Streamlining the Value Engineering Process and its Impact on Building Energy Performance

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ABSTRACT

Value Engineering (VE), as used in building design and construction projects, aims to identify opportunities to reduce construction cost, optimize the performance of the future building, reduce future operating expenses and cost, shorten building delivery time, and possibly avoid (future) legal problems and litigation. In its current practice VE action typically focuses on issues for which quantitative data are on hand (i.e. reduction of construction cost based on cost estimates), while leaving to speculation the assessment of the *impact* of a given construction cost reduction on the future building's performance. Most new building *designs* include features and measures to minimize energy consumption but, *once in use*, such buildings often fail to meet their energy performance expectations. Analyses of design histories usually show that the planned and designed energy efficiency features and measures were eliminated due to blunt cost cutting in VE events. This paper describes Performance Based Value Engineering (PBVE), which can mitigate problems encountered in standard VE events. It employs semi-automatic generation of input for simulation of building energy performance, which enables quick delivery of predicted energy performance and operating cost to provide a quantitative counter argument to blunt cost cutting.

INTRODUCTION

Basic principles of Value Engineering (VE) were developed during World War II (Investopedia 2012). VE was not seriously considered on large scale until the 1970's (U.S. General Services Administration 1992), and has since been deployed by the buildings industry in a variety of forms and with different results. While definitions of VE vary (Wikipedia 2012, Investopedia 2012, McGraw-Hill 2003), they all define the *same fundamental concept* and the *same goals*: the use of a systematic and organized method or approach, provision of the necessary functions in a project at the lowest cost, and *preservation of all basic functions without function reduction* as a consequence of pursuing value improvements. Public Law 104-106, Section 4306 - Value Engineering for Federal Agencies and *A Guide to Integrating Value Engineering, Life-Cycle Costing, and Sustainable Development* (Federal

Facilities Council 2001) require and define the process and use of VE for the public buildings.

VE was not seriously considered by the buildings industry until the 1970's, and has since been deployed in a variety of forms and with different results. No laws or regulations currently define or prescribe the use of VE in the private commercial buildings sector. There the use of VE in most cases considers only the analysis of issues for which up-to-date quantitative data are on hand.

CURRENTLY PREVAILING PRACTICE OF VALUE ENGINEERING

This typically amounts to reduction of construction cost based on available construction cost estimates, while leaving the assessment of impact of a given construction cost reduction on the future building's performance to *speculation* (Figure 1A).

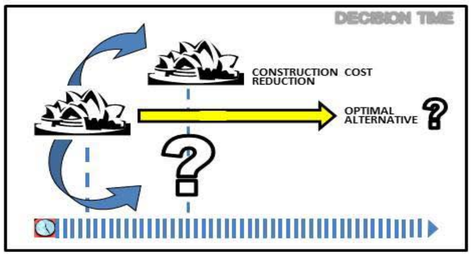
The impact of cost reduction on building energy performance and operating cost usually cannot be quantified by the time a decision is made and counter arguments cannot be supported quantitatively. By the time such quantitative assessments are generated, the cost cutting decision has typically already been made and implemented. The "savings" resulting from such cost cutting are hardly ever reinvested in the project, and are certainly hardly ever used specifically to improve the building's energy performance. This is particularly true in VE cases where the construction cost estimate exceeds the available or planned construction budget. Originally integrated design does not appear by itself to prevent the results of current VE practice – building designs developed this way are just as susceptible to blunt cost cutting to reduce the overall construction cost in VE as any other.

Such practice of VE deployed in commercial building design and retrofit projects typically results in decisions that are not optimal and are often counter-productive. It is one of the reasons why the resulting buildings do not meet their original energy efficient performance plans and expectations. Most offers for VE consulting service related to building procurement, found currently on Internet, emphasize their "cost reduction services" but do not discuss building energy performance.

