

# To Ship or not to Ship: An Engineering Ethics Case Study

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## Abstract

*The authors have developed a numerical-based engineering ethics case study for use in engineering courses. It has been shown that ethics case studies that involve technical calculations and real-world situations appeal more to engineering students than do purely qualitative cases. The case is a fictionalized account of several incidents that the second author witnessed while employed at a steel manufacturing company.*

*In this study, students are asked to evaluate several coils of steel and determine which ones meet certain minimum standards for yield strength. Statistical analysis is necessary to evaluate the strength of the steel. Test data is given for each of the steel coils, from one to five test samples per coil. After analysis, the students are presented with several scenarios and asked to decide which coils meet the minimum standards. In making the decision to approve coils for shipment, students must decide on the appropriate statistical measures to use and in particular how much of the confidence interval needs to be above the minimum standard.*

*The students are then asked several questions concerning how their knowledge, or lack of knowledge, of the ultimate use of the steel affects their decision-making process. Should the engineer have different standards for different applications?*

*Even though the calculations involved in this problem are relatively simple, the problem the students are presented with does not have an easy answer. This case study is appropriate for a sophomore-level materials or mechanics of materials course, however, with a short introduction to material properties, it could also be used in an introductory statistics course.*

## Introduction to Case Study

A steel mill has been asked to produce high strength low alloy steel (H.S.L.A.) that has a minimum yield strength of 60,000 psi. You are the quality control supervisor for the steel mill. As the steel is produced, each coil is tested for strength. The data shown at the end of the case study has been obtained. There are three options to this case study. Option #1 assumes that you only made one test per coil. Option #2 assumes you made three tests per coil, and Option #3 assumes you made five tests per coil.

The product is a thin sheet steel that is several feet wide and several thousand feet long. The strip has been rolled into coils to make them easier to handle. The samples are taken from the outside ends of each coil. The samples are nominally 0.5 in wide, 0.030 in thick and 2.0 in long. The samples are tested to yield in tension and the load at yield is read directly from the load displacement plot produced by the testing machine. The yield point can normally be determined within  $\pm 3$  pounds.

Your job is to decide whether or not to ship any of the coils of steel A—E. Carry out any numerical calculations necessary to assume that the steel shipped satisfies the minimum requirements of 60,000 psi yield strength. Calculations that may be important for you are the mean value of strength, standard deviations, and confidence intervals. You need to decide where (and how) these calculations may be useful.

The production control department has put you under pressure to ship all of the coils, since they all were produced from the same heat of steel (same batch) and have all been processed in the same manner, thus all have the same nominal properties.

## Ethical Issues to Consider

### Scenarios to consider

1. Your customer requires you to certify that your coils meet the required minimum strength levels. This means that you need to sign your name next to a statement that you have tested the coils and you guarantee they meet the specifications. How would this additional requirement affect your decision as to which coils you should ship? False certifications are considered a violation of the engineering codes, and could cost you your engineering license.
2. Your customer "requires" that your coils meet the specifications, but does not ask you to certify them. Your customer has no way to test the coils that you ship him. How would these facts affect your decision as to which coils should be shipped? Explain your answer.
3. Suppose that the customer had approached your company for advice on the steel properties needed for his product. The 60,000 psi minimum has been developed by a young engineer in your department. You have not checked his work, but he has been known to be conservative in his previous estimates. Are you more willing to ship coils in violation of an internal standard than a customer's one? Explain your answer.
4. If you knew the product for which this steel was intended, would it influence your decision? You should answer this question for each of the three possible assumptions described above in Scenarios #1-3. Suppose
  - (a) The steel was ordered by an aircraft manufacturer.
  - (b) The steel was to be used for non-critical equipment supports in restaurants.
  - (c) The steel was ordered by a subcontractor who was going to sell the steel to an unknown manufacturer.
  - (d) The steel will be used in the outside door panels of automobiles.
  - (e) The steel was ordered by a manufacturer that makes, among other things, automotive wheels.

