

LN4.3.1 INTRODUCTION TO ETHICS IN ENGINEERING – CASE STUDY - II

“William LeMessurier”¹

“William LeMessurier: The Fifty-Nine-Story Crisis; A Lesson in Professional Behavior,” Online Ethics Center, www.onlineethics.org/moral/LeMessurier/lem

1.1 Case Description

William LeMessurier: The Fifty-Nine-Story Crisis; A Lesson in Professional Behavior

William LeMessurier, one of the nation's most distinguished structural engineers, served as design and construction consultant on the innovative Citicorp headquarters tower, which was completed in 1977 in New York. The next year, after a college student studying the tower design had called him to point out a possible deficiency, LeMessurier discovered that the building was indeed structurally deficient.

LeMessurier faced a complex and difficult problem of professional responsibility in which he had to alert a broad group of people to the structural deficiency and enlist their cooperation in repairing the deficiency before a hurricane brought the building down.

¹ I would like to thank Dr. Kent Harries of USC's Civil Engineering Department who was essential to the development of this module and with whom I taught this module in his Structural Engineering course.

His story was recounted in detail in "The Fifty-Nine-Story Crisis," which appeared in the May 29, 1995 issue of *The New Yorker*, and on November 17, 1995, LeMessurier himself came to MIT, from which he received his doctorate, to speak to prospective engineers about the decisions he had to make and the actions he took.

Part 1: Background & the History of Skyscrapers

By the early 1970s, when Citibank began plans for a huge new headquarters tower in midtown New York, the art of designing and building a strong, safe skyscraper seemed nearly perfected. The skyscraper, like any other architectural form, had gone through a long period of evolution.

After Elisha Otis's successful introduction of the first safety-brake-equipped elevator in the 1850s and the introduction of steel-frame construction, buildings began to grow upward. In 1910, the [Metropolitan Life building](#) broke all records for height until that time: it was 50 stories high.

By the 1930s, with the construction of the 102-story [Empire State Building](#), skyscrapers, thanks to their widespread success, had begun to sprout in many cities worldwide. Areas populated with these tall buildings found themselves growing, literally, ever upward. The

skyscraper, coupled with the introduction of modern, efficient subway systems in cities like New York, made it possible for companies to employ workforces unprecedented in size. Consequently, city populations increased immensely.

By 1930, daring, creative architects and engineers had even begun to depart from what had been accepted as the "traditional" method of designing and constructing skyscrapers. Innovations in skyscraper design such as lighter materials, increased window area, and cantilevered supports, resulted in taller, lighter, and slimmer buildings.

For instance, Chicago's record-breaking [Hancock Building](#), incorporating an innovative system of diagonal bracing that allowed the building to be much leaner and lighter than it could be if it had been constructed in a traditional manner.

Part 2: LeMessurier's Innovative Citicorp Design

William LeMessurier was one of the country's most distinguished structural engineers when his Cambridge firm was called upon to act as a consultant to the planned Citibank corporate headquarters. LeMessurier had a vast array of experience with skyscrapers; the first building he designed, [Boston's State Street Bank](#), incorporate an inventive cantilever girder system, and his famous [Boston Federal](#)

[Reserve Bank](#), was designed so that an airplane could, quite literally, fly directly through what appeared to be a large hole in the building.

LeMessurier's experience with innovative designs was fortunate, since there was a criterion peculiar to the planned Citibank building. A church had partial ownership of the block where Citicorp planned to build. As a resolution, Citicorp agreed to build a new free-standing structure, located at one corner of the lot, to replace the current antiquated, dilapidated church. In return, the church granted "air rights" above its part of the block to Citicorp.

In order to provide space for the new church, the Citicorp tower would therefore have to be situated on nine-story-high stilts, so the church could be constructed underneath. However, the church was to be located at a corner of the block, not in the middle of a block. This meant that the Citicorp tower's stilts would have to be in the middle of each of its walls, and not at the building's corners -- an unprecedented feat of engineering if it could be accomplished.

The innovative LeMessurier sketched an idea for the Citicorp tower's framework and column support system. It called for large diagonal girders throughout the building. The girders would transfer the tower's great weight to the four huge columns that would anchor the structure to

the ground. The [new church](#) could then be constructed as planned, underneath one of the tower's corners.

