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Optimal Selection of Cities of Energy Outlets in Developing Countries: An Application of Fuzzy Set Theory to Sri Lankan Solar Industry

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The concept of benefit gains is inherently fuzzy in nature. Hence, this study seeks to propose a logic-based innovative formalism that helps in effective decision-making in dynamic, imprecise, inconclusive, and volatile business environments underpinned by technology. Such an attempt, deriving from Fuzzy Set Theory, is needed as we apply this model to the financial gain-based optimal selection of cities to establish business outlets with reference to the solar power generation industry. Modelling the perceptions of domain experts is an integral part of the fuzzy approach. However, these linguistic inputs of experts become intelligible only when quantified through similarity methods and fuzzy tolerance relations comparing the yielded values against proximity ratios. The acquisition of expert knowledge was made by interviewing five economic and finance-proficient individuals in Sri Lanka with tacit know-how. The fuzzy inference was used to transform qualitative words and quantitative data into objective crisp values. The study was operationalized through computing with words, cosine amplitude transformation, and Bellman Zadeh approach. Both the Fuzzy Inference System and Bellman Zadeh's approach were amalgamated for data analysis. In deriving the membership values, two business goals of monetary nature were formulated. The findings reveal that the country's politics, business owners' financial solvency, operational maintenance, and business foresight are the constraints that impact financial gains and accomplishing defined goals at variance. Among these, politics and business foresight are external factors, while solvency and operational maintenance are internalised.

KEYWORDS: Fuzzy Set Theory (Fst), Bellman Zadeh Approach (Bz), Financial Gain, Computing with Words, Constraints

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INTRODUCTION

Decision-making is a systematic approach adopted by managers, and it plays a supportive role in multiple disciplines. In real-life circumstances, there are hindrances to the processual nature to differing degrees due to incomplete, fuzzy, uncertain, and imprecise information, biasness of data, or linguistic barriers (Zadeh et al., 2017; Zwikael et al., 2018; Shelly et al., 2015). It is evident that decision-making often occurs in ambiguous, uncertain, and fuzzy environments.

Financial gains are the flow of value emerging from monetary projects-that are quantifiable, and measurable (Zadeh et al., 2017). Moreover, financial gains are tangible in nature, and the financial benefit of a project is calculable, and accountable, and it is possible to evaluate it on a short-term basis (Christian et al., 2008). Thus, the financial value of sustainable projects is a crucial discourse at present. Furthermore, power, and energy, too, have become key industrial domains in the same context.

Due to frequent power crises, the world has observed an electricity crunch, and therefore requires more coordinated efforts in renewable energy-related research (Ekel et al., 2013; Popov, 1987). Solar energy is a source of clean energy that is expected to reduce health hazards due to air pollution in cities and towns (Lu & Fang, 2001). In this context, solar power companies display potential by gearing themselves to export-related technologies to developing countries and by initiating new business outlets, enterprises, and business ventures in cities and towns to increase financial outlay and return on investment. Hence, decision-making is a crucial aspect of such business ventures. However, there are quantifiable and unquantifiable constraints or factors that affect the decision-making process (Sowell, 2005). The present study, therefore, intends to present a formalism on financial gain-based optimal selection of cities for establishing business outlets. Post-2021 was an unfavourable time for developing countries, and Sri Lanka is still suffering as a result of a scarcity of petroleum products.

The objectives of the present study are two-fold: firstly, to understand the goals and constraints that affect the initiation of business outlets in cities and apply the formulated model to a testing environment relating to the energy industry; and secondly, the application of fuzzy methods to determine energy-related business decisions from the perspective of financial goals. The study focuses on Sri Lanka’s business setting.

The significance of the study, on the other hand, is three-fold. Firstly, the study gives a new understanding of the fuzzy decision-making model. As a pioneering study, it attempts to determine financial decisions through the lens of the Fuzzy Inference System. Secondly, the study expands the applicability of the model. Therefore, the mathematical fuzzy inference will be performed concurrently through computing with words (text-based), and auxiliary methods and processes (numeric-based). Thirdly, the study posits the need for managers to formulate business strategies and decisions based on the opinions of field experts attuned to defined goals.

The paper is organised as follows: in the proceeding section, the research problem will be elaborated, and the next section will discuss the relevant literature reviewed, with particular emphasis on the theoretical background. The third section presents the mathematical preliminaries, related methods, and processes. This is followed by a description of an explanatory business case study and data, along with the analysis and presentation of results. The discussion of findings is followed by a discussion of theoretical and managerial implications beneficial for scholars and contemporary managers of businesses. The last section envisages the limitations and future research areas recommended by the present study.

The Issue of Fuzziness of Benefits

The increasing demand for enterprise project consultation for project management has resulted in the emergence of new academic disciplines in business projects in many organisations since project stakeholders are often unaware of the benefits that are identified in a project contract (Christian et al., 2008; Enoch & Labuschagne, 2012). Due to this lack of quantifiability, only 3% of novel projects succeed in achieving the end goals (Verdegay, 1984). It is generally viewed that the performance of projects is based on the yielding of benefits, and the benefits yield in turn, depends on the identification, planning, and evaluation of the said benefits. Therefore, in terms of benefits identification, the benefits are transferable among project parties and must align strategically with organisational goals (Mendel, 1995; Enoch & Labuschagne, 2012).

The Research Gap

Financial gains are associated with the monetary returns of a project. Recent studies show that financial gains, cost savings, performance, financial equity, return on investment, and return on equity are tangible project gains that can be identified and measured (Zadeh, 2016). However, there is a problem related to the long-term outcomes of the identified monetary returns. There is a lacuna in the literature about the measurement approach of long-term outcomes, which lacks scientific application (Wagholikar & Deshpande, 2008; Chen & Cheng, 2009). While the issue of evaluation exists for the long-term value of tangible benefits, there is an observation that approximately 81% of benefits that are identified in projects are intangible benefits such as efficiency, capability, etc. (Mendel, 1995). In the benefit approach, there is no significant measuring tool to deal with these intangible outcomes (Ross, 2009).

Research Problem

The project players can mislead stakeholders on whether 'what gets measured gets delivered,' and that can be grounds for termination of project contracts (Dwivedi et al., 2013). Both tangible and intangible benefits are united in the context of social economics, stakeholder value, customer satisfaction and futuristic monetary gains alongside the long term effect of monetary gains such as long-term financial profit, project solvency and project asset value (Ghildyal et al., 2020; Martinsuo & Killen, 2014). Yet, due to vagueness of the concept of benefit and its imprecision, complicated by the fact that no solid measurement technique or tool exists, the stakeholders are prejudiced as benefit measurement, monitoring and evaluation are largely hampered resulting in repeated high costs in project procurement, contracts, technology and investment (Lad et al., 2008; Christian et al., 2008).

The energy sector is considered to be a technology- oriented business venture (Bellman & Zadeh, 1970; Ghildyal et al., 2018). Moreover, business projects are considered to be a growing and evolving structure. Still, there is a scarcity of research on benefits management in the energy sector where the benefits and deliverables are considered emerging rather than existing because the energy field impacts the deliverables that are more qualitative than quantitative (Zadeh et al., 2017). Hence, this study aims to cover that gap in the existing literature concerning the energy sector.

