Applying concepts of Fuzzy Cognitive Mapping to model IT/IS Investment Evaluation factors

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Abstract.

The justification process is a major concern for many organisations that are considering the adoption of Information Technology (IT) and Information Systems (IS), and is a barrier to its implementation. As a result, the competitive advantage of many companies is being put at risk because of management's inability to evaluate the holistic implication of adopting new technology, both in terms of on the benefit and cost portfolios. This paper identifies a number of well-known project appraisal techniques used in IT/IS investment justification. Furthermore, the concept of multivalent, or fuzzy logic, is used to demonstrate how inter-relationships can be modeled between key dimensions identified in the proposed conceptual evaluation model. This is highlighted using fuzzy cognitive mapping (FCM) as a technique to model each IT/IS evaluation factor (integrating strategic, tactical, operational and investment considerations). The use of an FCM is then shown to be as a complementary tool which can serve to highlight interdependencies between contributory justification factors.

Keywords: Investment justification, management of IT, project appraisal, fuzzy logic.

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INTRODUCTION

Information Technology (IT) and Information Systems (IS) are widely acknowledged as one of the major enablers of business change. However, despite enormous capital IT/IS investments, organizations have not always been able to enjoy commensurate financial returns. Indeed, the proliferation of IT/IS has often coincided with lower macroeconomic figures of productivity and profitability in both the manufacturing and service sectors (Baily and Chakrabarti 1988; Roach 1991). The term '*IT productivity paradox*' has been offered (Brynjolfsson 1993) to describe the alleged inability of IT/IS to deliver in practice the benefits they promise in theory. In order for senior management to fully commit to this increasing level of expenditure, they need to be convinced of the business justification of such investments. Small and Chen (1995) have identified a variety of industries underlying concerns with regard to the justification of new technology. These typically include: (i) the fact that many of the achievable benefits are considered to be qualitative and hence difficult to quantify, (ii) a lack of readily accessible and acceptable techniques for appraising all project costs and benefits; (iii) the ability to assess the true performance of a system: as it is diminished if all benefits are not quantified during the justification process; and (iv) an insufficient level of internal skills (managerial and technical) to appraise proposed systems. As a result of these concerns raised by Small and Chen (ibid.) many corporate managers have been forced to adopt one of the following strategies:

- not undertake IT projects that could be beneficial to the long-term future of the organization;
- invest in projects as an 'act of faith'; or
- use creative accounting as a means of passing the budgetary process.

The adoption of new technology is clearly one of the most lengthy, expensive and complex tasks that a firm can undertake. The level of investment and high degree of uncertainty associated with the adoption of this technology implies that issues involving project justification should assume great importance.

This paper identifies a number of project appraisal techniques used to justify investments in IT projects. A holistic conceptual evaluation model that integrates strategic, tactical, operational and financial considerations is presented. Fuzzy logic is then used to demonstrate inter-relationships that may exist between key dimensions identified in the proposed model. The use of a fuzzy cognitive map (FCM) as a tool for investment justification is used to highlight pertinent aspects of the proposed model, and uses the assumption that the problem domain is ultimately vague and ill defined in terms of the solution techniques that are available.

INVESTMENT JUSTIFICATION OF IT/IS

The problems of IS evaluation are not new. Information Systems have always been taking too long to develop, cost too much to implement and maintain, and are frequently *not* perceived to be delivering the business benefits which were initially intended (Ezingeard *et al.,* 1999; Irani *et al.,* 1999, 2000; Khalifa *et al,* 2000; Remenyi, 2000). However, in recent years the changing role of IT/IS in organizations has given new impetus to the problem of IT/IS evaluation. The high expenditure on IT/IS, growing usage that penetrates to the core of organizational functioning, together with disappointed expectations about IT/IS impact, have all served to raise the profile of *how* IS investments can be evaluated. According to Willcocks (1992), '*IS evaluation is not only an under-developed, but also an under-managed area which organizations can increasingly ill-afford to neglect*'. The increased complexity of IT/IS combined with the uncertainty associated with IT/IS benefits and costs (Irani *et al.,* 1997; 2000) point to the need for improved evaluation processes.

In the majority of manufacturing companies, a formal justification proposal must be prepared and accepted by decision-makers, prior to any expenditure. Primrose (1991) identifies industry's perception of investment justification as a budgetary process that gives a final 'yes' or 'no' - 'pass' or 'fail' verdict on the success of a project's proposal. As a result, managers may view project justification as a hurdle that has to be overcome, and not as a technique for evaluating the project's worth. This has significant implications, as during the preparation of a project's proposal, managers spend much time and effort investigating its technical aspects and become committed to the belief that the project is essential. Therefore, team members may be easily susceptible to persuasion by vendors and consultants, and be prepared to accept untypical demonstrations that show unrealistically high levels of savings. Hence, project members may focus their efforts on trying to identify and estimate maximum benefits and savings at the expense of overlooking full cost implications.

Traditional project appraisal techniques such as Return on Investment (RoI), Internal Rate of Return (IRR), Net Present Value (NPV) and Payback approaches are often used to assess capital investments (Willcocks 1994). These methodologies are based on conventional accountancy frameworks and often facilitated under the auspices of the finance director. Specifically, they are designed to assess the bottom-line financial impact of an investment, by often setting project costs against quantifiable benefits and savings predicted to be achievable (Farbey *et al.* 1993; Hochstrasser 1992). However, the vast array of traditional and non-traditional appraisal techniques leaves many organisations with the quandary of deciding which approach to use, if any. Consequently, debate about the types of techniques that constitute meaningful justification have been ubiquitous (Small and Chen 1995).

Table 1 categorises many of the available investment appraisal methodologies into appropriate groups. These various approaches have been compressed into four principal classifications; economic approaches, analytic approaches, strategic approaches and integrated approaches. The classification of economic and analytic approaches to project justification has been further divided into two respective groups. Appraisal techniques that fall into each of the four classifications have been identified. These are summarised in Table 1.

