# The Engineering Economics Case Study at Greenfield Coalition

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*Abstract -The Greenfield Coalition (GC) located at the Focus:HOPE Center for Advanced Technologies (CAT) and funded by the National Science Foundation (NSF) offers a Manufacturing Engineering Program that integrates academic work with manufacturing skills learned in the workplace. Engineering Economics has been designed as an eight-module, three-credit course. The first seven modules present the basic fundamentals necessary to make investment decisions. The purpose of this paper is to describe the eighth module, which requires students to demonstrate their understanding of the principles on a real life engineering investment analysis case study. The case study deals with the manufacturing of pulleys involved in the balancing operation of machine components. Because of some malfunctioning in the balancing operation, the manufacturer is faced with a high percentage of scrap. The analysis involves the identification and evaluation of alternate strategies for meeting a projected market demand, as specified in probabilistic terms, leading to the recommendation of a specific strategy. A decision tree was developed depicting various alternatives along with their respective returns. Additionally, a sensitivity analysis is presented to demonstrate the possible impact of changes in crucial variables on the final recommendations. The case study is web-enabled, providing the learner a virtual environment in which to explore many resources impacting investment decisions. Resources include: scrap reports, pricing data, process charts, interviews with key production and engineering personnel, among many others. Learners must sort through these data, define the problem, and propose a solution which is supported by a financial analysis.*

*The Need for Authentic Learning*

Challenged with building a manufacturing engineering curricula that produces engineers who can problem solve and are ready to face real issues from the manufacturing engineering field, the Greenfield Coalition (GC) needed to develop a methodology for incorporating course contextual information and issues into all three of its degree programs. Furthermore, candidates at the Focus: HOPE Center for Advanced Technologies (CAT) have a unique learning environment whereby they work in a manufacturing environment in addition to attending classes. Manufacturing engineering students from other colleges and universities generally do not have the same opportunity. Therefore, GC devised a blended learning system including three components:

- Facilitated classroom activities and discussions,
- Experiential assignments, where credit is granted for actual shop floor tasks and projects, and
- Online interactivities and projects.

The course on Engineering Economics, for example, covers fundamental and advanced concepts ranging from the time value of money through depreciation accounting. These concepts are presented in seven modules which include classroom activities and discussions, as well as online interactivities, such as MS Excel spreadsheets in which students can change data and see results immediately over the web. While these activities allow students to practice calculations and assess trends, they do not allow application of newly-acquired knowledge and skills to authentic situations in manufacturing. In order to introduce the experiential component to this course, a capstone case study was developed. This particular case study in Engineering Economics is depicted from identification of the case to evaluation of implementation.

*The Need for Web-Enabled Case Studies*

Greenfield Coalition (GC) students at the Focus: HOPE Center for Advanced Technologies (CAT) possess a unique learning environment. They have an advantage over students enrolled in traditional manufacturing engineering curricula because they have the daily opportunity to apply new concepts learned in the classroom to real situations on the manufacturing shop floor. This characteristic of Greenfield Coalition's curricula is not only unique, but also provides a natural contextual environment for the application and transfer of new knowledge and skills. In terms of teaching and learning, we could not simulate a better environment. Therefore, we capitalized upon this feature by making it a critical component of our teaching and learning strategies.

However, we wanted to find a way to share this advantage and paradigm with other students enrolled in similar engineering programs, who can learn from the experiences of the CAT candidates. Presenting case studies from the CAT via the World Wide Web (WWW) seemed like an obvious choice.[2]

*Identification of the Case*

In the Engineering Economics case, management at the Focus: HOPE CAT, a tier one supplier, identified an inability to meet shipping schedules for pulleys. They believe this is a result of poor production through the balancing process. This situation is discouraging, considering Focus: HOPE's desire to expand their customer base. The concern is that if they cannot keep up with shipping requirements for current business, they will not be able to handle new business requirements. On average, 700 parts are produced daily. Although not all parts need to be balanced, at best, only 200 parts are balanced daily. It is management's belief that the current machines are outdated and inefficient, and that downtime during the balancing process is significant enough to consider replacing the machines. It is evident that management is fairly certain the balancing process is the root of the problem. However, with the operations being so interrelated, the actual source of the problem may lie in another area of the process. They are willing to research and consider other possible trouble areas.

