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Ethics in Structural Design and Mechanical Design for Live Entertainment Scenery

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Ethics in Structural Design and Mechanical Design for Live Entertainment Scenery

by

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Thesis

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Dedication

For the talented men and women that create the magic of production for live entertainment. I am forever in awe of your skills and dedication.

Acknowledgements

This thesis would not exist without the generous caring and support from many people. The last three years of graduate school have been a journey through some of the best and most challenging times in my life. My thesis truly is the culmination of three years of work and sacrifice.

First, I need to thank all of the eighty-six survey responders that took part in the most significant resource for this document. Your willingness to share your thoughts, opinions, and experience with me has made this project. I need to extend a special thanks to McLane Snow and Mike Hase for helping distribute the survey.

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The Design and Technology graduate class of 2014. You have listened to me talk about this for long enough. Thank you for accepting me into your world of art.

Most importantly I need to thank my dear sweet wife, Susanna. Her love, patience, support, and knowledge of fine food and beverages has been the only thing that has kept me going through this graduate school process. I can never thank her enough for the joy that she brings into my life.

Hook em!

May 2014

Abstract

Ethical Standards in Structural and Mechanical Design for Live Entertainment

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Scenic construction requires a strong understanding of a range of principles related to construction including: materials strength properties, mechanical components, electrical motor systems, fluid power systems, and finishing techniques. A manager of scenic construction, or a Technical Director (TD), is required to take artistic designs and ideas and create magical elements on stage that are safe for performers, installers, operators, and audiences. In order to create these onstage spectacles, a great deal of planning, engineering, and careful fabrication must take place. There are several ways for a Technical Director to gain the knowledge required to effectively work at any level of entertainment production. This mixed-methods research study asks: what are the ethical standards that guide how a TD's work is completed?

The thesis begins with a review of the job of the Technical Director in Live Entertainment and data from a survey conducted of professionals in scenic technology.

Results from the survey were analyzed to provide both quantitative data, in the form of statistics, and qualitative response data. Additional discussion addresses a sample of the resources for structural design support available currently to the field, as well as challenges that some professionals confront in their typical practice. The thesis concludes a review of literature around engineering ethics and liability in engineering practice and recommendations for the incorporation of new ethical standards in live entertainment scenic production.

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Chapter 1: Introduction

"In the theatre, we often build by the motto 'When in doubt, build it stout, out of things you know about.'" This quote, from a participant in my MFA thesis survey, illustrates the way I learned to design structure for the theatre. Now, as part of my Graduate School education I have taken the opportunity to look critically at my own structural design process. So I could stop building "stout" because I would no longer be "in doubt" about my structural design. Like many of my colleagues in the field of Technical Direction for Theatre, Opera, and Dance, I have a tremendous amount of on-the-job training. My carpentry, rigging, and automation practical production experience led to a job in large-scale opera with the title of Assistant Technical Director. I was confident in my hands-on technical skills, and I was growing in my skills with drafting, planning, and communication. It is in this environment that I began to realize how much I didn't know about the structures and machines I was designing.

It is difficult to point to a specific moment when I realized I wasn't confident in my engineering knowledge, but I can recollect a situation that made me start asking some difficult questions related to structural stability and liability for structural design of myself and others. I was asked to draft the framing for a portal, a scenic element consisting of two legs with a header to span the width of the stage, which is designed to frame the stage space. The legs and header of this portal were to be built out of steel tubing covered with lauan plywood and black velour (see illustration 1.1). The show would be performed in repertory with four other shows, thus this particular portal would need to be assembled and disassembled multiple times throughout the following six weeks. Then it would need to be packed into a truck to travel to a different theatre.

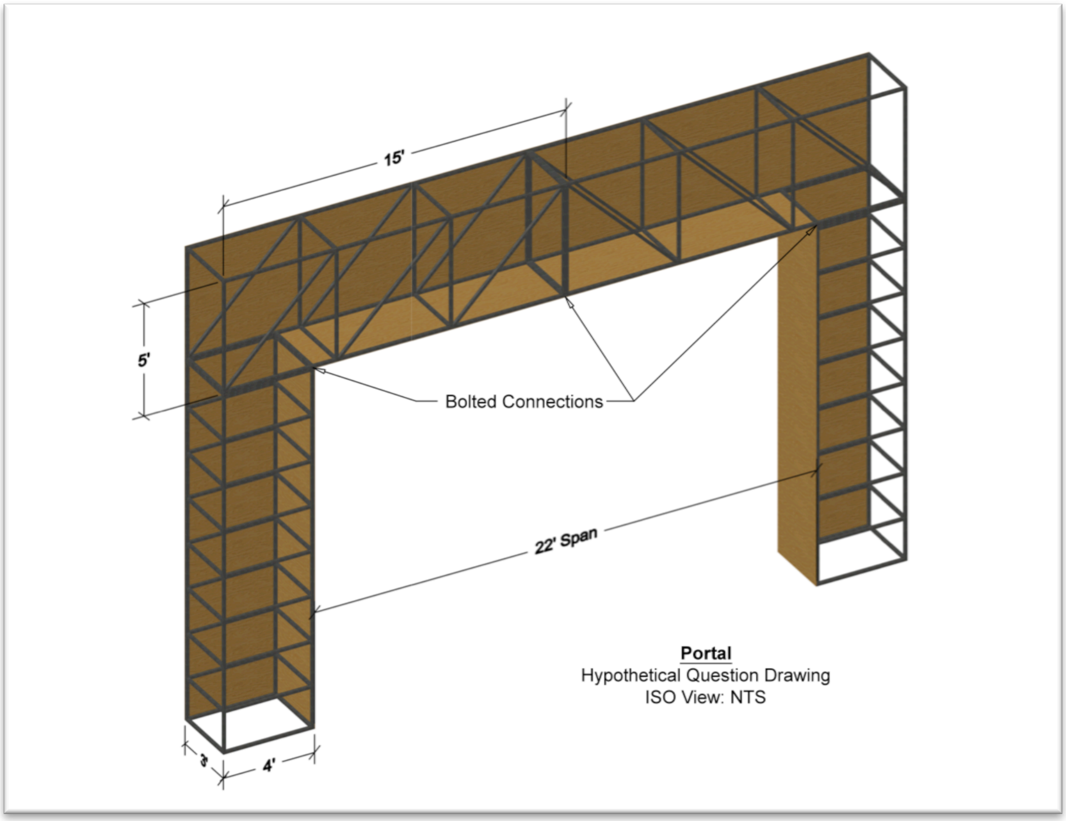


Illustration 1.1- Portal Structure Drawing

My task for this portal was to draft the structural design, specify materials to use, specify assembly methods, and plan construction. I wasn't totally sure where to start, other than I knew that the header should be a truss. At the outset this truss did not seem any different than any of the others I have designed and assembled previously. As I started working through the prescribed structural design drawing process, out of curiosity, I began to wonder why I was making the decisions I was making. Why was I using the material that I had picked out? Why was I setting verticals and diagonals where I set them? I realized I needed help feeling confident in this structure. Luckily, I was surrounded by some very intelligent, talented, and experienced scenic construction professionals. In consultation with these people, I finished the structural design with relative confidence. Structures very similar to the one I was working on had been constructed many times at this theatre, and I was able to take advantage of my coworkers' knowledge to create the structural design for this portal. Although I completed the design work and the portal was constructed and installed without incident, I left the experience wondering why am I qualified to make these structural design decisions?

A few months later, when my Father-in-law, Wayne Brown, came to visit the theatre some of my lingering "why" questions about this structure came back to me. Brown is the owner of a general contracting firm, and he is a Professional Engineer in the state of Louisiana. During a tour of the facility, he asked many questions about scenic construction planning and methods. I confidently answered them, sure of my own knowledge and training. However, when he asked about our specific structural design process, I began to wonder what an engineer might think about my work and design. He asked if theatres ever run this by anyone I answered, "not usually; we can take care of these simple designs, and if we need to we can run some math on this stuff." Simultaneously, those lingering "why" questions crept back, this time joined by worst-case scenario "what if" questions. I was not able to shake these questions as easily this time, and they grew into some serious doubts about my own knowledge and expertise needed to design sound structures. I realized that I needed some extra help dealing with these questions.

I met my advisor, Rusty Cloyes, from The University of Texas at Austin (UT Austin), at a United States Institute for Theatre Technology conference. I explained that these doubts in my structural design knowledge left me looking for the opportunity to go back to graduate school and learn the skills necessary to put them to rest. I was admitted to the UT Department of Theatre and Dance to study a custom program initially based on the course work required for engineering students. I was hopeful engineering training would allow me to conquer my doubts and move forward with first hand engineering knowledge. During my first year of course work I realized not only would I not be able to gain a mastery of engineering, but also I did not need to gain that knowledge. Through the ethics component of each of my engineering courses, I realized I was unable to supplant the engineer in the structural design process. The training and skills required for engineering would require that I become an engineer to master. I was not interested in becoming an engineer. My focus shifted. I no longer worked toward becoming an engineer of sorts, but now towards learning the language of engineering. Through engineering and construction management classes, I learned how engineers analyze problems, produce paperwork, and create designs.

RESEARCH QUESTIONS

That aforementioned shift in focus led me to my thesis questions and research topic. I began to investigate and speculate around a couple of questions.

A. *What factors influence the structural design or mechanical design decisions for Technical Directors in professional practice?*

B. *What are the ethical standards related to structural or mechanical design in scenic construction?*

   a. *What are the ethical standards and certification models in related industries that support the skills and training required of Technical Directors working in entertainment?*

   b. *What are the potential legal liabilities and risks that TDs are exposed to?*

For this text, I define structural design as, the process of analyzing and engineering structural requirements for size, shape, function, materials, and loading of a fixed object or structure. The execution of structural design consists of multiple phases including analysis of requirements, analysis of loading forces, analysis of building codes and standards, development of models or prototypes, testing, and fabrication. Only qualified, licensed professionals, as defined by local, state, or federal government laws, may carry out structural design for building construction. Design and structural requirements should be clearly communicated to the structural engineer before design analysis can take place ("Structural Design").

I define mechanical design as the process of incorporating moving and stressed components into a useful end product for a user. Mechanical engineering, the process to create mechanical design, is the application of the scientific principles of thermodynamics, mechanics, physics, and geometry to create solutions to problems. Author and professor of engineering at Imperial College London, Peter Childs cites, a mechanical engineer can create designs for prescriptive solutions to problems rather than trial and error solutions (24). However, in my experience in entertainment technology, practitioners typically rely on pre-engineered components and trial and error practice to develop mechanical designs.

Based on my graduate school class experience and consultation with architects, engineers, and contractors about structural design and mechanical design, and my experience with creating structural and mechanical design for live entertainment, I developed and considered my research questions. Architects, engineers, and contractors (AEC) face a greater burden of liability in their practice, and because of that burden they have formalized their working practice to limit that liability. In the world of growing complexity in structural and mechanical design for live entertainment, theatrical practitioners should borrow organizational and professional structures created by AEC.

RESEARCH METHODOLOGY

Literature Review

My research to answer these thesis questions took place in two phases. Phase one was a literature review of resources utilized by working Technical Directors (TD) and other related positions in the field of scenic technology. I also looked at resources utilized in similar industries including Architecture, Engineering, and General Contracting. Through my course work at UT Austin, I learned generally that construction is construction whether it is for a production with a $1,000 budget or a refinery with a $1 billion dollar budget. The processes undertaken may not be as elaborate for smaller projects like scenic construction, but the techniques for management, analysis, and design apply to both projects. Clear, well informed, and well-communicated structural design is critical to the safety of theatre staff and performers involved as well as audiences.

As an extension of the review of resources for other industries, I also analyzed articles and sources dealing with ethics, specifically ethics in engineering. I think formal ethics analysis is some of the most useful research that I have applied in my own practice. This research led me to ask questions around my own ethics in structural design. At what point do I decide that I do not know enough, or that there is a significant life safety risk? Where is the line that I, as a professional, do not cross in my practice? For engineers and architects, ethics training is part of their licensure both initially and as continuing education. There is no such formal ethics training for TDs.

I also reviewed literature around apprentice systems for skill development. I chose to conduct this research because most of what is learned about production in the performing arts is taught through some form of apprenticeship. Younger, less experienced technicians are trained on techniques and tools to create work by doing the work with experienced technicians who were taught the same way. This literature contextualizes the way understanding is communicated from teacher to learner.

The final section of my literature review is focused on professional liability in design practice. It seemed critical at the outset of this research project that I would need a clear set of consequences, proven through damaging civil or criminal court decisions, to be able to give my research recommendations weight. In my review of this research I realized that the court decisions do not exist. It seems as though the practice could fall under the same definition for professional liability that is used for engineers and architects, if it would be recognized at all. This area of the law is as specific as it is vague, and leaves a lot of room open for assigning liability and pursuing negligence lawsuits. I have not found or been able to glean from conversations with professionals any specificity in this particular area of research. Later in the thesis I will work to elaborate on my findings about liability, negligence, and due diligence in professional practice.

Industry Survey

The second phase of my research provided the bulk of the information I analyze in this document. I created a mixed methods research survey that was distributed to professionals in scenic construction and automation for live performance from across the country. The survey was delivered through email, and people were encouraged to forward the survey on to other colleagues in the industry. I will describe the people that took the survey in Chapter Two. Over the five months that the survey was open, it received eighty-four responses from industry professionals representing a combination of over 1,000 years of professional experience in the field.

The goal of the survey was to understand trends and mindset in the process of structural and mechanical design for the performing arts. The survey was created after two months of research in survey design. During this time I completed an application for exempt status with the Office or Research Support at UT. The study number 2013-05-0051 was granted exempt status. I vetted and tested the survey with colleagues including professional TDs, engineering graduate students, and graduate students in education research. It was important to me that the survey not take more than twenty minutes to complete. However, the average response time was thirty-four minutes. Some responders took considerably longer to complete the survey due to the length of their responses in the short answer portion. The survey was hosted on Qualtrics.com through The University of Texas at Austin. All survey results are anonymized. The entire survey can be found at the end of this document (see Appendix A) as well as select results (see Appendix B).

Survey Structure

The survey was split into three main sections. Section one dealt with the demographics of responders and their organizations. The questions in this portion of the survey were multiple choice, short answer, and scales asking about the individuals experience and training. The responders were also asked about the size and complexity of their employers or operations. I included an optional question where the responders could name the company that they work for. I will not share that information as part of reporting the survey results because the survey was confidential and this information is immaterial to the research findings.

The second section of the survey looked at complications that are faced by responders in working practice. These questions were again multiple choice, scales, and some short answer. The questions in this section focused on materials utilized in construction, resources available to responders, and job responsibilities. I wanted to know in this portion of the survey everything that was expected as part of the job for working professionals. I think it is important to understand what factors may be influencing the focus of the person producing the structural design, and further to attempt to basically understand the responder's structural design process. These people could be responsible for creating the structural designs and managing the build process, advising students, supervising construction, constructing, parking cars on opening night, or any other duties to be assigned.

The third section of the survey was a hypothetical scenario created similar to the portal example I presented at the outset of this thesis. The survey responders were presented with details about the hypothetical situation, and then were asked two questions with boxes for short-answer to essay length answers. This portion of the survey has yielded some fascinating qualitative results. I have used an adapted grounded theory data analysis method, called narrative thematic analysis, to analyze my findings under the direction and support of thesis committee member Sarah Coleman and thesis advisor Katie Dawson.

I chose this particular methodology, utilizing the technique of coding data for common themes and ideas. This coding technique was learned through studying John

Creswell's text, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, Creswell describes coding as, "a systematic process of analyzing textual data" (193). Generally, the researcher reads the data openly and allows themes and consistent meaning to come to light. These themes are then compiled into larger topics that the researcher can use to identify commonalities between responses.

Specifically, this survey was directed at looking for trends in mindset. Coding the responses in the aforementioned fashion allows for easier tracking of trends. I shared some of these responses with other colleagues in both the performing arts and engineering in order to diversify my understanding of themes in the responses. These colleagues were also encouraged to utilize a simplified grounded theory method to code the responses. Their coding was used through Creswell's idea of "reliability to check for consistent patterns of theme development among several investigators" (195). This effort further refined my own coding analysis.

THESIS STRUCTURE

The remainder of this thesis is organized into three chapters and a conclusion. Chapter Two focuses on the job description for a Technical Director (TD). I examine the quantitative survey results describing the people that took the survey. To scaffold the understanding of my recommendations, I think it is imperative to define the qualifications for the job of TD and the work of the TD. Additionally, this chapter looks at the educational and skills development model for Technical Directors and the required skills of a technical direction job candidate.

The third chapter looks at the structural design work happening in practice in live entertainment. I use both quantitative and qualitative data from the survey to demonstrate and comment on the work. I also include literature review research about resources to support and inform structural design in this chapter.

In the fourth chapter I present ethics for structural design in related fields of AEC, and tie those to the work happening in live entertainment. I present ideas from my literature review about engineering and architectural ethics. Also in this chapter, I cover the legal research I have conducted about professional practice and the legal definition of duty of care.

In the conclusion of the thesis, I present recommendations about ethics in the future professional practice for TDs and further research that needs to be conducted. I envision this thesis as the beginning of a larger conversation that will formally define the standards and ethics for Technical Directors and other structural designers in the performing arts. This research work is firmly rooted in my own experience and has come about because of my own doubts discussed earlier, but I wonder how many of my colleagues have faced similar moments or areas of doubt in their practice? I hope that this thesis will spark action in research and ethics standards creation for live entertainment structural design.

Chapter 2: The Job of Technical Director

INTRODUCTION

> Wanted: Candidates for position of Technical Director. Candidates should be experienced in scenic engineering, production scheduling, cost estimating, project controls monitoring, scenic construction skills including: carpentry, welding, mechanical component fabrication, and rigging, computer based drafting and modeling, automation systems design and control, lighting, audio, video, and team management. Qualified candidates will possess no degree and many years of work experience, a Bachelors degree and several years of experience, or, a Masters degree and a few years of experience. In addition to the above required skills the candidate might be asked to:
>
> Supervise students, manage construction operations, carry out construction operations, manage and conduct all production operations, hire and fire departmental staffing, finish all scenic elements, buy or construct all props, manage all venue facilities, perform maintenance on venue facilities, design scenery, lighting, audio, video, or costumes, supervise rehearsals, form strategic plans for future business growth, and any other duties to be assigned.