LITERATURE REVIEW

The relevant literature is posited here in the form of a systematic review that comprises a chronological systematic approach based on the year of publication, author findings, and technical aspects pertaining to the study, such as energy sector-based benefits, financial gains of enterprise projects, the uncertainty of project benefits, technical terminological concepts, and the industrial applicability contextualised to volatile enterprises like energy.

Energy sector-oriented project benefits

Energy sector-related benefits are rather fuzzy, uncertain, and ambiguous (Zwikael et al. 2017). Fuzzy means that the benefits are imprecise, qualitative in measurement, and uncertain. It is therefore difficult to identify, measure and realise the emerging benefits (Ekel et al., 2013; Lad et al., 2008). This also implies that the concept of a benefit is fuzzy in the enterprise sector (Sowell, 2005). The imprecision of the concept of benefit has impacted the tangible and intangible deliverables and its management. Hence, it is important to the project since project benefit management is an essential aspect. The benefit identification, realisation planning, measurement, and realisation are the four major phases influenced by the fuzzy concept of benefits (Verdegay, 1987). Against this backdrop, the project benefits, deliverables, and outcomes are mostly measurable and quantifiable. However, certain benefits are sometimes difficult to measure, evaluate and monitor. In this light, it can be concluded that there are intangible benefits which still do not have a defined scientific measure for benefit identification, planning, measurement, and realisation.

Gains of enterprise projects

The benefit is the flow of value from the project relating to cost, value for money, profit, and financial goals emerging from the project (Christian et al., 2008; Enoch, 2012). According to the extant literature, scientific measures related to the measurement of project success are emerging. This also extends to the need for developing intangible benefit measurement since the need for qualitative deliverables into quantifiable measures, in light of the project's success, is a growing need (Ghildyal et al,. 2020).

Research problem in literature

Financial goals are easily identifiable, but the issue is that the benefit does not have a base scientific method for effective measurement (Ghildyal et al. 2020; Verdegay, 1984). Therefore, the measuring, monitoring, and evaluating aspects of the benefit are undetermined and need to be reinforced. On the other hand, the intangible benefits that emerge from the projects need to be effectively measured. Moreover, there is a need for the project benefits to be effectively managed (Bellman & Zadeh, 1970).

Social impacts, efficiency, human factors are intangible in nature rather than tangible. These qualitative project benefits need to be effectively measured to curtail issues concerning evaluation of benefits and realisation of benefits (Ross, 2009).

Financial gains as a tangible benefit

Financial gains are the emerging benefits and outcomes of a business project underpinned by technological systems (Dwivedi et al., 2013). Financial gains of a business initiative are looked at from two aspects, namely, tangible gains and intangible outcomes (Ghildyal et al., 2020). At present, financial gains are rarely relevant to business although it is in the balance sheet of the company (Martinsuo & Killen, 2014; Dwivedi et al., 2013). In this light, financial gains can be classified as direct tangible and direct intangible benefits offered by the business or the project (Zwikael et al., 2018).

However, the former classification includes short term profit (Dwivedi et al., 2013), pecuniary goals (Ekel et al., 2013), Return on Investment (Lad et al., 2008) while the latter explains the long-term aspects of the financial gains. The essence of the time between short and long-term benefits reveals intangibility. That is because long-term profit, Return on Investment (RoI), and Return on Equity, among other indicators can impact the success of the business outlet in a longitudinal way rather than a cross-section of time in the business. In fuzzy business environments with uncertainty and risk, the money factor also has an intangible effect despite it being traditionally perceived as a quantified, measurable factor expressed in LKR, Indian Rupee or USD (Ghildyal et al., 2018). Hence, this paper recognizes the long-term intangibility effect of financial gains for the purpose of selecting cities to establish business outlets.

Organisational Goals and Project Gains

The goals of a company can be tangible primarily because the managers have a tangible target reachability that is intended to be realised. Moreover, the target is specific, measurable, achievable, realistic, and timely. The timeliness element is the turning point as the scope of time is short-term, medium-term, and long-term. From an intangible benefit point of view, if we say that the company intends to exceed a goal of more than 50 USD in the next 10 years and the scale of the project is large, it implies a time horizon with long-term effects and project value for the owners, sponsors, clients, suppliers, and assessors. Another perspective of cost/time ratio is the legal consequences of the project. In the case of project liabilities, they are in the vulnerability stage of imminent danger, harm, or damage caused by the solar energy project to the stakeholders. The profit earned can be eroded from the money reserves of the company to compensate for the loss or harm upon direct or indirect stakeholders. Long-term large -scale projects have a larger propensity to cause financial and sentimental loss for business owners or business users.

Uncertainty of Data

Real world is intricate and difficult to understand. Hence, complexity in measurability arises from uncertainty due to two reasons. Firstly, it is the randomness in parametric data, and secondly the fuzziness in perception of domain experts (Lad et al., 2008). Complexity and imprecision infuse into most social, technical, and economic issues faced by mankind results in ambiguity and change.

Amidst the paradigmatic changes in science and technology, the diversity takes into consideration the concept of uncertainty. Uncertainty is bifurcated where Newtonian Mechanics based on calculus methods involve no uncertainty and statistical mechanics based on probability theory captures uncertainty of random variables. Despite the divergence, both methods only cover issues and business dilemmas that are encapsulated in the diverse dual paradigms of complexity and randomness and refer to these problems as organised simplicity and disorganised complexity (Östermark, 1987).

Business and technology related issues exist between the two extremes of Business and IT and thereby involve non-linear systems consisting of larger arrays of facets that are non-deterministic. In this backdrop, uncertainty is predominant in diploid forms of vagueness or fuzziness and imprecision as it sets the platform for the study. While imprecision proceeds from the linguistic word precision, probability concept cradles precision as the standard deviation in numerical data (Klir & Yuan, 1996).

Fuzziness of Data and FIS

The Fuzzy set theory is regarded as a transformational approach used to convert qualitative data into crisp, meaningful, tangible and quantifiable values by means of a technological algorithmic intervention (Christian et al., 2008; Wagholikar & Deshpande, 2008). FST comprises primarily important phases of fuzzification, transformation and defuzzification, where the input, process and output are the crucial aspects of fuzzy logic. Fuzzy logic is the underpinning cementing stage of FST which emphasises the technical conversion of language-based quantifier values into crisp-oriented measurable values. Fuzzy logic is described by the scientific domains as the logical transition of the qualitative data and non-crisp, expressly non-measurable values into crisp, measurable quantifiers with the ability to quantify (Zadeh, 2016; Zadeh et al., 2017).

