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A Fuzzy Logic Based Decision Support System for Business Situation Assessment and e-Business Models Selection

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ABSTRACT

A new decision support system is developed for assisting business executives in deciding the e-business models to adopt for new business ventures. The developed system is based on a new framework using fuzzy logic theory. A detailed conceptual design is developed. The proposed system solves important challenges such as the use of linguistic terms to capture the executives' assessments of the key business measures. It uses fuzzy assessment rule to find the overall grade for each business dimension. Moreover, its rule-base allows adding large number of new e-business models. A prototype is tested with business executives and received positive feedback.

Keywords*:* E-business models, decision support, fuzzy systems.

INTRODUCTION

Many organizations rushed and invested heavily in e-commerce and e-business to leverage the widespread use of the internet technology. The term e-commerce focuses mainly on conducting transactions over the internet. However, e-business has a greater focus which covers e-commerce aspects as well as many other important business activities such as creating new product and services (Weil & Vitale, 2001). The dot-com bubble (1995-2000) of internet based companies and its spectacular failure demonstrated the vulnerability of e-businesses. It even demonstrated that successful companies would need to have traditional business and e-business models operating together (Porter, 2001), which means one possible successful scenario is that of a business executive of a successful traditional business, starts, and integrates a new e-business with the current organization. In this regard, many challenging questions face the executive, for example should the company invest in e-business or traditional business? If e-business is considered, which e-business model to use? Which is the integration model to use? And what are the key performance indicators (KPIs) to consider? These challenges are overwhelming and cannot be answered in a single study. The focus of this research is to help answer the second question that is *which e-business model to consider*. This is a difficult challenge as many business models exist with different categorization and classification schemes, which confuse many business executives. The aim is to help the executives by developing a decision support system (DSS) for assessment and selection of appropriate business models. This DSS system has the potential to assist entrepreneurs and decision makers in the development and application of new e-businesses. The following sections present the research method; the proposed fuzzy logic framework, the decision support system conceptual design, detailed design of key system parts; prototype development and results; and discussion of the results, conclusions and future work.

THE METHOD

This study uses framework, conceptual design and empirical work. The research starts by identifying the research statement and focus, and then uses study of the literature to identify the most appropriate e-business models framework to use. It develops this framework further using fuzzy logic theory and develops a new conceptual design for the sought decision support system. A block diagram presents the system structure. Finally the research concludes by developing a prototype and using empirical work based on interviews and questionnaires to assess the validity and usability of the developed system. Hence, the research is two main phases. The first phase is qualitative to develop the structure of the new system, and the second is empirical, in which a prototype is developed and tested.

E-business Models Frameworks in the Literature

Weill and Vitale (2001) define an e-business model as "a description of the roles and relationships among a firm's consumers, customers, agents, allies, and suppliers that identifies the major flows of product, information, and money, and the major benefits to participants," as shown in Figure 1.

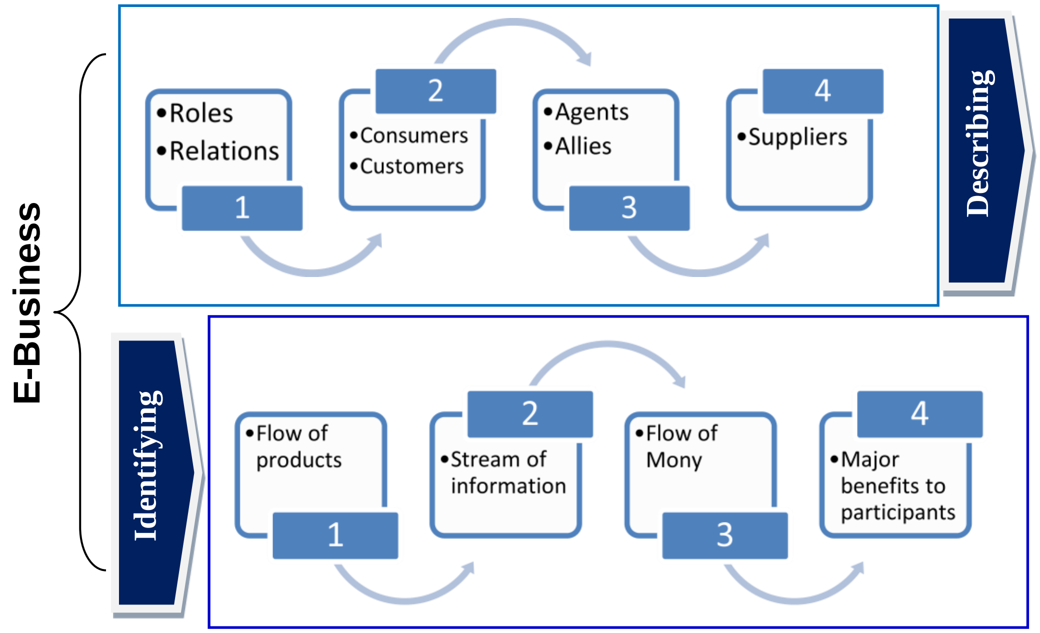

Figure 1: e-Business Model According to Weill and Vitale (2001)

However, numerous specific classifications for e-business models exist in the academic literature, but; there is no general unifying classification scheme. For example, Weill and Vitale (2001) identify 8 atomic e-business models that firms can use as building blocks to create tailored e-business models and initiatives, using their competencies as their guide. Another work by Tapscott, Lowy, and Ticoll (1998) proposes four types of e-business models. Rappa (2003) proposes 36 different e-business models made into eight categories. Timmers (1999) proposed 11 different e-business models and argues that a large number of models can be conceived through deconstruction and construction of the organization value chain. Osterwalder and Pigneur (2002) propose e-business ontology with four aspects of the business organization. These aspects are product innovation, infrastructure management, customer relationship, and financials. Figure 2 gives an overall comparative summary of these e-business models classification schemes. In essence, many e-business models exist in the literature with many classification schemes and different business aspects or dimensions. Even, some classifications present the same e-business model but with different names. Pateli and Giaglis (2004) suggest an analytic framework following a broad review of the research literature. This framework decomposes the area of business models into eight research sub-domains. The proposed framework is used to classify and review existing research under each sub-domain as well as to delineate an outline of future challenges on business model research. The framework can benefit researchers to focus their efforts in an overall context, and build a sound body of knowledge in the area of business models. Lambert (2006) identifies the business model classification schemes present in the e-commerce literature with their classification criteria. The usefulness of these classifications is investigated with a distinction made between specific and general classifications and between typologies and taxonomies.

