# Integrating Core Industrial Engineering Courses Through A Manufacturing Case Study

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## Abstract

This paper presents a summary of research conducted by a team of students from the University of Missouri-Rolla. The manufacturing processes at a local firm were evaluated. The case study illustrates the benefits of applying ergonomic, safety, work measurement, and quality assessment tools together. Additionally this team approach illustrates the importance of educating engineering students to think across course and discipline lines. The paper concludes with generalized recommendations for other educational applications.

## Introduction

Frequently engineering students and practicing engineers approach problems from a single perceptive. They tend to define problems as an ergonomics problem, a productivity problem, or a quality problem; rather, than seeing the broad cross-discipline nature of the problem. This not only limits the 'solutions' to the problems, but can also reduce the effectiveness of the engineer in justifying his or her solution. For example, despite ergonomics' recent wave of popularity, some ergonomists have continued to struggle to identify, quantify, justify, and correct ergonomic issues in a systematic fashion. Opponents argue that ergonomic hazards are difficult to quantify and costly to address. Similarly quality engineers often recommend changes to a manufacturing process only to find the suggestions are rejected. They are told that the changes are costly and the company cannot afford to make the changes.

There is a solution to this perception that safety, ergonomics, and quality compete against productivity. Operational analysis should be approached in an integrated fashion to process improvement. This type of approach is possible because often improvements in one area will also result in improvements in the other areas. For example, an improvement that reduces the physical demand of the work task will likely reduce the potential of worker injury caused by cumulative trauma or accident. This often results in productivity improvements due to the worker working more efficiently. It may also lead to improved quality, if the worker is less fatigued and more comfortable.

## Case Study Background

In the following case study a team of engineering management students from the University of Missouri-Rolla (UMR) approached a small manufacturing firm with the combined objectives of improving operations with respect to ergonomics, work measurement, safety, and quality. Engineering management is unique in that it combines the strong theoretical problem solving skills of engineers with an understanding of how the business world operates. In addition to taking classes commonly taught in industrial engineering and manufacturing engineering programs, students also study marketing, finance, and management. This provides the engineering management students with a wide variety of skills to identify and solve problems.

Funding was received from Missouri's Center for Technology Transfer and Economic Development and a small Missouri manufacturing firm to conduct an analysis of the manufacturing operation. The purpose was to recommend improvements. Suggestions could be made in any area, but implementation decisions were left to the firm's management. Students drew on a wide variety of course subjects including safety engineering, ergonomics, quality control, and metallurgy for their suggestions. The students saw the interconnection between a variety of college courses and applied the techniques jointly.

## Manufacturing Operations

The manufacturing operations at this firm took steel stock to form an assembled finished product. Bar stock was sheered to size and then heated to over a thousand degrees. The steel then was moved manually with tongs through a series of stamping and tapering operations. These operations presented a variety of safety and ergonomic hazards because the workers handled extremely hot and heavy pieces of steel. Once the parts had the desired shaped from the repeated heating and forming operations, they were placed in an oil quench. The parts were then tested for hardness and stored on pallets. Later they were shot peened to improve the part's finish for the painting and coating operations. After the shot peening, the parts were stored until required in the assembly process.

Next the various parts manufactured locally and some purchased hardware were assembled in a separate portion of the factory. The steel parts were loaded into the appropriate holding fixture. Adjustments were made to the parts with a small press as necessary. Assembly was completed and the products were labeled and moved to a paint booth for coating. These finished products then were labeled and stored locally.

## Assembly Operations

The student team found the assembly process very intriguing. The operator would lift the steel parts and position them in the table top assembly jig. The parts ranged in weight from 8 lbs. to 80 lbs. depending on the size of the product. More often than not, the parts would not fit exactly in the assembly jig, at which point the operator would carry the part across the room to a small press.  The operator would position the part on the press and manually adjust or "bump" the part. These adjustments were made based on the operator's judgment.  Once he felt the part had been bent enough, he would return the part to the jig and recheck the fit.  The process was repeated as necessary until all of the parts could fit into the jig and the assembly process completed.

This assembly operation concerned the students for several reasons.  Quality of the finished product was being affected as the metallurgy properties and shape of the parts were revised in an unscientific manner.  Ergonomic demands were placed on the workers, as they manually handled these large, heavy steel parts.  Productivity suffered since an operation determined to have a time standard of approximately two minutes would often take upwards of 20 minutes to complete due to the number of adjustments required.

If the students had looked at the assembly process from only one perspective they might have developed limited improvements.  Had they only considered ergonomics, the resulting recommendations might have included a rearrangement of the work station to reduce the distance covered with the material, lifting or carrying aids to reduce the load, or adding administrative policies concerning the lifting procedure.  Had the students only considered productivity they might have recommended revising the "bumping" process or the design of the assembly jig.

