A Need for Expansion: Mechanical and Electrical Courses

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Mechanical and electrical systems are becoming more complicated to understand, estimate, schedule, manage, and design. A poor selection, design, installation, and coordination of the mechanical and electrical systems will result in significant problems for architects, engineers, contractors, and building owners during and after construction. Highly trained professional construction project managers are essential for the successful delivery of mechanical and electrical systems on a construction project. This paper will present how many mechanical and electrical courses are offered by baccalaureate degree programs that are members of Associated Schools of Construction and also accredited by American Council for Construction Education. This paper will also portray the average mechanical, electrical, and plumbing cost for various construction projects.

Key words: Mechanical and electrical construction, mechanical and electrical costs, Associated Schools of Construction, American Council for Construction Education

Introduction

The mechanical portion of a construction project is often a significant percentage of the total project cost. Typically, mechanical construction consumes 15 percent and electrical construction consumes an additional 10 percent of the total project cost (Koontz and Alter, 1996). Both of these percentages will be much higher for buildings such as hospitals, medical buildings, and clean rooms. Mechanical systems are becoming more complicated to understand, estimate, schedule, manage, and design. For these reasons, and due to the increased importance of mechanical systems in a building, our educational efforts in the area of mechanical construction management need to expand (Koontz and Alter, 1996). This is the only way to ensure that construction project managers are adequately educated and prepared to meet the industry's demands.

There are different perspectives from the various parties in regards to deciding the building's mechanical systems. The building owner's primary concern is cost. The architect/engineer's primary concern is aesthetics. The contractor's primary concern is the speed at which the system can be installed. However, there are several other issues that the architects, engineers, contractors, and building owners need to consider, such as the use of the building, location, availability, flexibility, maintenance, reliability, and the initial and operating cost of the mechanical equipment. Even the size and placement of the mechanical equipment in the building can be critical. A poor selection, design, installation, and coordination of the mechanical systems will result in significant problems for architects, engineers, contractors, and building owners during and after construction. Plus, it is not uncommon when there are budget overruns at the start or near completion in a construction project that compromises are made in the mechanical systems. With today's problems of mold, high energy costs, and sick building syndrome, a poor mechanical system can result in a major problem for the project owner, architect/engineer, contractor and even the building occupant (Cooling System Selection, 2006).

The proper design, selection, coordination, and installation of a Heating, Ventilation and Air Conditioning (HVAC) system is a complex process considering today's efficiency standards and rising energy prices. According to a 1988 survey conducted by the Building Owners and Managers Association (BOMA) of 400 executives, the number one operation and/or design problem was HVAC. This problem was ranked 24.3 percent which was a factor of 2 to 1 over the second biggest problem of elevators which was 12.2 percent (Gann, 1997). Continuous adjustments and improvements on HVAC systems will add additional cost to building owners. However, HVAC system design, selection, and installation typically do not meet the building owner's expectations for energy efficiency nor the building occupant's comfort (Maisey and Milestone, 2006). According to a 1992 national building study, buildings cost more to build and cool and are not as comfortable as they should be due to a lack of HVAC system knowledge.

This is still true today because HVAC systems are being selected based on code requirements and design loads. For these two reasons, HVAC systems are costing building owners billions of dollars each year in energy cost and low building occupant performance and effectiveness (Maisey and Milestone, 2006).

Problem Statement

Due to budget constraints and mandated state and university general study requirements, some construction management programs are teaching one combined mechanical and electrical construction course. In most programs, this course is the only course that teaches construction management students about the different mechanical and electrical systems. This creates a critical void in adequate mechanical and electrical construction management education. If this trend of teaching mechanical and electrical systems together in one course is not changed, the construction industry will be hard-pressed to find qualified construction project management graduates who are knowledgeable about mechanical and electrical construction. This study intended to determine how many M/E/P courses are offered by baccalaureate degree programs that are members of ASC and also accredited by ACCE. It also intended to determine the average M/E/P cost for various construction projects. The goal of this paper is to show the importance of having one course in a construction management program that is dedicated to teaching mechanical construction management and a separate course to teach electrical construction management.