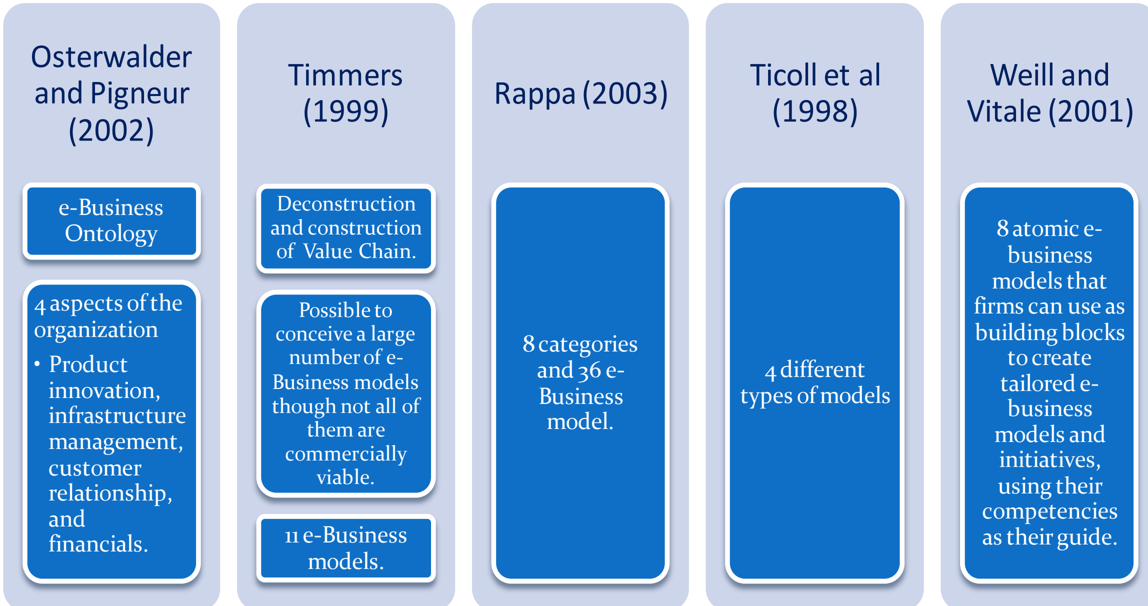

Figure 2: Different Classifications for e-Business Models

It can be seen that there is no general agreement on how e-business models can be classified and assessed. This compounds the challenge for business executives and confuses them about which e-business model to consider. Hayes and Finnegan (2005) realizing the severity and importance of such a challenge, propose five aspects or dimensions of the organization to assess and select e-business models. These aspects are, Economic Control, Functional Integration, Supply Chain Integration, Innovation, and Input Sourcing. Every aspect involves a large number of sub-aspects or measures which when assessed help in assessing the corresponding general aspect. Figure 3 below presents a pictorial view of this framework.

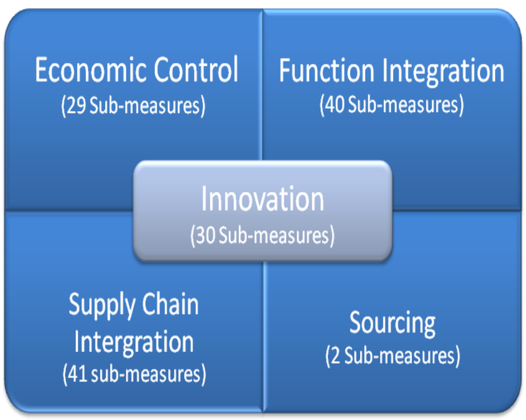

Figure 3: Pictorial Representation of the Framework Proposed by Hayes and Finnegan (2005)

It is worth noting that their framework uses the most comprehensive set business dimensions to assess the e-business models. This is a major advantage over the other literature frameworks. Moreover, the drive for their framework development is mainly to provide high level assessment which can assist executives during the intelligence phase of the decision making process rather than analysis or design of e-business models. Furthermore, the sub-aspects (sub-measures) for each general aspect are assessed using questionnaires with a 5-point Likert scale. The total general aspect score compared with the maximum possible score can be used to classify it as low, medium, or High. This is accomplished by splitting the 0-100% range into three equal and exclusive ranges. Hayes and Finnegan (2005) further studied a number of e-business models in order to present a high-level assessment based on their proposed five organization aspects. The list they propose is presented in Table 1. It is worth noting that it is a partial list and more research is needed to assess other models and add them to the list.

	E-Business Model	Nominal Characteristics				
		Economic Control	Functional Integration	Supply Chain Integration	Innovation	Sourcing
1.	E-Shop	Low	Low	Low	Low	Sys.
2.	E-Mall	Low	Medium	Low	Medium	Sys.
3.	E-Procurement	Medium	Medium	Medium	Medium	Sys.
4.	E-Auction	Low	Medium	Medium	Medium	Spot/Sys.
5.	Information Brokerage	Low	Low	Low	High	N/A
6.	Trust Services	Low	Low	Low	Medium	N/A
7.	Third Party Marketplace	High	High	High	High	Spot/Sys.
8.	E-Hubs	High	High	High	High	Spot/Sys.
9.	Virtual Communities	Medium	Medium	High	High	N/A
10.	Value-chain Integrators	High	High	High	High	N/A
11.	Value-chain Service Providers	Low	Medium	Medium	High	N/A
12.	Collaboration Platforms	Low	High	High	High	N/A

Table 1: Partial List of e-Business Models and Their Assessments (Hayes & Finnegan, 2005)

The main idea of that framework is to interview business executives, solicit their answers to all the sub-measure questions in the questionnaires, and find a collective assessment of the five dimensions. The last stage is to use these assessments to find out which e-business models do not match and exclude them from the search for a candidate model. It is difficult to recommend an e-business model to consider as the list of models assessed is not comprehensive and at the same time business executives can devise a novel e-business model which has never seen before. However, it is possible to save time and resources by excluding the models, which are identified to be not suitable through the decision framework and gain the advantage of narrowing the search. The following section presents our modifications to use fuzzy logic theory to develop new decision framework.