Insert Table 1 Here

Farbey *et al.* (1992) states that those companies using traditional approaches to project appraisal, often indicate an uncertainty of how to measure the full impact of their investments in IT. Furthermore, Hochstrasser and Griffiths (1991) suggests that those evaluation techniques exclusively based on standard accounting methods, simply do not work for organizations replying on sophisticated IT environments to conduct their business. Many managers have become too absorbed with financial appraisal, to the extent that practical strategic considerations have been overlooked (Van Blois, 1983) suggests that. In a similar fashion, Hochstrasser and Griffiths (1991) identified industries overwhelming belief that they are faced with outdated and inappropriate procedures for investment appraisal and that all responsible executives can do is cast them aside in a bold 'leap of strategic faith'. However, when the purpose of IT investment is to support an operational efficiency drive, the benefits of reduced costs and headcounts may be easy to quantify in financial terms. Thus, the use of many traditional approaches to project justification are often the natural choice, as they are usually in widespread use appraising other types of capital expenditure, such as the purchase of new machinery (Primrose 1991).

Maskell (1991) and Farbey *et al.* (1993) suggest that traditional approaches to project justification are often unable to capture many of the qualitative benefits that IT brings. They suggest that these techniques ignore the impact that the system may have in human and organisational terms. As a result, many companies are often left questioning how to compare a strategic investment in IT that delivers a wide range of intangibles, with other corporate investments whose benefits are more tangible. Hill (1993) suggests a shift in current justification emphasis, towards a strategic based review process. It is proposed that project focus should be placed on where progress can be measured against its contribution towards the corporate strategy, and not how well it meets the criteria determined by accounting rules and regulations. Similarly, Hares and Royle (1994) suggest that companies should identify opportunities for making strategic investments in projects pertinent to the objectives of their business and that investment decisions should not be made on the sole basis of monetary return alone. However, Kaplan (1985) explains that, if companies, even for good strategic reasons, consistently invest in projects whose financial returns are below its cost of capital, they will inevitably be on the road to insolvency.

The apparent success of traditional appraisal techniques on non-IT based projects has led many practitioners to search for appropriate evaluation methods that can deal will all IT projects, in all circumstances. Farbey *et al.* (1993) explains that this quest for the 'one best method' is fruitless because the range of circumstances to which the technique would be applied, is so wide and varied that no one technique can cope. Primrose (1991) suggests an alternative perspective, claiming that there is nothing special about IT projects, and that traditional appraisal techniques used for other advanced manufacturing technologies can be used to evaluate IT projects. Clearly, there are few universally excepted guidelines for evaluating IT projects, with current research suggesting that many companies have no formal IT justification process, and lack adequate post-implementation audit techniques against which project objectives can be measured (Hochstrasser 1992; Remenyi, *et al.* 2000).

PROPOSED EVALUATION MODEL

Hochstrasser and Griffiths (1991) and Farbey *et al.* (1993) suggest that the major problems associated with the application of traditional appraisal techniques is their inability to take into account qualitative project implications. As a result, the authors propose the de-coupling of the relative dimensions of the project, and the division into strategic, tactical, operational and financial dimensions, for further analysis. This methodology [originally proposed by Irani *et al.,* (1999)], as with Naik and Chakravarty (1992), proposes the analysis of each project on individual merits, unlike Garrett (1986) who begins with the analysis of a number of different proposals, resulting in the selection of the 'best' perceived option. The proposed conceptual model is detailed in Figure 1, and provides a broad range of variables for consideration when evaluating investments in IT.

Insert Figure 1

This model is divided into four hierarchical levels of evaluation; strategic, tactical, operational and financial. At the level of *strategic* evaluation, the emphasis is placed on the relative impact of the project in relation to the delivery of a competitive advantage. The framework begins with a consideration of the corporate philosophy, core values and beliefs, which translate into a mission statement. This provides a vivid description of what the organisation will be like when 'success' has been achieved. Furthermore, these issues are reflected in the organisations strategic business plan, which broadly identifies where the company is relative to its' market place; where it is going in its' market place; and how it is going to get there, with all these issues being broken down into long/medium term objectives. Once the strategic 'game plan' has been 'mapped-out' and resources identified, there is then a need to identify *tactical* project critical success factors (CSF's). These are project requirements that must be fulfilled at a tactical level, by isolating detailed tasks, processes and resources, to ensure short-term project success. If these CSF's are not achieved, they will ultimately become obstacles to corporate progress and will result in a loss of business, and a failure in the achievement of project objectives (Hochstrasser and Griffiths, 1991). It is essential that when tactical CSF's are identified, appropriate 'hybrid' performance indicators are identified. Figure 2 provides a pictorial description of the various levels of performance measures. Furthermore, it is essential to develop appropriate mechanisms for their quantification (performance enablers).

Insert Figure 2 Here

The next level specifies the identification of *operational* CSF's. These are requirements that must be achieved on an operational day-to-day level, to ensure project success. Again, when operational CSF's are identified, appropriate 'micro' performance measures must be detailed. Such indicators might include the impact the project has on inventory levels, production throughput, scrap levels, work-in progress, schedule adherence, machine downtime etc. It is then essential to develop appropriate mechanisms for their quantification (performance enablers). The formulation of 'best practice' performance enablers at both tactical and operational level provides an opportunity to identify and develop performance-measuring mechanisms. This will offer an accurate and consistent way to measure the performance of the project, which is correlated to the benefits and costs used to justify the investment. This process will therefore assist in culminating investment justification and post-implementation evaluation into one continuous activity.