*Case Investigation*

As the objective was to provide the students with a prescriptive real life experience, the data collection process was conducted utilizing a professional approach where all knowledgeable stakeholders were interviewed and all existing engineering and manufacturing documentation was reviewed.

*The Situation*

Interviews with Focus:HOPE management and key personnel were conducted in order to gather information about the situation currently facing the company. The following comments were recorded:

> "The balancers are a constant source of problems in making shipments. We are seeking new business from the market and it is important that either we make present balancers work effectively or invest in new, improved equipment." - Director of Manufacturing
>
> "The balancers are very old – The manufacturers of the balancers no longer stock replacement parts so if we want to order a part or a fixture, it takes a lot of time and money because they have to be custom manufactured." - Plant Manager

In addition, production associates, maintenance personnel responsible for keeping the equipment operational, as well as manufacturing engineers that specified the process and equipment needed to balance the pulleys were interviewed to obtain their assessments and experience with the operation.

Once the situation has been identified and described to the engineering students, it is their responsibility to investigate and uncover what they believe to be the real problem impacting expenses and revenue. They are challenged to determine what is relevant to the case, and analyze its importance. Utilizing the web-based resources helps them achieve this.

*The Product*

The pulley is part of the accessory drive system on a diesel engine. Most of the students at Focus:HOPE had access to the operation and actually operated the balancing equipment. Therefore, the documentation of that process is primarily for students at other institutions. Students were provided with information regarding the case including engineering drawings and photographs of the product. (Figure 1)


FIGURE 1. The Pulley

*The Process*

A process flow diagram shown in Figure 2 was created to introduce the students to the manufacturing process and to provide a graphical model for their reference. The cast pulleys, which arrive from the casting supplier, are normally rusted. They need to undergo a sandblasting operation. The sandblasting machine at Focus: HOPE has a limited capacity and can hold only one pulley at a time. This substantially increases the time required for a batch to be prepared for machining. Almost every pulley needs sandblasting. The product is then surface finished on either of two Cincinnati Milacron machining centers. Some of the castings need extra effort to be perfectly machined and in the majority of cases, this is due to a poor casting process. Holes are subsequently drilled through the castings based on each pulley's requirement. A broaching operation is performed on the drilled pulleys, based on the type being manufactured. The broached pulleys are then balanced on balancing machines, where drilling out the unbalance weight rectifies any detected unbalance. The Quality Control department then inspects the balanced pulleys for flaws. After passing inspection, the pulleys are painted and barcode labels are attached. After a final inspection, the pulleys are packed and are stocked for shipping in the Docking Area.

The Alternatives

In order to gain a better understanding of the problem, several analyses were conducted. Numerous logs were maintained by the research assistants to gain a better understanding of what actually transpired during a working shift for the balancing operations. This provided an excellent overview of the operation including estimates of set up duration, rebalancing cycle time, and frequency of downtime incidence. A work sampling study was performed to estimate the percentage of time the machine was being set up, operated, or unavailable due to breakdown and repair.