The Proposed Framework

We propose a decision support framework based on Hayes and Finnegan (2005) and the results of Fuzzy Logic Theory and systems (Zadeh, 1965, 1983). Fuzzy logic joins language and human intelligence together by using the mathematics of fuzzy membership functions and provides a formal framework to represent and reason with vague, uncertain, and linguistic terms (Barnes & Hammell, 2009). The framework presented by Hayes and Finnegan (2005) uses questionnaires assessed numerically on a 5-point Likert scale to evaluate each sub-measure. Although Likert-type scale questionnaires are popular in social sciences, they do not provide adequate flexibility and tolerance of ambiguity in the analysis of data (Mogharreban & Dilalla, 2006). Moreover, this approach is not at all times well-suited for the human imprecise evaluation and judgment process. Humans tend to use inexact, subjective evaluations and judgments, such as High, Less than High, or Very High. These examples would be inaccurately represented if humans were asked to choose between 4 or 5 points on the Likert scale. Although these linguistic terms are commonly used every day by humans, they are vague and inexact linguistic assessments. Fuzzy Logic theory provides an approach to deal with imperfect and vague information by allowing the assessment data to be fuzzy or linguistic. Therefore, by using fuzzy logic as a key approach in designing and developing the proposed decision support system, a better model of human assessment process and judgment is incorporated. Furthermore, Fuzzy logic can be conceptualized as a generalization of precision-based classical logic (Zadeh, 1965, 1983). Therefore, a framework based on fuzzy logic ideas and concepts can be conceived as the most general framework compared with the traditional ones. What's more, Fuzzy Logic has been successfully applied in many social and scientific fields such as education (Lalla & Facchinetti, 1999), accounting (Comunale & Sexton, 2005), engineering (Pundaleek, Rathi, & Kumar, 2010) and medicine (LaBrunda & LaBrunda, 2008). Figure 4 below presents our proposed framework to utilize fuzzy logic in assessing business situations and identifying proper e-business models for new business ventures.

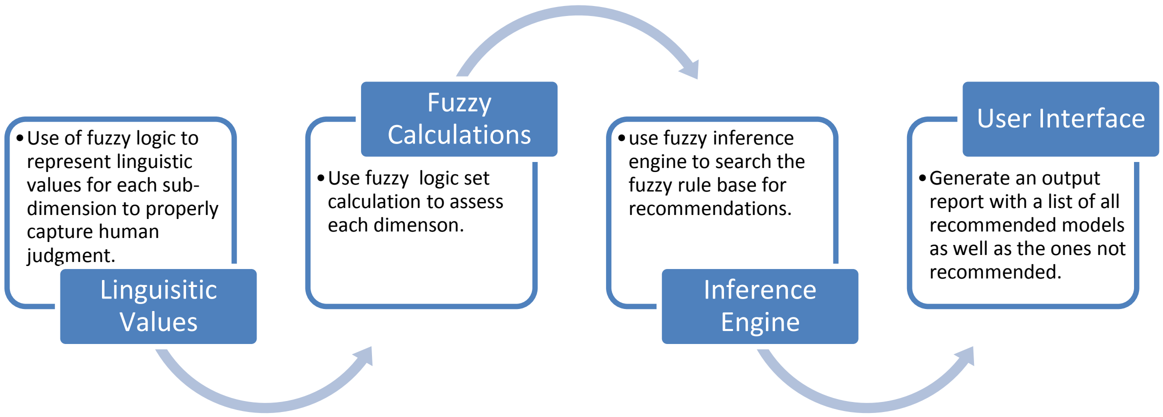

Figure 4: Proposed Fuzzy Logic Decision Support Framework

The proposed framework has the following key phases:

1. **Linguistic Values;** in which business executives are allowed to express their impressions and judgments about the level of any business aspect or sub-dimension using their normal daily life expressions and terms such as very high, high, less than medium .. etc. Fuzzy logic is used to capture these values and properly map them to fuzzy sets membership values. This would allow fuzzy assessment of each sub-dimension.
2. **Fuzzy Calculations;** the power of fuzzy set theory is utilized here to perform all necessary internal calculations to reach an overall fuzzy assessment of the business dimension which has many sub-dimensions already assessed using fuzzy terms.
3. **Inference Engine;** an inference engine and rule base can be designed and built following fuzzy logic theory principles. The fuzzy rule base will help to properly record all possible business models and their nominal characteristics assessed using linguistic fuzzy terms. On the other hand the inference engine is responsible for searching the rule base to identify all possible matches to the calculated fuzzy assessment of the business situation and retrieve these matches.
4. **User Interface;** this part is responsible for the proper communication with the user by generating a proper report in the format needed by the business executives to sum up the results and assist in the decision making process.

The following section presents detailed conceptual design of the new fuzzy logic based decision support system and the development of a prototype for validation and testing.

The Developed Fuzzy System

This section presents the key steps to develop a new fuzzy logic based decision support system for assessment of business situations and selection of e-business models. We start by examining the traditional basic fuzzy logic systems structure. Then, key parts are modified and designed in detail. At the end all parts are assembled to present a complete conceptual design of the new fuzzy logic based decision support system. In addition, details and results of a prototype development and testing are presented. Testing with colleagues and business managers received positive and encouraging feedback. The prototype development and testing have the salient advantage of not only operationalize the proposed fuzzy logic decision support framework but also make it more practical and accurate in capturing human assessment using words.

The Basic Structure of a Fuzzy System. Figure 5 shows the basic structure of a fuzzy expert system. It has four key modules namely, fuzzification module, fuzzy inference engine, fuzzy rule-base and defuzzification module.