Finally, *financial* evaluation is addressed. The objective here is to match the most appropriate financial appraisal technique to the characteristics of the project being implemented. Preliminary research (Hochstrasser 1990; Farbey *et al.* 1994; Farbey *et al.* 1995) suggests that this may be possible, as project characteristics affect the way in which an investment decision is made, and therefore indicates which of the available appraisal techniques might be more appropriate for a particular investment. The financial performance of the investment is then examined to see whether the financial returns achievable meet the specific requirements of the organisation (payback period, hurdle rates etc). It is essential to consider the financial implications of the project, as a successful investment decision must yield a return in excess of the cost of capital invested. If after financial analysis the outcome is positive, the project may be selected, otherwise, the evaluation process is repeated, starting again with a strategic analysis.

INVESTMENT DECISION-MAKING: AN EXPERT OR FUZZY VIEW

An Expert Systems View

Investment justification is notoriously subjective, complex and time consuming exercise. Many approaches exist which attempt to address this problem, such as those provided by expert systems. The justification process would entail asking the investment decision-makers a series of 'Yes' or 'No' answer type questions, with various chains of inferences held within a database. Expert systems have been widely used in many different fields of management and engineering to increase knowledge about a problem domain (Dilts and Turowski, 1989; Grierson and Cameron, 1987) and hence provide a means to a structured answer. These results are then analysed using IF-THEN-ELSE type structure (Jackson 1990) and some level of inference about what the nature of the problem is. A possible scenario solution can then be elicited.

Coats (1991), notes that expert systems cannot capture and deal with erroneous, inconsistent or incomplete knowledge, due to their reliance upon abstracted domain rules. Therefore, Coats views such systems as providing knowledge assistance rather than executing decision making insight. To try and overcome some of the limitations identified above, a more sophisticated level of 'intelligence' was sought, which prompted the investigation and subsequent application of fuzzy logic. The application of this technique offered a crucial contribution in providing a further insight into the relationships between the key variables pertinent to the proposed conceptual model detailed in Figure 1. One of the reasons for choosing this approach was to try and overcome the issue of brittleness, that is having an adaptable intelligent system that would be able to cope with increases in the knowledge domain without producing erroneous solutions and/or ceasing to function effectively. This AI approach is a method which is generally applied when vague or 'fuzzy' problems can be abstracted, simplified and overcome by using a derivative of standard mathematical set theory. These concepts have been used successfully in many areas of technology and science, and when used in the context of an investment justification framework, could help to increase the 'intelligence' of the decision making process.

A Fuzzy Logic View – Fuzzy Cognitive Mappping (FCM)

Fuzzy logic dictates that everything is a matter of degree. Instead of variables/answers in a system being either 'Yes' OR 'No' to some user-specified question, variables can be 'Yes' AND 'No' to some degree. The principles that form the genesis of fuzzy logic are built on the notion of variable(s) existing/belonging to a set of numerical values to some degree or not. Membership of variables to a certain set can be both associative and distributive: the whole can also be a part (Kosko, 1990). By extending this view further, fuzzy logic allows the membership of more than 1 set of concepts and consequently lets sets of statements overlap and merge with one another. It is not within the scope of this paper to present an overview of fuzzy logic and the reader is directed to the seminal work on the subject by Zadeh (1965) and in the more recent non-mathematical text by Kosko (1990).

In this paper, the concept of a Fuzzy Cognitive Mapping (FCM) is used to define the state of a set of variables/objectives. Cognitive and causal rules model the system and thus allow some of the inherent qualitative objectives to be related in a non-hierarchical manner. It should be noted that this is not the same idea as proposed by Zadeh (1996), with respect to 'computing with words' (CW) were words and semantic structure are used instead of numbers to achieve a better modelling of reality. The FCM, is essentially an Artificial Neural System (ANS) which seeks to mimic how the human brain associates and deals with different inputs and events, and is best summarised by (Kosko, 1990: p. 222):

> *"An FCM draws a causal picture. It ties facts and things and processes to values and policies and objectives... it lets you predict how complex events interact and play out".*

Typically an FCM is a non-hierarchic flow graph from which the effect of subsequent changes in local parameter values can be seen to effect global parameters. Each parameter is a statement or concept that can be linked to another such statement or concept to produce the nodes of the FCM. This can be achieved via some direct but usually indirect and vague association that the analyst of the system understands but cannot readily quantify in numerical terms. Changes to each statement, hence the fuzzy concept, can be governed by a series of causal increases or decreases.

These incremental variances are generally in the form of a normalized weighting measure (in the ordinal range of 0.0 – 1.0). The advantage with an FCM is that even if the initial mapping of the problem concepts is incomplete or incorrect, further additions to the map can be included, and the effects of new parameters can be quickly seen. This has the advantage over many quantitative methods in that no laborious 'accounting' of each parameter needs to be done. Each concept is judged not only on its own merits but also on the associated merits that link to it via the causal fuzzy weights. Furthermore, and most importantly, the analysis of a particular problem allows the analyst to view the holistic picture, as the system parameters evolve, therefore allowing the incorporation of the wider strategic perspective.

However, certain aspects of the problem being modelled may appear to be unimportant in the light of so-called 'hidden patterns of inference', within the causal links relating to each statement. As such, an FCM is a dynamic system model, which thrives on feedback from each concept (i.e. intercommunication). This is a key difference between the FCM and other cognitive maps that have been used frequently in psychology, such as those described by Axelrod (1976), and Mentazemi and Conrath (1986).

From an AI perspective, an FCM is a supervised learning neural system, where as more and more data becomes available to model the problem, the FCM becomes better at adapting itself and developing a solution. Hence FCM's (and their Neural Network counterparts, Neuro-Fuzzy systems) are very good at producing responses from a given set of initial conditions. A more rigorous appraisal of what is known as supervised learning in the context of the mathematical basis of FCM's can be found in Simpson (1990).

The FCM for Investment Evaluation

Figure 3 illustrates a Fuzzy Cognitive Map (FCM), which was developed to demonstrate the inter-relationships between the key dimensions of the conceptual model proposed in Figure 1.

Insert Figure 3 here

The FCM given in Figure 3 starts with the application of a suitable appraisal technique, from a financial accounting viewpoint. Practically, this would be in the form of accounting the fiscal benefits available to the company after initiating the project. The authors decided to initially isolate this problem domain, as identified earlier in the literature, in order to overcome some of the inherent generalisations that may have occurred by attempting to model the assumptions presented Figure 1.