Part 3: The Discovery of the Change from Welds to Bolts

The Citicorp tower was constructed using LeMessurier's diagonal-bracing design, and work was finished in 1977. LeMessurier's innovation translated into a great weight savings; the tower was unusually light for its size.

However, this meant that it would have a fair tendency to sway in the wind, so a [tuned-mass damper](#) was installed at the top of the building. The inertia of this 400-ton concrete block, which floated on pressurized oil bearings, worked to combat the tower's expected slight swaying. The Citicorp tower was the first structure ever to incorporate mechanical assistance to combat wind sway.

In May 1978, LeMessurier, acting as structural consultant to a new building being planned in Pittsburgh, again thought of using a sort of diagonal brace as part of his design. As in the Citicorp tower, the braces were intended to be joined with full-penetration welds, but the process of welding, though it resulted in extremely strong joints, was expensive and time-consuming.

A potential contractor for the Pittsburgh construction job pointed this out to LeMessurier, who immediately thought to counteract the contractor's fears with the success story of his Citicorp tower and its welded joints.

Unknown to LeMessurier, however, was that during the Citicorp tower's construction, the Citicorp contractors had decided, based on the cost of welding, to put the braces together using less expensive bolted joints. Though bolted joints were weaker than welded joints, the New York contractors had agreed that welds would be unnecessarily strong and that bolts would be sufficient for the job.

When LeMessurier referred the Pittsburgh contractor, concerned over the cost of welding, to the successful Citicorp job, he was told of the substitution of bolts for welds in the Citicorp project.

LeMessurier did not consider the change to pose a safety hazard, however, since the substitution was rather reasonable from an engineering standpoint, and there wasn't any reason for LeMessurier, a distant consultant, to have been previously informed. This assessment would change over the next month, however, as LeMessurier would soon encounter new data indicating that the switch from welds to bolts compounded another danger with potentially catastrophic consequences.

Part 4: Exploring the Effects of Quartering Winds

In June 1978, a month after LeMessurier was told of the switch from welds to bolts in the Citicorp building, he received a telephone call from a student.

This student's professor had been studying LeMessurier's Citicorp design and had concluded that LeMessurier had put the building's nine-story supports in the wrong place. The supports belonged on the tower's corners, according to this professor, not at the tower's midpoints.

The professor had not understood the design problem that had been faced, so LeMessurier explained his entire line of reasoning for putting the tower's supports at the building's midpoints. He added that his unique design, including the supports and the diagonal-brace system, made the building particularly resistant to quartering, or diagonal, winds -- that is, [winds coming on the diagonal](#) and so hitting two sides of the building simultaneously.

Shortly thereafter, LeMessurier decided that the subject of the Citicorp tower and quartering winds would make an interesting topic for the structural engineering class he taught at Harvard. Since at the time the requirements of the New York building code, like all other building codes, had covered only perpendicular winds, LeMessurier did not know how his design would fare in quartering winds.

Interested to see if the building's diagonal braces would be as strong in quartering winds as they had been calculated to be in perpendicular winds, LeMessurier did some computations. He found that for a given quartering wind, stresses in half of a certain number of structural members increased by 40 percent.

Then he became concerned about the substitution of bolts for welds. Had the New York contractors taken quartering winds into account when they replaced the welds with bolts? Had they used the right number of bolts? The second question was particularly important -- a 40 percent increase in stress on certain structural members resulted in a 160 percent increase of stress on the building's joints, so it was vital that the correct number of bolts be used to ensure that each joint was the proper strength.

What he found out was disturbing. The New York firm had disregarded quartering winds when they substituted bolted joints for welded ones. Furthermore, the contractors had interpreted the New York building code in such a way as to exempt many of the tower's diagonal braces from load bearing calculations, so they had used far too few bolts.

Shaken, LeMessurier reviewed old wind-tunnel tests of the building's design against his new quartering-wind calculations (these tests had modeled a [large part of midtown Manhattan](#)), and found that under adverse weather conditions, the tower's bracing system would be put under even further stress. The innovative tuned-mass damper, designed to reduce the building's normal slight swaying, was not designed to keep the building from being blown down in a major storm; this further worried LeMessurier.

