# Incorporating Industry-Based Research into an Undergraduate Course

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**Abstract**
There are many benefits associated with including industry-based research into an undergraduate engineering curriculum, but often academic and industry participants have different perspectives on project deliverables. This paper features a case study where senior-level students collect and analyze data in a retail environment, develop conclusions and recommendations for the organization, and present their findings to corporate executives. The paper discusses what techniques worked well for all involved parties, as well as. what changes should be made to make the learning experience more productive.

## Introduction

As with any engineering discipline, the interaction between industry and a senior-level engineering course offers many value-added experiences for the students and the sponsoring company. It gives students the opportunity to work on an interdisciplinary team to solve real-time problems in an ever changing industry environment. Students are also given exposure to corporate protocol in a project-driven environment. However, the most important attribute from a student perspective is the unique opportunity to experience a transition phase from an academic (classroom) setting to the aggressive and competitive industry environment.

The industry sponsor also benefits from the collaborative research efforts with undergraduate students. One clear goal for the sponsor is to identify future employees for the company, and there's no better means to evaluate a potential employee than to observe a student's performance in a semester long project. Individual and team relationships are developed between the student and company sponsor, which in many cases results in full-time employment opportunities upon the student's graduation. Finally, the sponsor has a sizable resource of 50 to 60 senior-level engineering students to perform a study where large sample sizes are necessary in obtaining credible data for analysis. In almost all cases, the technical support staff of a sponsoring company simply does not have the people resources to undertake a comprehensive study.

This paper will focus on the "Industry Experience through Special Course Projects (IE-SCP)" approach used to complete research projects for the Center for Engineering, Logistics, and Distribution (CELDi) at the University of Arkansas. CELDi is an Industry-University Cooperative Research Center which conducts sponsored research in all areas of Industrial Engineering, but primarily in the area of distribution and logistics. The Industry Experience

approach allows sponsors to be involved with the curriculum development of participating senior-level courses.

***Case Study***

A special project from an Industrial Engineering (INEG 4433) Administrative Analysis course will be used as a case study in this paper to illustrate the methodology for the IE-SCP approach. The following sections of the paper will discuss the methodology in greater depth. Specific detail will be provided, along with a case study application for each phase of the methodology.

First, a discussion of the selected undergraduate-level course is necessary. The INEG 4433 class is a required course for the Industrial Engineering undergraduate degree which integrates engineering and management principles and practices into managing an organization. Therefore, the topics discussed in class directly relate to the project deliverables. Students are to apply theories learned in the classroom to the dynamic settings of a retail merchandiser in the service sector.

This particular class consists of 60 undergraduate students. Seven teams are organized at the beginning of the semester. A team leader is elected for each team. The team leader will facilitate internal task assignments and delegation within the team, and representative the team at meetings with the project sponsor.

Each team is given one department to study within the sponsor's facility. A faculty representative, usually the course instructor, supervises the student teams, and each team is responsible for the collection and analysis of data, and final recommendations to the project sponsor. Student teams are also expected to present their findings to an Executive Council consisting of upper level officials within the sponsor organization. A report is presented at the conclusion of the project, culminating the total efforts of all student teams on the project.

The company sponsor is a small, regionally based, retail merchandiser who distributes goods and services to the end consumer. The study takes place at one of the company's retail distribution outlets. The company has experienced a recent and sustainable increase in sales volume in 80% of all product lines. The product lines showing an increase in sales are located in three of the six departments in the facility. Due to the increased sales, management is concerned with unbalanced spans of control throughout the various operational departments within the facility. There is also an interest to evaluate the consolidation of staffing across multiple departments within the selected facility.

A meeting was held between the class and company sponsor to discuss project scope, milestones, and specific details of the facility operations. In conclusion of the meeting it was agreed that a well-defined list of objectives for the project should be established to identify work activities for the INEG 4433 student teams. The next section presents the objectives for the project.