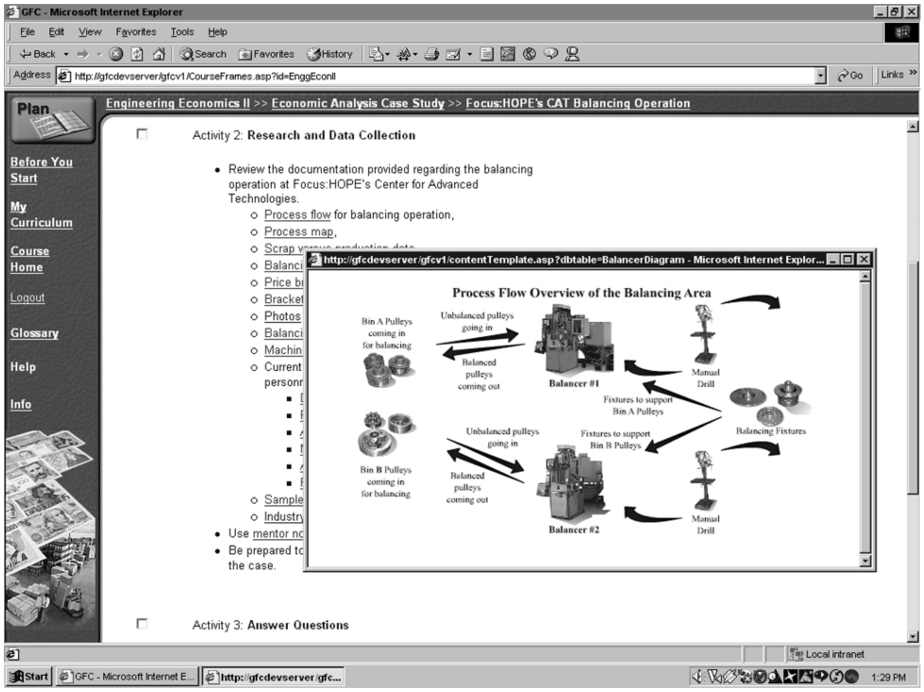


FIGURE 2. Balancing Process Flow

In addition, maintenance personnel provided historical records regarding reasons for failures and repair actions performed. Accounts payable provided the costs charged by the manufacturer of the machines for repair services.

Information was also collected from the interviews with the manufacturing engineers regarding estimates for various repairs and reconditioning actions that were considered by Focus:HOPE management.

All of the information collected from these investigations was documented in typical case study format. It was clear that management had few alternatives at this point: They could do nothing with the balancers and explore other options for improving pulley throughput; or they could look at replacing the balancers with newer, more productive equipment. The case study was then distributed to the students at Focus:HOPE for piloting, and to an instructional designer at GC who integrated the material into a web-based interactive session for current and future classes at Focus: HOPE; and for implementations at other institutions.

*The Pilot*

The first meeting consisted of describing the case study materials, outlining the situation facing management and defining the responsibilities of the class members to provide recommendations as engineers. Subsequent classes involved lectures on new tools needed to conduct the case study; a review session on key economic analysis principles[1], such as decision trees, guidance on conducting the case study analysis; writing the final report and presenting the final results to management.

The concept of decision trees was emphasized. In doing so, the following became clear:

- the choices facing management,
- the impact that uncertainty may have on a particular alternative,
- the need to estimate the probability of future events occurring, and
- the role of engineering economy tools in decision making.

The class was divided into three groups, with one student as the leader in each group. Although all three groups were responsible for conducting the economic analysis, writing the final report, as well as developing and participating in the report to upper management at Focus:HOPE, each group was assigned these specific additional responsibilities:

Group one was responsible for estimating new pulley business and future revenue streams over the next five years. They were to meet with sales to review historical revenues and to obtain probabilities of future business from subject matter experts within Focus:HOPE. They estimated that future sales volumes of 10,000, 20,000 and 30,000 with probability of occurrance to be 30, 60 and 10%, respectively.

The second group was responsible for researching new technologies and alternatives for rebuilding the existing equipment. They were also charged with researching the cost to keep the present equipment operational. They obtained quotations from two companies for new equipment and quotations from the manufacturer of the existing equipment for rebuilding.

The third group was responsible for extending the analysis that was started by the research assistants, and to analyze what must be done to improve the throughput with the current equipment and capability within Focus: HOPE. This group extended the work sampling study to get better estimates of the net practical capacity of the existing equipment. They also analyzed the causes of scrap, and estimated the percentage of pulleys that were scrapped as a result of the balancing operation.

The Economic Analysis

Three alternatives, shown in the decision tree in Figure 3, were decided upon and analyzed economically by the group:

Do Nothing strategy**:** The *Do Nothing* alternative evaluated the current lost dollars due to various factors like downtime, repair, scrap, overtime, losses due to poor setup, excessive cycle time due to poor machining of the pulleys, etc., versus the amount of profit that should be made on pulleys. Pulleys, a common part in need of balancing, seem to account for a large percentage of the overall scrap. In fact, the average scrap for pulleys approximates 25%, and that was deemed unacceptable. A comparison of the current system to other alternatives was then possible to determine if new investments would be cost effective. The *Do Nothing* alternative suggested improving upstream operations as an alternative to replace or modify the existing balancing equipment.

