

$$x_i^* = \frac{\min x_i^{(0)}(k) - x_i^{(0)}(k)}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)} \tag{14}$$

The analytical goal belongs to the specific goal:

$$x_i^* = 1 - \frac{\left| x_i^{(0)}(k) - OB \right|}{\max\left\{ \max\left[x_i^{(0)}(k) \right] - OB, OB - \min\left[x_i^{(0)}(k) \right] \right\}} \tag{15}$$

where $x_i^{(0)}(k)$ presents original data ; x_i^* presents data after grey relation systems analysis; $\min x_i^{(0)}(k)$ presents the minimum of the original data; $\max x_i^{(0)}(k)$ presents the maximum of original data.

In the hierarchical relations in the last level, each potential supplier has to fit or match each assessable sub-criterion matched in each evaluated criterion through pair wise-comparison criteria of each of the following sub-criteria. Hence, each expert will assign weights ($W_1, W_2, ..., W_n$) for each pattern, criteria and sub-criteria and, based on the concept of the de-fuzzification of two-triangles, the total fuzzy assessable numbers are calculated by Equation (16) as:

$$\text{the total fuzzy assessable numbers} = \sqrt[n]{\prod_{i=1}^{n} W_i} \tag{16}$$

In order to reflect the comparative score for three kinds of patterns of the corporation's demand, Equation (16) is applied to compute the comprehensively comparative related priority weight *w* (eigenvector) in the matrix. Consequently, the appropriate consolidation relations are selected by calculating the Comparatively Synergised Index (CSI), which combines the *weighted product* [19] and the *numbers of similarity measure* (S【A,B】).

SPECIFICATION OF ANALYTICAL DATA AND ASSESSABLE CRITERIA

In terms of the representativeness of the model using four analytical approaches through establishing fuzzy transitivity, the principle of comparing weights, evaluating criteria, and estimating the positive reciprocal matrix and super-matrix, the research data source must collectively and statistically consist of all the impacted experts' opinion related to each assessable criterion. According to the assessable characteristics of the ANP model, the pair wise comparison of the evaluation characteristics, criteria and attribution at each level are evaluated with respect to the related interdependence and importance from equal important of 1 to extremely important of 5, as expressed in Figure 2.

In terms of reliability, the Cronbach α of the surveying questionnaires was 0.832, which means the reliability of questionnaires can represent the population of users after the measurement of FA by collecting 82 completed questionnaires out of a total of 100 questionnaires sent to managers of publicly-traded companies listed on the Taiwan stock exchange. These companies have a minimum of five years' working experience. The 19 assessable sub-criteria (KPI) can be categorised further into four criteria (four perspectives of BSC), expressed in Figure 3.

Patterns of enterprise demand 1	1	2	3	4	5	Patterns of enterprise demand 2
	Equal---------------------Extremely Important					

Criteria of assessment 1	1	2	3	4	5	Criteria of assessment 2
	Equal---------------------Extremely Important					

Sub-criterion of each criterion 1	1	2	3	4	5	Sub-criterion of each criterion 2
	Equal---------------------Extremely Important					

Selected candidate of consolidation relation 1	1	2	3	4	5	Selected Candidate of consolidation relation 2
	Equal---------------------Extremely Important					

Figure 2: The evaluation scale of pair wise assessment.

Further, employing the effective model to measure the performance of consolidated strategy, in 1996, Saaty addressed the major differences s between AHP and ANP [20]; based on the original assumption, AHP is not able to directly evaluate each assessable criterion by hierarchical relations but, on the contrary, ANP can be utilised to dispose of direct interdependence relationships and inter-influence between each criteria at the same or different level through constructing the *super-matrix*.

Based on the principle of consistency ratio, the pair wise comparison matrix can be accepted when the CR is equal or smaller than 0.01. Further, the data sources in this research were derived from scholars and experts, who understand the four perspectives of BSC regarding R&D expenditure, and are in Taiwan or Mainland China. Additionally, according to Bidault and Cummings, the three basic performance measurements of R&D expenditure considering R&D management, are cost-down policy, Strategic Advanced Technological Demand (SATD) and business development [21].