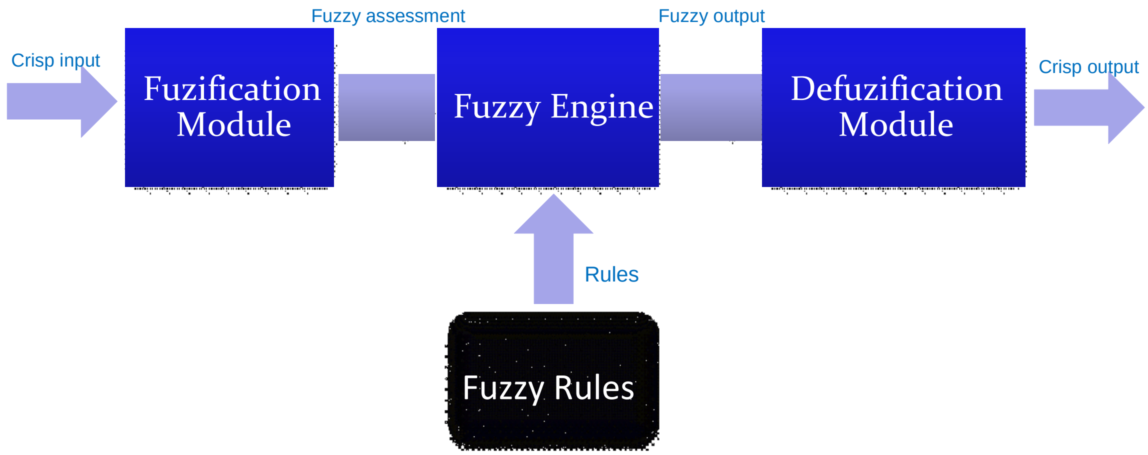

Figure 5: Basic Architecture of a Fuzzy Expert System (Abraham, 2005)

The fuzzification module is traditionally responsible for receiving crisp numeric measurements from the environment as input, process them and map them into fuzzy membership function values. The fuzzy engine is responsible for processing all calculated membership function values using fuzzy sets' calculations and communicates with fuzzy rule base to identify the most suitable fuzzy output. However, the defuzzification module is responsible for converting the fuzzy output into a numeric output suitable for the environment decision and control situation. In the following subsections, we modify and adapt these modules one by one to suit the situation of business assessment and selection of e-business models. These modification and development are in line with the proposed fuzzy logic decision support framework presented in the preceding section.

The Fuzzification Module. Fuzzy sets are defined as; (Zadeh, 1965; Negnevitsky, 2002; Zhou & Huang, 2009)

- Let X be a classical set of objects, called the universe, the elements in X are denoted as x: $X = \{x\}$.
- A fuzzy set, A, in X, is characterized by a membership function $\mu_A(x)$ that associates each element in X with a real number in the unit interval [0, 1].
- The fuzzy set can be denoted by the set of pairs, $A = \{(x, \mu_A(x)), x \varepsilon X, \mu_A(x) \varepsilon [0, 1]\}$.
- $\mu_A(x) = 0$, implies that x does not belong to A.
- $\mu_A(x) = 1$, implies that x absolutely belong to A.
- When X is a definite set, $\{x_1, x_2, \ldots, x_n\}$, the fuzzy set A can be represented as $(\mu_A(x_1), \mu_A(x_2), \ldots, \mu_A(x_n))$.

Fuzzy sets and membership functions can be represented in many mathematical forms. Many forms are proposed in Negnevitsky (2002). However, most of these forms are suitable for decision and control situations in engineering especially in the fields of computer control of machines and robots. In these situations, very sensitive sensors are used to measure different state variables of the machine in a digital or numeric fashion. However, in assessing business situations, it is people who provide assessment of the situation using natural and linguistic terms. Forcing people to present their assessments as numbers would be unnatural and creates serious issues in mapping their human mind linguistic perception into numbers for calculations. Hence, it would be logical to modify such a fuzzification module to accept human language as inputs and let the module do the mapping for any proper internal form needed by the decision support system. Hence, for the purpose of this research we will follow a similar representation approach to that used in (Zhou & Huang, 2009), and (Kamoun & Halaweh, 2010).

Let $G = \{g_1, g_2 \ldots g_d\}$ represents the set of assessment grades of an aspect of the e-Business model or the organization situation which are in fact a group of fuzzy sets; namely, G = {***Very High, High, Medium, Low, Very Low***}, and let the sub-measures of that aspect given as; $M = \{m_1, m_2, \ldots m_n\}$. The sub-measures are mapped (fuzzified) into the different grades using the matrix shown below in Figure 6, where $\mu_{ij} \in [0, 1]$ and represents the fuzzy membership value of sub-measure m_i into the fuzzy set (grade) g_j.

g_1 g_2 … g_d

m_1	μ_{11}	μ_{12}	….	μ_{1d}
m_2	μ_{21}	μ_{22}	….	μ_{2d}
…	…	….	….	….
m_n	μ_{n1}	μ_{n2}	….	μ_{nd}

Figure 6: Fuzzy Matrix According to Zhou and Huang (2009)

m_i can be a numeric assessment of its corresponding sub-measure (same order i).

As it is unnatural for humans to translate their subjective evaluation of each sub-measure into a numeric value, and to accurately capture the human evaluation and judgment, each sub-measure m_i is assumed to take a linguistic value from the set of values ***{Very Low, Better Than Very Low, Low, Better Than Low, Medium, Better Than Medium, High, Better Than High, Less Than Very High, Very High}.*** This linguistic scale represents 10 different linguistic levels. Hence, it helps greatly to model the human thinking and assessment process. However, the linguistic scale would still need to be translated into numeric values for all μ_{ij}'s. It is impractical if not impossible for humans to translate their subjective evaluation of each sub-measure into numeric values for each membership function representing a grade. To properly resolve this task we propose the use of the look-up table shown below which is a modification of the values used in Zhou and Huang (2009) by accounting for all linguistic values used and the addition of the linguistic value ***"Not Applicable".***