Rebuild Existing Equipment strategy: The *Rebuild* alternative suggests that any old operating system or worn balancer components will be replaced with a newer version. The rebuild of the current system would increase the life of the machine for a period of ten to fifteen years. The new operating systems should eliminate the current problems experienced with the circuit boards, which has been a major contributor to balancer downtime for repairs. *The Rebuild* option estimates the costs and revenues in performing minor repairs and updating the balancers programming.

Purchase New Equipment strategy**:** The *Purchase New Equipment* alternative will require a new machine to be purchased. Quotes were requested from two companies, resulting in one quotation that was $50,000 less than the other. The lower cost machine was chosen for evaluation for the study. This strategy not only looks at how profitable it would be for the Management to purchase a new machine, but also at the increased educational opportunities that the candidates will be provided with new technology.

The decision tree also shows the mean expected net present value for each alternative.

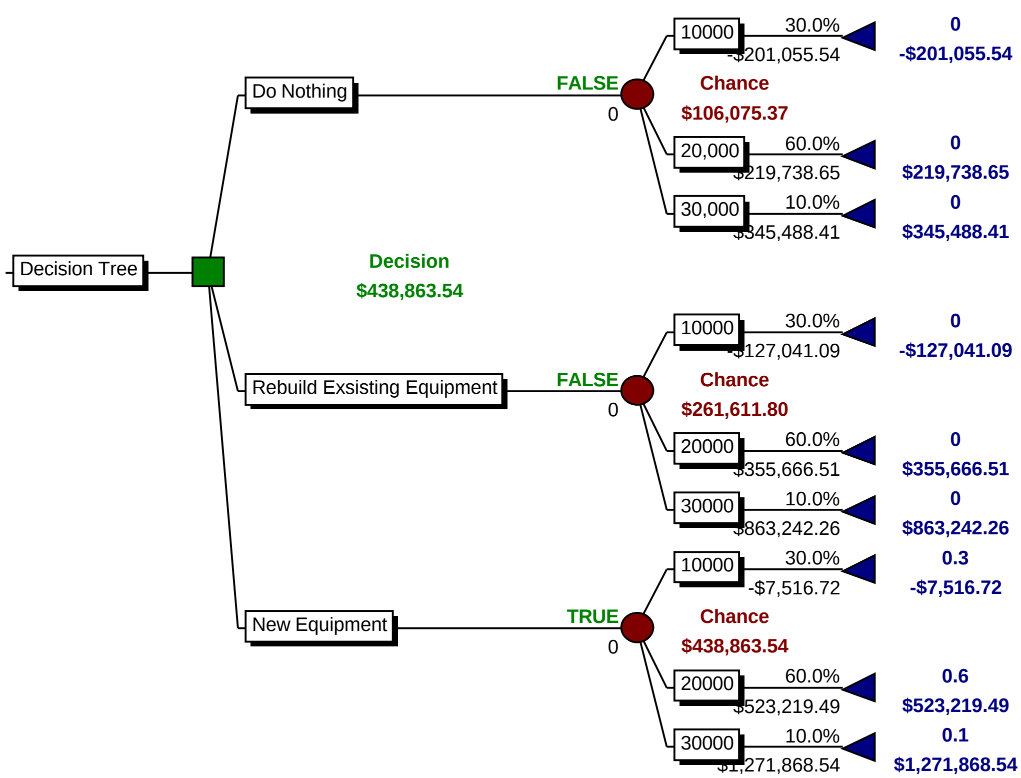


FIGURE 3. Decision Tree

Following instruction on how to conduct a sensitivity analysis, three sensitivity analyses were performed to determine if the most economic alternative would change as a result of fluctuation in demand. In the first case, the probability of demand for the products, which was set at 10,000 units with a probability of 30%(p1), was varied between 20% and 40%. In the second case, the probability of demand, which was set at 20,000 units with a probability of 60% (p2), was varied between 40% and 80% and in the third case, the probability of demand which was set at 30,000 with a probability of 10% (p3) was varied between 0% and 20%. The present value of payoffs generated for the three alternatives, was then plotted against the probability ranges, to obtain the sensitivity graphs, one of which is shown in Figure 4.

