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A Framework for Repeatable Structuring of Cost-Benefit Analysis

Leigh Kirkwood[1], Teresa Purse and Justyna Rybicka[a]
[a] *The Manufacturing Technology Centre, Coventry, CV79JU, UK.*

Abstract. Assessment of costs and benefits of projects in a consistent way is a challenge due to the inconsistent way benefits are captured and evaluated. This problem is made worse across organisations as different staff with varied experience and skillsets get tasked with capturing benefits. Confidence in such assessments can be reduced by the concern that the analysis is too subjective. Following a more structured methodology could lead to improved confidence in the assessment of projects and faster adoption of beneficial improvements in technology, products or processes. In this paper a framework for such assessment is presented and a case study from the construction sector presented.

Keywords. Cost, cost-benefit, value, modern methods of construction.

1. Introduction

To support decision-making a cost-benefit analysis is often used. Such an analysis will often seek to quantify the benefit of a project in financial terms and in this way allow a comparison of costs and benefits using defined metrics for success. Such analysis is well supported in guidance documents, but less clear is how to structure the initial identification of the benefits. This leads to subjectivity in a lot of cost-benefit analysis, which can erode trust in the analysis and the value of a project. When perceived risk is high this can result in cancellations of projects that would be transformative to their organisations.

Many organizations have some values based KPIs which attempt to capture nonfinancial performance information. For example, most large organizations have KPI's related to health and safety performance. Making balanced decisions between two KPI's can be possible with relatively simple processes, such as management intuition. A more complex lists of KPI's must be considered if sustainability issues are of concern to the organization. That means that social, environmental and economical KPI need to be evaluated as a whole. With increased numbers of KPI's the process for balancing decisions will require more rigor. A process for assessing KPIs is described in traditional cost-benefit approaches, such as included in the 'Green book' [1], however the accuracy of results is strongly dependent upon correctly identifying every Value that is impacted by a change. A further complication is that not all potential value will be captured by an organisations KPI's. Assessing projects between two (or more) organizations with different KPI's is also an area of complexity. KPI's are therefore of less use when

[1] Corresponding Author. leigh.kirkwood@the-mtc.org

compared to a more detailed Value framework. Given these details, there is therefore a research gap for a framework to capture the value of projects in a rigorous way that is then suitable for feeding into established cost-benefit analysis methodologies. This paper outlines an attempt at addressing this research gap.

2. Background

Decision making in manufacturing is often considered as only a cost decision, such as cost of remanufacturing [2], where wider benefits are mentioned but considered outside the analysis. General guidance on cost estimation methods can be found through the NASA Cost Estimating Handbook [3]. A more specific treatment of costs suitable for use within a cost-benefit assessment is outlined in the work of Rybicka *et al.* [4], which highlights a generic cost estimating approach that is used to demonstrate a case study for composites.

Assessment of cost-benefit has Guidance on generating a benefit-cost ratio (BCR) can be found within the 'Green book' [1], for example. The BCR at its simplest is a ratio of project benefits and project costs. To be meaningful and rigorous both benefits and costs need expressing within the same measurement unit, which can be challenging. Should a cost-benefit analysis scope include an in-service phase, guidance can be gained from the NATO [5] guidance on Lifecycle costing methodologies. The cost modelling methods outlined are well tested and viable for an organisation to do, but guidance on rigorous identification of benefits is somewhat lacking.

Searching for a framework for value identification returns many options. For this work the Construction Innovation Hub (CIH) Value Toolkit [6] will be used extensively. This framework of Values is structured in terms of relevant capitals and the values that are derived from these capitals. The capitals of interest are: Natural, Human, Social, and Produced. Natural capital focuses on the benefit associated with the natural environment, Human capital focuses on human skills, development and experience. Social capital includes values that address equality and diversity, among other topics. Produced capital covers such financial issues as Lifecycle cost and generated Return. The four Capitals of the value framework breakdown into a total of 17 Values. The 17 Values are considered a comprehensive list for this work. While this framework was used, it is important to note that other value frameworks can be substituted into the process, making this approach widely applicable.

Currently there is little guidance on meshing a value-framework to a CBA. Such a process would have the purpose of capturing value in a consistent way, reducing that vast amount of information down and ultimately supporting decision making.

3. Framework

The developed framework is shown in figure 1.