***Objectives for Admin class***

The Administrative Analysis class will face multiple objectives over the course of the semester-long project. These are as follows:

1. Identify productivity enhancements in each area of the facility.
2. Evaluate the work activities for each functional area of the facility.
3. Assist with the development and refinement of the data collection checklist.
4. Investigate whether the span of management for each area is adequate for suitable management control.
5. Determine if there is a need for changes in the current training format to accommodate student team recommended changes in the area work structures.
6. Determine if the staffing is adequate at different peak times during the week.
7. Record individual student observations during the data collection process.

**Literature Review**

Since the majority of the study is to focus on productivity for a retail operations facility the review of literature focuses primarily on performance measurement research in the service sector. Although there is not much work that has been done in service sector performance measurement, there are several key articles that have been identified and are discussed in the following sections. A review of the work sampling research literature has also been investigated to identify the most appropriate approach for the case study.

***Retail Productivity***

Growth in retail merchandisers from 1977 to 1997 has been marked by increases in investment in technology, such as the widespread use of Universal Product Codes (UPCs) (Sieling, et al., 2001). Ingene (1982) notes the increased use of electronic cash registers in retail has decreased the amount of time employees spend on checking out customers, inventorying goods, and pricing merchandise.

Ingene (1982) discusses two types of productivity measures. The first is total input productivity, the ratio of all outputs to all inputs. The other is partial input productivity, which is the ratio of all outputs to a single input. Possible output measured discussed are: transactions, physical units, value added, and sales. For measuring labor productivity, one could either use hours of labor utilized, or the labor could be weighted by measuring the wages spent on this labor. Ingene's paper includes an insightful discussion of the advantages and disadvantages of each of these labor measures.

Good (1984) looks at a variety of productivity measures in the retail sector, including:

- Value-added/man-hour
- Value-added/square-feet
- Sales/man-hour
- Sales/square-feet

- $$\text{Total factor productivity} = \text{Total man-hours worked} + \frac{\text{Value added (depreciation + leased equipment charges)}}{\text{Average hourly wage}}$$

The author states that the total factor productivity is probably the best measure as it "yields results that demonstrate the balance and trade-offs that have been made among the various factors of production." A difficulty inherent in the measurement of productivity in the service industry is that retail output is a combination of physical goods being sold and services rendered during the process of marketing and selling the physical goods (Brown and Dev, 2000). Also examined in Good (1984) is the relationship between productivity and store size (in square feet). He states that in the retail food industry, economies of scale are "quite pronounced." George and Ward (1973) also note that larger stores promote "a higher level of sales per person engaged per shop." However, this trend of economies of scale holds true only over certain ranges of output and that at some point the situation reverses. This suggests that a store can become too large and diseconomies of scale may predominate.

***Work Sampling***

Work sampling, also known as occurrence sampling, is a technique used to obtain information about various types of events (Konz and Johnson, 2000). This type of discrete sampling is used in place of continuous sampling when it is assumed that the underlying statistical distribution is binomial. A large sample of very short time intervals (or "snapshots") can provide a decision maker with an accurate picture of the types of events that take place of the period of time being examined.

Because there is a tradeoff between the high cost of a large sample, and the high risk of a small sample, it is important to determine an appropriate number of observations such that a balance is struck between cost and risk. A general rule of statistics states that the information gained from a sample is a function of the square root of the sample size. However, the additional cost of increasing a sample size is typically a linear function. This results in diminishing returns such that there is a point when additional information gained from increasing sample size is not worth the incremental cost.

An interesting case study of work sampling in a retail environment can be found in Tolo (2001). In this application, the workers being evaluated were responsible for self-administering the work sampling process which reduced the amount of error in interpreting the tasks being conducted by the subjects. A disadvantage of work sampling noted by the author, though, is that work sampling only measures what is actually being done by the subject. It offers no insight into "whether a team member is doing the proper work, working in an appropriate way, or using correct procedures." It also provides no detailed analysis of the tasks.

**Methodology and Case Study Application**

The methodology employed by the INEG 4433 class is a five-phase process that included: 1) preparatory work, 2) the creation of a work sampling plan, 3) data collection, 4) data analysis, and 5) decision making. These phases are discussed in the following subsections, and a pictorial can be seen in Exhibit 1.

