Work In Progress: A Thesis-based Option for Enhancing Pedagogy in Engineering Economy at the Graduate Level

Dr. Priyadarshan A. Manohar, Robert Morris University

Dr. Priyadarshan (Priya) Manohar Dr. Priyadarshan Manohar is a Professor of Industrial Engineering and Director of Grants and Research at the School of Engineering, Mathematics and Science (SEMS), Robert Morris University, Pittsburgh, PA. He has a Ph. D. in Materials Engineering (1998) and Graduate Diploma in Computer Science (1999) from University of Wollongong, Australia and holds Bachelor of Engineering (Metallurgical Engineering) degree from Pune University, India (1985). He has worked as a post-doctoral fellow at Carnegie Mellon University, Pittsburgh (2001 – 2003) and BHP Institute for Steel Processing and Products, Australia (1998 – 2001). Dr. Manohar held the position of Chief Materials Scientist at Modern Industries, Pittsburgh (2003 – 2004) and Assistant Manager (Metallurgy Group), Engineering Research Center, Telco, India (1985 – 1993). He has published over 80 papers in peer-reviewed journals and conferences including a 2007 Best Paper Award by the Manufacturing Division of American Society for Engineering Education (ASEE), three review papers and three book chapters. He has participated in numerous national and international conferences. He is a member of ASM International, TMS, ACerS, AIST, ASEE, and a registered Chartered Professional Engineer. Dr. Manohar's research interests include mathematical and computer modeling of materials behavior, thermo-mechanical processing of steels and other metallic materials, microstructural characterization, and structure – property relationships. He has conducted a number of technical failure investigations, consulted on various materials-related problems, and acted as an expert witness in the Court of Law. Dr. Manohar is the past chair of the Manufacturing Division of ASEE and ASM Pittsburgh Chapter.

Capt. Fahad Saad Almutairi , King Fahd Security College

Capt. Eng. Fahad Almutairi lecturer, King Fahd Security College, SA Project Manager Master of Engineering Management, USA Bachelor of Mechanical Engineering, SA

Work In Progress: A Thesis Based Option for Enhancing Pedagogy in Engineering Economy at the Graduate Level

Abstract

Engineering students typically learn the basics of engineering economics through an introductory Engineering Economics course. Such courses do cover the basic financial modeling and analysis techniques, however they don't provide an understanding of the complexity of economic analysis of real life situations. In particular, the financial analysis of public sector projects necessitates financial modeling based on incomplete data and multiple selection criteria along with flexible or diffuse financial frameworks. The costs in these projects are real while the benefits may be tangible and/or intangible which makes decision making very difficult. Teaching such topics in a traditional class room lecture setting may not be best suited to achieve the desired educational outcomes. We propose that adding economic analysis to a thesis-based project is a better way to learn engineering economics. This is demonstrated by a case study involving analysis of a public sector project that offers sufficient flexibility to the students and allows them to come up with viable economic solutions. The student research effort is expected to enhance and enrich the guided learning process. This paper presents some important results from this thesis research work. Preliminary results support the hypothesis that including economic analysis in a thesis option constitutes a better way to engage students in their learning process, and for enhancing their comprehension and interest in engineering economics of government projects.

1.0 Introduction and Rationale

It has long been realized that the engineering economics course content and teaching methods have not kept pace with time. For example, a study by Needy *et al*. [1], [2] conducted as a two-phase survey in 1995 and 1997 of pedagogy of engineering economics found that nearly 47% of the respondents felt the need to redesign how the subject is taught in the class. Another pedagogical issue suggested is that the curriculum of the course has failed to move forward with the times and has in fact "become stagnant" [3]; the curriculum being taught now is almost identical to that taught many decades ago. Efforts are being made [4] – [7] to address this issue by introducing computer-based methods, economic simulations and stochastic algorithms in course curricula. However, the main problem lies in the fact that the traditional engineering economy instruction puts more emphasis on routine and trivial calculations and places much less emphasis on the analysis and decision making processes [8]. Case studies are rarely used (less than 18% of the faculty surveyed utilized case studies) in the teaching tool box [9] – [11] even though case studies allow students to gain insight into the theoretical principles being presented in the class room *via* their practical applications described in the case studies. Curriculum enrichment has also been attempted via instructional videos [12], additional readings and writing research papers [13] and design based problem solving approach [14].