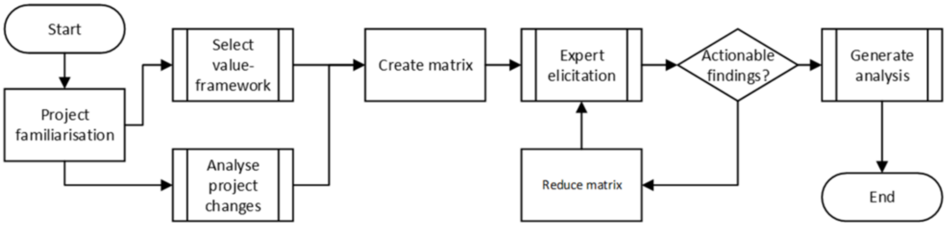

Figure 1: Framework for repeatable structuring of cost benefit analysis

The framework in figure 1, includes the steps needed to structure the analysis. ‘Project familiarization’ is when analysts will engage with the project team to understand the aims and objectives. Selection of value-framework could be set by an organization’s template document or a relevant industry framework. Alternatively, a detailed down-selection process could be used. At the end of selecting value-framework the ‘Values’ dimension of the Value-Changes matrix. Analysis of project changes creates the ‘Changes’ dimension for the matrix; and should aim to note all significant changes from normal operation introduced by the project. ‘Creating the matrix’ and the ‘expert elicitation’ steps will structure then populate the Value-Changes Matrix. With complex projects that introduce many changes or a large value framework the resulting matrix can be large; therefore a process of reduction can be done. If the analyst is confident their findings can be analysed and presented.

3.1. The Value-Changes Matrix

While the CIH value framework gives a comprehensive list of values to assess a project against, large or very novel projects are likely to have changes that can impact the 17 values in complex ways. The use of an array of 17 values will not give enough data on this complexity and therefore the array should be formed into a matrix through the use of a second dimension. This second dimension is labelled ‘changes’ and is used to track individual changes that might occur from a complex project.

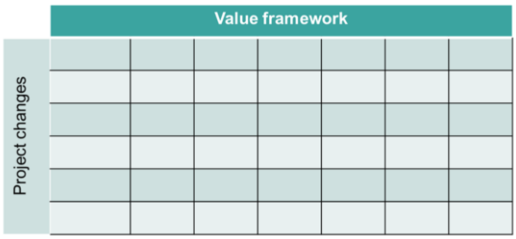

Figure 2: Initial matrix of value and project changes

As the assessment matrix is intended for use as a first stage of a detailed cost-benefit analysis, it is enough that each cell of the matrix is populated with limited information such as a 5-point Liekert scale, that maps to the terms “strong positive’, ‘mild positive’, ‘neutral’, ‘mild negative’ and ‘strong negative’. By using numerical data to capture this formation we allow some analytical approaches that verbal responses would not allow.

Data on a given row captures information about specific project changes and the impacts it has on those values.

Data on the columns captures value information and gives a view of how a singular value is impacted by the wider project. For example, a Health & Safety (H&S) value vertical slice looks at each identified Change caused by a project and the impact on the H&S value.

The Value-Changes matrix can be used to identify positive and negative impacts from a project and can be used to highlight areas that need more information. This matrix can be reduced to allow analysts to focus their efforts on the impactful areas. Once the Value-Changes matrix is deemed ready the deeper analysis of each value-change combination can start, using traditional cost-benefit approaches. Analysts and decision makers can be confident that the analysis has been done in such a way as to capture less-obvious impacts.

3.2. Metrics

During testing simple averages were found to be inadequate: a sum or average of scores across a row or column would be potentially misleading. For example a row that had a lot of very high values and very low values might average out to be fairly neutral looking which is clearly not the case. To support the use of the framework some metrics were developed:

- "Tall" metric: Defined as the sum of Liekert scale scores across a slice (vertical or horizontal). Gives a comparative score for how impacted a Value is or impactful a project change is expected to be.
- "Broad" metric: Percentage of Liekert scale scores that are considered positive along a given row/column. Gives different insight when compared to the "tall" metric as it looks for how broadly positive the Value or project change is impacted.
- "Threat" metric: Defined as the percentage of a vertical or horizontal slice that are considered disadvantageous. This metric is of use if there are negative impacts that would be hidden by the "tall" metrics summing of Liekert scale scores.

These three metrics give a picture of what is occurring on each row or column in a more complete way. They could be applied across the entire matrix if a very high-level view is required of the project, particularly if multiple projects are being compared against each other.

4. Case-study

The framework was applied to the SEISMIC II project [7], which explored modular design and manufacture in construction approach to demonstrate how through standardisation and manufacturing best practice, reduction in delivery times, increase of safety, quality and sustainability can be achieved. Assessment of benefits for technologies that are being demonstrated in the program is a key activity to provide confidence to business decision makers about the risks and potential gains. In this case-study the impact of SEISMIC II technology and its potential deployment in a public sector setting has been assessed through Value changes matrix to evaluate how different metrices change when adapting modern methods of construction. Key assumptions are:

- Economic changes are derived through the efficiencies expected from streamlined processes, like improved quality and reduced lead time.
- Reduced onsite waste impacts sustainability metrics in a broadly positive way.
- The skills required from the workforce will change: from the wide range of skills needed from a craftsman towards more specialised rolls more typically seen in factory settings

Capturing such a wide-ranging set of changes in a cost-benefit analysis would be challenging without this outlined framework.
The matrix was formed using changes identified in project documentation and expert elicitation. For the Values dimension of the matrix the CIH Value-framework was used. Using the metrics described vertical and horizontal slices of the matrix were analysed, as shown in figure 3, which outlines a horizontal slice exploring a particular project change (the wider use of apprentices).