Bellman-Zadeh Covenant

An analogous methodology is the Bellman-Zadeh approach which is a cornerstone of the fuzzy principles and mathematical principles (Bellman & Zadeh, 1970). The objective of BZ approach is prescribe a quantitative value for qualitative benefits. The approach explains that there are goals and constraints within the project or business or organisations. Organisational goals are logically related to the dominant project objectives that the organisation implements. In this context, there are constraints related to the project, i.e., the logical business barriers that restrain or prevent the project from achieving the objectives of the organisation relating to the projectare (Ross, 2009; Fang et al., 1999). Therefore, the constraints are restraining in nature rather than driving organisational-project goal achievement. Socio economic, technological, industrial, managerial, and contractual aspects are generally applicable constraints in novel, inventive and industrially applicable enterprise projects (Dwivedi et al., 2013; Enoch & Labuschagne, 2012).

Computing with Words and Reciprocity with Computing with Numbers

Technology-based projects are a developing concept in enterprise domains and there are allied areas of support such as computing with words. Words are linguistic expressions of the extent to which project related gains or benefits are realised. In this case, for illustration purposes, the realisation of financial gain is ‘high’, ‘medium’ or ‘low’ (Zadeh, 2016) At different granulations, English words can be used to express the entailed benefits (Zadeh et al., 2017). However, the English interpretation needs to be transformed into the paradigm of computer intelligible language since fuzzy logic is applied, which is achieved through a computerised process. Apart from words, numbers are another aspect of this methodology. Computing with numbers is a mathematical interpretation of processing numerical language in order to obtain a human intelligible linguistic expression (Zadeh, 2016). The gain measurement or project benefit measurement is a debacle between the human intelligibility vs. computer intelligibility which practically reciprocate and are meaningfully applied to the organisation in unison (Zadeh, 2017; Fang & Li, 1999).

Applicability of the concepts of Fuzzy Set Theory, Bellman-Zadeh approach and Goal-constraint Theory

The antecedent decision model in fuzzy environments prepared the ground for the theory and methodology on fuzzy optimization (Bellman & Zadeh, 1970). While primordial studies yielded findings of energy research, Peter et al. (2000) used frameworks based on fuzzy sets and approaches of multi-criteria decision making to overcome the present day power and energy engineering crises through a consensual methodology. Against this backdrop, a dual approach with general classes of models relating to multi-objective (<X, M>models) and multi attribute (<X, R>models) was popularised.

The vital use of the traditional BZ approach in fuzzy decision-making is the basis for the analysis of <X, M>models. The application of the model is precipitated on the principle of guaranteed result. This approach provides a constructive framework to achieve a unified mechanism on the rationale of the analysis of max-min problems. On the other hand, analysis of <X, R>models are posited on scientific grounds premised on the fuzzy preference modelling approach. While models and methods are rooted in the conceptual base, scholarly work has diligently reviewed its frequent practical applications in novel industries like power, IT and technology initiatives.

The use of fuzzy theory is compelling in handling and overcoming ambiguity in the benefit planning and monitoring process of power systems and subsystems. It also extends to resolving various issues in planning and operations of power systems, subsystems and micro-environments anchored on energy sources (Cox, 1995). The generalizability of erudite findings assists to settle fundamental problems of constructing fuzzy estimates of fuzzy ambiguous parameters, comparison of alternatives (Klir & Yuan, 1996) or substitutes and promulgating fundamental scientific norms (Ekel et al., 2013), conventions and models of mono-criteria and multi-criteria making in fuzzy environment.

The universal character of the power industry-specific seminal studies has triple importance paving way to application, model approaches and theoretical development (Kacprzyk & Esogbue, 1996). Therefore, the fuzzy approach has major residual effects in design and optimization of reliability in state estimation, fast analysis, distribution systems and operation of distribution systems. The practical utility value of fuzzy logics is evidenced in load measuring of power systems (Östermark, 1987). Thereby the deliverables, such as levels of territorial sustenance and temporal yielding of project benefits, situational leadership of project benefit managers, can be ascertained. Industrial power calibrations like red time control, depicting active power load, idle time and recouping time cycle (Popov & Ekel, 1987) demonstrate the industrial applicability of fuzzy methodologies even in a perennial point of view.

Aligning with application, theoretical dogma, and managerial practices to fuzzy linear programming (Fang et al., 1999; Fang & Li, 1999), fuzzy multi-objective programming (Sakawa & Yano, 1989), fuzzy integer programming (Chanas & Kuchta, 1998), fuzzy dynamic programming (Kacprzyk & Esogbue, 1996), and fuzzy nonlinear programming (Lu & Fang, 2001) have matured since time immemorial and nurtured domain know-how. A trade-off between fuzzy theory and practice has been exhibited in fuzzy ranking (Bortolan & Degani, 1993), fuzzy set operation, sensitivity analysis and fuzzy dual theory (Verdegay, 1984) which service timely and important propositions in fuzzy logic applications in inventive business sectors. Table 1 displays the summary of systematic literature in the field of project gain/benefit management.

Table 1: Systematic literature review of project benefit management

	1990-2000	2000-2010	2010-2014	Emerging (2015)
		Professional and normative literature		
Main Focus	Emerging concepts of benefit management and long-term financial gain identification	Case studies mostly focused on IT project and funded initiatives	Lessons learnt	Agile approach of Fuzzy logic, Bellman Zadeh and mathematical formalisms
		Academic literature		
Main Focus	***Scarcity of*** studies pertaining to describing a process in the IT field	Mainly in IT settings gradually opening up to other empirical observatory settings of the enterprise. Dearth of studies in the energy sector which is enabled by technological initiatives	Searching and reviewing of practices and methods to improve gain-based project enterprise evaluations on benefit approach	Integration of the project sector benefits measurement and management into the larger organisational structures of the enterprises in post- modern times.

MATHEMATICAL FUNDAMENTALS

The fuzzy logic formalism, which is the centrality of the paper, is grounded on FST. In this context, the numerical preliminaries are dichotomous in nature. Therefore, a discourse of Cosine Amplitude Method and Bellman-Zadeh approach constitute the mathematical basics.

Table 2: The four processual themes in financial gain based optimal decision-making

Major Themes	Perspectives on the main purpose of research	Contribution/limitation	Key authors of seminal and novel studies
Financial gains	Monetary gains are measurable, but the long-term gains in this classification are difficult and can inhibit the benefit measurement process.	Enterprise project success is based on the ability to identify, plan, monitor, measure and realise benefits as they emerge. Limitation posits that the nature of the project benefits can prevent the accountability of project benefit measurement. There is a lack of a robust scientific framework to measure long-term intangible project benefits.	Dwivedi et al., 2013; Aubry et al., 2017; Breese, 2015; Zadeh, 2016
Fuzzy logic formalism	The measurability and evaluation of project benefits are fitted and premised upon the process of logically transforming the qualitative values into the tangible values.	The qualitative benefits can be given a numerical interpretation and the granulation of benefit realisation can be ascertained in quantified terms. The accountability of project benefits is much more explicit and evidenced. Limitation posits that since crisp values are achieved for benefit measurement, the divisible values are not captured by the logic.	Ghildyal et al., 2021; Deshpande et al., 2016; Zadeh & Deshpande, 2015; Lad et al., 2008; Christian et al., 2008; Zadeh et al., 2021
Bellman-Zadeh approach	The mathematic fundamentals are applied because expert opinions are captured, extracted and analysed.	Expert opinions are the basis of findings and results of the study. They must be scientifically processed for the observers to understand and interpret the mathematical simulations. Limitations posit that the experts are limited in number in most studies, and it may not represent the populated, majority based responses. Social consensus and collective agreement are rarely achieved.	Bellman & Zadeh, 1970; Zadeh et al., 2021; Kacprzyk & Esogbue, 1996

