Quantifying the Cost Benefits of Commissioning

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Synopsis

Significant attention is often focused on the first costs of commissioning, and industry data is available to owners who wish to determine how much they should expect to pay for quality commissioning services. In order to promote the true value of commissioning, providers must also be able to quantify the cost *savings* that they generate for their clients. Quantifying the cost benefits of commissioning is of great importance to owners, contractors, and commissioning consultants; however, no clear method exists to define these savings. Individuals involved in the building commissioning process would benefit from a method for determining the cost benefits of commissioning.

This paper describes a cost benefit methodology that was developed based on the experiences of the authors. It takes the reader through a step-by-step process that formulates quantitatively the cost savings generated through the use of the commissioning process. This methodology is applicable throughout the planning, design, construction, and operation phases of the building project. A case study is used to demonstrate the methodology within the design phase of an actual project.

About the Author(s)

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Introduction

Building commissioning is often promoted as providing many benefits to owners, not the least of which are project cost savings. However, many owners who have never used the commissioning process are apprehensive, and cannot be convinced without case studies that show the value of the process. Unfortunately, while the first costs associated with using commissioning are fairly well documented and accessible to owners, very little data is widely known about the cost savings that the commissioning process often generates for a project. In order for the building commissioning industry to grow substantially and gain widespread acceptance, more data is needed to support the claim that commissioning saves the owner money.

Commissioning must be cost effective for the owner and the project team in order to survive the test of time. If the owner or project team views commissioning as increasing the costs of the project without an overall benefit, then eventually they will stop requesting it. Why do something that drives up project costs? Commissioning authorities must be vigilant in documenting the savings that they generate for the project, as it is in their own best interest. Documenting the cost benefit provided by commissioning must become a standard practice on every commissioned project.

Ironically, the most successful commissioned projects are the projects most in need of a cost benefit analysis. The commissioning process, which begins in the earliest stages of a project and lasts through the first year of operation, is designed to eliminate problems and resolve issues before they become major problems. When the commissioning process is highly successful, the number of change orders, RFI’s, scheduling problems, conflicts, etc. will be greatly reduced. When a project goes smoothly like this, the owner may wonder why the commissioning process was needed at all. The Commissioning Authority must document their activities to remind the project team that the seemingly “perfect” project was a direct result of the commissioning effort.

Commissioning authorities need a consistent means of showing their value on every project. To this end, this paper presents a methodology for evaluating the cost benefit of commissioning. It is intended for use by commissioning authorities, or anyone with the proper information, for application on individual projects.

Qualities of a Useful Methodology

The methodology developed in this analysis was designed with the following characteristics:

- Can be consistently applied no matter what type of project or the scope of the project;
- Can be applied to the entire project or just in one or more phases;
- Thorough, repeatable, and conservative;
- Gives the best possible estimate using available data;

- Can be developed with minimal time input and minimal additional effort by the commissioning authority;
- Can be understood by the owner and the members of the commissioning team;
- Gives a range of values based on valid, conservative estimates of cost factors and savings.

A Cost Benefit Methodology

The cost benefit methodology described below has been developed to embrace all the qualities listed in the previous section. It is based on the experiences of the authors and involves four steps as follows:

Step 1 – Identify and Record Issues

A commissioning issue is defined as a finding that does not meet the design intent of the project. From the moment a commissioning authority is hired, one of his or her main responsibilities must be to keep a detailed record of all *commissioning issues* that evolve as the project progresses. The term "issue" is used in place or "problem" or "deficiency" because it is a more neutral term, which tends to create a better sense of teamwork and cooperation on projects. With each issue, the following information should be recorded:

- Issue "birth" - the date an issue is discovered and brought to the attention of the appropriate team member or owner.
- Description of the issue - including information about the equipment affected and the current state of progress (in design, partially constructed, etc.).
- Contact person and party responsible for resolution (e.g., designer, architect, mechanical contractor, electrical contractor, etc.).
- Issue "life" - the amount of time between the issue "birth" and its resolution.
- Role of Commissioning - the role the commissioning process played in identifying and resolving the issue.

Although all issues that occur during a project should be recorded, the Commissioning Authority should determine which issues are to be included in the scope of the cost benefit analysis. Possible reasons for excluding a particular issue from a cost benefit analysis could be lack of adequate information or negligible effects on the project outcome. Also, if commissioning played a very limited role in the identification and resolution of the issue, then that issue should not be included in the analysis.