At the author's institution, a Master's in Engineering Management degree program is available that includes a required class in engineering economics. The class is entitled *Engineering Cost*

Estimation and Financial Analysis. The class is offered both online and on-ground with about 12 – 18 students enrolled in each section. The students are given a case study each week that requires them to extract financial data from stated conversations, build a cash flow model and conduct financial analysis. Any incomplete information needs to be filled in using internet-based research and/or by making appropriate assumptions that they need to state in their solution. In the present study we offered this class a research thesis option instead of a traditional classroom course to explore the effectiveness of this method in terms of the pedagogical outcomes. If this approach works then the thesis option can be utilized when enrollments are few and can be a viable option in summer sessions.

At this time, the Accreditation Board for Engineering and Technology (ABET) does not specify educational outcomes for master's level programs, however it is expected that the students would satisfy the requirements for undergraduate education Criterion 3. The master's level engineering program of study requires the completion of at least 30 semester hours (or equivalent) beyond the baccalaureate program. It also requires that each student demonstrate mastery of a specific field of study or area of professional practice. The thesis approach suggested here is expected to demonstrate ABET expectations. The graduate thesis project allows exploration of an open ended question and leads to significantly improved outcomes in terms of student engagement, enrichment and motivation. This option offers a better way to enhance their comprehension and interest in engineering economics.

2.0 Statement of the Problem

The specific problem being addressed with a thesis is related to the economic assessment of government projects. There are many types of government projects around the world that aim to provide multitude of services to society but they are not profitable projects in the financial sense. This leads to a major problem for the decision makers on how to evaluate public projects from a financial standpoint [15]. The success of government projects depends on several factors such as social, economic and technical but some components of these factors may be unclear to decision makers. The ambiguity that decision makers face is in part due to a lack of tools that measure the value of these projects. On the other hand, non-governmental projects anticipate quantitative profits that help evaluate them at the project approval stage. Cost estimation, time estimation, project delivery and subsequent performance evaluation are important for any project. There are many reports describing how government projects are not delivered on time, or on budget or not achieving other intended outcomes [16]. In this paper public school building projects are analyzed and a new evaluation methodology is suggested for determining financial benchmarks.

Government projects are often subject to cost overruns. At the same time, society may not realize their value and the money spent may be considered a waste. The dilemma facing governments is a lack of ways to balance costs versus societal need. They may not know if previously approved projects were well executed and in the case of future projects, the dilemma about proper execution may result if the evaluation and measurement processes are not planned well before project approval. This challenge does not exist in business because companies evaluate the revenues of their projects based on solid financial analysis before proceeding. Professionals in government who must produce a cost/benefit analysis or a business case for their projects come face to face with a unique challenge unknown to their counterparts in private industry. They ask questions like these:

- How do you write a business case if you are not in a business?
- How do you find financial benefits for a government organization besides cost savings?
- How do you use financial metrics such as net present value (NPV), internal rate of return (IRR), or return on investment (ROI) when you don't have benefits that can be measured in monetary terms?

Government organizations are expected to deliver services, not profits. But what is the financial worth of service delivery? [15]. The lack of numerical profit makes that evaluation difficult.

3.0 Suggested Project Evaluation Procedure

One of the solutions that can assist in providing metrics for government projects and evaluating them before approval is to treat them as business projects. There are two steps to make government projects measurable. The first step is to ensure the project will meet all the criteria adopted for project evaluation as shown in Figure 1.

Urgency: All projects that have to be implemented within one year are outside the scope. Some examples of such projects are equipment maintenance and replacement, and national defense.

Project Term: Short term projects are not included. Projects where the time horizon is over 10 years are best suited for the proposed analysis. Examples of such projects include schools, parks, roadways, libraries, and so on.

Similarity: Government projects which can use a numerical cash flow model so that they are similar to business proposals are best suited for this analysis.

Total Cost: Projects where total costs are supposed to be fixed are not included in this analysis. Projects where the total project costs are variable are best suited for this analysis. Some examples of such projects are phase wise expansion and construction.

Number of Users Criteria: The expected number of users needs to be estimated so that a cash flow model can be built.