Energy sector project gains	Energy industry is an emerging field of study and the gains emerging from projects are both long-term and fuzzy in nature.	Technology is the centric enabler of the energy sector after the priori efforts in 2020. Today, the energy sector is facilitated by energy technical processes and they are united on the benefits, process, mathematical formulae and approaches. Limitations posit that the change in organisations is likely to occur in this sector and industry with novel, inventive and industrially applicable enterprise initiatives. The issue is whether the system will adopt change in order to realise, capture and formally evaluate the emerging benefits and gains in the light of routine-based benefit evaluation processes.	Ekel et al., 2013; Enoch, 2012; Ross, 2009; Lad et al., 2008; Cox, 1995

Cosine Amplitude Method in expert classification

This method uses thoughts, ideas and views that are obtained from experts in the field of technology in order to bring a theoretical perspective and obtain and produce a fuzzy membership value for constraints. The authentication is carried out by Cosine Amplitude transformation, which is an explicit aspect of verification of experts, ensuring that the expertise combines with the energy conservation process (Bortolan & Degani, 1993). The probability values of data are a fundamental characteristic and a prerequisite in applying the Cosine Amplitude approach in the prescribed context. However, here the raw information is possibility values, and it is imperative to normalise data, column wise, to originate probabilities. It can override bivalent logic-based probabilistic approaches in the nature of data behaviour.

Similarity method

Probability data values must be converted into possibilities to ascertain a similarity relation between data. It is scientifically ascertained by similarity methods in data manipulation from which we derive the Cosine Amplitude Method.

$$r_{ij} = \frac{\sum_{k=1}^{n} x_{ik}\, x_{jk}}{\sqrt{(\left(\sum_{k=1}^{n} x_{ik}^{2}\right)\left(\sum_{k=1}^{n} x_{jk}^{2})\right)}} \qquad (1)$$

Equation 1: Similarity method formulae

The method expressed in equation (1) discerns that the cosine method relates to the dot product for the cosine function (Christian et al., 2008). There are two theoretical considerations, meaning that the dot product is unity when two vectors are collinear, and on the other hand, when two vectors are at right angles to each other, their dot product becomes zero.

The cosine amplitude method generates a similarity matrix and becomes the calculated fuzzy tolerance relation. In pursuance of similarities, we attempt to convert fuzzy tolerance relations into meaningful fuzzy equivalence by way of resemblance fuzzy operation expressed in equation (2).

$$\mathrm{R}^{n-1}{}_{1} = R_1\ 0\ R_1 0 \ldots \ldots .0 R_1 = R \qquad (2)$$

Equation 2: resemblance fuzzy equation

Fuzzy inference system (FIS)

Fuzzy Inference System (FIS) is a quasi-novel approach containing penta-phases in sequencing the input variables, fuzzification, inference rules, defuzzification and outputting the mandatory elements (Enoch & Labuschagne, 2012). The semi-sequential approach has a process and a substance. In this process, firstly the model accepts input variables, and then, the rules of inference are applied, and finally a qualitative output is derived. The substantive approach explains that a dual system of fuzzification and subsequent application of fuzzy inference rules for each constraint takes its course (Lad et al., 2008; Sowell, 2005).

As a secondary substantive stage, the qualitative outputs are amalgamated systematically and defuzzification technique is applied to produce a crisp value, yielding a deterministic contribution. Crisp value means a specific, quantifiable representation with meaningful, unambiguous values that are quantity-oriented constraint values corresponding to the defined goals (Zadeh, 2016). The scientific approach entails a subjective qualitative-quantitative information planning and is operationalized by FIS in an understandable manner (Ghildyal et al., 2018; Shelly et al., 2015).

The essential part of computing with words in FIS is a text-based transition of fuzzy output into crisp values by means of defuzzification. Since FIS is founded on fuzzy mapping rules, the fuzzy output is transformed into crisp output. Among different methods the centroid method for defuzzification by Mamdani toolbox is utilised in the present research (Zadeh, 2016).

Figure 1: Fuzzy Inference System

Source: Developed by the Author

Bellman – Zadeh Approach

In fuzzy industrial scenarios the goals and constraints are subjected to uncertainty, imprecision, and ambiguity, which consequently lead to decision-making approaches that are also shaped by fuzziness and uncertainty. Therefore, goals and constraints constitute a class of alternatives whose scope and borders are not explicitly expressed (Bellman & Zadeh, 1970). "The cost of a project should not be substantially greater than α," where α is a specified constant in an illustration of a typical fuzzy constraint. Moreover, fuzzy goal is represented as "x should be in the vicinity of x0," where x0 is an express constant (p,13).

Fuzzy decisions

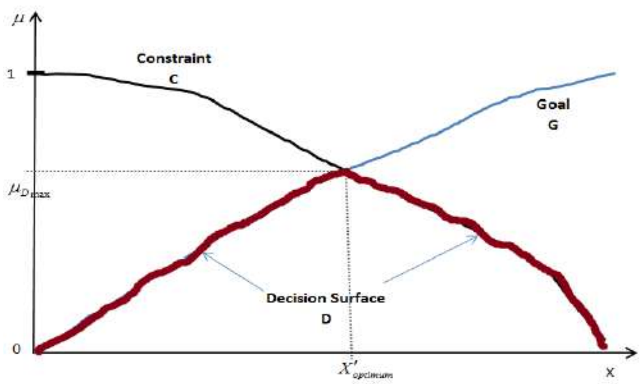
In the space of mathematical alternatives, fuzzy goals (G) and constraints (C) can be specifically developed as fuzzy sets to devise fuzzy targets, ideas and decisions (Ross, 2009). While G and C intervene at a point, this intersection of goals and constraints is theoretically positioned as reaching a fuzzy decision and managerially considered as perceiving a fuzzy endpoint. In the context of industrial settings, fuzzy decisions are mainly two classes, namely, maximising decisions and minimising decisions. Maximising decision, a sub class of fuzzy-based decisions, is a point among the alternatives at which maximum value of the membership function is obtained in an imprecise decision. Similarly, as a posterior-effect of the maximising decision, an aggregate operation on goals and constraints expressed as fuzzy sets make the framework of the model pertaining to fuzzy decision-making (Wagholikar & Deshpande, 2008).

Principal components

a) a set A of possible actions.
b) a set of goals $G_i (i \in N_n)$, each of which is expressed concerning a fuzzy set defined on A ;
c) a set of constraints $C_j (j \in N_n)$, each of which is also represented by a fuzzy set defined on A .