Part 5: Further Evidence of the Danger

LeMessurier now believed there might be serious danger. He turned to Alan Davenport, a Canadian consultant during the building's design. Davenport, who had run the original wind tunnel tests, now ran the tests again, using new calculations to reflect quartering winds and the change from welds to bolts.

The results, when compared with the building's original testing, confirmed LeMessurier's suspicions about increased stress in some of the building's structural members. His concern grew, since the results indicated that a 40 percent theoretical increase in a member's structural stress would be much greater under real-world conditions. During a storm, the whole building could shake, causing the structural members to all vibrate synchronously.

LeMessurier worked through the revised wind tunnel data, and quickly discovered that the entire building was vulnerable to a total structural failure -- if a storm pulled a joint apart on the 30th floor, the whole building would collapse. A "sixteen-year storm," that is, a storm occurring once every sixteen years, would have the strength to cause total structural failure.

Though the electric tuned-mass damper had an enormous steadying effect on the building, and might help to reduce the stress on that joint, a strong storm would knock out the electricity necessary for running the damper.

Solving the problem was not difficult from an engineering perspective; heavy steel welded "Band-Aids" over the joints would give the building more strength than it was even originally designed to have. But it was the last day of July, and in order to complete repairs before the start of hurricane season, LeMessurier would have to announce the building's vulnerability and take responsibility upon himself.

Doing so could cost LeMessurier his career and reputation as a structural engineer. He did not know how his news would be received by Citibank leadership, city officials, or the general public.

Part 6: Mobilizing Support

On July 31, 1978, LeMessurier contacted the lawyer of the architectural firm that had retained him as its structural consultant for the Citicorp tower and then the firm's insurance company. As a result, a meeting was arranged the following day with several lawyers for the insurers, to whom LeMessurier related the entire story.

The lawyers soon decided to bring in a special consultant -- Les Robertson, a respected structural engineer. Robertson listened to LeMessurier's description of the situation and soon took a more critical view than even LeMessurier himself.

Robertson did not believe, for instance, that the tuned mass damper would serve as a safety device despite LeMessurier's assurances that generators could keep the dampers running during an electrical power loss.

Citicorp had to be informed of the danger, so LeMessurier and his partner went about contacting Citicorp's chairman, Walter Wriston. Initially, Wriston was unavailable to them, but LeMessurier's partner was able to arranging a meeting with Citicorp's executive vice president, John Reed, who had engineering experience and played a part in the construction of the tower.

LeMessurier detailed the situation once more. When prompted for a cost estimate, LeMessurier guessed that one million dollars would be sufficient. He also explained that the repairs could be done without inconvenience to the tenants by isolating the bolted joints within plywood 'houses' and doing the necessary work at night within those 'houses.'

Reed appreciated the gravity of the situation, and arranged for a meeting with Wriston on August 2, at which point LeMessurier once again told his story. Much to his relief, Wriston recognized the importance of the tower as Citicorp's new corporate emblem, and so readily agreed to the repair proposal.

He approved a plan to install emergency generators as a backup power supply for the tuned mass damper, and oversaw much of the relations with the public as well as with the building tenants.

The next day, LeMessurier met with two engineers from the construction company that was to perform the repairs. After examining the joints, these engineers approved LeMessurier's plan to reinforce the bolted joints with welded "Band-Aids."

Before undertaking the repairs, several steps were necessary. LeMessurier contacted the company that had constructed the tuned mass damper to help assure the device's continuous operation. Meteorological experts were retained in order to give advance warning of any storm that could cause the building's destruction.

LeMessurier reluctantly agreed with Robertson that, as a further precaution, an emergency evacuation plan for the building and the ten-block-diameter surrounding neighborhood be drafted. In its final form, the plan was to involve up to 2,000 emergency workers provided by the Red Cross.

LeMessurier had to explain the situation to city officials, both to secure their cooperation with the evacuation plan and to comply with the building code. They responded with approval and encouragement, rather than the cynicism that LeMessurier expected. They too recognized both the seriousness of the problem and the immediate need to solve it. Energy was not wasted on rancor or placing blame.