This description might seem hyperbolic in scope, but this represents a simplified combination of potential skills and duties required of a person filling the job of Technical Director or related field. For the sake of simplicity, I will use the title Technical Director (TD) to refer to all related position titles including Scenery Director, Stage Carpenter, Scenic Supervisor, and others. On its website, the American Association of Community Theatre describes the job of the Technical Director as the person with, "daily responsibility for the technical operations of a theatre or performing arts center, including lighting, sound, set design and construction, and coordinating necessary maintenance" ("Technical Director"). This selection offers a very brief and broad description of the duties of the Technical Director, but in my experience this can be the expectation of the TD. A TD can be expected to be the one technical person in the theatre, responsible for all aspects of production. The TD is generally in charge of the scenic elements of production, and can also be responsible for managing and coordinating with other production areas including lighting, audio, and video projection. A TD may be required to design all of the structures, build the structure, and light the performance. Depending on the complexity of the production this could require skills in engineering, construction, machine maintenance, machining, fabrication, lighting design, scheduling, and management.

A TD may be called upon to deal with a wide range of technical issues, he or she benefits from a working knowledge of techniques, methods, and procedures of theatre, dance, and music productions and presentations including stage, set, sound and lighting design and implementation, stage management, computerized lighting systems, stage carpentry, and appropriate safety precautions and procedures ("Technical Director"). This description of skills is broad in scope and yet it also illustrates the need for expertise in some very specific skills. This source represents the community theatre definition for the job, and perhaps the lack of money or elaborate technical complications involved in the operations at the community theatre level requires a generalist with such broad skills.

In his book *Careers in Technical Theatre*, author Mike Lawler, provides a more succinct definition for the position: "They [TDs] are the ultimate problem solvers, the essential link between a director's vision and the realization of the design" (109). Lawler provides a character description for the person in the job of Technical Director with, "they oversee the building and installation of scenery in wildly varying shop facilities and load their sets into every imaginable kind of theater space and stage configuration" (109). Once again, this quote points to the very open job description and expectations of working Technical Directors. Generally, the Technical Director is responsible for the realization of the scenic design in whatever theatre space it may or may not fit inside. I have heard a TD describe it as "being responsible for the full scale model of the set."

Technical Directors earn their title through their employment. To fully understand the demands of the job, it is critical to paint the picture of the professional attempting to fill this job. Firstly, as I have illustrated, the skill set and requirements can vary widely from job to job. Perhaps it is the nature of work in the theatre. Perhaps it is the natural evolution of the Technical Director position. A person with technical skills and some expertise takes on more and more responsibility, as necessary, to serve the production process. There is no industry certification or oversight committee that awards the title to qualified candidates.

In order to get a clearer picture of the work of each responder, the first section of the survey dealt with the demographics, skills, and experience of professionals involved. The analysis of demographic data in this chapter will illustrate a cross-section of the people working in the field and the scope of what they are working on. My analysis attempts to create a snapshot of the job of TD based on the responses on the survey. Regardless of how the TD job came to exist in these multiple iterations, it is critical to understand the people and the range of work being done by the professionals in order to understand the challenges, limitations, and opportunities available for structural design.

INDIVIDUAL DEMOGRAPHICS FROM SURVEY RESULTS

Years of Professional Experience

Survey question one asked responders, "How many years have you worked as a professional in scenic construction or automation for live entertainment?" (Vieira).

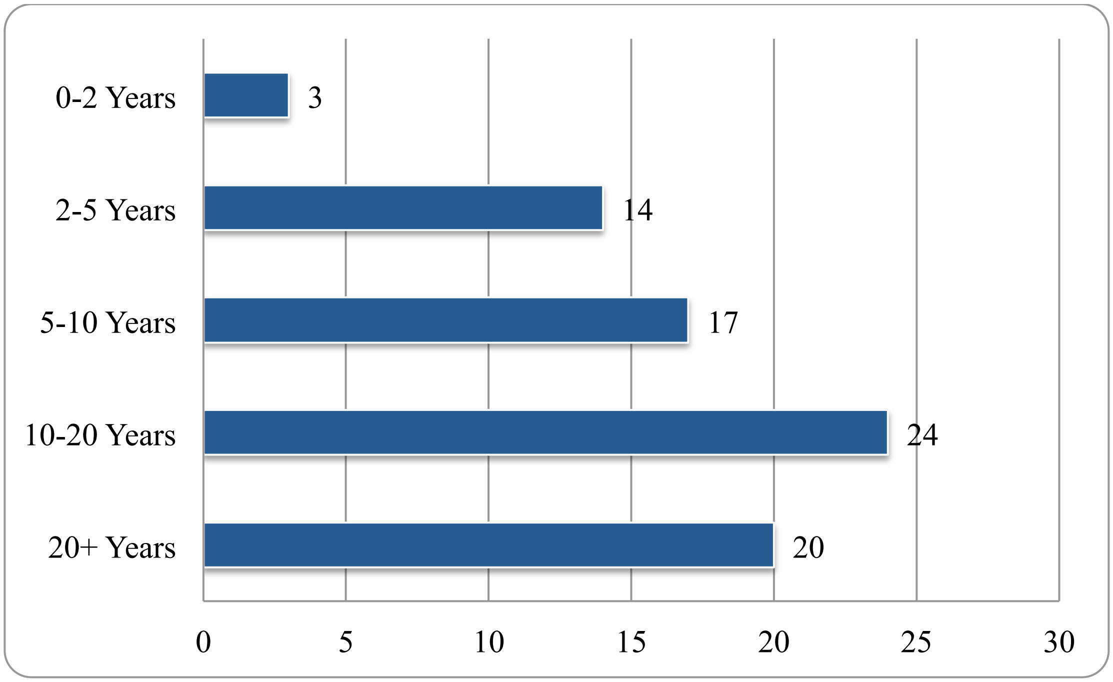


Figure 2.1- Years of Professional Experience

The majority of responders said they had over ten years of experience (see figure 2.1). This represents a tremendous amount of institutional knowledge and opportunities for on-the-job training. This is common in a craft skill evolving into manager employment system, as observed in the book *Construction Supervision*, where a skilled tradesperson eventually develops the skills, expertise, and political clout to supervise (Rounds and Segner 16). This also happens in construction operations where a skilled craftsperson might be responsible for supervising other craftspeople (Construction Supervisor 106).

The average amount of experience also could mean that the survey distribution skewed towards a more experienced set of professionals because of the email distribution or because of the time required to fill out the survey. Further, the high average could indicate that the field is more populated by people that have been working for a longer time, and that less experienced people leave the profession earlier. Regardless of the reason for the higher average number of years of experience compared with the ranges provided in the question, this means mostly very experienced and competent professionals took the survey.

The aforementioned institutional knowledge and on-the-job training competency aspect of theatrical experience is very common. For example, the majority of my own knowledge in the field was gained in this fashion. Without a unifying basic standard, competency for Technical Directors exists on a continuum. I will use a blended definition for competency from the Occupational Safety and Health Administration (OSHA) and psychological research. OSHA standard 1926.32(f) defines a competent person as, "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them." The term competent is used liberally throughout OSHA standards and is commonly used but not always clearly defined. In psychology, competency is defined as, "an underlying characteristic of a person that leads to or causes effective or outstanding performance" ("Competency" 54). For my research, competency is defined as the intelligent and ethical understanding of work scope, hazards, and challenges. The blended definition is an attempt to clarify the OSHA definition and add some job specificity to the psychological definition.

Years of experience is a typical qualification for most TD jobs. Individual job postings for TD positions will include the preferred number of years of professional experience required for applicant qualification. When put side by side with other qualifications like education, certifications, and skills, years of experience can illustrate level of mastery and varied experience. For Technical Directors, a field with no specific certifications or training methods, years of experience can be a deceiving statistic. The years counted as experience could be years of bad habit formation or poor working practices. These years could also have been spent in unrelated work compared to the specific requirements of that TD job description.

Level of Education

Another qualification commonly looked for is level of education. In the survey, question two asked, "what level of education have you completed?" (Vieira). All combined 90% of the seventy-eight responses to the question indicated the responder has a degree in higher education (see figure 2.2).

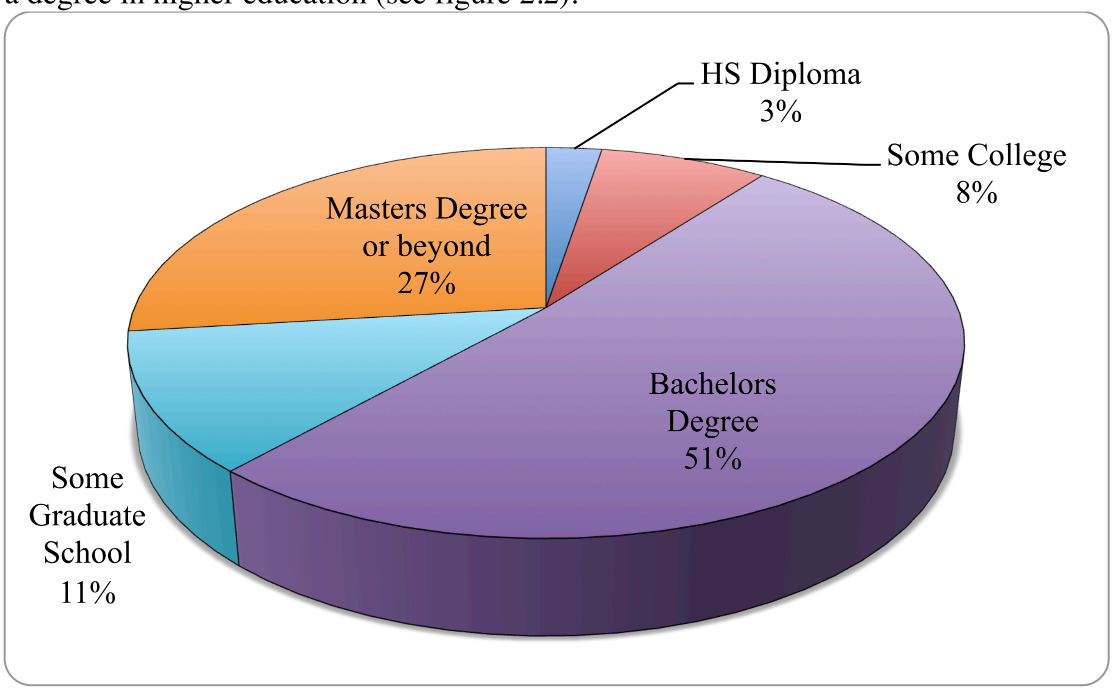


Figure 2.2- Level of Education Completed

This seems like a significant percentage of degrees in the field. I think this speaks to the required knowledge and skills for a TD. In addition, this is in line with the idea that the profession of TD is a “quasi-learned” profession more similar to architects or engineers than skilled labor. A learned profession requires that education is a key portion of the training for the profession.

Question three asked survey responders what type of degree they possess. The vast majority indicated either a Bachelor of Arts (B.A.) or a Bachelor of Fine Arts (B.F.A.) in theatre. Responses also included degrees in Mathematics, English, and Radio/ TV/ Film. In addition there were two survey responders with Bachelor of Science degrees in Mechanical Engineering and one in Electrical Engineering. With the exception of one master’s degree in Architecture, all of the masters’ degrees were Master of Fine Arts (M.F.A.).

These education results demonstrate two points. First, as an industry, the expectation is that a qualified job candidate will have a higher education degree, typically at least a B.A. The other point is that training for TDs is happening in higher education. Lacking other methods of certifying basic knowledge or skills, the degree has become the base level. On paper, and again lacking other certification methods, degree proven level of education seems like a completely reasonable basic requirement.

Unfortunately, not all degrees suggest the same quality and quantity of education. Based on my own experience in school and working with many undergraduates as part of the Apprentice training program at The Santa Fe Opera, the knowledge acquired from pursuing a degree in theatre technology can vary drastically from school to school. Theatre education is lacking a cohesive, accepted accreditation standard, like Accreditation Board for Engineering and Technology (ABET) for engineering or

National Architectural Accrediting Board (NAAB) for architecture; both of which are required accreditation standards for certification test qualification for students. The National Association of Schools of Theatre (NAST) has published accreditation requirements for a Bachelor of Fine Arts in Design/ Technology. These requirements dictate some guidelines for general study requirements to include "mathematics, physics, textiles, and electrical engineering…" (Standards 102). These guidelines further state that a student should, "demonstrate an understanding of basic engineering principles (electrical, mechanical, and/or structural) as they relate to chosen design specializations" (102). This information from the NAST Handbook demonstrates a basic set of skills for accreditation. However, there is no information about how these standards will be measured and independently assessed. Further, it is not clear what qualifies as "basic engineering principles." This could be broadly interpreted resulting in varying level of education and complexity in those classes.

The NAST Handbook also provides more detailed accreditation requirements for a Master of Fine Arts in Technical Direction. Specifically the guidelines state:

> The graduate must demonstrate advanced professional competence in technical direction including, but not limited to:
>
> > (1) The ability to supervise the safe construction of scenery and properties within the scope of allocated/budgeted materials, labor/time, and space.
> >
> > (2) The ability to understand various elements related to (a) theatrical design; (b) the set up and operation of lighting components and systems; (c) the use of sound reinforcement and playback systems; (d) methods of scenic art and construction; (e) rigging and motor systems; (f) fluid power systems (pneumatics and hydraulics) and motion control; and (g) mechanical, structural, and electrical engineering. The ability to work with these elements as appropriate to specific productions is essential.
> >
> > (3) The ability to read and direct personnel based on computer-aided technical drawings.

> (4) Personnel management, including the ability to safely supervise and, when appropriate, schedule the work of personnel within and across various theatrical shops.
>
> (5) The ability to work with theatre professionals in their processes of production.
>
> (6) The ability to articulate and apply federal, state, and local health and safety practices and regulations associated with production and performance including, but not limited to, appropriate Occupational Safety and Health Administration (OSHA) regulations and the National Fire Protection Association (NFPA) Life Safety Code.
>
> (7) Facilities management, including a) the ability to oversee the daily operations and maintenance of various theatrical shops; and b) the ability to maintain a working schedule of work done in, and outside requests to use, various shops and theatrical facilities. (NAST Handbook 126)

These guidelines for a Master of Fine Arts in Technical Direction are an excellent set of standards and expectations for the education that a Technical Director should receive in an MFA program. This list of requirements is a very ambitious undertaking for any student, and it once again speaks to the high general-knowledge requirement for TDs. While, this accreditation information puts a strong emphasis on practical skill development, it does not set standards for the source of the learning. It does not dictate the standards to which student competency should be tested.

These accreditation requirements represent an excellent starting place. The standards set forth show an attempt to normalize and standardize education for TDs, but I think that they fall short in a couple of critical areas. First, they do not provide a metric or benchmark for student achievement and testing. Second, they are under utilized. NAST lists only 180 Institutional members on their website, and all of these institutions do not carry the two degrees listed above (Accredited). In contrast, to qualify as a Professional

Engineer in Texas an ABET accredited degree is a requirement (Basic Requirements). This standard is pervasive throughout the profession of engineering.

The second point demonstrated by the education results from the survey is that generally, as an industry, training is happening through higher education institutions. Higher education programs provide an opportunity to gain skills and expertise in the field. Since so much training is happening in higher education institutions for TDs, a benchmarking standard could be created to test students shortly after graduation. All students should have the opportunity to learn similar skills in similar applications. Students should achieve to a common standard before advancing into their early career employment. This common standard would unify the education standard between universities.

The apprentice style of instruction is studied thoroughly in education research. In the book, *Action Strategies for Deepening Comprehension*, author Dr Jeffrey Wilhelm uses the example of himself learning to fix a roof to illustrate the transformation of a student going from novice and inexperienced to an empowered practitioner to illustrate an apprentice style learning method. The learning follows a "Show me, Help me, Let me" model that encourages the student to learn the basics of a task and begin supervised practice until competency (Wilhelm 19). This model of training is based on Lev Vygotsky's 1978 theory about creating mental tools that focus a student's learning. The evolution of a student is supported through experiences and development with others. In the article "Cognitive Apprenticeship: Making Thinking Visible," authors Allan Collins, Ann Holum, and John Seely Brown, point out that in apprenticeship, "learners can see the processes of work" and "apprenticeship involves learning a physical, tangible activity (6)."

Much of the work in entertainment production is taught in this apprentice model. The International Alliance of Theatrical Stage Employees, IATSE, the labor union that represents stage employees, uses this model in training its labor force. IATSE Local One, representing the greater New York City area, advertises their apprentice program as one of the three ways to join the union. Specifically the program advertises, "our apprentices receive hands-on training with some of the most cutting edge technology in the business, they get to work side by side with Local One members learning crafts that have been at the forefront of our Union for 125 years" ("Three Ways to Join"). Unfortunately, this model assumes that the training and learning is being supervised and administered by a competent teacher or master. The qualifications of the teacher need to be carefully studied and monitored, if this method is to be utilized effectively industry-wide. It is possible that many bad habits and poor techniques are taught along with the useful skills and quality knowledge. In the process to become a Professional Engineer (PE), Engineers-in-Training (EIT) must spend a prescribed amount of time working with a qualified PE as governed by state licensing agencies. The apprentice model is a powerful culture in entertainment production that can be utilized very effectively both in universities and in professional training situations with qualified supervision and structure.

Job Responsibilities

The final area of individual demographic information that was surveyed in my study was individual job responsibilities. In question four I asked survey responders, "What are your current job responsibilities, including any responsibilities not related to scenic structure?" (Vieira). Responders were allowed to select as many as applied (see figure 2.3).