***Phase I: Preparatory Work***

Create Checklist of Tasks: Creation of a task list is done primarily by the organization being studied, but the course instructor is implemental in the process to insure that the work done by

the student falls within the scope of the course. The tasks often vary across departments, and should take into account the current job descriptions and responsibilities of the employees in the affected areas.

In the INEG 4433 class special project it will take several iterations before the checklist of tasks is complete. Student teams will have to conduct multiple site visits before all tasks are identified. Another complication is that not all departments share the same task activities. Therefore, the student teams couldn't simply develop a general checklist for all departments.

Divide into Functional Areas: Division of the study tasks is divided into functional areas within the site facility. The company being examined is highly involved in this task as the departments within a single study area should ideally be similar in structure and function so as to consolidate research efforts. Proximity of the departments within the functional areas are also considered.

Since the retail outlet had seven departments, one for each team, the initial approach is to divide the study by department. After the development of the checklist, slight modifications are made to group department areas by location. This will save the student teams valuable time when tracking worker activities in areas grouped closer together in a department.

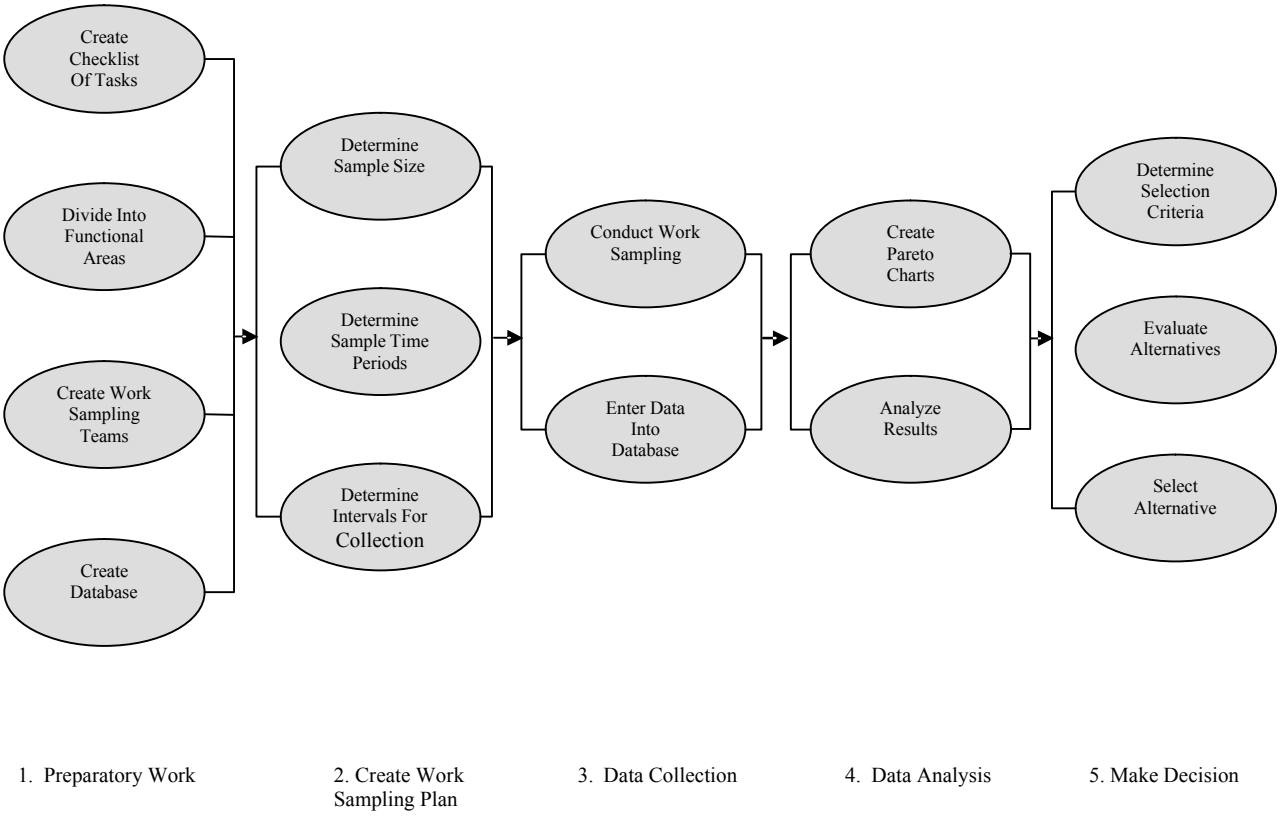


**Exhibit 1. Research Methodology**

Create Work Sampling Teams: Creation of the work sampling teams is done solely by the course instructor. This is done so that the individual skills of the students in a team complement