The study will expound a primitive, elementary decision-making framework consisting of a goal that is illustrated by a fuzzy set G with membership function μ_G (x) and a constraint illustrated by a fuzzy set C with membership function μ_C (x), which is industrially applicable. In this scientific approach, x is an element of the crisp set of alternatives $A_{alt.}$ While it is the antecedent of the theoretical model, it can be used to devise a definition-based consideration of a fuzzy decision. The fuzzy set D with a membership function can be explicitly expressed as μ_D (x). Consequently, the intersection of G and C can be expounded as a relation between G , C and D can be diagrammatically shown as in Figure 2.

Figure 2: Fuzzy goal G, constraint C, decision D, max decision x max



Source: Developed by the Author

In project environments, benefits are a multi-dimensional decision as the project deliverables are a collective outcome of the investment. There is a multiple decision-making process consisting of selecting possibilities from a set of alternatives. The selection of crisp data set $[d_1; d_2]$ from an appropriate set of alternatives A_{alt}; in which μ_D (x) indicates the degree to which any $x \in [d_1; d_2]$ belongs to the decision D. In project environments a schematic presentation explains that when $x \in A_{alt} \subset R$ and G and C have monotone continuous membership functions.

$$\mu_D(x) = \min (\mu_G (x); \mu_C(x)); x \in A_{alt} \qquad (3)$$

Equation 3: Continuous membership function equation

In this mathematical algorithm, the operation intersections are commutative G. Hence, the goal and constraint in the expression can be formally interchanged in the expression, i.e., $D = G \cap C = C \cap D$.

Utilitarianism or public good value of business initiatives expresses that, in fact, there is business realism and strategy based on the perspectives of industries and behaviour of project goals, organisational objectives and vision that goal could be considered as constraint and vice versa. In this context, the requirement to expressly define goal and constraint is submerged. In alignment the G and C can thereby have objectives or phases of the business problem.

In industrial settings the decision makers aim to gain a crisp result [24], a value among the elements of the set $[d_1; d_2]$ A_{alt} which represents best or adequately the fuzzy set D. This needs to apply defuzzification of D which is a natural approach adopted in scientific equations. The value x from the selected set $[d_1; d_2]$ with the highest degree of membership in the set D is a timely consideration. In the equation, a value x maximises is represented as μ_D (x) and is called maximising decision, where an optimum benefit or deliverable among possible alternatives is selected. Therewith, the membership functions are to derive an operation intersection which is expressed by:

$$x_{max} = \{x| \max \mu_D(x) = \max \min (\mu_G (x); \mu_C (x))\} \qquad (4)$$

Equation 4: Optimum benefit equation

METHODOLOGY

Population

The study seeks to understand the perception of finance-economic related expert stakeholders associated with the energy industry in Sri Lanka. The target population would be the experts related to that industry throughout the country. Thus, the population relevant to the study also consists of the holistic collaboration of experts in different organisations of the energy industry.

Sampling frame

The register maintained by the Ministry of Power and Energy, which contains a database of all listed experts relating to economic/financials of the energy industry and multidisciplinary experts in the different energy sectors during a particular project assessment period serves as the sampling framework for a study of the expert population in the energy sector.

Sampling design

The study seeks to obtain the knowledge-specific and cognitional information from energy related experts with tacit know-how of economies and financials related to this field. In this light, the information and rich data can be extracted from the experts with meaning and essential facts and information for the study. Energy experts possess enlightened opinions, views and practitioner perceptions about the financial gains in the energy industry. They are advantageously placed to provide necessary information. Therefore, judgement sampling is used to investigate the research questions. Accordingly, five financial proficient energy experts are selected for the study based on their expertise in the subject of renewable energy, solar power energy and other sectors, and they represent the correlated aspects of energy which are economies, social-impact, technology, ecology, and ethics/legal aspects. However, the generalizability of findings is constrained due to the fact that the study uses experts who are conveniently available and therefore the findings may not be applicable to the entire population.

Unit of analysis

Individual expert in the energy sector that was interviewed is the unit of analysis. Then, the organisational project that expert contributed to as a stakeholder is the embedded unit of analysis.

Data collection methods

The study uses face-to-face, semi-structured interviews and structured observation studies for data collection. Face-to-face interviews are used to clarify certain aspects relating to financial gains in the energy sector. The structured observational studies, on the other hand, are used to understand four predetermined phenomena, namely; benefit identification, benefit planning, benefit measurement and benefit realization, of the benefit gain evaluation process.

Data collection tools

A brief guide of the interview will be administered to the experts. Moreover, a structured observation guide will be followed to enable the data collection.

Data analysis

A case study approach will be used to extract the expert opinions, which will be analysed *vis a vis* the findings of the literature review.

EXPLANATORY BUSINESS CASE STUDY IN THE CONTEXT OF THE FUZZY LOGIC APPROACH

Suppose a leading renewable energy company decided to expand their business to a developing country with business outlets in six cities with one outlet per city. Five domain experts competent in economic and financial analysis were sought for advice on financial gain if the company decides to go ahead with the project. While it is necessary to consider the governing factors/ constraints, which could be quantifiable or perception based, the objective is to arrive at a financial gain-based optimal ranking of cities which will satisfy all the constraints. In this illustration, financial gain is expressed as a numeric value or goal.

Case study methodological approach

The identification of key respondents in organisations was based on Eisenhardt's (1989) approach to case studies, in which similarities and differences between cases are managed in a way to establish more solidarity in qualitative research (Singh, 2015). Organisations were selected for their diversity in energy specific industrial enterprises. The target interviewees were approached by direct emails to schedule interviews. Five interviews were conducted on a semi-structured basis to capture the respondents' opinions and tacit knowledge. The study also utilised secondary data relating to energy companies which explains the project benefit evaluation approaches explained in reports, graphical diagrams and project portfolio evaluation reports. The table below (Table 3) explains the interviewee profile.

Table 3: Organisations and Interviewees Profile

Organisation/sector in energy	Experience in benefit management	Number of interviews	Interviewee profile
Hydro power (HP)	low	1	Finance Manager
Solar power (SP)	Medium	1	Sustainability manager/project manager
Fossil fuel (FF)	High	1	Plant manager/project manager
Wind (W)	low	1	Financial compliance/eco manager
Sea water (SW)	medium	1	Compliance manager
Total No of interviews	**05**		

Source: Based on field data analysis

The data

All five experts (n=5), after diligent analysis of the financial position of the 12 business outlet owners in six cities of Sri Lanka (Colombo, Gampaha, Chilaw, Batticaloa, Nuweraeliya and Jaffna), categorised three financial gain states (m=3) as (1) no risk or more gain, (2) medium risk or medium gain, and (3) less financial gain.

Table 4: Expert's rating based on domain knowledge

Variable	x1	x2	x3	x4	x5
xi1 – Ratio with more financial gain	0.6	0.6	0.3	0.5	0.2
xi2 – Ratio with medium financial gain	0.3	0.1	0.2	0.2	0.6
xi3 –Ratio with financial less gain	0.1	0.3	0.5	0.3	0.2

Source: Based on field data analysis

Description of the cases

As seen in the literature, the financial gains process is one important theme in the extant literature. Table 4 provides an overall view of the implementation of project gains in the 12 outlets along with other managerial processes. The expert opinions are relevant to project benefits, but the experiences are at variance for the five organisations that cumulate the expert opinions.

