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# Lessons from an industry-university partnership for student research projects

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Ever since I was a child, I've been intrigued by every aspect of technology. This curiosity would propel me toward learning about technology and want to learn how items are made. Fast forward a few years, I am an electrical engineer who wishes to focus on RF & optics. It's been a hard journey getting through school but I enjoy every moment and lesson learned.

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# Industry-academia partnerships: Lessons from an industry-university partnership for student research projects


## Abstract

This paper presents a case of an industry-based student research project at Villanova University. The university partnered with a local electronics manufacturing company and was funded by the state. As a part of the funding requirement, students are supported during the project, the industry and university participate in cost-sharing and the students present their results to the state sponsor and company periodically during the project lifetime. In this paper, we discuss the project scope which is to improve the manufacturing process at the electronics company for assembly and packaging PCB. The project findings are presented in detail that includes creating and launching a key performance indicator-based (KPI) dashboard to predict and identify industry manufacturing limitations. We also report on the student learning experience, industry-academia collaboration, lessons learned, and several instructional insights with respect to project management. We believe that these instructional insights are applicable to other learning models.


## Introduction

This project received support from local state agencies to promote the transition of graduate students at local universities to manufacturing jobs in the local-industry in an effort to limit talent migration from the state [1–4] . The industry-academia project's technical objective was to find data from manufacturing productivity reports to create a dashboard with updates on Key Performance Indicators (KPIs). Key Performance Indicators (KPIs) are a measurement tool that quantifies the progress toward an intended strategic business outcome. KPIs allow for a methodical operational improvement, create an analytical basis for decision making and identify significant attributes. Managing a business with KPIs includes setting the desired level of performance and tracking progress against those levels.

Our project focused on optimizing custom circuitry assembly, which will benefit our industry partner's efforts in improving quote estimates and *number-of-profitability*. The *number-of-profitability* ratio is a category of financial measurement tools that are used to assess a business's ability to generate earnings relative to its revenue, operating costs, balance sheet assets, or shareholders' equity over time, using data from a specific point in time. These improvements will increase production quantities. This optimization study and its results in terms of recommendations will assist the company in maintaining high-quality products with improved reliability. Electro Soft Inc. creates custom electronics manufacturing solutions for clients in aviation, rail, transit, OEM and defense. Their specialties include building custom wiring harnesses, cable assemblies, printed circuit boards (PCBs), cabinet assemblies and military electronics. The corporate headquarters are located in Montgomeryville, PA, just twenty- miles from Villanova University. This project has analyzed data from the manufacturing shop management software to identify which data impact the key performance indicators (KPIs). More specifically, we are addressing a *quantifying jobs problem*: how to track custom jobs between different workers and departments, while better-managing workflow. For example, since the company features custom circuitry they quote contracts based on individual manufacturing steps. Occasionally, the company has experienced fluctuations in the timing of individual manufacturing steps. The company wanted a method to record the start and end times of individual manufacturing steps to identify the cause of the timing fluctuations. We were tasked to engineer a solution to standardize the timing of these steps. Although interrupted by COVID quarantines, we have completed on-site visits with in-person detailed reviews of the company's manufacturing floor. This has helped us develop an intuitive understanding of the assembly process for a variety of sectors. We have developed a preliminary tool that can identify and sort manufacturing shop data to better estimate the *number of profitability* and improve job quotes. These initial results are encouraging with customized feedback specific to job and assembly operator.

**Methods**

We evaluated the existing workflows according to the process outlined in figure 1. We first considered the tracking system employed and the points of calibration. The manufacturing facility employed a barcode-based tracking system. A product was tracked in terms of person-hours and machine hours. Our preliminary analysis of the data collected from the tracking system to help identify immediate patterns of desirable and undesirable attributes. For example, we tracked the jobs whose payments were above project costs and those with on-time/early product delivery. The fundamental limit that we approached was the database analytical tools. The analytical algorithms were not providing useful real-time logistic data in a useful platform. We then transitioned to the method outline in figure 2.