Ideally, VE should identify opportunities to reduce building delivery cost (i.e. reduce construction cost), to assure that the future building can be used effectively and efficiently in all aspects of its function, to optimize the future building's energy performance, to reduce future operating expenses and cost, to shorten building delivery time, to maximize the return on investment (ROI) in the future building, and to possibly avoid (future) legal problems and litigation. Unfortunately, cost cutting in the current practice of VE can seldom be countered with effective arguments that are supported by quantitative documentation of effects of debilitating cost cutting on the building's energy performance. This effectively transforms VE into an exercise in blunt construction cost cutting.

PERFORMANCE BASED VALUE ENGINEERING

Analysis shows that the currently standard way of generating the needed quantitative estimates of performance is too slow to provide the estimates when they are needed. This is mostly caused by partly manual definition of needed additional data, manual data exchanges, model testing, manual model correction and input creation for simulation of performance that generates the estimates. The objective of Performance Based Value Engineering (PBVE) is to enable immediate quantitative estimation of effects of any changes to building design on the performance of the designed building. The key issue is time: prompt delivery of performance estimates in direct response to a proposed change to the building (Figure 1B). Such quantitative estimates, if generated within the time frame of the decision making event, make it possible to quickly compare expected savings from the elimination of a building element or feature to the cost of not having that element or feature in the building. Immediate or semi-immediate (delayed by only hours, rather than days or weeks) performance estimates can now be obtained by the use of semi-automated simulation methodology.



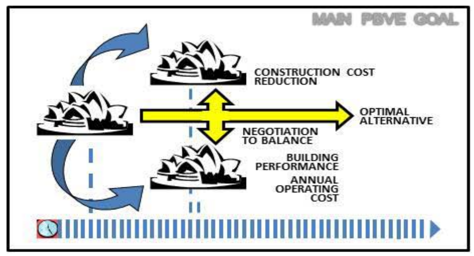


Figure 1. A. Blunt cost cutting in VE. Figure 1. B. Decision making in PBVE.

PBVE is just a special case of collaborative or integrated design. It "levels the field" in VE events – it allows all parties and disciplines participating in a design decision process to fairly present their case and to have their concerns truly considered. Correspondingly, PBVE makes it possible to negotiate optimal design decisions based on the comprehensive consideration of all estimated effects of the decision (Figure 1B). Its methodology can be relevant and applicable to other types of design decision making, as well as to the comparison of design alternatives.

As PBVE enables a quantitative comparison of performance, its use in VE events and in design decision making is critical to maximizing the energy efficiency of proposed building designs and retrofit plans. The consideration of building energy performance usually involves data from a smaller set of disciplines – architectural design, mechanical and electrical design, construction cost estimating. PBVE that is focused on the use of energy in buildings is here called "Core" PBVE, and the methodology described below is the Core PBVE methodology.

PBVE ENABLING TECHNOLOGIES

Successful PBVE events require the use of building models and software capable of simulating the given building performance. Building models must be "intelligent" (i.e. object-oriented, generated by model-based CAD tools capable of data export in IFC format specified by ISO (ISO 16739). They must be complete, must include the definition of thermal properties of all construction materials in the building, and must be error-free and tested by model checking software (Maile et al. 2013).

Simulation software must have the functionality required to provide reliable simulation of the given type of building performance. It must be able to import data in IFC format and use them; any necessary transformation of data must be done per rules embedded in applicable middleware. Simulation software must also be able to report any type of data it generated that are necessary to effectively document the needed building performance.

Building models must reside in a model server, so that data exchange is as efficient as possible. Data exchange itself must be automatic (or at least semi-automatic), direct and error-free. As all data interoperability is based on the IFC data model of buildings (buildingSMART International 2013) and its format, CAD software used in PBVE events must have properly tested and working IFC interfaces.

CORE PBVE METHODOLOGY

Since Core PBVE is focusing on the effects of the proposed changes to the building on its energy performance, the performance simulation must be done by a "whole building" Building Energy Performance (BEP) simulation engine. Core PBVE methodology described here is designed for a PBVE process that uses EnergyPlus (DOE 2013) as the BEP simulation engine. Other BEP simulation engines may be used in place of EnergyPlus if the middleware that transforms input data for the simulation and delivers data in the input format of the simulation engine is adjusted.