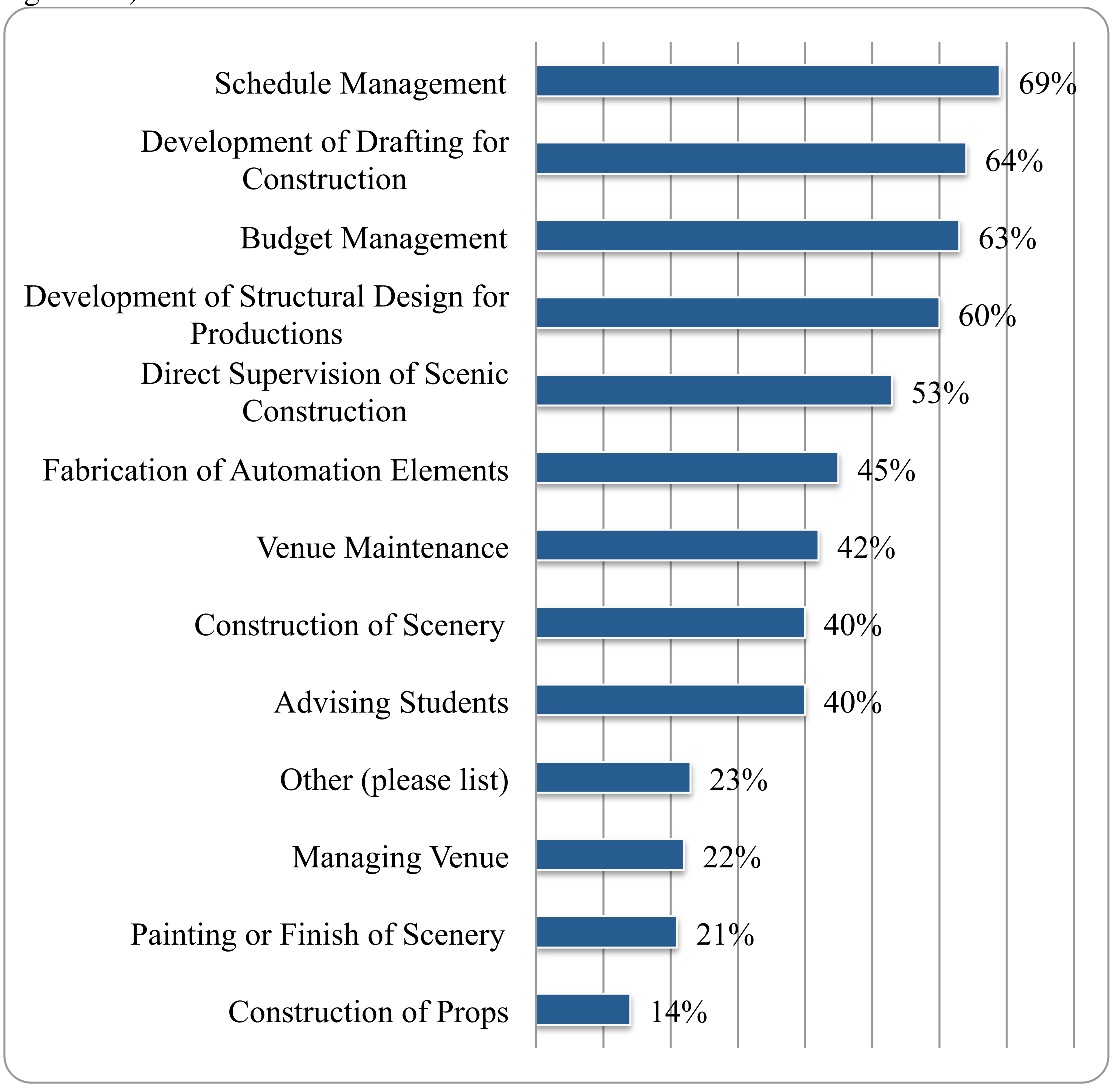


Figure 2.3- Job Responsibilities by Percent of Responses

Structural Design, a process that requires strict attention to detail, typically makes up only a small portion of the responsibilities of a professional Technical Director. These "other duties" represent a distraction to the complicated task of generating safe and effective structural design for production. I have heard many stories throughout my career about the extent of other duties assigned to Technical Directors. I have personally worked in parking lots on opening night, I have fixed house seats, toilets, and costume pieces, and I have been responsible for cleaning steel to keep construction moving. In an article in an Australian newspaper about the Leadership Management Australia study of productivity focus lost to "low-priority tasks" in business, the author observes that, "many leaders are too easily distracted by 'low pay-off activities' that can reduce their output, productivity and affect their performance as well as the organisation's bottom line" ("Wasting Time…" 202). This quote illustrates the damaging effects of distraction caused by "low pay-off activities" in a business setting. Similarly, in live entertainment production, structural design is a very high pay-off activity, because it is a critical point of safety for workers, audience, and performers. These other responsibilities are dragging time and attention away from the structural design activities that require a high attention to detail.

It is clear from the responses that the professionals surveyed share some very similar job responsibilities. Additionally, the responders did not completely overlap. There is not a single job responsibility that every single responder has to undertake. About 65% of responders indicate that Technical Directors are responsible for resource management, especially time and money. Also, a majority of responders are creating drafting for construction and developing structural design.

The most interesting responses came from the "other (please list)" responses. These responses gave the responders the opportunity to voice their own "other duties." These responses either indicated that people who were engaged in structural design activities are very distracted, or that the person surveyed was focused on other non-structural activities. These responses are grouped into the two categories: non-structural and distractions.

The non-structural activities, or activities that do not have to do with scenic structure for a performance, were varied. Several responders indicate involvement with automation operations, installations, and management. These are classified as non-structural activities because the people engaged in these activities generally responded that they were not engaged in the structural design or management operations, but more of the execution side of the project. There were a couple of responses indicating that people were engaged primarily in other activities including "Stage Management" and "Actor/ freelance carpenter."

The distraction activities, or activities that draw time and resources away from structural design processes, generally involve more elaborate management operations and other production area responsibilities. Several responders indicated that they are also engaged in generating the aesthetic design in addition to structural design. These people are making the decisions about aesthetics and structure, which presents a whole series of collaboration complications unrelated to the scope of this study.

The other potentially distracting or complicating activities are more management based. These responders indicated generally that they were responsible for larger operations and project management. Included in these responses are "Small Business Owner", "Rigging for the electrics, video, audio shops, and various touring productions…" and "Supervision of Engineers, Welding Inspection, Supervision of Flame proofing, Trouble Shooting." In addition, some of these responders are involved in departmental management including, "hiring/ firing/ supervising employees, liaise and lead creative teams… disseminate safety practices and enforce safety policy, network and maintain professional contacts in the industry, evaluate and set goals for employees" and "Managing other production departments." As illustrated already, the broad scope of responsibilities that face professionals in the industry can be distracting to the attention requiring task of structural design.

ORGANIZATIONAL DEMOGRAPHICS FROM SURVEY RESULTS

The second area of focus for the quantitative survey data dealt with the demographics of the organizations represented in the survey. As stated earlier, the title of Technical Director and the job responsibilities differ across organizations. Knowledgeable of this, I included multiple questions in the survey that asked about the type of company, the organization's scope of work, and the certification or structural design review standards utilized within the organization. The following results illustrate the slice of the industry that participated in the survey. The data gathered demonstrates that larger organizations with bigger budgets are employing more strenuous standards for structural design than smaller organizations. The meaning, causes, and consequences for this difference will be explored in this section.

Type of Organization

Question five of the survey asked responders, "What type of live entertainment organization do you work for?" (Vieira). This question had multiple options that the responder could select one answer. The question received seventy-two total responses (see figure 2.4).

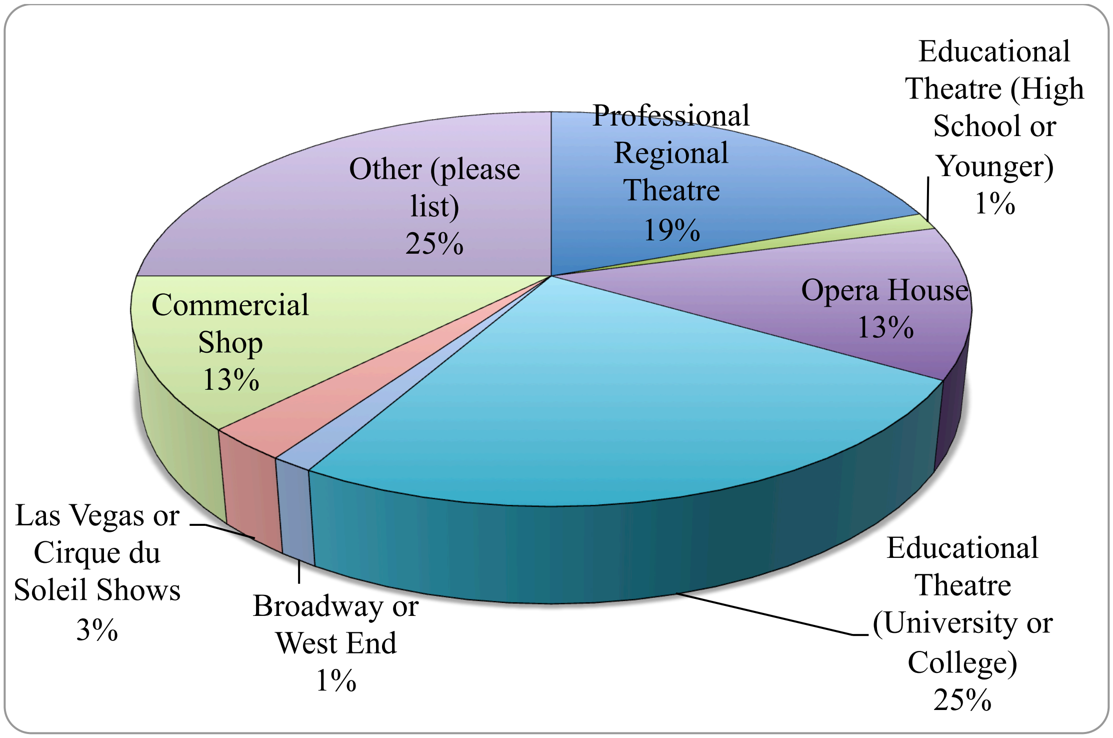


Figure 2.4- Types of Live Entertainment Organizations Chart

In hindsight, I should have written this survey question so that responders could select the type of organization that they work in primarily. This is why there is such a large amount of “Other (please list)” answers. In order to preserve the integrity of the raw data, I have not adjusted the results to reflect the intention of the question. The majority of the “other” answers that do not fall into one of the categories provided are for a touring show of some kind or some kind of freelance or self-employed status.

The responses indicate that none of the survey responders works for a community theatre or dance company, and only one person taking the survey works in a non higher-education education situation. This lack of responders is an unintended hole in the survey results. It was my hope to have the survey reach practitioners in all possible types of live entertainment organizations. The lack of responses from people working in community theatre, dance, or high school education indicates that either the survey was unintentionally not made available to those people, or that those people chose not to be involved with the survey. It is also possible that those people do not identify the jobs that they undertake as being structural or mechanical design for live entertainment.

Production Budget

Question seven asked, "What is an average budget per production for scenery materials including any automation or mechanical components? (In dollars)" (Vieira). The goal of this question was to understand production budgeting in an aggregate form (see figure 2.5).

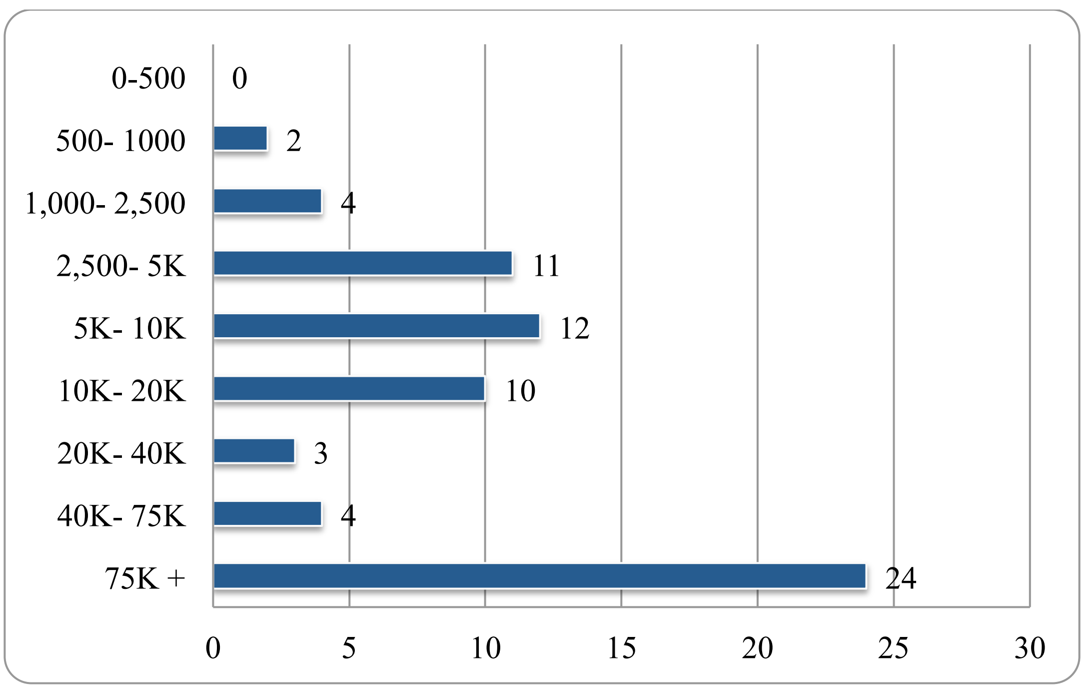


Figure 2.5- Average Budget for Materials per Production (in dollars)

I chose to ask the question based on materials per production to streamline comparisons between organizations. It is hard to judge production budgeting with the inclusion of labor cost because of the wide cost difference in labor regionally. Additionally it is challenging to understand entire season production budgets when compared to each other because of the number of productions included in the budget.

Budget per production is an indicator of possible size and complexity of productions. In an article from The National Arts Journalism Program, the author observed, after studying the budgets of four productions in New York City from Broadway commercial theatre to Off-Off-Broadway non-profit theatre, that, "within the Physical Production category, scenery is the largest expense, consuming 12.5 percent of the entire Broadway budget and 8.2 percent of the off-Broadway budget (48)." This quote demonstrates the relative cost difference between production scales, and furthermore that scenery is the largest single cost center in physical production. With this level of cost and investment in the scenic elements it is clear that scenery is a significant part of the allure of the show. Structural design is a critical part of scenery creation because it determines the safety and soundness of the physical scenic elements.

The most immediately striking part of these results is the normal looking bell curve spread with the balloon at the end. I provided ranges based on my own production experience and that of my advisors. I felt confident that these ranges would produce a typical bell curve in the results. Instead there is a large spike at the top of the monetary range indicating 34% of responders are working with more than $75K per production for scenic materials.

These results could reflect some things. The first could be a misunderstanding or lack of clarity from survey responders. Either they did not understand the question, or they answered improperly based on the intent of the question. For example a responder could have misunderstood and indicated their season budget, or they could have mistakenly included labor or other factors into their answer math. The second possibility is that the survey reached a specific demographic in the industry that works in very high budget production. Based on the responses from the type of live entertainment organizations represented this is possible. Opera companies, commercial shops, and touring shows can have very large budgets in my experience. In a *New York Times* article on the cost of producing shows on Broadway, author Patrick Healy noted, "plays invariably cost at least $2.5 million to mount these days," and "bigger-scale musicals tend to cost $10 million to $15 million these days" (Healy 1). The author goes on to highlight some significantly larger budgets like $25 million for *Shrek: the Musical* and $75 million for *Spiderman: Turn Off the Dark*.

The following analysis of survey results will use the assumption that a large amount of the survey responders come from larger, well-funded operations. This assumption will be more significant in the structural design analysis in Chapter Three featuring qualitative survey data. It is important to also note this when viewing the other organizational demographic factors.

Production Schedules

The next key operational demographic factor is scheduling. Scheduling is a critical factor in determining the complexity and scope of an operation because tight timetables can lead to fast decision-making. Structural design review can be truncated or eliminated in practice to save time. Timing can affect the amount of attention each production is given concerning structural design development. Additionally, structural design decisions can be adapted or informed by the proposed life span of the production. I have often heard Technical Directors disregard the potential effects of less than thorough structural design because the set will not be used long enough to require more in depth review. Three survey questions, questions eight through ten, asked about scheduling complexities. These questions examine the complicated relationship between time, or lack there of, and structural complexity.

Question eight asked responders, “On average, how many new [design/ build] productions does your company create annually?” (Vieira). The results of question eight demonstrate the number of new productions per year from seventy-one total responses (see figure 2.6).

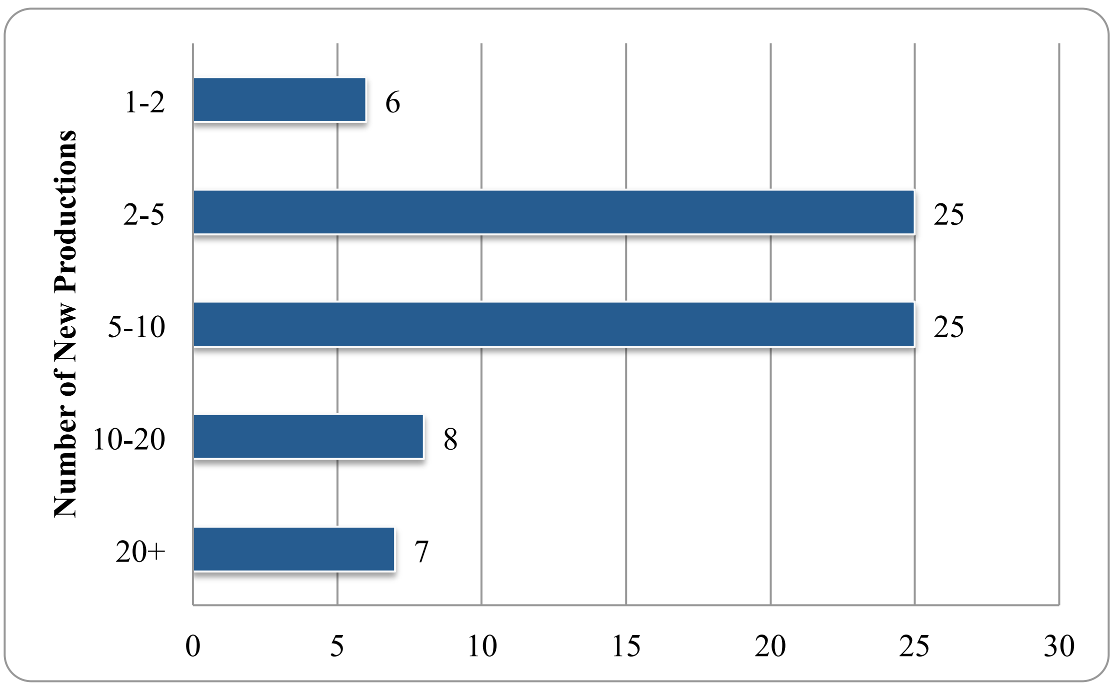


Figure 2.6- Number of New Productions Created Annually per Organization

The significance of this question is in the fact that production creation requires a lot of resources. The key resource in this analysis is time. For all of the reasons mentioned earlier, time can be a challenge to structural design. Production deadlines can cause the need for quick decisions to be made to not inhibit progress.