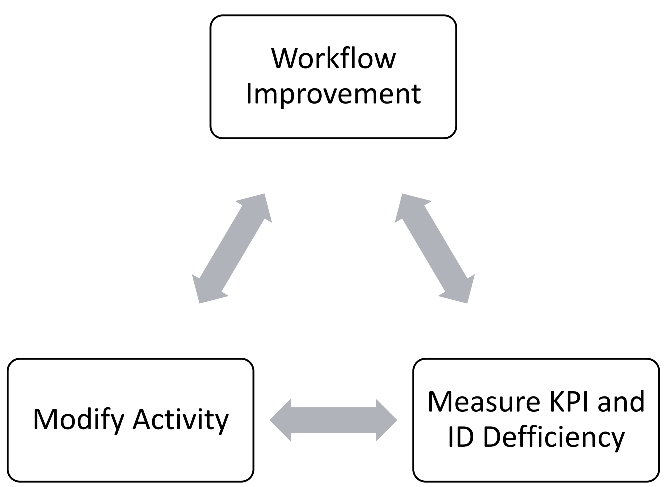


Figure 1: Initial objective of the industry project to improve manufacturing workflow. The chart shows the method of workflow improvement based on KPI results and workflow modifications.

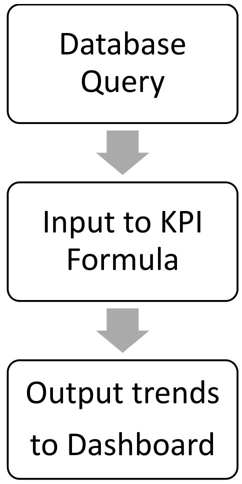


Figure 2: Modified project objective to create a rigorous KPI is outlined in this method. The operator will query the database to assess a particular $\text{KPI}_n$ and the system would display useful charts on the system dashboard.

The Key Performance Indicators ($\text{KPI}_n$) we used in this effort are listed below and we developed functions to drive our algorithms in our custom database dashboard.

1. 100% 1st article
2. Inventory each kit
3. On-Time Delivery
4. Percentage of revenue

In equation 1, $\text{KPI}_1$ is defined as how much time ($T$) it takes to get a final working product that is tested. For example, we can compute the time between dates such as physical work start ($PWS$) date, material procurement dates, 1st article test ($1AT$) dates, and final article test dates.

$$KPI_1 = T_{PWS} - T_{1AT}. \tag{1}$$

In equation 2, $\text{KPI}_2$ is defined as how long it takes to inventory each kit. For example, we can determine the function by comparing timestamps that track when items are collected for assembly and when items are complete and packaged for shipment.

$$KPI_2 = T_{ABLY} - T_{SHIP}. \tag{2}$$

In equation 3, $\text{KPI}_3$ is a function that captures the answers to: are products delivered at the quoted date? If not, how late are they? For example, we can determine the function by comparing timestamps that track the promised date ($QDEL$), shipping date, and actual delivery date ($DEL$) displayed in Gantt format with progress bars to predict cascaded lateness between jobs.

$$KPI_3 = T_{DEL} - T_{QDEL}. \tag{3}$$

In equation 4, $KPI_4$ is a function that captures the answers to: what are the profit/loss quantities? What is the price quoted vs. actual costs? For example, such a function is the difference between the quoted price and actual costs. We can use data such as quoted price ($QP$), actual costs ($AC$), profit, and loss.

$$KPI_4 = P_{QP} - C_{AC}. \tag{4}$$

**Results**

In our initial attempts to improve workflow by updating job tracking methods, we discovered that the database responsible for informing workflow decisions was outputting useless analysis. We investigated the database structure and found anomalies such as batched reports for a given period did not contain data that could be easily cross-referenced between the reports. For example, as shown in figure 3, the job cost report that contains data for labor, material costs, and profit could not be reconciled against the productivity analysis report that contained the labor hours, machine hours and overtime. When we exported the data from the reports there were inconsistencies with the data formatting as displayed in figure 4 . The data would be addressed to a particular column and then be switched to another column for every other row in the spreadsheet. We employed algorithms to correctly address the data inconsistencies . However, inconsistencies in the job labeling in the database prevailed and prompted us to create a custom database tool in figure 5 to control the data addressing.