Sub-measure range of values	Grades (Fuzzy Sets): Very High	High	Medium	Low	Very Low	Not Applicable
Very High	1.0	0.0	0.0	0.0	0.0	0
Less Than Very High	0.7	0.3	0.0	0.0	0.0	0
Better Than High	0.2	0.8	0.0	0.0	0.0	0
High	0.1	1.0	0.0	0.0	0.0	0
Better Than Medium	0.0	0.2	0.8	0.0	0.0	0
Medium	0.0	0.0	1.0	0.0	0.0	0
Better Than Low	0.0	0.0	0.2	0.8	0.0	0
Low	0.0	0.0	0.0	1.0	0.0	0
Better Than Very Low	0.0	0.0	0.0	0.2	0.8	0
Very Low	0.0	0.0	0.0	0.0	1.0	0
Not Applicable	0.0	0.0	0.0	0.0	0.0	1

Table 2: Step-wise Fuzzy Membership Functions Look-up Table

Each row in Table 2 can be regarded as a judgment term, which is very much different from a 5-point Likert scale and gives directly all membership degrees between 0 and 1 to all grades of any sub aspect of e-business model or organization business situation.

The fuzzy membership functions listed in the table proved to be a good approximation through literature research (Zhou & Huang, 2009; Kamoun & Halaweh, 2010).

One way to appreciate the step-wise fuzzy membership functions Look-up table effectiveness and validity is to construct a pictorial representation of functions as shown in Figure 7. This representation shows the expected overlapping ranges nature and the proper weigh emphasis of the corresponding fuzzy sets (Grades).

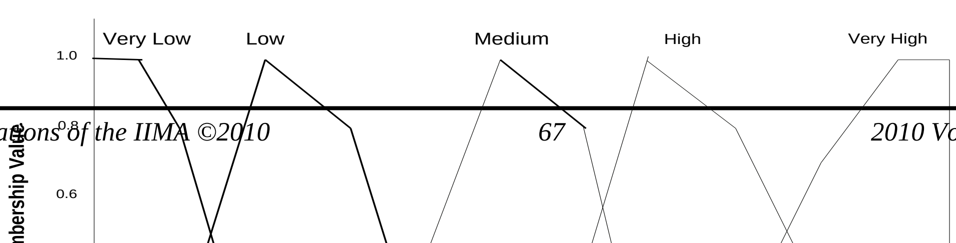

Figure 7: Pictorial Representation of the Step-wise Fuzzy Membership Functions

The fuzzification process aims at finding the overall grade of each main aspect such Economic Control or Supply Chain Integration. The fuzzification process would calculate the grade by first capturing all entered linguistic values for all sub-measures. For each sub-measure linguistic value, it would look up the corresponding fuzzy membership values from the look-up Table 2. All values looked up for all measures would create a virtual matrix similar to the one presented in Figure 6. The next step would be to average these values column by column; then, find the highest value column. Each column corresponds to specific fuzzy set (Grade), for example “High”. Hence, that Grade will be selected as the overall assessment of the business aspect. For example, if in assessing Economic Control the columns averages are found to be (0.0345, 0.0862, 0.1517, 0.3241, 0.4069), we can deduce that the overall assessment grade is “Very Low”, as it corresponds to the highest column average value.

The Modified Structure of a Fuzzy System. Considering the above proposed approach for fuzzification which is suitable for assessment of business situations, we can construct a new modified structure of fuzzy system as shown in Figure 8. As shown, the fuzzification module and the corresponding fuzzy system accepts linguistic value input, looks up fuzzy membership values, averages values across all sub-measures, finds highest value, generates general assessment for all business aspects such as Economic Control, then searches the rule base and generates a report listing e-business models with the proper recommendations. In addition, as we are interested in linguistic outputs, namely the names of e-business models and their recommendations, we see no need for the common fuzzy logic system defuzzification module.

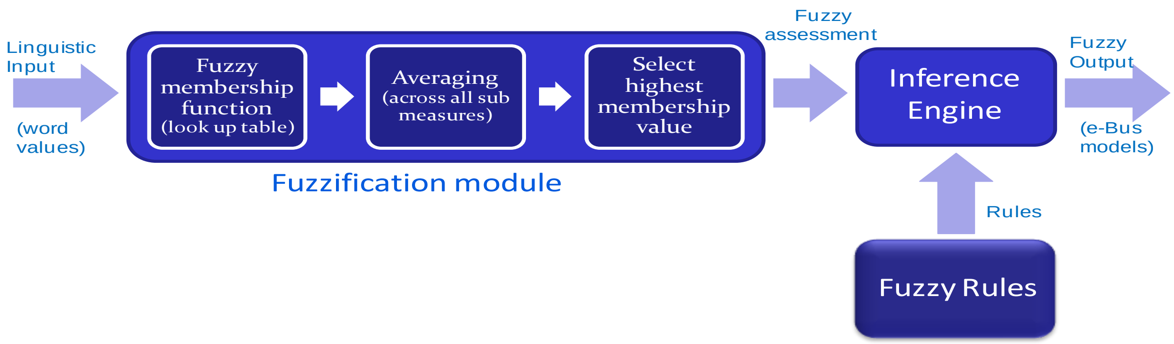

Figure 8: Modified Structure of a Fuzzy System

The Fuzzy Inference and Fuzzy Rule Base. According to Mamdani and Assilian (1975), fuzzy inference and fuzzy rule base uses a fuzzy expert rules structured as;

IF *Antecedent* THEN *Consequent*; (1)

Or more explicitly as;

IF *X is A* **AND** *Y is B* **THEN** *Z = C*; (2)

Therefore, the knowledge about the assessment of e-business models presented by e-business researchers such as Hayes and Finnegan (2005) can be conveniently re-written as fuzzy expert rules. For example, we can write the rule to select E-Auction model as;

IF *Economic Control is Low* **AND** *Functional Integration is Medium* **AND** *Supply Chain Integration is Medium* **AND** *Innovation is Medium* **AND** *Sourcing is Medium*

THEN *e-Bus = E-Auction*; (3)

Writing all assessment of e-business models in the form similar to (3) above, would represent the foundation for the fuzzy rule base. For the sake of uniformity in applying fuzzy set, we map sourcing values (spot/systematic, systematic) into (Medium, High) respectively. The fuzzy inference engine will need to scan all stored rules and generate a list of all stored e-business models categorized as "Recommend" and "Do not recommend". This part of the decision support system is in fact a fuzzy expert system.