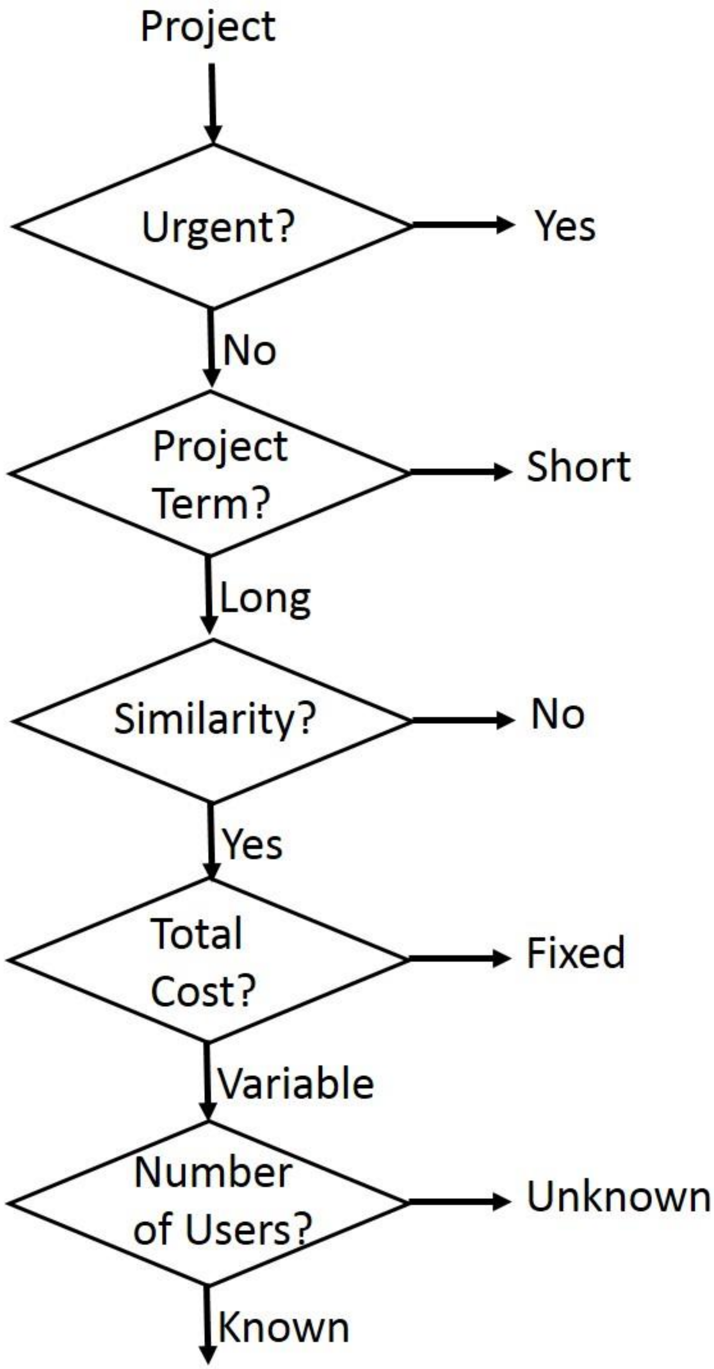

Figure 1: Suggested flowchart for a government project evaluation algorithm.

In some cases, governments do not have the option of whether to implement the project. The social need may be sufficient for the decision. For example, communities that have a high crime rate or high drug use need interventions without consideration of costs. However in a large number of cases where there is a choice, and where projects are not urgent the proposed algorithm will help optimize project costs.

4.0 Financial Modeling

Projects that filter through the algorithm given in Figure 1 are analyzed using well established financial analysis tools. For example, Net Present Value NPV analysis can be used. Net present value is a calculation that compares the amount invested today to the present value of the future cash receipts from the investment. NPV represents the total project cost at present time of all future cash flows:

Equal-payment series present-amount	Given A Find P	$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$	$P = A(^{P/A,\, i,\, n})$

$$\text{NPV} = \sum_{i=1}^{n} \frac{values_i}{(1+rate)^i} \qquad \text{(Eq.1)}$$

In some projects, the value of '***A***' is not constant and may change every year. In such cases ***NPV*** is given by,

$$NPV = P_1 + P_2 + P_3 + \ldots . P_N \qquad \text{(Eq. 2)}$$

Where '***A***' = an end of period cash flow in a uniform series, continuing for ***n*** periods. Government projects do not have '***A***' because the revenue from these types of projects can't be anticipated. However, expenses are known. Expenses are part of cash flow but knowing what they are is not enough to be able to draw the cash flow diagram. To complete all the parts of '***A***', the value of a government project must be turned into figures. One of the methods in which the value can be converted to a number is to take a sample of businesses from the private sector.