During the course of producing the entry-level FCM, the authors identified that the fuzzy mapping was automatically allowing the generalisation of the key concepts included in the conceptual framework, presented earlier in this paper. This meant that modelling a simple system via this fuzzy mapping technique, it is possible to quite easily extend the dimensionality of the problem.

In the FCM explanation that follows, the reader is directed to the legend shown in Figure 3, where strategic, tactical, operational and financial considerations are denoted by the letters 'A', 'B', 'C' and 'D' respectively. Each consideration, hereby a fuzzy concept in the FCM, is related to every other concept (i.e. to each fuzzy node) by linking it with an arrow, which shows where a relationship exists. It should be noted that there is no hierarchy between these fuzzy concepts and the letters (A, B, C, and D) which have been represented in the map for brevity. Further, the '+' and '-' signs situated above the lines connecting the encircled variables are not numerical operators or substantiators, in that they do not show (absolute) scalar quantity increases or decreases between each system concept. Instead these signs denote causal relationships in terms of descriptors, which in this case mean 'has greater effect on', and 'has lesser effect on' respectively. Additional fuzzy terms can also be used to delimit the meaning of these operators e.g. '+ often' would be read as 'often has greater effect on', etc.

The map can be read in any direction and relationships can be viewed in terms of any root concept, as it is a non-hierarchic flow diagram (as stated earlier). However, in order to clarify and highlight pertinent relationships between the key variables in the map, it is often easier to begin from a starting/root concept. The map is read by seeing which concept is linked together with another one, and uses the '+' or '-' signs above each arrowed line to provide a causal relationship between them. For brevity in what follows, we will denote such relationships in the following manner:

'<concept_1> <concept_2> [+ or -]'

For example, 'AB-' would mean an arrowed line connects 'A' to 'B' and would be read as "concept A has little effect on concept B". Taking a finance-orientated viewpoint to project justification ('D'), we can read the map shown in Figure 3 as follows :

(i) Justifying a project purely on financial terms has little effect on the strategic considerations ('A'). This has been read as the arrow going from ('D') to ('A') and taking the '-' sign above the line to mean 'has less effect on', i.e. 'DA-'. Similarly, strategic considerations have little impact on the financial justification process as many of the benefits are largely qualitative and hence not financially quantifiable (i.e. 'AD-');

(ii) Justifying a project based upon tactical considerations, is more quantitative than assessing a project based upon strategic investment criteria (but less so than an operational investment) (i.e. 'BD+');

(iii) Operational considerations can be appraised financially without much difficulty as 'day-to-day' operations can be quantified in terms of current resources and operational CSF's (i.e. 'DC+' and 'DC-');

(iv) Strategic issues help to justify investments and substantiate tactical considerations/tactical CSF's and vice versa : since tactical and strategic dimension can be viewed as being long/medium term processes. Appraising a project in terms of any of these two would mean that a tactically based justification would be well suited to meeting the strategic goals of the company eschewed in the corporate mission/vision statement (i.e. 'AB+' and 'AB-');

(v) Since strategic considerations take account of long-term objectives and goals, appraising a project based on operational factors is best suited to traditional methodologies, largely because of their quantitative nature. If an operational project was to be appraised solely on its operational characteristics, the strategic consideration for this would be weak, or rather would not be substantial enough to justify a project by itself (i.e. 'CA-'); and,

(vi) In order to justify projects solely on operational or tactical grounds, via a financial project appraisal impetus, it can be argued that operational considerations have greater effect justifying tactical considerations and vice versa. This is due to the fact that operational processes can be accommodated within the slightly longer time scales involved with tactical goals and objectives - this is a similar situation as shown in (v) above (i.e. 'CB+' and 'BC+'). However, these relationships are not always applicable to all types of investment, and can be detrimental to the appraisal of a project by any other means (either strategic or financial) (i.e. 'CB-' and 'BC-').

The above causal route through the FCM is but a single pattern that has emerged from the mapping of the conceptual framework. Other patterns can be found by adopting a similar method of beginning a causal route from a starting concept (i.e. from 'A', 'B', 'C' or 'D' respectively) and seeing how each concept can, potentially, be related to any other. The FCM itself shows a low-level representation of the key considerations of the project evaluation model, as opposed to the much higher level conceptual framework given in Figure 1. By producing this FCM, the authors were able to produce a simplified version of the conceptual matrix, which includes some of the pertinent aspects found by analysing the dynamic relationships hidden in the fuzzy mapping. This is summarised in Figure 4. It should be noted that the term 'largely' signifies 'in the majority of cases' and the term 'entirely' signifies a focused financial perspective, in this instance.

Insert Figure 4 here

It should be noted that the FCM is a dynamic modelling tool in that the resolution of the system representation can be increased by applying a further mapping to the strategic, tactical, operational and financial considerations as desired. Further detailing of the exact nature of each consideration would ultimately help develop a more comprehensive map, which would show causal patterns that would not ordinarily have been seen, and even possibly, sought. However, other quantitative/qualitative analysis tools such as $IDEF_0$ (Sarkis and Liles, 1995) have been used to assist in the analysis of the aforementioned considerations, and might be able to give further dimensions to the holistic evaluation of project proposals.

CONCLUDING COMMENTS

Traditional appraisal techniques focus on non-strategic, short-term, tangible benefits, with the 'larger picture' often missing from the formal justification process. However, as the nature of many IT projects change from short-term operational investments, to ones with long/medium term strategic focuses, the limitations of traditional approaches to investment appraisal are barriers to project justification and implementation. The issues associated in the use of traditional appraisal techniques for justifying IT investments have been identified from the literature and used to develop a conceptual model.