Actors in PBVE events have a modeling, a decision making and/or an advisory role, depending on the decision that is being evaluated. In Core PBVE events four actors have modeling roles: the architect, the HVAC designer, the energy modeler and the cost estimator. Each is responsible for the maintenance and operation of their discipline's model of the analyzed building. While models of other disciplines may be affected by the proposed changes to the building, they are not directly involved in Core PBVE. Building owners and operators, facility managers, other engineering consultants, construction managers and other event participants may have a decision making and/or an advisory role, again depending on the decision being evaluated.

All discipline models are prepared in advance of the PBVE event. Current-status models for each discipline are tested for errors and "cleaned" if necessary as a pre-processing step. Data exchange among all models is also tested and verified. When possible, proposed or expected changes to the building, as well as associated cost estimates, are modeled in advance.

PBVE process starts by defining and modeling changes to every current-status discipline model of the building that is affected by the proposed modification or by the elimination of a building element or feature. Changes to the building's geometry model are made by architects representing the project architectural design team, changes to the HVAC design by HVAC designers representing the project HVAC design team, changes to input for EnergyPlus simulation by the project energy modeler (who executes the EnergyPlus simulation), and changes to construction cost estimates by cost estimators representing the project cost estimating team (Figure 2).

All models reside on the same model server and model changes are made in parallel. Model changes to building geometry are seamlessly transmitted to HVAC designers, the energy modeler and cost estimators, who then promptly adjust their models accordingly. HVAC model changes are seamlessly transmitted to architects, the energy modeler and cost estimators, who then promptly adjust their models as necessary. The results of BEP simulation with EnergyPlus are displayed in detail as they are generated. The cost estimate reflecting the analyzed change to the building is also shown in any desired detail.

All model data and results of computation are immediately displayed on large monitors (see Section CORE PBVE EVENTS below) to everyone involved in the Core PBVE event (Figure 2). This allows direct real-time examination of provided data and facilitates a detailed quantitative discussion of the effect of the analyzed change to the building on its performance. Figures showing the reduced construction cost can be directly compared to simulated figures showing the resulting change in operating cost and energy consumption. In this way Core PBVE event participants can reach an informed, negotiated and balanced decision about the considered change to the building design or retrofit that truly considers building energy efficiency and may not scarify it for the sake of construction cost cutting.

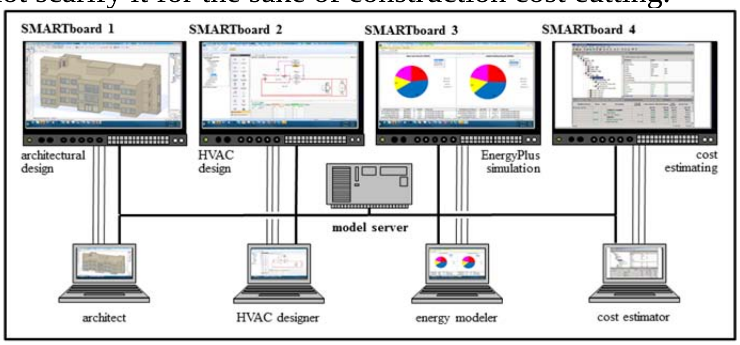


Figure 2. All actors in a Core PBVE event work in parallel on their models.

SEMI-AUTOMATED GENERATION OF INPUT FOR BUILDING ENERGY PERFORMANCE SIMULATION

Elimination of originally planned and designed building energy efficiency measures and features inevitably increases the operating cost and the energy consumption of the future building. BEP simulation generates the critical data that provide quantitative explanations of the effect of the proposed change to the building on the building's energy performance: It calculates the operating cost and the amount of all forms of energy used by the building during any period of interest.