The true value of the commissioning process lies in its ability to identify and help resolve the issues that arise on a project. The commissioning process is a method for identifying these issues as early as possible and resolving them as quickly as possible. If an issue is discovered late into construction or even during testing or occupancy, it will be more costly to fix. Likewise, even if an issue is discovered early in the project, the project costs will be higher if the issue is not resolved quickly. The earlier an issue can be identified and resolved, the more money the owner and project team members will save.

Figure 1 illustrates these time aspects of a project issue.

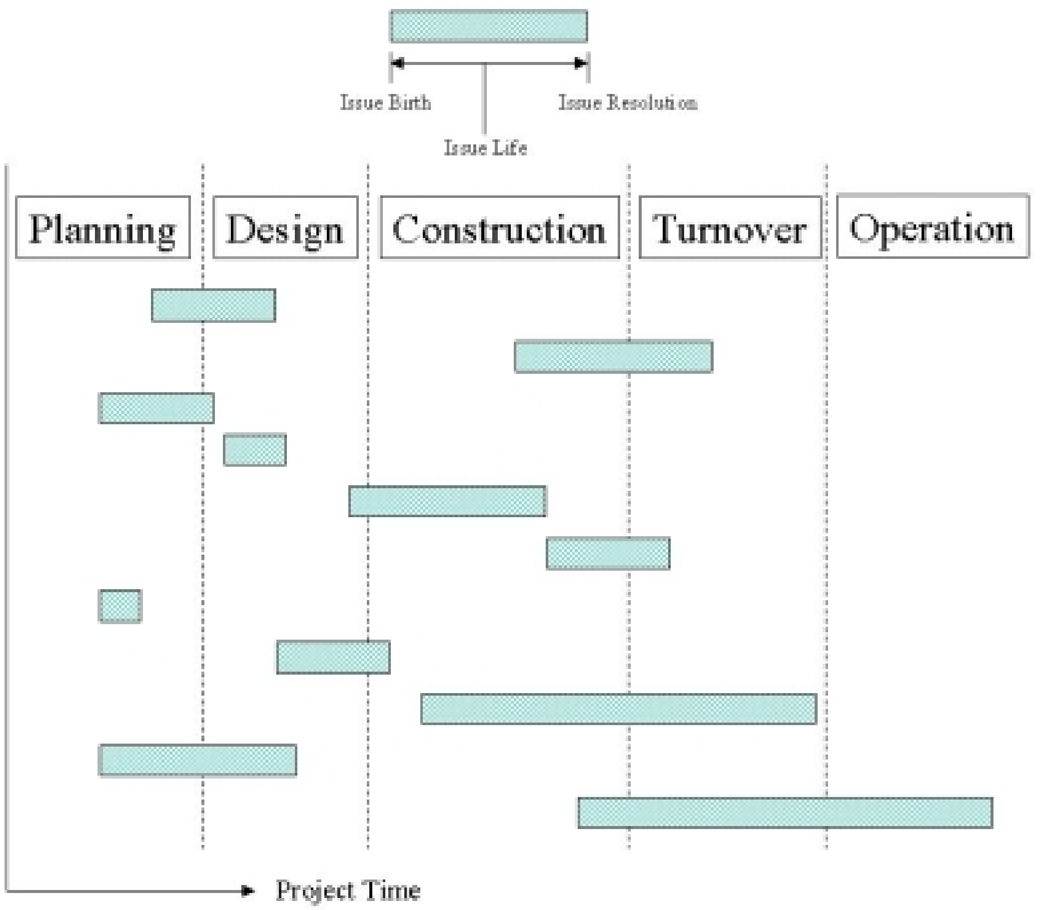

Figure 1 Issue "birth" can occur at any project stage and issue "life" may vary

Ideally, issues will have an early "birth" and a short "life". This type of scenario will keep the issue-related project costs to a minimum. The commissioning process will offer the most value to the project if it can find issues as early as possible and facilitate a quick resolution.