each other and are evenly distributed across the study teams. As mentioned earlier, the INEG 4433 class is divided into seven teams with a team leader elected for each team.

Create Database: Because of the vast amounts of data to be collected over the life of the project, it is imperative that a system be developed that can store, organize, and analyze the information. A database such as Microsoft Access is recommended due to its availability and ease of use. For a work sampling study, the following data fields are likely to be required:

- Team Number
- Observer's Name
- Store Number
- Date of Observation
- Time of Observation
- Department Number
- Department Name
- Employee Name
- Task Number
- Grade
- Comments
- Number of Queued Customers

***Phase II: Create Work Sampling Plan***

Determine Sample Size: Before the number of samples to be taken can be calculated, it is first necessary to determine the statistical requirements of the research and any relevant constraints in the work. This is a joint effort by the organization, which is most familiar with the constraints and the nature of the business, and the instructor, who is likely more knowledgeable in the area of statistical analysis. In the special project it is determined that 16,800 samples are necessary in order to have a 95% confidence level. This equates to 60 hours per team in each department.

Determine Representative Sample Time Periods: Because of the natural fluctuations in a sales environment, determining when to collect samples is vital to accurate portrayal of the organization in a work sampling study. It is important to account for the peak and non-peak sales times, as well as those periods in the day when workers are likely to be stocking, cleaning, conducting inventories, or other non-sales-related functions.

Several considerations need to be made when setting the sample time periods. Typical retail operations have normal peak and off-peak periods. Both of these periods should be observed to obtain useful data for analysis. The INEG 4433 class decided to collect data on slow days (Monday and Wednesday), and busy days (Saturday and Sunday). Each team had to build an observation schedule from 10:00 AM to 10:00 PM for the busy and slow days.

Determine Time Intervals for Collection: Periodic sampling, such as making an observation every three minutes, is often used in a situation such as this, but it must be done so with care. Although retail has natural business fluctuations, they tend not to follow a cyclical pattern, which is a major cause of problems with periodic sampling. Also, if a large enough sample size is used, periodic sampling is more acceptable (Konz and Johnson, 2000). The INEG 4433 student teams determined that a 3-minute sampling interval is necessary to obtain enough data to satisfy the

statistical requirements of the study. It is assumed that periodic sampling is sufficient since the study has such a large sample size.

***Phase III: Data Collection***

Conduct Work Sampling: The collection of the data for the work sampling study is done exclusively by the students in the class, but cooperation by the organization is critical for success. Students must have easy access to the departments and employees involved in the study. It is necessary for the organization, though, to inform the employees about the nature of the research and to assure them that their positions within the company are not at stake. If the employees are resistant to the study, the results of the analysis may be tainted.

The data collection phase for the teams didn't start smoothly. Even though the checklist was developed and pre-tested there were still task activities that are not on the checklist. Modifications to the checklist have to be made. General observations are recorded that provide additional information to the sponsor company.

Enter Data Into Database: Once the data relevant data are collected, the information must then be entered into the database developed for the study. It may best to devote a single team to the design, upkeep, and utilization of the database to eliminate potential problems with data corruption or the database's structure.

The data input phase of the project goes smoothly for the teams. One team volunteered to develop the database program that would easily and quickly download the data into files. All of the data for each team is stored in a consistent manner.

***Phase IV: Data Analysis***

Create Pareto Charts: Following the collection of data for a department, it is necessary to conduct analysis to determine the utilization of the employees' time. Pareto chart, though simple, are extremely effective as a visual display to account for how an employee within a department spends his or her day. The student teams use the Pareto charts to present the results of sampling data to the class. The charts are also easily explained in the presentations to the company's executive council.