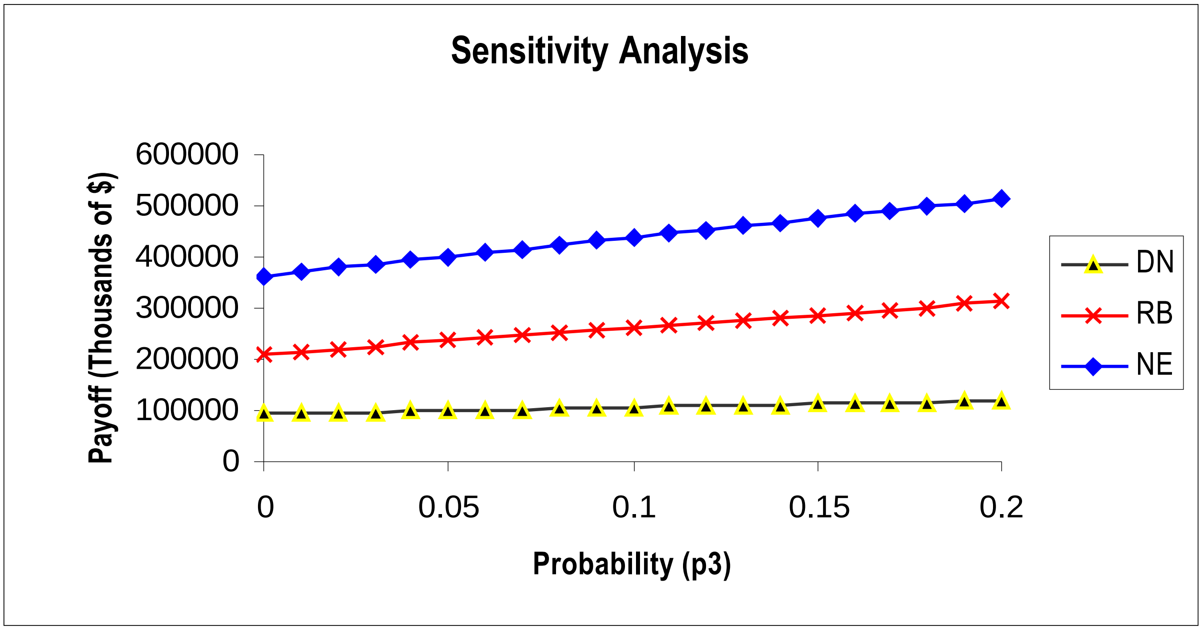


FIGURE 4. Sensitivity Analysis for the *Purchase New Equipment* strategy

*Presentation to Management*

The candidates recommended that the most economic course of action was to reduce the amount of scrap that was being generated. It was felt that the quality of the raw castings was a significant source of this scrap that prevented machining to tolerances, and achieving acceptable balancing. They also recommended that training be provided to balancing operators that would result in reduced set up time, increased throughput and a reduction in pulleys that could not be balanced. The management representatives, who included the Director of Focus: HOPE, the Director of Manufacturing and the Plant Manager were pleased with the analysis conducted by the class. They were appreciative of the fact that the root cause constraining delivery of pulleys to the customer was the inherent scrap in the process and not the balancers.

There was still concern on the part of the Plant Manager that the equipment was prone to failure and a strategy of “do nothing” was not acceptable. The second most economical alternative was the reconditioning of the equipment.  The plant manager challenged the students regarding the rebuild timing and duration; and the effect of losing a machine during reconditioning on delivery schedules.  The class had not considered this and agreed it was a significant element that they had overlooked.

*Student Experience*

While the expectations were made clear from the beginning of the case study, learners were surprised by the depth of investigation needed to strongly support one alternative over others. The students that piloted the case study expressed concern that the workload was too much for a one credit hour course. Because it was a pilot, the students were expected to contribute to data collection as well as performing the analyses. At times, students were required to revise documentation that the professor deemed insufficient for presentation to management. This caused some disenchantment by the class members who felt it was unfair to be asked to redo elements of their report. The team leaders responded to the challenge and made many significant improvements. This resulted in differential grading for the project between team members.