The final task, the one that LeMessurier most dreaded, was informing the press of what was going to be a major undertaking on the brand-new Citicorp tower. An initial press release was issued. It indicated that the building was being refitted in order to withstand slightly higher winds. This was true to some extent, for the meteorological data suggested that

the winds for that year were going to be somewhat higher than normal. But the *New York Times*, for one, was sure to express further interest in what could be a very juicy story. After an initial phone call from a reporter, though, LeMessurier found an unexpected reprieve in a citywide press strike.

Part 7: Accomplishing the Repair Without Causing Panic

Repairs to the Citicorp building commenced immediately. The plan of action was to expose each bolted joint in the building by ripping away the flooring and walls around it, to cover each joint with a plywood 'house' in order to minimize any visible signs that things were awry with the building's structure, and to complete the repair welding at night when the tenants were not in the building, so as not to inconvenience them.

The pace of work was fast. Parts of the interior around the bolted joints were torn up at night and put back together in the morning. LeMessurier occupied himself with repair process calculations. Les Robertson calculated how to repair the joints, and, suspecting that other components of the building could be vulnerable, went about investigating the floors, columns, and braces for weakness.

The repair work was in full swing on the first of September, when a hurricane moving toward New York was detected. The news was met

with alarm. The partial repairs -- along with the tuned mass damper -- greatly improved the building's strength, but no one wanted to see it tested. There was great relief when the hurricane moved out over the ocean.

Two weeks later, repairs had progressed to the point that, with no storms predicted, the elaborate evacuation plans could be scrapped. The next month, repairs were complete. Even if the tuned mass damper were to fail, a 700-year storm would not pose a threat to the Citicorp Center.

The engineering problem had been solved, and today the repaired building now exceeds even its originally intended safety factor.

Part 8: The Final Touch: LeMessursier's Good Name

LeMessursier feared for his career but did not allow any worries or self-protective impulses to sidetrack his attention from carrying out the repairs. In the middle of September, when repairs were almost complete, Citicorp notified LeMessurier and his partner that it expected to be reimbursed for the cost of the repairs.

The estimated total cost for the building's repair ranged between a high of \$8 million for the structural work alone, given by one of the

construction companies involved, to \$4 million, which, according to LeMessurier, was the Citicorp estimate (Citicorp did not make public its estimate.)

LeMessurier's liability insurance company had agreed to pay \$2 million, and LeMessurier brought that figure to the negotiating table. The Citicorp officials eventually agreed to accept the \$2 million, to find no fault with LeMessurier's firm, and to close the entire matter.

A relieved LeMessurier nevertheless expected his insurance company to raise the premiums on his liability insurance. He would, he reasoned, appear as an engineer who had bungled an expensive job and brought about a large cash settlement.

At a meeting with officials from the insurance company, LeMessurier's secretary was able to convince them that LeMessurier had "prevented one of the worst insurance disasters of all time!" Far from behaving in an incompetent or devious manner, LeMessurier had acted in a commendable way: he had discovered an unforeseen problem, acted immediately, appropriately and efficiently to solve it, and solved it.

LeMessurier's handling of the Citicorp situation increased his reputation as an exceptionally competent, forthright structural engineer. It also prompted his liability insurers to lower his premium.

1.2 Materials

“William LeMessurier: The Fifty-Nine-Story Crisis; A Lesson in Professional Behavior,” Online Ethics Center, www.onlineethics.org/moral/LeMessurier/lem

This is a good discussion of the case which includes some useful diagrams, a brief discussion of the history of skyscrapers, a video clip of LeMessurier and has the advantage of being available online. The text of this discussion is reproduce below with the kind permission of the Online Ethics Center and Caroline Whitbeck.

Joe Morgenstern, “The Fifty-Nine-Story Crisis, The New Yorker, May 29, 1995. Reprinted in Journal of Professional Issues in Engineering Education and Practice, January 1997, 23-29.

LeMessurier's story has been retold in several different articles, but they all depend on this piece by Morgenstern that first made the story

broadly available. It remains the best reading for this case. It is simply an account of what happened so it lets the students develop their own ideas about the ethical issues of the case.

Caroline Whitbeck, “William LeMessurier’s Handling of the ‘Fifty-Nine-Story Crisis,’” Ethics in Engineering Practice and Research, Cambridge, Cambridge University Press, 1998, 146-156.