The results of this question are in line with expectations with roughly 70% of the companies represented in the survey producing between two and ten new productions a year. These results demonstrate that there is a significant amount of new productions being produced industry wide. In fact 92% of survey responders work for companies that produce more than two new design/ build productions per year.

The graph is slightly different when the answers are limited to the twenty-four people that answered that they work with production budgets over $75,000 for scenic materials. Because of the significant spike in the per production budget question it is interesting to review those answers separately to analyze trends. This demographic set is typically creating two to five new productions a year (see figure 2.7).

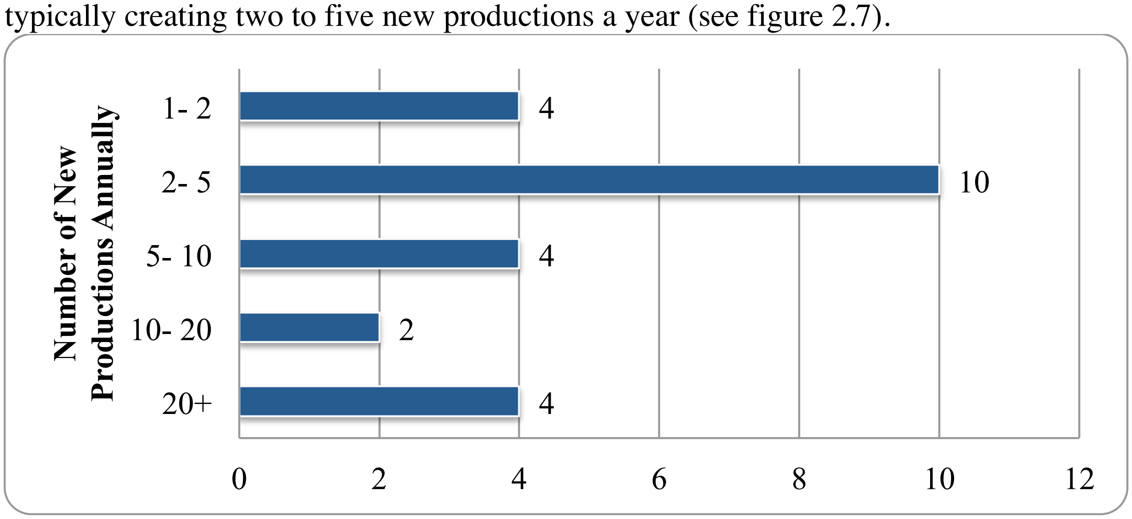


Figure 2.7- Number of New Productions Created Annually: Budget of $75K+

This indicates that the larger budget operations are producing fewer new productions per year generally. An assumption might be made that fewer new productions allow more time, per production, to support the structural design process, but that assumption cannot be made based on survey results alone.

The second scheduling question, question nine, asked responders, “From acceptance of final design to first preview, how long is a typical structural design and construction period for your company?” (Vieira). The organizations represented generally have between a month and two months between these two milestones (see figure 2.8).

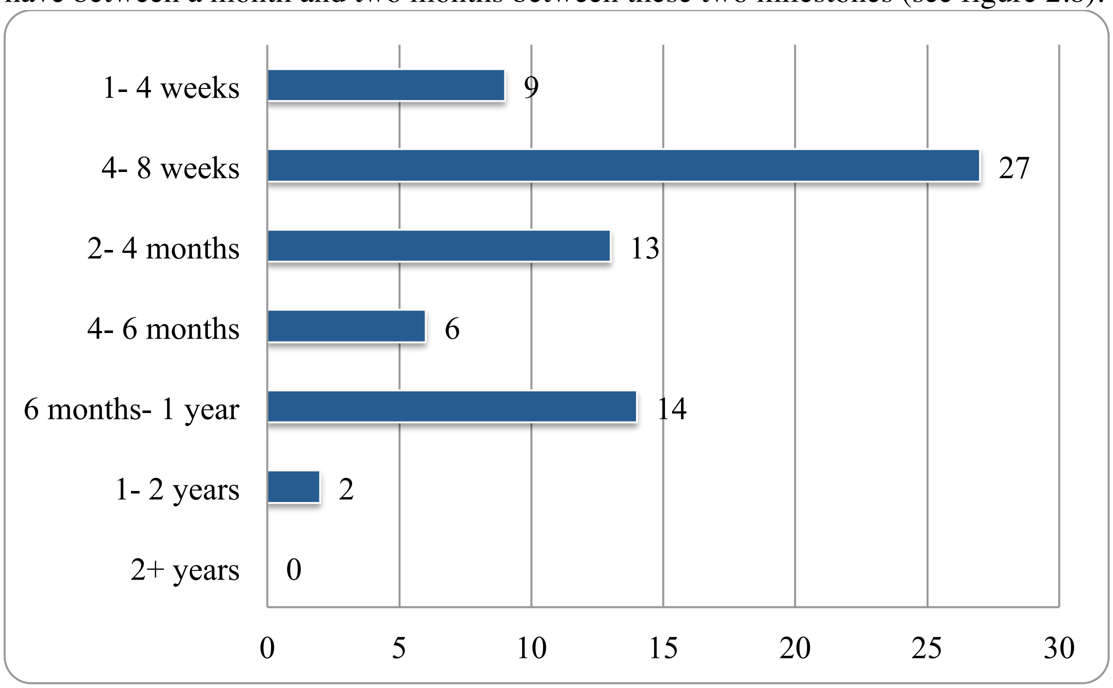


Figure 2.8- Amount of Time Between Final Design and First Preview

This question focused on a critical period of time in any production. This period is critical because it can determine the amount of structural design oversight and review taking place. This also accounts for the time during which companies can solve problems related to accomplishing the aesthetic design in addition to the structural design. This is the time when the construction process is also taking place, which requires time to structurally design, review, and construct. It is also significant to note that two responders are working with a period of between one and two years. Both of those responders also indicated that they work for organizations that are utilizing budgets over $75K per production. It is possible to deduce that these are very large projects when compared to the shorter average time frame.

The final component of scheduling is the life span of the created structures. Survey question ten asked responders, "On average, how long is the life span of a set constructed by your company from construction completion to strike?" (Vieira). Just over half of the seventy-one responses indicate the life span of structural scenic elements between three months and over one year, with 30% of the total responses indicating a life span a year or longer (see figure 2.9).

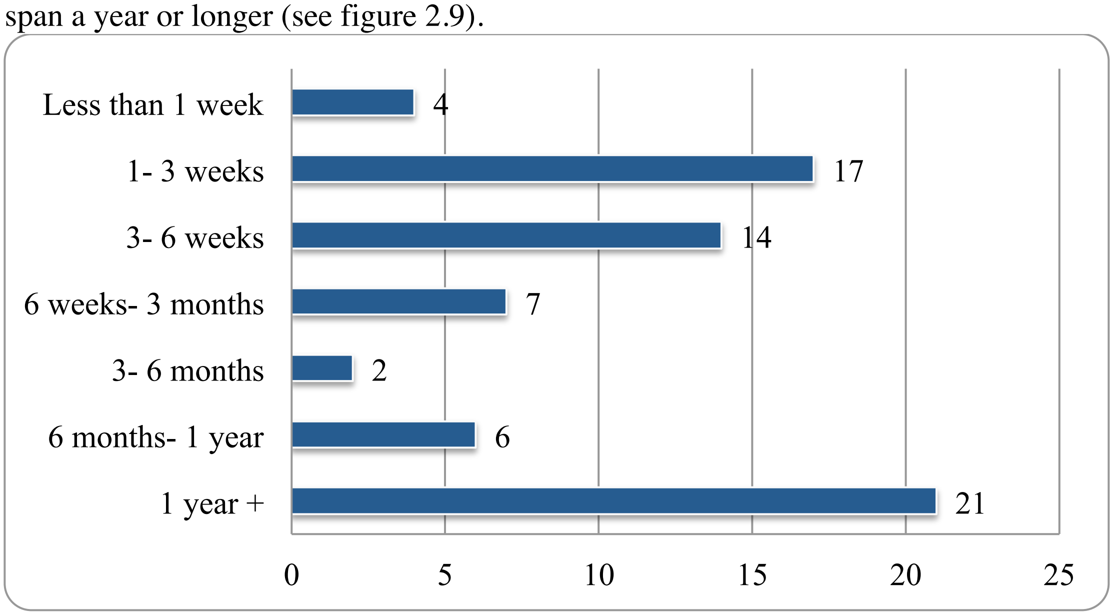


Figure 2.9- Average Life Span of Scenery Constructed

I have heard many times that the reason corners could be cut or things could be overlooked is because of the short life span of constructed scenery. While it is true that some constructed scenery does live a short life, possibly a single weekend, short life does not seem like a reasonable excuse for sub-standard structural design. The biggest complication this longevity of life creates is the need for preservation against wear on the scenery. This amount of time can indicate the need for long-term disassembled storage, assembled usage on stage, or periods of both. Any of these factors represent added complexity for the structural design. Limitations due to size of a storage or travel container can mean the scenery needs additional joints, as an example of an additional complicating factor.

Many times I have heard entertainment structural designers invoke the idea that since scenery is a temporary structure it does not need the sort of rigorous engineering that a more permanent structure would. Some of the times described in the answers to the survey question are a significant amount of time for a temporary structure to exist, especially a temporary structure not attached directly to a fixed structure. Temporary structures are defined in the *McGraw-Hill Concise Encylopedia of Science and Technology* as structures that, "aid in the construction of a permanent project" ("Temporary Structures" 2209). Further the source highlights that, "codes and standards do not provide the same scrutiny as they do for permanent structures" ("Temporary Structures" 2209). The majority of live entertainment scenery can be characterized generally as temporary structure because it is not fixed permanently to the structure around it, and because it is not intended to exist permanently. That characterization is not completely accurate when viewed in light of the definition presented because the scenery is not used in service of a permanent structure. The temporary scenic structure is the final and only product of scenic structural design and construction.

Production Construction

The final key operational demographic factor is construction. Survey questions eleven through fifteen inquired where and how scenery is constructed, complicating factors such as doorway size limitations, repertory performance, time for assembly or disassembly in the construction process, construction materials usage analysis, and two questions about certifications for employees engaged in the construction process. These questions were developed to analyze the relative complexity of the structure creation happening in the field. Realization of structural design and the variety of techniques and materials can greatly complicate the structural design process by introducing multiple variables that complicate simple analysis.

The first construction subject question, question eleven, asks, “Where are sets for your company constructed?” (Vieira). This question acknowledges that not every company has dedicated construction facilities, and that some companies are required to contract with commercial shops or freelance fabricators (see figure 2.10).

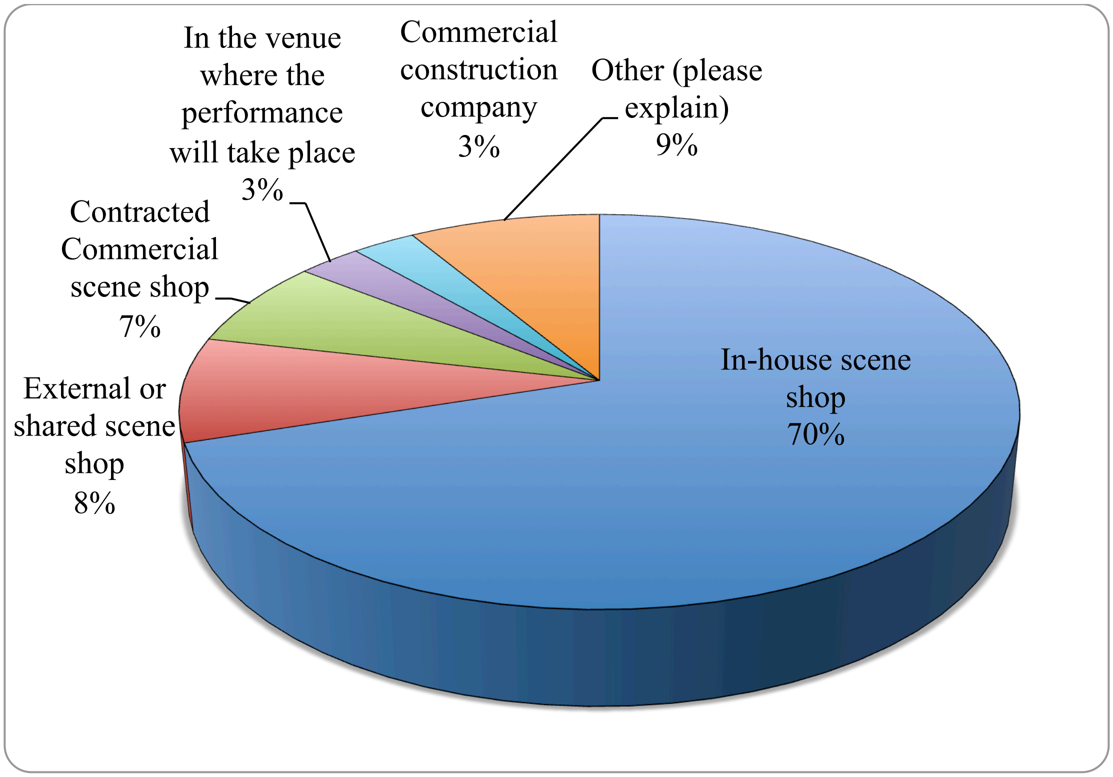


Figure 2.10- Set Construction Facilities

Of the seventy total responses to this question, 70% of responders indicated that construction took place at an in-house scene shop. I should note that this result likely encompasses a wide range of possible shop facilities. In my experience the definition of "scene shop" can vary widely from a two-car garage to a 10,000 square foot state-of-the-art facility. Both entities could be considered scene shops.

It is clear from the graph that the majority of construction work is taking place in in-house scene shops. The six "other (please explain)" results were typically a combination of locations. Either they were an in-house scene shop and performance venue construction, or they were in-house scene shop and custom fabrication shop. It is not uncommon to supplement the construction capabilities of an in-house scene shop with work from a commercial shop. This is especially common for very large production implementing custom automation and/ or rigging technology. All but one of the "other (please explain)" answers came from responders representing companies with more than $75K per production for materials. These companies are likely using multiple facilities to compile elements for construction.

The second construction question, question thirteen, asked, "Are there any complicating conditions that scenic or automation elements at your company have to endure?" (Vieira). This question allowed responders to check multiple answers (see figure 2.11).

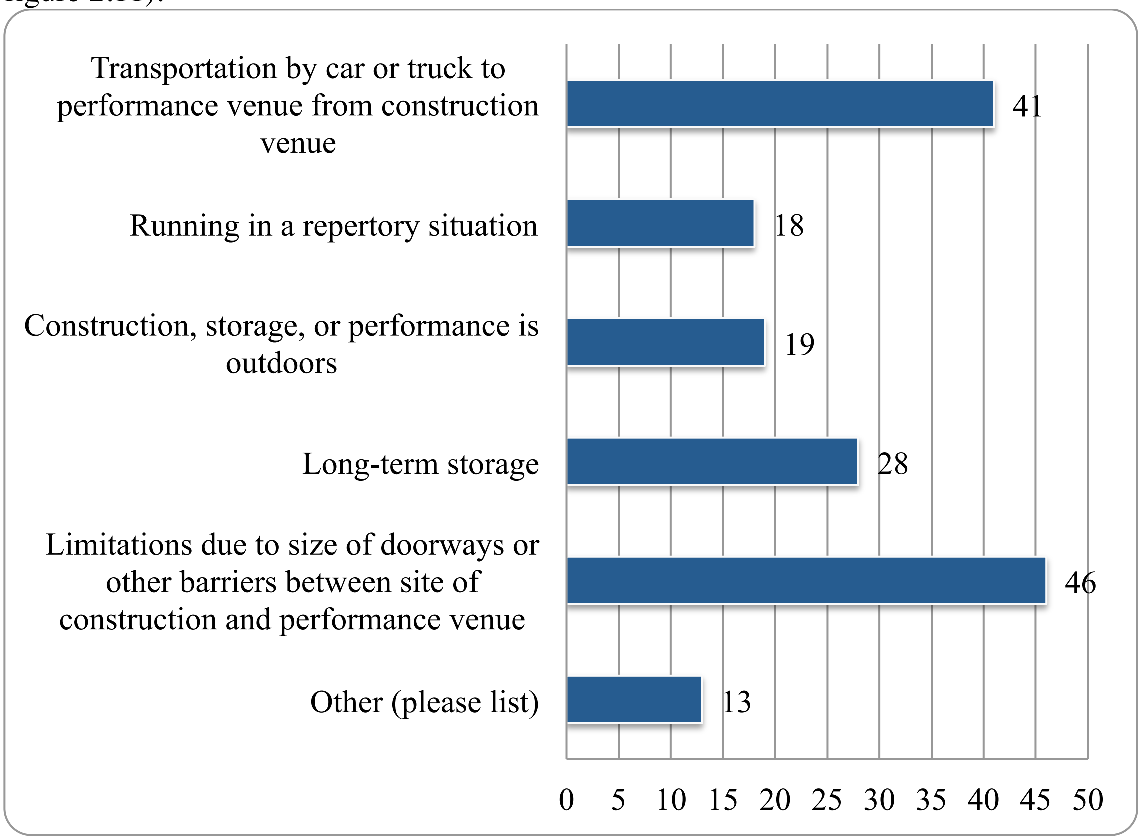


Figure 2.11- Complicating Conditions for Scenic Elements

Whether it is the limit of the door size to the stage, the need to break the scenery down to fit into a truck to transport it to the performance venue, or the need to assemble and disassemble scenery daily or weekly for repertory performances, Technical Directors are always dealing with limitations on size or complexity.