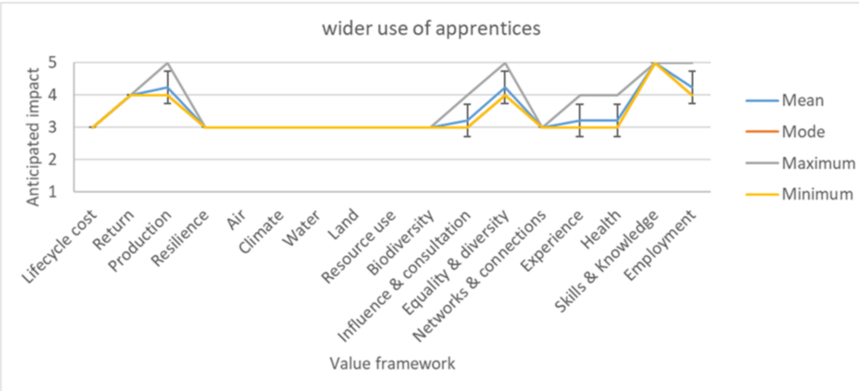

Figure 3: Impact of wider use of apprentices

As figure 3 shows, there are several strongly positive impacts on the Values from the CIH. "Production" and "Return" both being positively impacted, providing an economic impact. Looking at social impact we see good news for the "Equality & Diversity" value which is driven by anticipated improvements in equality and diversity measures based on the perception of the trends seen within the relevant industries (manufacturing is seen to be doing better at diversity challenges than the construction industry). No significant environmental changes were expected from wider use of apprentices; hence the very flat line at a "no-change" level.

The "Tall" metric indicated that this was a good but not spectacular change of the project. The "Broad" metric indicated that 33.8% of values were positively impacted by the change. In terms of the Broad metric, this was the 6th Broadest change.

The above change does not introduce any negative impact on values and therefore the slice shown would measure as 0% on the "Threat" metric.

These metrics together indicate that the change "wider use of apprentices" would be mildly beneficial, doesn't introduce any significant issues, but maybe wouldn't be something to focus exhaustive efforts upon during a cost-benefit analysis as more impactful changes have been identified. The comparison of metrics between changes introduced by the project is a simple task, thereby allowing an analyst to focus on the areas requiring more attention during detailed cost-benefit analysis.

5. Conclusion

This paper has presented a framework for the structuring of cost-benefit analysis and demonstrated its use on a construction transformation project – SEISMIC II. A case-study presented by the National Composites Centre (NCC) [7] highlights improvements in H&S performance, reduced lead-times and lower carbon intensity of their modular build approach. All these benefits were initially identified using the framework discussed within this paper. As the framework can use the organizations KPI to capture benefits then practitioners can be confident that the benefits captured are very relevant to the objectives of that organization.

Challenges and areas for potential improvement are focused on usability. Some respondents noted that completing the first pass of the value-matrix was time consuming. It became necessary for researchers to guide and facilitate competition in some instances. The lesson learned from this is to reduce the value framework as quickly as possible and to group similar project changes together as much as possible. The CIH value-framework used in the case-study has detailed breakdowns of areas of potential value from a project, but that detail adds to the volume of data required. Efforts to reduce the value-framework down to a sub-set of most relevant values before data collection would make data-collection more efficient.

One last conclusion is that the framework could be digitalized quite easily to take advantage of internet survey providers. Through such an approach many more respondents could be consulted and a more complete picture of the likely benefits gathered. This would be particularly suited for projects with large numbers of relevant experts to consult.

References

[1] HM Treasury, Green Book central government guidance on appraisal and evaluation, (2022), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf

[2] Y. Xu & W. Fang, Develop a cost model to evaluate the economic benefit of remanufacturing based on specific technique, Journal of remanufacturing, (2014), 4:4.

[3] National Aeronautics and Space Administration: NASA Cost Estimating Handbook. NASA Headquarters, Cost Analysis Division, Washington, DC (2008)

[4] J. Rybicka, T. Purse, B. Parlour, A Generic Cost Estimating Approach for a Composite Manufacturing Process Assessment, *Advances in Manufacturing Technology XXXIV,* (2021), 414-418.

[5] North Atlantic Treaty Organisation: NATO, TR-SAS-054: Methods and Models for Life Cycle Costing, (2007).

[6] Construction Innovation Hub, Value Definition Framework, (2022) https://constructioninnovationhub.org.uk/wp-content/uploads/2022/06/Value-Toolkit_Value-Definition-Framework_v3.0-RGB.pdf 3

[7] National Composites Centre, Seismic II – Platform-based approach for construction, (2002) https://www.nccuk.com/media/gevc2iw2/seismic-case-study-8.pdf