The authors have also shown the probable part that fuzzy logic can play via the use of a Fuzzy Cognitive Map (FCM) in elucidating key aspects of the justification process, and identifying the causal relationships between the key dimensions of the conceptual framework proposed. An especially important point to note is that a very insubstantial level of expertise is required to construct and decipher the FCM. Hence investment justification and the related strategic considerations of the organisational goals can be decentralised from senior management, by shifting some of the responsibility to non-expert employees but with access to expert staff (i.e. people with special appraisal skills within IT and manufacturing). The delegation of responsibilities from appraising and justifying new investment in IT might cause concern for many line managers but the benefits of allowing cross-functional teams to get involved in the justification process will clearly add synergy and value to the decision making process. Hence by increasing the level of known data about such a vague and, to some extent, intrinsically incalculable problem, a causal route to justifying a project has been found via a fuzzy cognitive map. Although more research is required to further refine and apply the framework developed, the adoption of the proposed methodology and further application of fuzzy logic could clearly avoid some of the difficulties encountered while using traditional approaches to project justification.

REFERENCES

Aleksander I, and Morton H, (1990), *An introduction to neural computing*, Chapman and Hall.

Axelrod R, (1976), *Structure of design,* Princeton University Press.

Baily, M.N. and Chakrabarti, A. (1988) *Innovation and the Productivity Crisis*, Brookings Institution, Washington, DC.

Badiru A, Foote B and Chetupuzha J, (1991), A multi-attribute spreadsheet model for manufacturing technology justification'. *Computer & Industrial Engineering*, **21**(1-4): 29-33.

Barat J, (1992), Scenario planning for critical success factor analysis, *Journal of Information Technology*, **7**, 12-19.

Boaden R.J and Dale B, (1990), Justification of computer integrated manufacturing: some insights into the practice, *IEEE Transactions on Engineering Management,* **37**(4): 291-296.

Bougon, M., Weich, K., Binkhorst, D., (1977), Cognition in Organization: Analysis of the Utrecht Jazz Orchestra, Administrative Science Quarterly, Vol.22, pp. 606-639.

Brynjolfsson, E. (1993) The Productivity Paradox of Information Technology, *Communications of the ACM, 36, 12*, pp. 67-77.

Burstein M.C, (1986), Finding the economical mix of rigid and flexible automation for manufacturing systems, *Proceedings of the Second* ORSA/TIMS *Conference on Flexible Manufacturing Systems,* 69-81.

Coats, P.K, (1991), A critical look at expert systems for business information applications, *Journal Information Technology*, **6**, 208-216

Datta, V., Sambasivarao, K.V., Kodali, R., Deskmukh, S.G., (1992), Multi-attribute decision model using the analytic hierarchy process for the justification of manufacturing systems, *International Journal of Production Economics*, Vol. 28, No.2, 227-234.

Demmel, J. G. and Askin, R.G., (1992), Integrating financial, strategic, and tactical factors in advanced manufacturing system technology investment decisions, *Economic and Financial Justification of Advanced Manufacturing Technologies*, H.R.Parsei, W.G., Sullivan, T.R. Hanley (Editors), Elsevier, 209-243.

Dilts D.M, and Turowski D.G, (1989), Strategic investment justification of advanced manufacturing technology using a knowledge-based system, *Proc. 3rd Int. Conf. Exp. Sys. and the Leading edge in Prod. and Op. Man., University of South Carolina Press, 193-206.*

Ezingeard J-N, Irani Z and Race P. 1999. 'Assessing the value and cost implications of manufacturing information and data systems: An empirical study'. *European Journal of Information Systems*, **7**(4): 252-260.

Farbey B, Land F and Targett D, (1992), Evaluating investments in IT, *Journal of Information Technology*, **7**, 109-122.

Farbey B, Land F, Targett D, (1993), *IT investment: A study of methods and practices,* Published in association with Management Today and Butterworth-Heinemann Ltd, U.K.

Farbey B, Targett D, Land F, (1994), Matching an IT project with an appropriate method of evaluation: a research note on evaluating investments in IT, *Journal of Information Technology*, **9**(3): 239-243.

Farbey B, Land F, Targett D, (1995), System - Method - Context: a contribution towards the development of guidelines for choosing a method of evaluating I/S investments, *Proceedings of the Second European Conference on Information Technology Investment Evaluation,* Henley Management College, Henley on Thames, England, 11-12 July.

Gaimon C, (1986), The strategic decision to acquire flexible technology, Proceedings of the Second ORSA/TIMS Conference on Flexible Manufacturing Systems, 43-54.

Garrett S.E, (1986), Strategy first: A case in FMS justification, Proceedings of the Second ORSA/TIMS Conference on Flexible Manufacturing Systems, 17-29.

Goldberg D.E, (1989), Genetic algorithms in search, optimisation and machine learning, Addison-Wesley.

Goonatilake S, and Khebbal S, (1994), *Intelligent hybrid systems,* John Wiley.

Grierson D.E, and Cameron G.E, (1987), A knowledge based expert system for computer automated structural design, The application of artificial intelligence techniques to civil and structural engineering, Proceedings of the 3rd international conference on civil and structural engineering, Civil Comp. Press, 93-97.

Griffiths C, and Willcocks L, (1994), Are major information technology projects worth the risk ?, *Proceedings of the First European Conference on Information Technology investment evaluation,* Henley management college, Henley on Thames, England, 13th-14th September.

Hares J and Royle D, (1994), *Measuring the value of information technology,* John Wiley and Sons Ltd, U.K.

Hill T, (1993), Manufacturing strategy; The strategic management of the manufacturing function, Second Edition, The Macmillan Press, U.K.

Hinton E, (1992), How neural networks learn from experience, *Scientific American* #267, 144-151.

Hochstrasser B, (1990), Evaluating IT investments - matching techniques to projects, *Journal of Information Technology,* **5**, 215-221.

Hochstrasser B and Griffiths C, (1991), *Controlling IT investment; strategy and management,* Chapman and Hall, London, U.K.