Analyze Results: Based on the data from the Pareto charts, inferences can be made on the amount of time to complete a specific task or multiple tasks. Standard times can be calculated for each task. The span of control for a department can be determined once the proper staffing is identified. The INEG 4433 student teams are able to calculate standard times for each job task, and identify the specific staffing needs for each area in the retail outlet facility.

***Phase V: Make Decision***

Determine Selection Criteria: Selection of the optimal alternative will be based on four criteria: utilization of the employees; customer service quality; labor and training costs; and employee retention and motivation. These are described with respect to this study more fully in the following paragraphs.

1) *Employee utilization* – Improved utilization of employee-hours will be an important factor in the selection of an alternative. More efficient staffing figures will be determined for each

department, for all hours of operation. These figures will be based on weekly sales forecasts, observations made by the student teams, and feedback from department managers. The goal is to maximize the ratio of pre-determined optimal task times versus observed task times. An alternative way to look at the situation is to maximize the tasks completed per employee-hour. Manpower figures must also take into account that all essential tasks for each department are completed on time.

2) *Customer service quality* – the selected alternative must, at a minimum, maintain the current level of customer service. Although this metric is currently unable to be measured, future research may be suggested to provide value for customer service. However, it must be noted that this is a subjective metric with a projected impact. Customer service should improve with the increase in the utilization of employees.

3) *Labor and training costs* – Initially, labor costs will likely increase due to cross-training employees in new departments. However, as employees begin to progress on the learning curve and become more familiar with the new system, labor costs should decrease. Increasing the utilization of the employees will in turn decrease the cost of labor. Improved retention among employees will decrease the cost of training new employees. The primary alternative should see long-run reductions in labor and training costs. Labor cost per employee-hour and training cost per employee-hour will be measured to evaluate these expenditures.

4) *Employee retention/motivation* – Cross training of employees will help to reduce the monotony that many workers encounter when assigned to the same department or task for long periods of time. This will give employees the opportunity to learn different skills and the chance to work with different employees within the organization. It is anticipated that some workers will be reluctant to this change in the early stages. However, it will enhance the work environment of the retail sales facility and increase worker satisfaction, and later employee retention. Following implementation of this cross training, continued analysis will be required to confirm improvements in these areas.

Evaluate Alternatives: Once several alternatives have been generated by the student teams, the performance level of the selected metrics will need to be determined. It is unlikely that a single alternative will have the highest level of performance in all four metrics, so the decision makers will need to rank the alternative with respect to each of the selection criteria. It may become necessary to choose an alternative that is not the highest performer in any category, but presents the best overall potential.

Select Alternative: An optimal alternative will be selected based on economic analysis and the anticipated performance in the selection criteria discussed previously. This final selection will be done primarily by the sponsor company being studied, with input by the course instructor.

## Conclusions

In conclusion, the overall success of the study isn't just the results of the data collected for a service-oriented retail sales facility. Every student team has the opportunity to experience the rigors of planning out a detailed work sampling study, and be responsive to changes in study parameters due to unexpected business fluctuations. Students are grouped together in teams, much like they would in a corporate setting, and are given a department to study in the facility. Each team presented the final results and recommendations to the project sponsor in a formal presentation to the upper-level management at the sponsor company.

In addition to the student involvement in an industry-based research project, a formal methodology is developed to systematically approach the problem. The methodology consisted of five phases of 1) preparatory work, 2) create a work sampling plan, 3) data collection, 4) data analysis, and 5) make decisions. Each phase has additional steps for completion before moving on to the next phase of the project.

Further refinement of the "Industry Experience through Special Course Projects" approach will address other areas of the Industrial Engineering discipline such as: operations research, simulation, quality control, ergonomics, etc. Specific steps in each phase will be added to the methodology as necessary to incorporated fundamental procedures to assess the Industrial Engineering discipline under evaluation. Other opportunities for changes in the approach will be to integrate other classes that would be able to add value to the project outcomes. Courses in Business Administration, Transportation Logistics, Micro-Electronics Photonics, etc. would be excellent candidates to provide equal support in a special course project.

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