The Fuzzy Rule Space. Another important point to consider is the maximum number of fuzzy rules that can be considered. That is how many e-business models can be stored and used in this system. Considering only two business aspects such as Economic Control and Functional Integration and fuzzifing into three fuzzy ranges, as shown in Figure 9 below, we see that the rule space is subdivided into 9 sectors which can store 9 different fuzzy rules or e-business models. Generalizing on this fact to use 5 different business aspects and mapping each aspect to 5 fuzzy ranges as we did before, the space is subdivided into 5^5 sectors i.e. 3125 sectors. Therefore, in theory the proposed system can store up to 3125 different e-business models rules. This is quite a good number and much higher than the available numbers of models in the literature. This fuzzy expert system does not restrict future development and additions of new e-business models. This in itself is important result as research proves that a large number of e-business models can be conceived and developed (Timmers, 1999).

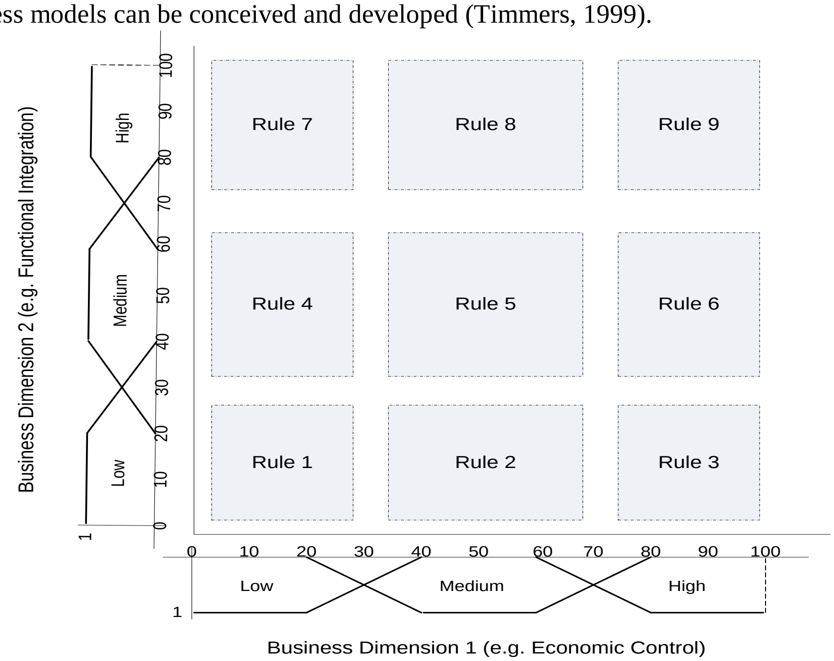

Figure 9: 2-D Rules Space Segmented into Nine Areas

The Complete Fuzzy Decision Support System. Putting all pieces together, we can construct a conceptual design of the fuzzy logic based decision support system for assessment of business situations and selection of e-business models. The proposed system design is illustrated in Figure 10.

The system is made of 6 main components. The first component is an input sensory layer which measures the human executive assessment of the business organization aspects, economic control, functional integration, supply chain integration, innovation and sourcing using 10 different linguistic terms. These linguistic terms are; very low, better than very low, low, better than low, medium, better than medium, high, better than high, and high. These terms are chosen because they represent a fine linguistic scale, also, these terms are similar to the ones used in literature and have proven effective (Zhou & Huang, 2009; Kamoun & Halaweh, 2010). The second component is a fuzzification modules layer. Each fuzzification module is responsible for converting the collective linguistic terms used to assess the sub-measures of any aspect into a general assessment of that aspect as very low, low, medium, high, and very high. All these assessments are fed into a key system component, the Fuzzy Inference Engine, which is a search and matching algorithm. The Fuzzy Inference Engine would work with a Rule Base and generate a report through the User Interface (UI) component to report to the executive which business models do not match, and which match the assessment of the business situation. The last component is an Acquisition tool to allow adding new rules to the rule base and set the parameters of the inference engine.

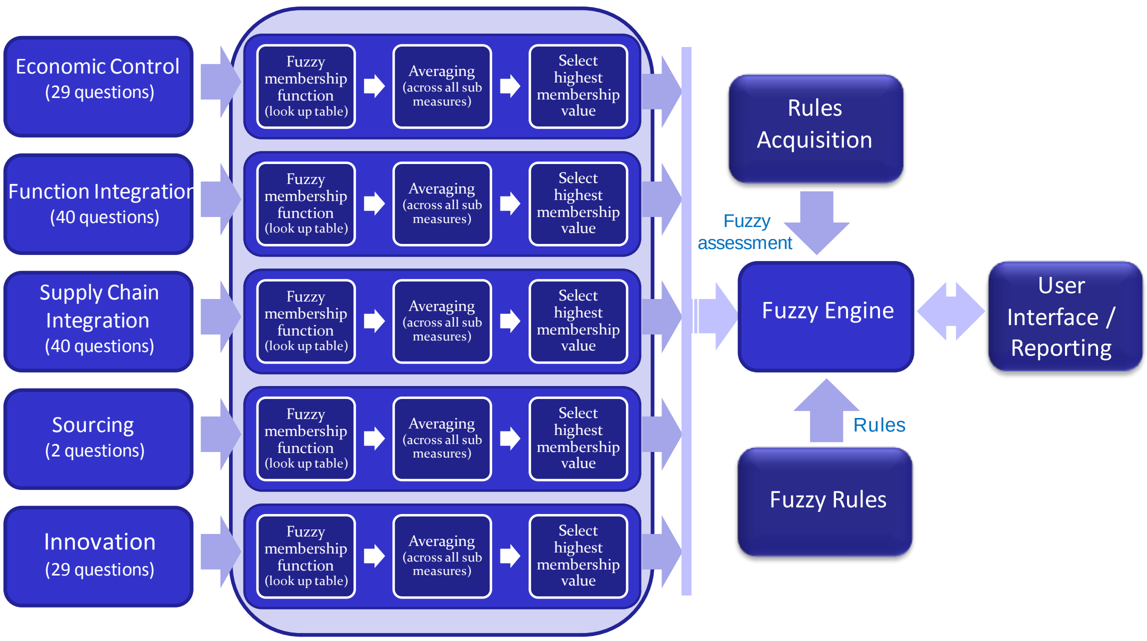

Figure 10: Proposed e-Business Model Selection Decision Support System

This conceptual design can be implemented using any proper computer programming language and data base management technology. It can even be modified at the logical and physical design levels to allow web access enabling business executive to use the system over the internet. However, light development can even be loaded and used on executives PDA's and smart phones.