Hochstrasser B, (1992), Justifying IT investments, Conference Proceedings: Advanced Information Systems; The new technologies in today's business environment, 17-28.

Holland J.H, (1992), Adaption in natural and artificial systems: An introductory analysis with applications to Biology, Control and Artificial Intelligence, MIT Press.

Huang P and Sakurai M, (1990), Factory automation: The Japanese Experience, *IEEE Transactions on Engineering Management*, **37**(2): 102-108.

Huber R.F., (1985), Justification- barrier to competitive manufacturing, *Production* , 46-51.

Huber R.F, (1986), CIM: inevitable but not easy, *Production Engineer,* April, 52-57.

Irani Z and Sharif A. (1997). '*Genetic Algorithm Optimisation of Investment Justification Theory*'. Proceeding of the Late Breaking Papers at Genetic Programming 1997, 13-16 July, Stanford University, California, USA.

Irani Z, Ezingeard J-N and Grieve R.J. 1997. 'Integrating the costs of an IT/IS infrastructure into the investment decision making process'. *The International Journal of Technological Innovation, Entrepreneurship and Technology Management (Technovation)*, **17**(11/12): 695-706.

Irani Z, Ezingeard J-N, Grieve R.J and Race P. 1999. 'Investment justification of information technology in manufacturing'. *The International Journal of Computer Applications in Technology*, **12**(2): 90-101.

Irani Z, Love P.E.D and Hides M.T. 2000. 'Investment Evaluation of New Technology: Integrating IT/IS Cost Management into a Model'. Association for Information System, 2000 Americas Conference on Information Systems (AMCIS 2000) [CD Proceedings], August 10-13th, 2000, Long Beach, California, USA.

Jackson P, (1990), *Introduction to expert systems,* Addison-Wesley.

Kaplan R.S, (1985), *Financial justification for the factory of the future,* Harvard Business School, U.S.A.

Kaplan R.S., (1986), Must CIM be justified on faith alone?, *Harvard Business Review*, 87-95.

Khalifa G, Irani Z and Baldwin L.P. 2000. 'IT Evaluation Methods: Drivers and Consequences'. Association for Information System, 2000 Americas Conference on Information Systems (AMCIS2000) [CD Proceedings], August 10-13th, 2000, Long Beach, California, USA.

Kosko B, (1990), Fuzzy thinking: The new science of Fuzzy Logic, Flamingo Press.

Maskell B, (1991), Performance measurement for world class manufacturing: A model for American companies, Productivity Press, U.S.A.

Mentazemi A, and Conrath D, (1986), The use of cognitive mapping for information requirement analysis, *Manufacturing Information Systems Quarterly*, March.

Meredith J.R and Suresh N.C, (1986), Justification techniques for advanced technologies, *International Journal of Production Research.* **24**(5): 1043-1057.

Naik B and Chakravarty A.K, (1992), Strategic acquisition of new manufacturing technology: a review and research framework, *International Journal of Production Research,* **30**(7): 1575-1601.

Nelson C.A, (1986), A scoring model for flexible manufacturing systems project selection, *European Journal of Operations Research*, **24**(3): 346-359.

Nozicka, G.J., Bonham, G.M., Shapiro, M.J., (1976), Simulation Techniques, Structure of Decision,Princeton University Press, Princeton, NJ, in R. Axelrod (ed.), pp. 349-559.

Parker M, Benson R and Trainor H, (1988), *Information economics: linking business performance to information technology,* Prentice-Hall International, U.S.A.

Primrose P.L, (1991), *Investment in manufacturing technology,* Total Technology Department, UMIST, Manchester, Chapman and Hall, London, U.K.

Roach, S.S. (1991) Services Under Siege: The Restructuring Imperative, *Harvard Business Review, September/October*, pp. 83-91.

Remenyi D, Money A, Sherwood-Smith M, Irani Z. 2000. *'The Effective Measurement and Management of IT Costs and Benefits'*. Butterworth Heinemann/Computer Weekly - Professional Information Systems Text Books series, Second Edition, ISBN 0 7506 4420 6, UK.

Sarkis J and Liles D, (1995), Using IDEFO and QFD to develop an organisational decision support methodology for the strategic justification of computer-integrated technologies, *International Journal of Project Management*, **13**(3):177-185.

Serafeimidis V and Smithson S. 2000. 'Information Systems Evaluation in Practice: a case study of organisational change', *Journal of Information Technology*, **15**(2): 93-105.

Simpson, P.K, (1990), Artificial neural systems: foundations, paradigms and applications, Mcgraw-Hill.

Small M, H. and Chen J, (1995), Investment justification of advanced manufacturing technology: An empirical analysis, *Journal of Engineering and Technology Management*, **12**(1-2): 27-55.

Sullivan, W.G. and Reeve, J.M., (1988), XVENTURE: Expert systems to the rescue- They can help justify investments in new technology, Management Accounting, 51-58.

Suresh N.C and Meredith J.R, (1985), Justifying multi-machine systems: An integrated strategic approach, *Journal of Manufacturing Systems*, **4**(2): 117-134.

Swamidass P and Waller M, (1991), A classification of approaches to planning and justifying new manufacturing technologies, *Journal of Manufacturing Systems*, **9**(2):181-193.

Van Blois J, (1983)*, Economic models: The future of robotic justification,* Proceedings of the Thirteenth ISIR/Robots 7 Conference, April 17-21.

Willcocks L, (1994), Information management: the evaluation of information systems investments, Chapman and Hall, London, U.K.

Zadeh L.A, (1965), Fuzzy sets, *Information and Control*, **8**, 338-353.

Zadeh L.A, (1996) Fuzzy logic = computing with words, *IEEE Transactions on Fuzzy Systems* **4**(2): 103-11.