The team looked at the entire manufacturing process not just the assembly process.  They found that the problem was actually earlier in the manufacturing process.  The parts were being formed correctly, but the cooling processes had effected the final shape of the parts.  This led to the difficulties in the assembly process.  By studying the quenching and final cooling operations the students were able to make recommendations to improve the consistency of the parts produced. These changes would significantly reduce or eliminate the "bumping" process to make part adjustments.  This in turn improved productivity and  reduced the ergonomic demands.  Thus, the quality process improvement had productivity and ergonomic benefits as a side effect.

**Manual Material Handling**

All of the transportation of work-in-process was done manually.  These activities raised many concerns.  The red-hot temperatures of the metal parts, their awkward shapes, and heavy weight combined to make physically demanding tasks.  From the productivity standpoint there was a concern about the work load.  Could these worker work without additional rest allowances or were additional breaks needed?  Developing time allowances is one of the most elusive parts of work measurement.  However, by combining productivity with ergonomic objectives the team was able to quantify the physical demands of the material handling tasks.  The students measured the various dimensions of the worker's motions including horizontal and vertical movements. Twisting motions were also considered along with frequency and duration of the worker's motions.  The tongs used to hold the parts were also considered.  This information was used with the NIOSH Lifting Equation [3] to quantify the physical demands on the worker.

All of the manual material handling activities in the factory fell within the NIOSH guidelines and it was decided that no additional work breaks were necessary. The students also used this data to compare ergonomic and safety objectives for these activities. For ergonomic reasons, it would be preferable for the workers to hold the parts as close to themselves as possible. This reduces the moment forces on the spine. However, for safety reasons it would be preferable to move the red-hot parts away from the body to prevent burns or fires. The students balanced these conflicting goals when redesigning the tongs. Since the existing tongs did not place excessive ergonomic demands on the worker, it was decided to leave the length of the tongs the same, maximizing the distance between the worker and the hot parts. The major design modification was to the ends of the tongs. A suggestion was made to flatten the tips to increase the contact surface and improve the gripping and handling of the tongs.

**Working Conditions**

The working conditions provided the team the opportunity to make several additional suggestions. The students measured lighting, temperature, and noise levels. It was suspected that these could influence the comfort level of the workers that would in turn influence productivity. It would, however, be difficult for the students to persuade management to adjust the working conditions based solely on this assessment. The students referenced existing safety guidelines to determine what changes were required [1].

Suggestions were made to increase lighting to comply with Illumination Engineering Society (IES) specifications [2]. This was particularly important in the inspection areas where tasks required significant visual activity. Recommendations were also made for the temperature exposure of the workers near the furnaces. Noise readings confirmed the necessity of the noise protection program in place.

Recommendations also were made concerning the housekeeping throughout the factory. As is frequently the case in small manufacturing facilities, there was room for improvement in the housekeeping enforcement. The existing facilities were crowded with parts and equipment. Floors tended to be dirty. Recommendations were made to remove unnecessary items from the work areas and to clearly define aisles throughout the factory. These changes were advocated based on safety requirements. It was argued that improved housekeeping would reduce hazards and possible OSHA fines. These improvements should also improve productivity and possibly quality. Having clean work areas would tend to reduce wasted motion and allow easier movement throughout the factory. The improved cleanliness would reduce the possibility of contamination or damage to the parts in the manufacturing process. However, there was no readily available method to quantify these improvements. So, the housekeeping improvements were presented based solely on safety concerns even though they would also influence productivity and quality.

## Conclusions

The previous case study illustrates the benefits of applying ergonomic, safety, quality, and productivity assessment tools together. Despite the fact that ergonomics, safety, and quality are often considered detrimental to productivity there are frequently situations where improvements in these areas also result in productivity improvements. This is an important result not only to improve the quality of results by combining the analysis tools from these various disciplines, but also to aid in the justification process.

Frequently industrial engineers face a resistance to their suggestions and have had to resort to an OSHA fear factor or customer satisfaction issues to convince upper management of the necessity for change. This case study illustrates that a combined justification process is often the best method of winning upper management approval.

Additionally this team approach illustrates the importance of educating engineering students to think across course and discipline lines. By working as a team and drawing from course work in metallurgy, quality control, ergonomics, safety engineering, and work measurement, the students made more improvements than would have been possible if they had limited themselves to a single area.

As engineering educators we often assume that industrial engineering students see the interconnections between the various courses they have taken. Others assume that the senior design capstone course will "bring it all together" for the students. Unfortunately, this is not always true and students tend to approach problems with a single minded focus. This problem can continue as they enter the workforce and receive specific narrow job titles such as manufacturing engineer, ergonomist, or quality engineer. We need to clearly illustrate the need for an integrated approach to our industrial engineering student whether it is through industry class project, case studies, or personal experience.

## References


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