Step 2 –Calculate Avoided Costs

To show the cost benefit that the commissioning process provides, the costs *avoided* due to commissioning must be determined. In other words, the issues must be evaluated as if commissioning was not done on the project. When would the issues have been found? How quickly would they have been resolved? How much higher would project costs have been without the commissioning process in place? The goal of the calculation is to determine the

Avoided Cost (AC). The AC is the amount of money that the commissioning process saved. If commissioning had never been implemented on the project, the AC is the additional cost that the owner would have paid in order to receive the same high quality facility that the commissioning process produced. Before a cost formula can be used to calculate the AC, cost types must be first determined for the particular project in question. Although facility types will differ, the cost types can be described in similar categories. The following sections will provide examples.

Cost Types

The two main types of costs are *issue resolution cost (IRC)* and *issue effect cost (IEC)*. IRCs, as the name implies, are costs associated with resolving the issue and include:

- Repair Costs (Rep) – the total costs to fix systems, subsystems or components (may include purchase of parts and transportation).

- Replacement Costs (Repl) – the total cost to replace systems, subsystems or components (may include purchase of parts and transportation).

- Installation Costs (Inst) – the total cost to purchase, transport and install systems, subsystems or components.

- Professional Costs (Prof) – the total cost of professional time (architects, engineers, designers, etc.) needed to evaluate the issue and implement a remedy.

IECs are the costs associated with the effects of an issue from the issue birth until the issue resolution and include:

- Energy cost (Ener) – the total costs due to higher energy consumption.

- Depreciation cost (Depr) – the total costs due to an increase in the rate depreciation of systems, subsystems, and components.

- Maintenance cost (Maint) – the total costs due to an increase in maintenance of systems, subsystems and components.

- Revenue loss cost (Rev) – the total income lost due to decrease in sales (e.g., in stores, supermarkets, etc.) and decrease in business opportunities and services rendered (e.g., in commercial buildings, medical facilities, etc.).

- Productivity loss cost (Prod) – the total income lost due to the decrease in employees' work performance and output.

Before calculating the costs listed above for each issue, the basic assumptions must be recorded. Basic assumptions that go into the above values include the average cost of professional time ($/hr), cost of lost productivity (worker salary wasted during unproductive time), lost sales or business opportunities ($/hr or $/day), cost of energy, cost of replacement equipment, or any other basic value that must be known for the calculation of a particular issue. These numbers will vary for every project, so a reasonable effort must be made to accurately determine them. Whenever possible, exact numbers should be obtained from the owner. If exact values cannot be obtained, then reasonable estimates based on published values (such as % productivity losses) or industry average rates (such as equipment costs and professional fees) should be used.

Cost Formula

Once all the pertinent cost factors are obtained, a cost formula can be used to calculate the results. The cost formula used in this methodology is shown in Equation (1), Equation (2) and Equation (3):

$$AC = IRC + IEC \quad (1)$$

where,

$$IRC = Rep + Repl + Inst + Prof \quad (2)$$

and,

$$IEC = Rev + Prod + Ener + Depr + Maint \quad (3)$$

These formulas show that the Avoided Cost provided by the commissioning process is the sum of all the costs associated with the commissioning issues. These are the costs that were *avoided* thanks to the commissioning effort.

Step 3 – Evaluate Range of Avoided Costs

The above methodology calculates the additional amount of money that would have been spent without commissioning. In reality, the money was never actually paid. Therefore, the calculation of the Avoided Cost is a detailed estimate of the cost of resolving the issue without the aid of commissioning. It is impossible to know for certain what the exact cost associated with each issue would have been, since it is impossible to predict exactly how the issues would have been resolved by the owner and other team members. This last step of the methodology establishes a reasonable range for the AC estimate.

To establish a range of likely costs, two scenarios should be evaluated. The first scenario describes the *most likely* costs for each issue. These costs will be the ones calculated assuming that the design, construction, and operation of the facility occur as in a typical project that does not use commissioning. In this scenario, most issues are not discovered until late into construction or more likely during the first year of operation. Therefore, the first scenario describes costs that would have occurred if each issue had a late "birth" and typical issue "life". For issues that may go unresolved, the recurring cost over a period of years should be included.

The second scenario should describe the least cost solution to the issue. In this case, the costs should be calculated assuming that the solution is remedied "perfectly" by the other team members, resulting in the least possible cost to the owner. This may require making unlikely assumptions, such as issues being discovered very quickly or by chance.

The two scenarios will produce a larger AC and a smaller AC. These two cost numbers represent the most likely savings and the minimum savings attributable to commissioning on the project. Both the Commissioning Authority and the owner can look at these numbers and compare them to the Commissioning Authority's fee to see whether the commissioning process is a worthwhile investment.