Table 1. Summary of Appraisal Techniques

Economic Approaches

1. Payback Period Technique
2. Return on Investment (RoI)
3. Benefit/Cost Analysis
4. Net Present Value (NPV) (Demmel and Askin, 1992)
5. Internal Rate of Return (IRR)
6. Equivalent Uniform Annual Value (EUAV)
7. Future Value (FV)

Strategic Approaches

8. Technical Importance
9. Competitive Advantage
10. Research and Development
11. Management Commitment
12. Look Long Term (Huber, 1985)
13. Emphasis on Intangibles (Kaplan, 1986)
14. Business Strategy First (Huber, 1985)

Analytic Approaches

15. Non-numeric
16. Scoring Models
17. Computer Based Techniques
    18. Risk Analysis
19. Value Analysis
    20. Analytic Hierarchy Process (Datta *et al*., 1992)
21. Expert Systems (Sullivan and Reeve, 1988)

Integrated Approaches

22. Multi-attribute Utility Theory
23. Scenario Planning & Screening
24. Information Economics

	Analysis Technique															
Researchers	1	2	3	4	5	8	9	10	15	16	17	18	19	22	23	24
Garrett (1986)															*	
Swamidass & Waller (1991)			*	*	*	*				*		*				
Burstein (1986)											*					
Huang & Sakurai (1990)	*	*														
Primrose (1991)	*			*	*											
Nelson (1986)										*						
Meredith & Suresh (1986)						*	*	*				*	*			
Gaimon (1986)											*					
Suresh & Meredith (1985)		*	*	*	*				*	*		*				
Naik & Chakravarty (1992)															*	
Badiru *et al* (1991)										*						
Parker *et al* (1988)	*				*									*		
Griffiths and Willcocks (1994)												*				
Barat (1992)																*