The KPI Dashboard allows the user to access the industry partner's databases in real-time. The user may then select the desired KPI function. For example, the user may launch an "On-Time Delivery" query on the dashboard which will perform the function $KPI_3$ according to equation (3). The Dashboard will then display a convenient graphic illustrating the jobs that are on-time and those that are delayed. The KPI Dashboard development was hired out to an external software development firm at the industry partner's discretion due to time constraints. The students met every two weeks with the software developer to create the Dashboard. The students tested the Dashboard and demonstrated its functions to the industry partner on a similar schedule. The students relayed the industry partner's feedback to the software development firm. The industry partner was satisfied with the operation of the KPI Dashboard.

**Discussion: Lessons Learned**

*Student Learning Experience*

Students applied to the project position using conventional university hiring platforms. Students were at the Master's level of classification. Three students participated in the project. The project was not part of the curriculum and no credit academic was awarded to the student. The project was awarded to students as a one-year fellowship. Students met weekly with the project advisor and quarterly with the industry contact. The weekly meetings were documented in a template that highlighted the long-term project goals and the short-term weekly or quarterly goals [5–8]. The student logged the date, project-related tasks and any noteworthy findings. These logged workbooks were hosted on an online server archive similar to One-drive. The workbooks were reviewed by the


Figure 3: Excerpts from productivity analysis and cost summary reports are shown. Profit margins and project times are taken from the reports to calculate KPI.

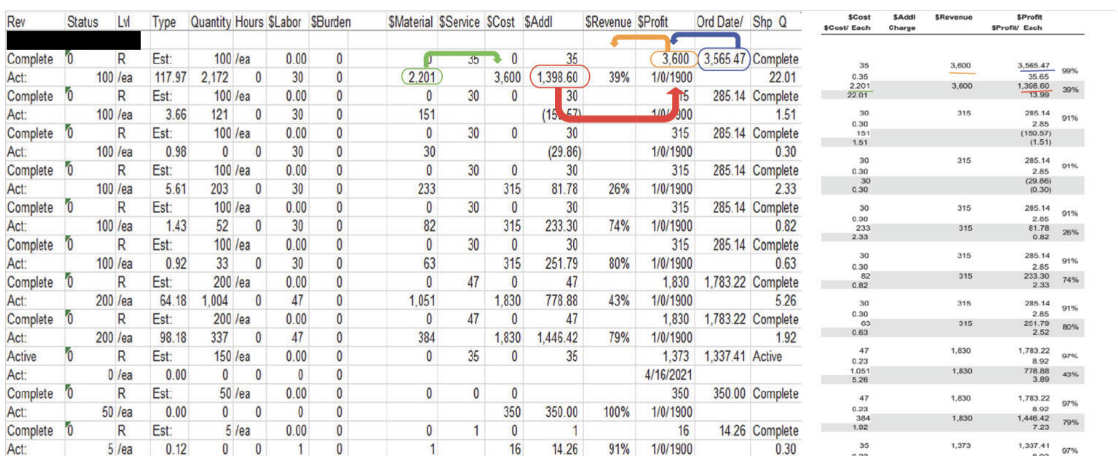


Figure 4: Excerpts from productivity analysis are shown. Data were transposed into neighboring columns for alternate rows making it difficult to automate data selection from the reports to calculate KPI.

project advisor during the weekly meetings. All student workbooks followed a template and were submitted to the server weekly. The first weekly meeting between the project advisor and the student is dedicated to explaining the workbook template format, the project calendar and site-visit logistics (i.e. car rental). The workbook would include the project tasks for the week which would include student notes from discussions with the industry collaborator like the equations (1-4) or sometimes screenshots of database discrepancies such as figures (3 and 4). The workbook also captured logistical events and issues (i.e. housing or transportation issues). Student workbooks were used to populate the quarterly reports that were provided to the industry partner. The student was able to travel to the manufacturing site during the project to better evaluate the manufacturing workflow. The state project supported the visit, which secured a rental vehicle for transportation between campus and the manufacturing site. The state funding agency asked student participants to discuss their research experiences in video submissions. Students received a regular stipend inline with their academic classification. The students all had a positive experience with the project.