The observations of the experts are thus: FF has high focus on financial gain process while SP & SW have a moderate focus, and HP and W have a low focus on the same.

Table 5: Components of Benefit Management Process in Cases

	Evaluation of financial project gains			
Organization of the expert	Identification of benefits	Benefit realization planning process	Gain/loss monitoring/ measuring	Benefit realization
	Fuzziness of projects and data	Application of Bellman-Zadeh formalism	Implementation of Computing with words	Achieving the relation between project goals and organizational objective(s)
HP	low	Adhoc	In implementation	In implementation
SP	Medium	Partially formal	√	few
FF	High	Formal approach	√	√
W	low	Adhoc	In implementation	In implementation
SW	Medium	Partially formal	√	few

Source: Based on field data analysis

The ranking of decision-making is based on five granulations as illustrated below (see Table 6). The experts' knowledge is used to construct the application of financial goal-based decisions as follows: in full agreement, partially, to a certain extent, sufficiently or not at all.

Table 6: The Fuzzy Decision Linguistic Rep

Linguistic quantification	Fuzzy value crisp approach	Application to ranking process
Highly Satisfies	5	The enterprise will accept the financial goal-base decision in full agreement
Satisfies	4	The enterprise will accept the financial goal base decision partially
Moderately Satisfies	3	The enterprise will accept the financial goal-base decision to a certain extent
Somewhat Satisfies	2	The enterprise will accept the financial goal base decision partially
Rarely Satisfies	1	The enterprise will not accept the financial goal base decision
Linguistic Quantification	Fuzzy value crisp approach	Application to ranking process
Highly Satisfies	5	The enterprise will accept the financial goal-base decision in full agreement
Satisfies	4	The enterprise will accept the financial goal base decision partially
Moderately Satisfies	3	The enterprise will accept the financial goal-base decision to a certain extent
Somewhat Satisfies	2	The enterprise will accept the financial goal base decision partially
Rarely satisfies	1	The enterprise will not accept the financial goal base decision

RESULTS

Similarity among experts was obtained using FST. The experts whose perceptions on the basis of data are similar, in this case, with 0.93 possibility; will be considered in decision analysis for assigning membership values to all the constraints, C. A useful method to estimate similarity among experts is the Cosine Amplitude Method. In this post-modern method, the similarity metric uses a collective of data samples, and a group ‘n’ specialised experts in energy and technology. Once these data samples are collected, they form a data array, X,

$$X= \{x_1,x_2,\ldots,x_n\} \quad (5)$$

Each of the elements, x_i, in the data array X is by itself a vector of length m, that is,

$$X_i = \{x_{i1}, x_{i2}, \ldots\ldots\ldots, x_{in}\} \qquad (6)$$

In the present case, each expert will describe the six business outlets pertaining to its individual financial risk levels.

The model requires a pairwise comparison of two data samples, illustrated as x_i and y_j, that yield each element of a relation r_{ij}. The strength of the relationship between data sample x_i and y_j is expressed by the membership value. The expressive strength is facilitated through the Cosine Amplitude Method:

$$r_{ij} = \mu_R (x_i, y_j) \qquad (7)$$

In a scientific mathematical approach, the size of the relation matrix is (n×n) and is a common consideration among all similarity relations. Moreover, this antecedence is the basis for a matrix of systematic symmetry and reflexive nature. The symmetric means the equal, proportionate values of data while reflexive is the inherent ability of the data to accustomed to the fuzzy business system. In the illustration, financial goals and employee satisfaction are the data variables. By symmetric it means the ability to combine pairwise and by adaptability it means the value to resolve the fuzzy issue of reflexivity. Therefore, the consequential effect is a tolerance relation that aids in the fuzzy tolerance and effect.

Application of Fuzzy Rules

A fuzzy tolerance relation, R~1, has inherent properties of reflexivity and symmetry and it can be reformed into a fuzzy equivalence relation by the process of (n − 1) compositions. In the pursuit of crisp data values, a crisp tolerance relation through a similar approach can be obtained by the transition of crisp tolerance relation into crisp equivalence relation. This is a decomposition process that will alter the texture, character, nature and identity of the relation from tolerance to equivalence. Unless fuzzy tolerance relation is not transformed to fuzzy similarity relation, that fuzzy value could be defuzzified at different levels of alpha cut or possibility levels.

Computing the other elements of the relation results in the following tolerance relation:

$$\mathbf{R} = \begin{vmatrix} 1 & 0.91 & 0.69 & 0.93 & 0.71 \\ 0.91 & 1 & 0.54 & 0.97 & 0.53 \\ 0.69 & 0.54 & 1 & 0.88 & 0.68 \\ 0.93 & 0.97 & 0.88 & 1 & 0.68 \\ 0.71 & 0.53 & 0.68 & 0.68 & 1 \end{vmatrix}$$

Is reflexive and symmetric. However, it is not transitive because

$$\mu_R(x_2,x_4)=0.91 \ \mu_R =(x_4,x_5)=0.68$$

but,

$$\mu_R(x_2,x_4)=0.53 \le \min\ (0.91,0.68)$$

So, it is not fuzzy equivalence relation. It is fuzzy tolerance relation

To convert fuzzy tolerance relation to fuzzy equivalence we have to use resemblance Max-min composition of R with R

$$\mathbf{R^2 = R \,.\, R} = \begin{vmatrix} 1 & 0.93 & 0.88 & 0.93 & 0.71 \\ 0.93 & 1 & 0.88 & 0.97 & 0.71 \\ 0.88 & 0.88 & 1 & 0.88 & 0.69 \\ 0.93 & 0.97 & 0.88 & 1 & 0.71 \\ 0.71 & 0.71 & 0.69 & 0.71 & 1 \end{vmatrix}$$

$$\mu_{R^2}(x_3,x_2)=0.88 \ \mu_{R^2} =(x_2,x_5)=0.71$$

but,

$$\mu_{R^2}(x_3,x_5)=0.69 \le \min\ (0.88,0.71)$$

So, it is not fuzzy equivalence relation. It is fuzzy tolerance relation

To achieve a fuzzy equivalence relation

$$\mathbf{R^3 = R^2 \,.\, R =} \begin{vmatrix} 1 & 0.93 & 0.88 & 0.93 & 0.71 \\ 0.93 & 1 & 0.88 & 0.97 & 0.71 \\ 0.88 & 0.88 & 1 & 0.88 & 0.71 \\ 0.93 & 0.97 & 0.88 & 1 & 0.71 \\ 0.71 & 0.71 & 0.71 & 0.71 & 1 \end{vmatrix}$$

