Conceptual Framework for Measuring Project Benefits Using Belief—Plausibility and Type 1 Fuzzy Inference System

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Abstract We propose a combination of belief and plausibility (Bl–Pl) and Type 1 fuzzy inference system (FIS) methods to measure benefits realization in this reserach. This approach can help line managers trace the project outcomes and validate the benefits and return on investment. BI–Pl computations are centered around an expert's belief as a focal element or a power set of a classical set. This is part of Type 1 FIS, which is embraced by concepts of partial belief and fuzzy sets due to the approximate reasoning of the experts and the fuzzy rule base system. The project's output can be ranked based on the difference between Bl-Pl, while Type 1 FIS allows us to transform expert knowledge or experience and then trace the project benefits automatically. A commentary on various governing parameters in enterprise benefit management, expert classification and an illustrative example using belief and plausibility form an integral part of this Chapter.

Keywords Benefit realization · Benefit measurement · Belief · Plausibility · Fuzzy inference systems

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S. N. Shahbazova et al. (eds.), *Recent Developments and the New Direction in Soft-Computing Foundations and Applications*, Studies in Fuzziness and Soft Computing 393, https://doi.org/10.1007/978-3-030-47124-8_20

1 Introduction

Measuring project benefits is a key process in benefit management and has been one of the prime objectives of policy makers. Operation automation, improved system mobility, data security are a few facets of the many project benefits. Electronic Information Management (EIM) 2025 is a digital strategy for the Australian Defence Enterprise Management Strategy delivering promising enterprise benefits guided by imperatives. There are two distinct challenges: firstly, the framework used to measure benefits at different levels of the project and secondly, the application of belief and plausibility of the Dempster-Shafer theory as well as the fuzzy approach to realize benefits. It can be argued that effectiveness, efficiency, responsiveness, compliance and interoperability are intangible yet measurable benefits [1]. A significant contribution to the analysis from the benefit management perspective was made, perhaps, by using the concept of random variable. For a long time, we have embraced two valued probability models based on Aristoteles logic. What might not be realized, is that available information may not always be in numbers but is often in the realm of linguistic description which is imprecise/ambiguous or fuzzy. Professor Lotfi Zadeh brought out this aspect of human culture and suggested the concept of fuzzy sets based on partial belief of experts and wrote a seminal paper in 1965. He coined the term fuzzy logic in 1973, which subsequently formed the concept, which was then applied in various decision making and industrial settings, computer engineering and in other areas of science and technology [1, 2]. Several books and research papers on fuzzy sets and fuzzy logic are available [3, 4] and [5]. The Dempster-Shafer Theory is based on experts' beliefs/evidence and belief and plausibility of selected experts and helps in ranking the decision on project benefit realization in linguistic terms.

2 Enterprise Benefit Management

Benefits include value, financial goal, cost, budget, performance, economic gain, and profit as illustrated in literature [6]. Benefit management is comprised of four processes, namely: benefit identification, benefit monitoring, benefit measurement, and benefit realization. "Intangible benefits", "expected benefits" and "future-oriented benefits" are important for the project success from a strategic viewpoint [7]. The reasons benefit measurement is the focus of this paper are twofold. Firstly, best practice studies do not include measures of strategic value created through present-day projects [8] and, secondly, there is a need for considerable development of the theory on the process of benefit measurement, as little theoretical work has presently been undertaken in the field of benefit management [9]. A trade-off between project benefits and organizational objectives is essential to realize project, program or even portfolio level benefits and visualize the overall organizational vision [10].

3 Challenges in Benefit Measurement for Benefit Realization

Benefits are not only about rational thinking and calculations from experts or project/program managers. Benefits frequently attribute values of all project stakeholders to individuals. Interestingly, benefits also involve human aspects such as emotions and interpretations regarding different types of benefits [11, p. 16]. While some work already exists, there is little work done at P3M levels, namely:

(1) Benefit at Portfolio level
(2) Benefit at Program level
(3) Benefit at Project level [12, 13]

P3M is defined as the essential strata or levels of enterprise or organizational projects, where different types of benefits are identified, organized, measured, delivered, and effectively realized at Portfolio, Program and Project levels [14]. This further extends to a mixed approach as practiced.