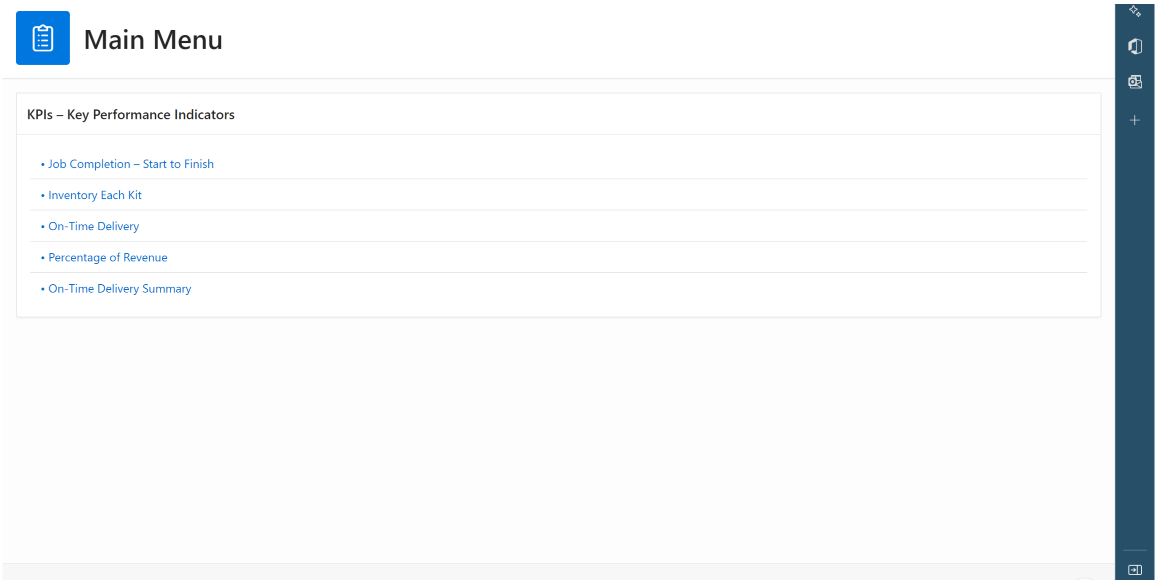


Figure 5: Preliminary prototype Key Performance Indicator Dashboard.

They appreciated the benefit of mentorship from an industry professional. However, logistical matters such as student summer housing and transportation to the manufacturing site required additional personnel and effort. Student participants expressed frustration regarding these logistical issues.

*Project management*
Contingency plans are key to a successful industry-academia partnership. The logistics of securing transportation to the manufacturing site can cause scheduling conflicts, excessive administrative burdens of sending emails that are incorrectly routed, and confused students and industry contacts when scheduled site visits are canceled because there is no transportation. For example, reservations must be continuously updated for rental car access to support trips to the manufacturing site. The university rental system requires a month's lead time for reservations. Standing reservations are required to be scheduled weekly regardless of the need and can only be managed by manual cancellation.

Managing access to the manufacturing site database is also important to the success of the project. The data that is required to determine KPIs are extracted from the on-site database. This database is a functioning system constantly updated for materials purchasing, payroll allotments, financing, market projections, supplies, and product routing[9, 10]. Data retrieval must be timed to not interfere with the everyday activities of the company. A simple retrieval can disrupt important company-wide tasks like payroll disbursement.

**Conclusion**
This project provided a unique opportunity to highlight and contrast the skills and strategy required to manufacture technologically advanced products. In contrast, the industry-academic project also illustrated in real-time how to finance and make those products profitable in an industrial setting. The next steps of this project are to partner with software developers to prototype the tool to analyze larger datasets. Ultimately, if this is successful, we may be able to assist other Pennsylvania

manufacturing companies. The goal of this project is, in part, to encourage student interest in the manufacturing sector of the American economy. One student continued their interest in the manufacturing sector and is currently employed in the manufacturing sector. We propose a project course to accompany such experiences to help students extract the long-term benefits of such projects. For example, students should receive a template demonstrating how to document the industry experience on resumes. Especially for students who completed certifications and trainings for specialized equipment. Furthermore, the students can receive additional support for managing administrative tasks like car rentals. Constantly managing and requesting rental reservations was a distraction during this experience. Student industry participants should have a single point-of-contact to assist them with administrative duties such as car rentals and travel reimbursements.

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