Methods

A study was performed during the summer 2006 investigating the total mechanical construction cost for Construction Specifications Institute (CSI) Division 15 Mechanical Construction and electrical construction cost for CSI Division 16 Electrical Construction in their entirety. The fire protection costs were excluded from this study because a majority of mechanical contractors do not perform fire protection work. General contractors and construction managers, mostly from the Midwest, were contacted to obtain the mechanical, electrical, and fire protection cost break-downs for new construction buildings. The general contractors and construction managers were emailed a form and asked to record the building square footage, total building cost, HVAC and plumbing cost, electrical cost, and fire protection cost for three projects in each of the listed categories (see Appendix). Even though fire protection was omitted from the study, the cost breakout was still requested to ensure it was not included in the mechanical construction cost by the general contractor or construction manager.

Figure 1 shows the breakout percentages of the different projects. The study had 65 new construction projects that were constructed between 1997 and 2006, such as office buildings, hospitals, hotels, apartments, nursing homes, medical buildings, schools, banks, retail stores, and specialty buildings. Because the study had two unique buildings, an animal hospital and ice arena that did not fit into specified categories; they were grouped as other.

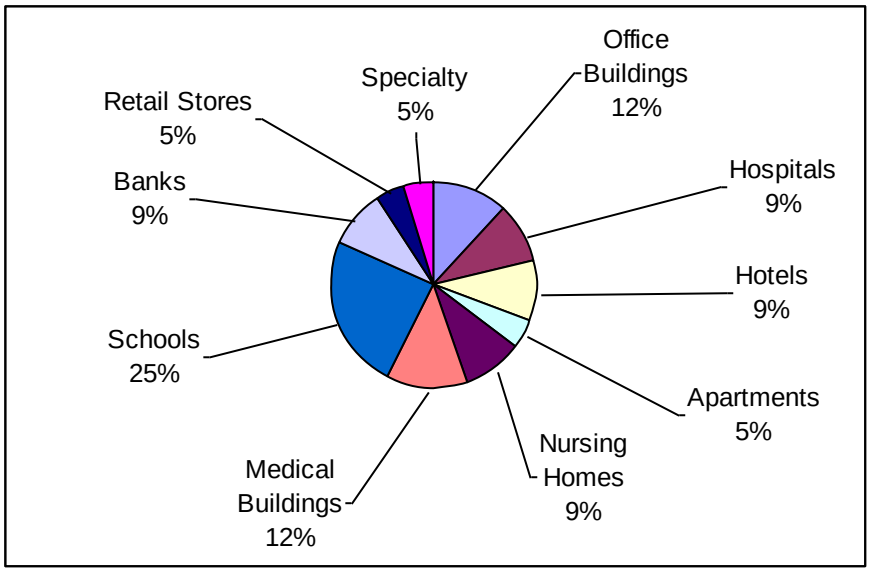

Figure 1: Percentages of Different Construction Projects Used

Findings

The total project construction costs ranged from $741,765 to $132,604,600 with an average cost of $13,136,431. The total mechanical construction costs ranged from $37,300 to $33,655,044 with an average cost of $2,511,893. The total electrical construction costs ranged from $55,750 to $19,856,898 with an average cost of $1,585,384 (see Table 1).

Table 1
Minimum, Maximum, and Average Total Project, Mechanical, Electrical Costs

Category	Minimum	Maximum	Average
Total Project Cost	$741,765	$132,604,600	$13,136,431
Mechanical Cost	$37,300	$33,655,044	$2,511,893
Electrical Cost	$55,750	$19,856,898	$1,585,384

The total project square footage costs ranged from $73 to $305 per square foot with an average cost of $164 per square foot. The total mechanical square footage costs ranged from $9 to $72 per square foot with an average cost of $24 per square foot. The total electrical square footage costs ranged from $6 to $34 with an average cost of $17 per square foot (see Table 2).

Table 2
Minimum, Maximum, and Average Cost Per Square Foot

Category	Minimum Cost Per Square Foot	Maximum Cost Per Square Foot	Average Cost Per Square Foot
Total Project	$73	$305	$164
Mechanical	$9	$72	$24
Electrical	$6	$34	$17

Table 2 shows that the mechanical cost on average is $24 per square foot and electrical cost on average is $17 per square foot. If the construction project is a medical building, or hospital, the mechanical cost per square footage is much higher. If the construction project is an office building, hospital, or medical building the electrical cost per

square footage is higher (see Table 3). It should be noted that the square footage was only obtained from 45 out of the 65 projects.