Benefit measurement for benefit realization in the dynamic business and enterprise environments involves uncertainties. Fuzzy logic embraces the idea that non-statistical data is vague. Uncertainty is classified into conventional stochastic and lexical uncertainties [15]. In most projects, it is uncertain whether benefits would be realized [16, 17] and there is ambiguity defining benefit measurements to be realized in enterprise settings [18, 19].

4 Relationship Between Portfolio Components and Organizational Objectives

Successfully overcoming the challenges is an indicator of accountability in information management for the enterprise. Project stakeholders expect trust and protected information, business-led, agile and innovative solutions. This benefit along two-dimensional table incorporating objectives and portfolio components are presented in Table 1.

Most complex projects yield benefits, outcomes and deliverables at different levels. Operation automation is important for users and the organization. It increases speed of business transactions and organizational efficiencies. It impacts the enterprise performance and the effectiveness of digital strategy. Customer engagement with the system facilitates the achievement of organizational objectives.

Time is of the essence for developing innovative business applications for the organization. This increases clear accountability towards customers and upholds standardized businesses. Systems could replace human resources in a limited way and increase overall effectiveness. While HR (Human Research) per head cost decreases, staff performance would increase as employees are deployed in other business processes.

Table 1 Relationship between portfolio components and organizational objectives

Portfolio components (PC)		Vision				
		Objective 1: innovation	Objective 2: enterprise performance	Objective 3: effectiveness	Objective 4: clear accountability	Objective 5: standardized business
Portfolio	PC 1: Staff performance			F	I	
	PC 2: Stakehloders		C			J
	PC 3: Time	A				
	PC 4: Customer engagement		D			
	PC 5: Operation automation	B	E	G		K

The RoI (Return on Investment) for projects is expected to be high and the organizational systems create value for the invested money, as an example. As an integral part of the organization, stakeholders' benefit from such initiatives generating billions of dollars in return for large organizations. What was once a tedious process is now simplified, automated and agile. The strategic mapping between the organizational vision and project benefits helps us to measure the collective contribution of projects towards achieving strategic objectives.

5 Classification of Domain Experts

The experience of users infers that the success of the application of the two possibility methods; 1. fuzzy inference system; and 2. the Dempster Shafer Theory of Evidence, to real world problems depends upon selection of the experts. No two persons think alike. Therefore, it is necessary to compute mathematical similarity within and between experts. In this chapter, the belief/evidence assignment of domain experts has been considered in estimating similarity between and within experts.

It is important to identify several experts, in this case, from Army, Air Force and Navy who are involved in the decision-making process of project benefit realization. The statistical method of proportional sampling could be used in selecting the experts for the task. Say, around 100 experts each from the Army, Navy and Air Force are identified for the estimation of their similarity.

The experts will study all the parameters of the project in detail and assign belief, based on their belief/experience in the following way: A. Project benefits very highly realized, B. Project benefits highly realized, C. Project benefits partially realized, and D. Project benefits not realized, A U B project benefits very highly realized OR highly realized. These are known as power sets (and not fuzzy sets) of a classical set.

6 Illustrative Example

6.1 The Example

We select for example, seven experts from the Defense services and they assign the degree of belief between 0 and 1 as Basic Belief or Basic Evidence Assignment (BBA/BEA). The similarity coefficients between the domain experts will be worked using expressions 7 through 13 and will be categorized in various possibility levels (α-level cut). Those experts who satisfy, for example, 0.95 possibilities will be considered in further investigations in decision research. The identified experts can be requested to draw fuzzy sets for the defined parameters based on their perception. Since the authors propose to use a Mamdani type Fuzzy Inference System, an average fuzzy set for the linguistic classes of each parameter will be used in the fuzzification and defuzzification process. Mamdani FIS is now commonly known as Type 1 FIS. Table 2 presents the Basic Belief/Evidence Assignment (BBA/BEA) of identified. For example, seven experts (out of, say 250 experts who finally agree with 0.95 possibility level). The normalized values of the evidence/belief function of experts (E1–E7) are presented.

In Table 2, we have assumed that A is Very High Benefit received, B is High Benefit received, C is an Acceptable level Benefit received, and D is Benefit Not received.