There are several different ethical issues that you should consider.

1. The first issue is to decide what basic ethical analysis method you will use to analyze the problem. One way to consider the cases is to examine them as a line drawing problem. In a line drawing problem, you set up a scenario where the choice made was obviously good, and one where the decision that is made was obviously bad. You set up various intermediate cases, where the ethical correctness of each choice is less clear. You can use this to draw the line between acceptable and unacceptable choices. When you examine your calculations you may find that some coils are obviously good, and some obviously unacceptable. You can then concentrate on the coils that are in the middle, in which the shipping decision may not be obvious.

Another way to consider some cases is to examine them as if they were a conflict between two different people or standards. If you use this technique, you may wish to consider whether some middle way might be obtainable, that will satisfy all parties in the conflict. If that is not possible, then you may have to make a hard choice that may not satisfy all parties in the conflict.

2. A second ethical issue relates to how you will use various mathematical tools. Your choice of tool is not neutral, for it may change your decision as to which coils can be shipped. This has definite ethical implications. Using the wrong mathematical tool could result in shipping bad coils. This could have safety implications, as well as damaging both yours and your company's reputation. On the other hand, if you do not ship coils that are actually good, then you are costing your company money and not fulfilling your obligation to be a faithful trustee of your company's resources.

You may wish to use various math tools in doing Options 2 and 3. The use of these math tools is designed to make the decision process easier. Depending upon the data, that may or may not be true. You will face the decision as to whether you should use the mean as your acceptable criteria, or whether you will also use

the standard deviations and confidence intervals as well.

Using either standard deviations or confidence intervals will produce a range of strengths that could be used to represent the strengths of each coil. When you use these intervals, you are faced with several options:

- (a) You could ship only the coils whose entire interval is above the minimum.
- (b) You could ship only the coils who have some part of their interval above the minimum. You would need to decide which portion of the interval must be above the minimum strength.
- (c) You could decide to ignore the issue of these intervals, and just make the decision using the mean values of strength.

Engineers frequently define their data interval as the mean plus or minus the standard deviation. An analysis of your data may show that the confidence intervals are smaller than those produced using a standard deviation (in some cases) and larger than a standard deviation (in other cases). These two different methods may result in different recommendations as to shipping a particular coil. You will then need to decide which of these methods to use.

- 3. The fourth scenario described above also has ethical implications. If the application is determined to be a critical one in terms of protecting human life, then you may wish to use some type of respect for persons test. This examines the issue of whether the advantages of using this particular coil outweigh a potential damage to human life. If you use a cost benefit approach to this problem, then you would need to decide what is the value of the damage to human life. If the part is not in a critical application, then you may wish to use a more utilitarian approach which examines the benefits and costs of each decision.

This scenario also brings out the issue of loyalty. The engineer is required to be a "faithful agent" of his employer. To what extent does this loyalty conflict with his need to protect the public?

- 4. There is a potential ethics problem relating to whether these samples are representative of the entire coil. All of the samples are taken from the end of the strip that is on the outside of the coil. It is well known that the properties at the ends of the steel strips are frequently different from the properties in the middle of the coil. What ethical issues are involved in using such data?

If you use poor data, and ship coils that are not satisfactory, you are not fulfilling your obligation to provide satisfactory steel to your customer. You also may be guilty of deception, for you know that the data may not be representative of the properties of the bulk of the coil. If unrepresentative data causes you not to ship a good coil, then you are not being a faithful trustee of your own company's resources.

What other alternatives could you suggest that would allow you to obtain more representative data? Rewinding the coil to allow you to get samples from the other end is a rather expensive operation. The customer's requirement for a certain minimum weight coil makes it unlikely that you will get permission to cut every coil into half so that you could get test samples from the middle of the original coil.