The current prevailing practice of preparing simulation input for a state-of-the-art simulation engine like EnergyPlus, energy model debugging, simulation execution and the analysis of results take quite a long time. Simulation input preparation is the main culprit for that: It is mostly created manually and is error prone. Inclusion of data from different disciplines that are used in the simulation is also manual and time consuming. Simulation results are typically made available only after (sometimes long after) the proposed cost cutting decision has already been made in VE.

The only feasible way to reduce the simulation preparation and execution time today is to deploy *semi-automated* simulation with a BEP simulation engine like EnergyPlus. This approach uses original sources of information (i.e. information developed or provided by the party contractually or legally responsible for it), automates data transformation and generates input data in a file that has proper content, form and format for use by EnergyPlus. Figure 3 illustrates semi-automated generation of input for EnergyPlus (Bazjanac 2008).

All data transformation in semi-automatic generation of input for BEP simulation is done automatically per data transformation rules built into software. Building geometry data are transformed by the Space Boundary Tool (SBT), which imports original architects' data defined in a model-based CAD tool in IFC format, calculates all "space boundaries" (modeling name for building surfaces in EnergyPlus), assigns correct thermal properties to each construction material defined in the model, and generates a complete geometry input file in IDF format (input format for EnergyPlus). SBT can also interactively set simulation run control parameters (Rose and Bazjanac 2013).

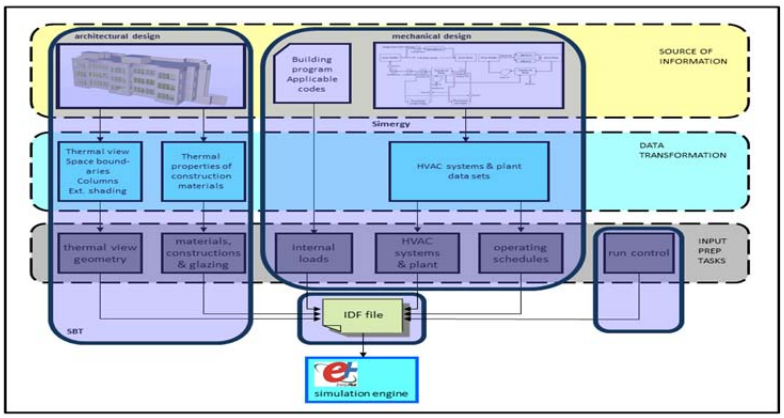


Figure 3. Diagram showing the semi-automatic generation of input for BEP simulation with EnergyPlus.

Manual definition or copying of HVAC equipment, systems and plant definitions into EnergyPlus input files is too subjective, error prone and time consuming. In semi-automatic generation of input HVAC definitions are created with the Simergy graphic user interface (GUI) for EnergyPlus (Simergy 2013). This GUI facilitates dragging-and-dropping of HVAC symbols (which graphically represent HVAC objects in Simergy's HVAC object library) into graphically represented HVAC "loops." It also facilitates graphic definition of building use and performance schedules based on templates in the schedules library. The process defines the building's HVAC system and plant and their use and operation, and it automatically generates the HVAC portion of the IDF file. This is much faster and much less error prone than the manual process.

BEP simulation engines need data to calculate internal loads for the simulation. Simergy generates such data interactively. Spaces are quickly agglomerated into thermal zones by dragging-and-dropping their symbols into thermal zones shown in the building model object tree. Occupancy schedules and related load profiles are selected from associates Simergy libraries. Internal loads data defined in this way are automatically added to the HVAC part of the input file for the simulation.

EnergyPlus can report virtually any data it contains or generates. Data are documented in standard or custom reports of simulation results. Simergy can also facilitate the selection and effective display, as well as documentation, of simulation results that estimate the analyzed building's energy performance for consideration in PBVE event discussion and decision making.

BEP simulation is the critical component in Core PBVE. It generates the quantitative data needed to illustrate the effect of design changes and alternatives on the energy performance of the building. The speed at which it delivers its results can be detrimental to design decision making – if not delivered in decision making time frame, consideration of energy performance may not be effective. Semi-automatic generation of input for BEP simulation makes it possible to prepare and execute BEP simulation much faster than before and in time for its results to be fairly considered.