There are many important factors in the selection process such as the similarity of the businesses' field and level. Also, the sample must be at the same location of the government project. For example, if the government decides to open a new school, the expected profit should be taken from a private school which has same properties and rank.

The interest rate, ***i*** (expressed as %), is the ratio of the borrowed money to the fee charged for its use over a specific period (usually a year). In our case, the interest rate can be determined by the government or by the interest rate of private sector in the same field. For example, the interest rate of a government health project should be at the same rate of a health care company or better.

A period of time, (***n***), called the interest period (or compounding period), that determines how frequently interest is calculated, is needed. An annual interest rate is typically used in capital projects. The influence of inflation is not included in to keep the analysis somewhat easier.

5.0 Model Data

The data for testing the proposed financial model was acquired from public records. Montour High School [17], [18] is a public high school, opened in 1957, located at 223 Clever Road in Pittsburgh.

The total number of ninth through twelfth grade students at Montour High School is 969. It serves the suburban townships of Kennedy and Robinson, and the boroughs of Ingram, Pennsbury Village, and Thornburg.

In 2006, Montour School District officials announced a plan to remodel the buildings of the existing high school campus and construction officially began in January 2008. The high school renovation was completed, at a cost of $50 million, in September 2011 in time for the start of the school year. This example is to learn whether the project costs of $50M were justified based on cash flow modeling.

According to the school district's website, the total annual expenditure of the school and the cost per pupil is given in Table 1 shown below

Table 1. Cost per pupil and total expenditure for the school district.

Year	Cost per pupil $	The total annual expenditure
2011	19,891	19,274,635
2012	19,978	19,358,682
2013	20,220	19,593,180
2014	21,181	20,524,389
2015	21,362	20,699,778
2016	21,918	21,238,542
2017	21,980	21,298,620
2018	22,315	21,623,235
2019 (expected)	22,700	21,996,300
2020 (expected)	23,000	22,287,000

Montour High School was ranked 28th out of 122 western Pennsylvania high schools and 14th of 77 school district in Pittsburgh. The closest comparable from the private sector is Sewickley Academy. Yearly tuition at Sewickley Academy is $26,670 per pupil. Pittsburgh Public Schools, of course, do not receive tuition fees from students but for the purposes of a comparable analysis, it is assumed they would receive the same amount of fees that a private school such as Sewickley Academy receives. This is considered the revenue stream for the public school for financial analysis.

6.0 Results

The annual revenues are calculated based on the tuition per pupil of the private school ($26,670) multiplied by the number of students in Montour High School (969 students). Based on these calculations a cash flow model is developed as shown in Figure 2 below.

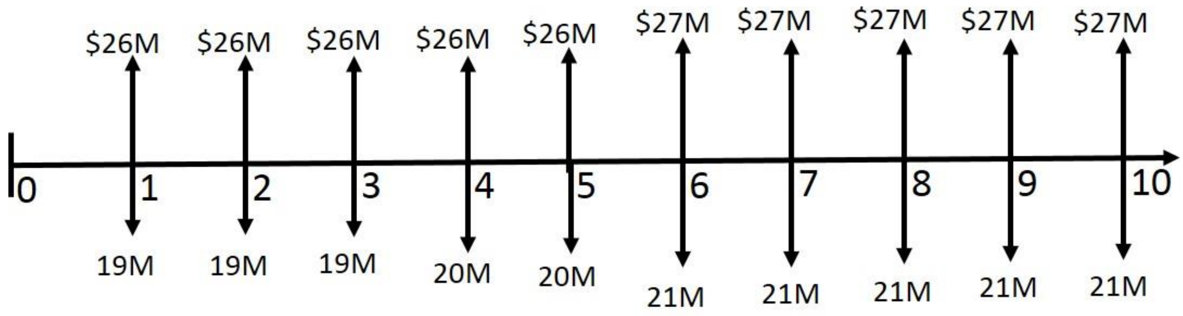

Figure 2: Constructed cash flow model for Montour High School renovation project.