Table 2 Normalized values of the evidence/belief function of experts

Focal element no.	Basic belief/evidence assignment	E-1	E-2	E-3	E-4	E-5	E-6	E-7
1	A	0.04	0.15	0.15	0.04	0.09	0.10	0.10
2	B	0.08	0.12	0.05	0.07	0.08	0.08	0.08
3	C	0.01	0.03	0.14	0.01	0.02	0.03	0.02
4	D	0.02	0.00	0.03	0.01	0.01	0.01	0.02
5	A∪B	0.09	0.14	0.07	0.09	0.10	0.10	0.10
6	A∪c	0.05	0.09	0.15	0.04	0.05	0.08	0.07
7	A∪D	0.05	0.08	0.05	0.06	0.06	0.06	0.04
8	B∪C	0.08	0.08	0.08	0.08	0.08	0.06	0.05
9	B∪D	0.09	0.06	0.02	0.08	0.04	0.05	0.05
10	C∪D	0.02	0.02	0.04	0.02	0.02	0.02	0.02
11	A∪B∪C	0.09	0.10	0.10	0.10	0.10	0.10	0.10
12	A∪B∪D	0.10	0.07	0.03	0.10	0.11	0.12	0.10
13	A∪C∪D	0.09	0.03	0.05	0.09	0.09	0.05	0.10
14	B∪C∪D	0.10	0.02	0.03	0.09	0.03	0.03	0.04
15	A∪B∪C∪D	0.10	0.02	0.01	0.10	0.11	0.12	0.10

The elements of 2 × 2 matrix in Table 2 are on two universes i.e. column as experts E1–E7 and row as BBA/BEA. To compute similarity coefficient, Cosine Amplitude algorithm will be used. Salient details of the method are explained in the next section.

6.2 Cosine Amplitude Method in Expert Classification

Fuzzy membership values for constraints are the perception of experts. So, there is the need to verify similarity between experts. This is done by Cosine Amplitude transformation. To apply Cosine Amplitude transformation, data must be probability values. Here, the data is possibility value. So, we normalize the data column wise which will become probabilities. This data must be converted into a possibility relation to find the similarity relations between them. This is done by Similarity methods in data manipulation.

$$r_{ij} = \frac{\sum_{k=1}^{n} xikxjk}{\sqrt{\left(\left(\sum_{k=1}^{n} x^2ik\right)\left(\sum_{k=1}^{n} x^2jk\right)\right)} \quad (1)$$

Expression (1) reveals that this method is related to the dot product for the cosine function. When two vectors are colinear (most similar), their dot product is unity. When the two vectors are at right angles to one another (most dissimilar), their dot product is zero.

Similarity matrix generated from the cosine amplitude method will be invariably fuzzy tolerance relation. It is necessary to transform fuzzy tolerance relation into fuzzy equivalences relation using resemblance fuzzy operation (Table 3).

$$\mathrm{R}_1^{n-1} = \mathrm{R}_1 \mathrm{o} \mathrm{R}_1 \mathrm{o} \cdots \mathrm{o} \mathrm{R}_1 = \mathrm{R} \quad (2)$$

Table 3 Fuzzy equivalence relation using transitivity closure

Experts'	E1	E2	E3	E4	E5	E6	E7
E1	1.00	0.80	0.64	1.00	0.94	0.92	0.93
E2	0.80	1.00	0.86	0.79	0.88	0.90	0.88
E3	0.64	0.86	1.00	0.64	0.74	0.77	0.77
E4	1.00	0.79	0.64	1.00	0.94	0.92	0.93
E5	0.94	0.88	0.74	0.94	1.00	0.98	0.99
E6	0.92	0.90	0.77	0.92	0.98	1.00	0.97
E7	0.93	0.88	0.77	0.93	0.99	0.97	1.00

(E2, E3) = 0.86 and (E3, E5) = 0.74, but (E2, E5) = 0.88 ≥ min [0.86, 0.74]
(E1, E5) = 0.95 and (E5, E4) = 0.94, but (E1, E4) = 1 ≥ min [0.95, 0.94]
(E2, E1) = 0.80 and (E1, E7) = 0.93, but (E2, E7) = 0.88 ≥ min[0.80, 0.93]

Fig. 1 Transformed fuzzy equivalent relations between experts

$$R^3 = R^2 \circ R = \begin{bmatrix} 1 & 0.93 & 0.88 & 0.93 & 0.71 \\ 0.93 & 1 & 0.88 & 0.97 & 0.71 \\ 0.88 & 0.88 & 1 & 0.88 & 0.71 \\ 0.93 & 0.97 & 0.88 & 1 & 0.71 \\ 0.71 & 0.71 & 0.71 & 0.71 & 1 \end{bmatrix}$$

$$\mu_{R^3}(x_3, x_2) = 0.88 . \mu_{R^3} = (x_2, x_5) = 0.71$$

$$but$$

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

Now it become fuzzy equivalence relation

Fuzzy tolerance relation has been transformed to fuzzy equivalence relation using transitive closure (Expression 2).