Several textbooks discuss the LeMessurier case, but Whitbeck’s discussion is the most thorough. I would recommend this at least as background reading for the instructor. This piece has the weakness discussed below of accentuating the positive without looking critically enough at how such problems might be avoided, but it remains a very good discussion of the case.

1.3 Discussion

While most case-based modules develop from situations where individuals acted badly, this module has the advantage of being based on a case where individuals acted well. And indeed the tendency is to look at how well LeMessurier in particular, but Citicorp and New York City officials as well, acted.

This tendency to accentuate the positive is laudable. There is much to learn from individuals who act in exemplary ways, but the tendency to discuss this case simply from the point of view of what was done well is a bit one-sided.

In the discussion of the pedagogical approach I argue that concentrating on the amoral calculator is a mistake because it leads students to try and place blame instead of concentrating on avoiding the ethical dilemma in the first place. The LeMessurier case tends to lead students to find individuals to praise, but again at the cost of asking how such a situation could have been avoided.

When approaching this case the goal is to encourage the students to consider how such a crisis can be prevented so that we do not have to depend on the good actions of a series of individuals and institutions who often find themselves in conflict with each other.

Here it is useful to look at the design process for an innovative design and ask whether existing codes are always effective criteria from which to judge innovative designs. The student might be asked to consider why LeMessurier and his partners were confident in their original design and why the problem of quartering winds was not originally considered. What role do they think that the fact that the codes simply did not ask

designs to account for quartering winds play?² Should LeMessurier have known enough to take these into account, or is this simply the type of mistake that is part of innovative design.

These questions lead naturally into consideration about the ethics of innovation. How do we both recognize that innovation is clearly desirable in design, while at the same time that it brings the potential not just for error, but also for unrecognized error? What is an acceptable level of risk in developing innovative designs and how do we establish such acceptable levels? How do we control for errors?

This case is particularly interesting as a discussion of the ethics of innovation because in cases of innovative building design some of the more common approaches for controlling for error are not available. For example the safety of a new building design cannot be tested in a laboratory with multiple replicates and control groups. This kind of testing would require from several to many copies of the building to be built, an obviously unavailable option.

Mike Martin and Roland Schinzinger argue that these situations point out that engineering is often a type of social experimentation (Martin and Schinzinger 80-96). Students can be encouraged to consider what

² It would be useful to point out to the students that when the main supports are in the corner of a building quartering winds are not a significant problem. The different stresses and wind loads involved in this case might provide some interesting technical problems to go along with the module.

kind of ethical responsibilities are demanded of engineers by such experimentation.

This module is also effective to model the kind of cooperation that is desirable between different entities. Here Citicorp, New York City, and LeMessurier all cooperated effectively to implement a solution, but even in this case the cooperation was ad hoc. It is interesting to raise the issue of why such cooperation is ad hoc and whether such cooperation could be institutionalized. Is there some way to encourage such cooperation in all cases?

A further issue is the responsibility an engineer has for a design once that design is in the hands of those who are to put it into effect (in this case the contractor). The change from welds to bolts was crucial, was a change that LeMessurier did not make, and which he discovered serendipitously. Such changes in design by a contractor are standard practice and probably quite defensible in most cases, but in a case where a new design is being put into place does the designer have to take special care to be informed of such changes? What role should the designer play once the design is in the production phase?

A final issue is whether, even given the praiseworthiness of the actions by most individuals involved, a problem remains with the failure to

adequately inform the individuals using the building of the situation. The repairs were done in secret and the occupants of the building were not informed. The reasoning here was that no one was in any immediate danger. But this required that LeMessurier, the city, and Citicorp make a judgment about what risk the building occupants should be willing to undertake. Was it appropriate for LeMessurier and the others to make this judgment or is this something that the occupants should have decided for themselves. This can lead to an interesting discussion of informed consent and the role that it plays in ethics.

These are some of the possible issues that one can raise out of the LeMessurier case. As I argued earlier what is important is that the students be encouraged to pursue different avenues to discussing and resolving the issues raised by this case. For this to be successful the instructor needs to have a direction toward which he or she wants to take the discussion. This requires the instructor to develop a reasonably sophisticated analysis of the issues without then using the analysis as a rigid framework. The material provided is meant to help an instructor develop such an analysis.