The cash flow model in Fig. 2 shows that the net present value of the renovation project should have been $44,460,000 when the interest rate was assumed to be 7%. This result computes $44.8M to be the optimal amount of money to fund the project based on the actual expenses and the estimated revenue from student tuition. However, the actual cost was reported to be $50M. Therefore, it can be concluded that the cost of the project should have been $6M less in order to consider the project a financially efficient project.

7.0 Discussion

The model presented in Figure 1 and Equations 1 and 2 were applied to the data given in Table 1 for the case of Montour High School. The data analysis was conducted by varying input data over a range of values. One of the variables which affects the result is the interest rate. In this case, the interest rate is assumed to be 7% because this is the average of return rate in business projects. However, the government has option to set the appropriate interest rate. To explore the effect of interest rate on NPV, an additional financial analysis was conducted and its results are as shown in Figure 3.

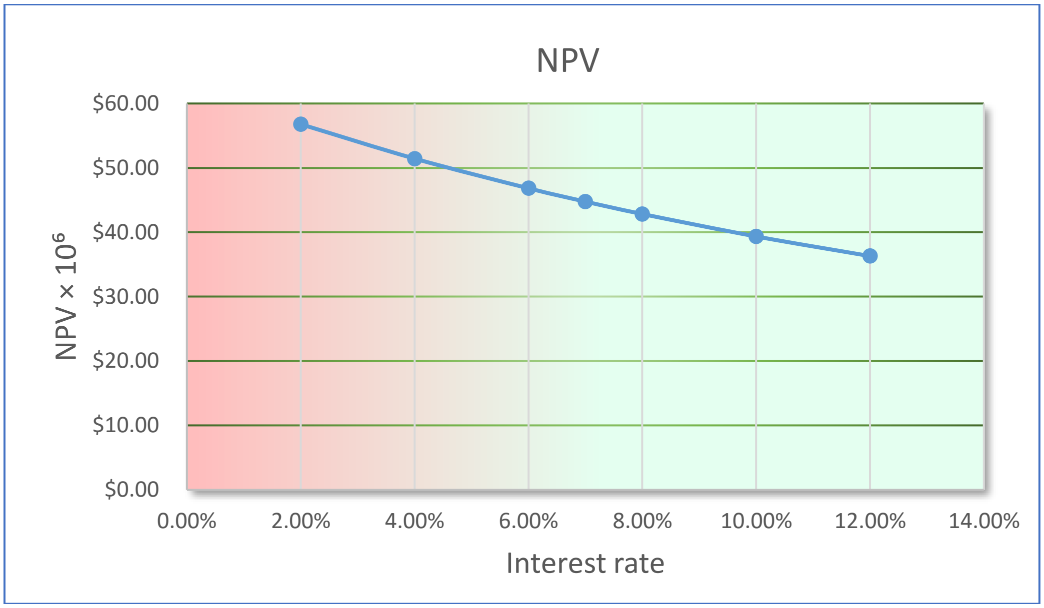

Figure 3: NPV for Montour High School project, present worth as a function of interest rate.

The actual cost of the school project was $50M. The chart in Fig. 3 provides the estimation of an interest rate of 4% based on the actual cost.

Another variable that affects the result is the number of years of operation. Usually, there is some expected lifetime for any given project where the organization will operate and provide its services. This time period will be the input data of the financial modeling. In this project, the number of years is assumed to be 10 years, which is the bond period. If the number of years (***n***) change, the net present value will change too, as shown in Figure 4. It can be seen from Figure 3 that to obtain the best value from the renovation school project, the school must operate the building for at least 12 years.