**Data for Various Options**

Data for Option #1		Data for Option #2			
Coil	Yield Load (lbs)	Coil	Load for test #1 (lbs)	Load for test #2 (lbs)	Load for test #3 (lbs)
A	938	A	970	943	947
B	903	B	925	888	894
C	899	C	884	898	910
D	890	D	872	871	901
E	843	E	832	838	864

Data for Option #3					
Coil	Load for test #1 (lbs)	Load for test #2 (lbs)	Load for test #3 (lbs)	Load for test #4 (lbs)	Load for test #5 (lbs)
A	966	968	960	932	931
B	877	907	917	926	918
C	905	919	889	917	914
D	884	885	893	888	880
E	825	819	868	862	869

### A Note to those who Will use this Case

If this case is to be used in an actual class, this last section should be excluded from what is given to the students. The following discussion is based on the second author's use of this case study in fall 1995 in a senior level failure analysis technical elective and in spring 1996 in an engineering ethics course. It was used in the failure analysis course to help make the point that it is not always easy to define when something has failed a particular standard. While failure in the context of something actually breaking into several pieces is usually obvious, failure can be more generally described as occurring when a part does not meet the standards required in a particular application.

The three options were meant to be three separate situations. This means that coil A in the first option is not the same physical coil as coil A in the second or third option. Several students got confused at this point. The data was created so that coil A in all three options would be obviously acceptable, and coil E would be obviously unacceptable. Coils B, C, and D were tougher choices for the students. On each of these cases the confidence intervals (for options 2 and 3) were partially above and partially below the minimum standard. This forced the students to make a choice as to whether the mean, median, some portion of the confidence interval, or the entire confidence interval had to be above the standard in order to approve the coils for shipment. Most of the students at Louisiana Tech required that the mean be above the minimum acceptable level. A significant group of students required that the

entire confidence intervals be above the minimum acceptable level.

For each of the three options (which concerned how many tests were made on each coil), the students were presented with four scenarios. These scenarios dealt with the issue of how firm to hold to a given standard. For example, does it make any difference if you have to certify the results to the customer? The students were also forced to consider whether the end use of the part should play a role in deciding which coils to approve.

The way this case study is written, it implies that this should be one assignment. This is the way that it was actually handled in fall 1995. This was given as one large homework assignment, where the students had about one week to complete it. During spring 1996, this problem was presented to an engineering ethics class. In this class, the data for option #1 was presented by itself. The students were required to respond to the various ethical issues without worrying (at this point) about the issues raised by doing a statistical analysis of the data. After the students had turned in this assignment (and it had been graded and returned to them), they were presented with data options #2 and #3. The students were then forced to examine the same ethical issues in light of some sort of statistical analysis of the data.

Student reviews of this problem were very positive. A number of them stated that this has exposed them to real world situations more than any of the other topics we discussed in the ethics course. A few students thought that doing the statistics twice was a bit redundant. If the professor is pressed for time, it would be possible to eliminate data option #2. However, we believe that doing both data options #2 and #3 are useful, for this helps to make the point that there may be problems when you try to statistically analyze very limited data.

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the A.S.E.E. Gulf Southwest Regional Meeting in March 1996.

### **Biography**

Michael Latcha has been a faculty member at Oakland University in Rochester, Michigan, since 1986. He teaches in the solid mechanics track of Mechanical Engineering, from introductory statics to senior-level design to graduate dynamics. He received his Ph.D. in 1989 from Wayne State University. His current research includes numerical acoustics and the simulation of multi-body dynamic systems.

William Jordan is an associate professor in the Mechanical and Industrial Engineering Department at Louisiana Tech University. He has obtained B.S. and M.S. degrees in Metallurgical Engineering from the Colorado School of Mines, an M.A. degree in Theology from Denver Seminary, and a Ph.D. in Mechanics and Materials Engineering from Texas A & M University. He is in his twelfth year at Louisiana Tech, and his teaching and research interests focus on the areas of composite materials, fracture mechanics, failure analysis, and engineering ethics. He is a registered professional engineer (Metallurgical Engineering) in the state of Louisiana.