Further, based on the collected data of experts' opinion, this research was organised based on the BSC theory and includes four criteria: learning and growth, the internal business process aspect, the customer aspect and the financial aspect. There are also 19 homologous sub-criteria presented as KPIs of the performance assessment of BSC. Figure 3 hierarchically expresses the relations among pattern, criteria, and sub-criteria. These criteria were then used in this research to identify and analyse the consistency of three kinds of consolidation strategies: alliance (upstream/downstream vertical, horizontal and diversified), takeover (merger/acquisition) and partner (light-handed).

1. *Learning and Growth Aspect:* The employment performance evaluation of production is in accordance to the concepts and the experts' discussion regarding diminishing R&D expenditure. The four sub-criteria (KPI) were considered in the criterion of the learning and growth aspect: employee's performance rate (EPR), employee's growth rate (EGR), employee's satisfaction rate (ESR) and employee's quit rate (EQR).
2. *Internal Business Process Aspect:* In terms of ensuring the improvement of the enterprise's internal process performance after consolidation, the four assessable sub-criteria (KPI), based on the experts' opinion, are considered in the criterion of qualitative and quantitative review: identified demand R&D research rate (IDRR), supplier's performance rate (SUPR), manufacture cycle effectiveness (MCE) and yield rate (YR).
3. *Customer Aspect:* In order to realise the effect of the consolidated strategy for the customer's impression, the five sub-criteria (KPI) according to the three enterprises' demands after the experts' discussion, are: market-showing rate (MSR), customer's satisfaction rate (CSR), customer's profit rate (CPR), customer's reclusion rate (CRR) and customer's maintenance rate (CMR).
4. *Financial Aspect:* In terms of evaluating financial performance after consolidation, the experts surveyed in this research considered the most important six main evaluated sub-criteria (KPI) to be: cash turnover rate (CTR), R&D return rate (R&DRR), net income rate (NIR), return on asset (ROA), earning per share (EPS) and P/E rate (PER).

In hierarchical relations in the last level, each potential consolidation partner has to fit or match each assessable sub-criterion matched in each evaluated criterion through the pair wise compared performance of each relation in consolidation. To reflect the comparative score of three kinds of relations in consolidation, Equation (21) is applied to compute the comprehensively comparative related priority weight *w* (eigenvector) in the matrix. Consequently, the appropriate consolidation relation was selected by calculating the CSI (D_i) [22], defined by:

$$D_i = \sum_{j=1}^{s} \sum_{k=1}^{kj} P_j T_{kj} R_{ikj} \tag{21}$$

Where the importance of the related priority D_i is the weight w (eigenvector) for assessable criterion j; T_{kj} is the importance of the related priority weight w (eigenvector) for the assessable attribute k of criterion j and R_{ikj} is the important potential consolidation of relation i on the attribute k of criterion j.