Table 3
Cost Per Square Foot

Category	Mechanical Cost Per Square Foot	Electrical Cost Per Square Foot	Mechanical & Electrical Cost Per Square Foot
Office Buildings	$22.99	$21.59	$44.58
Hospitals	$60.70	$29.58	$90.28
Hotels	$20.60	$15.98	$36.58
Apartments	$13.42	$7.80	$21.22
Nursing Homes	$17.74	$13.36	$31.09
Medical Buildings	$39.31	$20.69	$60.01
Schools	$21.39	$15.68	$37.06
Banks	$13.80	$14.89	$28.69
Retail Stores	$11.66	$10.69	$22.35
Specialty	$17.72	$6.39	$24.11

The mechanical cost represents on average 15 percent of the building's total construction cost. If the construction project is an office building, medical building, or hospital, this percentage will be much higher (see Figure 2).

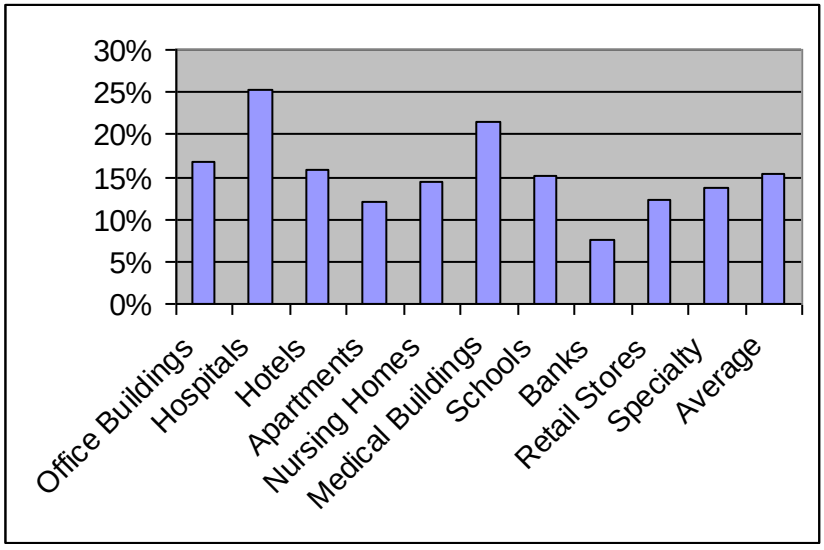

Figure 2: Average Mechanical Construction Cost on Projects

The electrical cost represents on average 10 percent of the buildings total construction cost. If the construction project is an office building, hospital, medical building, or retail store, this percentage will be higher (see Figure 3).

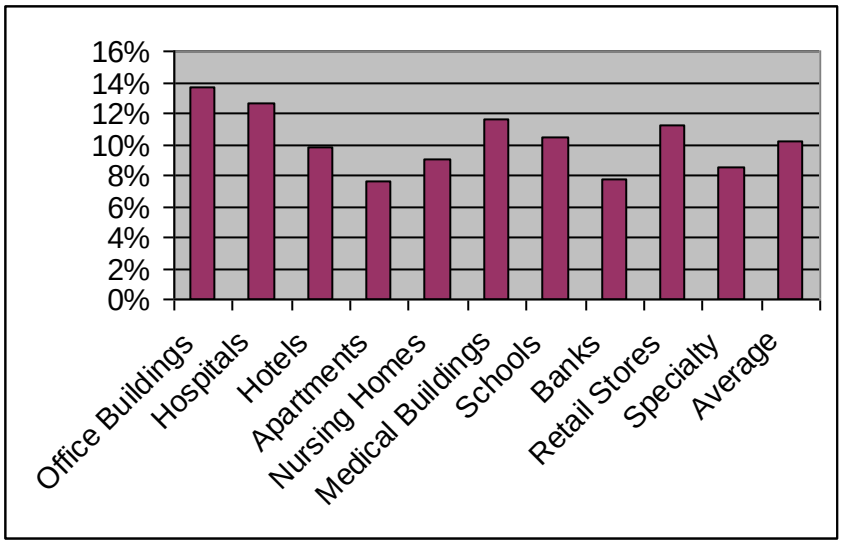

Figure 3: Average Electrical Construction Cost on Projects

The mechanical and electrical cost together represents on average 26 percent of the building's total construction cost. If the construction project is an office building, hospital, or medical building, this percentage will be higher (see Figure 4).