A Case Study Project

Background

This methodology has been applied to previous projects to determine the value of the commissioning process for clients. Often, the numbers help to convince owners that the up-front fees for commissioning are worthwhile. The example project shown here is a supermarket. Some basic information about the project is shown in Table 1.

Table 1 General Case Study Information

Building Size	*14,350 ft²*
Building Type	*One-story retail*
Location	*Wisconsin*
Groundbreaking	*April, 1999*
Store Opening	*March 13, 2000*
Budget	*$2 million*
Construction Method	*Design-Build*

Applying the Methodology

There were several issues identified in this commissioning project. However, only four issues were selected for the cost benefit analysis. All four issues were discovered during the design phase of the project and were selected to highlight the importance of early-stage commissioning efforts. The four issues are described briefly below. For each issue, the calculation of the two cost scenarios is described. Table 2 shows the assumptions that were used in making the calculations.

Table 2 Basis of Calculations for Case Study

Factors in Cost Formulas	Value	Units
Cost of Contractor Labor	50	Dollars/hr
Cost of Professional Time	75	Dollars/hr
Average Revenue	16,000	Dollars/day
Productivity Loss	5	%/employee/day
Revenue Loss	2	%/customer
Employee Labor Cost	7	Dollars/hr
Employee Labor Period	8	Hrs/day
Time Period for Recurring Costs	20	Year

Issue 1: Rooftop Cooling Capacity

Early in the design process, the packaged rooftop air-handling unit was specified with a cooling capacity of 25 tons. Using the information supplied by the design engineer for the Basis of Design, the commissioning authority reviewed the calculations for the rooftop unit sizing and discovered a mathematical error. Correction of the calculations showed that additional cooling capacity would be required, and the next largest available standard size for a comparable packaged unit was 40 tons.

Action

The specified rooftop cooling capacity was increased to 40 tons.

Avoided Cost

Scenario 1(Most Likely): The rooftop unit with 25 tons of cooling must be replaced with a rooftop unit with 40 tons of cooling capacity after the 25 ton unit was installed and discovered to be too small. The cost for the rooftop unit with 25 tons cooling capacity that must be discarded is estimated at $18,000. It is assumed that 50% of this cost is recoverable. The replacement will take 2 workers three days, 2 workers*3 days*8 hours*$50 per hour = $2,400. Transportation and crane cost is estimated at $500. The engineer, contractor and owner will spend time discussing who has to pay for the changes, each about one day, 3 professionals*1 day*8 hours*$75 per hour = $1,800. The store will be without ventilation, heating and air conditioning for 3 days, and must be closed, causing a considerable loss in sales, 3 days*$16,000 per day =$48,000. In addition, the store will be uncomfortably hot until the unit can be replaced, causing lost sales and decreased worker productivity. An estimate of 5 workers suffer from a productivity decrease of 5% each due to the warm temperature, and 10% of the shoppers who enter the store are uncomfortable, resulting in a 2% decrease in purchases per shopper for an arbitrary period of 10 days. The cost of the lost worker productivity is 0.05*10 days*$7 per hour*8 hours per day*5 workers =$140. The cost of the lost sales (prior to closing the store) is 0.02*10 days*0.10 of shoppers*$16,000 total sales per day =$320. The total cost would have been at least $62,160.

Scenario 2 (Least Cost Solution): The contractor or engineer discovers the error when the submittals are given from the supplier. They will both spend a day to correct the mistake, 2 professionals*1 day*8 hours*$75 per hour = $1,200. The change order will not be competitively bid and cost 10% more than competitive bids, $2,000 added cost to the owner. The schedule will be delayed at least three days due to the correction, which will cause lost sales, 3 days*$16,000 day = $48,000. The total cost would have been at least $51,200.

Issue 2: Outside Air Intake Location

The original design for the rooftop unit showed the location of the air intake close to the loading dock, which presented the possibility that the unit would draw in exhaust from the trucks. Part of the owner's Design Intent stated that the store must have good indoor air quality, so the design team felt that a change in the positioning of the rooftop unit was desirable.

Action

The layout of the roof design was changed to move the rooftop unit further away from the loading dock, and the unit was rotated 180 degrees to position the air intake on the side facing away from the dock area.