$\mu_R{}^3(x_3,x_2)=0.88$ $\mu_R{}^3=(x_2,x_5)=0.71$

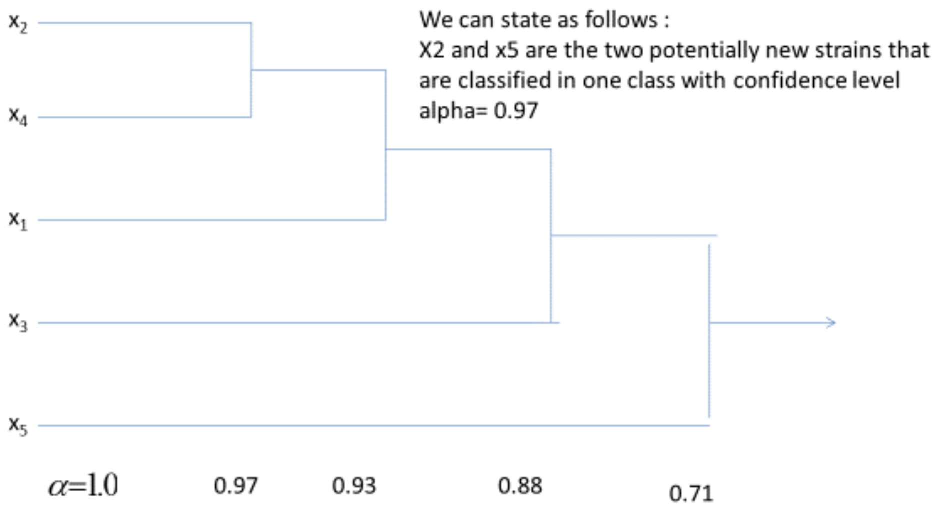
but,

$\mu_R{}^3(x_3,x_5)=0.71=\min(0.88,0.71)$

Now it become a fuzzy equivalence relation

Figure 3: Transformed fuzzy equivalence relations between the five experts

Cluster of Classification Diagram



The study considers 0.93 as a possibility level. Therefore, experts X_1, X_2 and X_4 are selected for further analysis on financial gain-based optimal ranking of cities for establishing business outlets. As profit driven entities, companies are interested in financial gain, but optimal ranking of cities should satisfy the constraint. Therefore, two goals (G_1, G_2) as fuzzy sets are useful.

G_1: Financial gain, x, should be substantially greater than 10 million US dollars (m USD)/year. The fuzzy set can be expressed as:

$$\mu_{G1} = 0 \qquad x < 10$$
$$= [(1+ (x-10)^{-2}]^{-1} \qquad x \geq 10 \qquad (8)$$

G_2 can be linguistically expressed as a fuzzy set since the financial gain could be in the proximity of 20 million US dollar/year.

Expert classification using Cosine Amplitude Method inferred that only three experts are classified at 0.93 possibility. Therefore, average membership values of these three experts are considered for two defined goals and four constraints in the final analysis.

Two goals and four constraints with membership values results as follows:

G_1: Financial gain, x, should be substantially larger than 10 million US dollars (m USD)/year.

{ (1, 0.10); (2, 0.20); (3, 0.80); (4, 0.70); (5,0.30); (6, 0.20)}

G_2: Financial gain could be in the proximity of 20 million dollar/year.

{ (1, 0.10); (2, 0.40); (3, 0.55); (4, 0.65); (5,0.40); (6, 0.20)}

In formulating decisions, the three selected domain experts in the field of energy and power representing the Government, ministries, public authorities and utilities commission based on mutual discussion identified a total of four constraints. The four constraints can be expressed as membership values:

C_1: Political stability of the country { (1, 0.30); (2, 0.40); (3, 0.70); (4, 0.60); (5,0.50); (6, 0.15)}

C_2: Financial solvency of outlet owner { (1, 0.50); (2, 0.60); (3, 0.75); (4, 0.80); (5,0.55); (6, 0.30)}

C_3: Sufficiency of operations maintenance facilities (1, 0.40); (2, 0.50); (3, 0.60); (4, 0.55); (5,0.45); (6, 0.40)}

C_4: Overcoming unforeseeable situations { (1, 0.20); (2, 0.40); (3, 0.65); (4, 0.40); (5,0.30); (6, 0.20)}

Table 7: Membership values: Two Goal and Four Constraint for Six Cities

Membership value Goal/ Constraint	City 1 Colombo	City 2 Gampaha	City 3 Chilaw	City 4 Batticaloa	City 5 Nuwara Eliya	City 6 Jaffna
m_{G1}	0.10	0.20	0.80	0.70	0.30	0.20
m_{G2}	0.10	0.40	0.55	0.65	0.40	0.20
m_{C1}	0.30	0.40	0.70	0.60	0.50	0.15
m_{C2}	0.50	0.60	0.75	0.80	0.55	0.30
m_{C3}	0.40	0.50	0.60	0.55	0.40	0.45
m_{C4}	0.20	0.40	0.65	0.40	0.30	0.20

Source: Based on field data analysis

The final decision on financial gain-based ranking of six cities alternatives is the logical intersection of G & C.

$$D = G \cap C \qquad (9)$$

$$\begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array}$$
$$G \cap C = [\, 0.10,\ \ 0.20,\ \ 0.55,\ 0.40,\ \ 0.30,\ \ 0.15 \,]$$

Financial gain-based optimal ranking of cities for establishing business outlets are as follows:

Rank	City
1	3
2	4
3	5
4	2
5	6
6	1

DISCUSSION

The Cosine Amplitude method relates to the attribution of expert opinions and the similarities between them. Therefore, the economic fundamentals, as expressed in extant literature, posit that the project gains have a proportionate logical relationship with financial outcomes which influence decision making (Wagholikar & Deshpande, 2008; Chen & Cheng, 2009). In the process of decision making, city 3 ranks 1st as it highly satisfies all the 4 constraints for the defined Goals 1 and 2. Moreover, the procedure detailed in the current paper infers that cities 5 and 2 ranked in 3rd and 4th positions respectively as they moderately satisfy the constraints and goals. On the contrary, city 1 ranks 6th as it rarely satisfied the constraints and defined goals, highlighting that when project gains are low and short termed, the financial goals are curtailed (Enoch & Labuschagne, 2012; Zadeh et al., 2017). In this process, while city 4 ranks 2nd place it can be posited that city 4 satisfies the constraints and defined goals. Moreover, city 6 ranks in the 5th place which indicates that the constraints and defined goals are somewhat satisfied. The decision-making process of duly establishing business outlets in the cities is based on the rankings in five variations, namely, highly satisfies, satisfies, moderately satisfies, somewhat satisfies, and rarely satisfies the defined goals and constraints.

City 3 has the highest potential to achieve financial gain (G_1), whereas city 1 has the lowest potential. While city 4 has the efficacy to achieve financial gain (G_2), city 1 has the lowest efficacy in financial goal achievement. City 1, as inferred by experts, achieves both the defined goals with lowest potential. Therefore, according to expert inferences in real business situations, goals and constraints are dependent on the perceived knowledge base of the expert as membership grades in fuzzy business environments. Paradoxically, an outlet manager can rank cities in the opposite order or give last preference to the findings of experts as the manager focuses on corporate plans and a city rarely satisfies the constraints for a defined goal.