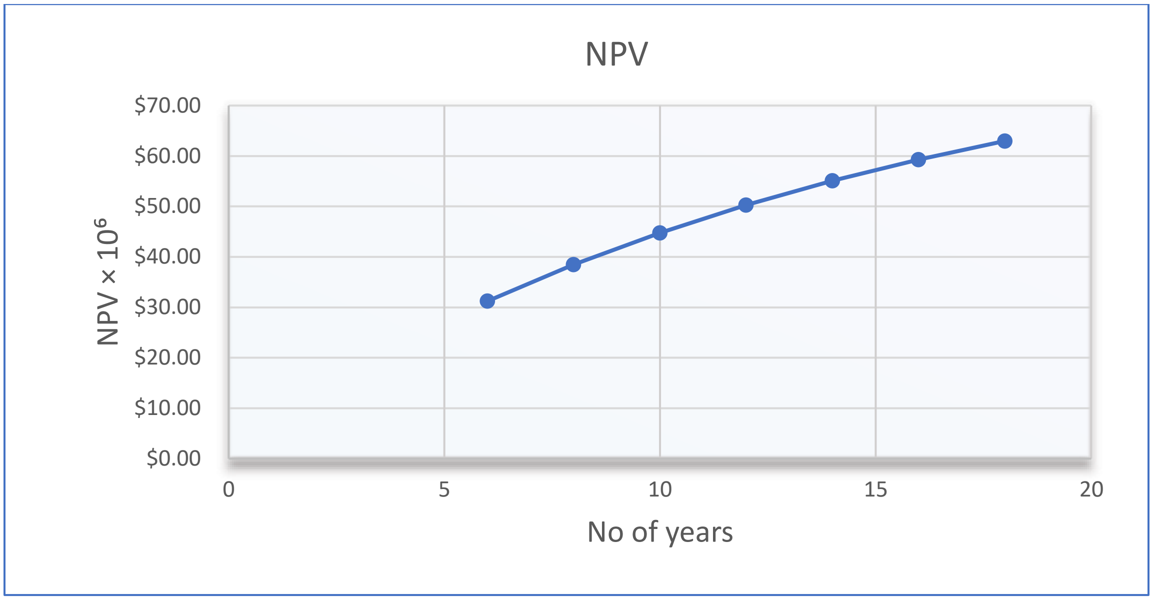

Figure 4. NPV for Montour High School project, present worth as a function of project time.

8.0 Pedagogical Evaluation

The use of engineering economic analysis in this work has helped students to (1) understand complex issues; (2) gain insight into decision-making processes that could be either politically or socially charged; and (3) engage in objective, informative and focused discussion. The work indicated that the use of financial analysis in the case study provided an active learning tool. It has been suggested that engaged active learning helps students develop problem-solving, critical-reasoning, and analytical skills, all of which are valuable tools that prepare students to make better decisions and, ultimately, become better employees [19]. These pedagogical outcomes could be explained in terms of the revised Bloom's taxonomy [20] where higher order learning such as analysis and synthesis are enhanced. In particular, we believe that the case study has enriched the following aspects of student learning:
Taxa V—Advanced Knowledge and Analytical Skills: Can the student distinguish between different parts of a problem? -- Inter-domain and open-ended problem solving skills.
Taxa VI—Project-based Knowledge: Can the student create a new product or develop a new point of view? --Creative, conceptual, analytical, design, manufacturing and management skills.

The thesis work clearly demonstrates that the student attempted to creatively solve the problem by coming up with appropriate evaluation criteria (Fig. 1), conducting financial analysis (Figs. 2 and 3) and developing a new point of view by comparing a government project with a comparable private sector project. This satisfied the pedagogical outcomes specified in Taxa V mentioned above. Further, the student has explored inter-domain problem analysis (e.g. data collection and cash flow modeling) and also dealt with an open-ended problem of how to evaluate a government project where numerical values of annual revenues and benefits are uncertain. This satisfies the pedagogical outcomes specified in Taxa VI mentioned above. It is also interesting to note that the student comes from an overseas culture where appropriate criteria for the selection, prioritization, and evaluation of government projects are not transparent to the public. The thesis option provided him with a learning opportunity in an American setting and subsequently take what he learnt back home to improve the financial system in project planning in his home country. This ability of higher education to build potential in a student to cause positive change is one of the best educational outcomes one could hope for. Thus it seems that the thesis option is well founded on the pedagogical outcomes mentioned above. However, this illustration is just of one student's performance and further data on this teaching method would build stronger evidence for a thesis-based option in lieu of a lecture-based class. Areas of future work include obtaining more detailed information regarding government financial analysis models and guidelines to compare financial outcomes of public sector projects with comparable private sector projects. The symbiosis would enhance students' use of and understanding of economic analysis and design efficiency of public sector projects.