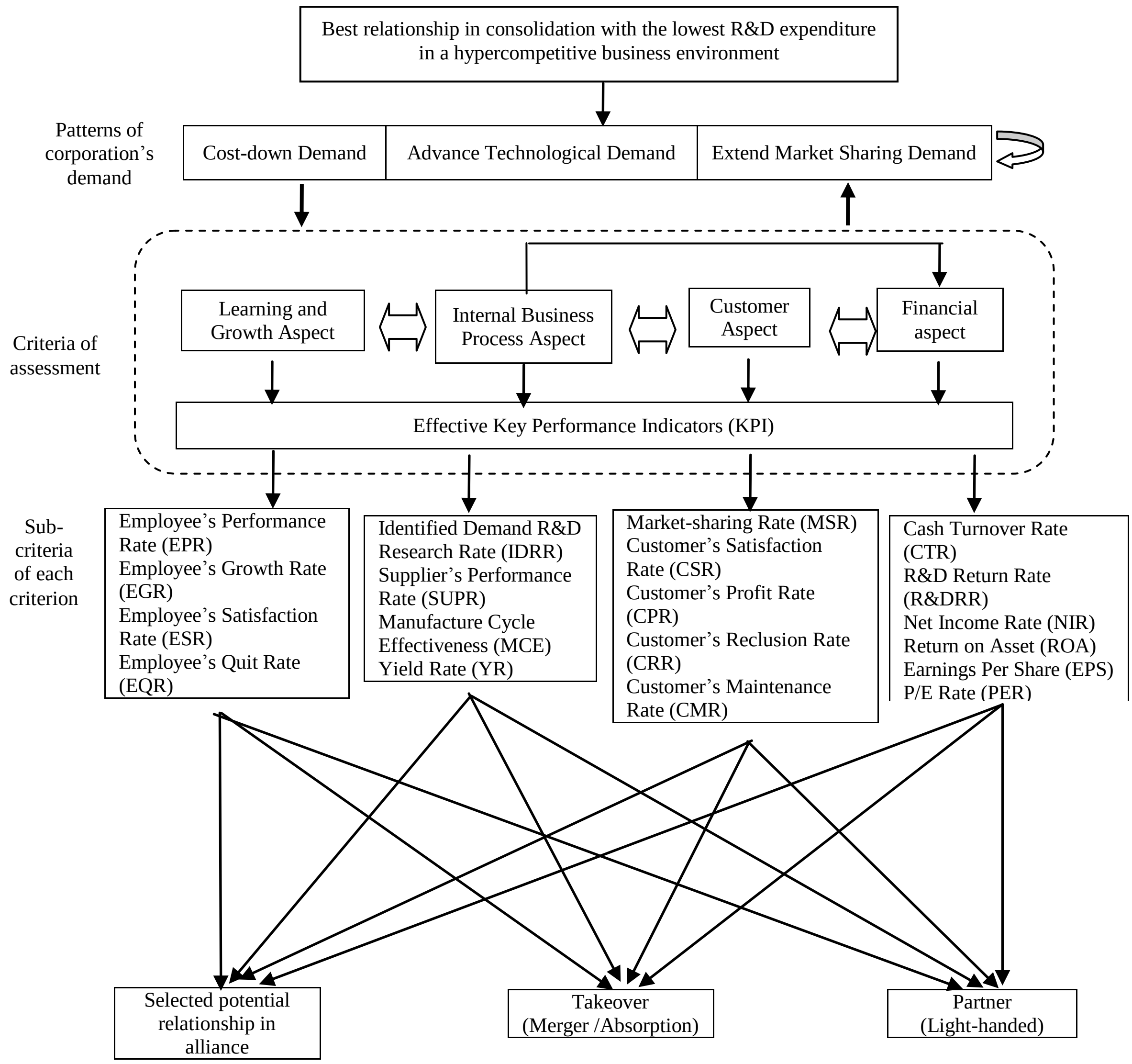

Figure 3: The relationship for characteristic, criteria, sub-criteria and selected candidates.

For handling the measurement of ANP, based on Equation (21), and after some processing manipulation, the ultimate evaluated step was to combine the outcome of the complete importance of related priority weights w. Consequently, Table 1 reflects the three relations in the CSI. The highest evaluated score of 0.6853 was the relation of Takeover (merger/absorption). Through the ANP approach this means the largest consolidation performance under the lowest R&D expenditure are amalgamating enterprises that keep an independent attitudes toward takeovers to produce a merged enterprise (Table 1).

However, is the annihilative takeover a better strategy for consolidation? Yes, based on the results of ANP. But the different evaluated consequence of FANP is *partner* after further estimating survey data using fuzzy theory. The main reason is that the experts pay more attention to the financial aspect than the pair wise comparison of the traditional ANP approach.

Hence, to penetrate linguistic amphiboly and to promote a degree of satisfiability, fuzzy theory is utilised to survey the ulterior meaning of the results of questionnaires. Table 1 presents the vectors of the CSI and the similarity measure of the three relations in consolidation, based on Equation (9) of the similarity measure (S【A,B】) of the defuzzification processes and the overall outcome of the complete importance of the related priority weight $\boldsymbol{w}$ (eigenvector). As a result of the defuzzification assessment of processes, the highest vector of the CSI was (1.2056, 1.4615, 1.72) in the *partner relation* and the highest similarity measure was (1.1655) in the *partner* relation, as well (Table 1).

As an opposite view, the majority opinion of most experts was that the *partner relation* was the most important consolidation relationship for the lowest R&D expenditure from BSC. This is definitely different from the results using

ANP, which pointed to the *takeover relation*. Hence, through the addition of fuzzification, the evaluated score is more closely related to the comments of experts.

Further, to consider the linguistic experts' comments to amend the evaluated scores, this research not only utilised the five-level quantified evaluation scale between the languages of interviewees in the pair wise assessment in Table 1, but also estimated the grey relation (GRA) by applying Equation (15). Equation (15) is utilised to satisfy two analytical research situations: the analytical goal belongs to the efficient goal and satisfies the maximised analytical goal, and the analytical goal belongs to the cost goal and satisfies the minimised analytical goal.