Avoided Cost

Scenario 1 (Most Likely): The customers and workers would have been exposed to exhaust gases (CO, NOx, etc.) causing them to feel bad and smell fumes intermittently. The problem is not considered serious and is not corrected. Over a 20-year period, worker productivity and sales are lost. An estimate of 5 workers suffer from a productivity decrease of 5% each due to the fumes, and 10% of the shoppers who enter the store are affected, resulting in a 2% decrease in purchases per shopper per day. The cost of the lost worker productivity is 0.05*355 days*20 years*$7 per hour*8 hours per day*5 workers =$99,400. The cost of the lost sales is 0.02*355 days*20 years*0.10 of shoppers*$16,000 total sales per day =$227,200. The total cost would have been at least $326,600, or $16,330 per year.

Scenario 2 (Least Cost Solution): The customers and workers would have been exposed to exhaust gases (CO, NOx, etc.) causing them to feel bad smell fumes. The rooftop unit would have been relocated. The engineer and contractor would have to work one day each to solve the problem, 1 day*2 professionals*8 hours*$75 per hour = $1,200. The relocation will take 2 men five days, 2 workers*5 days*8 hours*$50 per hour = $4,000. The store would have had decreased productivity and possibly lost sales until the relocation. An estimate of 5 workers suffer from a productivity decrease of 5% each due to the fumes, and 10% of the shoppers who enter the store are affected, resulting in a 2% decrease in purchases per shopper for an arbitrary period of 10 days. The cost of the lost worker productivity is 0.05*10 days*$7 per hour*8 hours per day*5 workers =$140. The cost of the lost sales is 0.02*10 days*0.10 of shoppers*$16,000 total sales per day =$320. The total cost would have been at least $5,660.

Issue 3: Store Relative Humidity

As part of the owner's green building goals, the Design Intent for the store required low energy consumption. To minimize the energy use in a supermarket, the humidity must be maintained at a level that minimizes both the energy required to cool the air and the energy required to defrost the refrigerated display cases. Energy modeling determined that the optimum relative humidity for this store was about 40%. The design originally called for 55% relative humidity.

Action

The humidity ratio for the calculations of the required cooling capacity was decreased to 40% before the unit size was specified.

Avoided Cost

Scenario 1 (Most Likely): The store was designed and constructed with a higher humidity than the optimal 40%, calling for more frequent defrosting and higher energy consumption. The higher humidity was identified as a problem, and the rooftop unit was replaced. The cost for the rooftop unit with 25 tons cooling capacity that must be discarded is $18,000. It is assumed that 50% of this cost is recoverable. The replacement will take 2 workers three days, 2 workers*3 days*8 hours*$50 per hour = $2,400. Transportation and crane cost $500. The engineer, contractor and owner will spend time discussing who has to pay for the changes and how it can be done, each about one day, 3 professionals*1 day*8 hours*$75 per hour = $1,800. The store will be without ventilation, heating and air conditioning for 3 days, and must be closed, causing a considerable loss in profits, 3 days*$16,000 per day = $48,000. In addition, the store will operate at the higher humidity until the unit can be replaced, causing increased energy consumption for an arbitrary period of 10 days, $5 per day*10 days = $50. The total cost would have been at least $61,750.

Scenario 2 (Least Cost Solution): The store was designed and constructed with a higher humidity than the optimal 40%, calling for more frequent defrosting and higher energy consumption. The higher humidity was not identified as a problem. The approximate cost of the increased energy consumption is $5/day, 20 years*365 days*$5 per day = $36,500. The savings due to lower investments in cooling capacity would have been about $10,000. The total cost would have been at least $26,500.

Issue 4: Diffuser Selection

The review of submittals by the commissioning authority revealed that several of the submitted diffusers had too long of a throw and would have caused a draft on customers. The location of the three office diffusers would have caused a draft on employees and poor mixing of the room air.

Action

New diffuser types with shorter throw distances were selected and the diffuser locations in the offices were adjusted to address the problem before installation.

Avoided Cost

Scenario 1 (Most Likely): The store never realizes or fixes the problem. Over a 20-year period, worker productivity and sales are lost. An estimate of 2 workers suffer from a productivity decrease of 5% each due to the drafts, and 5% of the shoppers who enter the store are affected, resulting in a 2% decrease in purchases per shopper per day. The cost of the lost worker productivity is 0.05*355 days*20 years*$7 per hour*8 hours per day*2 workers =$39,760. The cost of the lost sales is 0.02*355 days*20 years*0.05 of shoppers*$16,000 total sales per day =$113,600. The total cost would have been at least $153,360, or $7,668 per year.