Figure 1 below shows the transformed fuzzy equivalent relation between the experts.

Using α-cut level for defuzzification method for fuzzy to crisp converse, we will get similar experts the desired α-cut levels which is portrayed in Fig. 2 as a dendrogram.

Based on the computations, it can be inferred that except for E3, all the experts agree over 0.95 possibility levels.

7 Belief and Plausibility in Dempster-Shafer Approach for Benefit Measurement

7.1 Belief and Plausibility Model

A monotone measure [20] describes the vagueness or imprecision in the assignment of an element A to two or more crisp sets. This can also be termed as a power set in classical set. A special form associated with preconceived notions is called a belief measure. A form associated with information that is possible, or plausible is called a plausibility measure. Specific forms of belief measures and plausibility measures are known as certainty and possibility measures, respectively. A belief measure is a quantity, denoted bel(A), that expresses the degree of support, or evidence for a collection of elements defined by one or more of the crisp sets existing on the power set of a universe.

The plausibility measure of this collection A is defined as the “complement of the Belief of the complement of A,” or as:

$$pl(A) = 1 - bel(A) \quad (3)$$

In Professor Zadeh's words, "Dempster's rule of combination may lead to counterintuitive results because of the normalization issue. The reason for this [21] is that normalization throws out evidence that asserts that the object under consideration does not exist, that is, is null or empty (Ø)". This is the reason why the computation for belief and plausibility should be carried out for each single expert and their variants.

Belief (and not combined belief) are computed for all the experts [3]. When the distance between plausibility and belief is minimum for the decision parameter such as very high benefit realization, high benefit realization and so on, then the decision is acceptable by that expert. The exercise needs to be carried out for all the Experts (in this case for 6.7 as Expert 3 does not satisfy the desired possibility level (Ref Fig. 1). The final decision will be based on maximum principle. The parameter which occurs the maximum number of times will be considered. Say, Project Benefit is highly realized, it is possible to rank the output based on belief plausibility proposed in the Dempster Shafer Theory.

7.2 *Output of Belief and Plausibility Model*

From the illustrative example, the overall minimum distance between belief and plausibility is presented below (Table 4) from the identified six experts as shown in Fig. 2, Experts E1, E2, E4, E5, E6, E7, except Expert 3.

Table 4 Minimum distance between belief and plausibility

Decision variable Description	Symbol	Min. distance between Bel and Pl	
Project benefits very highly accepted	A	0.56	
Project benefits highly accepted	B	0.48	
Project benefits partially accepted	*C*	*0.06*	*Option C—Project benefits partially accepted is the final decision from the hypothetical data*
Project benefits not accepted	D	0.13	

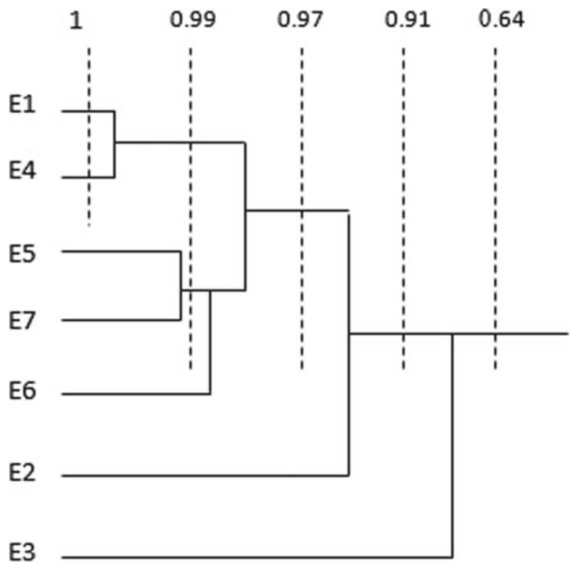

Fig. 2 Fuzzy similarity between experts for various α-cut or possibility levels

7.3 Discussion

After scientific examination based on the hypothetical data on belief of the identified six (E1, E2, E4, E5, E6 and E7) domain experts (Fig. 2), except E3 (Expert 3), it can be concluded that the project benefit is partially realized or accepted.