The results indicate that a large majority of the responders plan around doorways or barriers. The common solution for that condition is modularization, or creating completed units in a pre-assembly fabrication facility. Modularization provides many advantages to site construction in both commercial construction and entertainment construction. However, modularization makes more demands of the engineering process. In the article, "Modularization: Prefabricating a Process Plant," authors Derick Emes and David Stubbs observe the key design challenge in modularization, "a balance must be struck between module size and movement costs" (63). TDs must balance the coordination and preplanning in modularization, and ease of assembly in the performance space against the cost of moving the modular scenery.

In addition to the limitation of doorways or barriers, the second most common response was, "transportation by car or truck…" 61% of the responders have to consider the process of loading, securing, and transporting in a vehicle as part of the life cycle of the scenery. This challenge also complicates the structural design process. The size of the truck, the size of the loading dock, or the limitations of loading labor are a few of the factors that make this complicating condition so difficult for structural design. This limitation is also typically overcome with some kind of modularization for size, weight, or shape.

The shape limitation can be a particularly challenging detail to deal with. Technical Directors are often asked to create aesthetically interesting shapes in finished scenery but these shapes are not always conducive to safe travel or loading (see illustration 2.1).

Illustration 2.1- Scenery from the Santa Fe Opera Production of *Arabella* (Photo by Ken Howard, Director Tim Alberry, Scenic and Costume Designer Tobias Hoheisel)

Large curves, as demonstrated in Illustration 2.1, ramps, and other shapes that are complicated to stack together are common in the aesthetic design of scenery. The structural designer must consider the trucking or travel complication in the design development process. The scenery may be exposed to forces in the trucking operation that are not immediately obvious to the structural designer such as point loads from lifting, securing, or resting operations related to travel.

The thirteen "other (please list)" responses indicated dealing with the more extreme travel conditions of touring scenery or some kind of extreme condition that is present in the specific performance venue. One responder indicated that scenery has to endure, "corrosive environments such as aquatic showrooms as well as long term exposure to pyrotechnic residues," and another responder said, "show is done on an ice floor." Obviously these two extreme complications don't exist in every performance space, but challenges in every performance space require TDs to navigate complex structural design solutions.

The next area of complication in construction is the material utilized in construction. Materials in construction are important to consider structurally and aesthetically. Scenic construction relies on repurposing materials and finishes to create the aesthetic vision on stage. In an effort to creatively solve problems presented in design, Technical Directors are required to look at materials in creative and innovative ways for weight, structural properties, finish, and cost.

In addition to the aesthetic demands of materials in production, materials also need to be considered for their structural properties in application. Certain materials are more appropriate to certain applications than others. Materials strength analysis is a topic covered in great detail in many basic engineering sources, and is a class topic in architecture and engineering education. Popular material strength, or material mechanics, texts include *History of Strength of Materials* by Stephen Timoshnko, *Mechanics of Materials* by Russell C. Hibbeler, and *Applied Strength of Materials* by Robert L. Mott. A simple Internet search will provide pages of charts, explanations, and considerations about almost every possible material for construction. This information is published widely because of the volume of information that exists. It is required knowledge in structural design but it would be impractical to think someone would memorize all of the information. In addition, Holden and Sammler's indispensable resource for scenic structural design, *Structural Design for the Stage*, includes many pages about materials strength and analysis specifically focused on theatrical applications.

My discussion of materials for this thesis document focuses on practical utilization of materials rather than the analysis of strength of materials. In addition to the analysis of its physical properties, the Technical Director must consider the tools and techniques required for utilizing different materials. Some materials may require more time and more attention to detail than others. Also, certain physical factors of the performance space or installation may require materials to be put into situations they were not intended by the manufacturer. I want to know how often specific materials are being used in practice. That information will inform where potential future standards for scenic structure should focus. It is more critical to recognize the challenges and limitations presented by working with certain materials because of the effect the combination of materials has on overall structural design.

My main area of interest in materials is how the diversification of materials utilized in construction affects the structural design process. Basically, TDs are required to utilize such a broad range of materials that the amount of possible materials has become a potential distraction. Through survey question twelve, "How often are the following materials utilized in scenic construction or automation fabrication at your company," I tried to understand the spread of materials being utilized in practice (Vieira). The question had five scale options, from "never" to "very often," for each material listed. These results are based on seventy responses (see table 2.1).

Material	Never	Rarely	Sometimes	Often	Very Often
Dimensional Lumber (1x4, 2x4, etc.)	9%	12%	3%	21%	56%
Engineered wood products (Plywood, OSB, MDF, etc.)	6%	6%	4%	15%	69%
Pre-engineered wood trusses	46%	39%	11%	4%	0%
Steel tubing or pipe	3%	3%	15%	16%	63%
Heavy structural steel (I-beam, Channel, etc.)	20%	14%	37%	13%	16%
White bead foam (EPS)	10%	20%	41%	19%	10%
Extruded Polystyrene Foam (XPS or Blue Foam)	11%	13%	39%	24%	13%
Ultra High Molecular Weight Plastic (UHMW)	11%	9%	33%	27%	20%
Polycarbonate (lexan, etc.)	9%	14%	41%	24%	11%
Aluminum	16%	26%	14%	16%	29%
Steel wire rope	1%	0%	9%	24%	66%
Fibrous or synthetic rope	1%	7%	32%	33%	26%

Table 2.1- Materials Utilized in Scenic Fabrication

The list of materials was created based on my own experience in the field and through consultation with graduate colleagues familiar with scenic construction and professional shop personnel at UT Austin. It is not an exhaustive list of possible materials utilized in scenic construction, but it is a list of commonly used materials with very different physical properties.

It is immediately clear from these results that engineered wood products and steel wire rope are heavily utilized in scenic construction, and that pre-engineered wood trusses are not regularly utilized. If the scale is viewed just in the “sometimes” column, it is interesting to notice the array of material usage. Basically put, scenic fabrication uses lots of different materials sometimes.

It is hard for me to empirically state that the shear volume of possible materials to be used in construction distracts Technical Directors. However, I do think that it is a difficult task to consider all of these possible materials, the adhesives that work or don’t work with them, the cutting and joinery, and the potential disparity in finish between these materials. These results once again speak to the large amount of both general knowledge and expertise required of Technical Directors in practice.

The final aspect of the construction analysis is the certifications required of or incentivized for the work force. My interest in these certifications is not about what they cover or how they test that information; nor do I want to talk about the process to become certified. I think there are challenges in those areas, but that is a topic for another document. My interest in certifications is based in the company requirement for certification of the work force, or the company incentivization of certifications for the work force.

The new standards for rigging and electrical work developed by the Entertainment Technician Certification Program (ETCP) are a tremendous step forward for the work force of entertainment professionals. ETCP created testing that encourages proven work experience, safe practices, and knowledge of skills and research. Since the first rigging examinations were given in 2005, ETCP has changed the nature of the conversation about qualifications in entertainment (Geraghty 53). These standards are the beginning of a safer more legitimized work force in entertainment.

The first certification survey question, question fourteen, asked, “Does your company require any of the following certifications of any employees?” (Vieira). The certifications listed were chosen through consultation with colleagues and mentors in the field (see figure 2.13).

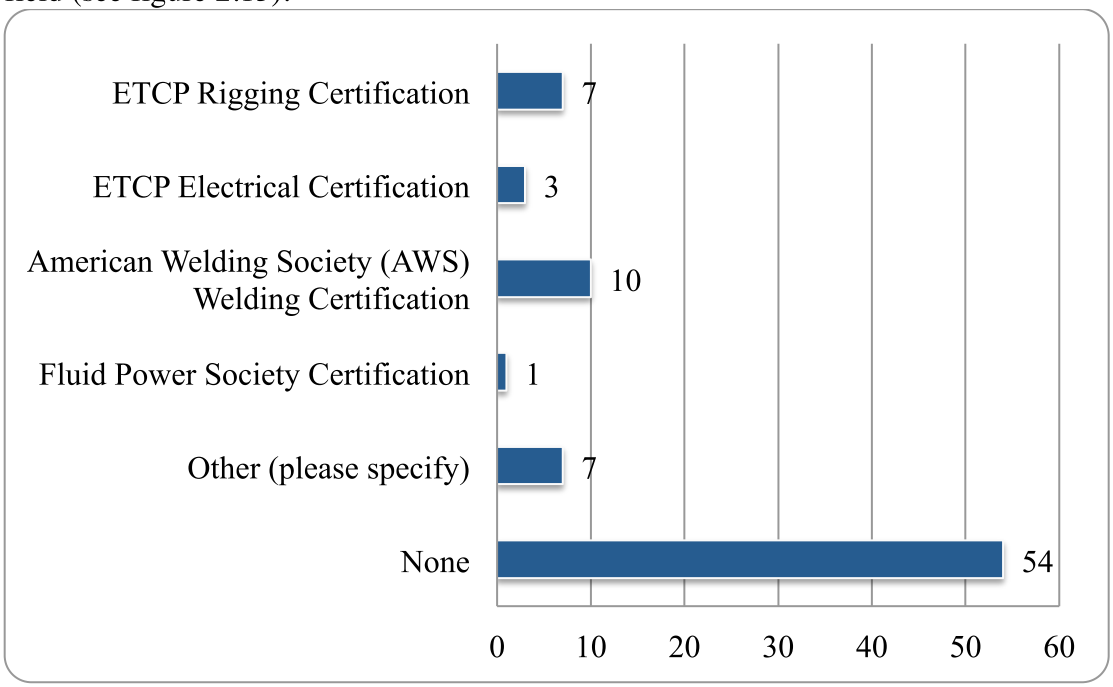


Figure 2.13- Certifications Required by Company

It is overwhelmingly obvious that certifications have not taken a strong hold in live entertainment construction yet. The “other” results are all New York City specific fire, welding, scaffolding, and electrical certifications. New York City has more city regulations governing building for performance than most other places. It is possible that the survey did not reach organizations that have certification requirements. Conversely, it is also possible that the survey results represent companies that have more certification requirements than others because of their relatively large size. Regardless, it is clear that the vast majority of companies are not requiring any certifications currently. This is a challenge to the structural integrity of the scenery on the stage. Additionally, it is a challenge to the power of the certifications themselves because the constructors are not required to prove their proficiency and mastery of the structural creation techniques.

The second certification based survey question, question fifteen, asked, "Does your company provide any incentives for employees to have any of the following certifications?" (Vieira). The question received seventy responses (see figure 2.14).

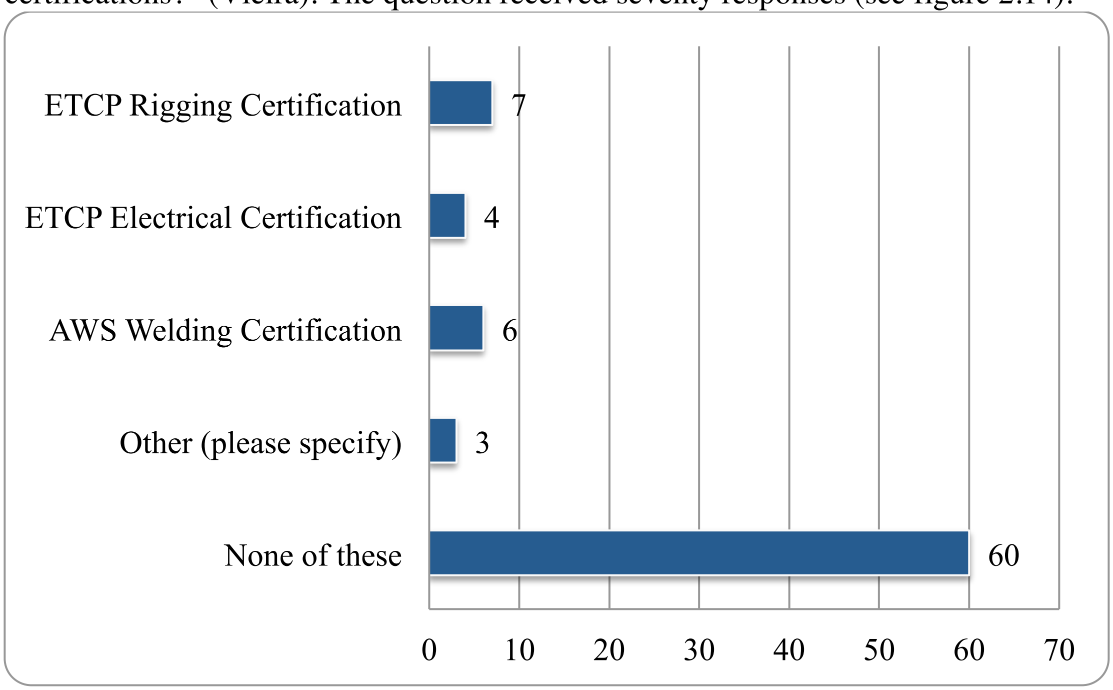


Figure 2.14- Company Incentives for Certification

Again, it is clear from these results that certifications are not highly valued in the industry. It would be a tremendous structural and mechanical safety improvement in the industry to see companies provide incentives to the work force for achieving and maintaining certifications. Any improvement in structural design practices needs the support of a better-trained, safer work force.

CHAPTER CONCLUSION

Through an examination of the job requirements for a Technical Director, a review of the demographic survey results for the individual responders, and a review of the organizational demographics of the companies represented in the survey, I have laid out the basis for what a Technical Director is doing in practice. The review of factors that complicate operations and decision-making is a critical point of understanding for the analysis in the following chapters. Without a clear understanding of the people and the processes involved in structural design for productions, it is impossible to understand the commentary on the process of structural design. In Chapter Three, I will look at the specific tools, resources, and practices of structural and mechanical design in entertainment and in other related construction industries.

Chapter 3: Structural Design for Live Entertainment in Practice

INTRODUCTION

The previous chapter described the people and places involved in structural and mechanical design for live entertainment. This chapter will focus on the details of structural and mechanical design for live entertainment in practice as reported through survey results. Further, the chapter will examine different opinions about how the structural design process should work in live entertainment. I use both qualitative and quantitative survey results to demonstrate who is currently responsible for making structural or mechanical decisions in live entertainment, what resources these people are using, and what support is available for the structural design decisions being made.

To begin, I will return to the working definitions for structural design and mechanical design. These terms can mean a lot of different things across the industry, and it is critical that I explain how I am using the terms in relation to my thesis. As discussed in Chapter One my definition of structural design is the process of analyzing and engineering structural requirements for size, shape, function, materials, and loading of a fixed object or structure ("Structural Design"). Mechanical design is the process of incorporating moving and stressed components into a useful end product for a user. These definitions inform the analysis of the qualitative data by setting a common entry point definition for the work of structural design and mechanical design.

The qualitative data in this chapter comes from the hypothetical situation questions in the survey. The hypothetical situation presented in the survey is as follows:

> In the service of a show, Mike was asked to draft the structure for a portal (shown above). This portal consisted of two towers framed with steel and a header truss framed with steel. The towers had a footprint of 3'-0"x 4'-0" and the top of the

> tower was at +16’-0”. The header had cross sectional dimensions of 5’-0” tall x 3’-0” deep and was made in two 15’-0” sections for a total length of 30’-0”. The towers were at opposite ends of the header which created a span of 22’-0”. The header was covered on the bottom and the front with ¼” lauan skin and black velour.
>
> In the process of creating the drawings for this piece, Mike became very interested in the complicating factors around this structure. It would need to be assembled and disassembled as part of the run of the season. Also, the unit would be exposed to the elements, including wind and rain, as part of its running and storage life. Further, this piece would need to be packed into a truck at the end of the season for long-term storage or potential travel to a different theatre.
>
> Mike asked a few questions of his colleagues about the structural needs of the piece, and about other structures that had been created at the theatre that served a similar structural purpose. With advice about framing material and basic statics analysis of similar trusses, Mike drafted the structural design for the towers and the header. The towers and header were constructed and installed, and the show ran without any problems at all. However, Mike was unsure he had a complete understanding of the forces involved in the problem. (Vieira)

Question twenty-three asked survey responders to explain if this situation seemed realistic or not. Question twenty-four asked, “As a professional, what advice would you have given Mike to help him feel more comfortable about the structure of the portal?” (Vieira). The answers to these two questions were coded as described in the introduction to this thesis document. I will not specifically reference the questions when presenting data from answers. I will utilize my coded analysis for themes and sub-themes to access the data. The complete, not coded hypothetical situation survey responses are available in Appendix B.

THE STRUCTURAL DESIGNERS

Outside the realm of the live entertainment industry, architects, engineers, and construction personnel handle structural and mechanical design. All United States states require adherence to building codes for structural design work for commercial, residential, and industrial construction. There are multiple sources for these codes including the International Code Council and the Council of American Building Officials ("Building Codes" 171). Codes are written in an effort to make structures safer, more secure, and sanitary. Building codes are created when, "industry experts develop standards, which are documents that contain industry consensus regarding the methods by which the products, materials, or methods should be designed or employed" ("Building Codes" 171). These developed standards are the product of materials testing, analysis, and construction processes testing. Initially, these codes are developed to limit the liability of the designer, and protect the public. Based on these strict guidelines, building codes provide the environment for development of structural and mechanical design for buildings.

Unlike commercial, residential, and industrial construction, a uniform building code does not exist specifically for live entertainment scenery construction. Practitioners typically rely on professional experience, advice from other professionals, and adaptation of techniques and codes utilized by engineers and architects to create structures. Without a building code, base level structural design requirements do not exist for scenery specifically. In my experience, scenery is structurally designed and constructed utilizing a "best practices" method.