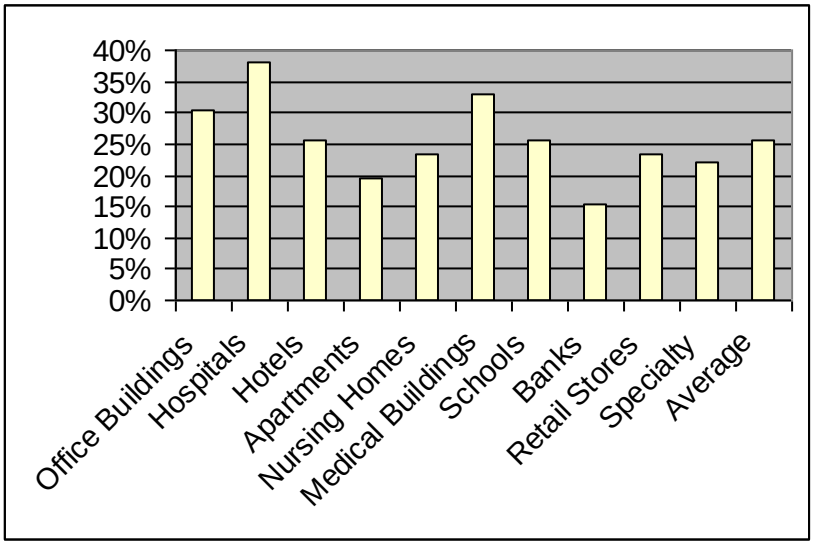

Figure 4: Average Mechanical and Electrical Construction Cost on Projects

In reviewing the curriculum of 60 baccalaureate degree programs that are members of the ASC and also accredited by ACCE, 50 percent of the construction management/engineering programs offer one mechanical, electrical, and plumbing (M/E/P) course, 37 percent offer two M/E/P courses, and 13 percent offer 3 or more M/E/P courses (see Figure 5). This information was also obtained during the summer 2006 by reviewing each program's web site.

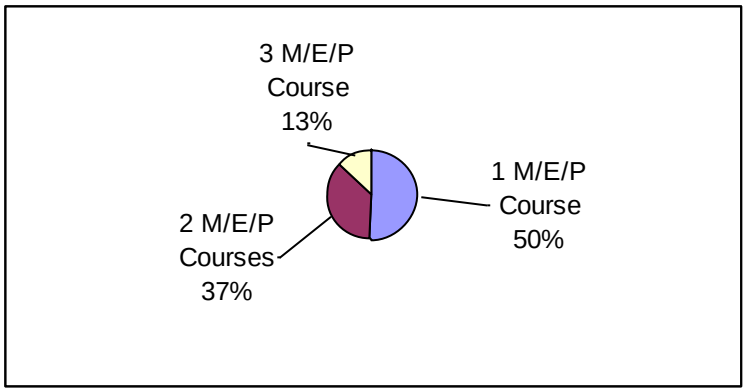

Figure 5: Percentage of Schools teaching M/E/P Courses

This means that 50 percent of the schools only offer one course in their curriculum that has to cover mechanical and electrical systems. Furthermore, on average, the schools' degree requirement to graduate is 127.5 credit hours. This illustrates that a majority of university construction management programs are not dedicating enough of their curriculum in reflection of the total project cost. For example, if mechanical and electrical construction cost is 15 and 10 percent respectfully of the total project cost; collectively they would be 25 percent of the total project cost. ACCE only requires one three-credit-hour course to be taught on M/E/P systems. Assuming the university construction management program only requires one three-credit-hour course on M/E/P and the degree program requirement is 127.5 credit hours, this means that only 2.3 percent of their curriculum is spent on M/E/P systems compared to 25 percent of the total project cost.