7.4 Limitation of Dempster Shafer Theory (DST) of Evidence

The experts, without going into sufficient details of all the governing parameters, assign their degree of belief or degree of evidence. This is one of the limitations of DST. To overcome this difficulty in decision analysis, it is proposed to use Type 1 Fuzzy Inference Method in project benefit realization.

8 Type 1 Fuzzy Inference System for Total Project Output Realization

DST is one of the approaches based on belief and plausibility/possibility. Possibility can also be effectively approached using Type 1 FIS (Fuzzy Inference Systems). Fuzzy Inference Systems have the following five vital phases of the fuzzy logic process, namely input variables, fuzzification, inference rule engines, defuzzification

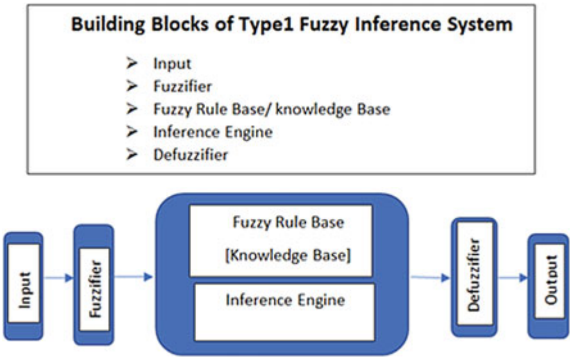

Fig. 3 Fuzzy inference systems

and outputs. Firstly, values for the input variables are entered into the model, then the rules are applied, and a qualitative output is derived for each portfolio component.

The fuzzification and application of fuzzy rules is undertaken for each portfolio component (denoted by PC variable). The contribution is determined by aggregating the qualitative outputs and then applying defuzzification to produce a crisp value. This crisp value is meaningful as it represents quantitative contributions of portfolio components aligned with organizational objectives. Qualitative/quantitative information is managed subjectively and made more meaningful objectively by FIS.

Defuzzification Process

The most important step in Type1 FIS is to transform fuzzy output into crisp output using the process of defuzzification. All the rules will fire parallel and partially in FIS. Most of the rules fire to zero degrees. Invariably, nearby rules are fired partially if the fuzzy rule-based system is well designed and with no abrupt changes in input parameters. The output, after firing of fuzzy rules using fuzzy implication rules, will be a fuzzy set and not a fuzzy number. Defuzzification transforms fuzzy output into crisp output as FIS is based on fuzzy mapping rules. The Mamdani fuzzy toolbox follows the Centroid method for defuzzification, though there are other defuzzification methods available. Figure 3 presents the salient feature of the centroid method of defuzzification.

9 Hierarchical Structure of Type 1 Fuzzy Inference System for Total Benefit Realization is Based on the 5 Categories

The linguistic term "project benefit realization" can express linguistic hedges such as Very High, High, Moderate, Poor and Very Poor. Human perception which is fuzzy or imprecise is at the center stage of any fuzzy inference system. The total benefit realization is based on the five categories which are dependent on 12 PC (Project Component) variables. Figure 4 portrays the details of Hierarchical Structure of

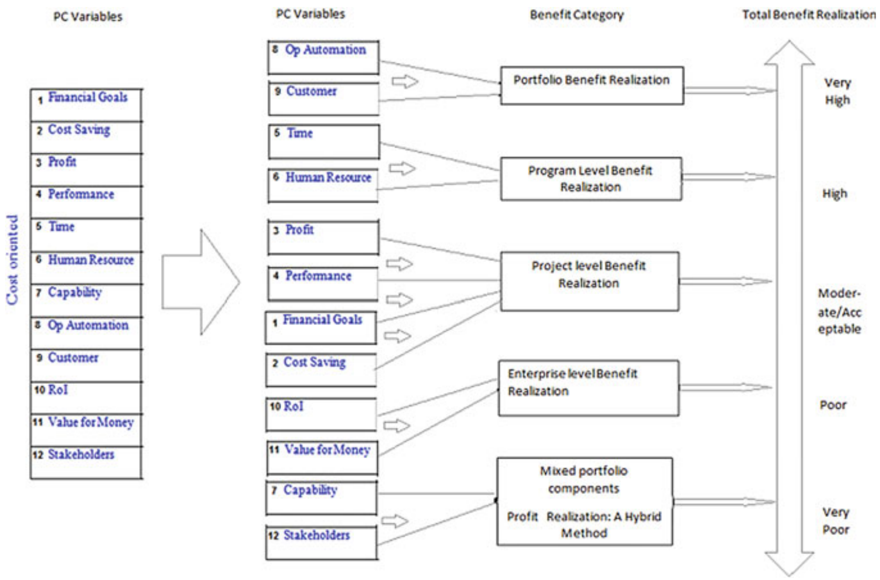

Fig. 4 Hierarchical structure of Type 1 FIS for total benefit realization is based on the 5 categories

Project Benefit Realization. Some of the features of the categories and a typical fuzzy rule base are presented in this section.