"Best Practices," for the scope of this thesis, is defined as accepted and widely utilized methodology for technical problem solving. According to the *Encyclopedia of Small Business*, best practices are defined as, "business jargon arising from the management tool known as 'benchmarking'" ("Best Practices" 115). The definition continues with, "production and management processes are uniform enough so that a 'best practice' can be identified and then adopted more or less 'as is' by another entity"

("Best Practices" 115). These quotes provide a basic application and origin for the phrase best practices. Best practices are generally assumed from repetitive practice, and in the case of structure for live entertainment, they are built on the idea that something has worked before safely, so it will likely work again. Best practices, especially concerning live entertainment scenery, are not necessarily built on structural design standards or strict scientific testing.

The wide use of "best practices" is evidenced in some of the hypothetical situation responses given in the survey. One responder observed that, "with a breadth of knowledge that exists in our industry the usual questions 'hey...do you think this is a crazy idea?' among collegues (sic) is enough to create an environment where an idea can be nurtured safely and efficiently." Another observed that, "This is how it has worked in the past, so we should be safe to do it again." These two responses illustrate the "best practices" approach to structural design that typically exists in live entertainment. Without the uniformity of the building code these best practices are without a unifying standard.

Technical Director as Structural Designer

As examined more closely in the previous chapter, the survey results represent information from multiple sizes and types of live entertainment organizations. The responses to the questions concerning structural and mechanical design practice reflect these broad demographics. The first structural design specific question, question sixteen, asked responders "Who is responsible for making structural and mechanical design decisions at your company?" (Vieira). Of the sixty-three short answer responses to this question the most common was overwhelmingly the "Technical Director" (see figure 3.1).

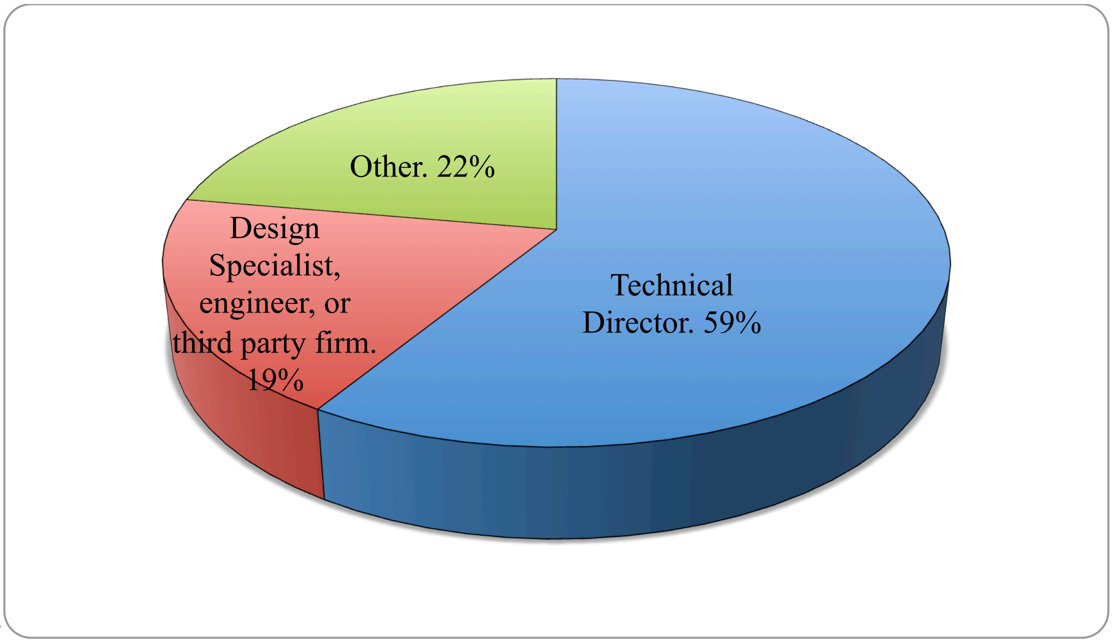


Figure 3.1- Structural Design Decision Responsibility

These results suggest that despite different demographics represented in the survey results, Technical Directors are generally making structural decisions at all levels.

Very few responders indicated that an engineer was responsible for design decisions. This was further indicated in the survey long answer responses. For example, responders said:

> We often build based on construction experience rather than engineering knowledge. It seems it is rare for Technical Theatre managers to have had any formal engineering training. I typically try to compensate by over-building to some degree.

> "When in doubt, build it stout" was a mantra I learned very early on in scenery construction, and until one comes across a situation where the weight of "stout" becomes part of the "doubt" and one is responsible for the outcome, there is not much impetus to learn the structural math to calculate forces and stresses.

These responses indicate a bit about the mindset surrounding structural design decision making in live entertainment. The person or people responsible are usually not formally trained in structural design, but they are typically experienced and know how to navigate through practical challenges in production based on experience. This assertion is supported by the quantitative survey results directly.

Overcompensating can be an effective way of making up for a lack of formal structural design knowledge or oversight. Recall the previously quoted phrase, "when in doubt, build it stout." A survey responder observed a challenge for Technical Directors when they are faced with a decision they are either not comfortable handling or not fully equipped to handle structurally.

> I would advise consulting the management of the company and push for their (sic) to be outside analysis of a structure that he were not comfortable. However, this is very much a catch-22 in our industry. This often makes producers and managers respond "why did we hire this guy." There must be a mutual understanding of what is and is not expected as far as engineering.

This observation acknowledges directly one of the biggest design challenges facing Technical Directors in practice. How does the person responsible for structural decisions find help and guidance? This question is a critical question and one that can only be speculated on in the scope of this thesis. I will expand more on this point later in this chapter in the resource review.

Large Budget Structural Design Decision Making

When the responses to the "who is responsible…" question are filtered to only include responses from people that indicated that an average budget was over $75K, the number of responses that indicate that the Technical Director is ultimately responsible is cut significantly (see figure 3.2).

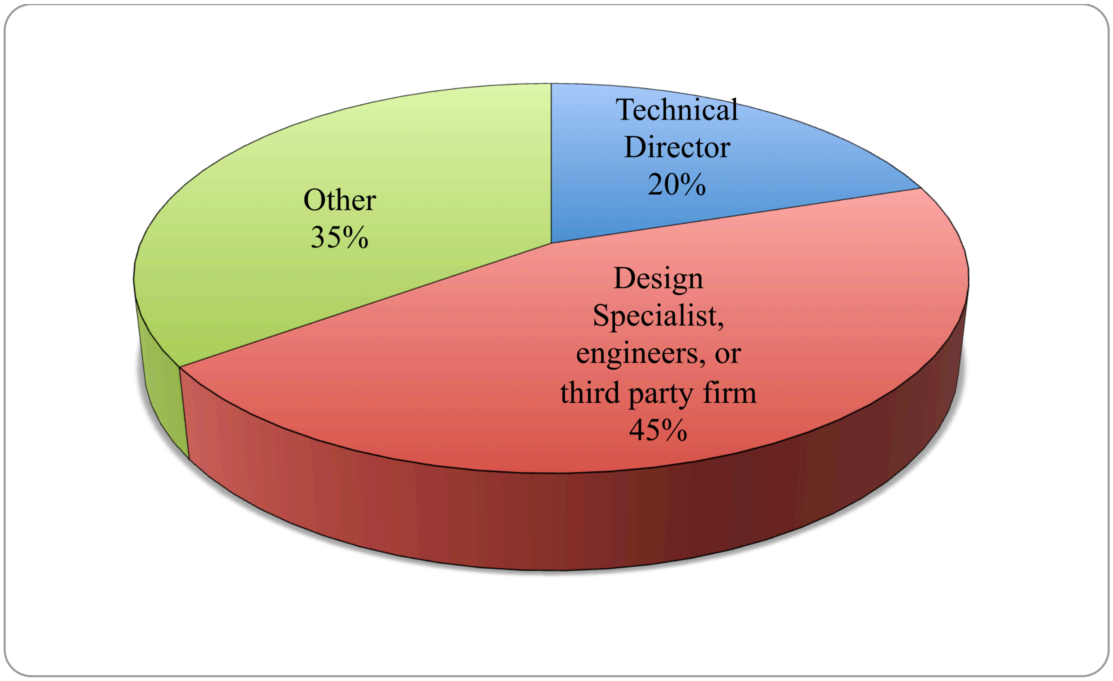


Figure 3.2- Structural Design Decision Responsibility ($75K+ per production)

Only four of the twenty responses included in those filtered results indicate that the Technical Director is responsible. Nine of the twenty responses indicated the use of design specialists, engineers, or third party design or engineering firms, and the remaining responses are inconclusive.

This is significant because this indicates that companies engaged in more expensive work are also engaging more formalized structural design decision making processes or experts. A responder noted:

> I often see ATD [Assistant Technical Director], TD types out of their depth in structural design situations in the NFP [not for profit]/academic world. It is my experience that it is infrequent that an engineered, or even analyzed approach is taken until you hit the for-profit shop world where liability and major financial losses are of paramount concern.

These companies could be utilizing a more formal structural design process because of a number of factors. The most significant being that these operations utilize more complex structures, and they have recognized the need to have a more formal review of structural design. It also could be that these organizations have more at stake monetarily and are seeking to limit liability.

Additionally, that response points to an interesting divide in the live entertainment structure world between for-profit and nonprofit work. The majority of my experience has been in nonprofit organizations. I also did not understand the relative liability concerns until I worked in a for-profit shop. The need for greater oversight of design operations in for-profit is a product of the potential for significant financial loss related to liability. In an article for the American Society of Mechanical Engineers, about non-traditional mechanical engineering opportunities for students, author Carol Milano quotes Bill Gorlin, Professional Engineer and Vice President of the Entertainment division of McLaren Engineering as saying, "it's vital to be able to get these non-engineers to appreciate the design issues that may not be obvious to them." The author then points out that those issues typically affect project cost, and Gorlin's firm works on projects in the range of, "$50,000 to tens of millions." Gorlin illustrates the demand for experienced engineers to be involved in the process of designing and specifying equipment for large projects because they have the necessary expertise. I believe that with the growing complexity of work being undertaken in nonprofit organizations that the significance of potential losses related to structural liability will begin to be more seriously considered, and more attention will be paid to the need to consult experts.

Resources for Structural Design in Entertainment

The structural design research process of analyzing materials and structural shapes is a key portion of any construction project. Structural and mechanical design resources are invaluable in the work of designing. The amount of information needed to successfully complete the operation is far too great for any person to completely master or memorize. The resources presented in this section of the chapter represent just a few of the many available and utilized in practice. Resource collaboration between colleagues in structural design is an important piece of continuing education, and skills development.

In survey question seventeen, responders were asked to rate fifteen different resources based on how often they use them when creating structural or mechanical designs. I selected the resources based on my own experience with the structural design resources and consultation with fellow theatrical and structural design professionals. The resources are source material common in theatrical production, training, and practice, design and practice guides for architecture and engineering, and manufacturer's catalogs. Because of the complexity of aesthetics and structure in live entertainment design and production the resources utilized can be varied based on the needs of the production. This list of resources was not exhaustive, and survey responders were encouraged to indicate other resources that they utilize. In live entertainment scenic construction there are clear "standard" resources pervasive throughout the industry.

All of the resources were presented in a chart that asked responders to rate how often they use the resource on a scale from "Never" to "Very Often." As part of the survey, I wanted to document as many of the resources being used in the industry as possible so that practitioners can benefit from their colleagues. The complete list of these other resources is in Appendix B with the other selected survey results. I will focus my analysis on the three resources most utilized in practice according to the survey (see figure 3.3). Those resources are the *Backstage Handbook* by Paul Carter, the McMaster Carr Catalog, and *Structural Design for the Stage* by Alys Holden and Bronislaw Sammler.

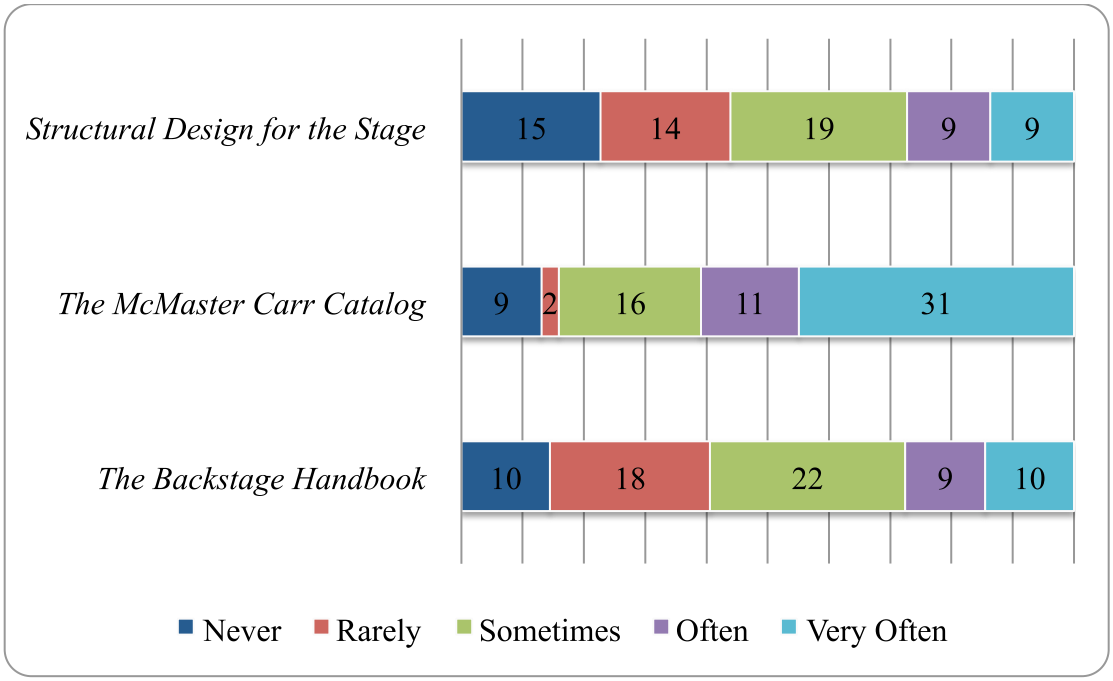


Figure 3.3- Resources Most Utilized in Creating Structural Design

The Backstage Handbook

The first resource that is most commonly found on every Technical Director's bookshelf is the *Backstage Handbook* by Paul Carter, 1995 revision. This resource contains a tremendous amount of general information about almost everything pertaining to production work in live entertainment. The book is full of practical information about materials, construction, and hardware. Additionally it contains information about entertainment specific hardware and terminology. The *Backstage Handbook* exhibited the most traditional looking bell curve of all of the resources asked about in the question. Of sixty-nine responses on a scale from "Never" to "Very Often" that book received twenty-two "Sometimes" responses.

The McMaster Carr Catalog

The resource that received by far the most "Very Often" responses was the McMaster-Carr Catalog. Of sixty-nine responses, 44% of responders indicated that they use that catalog "Very Often." This is clearly a significant source of information for people working in entertainment. The catalog, and website, is a primary source for manufacturer information about almost any product that can be utilized in the construction or fabrication of structures or automated effects. The information contained in that resource includes manufacturers ratings, any specification status, and clear dimensions, often including 3d computer drafting, to aid the designer in making decisions. This resource is an excellent broad level source for hardware information from manufacturers.

The manufacturer rating, the certification of strength or durability in certain applications provided by the manufacturer, and information is a good "best practices" method for insuring some security in design and implementation. However, I would argue that often in entertainment TDs utilize products from this catalog, and others like it, in ways that they were never intended or tested for by the manufacturer. In my own practice, I see hardware and manufactured components fail. I also hear stories, some bordering on tall-tales, about the unintended stresses experienced by load rated hardware in a structure or machine in entertainment that has failed. Too often in entertainment ratings and due diligence of a product manufacturer is the only information that goes into a structural or mechanical design. This is especially problematic when the piece of hardware is often being used in a manner in which it was not intended nor tested by the manufacturer.

Structural Design for the Stage

The final resource of the three resources that was indicated to be "most used" in the survey is *Structural Design for the Stage*, by Alys Holden and Bronislaw Sammler. It includes a significant amount of information about basic physics and engineering principles directed at a theatrical construction audience. This resource features a wealth of practical information about analyzing stresses, designing members, loading, and basic materials properties for wood and steel. This book was written as a textbook to accompany a course for non-engineering theatre structure personnel in basic mathematics, physics, and statics for structures (Holden and Sammler xi). Clearly stating their own credentials and the target audience for the book, the authors make the statement, "the authors do not have degrees in engineering and have written this text for non-engineers" (Holden and Sammler xi). Further the authors say, "…the text is relatively heavy with 'how-to' theatrical examples and is relatively light on theory" (Holden and Sammler 3). This quote again reinforces that the book is intended as a textbook for a specific audience.

The popularity and usefulness of *Structural Design for the Stage* is clear from reading the responses to the hypothetical situation survey questions. Nearly 10% of the responders, when asked what advice they would give a hypothetical young structural designer in entertainment, specifically mentioned consulting that book as the first level resource.

> For this relatively simple header truss I think we might just sit down with Holden/Sammler and figure out the stresses.

> Take an adequate course in Structural Design for the Stage from a competent practitioner. Otherwise, contact a qualified engineer.
>
> I would have pulled out my "Structural Design for the Stage"(sic) book and told him, ‘Lets sit down and do the math to make sure what you have come up with is safe.’
>
> Study Structural Design for the Stage and consult with industry colleages (sic)

These survey responses illustrate the level of confidence and respect that *Structural Design for the Stage* receives from some practitioners in the industry. The problem with this confidence, without the formal framework of engineering training, is the potential for misapplication, faulty analysis, or lack of understanding of all aspects of the problem. Most simply, the potential for math mistakes is always present, and without an approval or oversight process for structural design the Technical Director is not qualified to fully handle the potential challenges with structural design and the liability risks associated with those challenges.