Furthermore, to calculate the total score of these three kinds of relations in consolidation, the organised grey relation coefficient results from the calculation after transformation of the qualitative data of the survey interviewees' opinions of the quantitative data. Finally, with the identification of research goals, the identified coefficient (δ) was 0.5.

The grey relation is the equal weights among the analytical influence and, therefore, Equation (15) was utilised for five usages: first usage time to calculate the weights of the grey relation coefficients between three assessable patterns; second usage time for computing the weights of the grey relation coefficients between four assessable criteria; third usage time to count the weights of the grey relation coefficients between 19 sub-criteria matched in four criteria groups; fourth usage time for calculating the weights of the grey relation coefficients for the current alliance theory and BSC theory; in the fifth usage time, to avoid errors, the aggregate of the weights of the grey relation coefficients is used to produce the sorted score of the CSI for three relations for consolidation. Table 1 presents the calculations and results. The CSI of the *partner relation* is 3.5324, which is the highest score of the three kinds of relations under the lowest R&D expenditure to satisfy the demands (cost-down, advance technologies and market sharing) of enterprises.

As a result of this research, a crucial consequence is that the *partner relation* was the best relation under the lowest R&D expenditure requirement. This research used FANP and GRA, which is different from the results of the original ANP as expressed in Table 1. This is because most academic and empirical experts have concentrated on the financial aspect in singular pair wise comparison of patterns, criteria and sub-criteria.

Table 1: The comparative results of consolidation demand indexes for three approaches using BSC with the lowest R&D expenditure criterion.

		Alliance (upstream/downstream vertical, horizontal and diversified)	Takeover (merger/absorption)	Partner (non-changed condition)
		Evaluated Score	Evaluated Score	Evaluated Score
ANP	Comparatively synergised index	0.6461	0.6853	0.6782
FANP	Vectors of comparatively synergised index	(1.1343,1.3182,1.5292)	(1.1169,1.3236,1.5794)	(1.2056,1.4615,1.722)
	Numbers of similarity measure	0.8139	0.8443	1.1655
GRA	Comparatively synergised index	3.4767	3.2097	3.5324

CONCLUSIONS AND RECOMMENDATIONS

In a hypercompetitive and baptism-by-fire business environment, enterprises have devoted resources to minimise their R&D expenditures to strengthen their competitive advantages to survive. This has motivated global enterprises to undertake their fundamental R&D activities through consolidation with competing companies (local and foreign). This research, therefore, not only focuses on the original central concept of three types of theory (alliance, fuzzy and BSC) but also concentrates on the long-term enterprises' selection of the best potential relation formation from BSC's four perspectives and the novel MCDM approach.

The MCDM approach was used not only to establish hierarchical relations between each assessable criterion but also to assist the decision-maker to select the best potential consolidation to achieve advance reduce costs and technology improvement for the lowest R&D expenditure. The research used academic users (FA) and experts' surveys (Delphi method of MCDM). It was found that there were four main assessable criteria, which cover key points to evaluate the best innovative competitive relation after consolidation.

However, to ameliorate linguistic amphiboly and to improve the degree of satisfaction, this research not only emphasises the unitary financial aspect and pure assessment. It also values the three aspects (learning and growth, internal business process and customer) and used the defuzzificated evaluation by applying the BSC and fuzzy theories.

Empirically, the trend of consolidation, especially in fast-growing enterprises, is oriented towards amalgamation that only offers capital (money) in place of the more traditional merging or absorbing of enterprises to create more comprehensive synergies from three innovative contentions:

1. *Retaining an independent organisation*: the implicit costs created from dealing with various conflict-issues (such as culture conflict, time conflict, etc) are greater than the reduced costs of the integrated organisations;
2. *Holding separate sales channels*: managerial links are constructed by interim overseas teams in merged companies to achieve higher sale-synergy;
3. *Retaining autonomous operation*: critical management resulting from assigning a few higher level managers as communication channels, in place of complete control, to reduce conflicts and strategic mistakes due to misunderstanding of core conflicts of the merged companies.

The next step, beyond this research, is to determine additional influences on R&D expenditure. This should determine factors that impact on the consolidated strategy using vertical and horizontal assessment. Thus, enterprises would be able to obtain valuable consolidation strategies for the lowest R&D to survive in this complex, higher-competitive and lower-profit era.

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