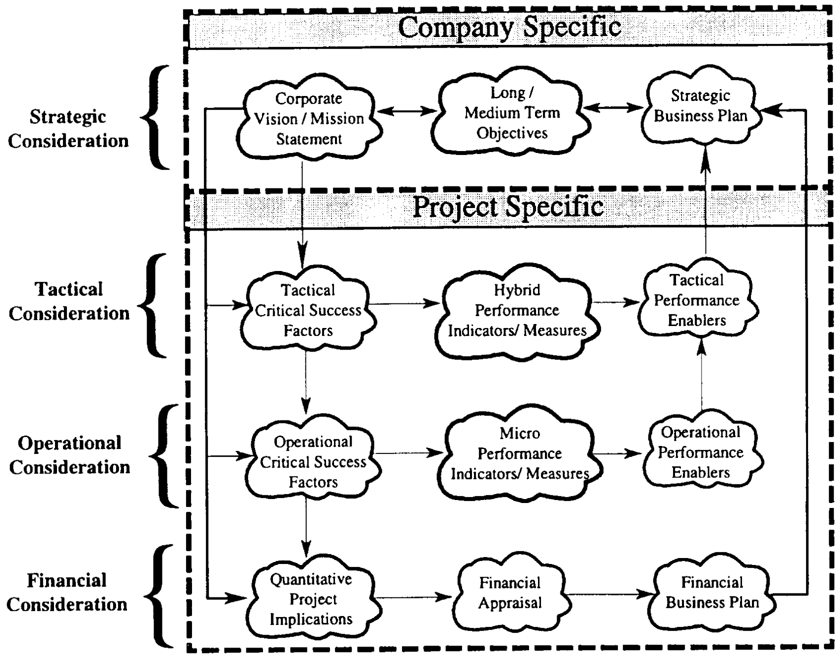


Figure 1 *A conceptual model for investment justification.*

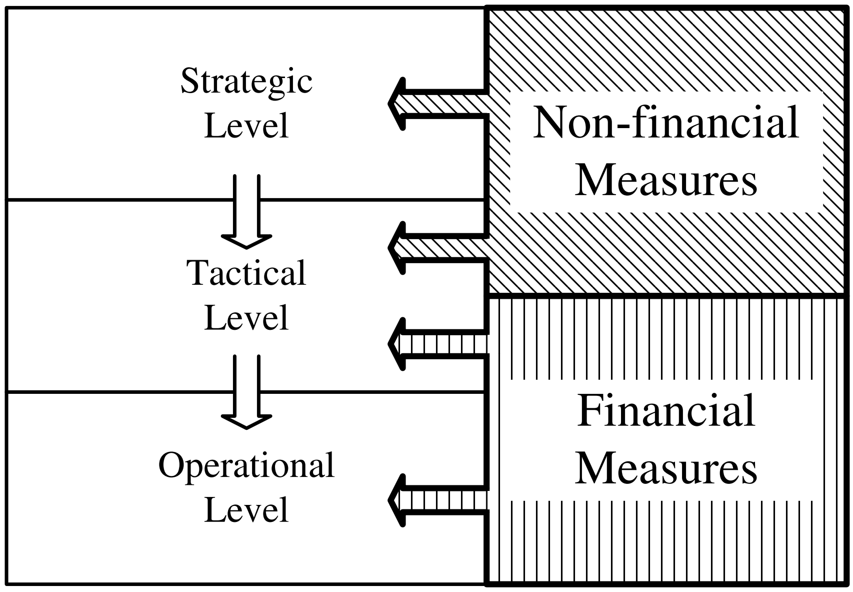
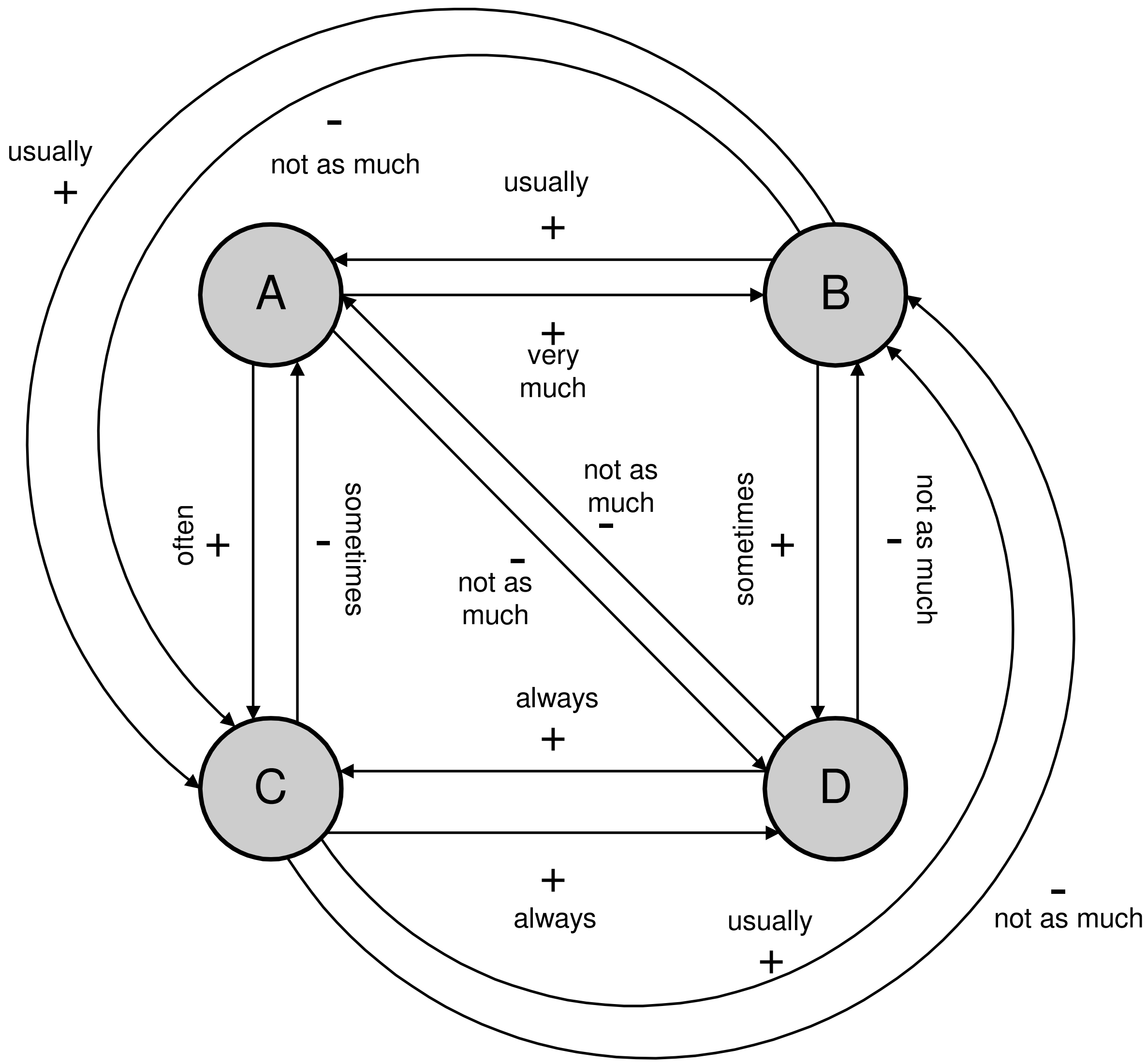


Figure 2. Tangible and Intangible Performance Measures



A	Strategic Considerations
B	Tactical Considerations
C	Operational Considerations
D	Financial Considerations
+	Causal Increase: 'has greater effect on'
-	Causal Decrease: 'has lesser effect on'

Figure 3. Conceptual FCM for Investment Appraisal

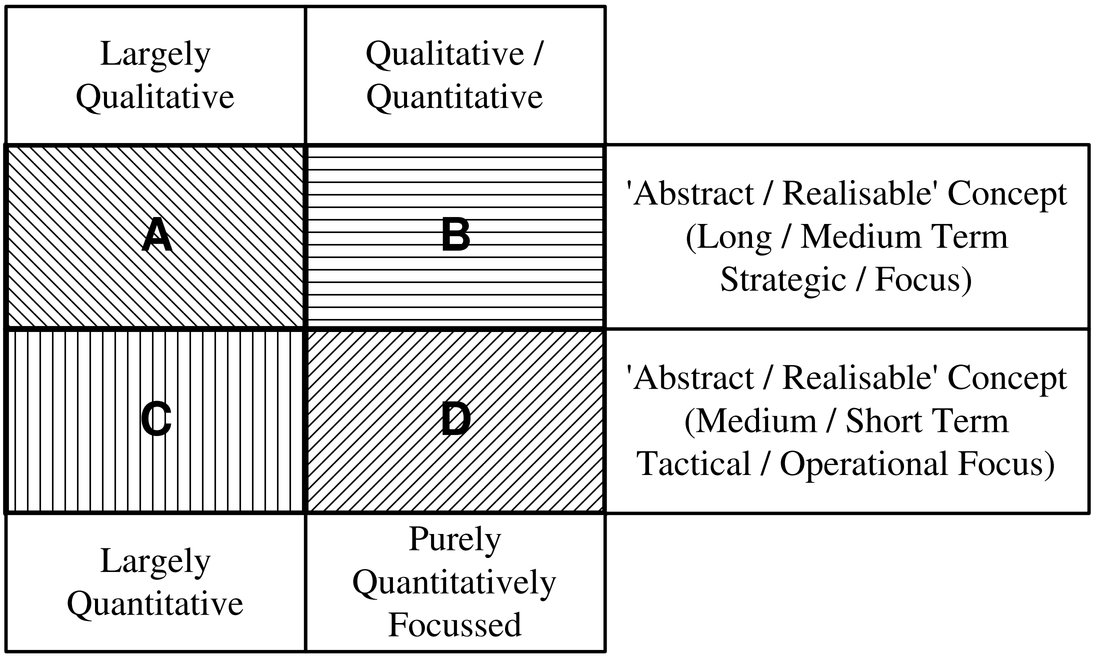


Figure 4. Simplified conceptual framework for Project Evaluation based on a Fuzzy cognitive mapping