THE SIMULATION RESULTS

The computational process of the proposed decision support system is simulated using a prototype developed in MS-Excel, although work is underway to develop the complete system with full structure using VB.Net, ASP.net and MS-SQL Server. The full system will be web-enabled system to allow a large number of business executives to access it for trials to provide valuable testing and practical data. Figure 11 shows screen shot illustrating the linguistic interface of inputting judgment values such as very low or better than medium. The fuzzy logic calculations to assess the sub aspects and calculate an overall assessment of the corresponding main aspect are shown in Figure 12.

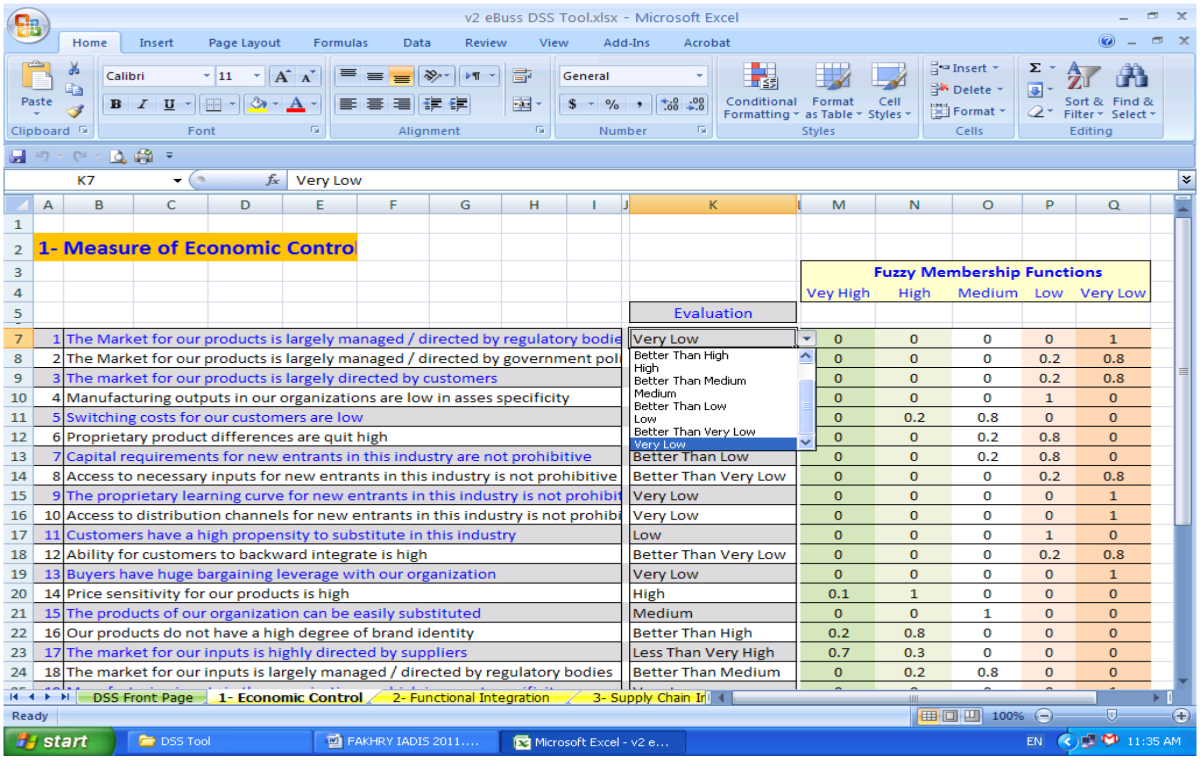

Figure 11: Screen Shot of Economic Control Questionnaire Using Linguistic Evaluation Terms

		Evaluation	Fuzzy Membership Functions				
			Vey High	High	Medium	Low	Very Low
1	The Market for our products is largely managed / directed by regulatory bodies	Very Low	0	0	0	0	1
2	The Market for our products is largely managed / directed by government policy	Better Than Very Low	0	0	0	0.2	0.8
3	The market for our products is largely directed by customers	Better Than Very Low	0	0	0	0.2	0.8
4	Manufacturing outputs in our organizations are low in asses specificity	Low	0	0	0	1	0
5	Switching costs for our customers are low	Better Than Medium	0	0.2	0.8	0	0
6	Proprietary product differences are quit high	Better Than Low	0	0	0.2	0.8	0
7	Capital requirements for new entrants in this industry are not prohibitive	Better Than Low	0	0	0.2	0.8	0
8	Access to necessary inputs for new entrants in this industry is not prohibitive	Better Than Very Low	0	0	0	0.2	0.8
9	The proprietary learning curve for new entrants in this industry is not prohibitive	Very Low	0	0	0	0	1
10	Access to distribution channels for new entrants in this industry is not prohibitive	Very Low	0	0	0	0	1
11	Customers have a high propensity to substitute in this industry	Low	0	0	0	1	0
12	Ability for customers to backward integrate is high	Better Than Very Low	0	0	0	0.2	0.8
13	Buyers have huge bargaining leverage with our organization	Very Low	0	0	0	0	1
14	Price sensitivity for our products is high	High	0.1	1	0	0	0
15	The products of our organization can be easily substituted	Medium	0	0	1	0	0
16	Our products do not have a high degree of brand identity	Better Than High	0.2	0.8	0	0	0
17	The market for our inputs is highly directed by suppliers	Less Than Very High	0.7	0.3	0	0	0
18	The market for our inputs is largely managed / directed by regulatory bodies	Better Than Medium	0	0.2	0.8	0	0
19	Manufacturing inputs in the organization are high in assest specificity	Very Low	0	0	0	0	1
20	Switching costs for suppliers from our organization are low	Medium	0	0	1	0	0
21	The market for our inputs is largely managed / directed by government policy	Very Low	0	0	0	0	1
22	The market for our products is highly directed by competitor behaviour	Low	0	0	0	1	0
23	Manufacturing inputs of our organization cannot be easily substituted	Better Than Very Low	0	0	0	0.2	0.8
24	Suppliers place great importance on transaction volume	Better Than Low	0	0	0.2	0.8	0
25	Suppliers are not very concentrated in our industry	Very Low	0	0	0	0	1
26	Input costs have a large impact on total costs	Low	0	0	0	1	0
27	Proprietary input differences are quit high	Low	0	0	0	1	0
28	We have a low propensity to substitute suppliers	Better Than Very Low	0	0	0	0.2	0.8
29	We do not have much bargaining leverage with suppliers	Better Than Low	0	0	0.2	0.8	0
	Averages		0.0345	0.0862	0.1517	0.3241	0.4069
	Measure of Econmic Control	Maximum MF value	0.4069				
		Index of Max value	5				
		Measure Grade value	Very Low				