Scenario 2 (Least Cost Solution): The customers complain about drafts. The engineer and contractor each spend half a day to solve the problem, 2 professionals*0.5 day*8 hours*$75 per hour = $600. The contractor replaces the three diffusers, 1 worker 1 day, 1 worker*1 day*8 hours*$50 per hour = $400. The diffusers cost approximately $50, 3 diffusers*$50 per diffuser = $150. The three office diffusers were replaced, 1 worker 1 day, 1 worker*1 day*8 hours*$50 per hour = $400. The productivity of the workers would have decreased and sales would have been lost until the replacement. An estimate of 2 workers suffer from a productivity decrease of 5% each due to the drafts, and 5% of the shoppers who enter the store are affected, resulting in a 2% decrease in purchases per shopper for an arbitrary period of 10 days. The cost of the lost worker productivity is 0.05*10 days*$7 per hour*8 hours per day*2 workers =$56. The cost of the lost sales is 0.02*10 days*0.05 of shoppers*$16,000 total sales per day =$160. The total cost would have been at least $1,766.

Results

The totals for the four issues described above are summarized in Table 3 below. The two scenarios provide a range of values that describe the minimum and most likely savings generated by the use of the commissioning process. The most likely scenario includes issues that are left unresolved, so the values include recurring costs over a period of 20 years. Due to the relatively small size of the project, the commissioning fee for the project was well below both estimates. This result showed that the commissioning process was a very worthwhile investment for the owner.

Table 3 Total Cost Avoided due to Cx Issues Identified and Resolved

Issue	Cost Avoided	
	Scenario 1 (Most Likely)	Scenario 2 (Least Cost Solution)
Rooftop Cooling Capacity	62,160	51,200
Outdoor Air Intake Location	326,600	5,660
Store Relative Humidity	61,750	26,500
Diffuser Selection	153,360	1,766
Total	**603,871**	**85,128**

Discussion

In all cases, the numbers used as the basis of calculations must be conservative, unless the owner can provide the exact values. The Commissioning Authority must be careful not to overstate the savings generated by the commissioning activities. The values should be clearly documented, so that those who read the report, especially clients, can understand why the numbers were used and that they represent conservative estimates of the savings.

This cost benefit methodology shows that keeping issue-related project costs low is dependent on time. On the whole, the earlier an issue is found and resolved, the greater the savings that can be generated. Consider the typical project that has five phases: (1) planning, (2) design, (3) construction, (4) turnover, and (5) operation. If an issue is found in the planning phase, then there are at most five phases (including the planning phase) in which cost can be avoided based on the resolution of that issue.

Contrarily, if an issue is found later in the turnover phase, then there are at most two phases (including the turnover phase) in which cost can be avoided based on the resolution of that issue. Sometimes it is very difficult to resolve the issue when identified this late, so the owner may have to "live with it" for an extended period, or even permanently, during the operation phase while paying for it over and over again. This is why the commissioning *process*, which begins early in a project's timeline, can offer far more value to the owner than commissioning begun later during construction or startup.

An important concept that affects time indirectly and thus the magnitude of avoided costs is teamwork. A project that has a well-oiled team that works together well especially whenever issues are raised is likely to spend only the least amount of time needed to deliberate an issue. However, a group of professionals that do not work together well as a team and resort to excessive "finger-pointing" and malicious conflict resolution steps will likely spend a considerable amount of time resolving the issues and thus may increase the overall cost of a particular issue. The commissioning process' ability to facilitate teamwork and cooperation is an additional benefit that is difficult, if not impossible, to properly estimate.

Conclusion

The cost benefit analysis methodology presented offers a way for commissioning authorities to provide clients with reasonable estimates of the value of their services. The methodology is designed to be useful for any commissioning scope and without regard to when commissioning is begun. As long as the commissioning effort had a positive effect on the outcome of the project, then this methodology can be used to assign a dollar value to that contribution.

The authors intend to implement this procedure on every commissioning project, and encourage others to do so as well. Providing widespread, reliable data on the true value of commissioning, not just the first cost, is essential to the continued growth and success of the industry.