Because of the weight given to this resource by survey responders, and because of the context of this textbook, I will analyze this source further than the other two previously mentioned sources. One survey responder remarked, “it is rather obvious that, while the investigator might have had some training in structural design for the stage, that training was sadly incomplete.” This comment illustrates my most basic argument with this resource, and it is not with the textbook at all. I believe that the simple application of this text without an ethical model for utilization, or documented proof of understanding of the text is problematic. Empowered by a basic understanding of some of the tasks involved in structural analysis gleaned from *Structural Design for the Stage*, a TD could inappropriately present that structural analysis as evidence of structural design soundness. From my courses in engineering at UT Austin and my own practical experience, I know that there are many potential variables involved in structural design, and these variables can compound each other very quickly. Without a complete in-depth understanding of all variables, including the ethics of structural design decision-making, the Technical Director should not necessarily declare that something is secure. Further, a book cannot insure the necessary basic mathematics and physics knowledge that is required in engineering training.

I am not asserting that the authors of this book are compelling Technical Directors to make such a statement, but I am presenting that *Structural Design for the Stage* represents one piece of a necessary larger training. The book is a textbook for training specific skills and does not include the necessary training in the ethical application of those skills. It should not be used to supplant professional consultation with an engineer when the need arises. My work is in no way trying to diminish the usefulness and utilization of *Structural Design for the Stage*. In contrast, I am working to take the next steps in developing sound structural design training, certification, and implementation for the stage.

"Other" Resources Used for Structural or Mechanical Design

Some responders suggested software based resources for structural analysis. Most commonly suggested was the use of software that can provide Finite Element Analysis (FEA). According to Professor of Aeronautical Engineering G. Lakshmi Narasaiah, in the book *Finite Element Analysis*, FEA is based on a mathematical model developed using the Finite Element Method (FEM) of structural design (31). FEM uses the idea of total structural analysis, which considers all of the component parts of a structure and their individual properties to determine overall structural strength (Narasaiah 4). The FEA software is able to perform multiple iterations of the FEM calculations very quickly. There are many 3d modeling applications that will perform this sort of analysis. The challenge in using this sort of analysis is similar to the challenge in using other structural design tools, defining the problem for the computer program to analyze. Professor Narasaiah points out, "conditions are simplified based on the analysts' understanding of what features are important or unimportant in obtaining the results required" (31). Further, "FEA is a solution technique that removes many limitation of classical solutions techniques; but does not bypass the underlying theory or the need to devise a satisfactory model" (31). The author illustrates the limiting challenge in utilizing FEA in design; once again, the analyst, or designer, needs a complete understanding of the structure to be analyzed to utilize the tool. This analysis should include any ethical sensitivities that are present in the specific structural design need.

SUPPORT FOR STRUCTURAL DECISIONS

The final section of this chapter focuses on the supporting documentation or consultation implemented in the execution of structural design for live entertainment. Structural design documentation is typically only reviewed critically in the event of an accident or malfunction. During this review, lawyers, inspectors, or managers are looking to assign or mitigate risk in liability. It is in these moments that the documentation is most critical and possibly most damaging. Most people that interact with the final product of structural analysis never see any documentation. Some loading information, warning labels, or basic instructions will exist on structures and machines in entertainment, but the detailed specifications and drawings sheets that are utilized in construction and installation typically end up in a drawing tube in storage if they existed to begin with.

Live entertainment production is built on a tradition of strong problem solving skills. This was indicated through a few of the survey hypothetical situation responses:

> Many individuals […] learn from a ‘hands-on’ approach and gain knowledge through experience and trial and error. They never really gain the academic knowledge of structural design

> It is more common in smaller shops & regional theatres for newer A/TD's to "go with their gut" than to buckle down and do true engineering calcs.

> Traditionally, this issue is handled by slightly over-designing a piece to account for unforeseen factors […]. There comes a point in the design process where things must move forward as best they can, even if the problem is not fully fleshed-out.

> I think, many TDs also go with their "gut feeling" and past experience when doing technical design more often than not.

These observations speak broadly to the often, informal nature of documenting or preplanning problem solving for structural design in live entertainment.

Most practitioners I have worked with live to solve problems created through challenging design aesthetic decisions, difficult time circumstances, or challenges inherent in the performance. This problem solving at all costs effort can create an environment rooted in trial and error experimentation and lots of in-the-moment changes and decisions. Work of this type does not naturally lend itself to thorough documentation or expert consultation.

I asked survey responders about the amount and type of documentation they produce and how often they consult an outside expert, an engineer in this case, for added support. Because the survey was meant to be an assessment of the field, I thought it was important to understand the range and types of documentation produced and understand generally how often engineers are utilized in live entertainment production. The two questions related to this topic received varying levels of enthusiasm from entertainment industry colleagues who vetted the survey. The questions remained in the survey and the results provide insight into the sensitivity about the issue of professional engineering consultation.

Question nineteen asked responders, “What, if any, structural design supporting paperwork do you produce?” (Vieira). This short written answer question received only forty-two responses. One third of the forty-two responses indicated that they either produce no supporting paperwork or they produce very little other than simple construction or installation drawings. This is pretty consistent with my working experience. I have very rarely seen paperwork beyond detailed construction drawings. Based on the position of the question toward the end of the survey, some responders may have chosen not to answer due to time. However, it is possible that the people that did not answer the questions because they do not think they are producing structural design supporting paperwork at all.

The more surprising answers to this question were the two-thirds of forty-two responses that indicate more formal paperwork is produced, including reports and stamped drawings from third party engineering firms. These results are very encouraging to me because they indicate a larger amount of outside professional design consultation than I thought existed in the industry. Some of the responders indicated very elaborate documentation requirements and support systems. These responses were typically from responders working with very large entertainment organizations based on responses to other questions. As discussed earlier in this chapter, these organizations are working with larger budgets, or larger projects with more money and liability at stake. It seems these organizations are seeking to limit their own liability.

In addition to the supporting documentation question, question twenty asked, “How often do you consult an engineer for scenic or mechanical elements to be constructed by your company?" (Vieira). This multiple-choice scale question received sixty-eight total responses (see figure 3.4).

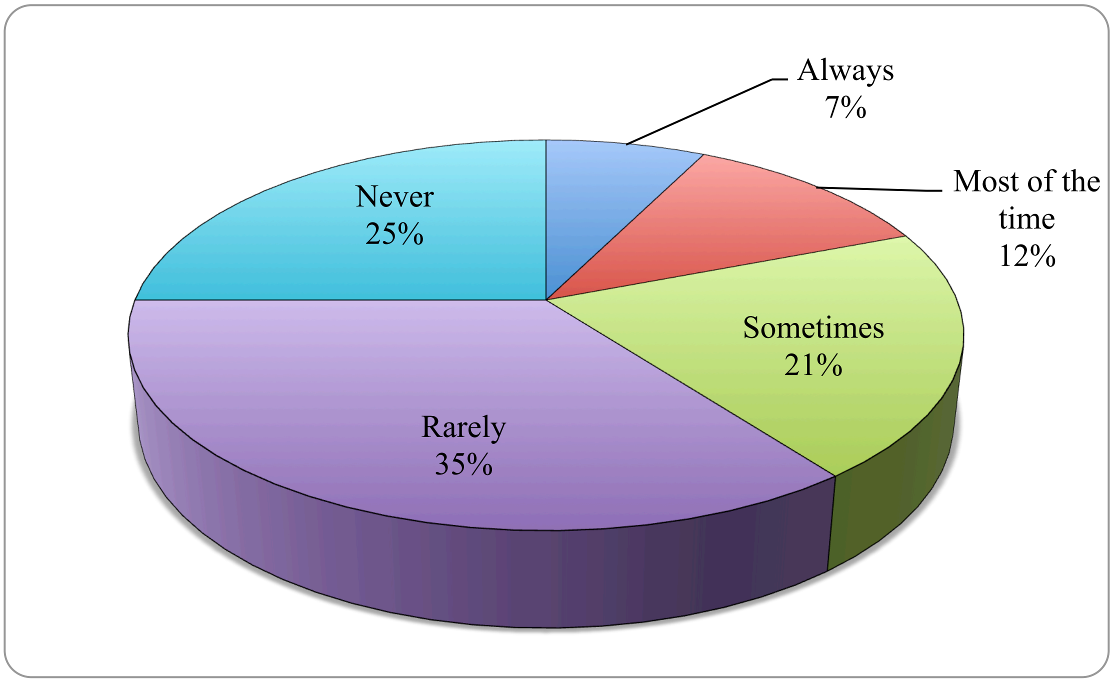


Figure 3.4- How Often Responders Consult an Engineer for Productions

Of those sixty-eight responses, 60% indicated that they either "never" or "rarely" consult an engineer.

Conversely, several of the survey responders recognized the need for engineering in live entertainment structural design. One such responder pointed out, "If in doubt consult a professional engineer. It is cheaper to have a structure analyzed than to pay for an accident." Additionally, "Seek out people with more experience to help evaluate your designs. Hire professional engineering support when needed." "I would recommend that he seek out an(sic) structural engineer to ensure the framing material, truss design and bolt connections meet the loading conditions." "Engineers are getting less expensive these days and I would say that he should send his designs to an engineer for review and approval." This advice about dealing with structural design from survey responders illuminates the point that there is a shift to desire a safer, more complete structural design review and documentation process in live entertainment.

Alternatives to Engineers in Production

Everyone in the industry does not share the opinion that engineers need to be consulted more widely in production, and their points, as exhibited in survey results, need to be recognized as well. This disagreement comes in two forms generally. It seems that there is a "best practices" or experience based qualification camp and a sufficient education short of engineering camp.

As far as the "best practices" or experience argument is concerned, I find it difficult to disagree with an experienced entertainment structural designer in this field. Several survey responders indicated reliance on past experience including, "Seek out drawings from other theatres in similar situations to understand how and what they did to build this piece." "With all this said, your 'best practices' method is perfectly adequate for scenery built on such a small scale." "Seek advice from people who have done it before, see how they succeeded (or failed) and use that experience to inform your decisions." These ideas illustrate an interesting cross-section of more practically experienced structural design in the field. "Best practices" and past experience can be used to produce quality structural design. These people have made their career on the fact that they can produce structures that are secure, artistically true to design, and within the project scope.

Unfortunately, without formalized training or documentation of structural design standards, there is nothing to insure that any one person's "best practices" are adequate. Several of the survey responders commented to this point with:

> …just because something has been done before, doesn't mean it was safe. Too often, this process is used.

> This sort of thing happens all the time, all over the industry. Someone with little or no structural design experience is asked to design or build something beyond their expertise, then they must cross their fingers that it's welded well enough, or at least overbuilt enough to handle the stresses.

These responses indicate recognition of challenges to a strictly "best practices" method of structural design in the field. Even a team of collaborators cannot insure that decisions made are adequate to a cohesive standard. These "best practices" and experience-based decisions need to be formalized in order to insure good base level standards that are consistent.

The other alternative to the wider use of engineers in scenic structural design is the creation of a well-trained, specifically educated entertainment structural designer. This person, or people, would have some training in structural or mechanical design but does not need to be an engineer. Some responders illustrate this idea:

> The only person technically "qualified" to asses the structure of the portal would be a licensed engineer. Consider what they do for a moment. They asses buildings, houses, bridges, etc., making sure it can last for 20+ years through disastrous (with a distinction to be made as disastrous being earthquake, tornado, etc.) weather, and including propogation (sic) of uncertainties with every calculation they make.

> Work as a team, not alone. The head carpenter, riggers and technical department all need to be comfortable with everything, or it doesn't happen.

> Basically, this […] is too simple and too routine to have much engineering to worry about.

These responses exhibit a belief that professional engineering consultation is not necessary in live entertainment because of a perceived lack of complexity or lack of needed product longevity. This argument also asserts that, for the most part, the work being done in entertainment does not require the specialization of engineering review. I am not claiming that engineering consultation is required on every project, or even every piece of every project, but without formalized training, documentation, or experience standards, an entertainment structural designer cannot be proven to understand a sufficient amount about structural design. Further, without some consistency in training, through certification or university accreditation, entertainment structural designers could operate without any consistency in decision-making. I disagree with the idea that because the structure does not have the longevity requirements of a building or other more elaborate consumer goods that it is any less in need of qualified review. If people will interact with it, it needs to be reviewed professionally in some way for safety and soundness. As mentioned earlier, I will review the ethics of this effort in the next chapter.

CONCLUSION

In this chapter, I explored the current tensions in the structural design process for live entertainment. Through an analysis of survey responses to questions about resources for supporting structural design decisions, documentation, and professional engineering consultation, I have demonstrated the challenges present in structural design for live entertainment. In a field that utilizes both apprenticeship and "best practices" so heavily, there needs to be a clear standardization of those "best practices" learned through apprenticeship. Through this analysis it is clear that there are many ethical and legal issues needing more attention in structural design for live entertainment. In the following chapter, I will explore ethical models and training in the related AEC industries, and analyze the risks of liability in scenic structural design.

Chapter 4: Ethics and Liability in Structural Design

INTRODUCTION

Ethics are generally considered to be the accepted and understood moral difference between right and wrong ("Ethics" 632). Ethics are different than laws and rules because ethics are not necessarily written, required rules to be followed. Mohammad Iqbal describes the difference by stating, "ethics are considered precatory and not mandatory; however, ethical commitments are of no less importance than legal obligations" (24). Iqbal goes on to quote Former Chief Justice Earl Warren who said, "society would come to grief without ethics, which is unenforceable in the courts and cannot be made part of law" (24). Professional organizations and groups that represent the good of the industry undertake the creation of ethical standards to unify ethical standards for a field. Iqbal describes, "it provides a framework for the professional's ethical judgment" (27). This is an imperative unification that exists in Architecture, Engineering, and Construction (AEC), which needs to exist for structural design for live entertainment.

This chapter will focus on the ethics involving the work of structural and mechanical designers for live entertainment. It is imperative that live entertainment constructors, as a field, develop ethical standards for professional practice to legitimize and standardize the industry. As one survey responder noted, "if the situation is one or two guys sitting around guessing at what the best solutions is, they should stop before they hurt someone." I think this quote illustrates a very ethically suspect practice that happens all too often in the industry.

Through an analysis of ethical codes in related occupations, a review of organizations that provide those ethical codes, and a survey of the legal liabilities involved in structural design, I will demonstrate the need to bring all of the people and organizations discussed in Chapter Two and the work described in Chapter Three to a new safer place. I recognize that there are many ethical, responsible, and conscientious practitioners in our industry, and just because there is a unifying ethical code does not mean unsafe things will not happen. However, as a field, TDs need to set ethical structural design standards for the security and safety of the end users of scenery and the structural designers as a whole.

ETHICS IN RELATED FIELDS

Structural and Mechanical design and implementation outside of the entertainment field is handled by architects, engineers, and construction contractors. All of these fields adhere to different, but very similar, codes of professional ethics and conduct. I will present highlights from each field and provide published commentary on the challenges to their ethical standards in practice in this section of the chapter. Then I will discuss how these ethical standards can be used as a model for ethical standards in entertainment structural design.

Architecture

Architects practicing in the United States are typically members of The American Institute of Architects (AIA). The AIA is a collective of local chapters and regions that are unified by a national board of directors that support the work, training, and ethical practice of architecture (“About the AIA”). The AIA members adhere to “The Code of Ethics and Professional Conduct” as assembled and governed by the National Ethics

Council. The council is made up of seven AIA members that meet three times a year to review the code and any member violations. Violations of the code by AIA members can be punished by admonition all the way to termination of membership. Membership in the AIA, while not required of an architect, is an industry standard among architects. Furthermore the AIA rules and by-laws typically function as the basis for the rules and by-laws of each state's architectural governing and review board. The professional practice of architecture requires recognition from a state regulatory board. Only a licensed professional can use the title "Architect" ("Architects"). Each state board regulates the licensing and requirements for the use of architects on projects. Further, the state organization handles violations of law by architects in practice, up to and including termination of license and recommending criminal action.

According to the AIA, the ethics of architecture are focused on, "the highest standards of professionalism, integrity, and competence" (The American Institute… 1). Further:

> It addresses responsibilities to the public, which the profession serves and enriches; to the clients and users of architecture and in the building industries, who help to shape the built environment; and to the art and science of architecture, that continuum of knowledge and creation which is the heritage and legacy of the profession.

This multi-level effect of architectural ethics demonstrated in the previous quote is in line with the prestige of the career. Architects belonging to AIA recognize that they represent their field through their actions.

Architectural ethics deal with two key areas. First, they focus on business dealings as professionals. The second key aspect of ethics in architecture is the development of ethically created designs that insure security and safety for the public. In the chapter "Ethics and Rules of Conduct Governing Design Professionals," by Mohammad Iqbal, PE, Esq, in the book *Design Professional and Construction Manager Law*, the author cites the need for ethical responsibility because, "the public at large requires protection from potentially devastating effects of poor and insensitive building practices" (25). This illustrates the implied public ethical responsibility faced by architects and engineers, and illuminates the more applicable aspect of ethics in engineering and architecture for inclusion in live entertainment practice.

Architectural ethics prevent architects from engaging in design practices that are knowingly harmful or negligently dangerous. This covers the entire architectural process from early concept and design work through the life of the structure created. Some states have laws that include a statute of repose that prevents architects from being responsible for a structure forever. Ethically speaking though, an architect, as a member of a learned profession, has a duty as a professional to insure the safety of the public through their actions (Iqbal 23). Further, an architect must consider the ethics of aesthetic design, especially in structures that are meant for incarceration or other more oppressive purposes.

The biggest challenge to architectural ethics comes from the balance between ethics, aesthetics, and function. An architect must create spaces that are not harmful for people, but how is this always possible? This is the root challenge in architectural ethics, and was observed by Maurice Lagueux in the article "Ethics versus Aesthetics in Architecture" with, "when it comes to architecture, ethical judgments are hardly distinguishable from aesthetical ones" (123). The author is contending that ethical decisions and aesthetic decisions in architecture are dependent on each other because an unethical but aesthetically satisfying solution will not work and vice versa. Architectural ethics are a simple set of rules and understandings that present complicated situations for architects. The requirements of ethics in architecture are central to the practice of the discipline.

Engineering and Construction

Ethics in engineering and construction are similar to architecture in many ways, but they are not as critically intertwined with the practice as it is in architecture. Ethics in engineering, like architecture, is based on the idea that engineers should use their skills in a learned profession for the good of the public (Iqbal 23). Engineering ethics is divided into codes that adhere to the “paramountcy clause” which, “requires engineers to hold paramount the safety, health, and welfare of the public” (Harris 628). Unlike architecture, engineers are afforded ethical room for innovation and exploration like scientists.