Figure 12: Fuzzy Calculation to Generate Overall Assessment of the Economic Control Aspect

All business aspects can be assessed in a similar fashion. Test data representing hypothetical business situations are used to enable experimenting with the prototype. The final assessment of the given business organization situation is generated, reported and stored as shown below in Figure 13.

	Fuzzy Value	Membership
Measure of Economic Control	Very Low	0.4069
Measure of Functional Integration	Medium	0.3300
Measure of Supply Chain Integration	Low	0.2829
Measure of Innovation	Medium	0.3800
Measure of Sourcing	Very High	0.5500

Figure 13: Business Scenario Overall Assessment of all Business Aspects

The Fuzzy Logic Rule base is programmed in MS-Excel, and takes the form shown below in Figure 14.

	Antecedents					**Consequent/Conclusion**
	Economic Control	**Functional Integration**	**Supply Chain Integration**	**Innovation**	**Sourcing**	**E-Business Model**
Rule 1	Low	Low	Low	Low	High	E-Shop
Rule 2	Low	Low	Low	High	Not Applicable	Information Brokerage
Rule 3	Low	Low	Low	Medium	Not Applicable	Trust Services
Rule 4	Low	Medium	Low	Medium	High	E-Mail
Rule 5	Low	Medium	Medium	Medium	Medium	E-Auction
Rule 6	Low	Medium	Medium	High	Not Applicable	Value-chain Service Providers
Rule 7	Low	High	High	High	Not Applicable	Collaboration Platforms
Rule 8	Medium	Medium	Medium	Medium	High	E-Procurement
Rule 9	Medium	Medium	High	High	Not Applicable	Virtual Communities
Rule 10	High	High	High	High	Medium	Third-party Marketplace
Rule 11	High	High	High	High	Medium	E-Hubs
Rule 12	High	High	High	High	Not Applicable	Value-chain Integrators

Figure 14: Used Fuzzy Logic Rule Base

The inference engine search process is modeled in this prototype through the repeated application of IF Then statements to assess every fuzzy rule and generates a final list of recommendations. The prototype final report generated is shown below in Figure 15.

Recommendation Report		
1.	E-Shop	Do not recommend
2.	Information Brokerage	Do not recommend
3.	Trust Services	Do not recommend
4.	E-Mall	Recommend
5.	E-Auction	Do not recommend
6.	Value-chain Service Providers	Do not recommend
7.	Collaborative Platforms	Do not recommend
8.	E-Procurement	Do not recommend
9.	Virtual Communities	Do not recommend
10.	Third Party Marketplace	Do not recommend
11.	E-Hubs	Do not recommend
12.	Value-chain Integrators	Do not recommend

Figure 15: Final Recommendations Report

As pointed out before, the system output is a complete listing of all e-business models stored in the rule base along with an assessment of their status relative to the given business situation data as either “Recommend” or “Do not recommend”.

CONCLUSIONS AND FUTURE WORK

This research presents a detailed framework, conceptual design and prototype of a new decision support system which can aid business executives in deciding the appropriate e-business models to use. The design is based on the ideas and concepts of fuzzy logic theory and fuzzy expert systems. The developed prototype is first tested with faculty colleagues and has received positive feedback. Further testing and empirical work based on interviews and questionnaires to assess the validity and usability of the developed system have been conducted with a number of middle level managers. The managers’ feedback validated the value and usefulness of this system prototype with an encouraging feedback to develop the full system. The development of the full decision support system will enable testing with a larger number of business executives throughout the country. Plans are currently under way to make this full system development using VB.Net, ASP.net and MS-SQL Server as a web-enabled system hosted on the university web site. Executives in the private sector will be able to access it for trials, thus providing valuable testing, and practical data. These trials and testing will help to develop deeper insights and further improve e-business models assessment using fuzzy rules. On the other hand, this research further raises the importance of evaluating all available e-business models in practice to add them to the rule base as currently, only twelve e-business models are used in the rule-base of the system. In addition, there is a need to research and develop new and hybrid e-business models. Adding all available e-business models to the rule-base would give the decision support system a very high practical value and allow for comprehensive testing of the system. Moreover, the research shows the importance of assessing e-business model aspects using five grades (*Very High, High, Medium, Low,* and *Very Low*) rather than the crude three levels presented in the literature. Further research can consider the context sensitivity of the e-business models or in other words the industry specific influence on the business dimensions and their assessments. Moreover, the proposed framework and system can be used to establish a framework for organizational learning when a formal feedback system is incorporated to learn from mistakes, adjust assessments to improve performance and capture the industry specific influence. Furthermore, future research can look into the possibilities of inner-relations between business dimensions especially with the continuous development of new technology to implement e-business models.

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