The authors realize that a university construction management program cannot dedicate 25 percent of its degree program to teach M/E/P systems. However, university construction management programs need to be aware of this issue and begin offering more than just one M/E/P course. In addition, ACCE needs to call for universities to require at least one three-credit-hour mechanical construction course be taught and one three-credit-hour course on electrical construction.

Another important reason more time needs to be spent on teaching mechanical and electrical systems is the issue of rising energy costs causing energy efficiency to become even more important. Every building owner tries to spend as little as possible on energy and equipment cost to maintain building comfort. The Leadership in Energy and Environmental Design (LEED) Green Building is becoming more prevalent. Mechanical and electrical contractors have a vital role in the green building process and many are selected as key members of the design and development team for their expertise in heating and air conditioning, plumbing, service and energy efficiency. Mechanical and electrical contractors are being expected to participate and discover ways to identify potential LEED points for a project (Kruse, 2007). A third reason more time needs to spent on teaching mechanical and electrical systems is the use of Building Information Modeling (BIM). BIM allows better decision-making and building performance analysis support for mechanical/electrical/plumbing (M/E/P) engineers and helps minimize coordination errors between M/E/P contractors (Autodesk, 2007).

LEED and BIM are stand-alone taught courses, but an increasing number of mechanical and electrical contractors are asking construction management students if they have any knowledge of LEED and BIM. These two topics just further complicate what needs to be taught in a M/E/P course. Most M/E/P contractors are willing to train the students about LEED and BIM, but they do expect the students to have a sound knowledge of M/E/P systems. With only teaching one combined M/E/P course it is very difficult, if not impossible, to properly educate students on M/E/P systems.

Conclusion

With talking to general contractors' and construction managers' who participated in the study, one of the weakest areas in managing a construction project is in mechanical and electrical construction. It is difficult because of the

increased complexity of the systems, demanding owners' expectations, and shorter project durations. Some of the general contractors' and construction managers' try to solve this weakness by hiring individuals who have worked for a mechanical or electrical contractor or a mechanical or electrical design firm. Most of the general contractors' and construction managers' who participated in the study have an individual or group of individuals that are required to be an M/E/P expert.

Typically, 75 percent of the students who graduate from an ACCE accredited construction management/engineering program go to work for a general contractor and/or construction manager. When this is combined with the fact that 50 percent of the ACCE accredited construction management/engineering programs only offer one M/E/P course, the lack of M/E/P education is not getting fixed. Upon graduation, students should have a basic understanding of M/E/P systems and talk intelligently with M/E/P contractors when a problem arises. However, this is not the case when talking with mechanical and electrical contractors. When talking with mechanical and electrical contractors, they state the biggest problem with general contractors and construction managers and even the architects and project owners is that they do not understand the mechanical and/or electrical contractor's business or what the M/E/P contractor is suppose to do on the job. At a majority of project startup meetings, M/E/P contractors have to spend part of the time educating everyone about the M/E/P systems and what has to happen on the project.

Highly trained professional construction project managers are essential for the successful delivery of mechanical and electrical systems. The construction project manager is responsible for equipment purchasing, delivery, installation, integration into other systems of the building, and commissioning. Therefore, highly qualified construction educators are required to be student-oriented and experts in their fields. Probably, the biggest challenge of teaching a combined mechanical and electrical construction course, is trying to find an instructor who has the proper background and education to teach both subjects. This creates a critical void in adequately educating construction management/engineering students about mechanical and electrical construction management.

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Appendix

Project	Building Square Footage	Total Bid Amount	Fire Protection Amount	HVAC & Plumbing Amount	Electrical Amount
OFFICE BUILDINGS					
Office building #1					
Office building #2					
Office building #3					
HOSPITALS					
Hospital #1					
Hospital #2					
Hospital #3					
HOTELS					
Hotel #1					
Hotel #2					
Hotel #3					
Apartments					
Nursing Home #1					
Nursing Home #2					
Nursing Home #3					
NURSING HOMES					
Nursing Home #1					
Nursing Home #2					
Nursing Home #3					
MEDICAL BUILDINGS					
Medical building #1					
Medical building #2					
Medical building #3					
SCHOOLS					
School #1					
School #2					
School #3					
BANKS					
Bank #1					
Bank #2					
Bank #3					
RETAILS					
Retail building #1					
Retail building #2					
Retail building #3					