Figure 4 portrays the Hierarchical Structure of Type 1 Fuzzy Inference System for the Total Benefit realization based on the five Categories.

9.1 Portfolio and Program Level Benefits Realization

The beneficiaries are key players in driving project deliverables and user requirements. If the portfolio component is contributing to the project delivery, then it is rated 'high'. If experts intervene to improve the user requirements on behalf of the customer, then the portfolio component is rated 'medium'. If customers do not contribute ideas towards executing deliverables, then the component is rated 'low'. Using the majority of voting algorithm, we find that most experts believe that Customer engagement has "increasing" relation with benefit realization.

Thereafter, the experts in the organization will develop a set of fuzzy rules for different linguistic hedges with the following combinations and construct a knowledge base associated with fuzzy rules. Strategically managed information is the critical success factor of the public sector across the different portfolios. Using the majority of voting algorithm, we find that most experts believe that operation automation has an "increasing" relationship with benefit realization.

Table 5 Fuzzy rules in measuring portfolio level benefits

Rule 1: If PCVar8 is low AND PCVar9 is high, THEN contribution to benefits realization is sometimes
Rule 2: If PCVar8 is low AND PCVar9 is medium, THEN contribution to benefits realization is seldom
Rule 3: If PCVar8 is low AND PCVar9 is low, THEN contribution to benefits realization is never
Rule 4: If PCVar8 is medium AND PCVar9 is high, THEN contribution to benefits realization is on most occasions
Rule 5: If PCVar8 is medium AND PCVar9 is medium, THEN contribution to benefits realization is sometimes
Rule 6: If PCVar8 is medium AND PCVar9 is low, THEN contribution to benefits realization is seldom
Rule 7: If PCVar8 is high AND PCVar9 is high, THEN contribution to benefits realization is always
Rule 8: If PCVar8 is high AND PCVar9 is medium, THEN contribution to benefits realization is on most occasions
Rule 9: If PCVar8 is high AND PCVar9 is low, THEN contribution to benefits realization is sometimes

9.2 Typical Fuzzy Rule for Portfolio and Program Level Benefits Realization

Typical fuzzy rules represent customer, we use PC8 and PC9 variables to develop Fuzzy rules as shown in Table 5.

Customer engagement is an integral part of a project, program or any other work associated with portfolio components and its success.

Similarly, fuzzy rules in different linguistic hedges (Low, Medium, High) for Program level, Project level and Enterprise level benefits realization can be formulated. These fuzzy rules are formulated based on domain experts' tacit knowledge which is based on their partial belief and approximate reasoning because of (their) shallow knowledge.

The expected output of Type 1 FIS will be the total benefit realization of the project in linguistic hedges, following the standard defuzzification procedure. The outcome of these investigations will ensure the health of the project which will help the management to make a final decision on the improvement of some of the portfolios, if need arises.

10 Conclusion

In this chapter, a conceptual framework for measuring total project benefits using belief-plausibility and Type 1 Fuzzy Inference System has been proposed. We believe this is the first attempt to tackle the benefit realization measurement. It aimed to help enterprise managers or contract officers track and trace the project outcomes and measure it against committed project benefit. The conceptual model with illustrative examples was demonstrated. The next step is to apply to real world case studies such a conceptual framework and evaluate the practical significance including the measuring benefit realization at four levels namely; portfolio, program, project which leads to enterprise benefit.

Acknowledgement This research is supported by the Australian Defence Study Bank scheme, and Strategic Funds from the Rector's office of the University of New South Wales at the Australian Defence Force Academy. The authors would like to thank the many senior executives from Australian Defence (CASG, CIOG and VCDF), in particular Assistant Secretary of DoD Acquistion and Sustain Reform Chris Horscroft and the late Major General Michael Clifford of ADFA for their mentorship and encouragement to this work.

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