The financial solvency (C2) and sufficiency of operations maintenance facilities (C3) as envisaged in literature are tangible and system-related aspects that facilitate or hinder the measurement, evaluation and realisation of project gains (Enoch & Labuschagne, 2012; Shelly et al., 2015). Political (C1) and unforeseeable situations (C4) are generally considered as the extrinsic factors that are influencing the project benefits and goals (Klir & Yuan, 1996). City 3 depicts conductive political stability (0.70) that infers that the government will empower the city to start future-oriented legal energy business and grow profitably. City 3 and 4 display solvency of outlet owners (0.80, 0.75), thereby it can be deduced that the assets are greater than liabilities and stated capital of the business can attain a balanced business outcome (Popov & Ekel, 1987). Furthermore, city 3 (0.60) illustrates the ability to maintain the business facilities as the energy industry demands higher investment in technology and ecological protection. There are sufficient operations maintenance facilities (Chen & Cheng, 2009), and so, city 3 is capable of overcoming unforeseeable demands like energy production and competition for different energy sources with a relatively high value of 0.65.

Solar energy applications are a novel business initiative for developing countries. Energy-specific business venture owners need to understand the gravity of new, inventive and industrially applicable statistical models with practical applicability. In the light of business G & C, the determination of business outlet selection is a new way of thinking because the business is looking at the application of new ideas to resolve a practical issue. The deposition of the approach to rural parts of developing countries are 80% beneficial as the resources, capabilities, culture, governance mechanisms are petty, mushroom, and progressively developing (Bellman & Zadeh, 1970; Fang et al., 1999). There are business owners with low income and greater potential to apply the model appropriately. On the other hand, there are low-income business owners with mediocre business acumen to start-up energy-based business ventures.

PRACTICAL IMPLICATIONS

As power energy is a limited and non-renewable resource, it is a costly asset. Prioritising investments to manage company expenditure is a crucial stage pertaining to the process-based approach of decision making in the energy sector. Identifying and measuring emerging benefits after large monetary, pecuniary investment is a further challenge. The long-term risky decision entails the fact that an imminent demand-supply issue will rise in the future with reference to energy specific industries empowered by fuel, fossil fuels, kerosene and related energy sources (Public Utilities Commission-SL, 2022). Therefore, consequential effects including increased electricity disruption, scheduled power cuts and low-pressure water distribution are inherent crises.

It is a scenario of fuzziness, business, financial and economic turbulence and uncertainty because of the instability and risk faced by business owners.

Thus, their intention to move to alternative energy sources including solar, wind and heat. This calls for a trade-off between investment and realisation of financial gains which are short-term but could be significantly long-term in 2028.

The fuzzy decision-making model plays an influential role as a blueprint to seek expert opinions before initiating the business, and managers of businesses can learn the financial viability and long-term impact of the energy venture.

Energy companies can anticipate the future values of power generation with clean energy sourcing and distribution facilities with the lens of fuzzy decisions to benefit the citizens, the enterprise, and the country. In countries where energy and power sectors are either monopolised or under duopoly, the policy makers can draft proposals to expand energy production and supply chain facilities in government owned or private companies. Specific to Sri Lanka, the Ministry of Power and Energy can initiate optimization of energy consumption by implementing the fuzzy approach in the planning and scheduling of demand-supply. This policy can also facilitate business owners of Sri Lanka to plan, manage, monitor and control the energy needs of their business outlets and realise the desired long-term financial gains.

Three tiers of practical usage can be envisaged in this study. Firstly, at the macro level the country can use the fuzzy innovative approach to design feasible policies to generate and distribute energy to different cities or districts in the country. It is a predecessor to make effective plans to generate and justly distribute essential services and utilities to all parts of the country proportionately and equitably. Secondly, from the business owners' perspective, their financial gains based decisions for the entities will be governed and regulated optimally. Business owners in rural areas can particularly be guided to manage their resources (financial, physical assets and human intellectual capital) effectively. Thirdly, the citizens can be provided with the business needs in a just and equitable manner with merchantability and consumer fairness.

LIMITATIONS

The defined goal expression μ_{G1} presumes the value of exponents as explained by the forefathers of fuzzy algorithms (Bellman & Zadeh, 1970). However, theoretical exponents are onerous to justify as they have subjective values. Hence, the study prefers a distinctive approach of assigning membership function values on the basis of expert's tacit knowledge in the fields of financial economics and energy. The number of qualified experts for the study in the energy discipline is limited (Christian et al. 2008). \

The fuzzy decision-making model is used to make decisions on financial gains associated with the business owners. It is measuring the realisation of the benefit/dis-benefit from the business outlet viewpoint. However, it lacks a holistic approach as the external stakeholders such as suppliers, consumers and customers are not considered in the application of the model. Thereby the extent of application is narrow and specific to the company perspective though it is a versatile model for any fuzzy-based environment.

Future research

Scarcity of knowledge in the energy sector and fuzzy logic call for prospective novel studies in determining goal constraint relationships for hybrid energy companies sourcing traditional and modern power. In the backdrop of the clean energy concept, there is a need to revamp constraints from ecological perspective and define ecology related goals to test in a fuzzy environment.

Moving from inflationary exclusive political, financial, economic and risk factors to deflationary inclusive factors such as technologies, social trends, ethical and legal approach, will change the decision-making approach in the developing world, both culturally and philosophically.

Moreover, the future researchers can be motivated to study how the fuzzy decision model can be utilised to initiating energy-related sectors' manufacturing and production plants of product lines and energy non-related industries like financial, banking, and legal services that show evidence no relevant studies at present.

CONCLUSION

While the fuzzy decision-making model explicitly regards the defined goals and constraints in an imprecise system, it is an observable phenomenon in business realities, sectors and industries. Research outcomes of the present study contend that financial goals with two monetary parameters are significant in fuzzy decisions followed by four constraints relating to political, financial, operational and unforeseeable demands to realise the final business outcome of energy-oriented companies. Furthermore, based on domain knowledge of expert evidence, there are three identified states of financial gain associated with risk and gain. After fuzzification, these linguistic inputs are defuzzified to achieve membership function values of objective crisp nature. Cosine Amplitude based expert inferences and Bellman-Zadeh approach imputes check and balance to harmonise tacit opinions of field experts with profit ideologies of business managers, in order to exploit the industrial applicability in the context of FST.

In the framework of disorganised complexity, the fuzzy logic innovative formalism was meaningfully applied. Post Covid-19 the identified study constraints are becoming much enlarged and useful because C1 and C4 are macro level external factors which are similar to the effects of the persistent health crisis. The ravaging political instabilities, economic crises and unforeseeable socio-business environments in developing nations like Bangladesh (2020), Myanmar (2021), Indonesia (2019) and South Sudan (2018) are learning to mitigate its direct and indirect effects on business owners through the fuzzy approach. The findings of this study can be appropriately applied for any pandemic situation even in least developed and developing nations particularly Sri Lanka. Subsequently, the micro factors C2 and C3 are addressed as internal factors which are either mitigated or enhanced by the pandemic, and future effects of its recurrence in converging common issues.

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