This effort was well spent, however. Applying their knowledge and skills to real situations gave students greater confidence in their abilities. Furthermore, the experience of working on a real case, where the variables are plentiful and where there may be more than one possible resolution, gave them valuable experience and set their expectations for working in the field. The students were genuine in their appreciation to the professor for the depth of learning and the opportunity to present their work to decision-makers that could implement their recommendations.

*Instructor Experience*

The instructor at GC played several roles simultaneously: traditional instruction of course concepts, mentoring and coaching during the investigation, and finally that of a supervisor challenging the recommendations from a manufacturing enterprise perspective. Because the case was implemented in real time, i.e., the answers were not determined before the case was assigned, more work and coaching was necessary to develop solutions that were relevant to solving the problem posed by management. The value of techniques such as sensitivity analysis became apparent when it became obvious that the recommendation might change based on the level of probability estimated for the level of sales in the future. This technique encouraged a dialog between the student engineer and the subject matter experts for their level of belief in an event occurring.

The role of supervisor became necessary when the teams resisted reworking their report prior to the management presentation. The instructor, who had considerable industry experience, pressed the students to expend additional effort to make the results more useful to the enterprise. He recognized that this was a real problem facing management that needed a recommendation for the most appropriate alternative. Clearly the management effort and resources should be expended where they will do the enterprise the most good. The students had discovered that throughput was not affected by the balancers as was perceived, but by the quality of the incoming castings. The instructor was insistent that the report and presentation reflect this and pulled rank like a superior would in industry. Without a doubt, this is a shift from the "sage on the stage" approach.

*Lessons Learned*

First, appealing to management for something that is relevant to the success of the enterprise proved to be valuable. The students felt they were solving a significant case. The enterprise itself was willing to participate because resolution to this issue was considered important. There was an expectation that a solution would be forthcoming and helpful to management.

Secondly, in capturing the case for simulation via the Web, the instructor used documents and reports that the learner would expect to find in a well-run enterprise. This proved to be instructive to the students by itself. In this regard, this same set of resources could be valuable for another case analysis in a course on workplace design, process flow analysis, operations management and quality engineering.

The piloting of the case study, although difficult at times, proved to be the most valuable part of the development process. It is not recommended to assign a case where the solution has not been worked through completely by the instructor. It is important to make certain that a viable solution can be achieved. Alternatively, there is an advantage to gathering information on the fly since it then becomes a realistic discovery process for both students and the instructor; looking back, it was a great learning experience.

The conclusion by the management, the class, the professor and the Greenfield Coalition staff was that the case study, the pilot and the resulting web based module was a success and provided a model for future experiential learning. It is expected that with the use of the web-based embodiment, other institutions can achieve similar experiential learning results.

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Biography

Francis E. Plonka, Chair of Industrial and Manufacturing Engineering at Wayne State University, has been a faculty member for 15 years. In addition, he has over 24 years of experience in industry, including several years working for Daimler Chrysler.

Diane M. Schuch Miller, Instructional Design Manager for Greenfield Coalition, has a Masters degree in Education specializing in Instructional Technology. She is well versed in web-based instruction and interface design. She continues to conduct research in the area of problem-centered instruction. She has worked on the Engineering Economics case as well as several others.

Dr. Snehamay Khasnabis, Professor of Civil Engineering has over 25 years of research and teaching experience at Wayne State University (WSU). His area of expertise is Transportation, and his research in the area of economic impact of transportation investments has been supported by the U.S. Dept. of Transportation, Michigan Dept. of Transportation, and the National Research Council. He has published his research in leading transportation journals, and has presented his work at numerous national and international conferences.

Dr. Ellis received his B.S. in Industrial Engineering from Kettering University (formerly General Motors Institute). He continued his studies in Industrial Engineering with an emphasis in Human Factors Engineering at The Pennsylvania State University, where he obtained his M.S. and Ph.D. He joined Wayne State University's Institute of Gerontology in 1994, and is jointly appointed in the WSU College of Engineering, where he is on the faculty of the Industrial and Manufacturing Engineering and Biomedical Engineering programs.

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