9.0 Summary

The thesis based research option has demonstrated that student had engaged with engineering financial analysis in a significant way. He has collected relevant data, developed appropriate models, selected applicable data analysis method, conducted data analysis, performed critical thinking, and drawn relevant conclusions. The work provides a technique to convert the value of the government projects to figures. In so doing, a rigorous evaluation process can be applied. Such financial analysis is expected to reduce wasted resources because the decision for a project's approval can be based on much clearer, numbers-based criteria. The proposed model can also be used in other non-profit projects that contribute to the development of communities. The objective and insightful financial analysis of a complex project presented in the thesis demonstrates enriched student learning. Thesis based option thus seems to be viable alternative to traditional class room based option to teach this course. The educational outcomes are aligned with revised Bloom's taxonomy where educational enrichment is found in the areas of advanced knowledge, analytical skills and project based learning.

References

1. Needy, K. L., Lavelle, J. P., Nachtmann, H., and Eschenbach, T. G., “An Empirical Analysis of Engineering Economy Pedagogy,” The Engineering Economist, Vol. 45, No. 1 (2000), pp. 74 – 92.
2. Nachtmann, H., Needy, K., Lavelle, J., and Eschenbach, T., “Investigating Engineering Economy Pedagogy”, American Society for Engineering Education Annual Conference Proceedings, 2007.
3. Hartman, J. C., “Suggestions For Teaching Engineering Economy at the Undergraduate Level,” The Engineering Economist, Vol. 44, No. 1, 1999, pp. 110-125.
4. Hartman, J. C., “Engineering Economy: Suggestions to Update a Stagnant Course Curriculum”, American Society for Engineering Education Annual Conference Proceedings, 1998.
5. Bafna, K. and Aller, B., “Enhancing the Learning of Engineering Economy with Innovative Technology and Teaching,” American Society for Engineering Education Annual Conference Proceedings, 2007.
6. Coates, E. R., Vajpayee, S. K., and Juneau, J., “Introducing Engineering Economy Students to Real Options”, American Society for Engineering Education Annual Conference Proceedings, 2003.
7. Evans, E., Nachtmann, H., and Needy K., “A Look into Engineering Economy Education Literature”, American Society for Engineering Education Annual Conference Proceedings, 2010.
8. Elizandro, D. W. and Matson, J. O., “Taking a Moment to Teach Engineering Economics Education,” The Engineering Economist, Vol. 52, No. 2, 2007, pp. 97-116.
9. Lavelle, J. P., “Engineering Economy: A Survey of Current Teaching Practices”, American Society for Engineering Education Annual Conference Proceedings, 1996.
10. Lavelle, J. P., Needy, K., and Nachtmann, H., “Engineering Economy: A Follow Up Analysis of Current Teaching Practices”, American Society for Engineering Education Annual Conference Proceedings, 1997.
11. Manohar, P. A., “Case Studies in Engineering Economics for manufacturing Competitiveness”, American Society for Engineering Education Annual Conference Proceedings, 2012
12. Pohl, L. M. and Walters, S., “Instructional Videos in an Online Engineering Economic Course” American Society for Engineering Education Annual Conference Proceedings, 2015
13. Leland, R. P., “Enriching the Engineering Economics Class”, American Society for Engineering Education Annual Conference Proceedings, 2017
14. Grasman, K., and Cernusca, D., “A Design-Based Approach to Refining Pedagogy in Engineering Economics Online”, American Society for Engineering Education Annual Conference Proceedings, 2016
15. Schmidt, M., “Building the Government Business Case: Measure and Document Business Value in Government, downloaded 12/11/2018, https://www.business-case-analysis.com/government-non-profit-business-case.html
16. Morse, A., “delivering Major Projects in Government: A Briefing for the Committee of Public Accounts”, Jan. 06, 2016, downloaded December 12, 2018, the Comptroller and Auditor General, National Audit office, USA, https://www.nao.org.uk/report/delivering-major-projects-in-government-a-briefing-for-the-committee-of-public-accounts/
17. Pennsylvania Department of Education: Tuition Rate Calculation LEA 201
18. Montour High Schools: https://highschool.montourschools.com/
19. Kunselman, J.C. and Johnson, K.A., Using the Case Method to Facilitate learning, College Teaching, Vol. 52. No. 3 (Summer 2004).
20. Girgis, M. “A new engineering taxonomy for assessing conceptual and problem-solving competencies”, ASEE Annual Conference, Louisville, Kentucky, 2010.