COMPARING CONSTRUCTION AND ENERGY PERFORMANCE COSTS

To be useful, the effect of change in construction cost on the resulting energy performance of the building must always be expressed in monetary units. Only in that way can the two be properly compared.

Construction cost estimates are generated by cost estimating tools that can calculate meaningful estimates with data available at a given stage of the building's design. Generated cost estimates must fairly reflect the building data available at that stage of design, because energy performance estimation uses data available at the same stage. Different cost estimating tools may be used at different stages of the project development process, as more detailed data become available when the project is farther developed. This, in time, may warrant the use of more and more sophisticated estimating tools.

Operating costs of the future building are calculated from information supplied by building operators and facility managers. Energy performance costs account for the cost of operating the building over its entire life-cycle; they also include the cost of energy consumed in the building. Operating cost includes regular as well as increased or decreased maintenance and replacement costs.

CORE PBVE EVENTS

PBVE is most effective when its events are conducted in special facilities designed to support collaborative design and engineering, such as iRooms. These facilities provide the hardware (SMARTboards, a model server, all necessary local and remote connectivity and networking) and software needed to conduct successful virtual building performance simulation experiments (Figure 3). PBVE event participants bring their own laptops, software and models of buildings, and are easily immersed in the facility's environment.

Advanced preparation of the necessary data and models helps Core PBVE events run more smoothly. The same is true when participating actors are experienced, well prepared and have the necessary skills and knowledge needed to effectively participate in the event. The conduct of the event, participation of actors and used software will depend on the analyzed building's type, size and location, and on the stage of the building's design or development. Some form of PBVE can be usefully deployed at any stage of development of a commercial building design or retrofit.

CONCLUSION

Performance Based Value Engineering is a collaborative design/engineering process which can assure that the contribution of all parties involved in design and construction of a given building are fairly considered. It can help preserve the originally designed building energy efficiency features and measures and can help, within acceptable construction cost, even maximize the energy performance of the building once the building is in operation.

The building construction industry needs to start deploying PBVE regularly in their projects. Building project owners will have to start requiring PBVE use in their projects, which in turn will necessitate changing the content and form of current project contracts. The industry will also have to significantly increase it overall modeling capability and competence, as the success of PBVE deployed in individual projects depends on the quality of building models used in PBVE events.

Thoughtful use of PBVE can also help meaningfully reduce construction cost. It can provide a forum for negotiation when design decision making has conflicting aspects – quality design and engineering often involve effective negotiation.

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REFERENCES

Bazjanac, V. (2008). IFC BIM-based methodology for semi-automated building energy performance simulation. In L. Rischmoller (ed.), *CIB W78, Proc. 25th conf., Improving the management of construction projects through IT adoption, Santiago, CL*: 292-299. Universidad de Talca. ISBN 978-956-319-361-9.

buildingSMART International (2013). http://www.buildingsmart-tech.org/downloads

DOE (2013). http://apps1.eere.energy.gov/buildings/energyplus/energyplus_documentation.cfm

Federal Facilities Council. (2001). Technical Report No. 142.

Investopedia (2012). http://www.investopedia.com/terms/v/value-engineering.asp.

ISO 16739:2013 Standard (2013). http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=51622.

Maile, T., Bazjanac, V., O'Donnell, J. T, and Rose, C. M. (2013). BIM – geometry modeling guidelines for building performance simulation. *Proceedings of BS2013: 13th Conference of International Building Performance Simulation Association*, Chambery, France, August 26-28.

McGraw-Hill. (2003). Dictionary of Scientific & Technical Terms.

Rose, C. M., and Bazjanac, V. (2013). An algorithm to generate space boundaries for building energy simulation. *Engineering with Computers*, Vol. 29, No. 4, 2013, ISSN 0177-667.

Simergy. (2013). http://energy.lbl.gov/bt/simergy/key.html

U.S. General Services Administration. (1992) GSA PBS-PQ250.

Wikipedia. (2012). http://en.wikipedia.org/wiki/Value_engineering.