More simply, ethics in engineering is built on the ancient Roman Cicero’s Creed “to insure the safety of the public” (Pinkus 39). Pinkus, a professor of ethics for bioengineering at the University of Pittsburgh, elaborates suggesting that, “the engineer should be cognizant of, sensitive to, and strive to avoid the potential for harm and opt for doing good” (39). These quotes illustrate the basis for the study and practice of ethics in engineering. However, all engineers do not strictly follow this mindset, and there are other amendments or limitation to this basic ethic. Much like in architecture, engineers are typically members of professional organizations. In engineering these organizations are typically split by engineering discipline. The American Society of Mechanical Engineers (ASME) represent mechanical engineers, the American Society of Civil Engineers (ASCE) represent civil engineers, and the Institute of Electrical and Electronics Engineers (IEEE) represent electrical and related engineers. There are other organizations, but these are the largest. Additionally, in a related field the Associated

General Contractors (AGC) has a code of construction ethics and supports the Construction Industry Ethics and Compliance Initiative (CIECI).

Most of these organizations adopted codes of ethics that utilize Cicero's Creed as the cornerstone. The first canon of the ASCE code of ethics is directly that, "engineers shall hold paramount the safety, health and welfare of the public [...] in the performance of their professional duties" ("Code of Ethics"). This is not the totality of the ethics codes for these organizations. IEEE provides, as Broome notes in the article "The Slippery Ethics of Engineering," "three other imperatives opposing him [Cicero] —without giving a way to resolve conflicts between those four paths" (D3). These other "imperatives" deal with shifting of responsibility to the end-users of engineering. Arguing that, the public, as consumers of engineered products, should take some responsibility for the safety and security of those consumer goods by learning enough about engineering or not consuming those items (Broome D3). This is a potentially dangerous ethical situation. However, this is typically tempered by the idea that reasonable people will find a balance based on individual morals because they will accept a certain amount of risk relative to their own understanding (Broome D3). The complex challenges to ethics in engineering are unique to the work of engineers, especially engineers working on ethically challenging projects. Generally, and for the sake of simplicity of building a unifying ethical standard for live entertainment engineering and construction ethics, I will focus on the utilization of Cicero's Creed.

Disagreement exists in engineering ethics between the perceived split in engineering practice and management of engineering. This is significant to note for application to live entertainment structural design because TDs could be caught between the monetary, time, or management demands for production and the need to develop sound structural design. This split in engineering is typically taught in engineering ethics courses by looking at the *Challenger* shuttle disaster as a case study. This study presents a group of engineers on the night before the accident expressing concern about the safety of the o-rings in the relatively low temperature weather conditions. These engineers present their case to management, and management makes the decision because of cost, time, or other pressure to proceed. Lynch and Kline present this story in their article "Engineering Practice and Engineering Ethics," including the most potentially damning quote from a conversation between two managers on the project, "'It's time to take off your engineering hat and put on your management hat.' Lund capitulated, and the launch went forward" (196). This quote illustrates the potentially hazardous ethical challenge that engineers must deal with because they are not operating in a vacuum. Later in the article the authors observe a common assumption that, "managers acting on behalf of corporate interests are assumed to engage in cost-benefit analysis that may lead to decisions that value safety less than engineers' professional responsibility would require" (Lynch and Kline 198). This quote demonstrates a potential assumption that management is concerned with the financial bottom line only, and that engineers must fight against this to maintain the safety and health of the public. This case is just not that simple. Especially considering the *Challenger* example where engineers were presenting a case for scrapping the launch to management. Management, in that case, were all also engineers. All of these people should have understood the ethics of the decisions being made, and should have exhausted their due diligence to understand and eliminate any dangers. Unfortunately the outcome of the accident is the engineering ethics lesson learned.

This case illustrates the "whistle-blowing" aspect of engineering ethics. In this battle between the conscientious engineers and profit-focused management, the only recourse the solo engineer has is public "whistle-blowing." This is a very tricky power to wield and must be utilized with extreme prudence. It is possible that a whistle-blower could have prevented the tragedy of the *Challenger* accident.

The most significant modern case that is presented in all examples of engineering ethics and the discipline for negligence in engineering is the Hyatt Regency Walkway Collapse in Kansas City in 1981. The details of this case have been presented in many other sources, including *Structural Design for the Stage*, in a more complete way than I will here. Simply, the second and fourth floor suspended lobby walkways collapsed during a dance contest in the lobby and killed 114 and injured 185 (Roddis 1546). This case featured an initial design that did not meet Kansas City Building Code, but was overlooked in the details of such a large construction project. This also took place because the main engineering firm for the project subcontracted the structural steel work including the preparation of drawings to a different firm. The main project engineer did not carefully or completely review the drawings from the subcontractor, and thus did not do his due diligence as the engineer of record on the project (Roddis 1550). There were no criminal actions brought against any of the engineers, but the main project engineer and the supervising project engineer were found to be grossly negligent and were stripped of their Missouri engineering licenses (Roddis 1550). The most important ethical practice change that came out of this disaster was the, "recognition that structural detailing needs more attention in routine design practice and engineering education, and that structural schemes that lack redundancy demand an especially thorough design and careful review" (Roddis 1551). Simply, structures that lack redundancy by design need careful oversight.

Holden and Sammler noted this same thing in their review of the case, recommending practitioners "design a system that is single failure proof" (2). Meaning that the structure is not completely dependent on one aspect of the design. The challenge in this case is that a modern, large project facing similar challenges that all projects face was able to produce such a tremendous lack of professional ethics.

One of the most significant problems with ethics in engineering is the way that it is taught. As mentioned in chapter two, ABET requires engineering students to study engineering ethics as part of their education, but how can it be truly relevant to a student? This is a source of some disagreement in the crowded field of engineering education. Also, ethics in engineering is built on a history of tragedies. Students study a list of cases where engineers either made poor decisions or did not prevent poor decisions from being set into action. While learning from tragedy is an important step in preventing future tragedies, it is sad that these tragedies had to happen to be the source material for ethics training in engineering and construction. In live entertainment it is possible to avoid these tragedies and have the opportunity to learn the ethical lessons from engineering tragedies.

Nevertheless, the ethical standards and training for engineers are likely the best base material for the ethics model for live entertainment structural designers. Informed by a more clear knowledge of the work being undertaken in live entertainment, presented in Chapters Two and Three, and the ethics of related fields I will propose to create a unified code of structural design ethics for live entertainment.

Application to Live Entertainment

The key to the review of these models of ethics training, implementation, and discipline for violation is the fact that this does not exist for live entertainment. Unsafe or unethical practices and safe, highly ethical practices alike, in live entertainment, are documented and delineated purely by word of mouth. Also, as mentioned before, there is no unification of ethical standards in live entertainment scenic construction. I have drawn the following lessons from a review of models of ethics in related professions.

Similar to the work of architects, structural designers for live entertainment must function to create aesthetic solutions. Live entertainment is not held to the same standard for aesthetic responsibility that architects are, but there is a requirement that ultimately the end product be true to the design presented by the artistic team. The structural designer for live entertainment has the duty to assess and report to the artistic team about the structural feasibility of designs. It is not ethically responsible to adjust the aesthetics of the final product without the collaboration of the artistic team.

Similar to architects, entertainment structural designers must review design and consider the end-user. The Health and Safety Executive, an "independent regulator" that functions in Great Britain similar to OSHA in the United States, specifically highlights that event organizers are responsible for, "ensuring that as far as reasonably practicable, employees and others at a venue who could be affected by the construction and use of a [temporary structures] (such as scaffolders, riggers and members of the public) are not exposed to risks to their health and are kept safe from harm" ("Temporary Demountable Structures"). As a live entertainment structural designer, I should review the design with an eye for the safety, health, and security of the "public" that will interact with the final product of structural design. The "public" in this case are any performers, workers, audience, or other people that may come into contact with scenic elements, either intended or accidentally. The decisions regarding the aesthetic review and security must be continually reviewed and changed as necessary to insure the "public" safety throughout the life of the scenic element.

For structural designers in live entertainment, there are two significant lessons to be learned from studying engineering ethics. First, structural designers for live entertainment need to recognize an adherence to Cicero's Creed, "to insure the safety of the public." It is clear that there are problems with a strict adherence to that principle because of the nature of innovation in engineering, but it still functions as an ethical cornerstone in engineering education and practice. This should also be the case in live entertainment. Essentially, some of the work being undertaken by Technical Directors is engineering in nature. Therefore, it should be governed with the central mission of the safety of the public. The recognition, articulation, and teaching of this idea will lead to clearer adherence to other guidelines and standards that should be set.

I am positive that many practitioners in live entertainment hold and practice this ethic inherently, but they do not realize that they already operate this way. The need for this sort of ethical standard is presented by Philippe d'Anjou in his article, "Theoretical and Methodological Elements for Integrating Ethics as a Foundation into the Education of Professional and Design Disciplines." He states "students should be educated to reach global ethical responsibility and not only competence, which is certainly part of being responsible" (217). With Cicero's Creed as the basis for their ethical standard, students can move beyond the simple ethical conversations in basic practice and skills building into more complex ethical challenges presented in some live entertainment production innovation. More often than not, practitioners in live entertainment spend the great majority of their energy solving the complicated production construction problem without ever fully analyzing the ethical complexity of their solution.

The second significant thing that live entertainment can take away from engineering ethics is the case study material for education. As mentioned before, ethics case studies are based in large part on failures and tragedy. There is an opportunity to utilize these lessons and avoid experiencing the failures in our own field. The key challenge here is making the lessons relevant to the live entertainment audience. Building an empathetic understanding between entertainment students and engineering practitioners will be a challenge that must be overcome. Holden and Sammler recognized the significance of the lessons present in the Hyatt Regency accident by including it in their text. It is the only significant discussion of ethics in their text. This accident was a tremendously unnecessary loss of life, and it has become a key to ethics training in engineering. I think that live entertainment should more elaborately study this accident and the ethical lessons it can teach so we do not have to have our own tragic accident before we reform our way of operating. There are many accidents that exist in the realm of live entertainment production, including the recent accidents related to the cutting-edge automation effects in *Spiderman: Turn off the Dark* and the 2011 stage collapse at the Indiana State Fair that resulted in seven dead and many others injured. The Indiana Occupational Safety and Health Administration found the IATSE Local, local 30, liable, as the employer, for having a competent person oversee and certify the structure, according to a local Indiana NBC report from the 8th of February 2012 (Chapman). This means that the IATSE local was held responsible for the loss of life accident because they were responsible for the structure.

As noted previously, the ethical challenges presented in the Hyatt Regency case are not purely structural in nature. There are serious implications to be gleaned regarding working processes, submittal review, and supervision. Chapter Two extensively explored the many distractions that face Technical Directors in practice, these distractions, or distractions like them exist in all industries, and the Hyatt Regency happened in part because of distractions. Several survey responders recognized a similar condition present in the industry.

> …confident in the decisions and calculations […] made, but continues to analyze the forces involved because he is probably not a licensed structural engineer and most likely wears many "hats" in his position. In my experience, it's not doubting your understanding of the forces you calculated but rather the forces you didn't plan on.
>
> Typical of the situations I see that there is short term needs to design and construct something in time for the current production without considering other ways of doing things based on a complete understanding of how else the item may be built better. In this case, I think full drawings and even asking the questions was more than happens all too often.
>
> Don't ever be afraid to ask others for help or seek out additional information if you are at all unsure […]. Always verify, never assume anything. If any part of your work makes you uncomfortable or reluctant to show to someone else, you haven't done all of your due diligence. Safety is an obligation not to be taken lightly.

If, as an industry, we take nothing else from the study of engineering ethics, we should use their examples so that we can avoid our own. "Fortunately, the consequences of most structural failures in theater are not so extreme" (Holden and Sammler 2). This is very fortunate, but with the growing size and scope of structure and machines utilized in live entertainment we are quickly approaching a place where an accident could easily hurt a significant number of performers and audience very quickly. A survey responder noted this same idea with:

> As scenery construction becomes increasingly complex it is necessary that we broaden the scope of our industry's expertise. Many scenic solutions are now beyond the depth of the standard curriculum TD type training programs. We must otherwise equip ourselves to make responsible decisions.

An important broadening step to be undertaken is the unification of ethical standards based in the proven ethical models of related industries. Armed with unified ethical standards Technical Directors can be better equipped to make responsible decisions because they will have a standard code to inform decision-making.

LIABILITY IN DESIGN

The second section of this chapter explores issues around liability in structural design. The research in this section of the chapter is mostly from law reviews, and is focused on architecture and engineering professional liability. I chose this focus because architects and engineers are the professionals that are legally qualified to produce structural and mechanical design for consumption by the public. I will expand on the requirements of licensure in both of those disciplines later in the chapter.

In my informal consultations with architects and engineers during the research on this project, the idea of proving liability came up repeatedly. Because of the litigious nature of our society, most of the people I consulted in the legal research, thought that discovering a clear link to personal liability would be necessary to motivate change in the practice of structural design for live entertainment. The more research I conducted in this area, the more I realized that this should not be the case. Now, I contend that there is not a need to focus on potential litigation because structural design for live entertainment falls in a very dangerous “grey area.” Based on the legal view of the case, a Technical Director could either be completely liable or not liable at all. I will explore this more later in this section.

Liability is the legal term for formal responsibility regardless of intention or desire. In law, civil liability is defined as, “breaches of explicit or implicit contract in which injured parties may sue for compensation or damages" (Mitcham 1610). In other words, in engineering the end consumer assumes a contract with the engineer for structural stability and soundness, and because of this contract the engineer should approach the structural solution from a place of confidence and certainty. When assuming responsibility for structural decisions in production, a Technical Director is assuming the liability for the end users.

With this definition it is critical to note again the difference between ethics and legal liability. Ethics cannot be enforced in a court. Individual trade organizations may be able to discipline members for ethical violations, but state licensure boards, civil, or criminal courts cannot enforce ethics purely (Iqbal 26). "A code of ethics is not a legal document" (Iqbal 36). This being said, many licensure boards have rules and laws based on ethical standards in practice. Additionally contracts for professional design services can include provisions requiring ethical standards. This is a way of adding consequences for professional liability and potential civil damages for breach of contract to ethical standards.

Liability and ethics for design professionals are based on the principle of a standard duty of care. Iqbal describes this by stating, "it is well-accepted that a design professional's duty is to conform to the reasonable standard of care prevalent in the industry and regulations applicable to that profession" (23). Simply put, this means that engineers should achieve and conform to the same standards of other engineers. Likewise architects should conform to the same standards as other architects. This standard applies to doctors and lawyers as well. State licensing boards base their regulations and rules on the common ground for engineers and architects as established by engineers and architects. In order to achieve the title of "Professional Engineer" (PE) or "Architect" professionals must demonstrate the necessary skills, experience, and training required. All of this is checked through a review and testing process (Iqbal 40 and "Basic Requirements…"). Licensing can be issued to both businesses and individuals, and is regulated carefully. State licensing boards have authority because of state laws that created them. These boards have power to regulate and discipline anyone practicing within the state jurisdiction regardless of membership in professional organizations or license standing. The National Council of Examiners for Engineering and Surveying (NCEES) unifies state licensing (Iqbal 41). Liability in design is dictated by the state licensing boards. In addition, these boards and state laws set requirements for the utilization of design professionals on projects.

Civil and criminal courts can become involved in the proceedings of the state licensing boards. While the licensing board has jurisdiction over the granting and repeal of licenses, civil or criminal courts can issue punishment for certain violations brought before the state boards. Negligence and gross negligence are the two charges typically brought before a judge in a courtroom (Iqbal 45). These two charges carry possible jail time and fines in addition to punitive damages.

Negligence in tort, or civil, law is loosely defined as not adhering to the standard of a "reasonable person" in that situation according to Donal Nolan in his article "Varying the Standard of Care in Negligence" from the *Cambridge Law Journal* (652). Vickie Bajtelsmit and Paul D. Thistle define the "reasonable person" standard in their article in *The Journal of Risk and Insurance* as, "the level of care that would be taken by an average reasonable person" (815). The "reasonable person" standard is proven in court through expert testimony. In the case of a design professional's negligence, this would mean analysis of documents, communication, and actions by fellow design professionals.

Gross negligence is generally understood as any willful disregard for the standards of the "reasonable person" standard. The Missouri appellate court defined gross negligence in the case of the Hyatt Regency disaster as, "an act or course of conduct which demonstrates a conscious indifference to a professional duty" (qtd in Iqbal 49). Gross negligence was not proven in a criminal case related to the Hyatt Regency, but it was proven in a civil review case and was grounds for engineering license revocation (Iqbal 48). It is clear that there are potentially severe cases of liability in the work of design professionals.

Applications to Live Entertainment

Live entertainment producers and practitioners are by no means immune from liability and any potential litigation. The very public documentation of recent accidents for *Spiderman: Turn off the Dark* on Broadway illustrate this is true. The question then becomes focused on how practitioners limit their own liability in these circumstances. The simplest way to handle this would be to divert individual liability to insurance, employers, or other organizational locations. Authors Vickie Bajtelsmit and Paul D. Thistle, assert that, "liability insurance protects individuals against the risk of having to pay legal sanctions" (816). This quote illustrates the role of liability insurance, a $39.5 billion for commercial liability premiums business in 2005, in protecting the individual. Unfortunately, this commercial insurance does not make the practitioner completely contractually immune from potential litigation and liability. Artists that produce art installations typically sign contracts with museums that make the artist assume full liability for the structure. In the article "Public Art Liabilities," author Henry Lydiate, points out that, "it is reasonable and sensible for the commission contract to require the artist to give a legal warranty or guarantee of the work's being free from inherent/latent faults/defects for its agreed lifespan" (37). Typically these artists are functioning as contractors and are solely responsible for their creations regardless of venue, but what is to say that a similar precedent cannot be used with contractors involved in live entertainment structural creation? Lydiate further recommends that artists procure their own insurance to mitigate potential losses due to liability (37).

For these reasons, structural design for live entertainment falls into a very unfortunate, "grey area" of liability governance. The critical question is whether the practice of structural design or mechanical design for live entertainment is considered engineering without a license, and therefore governed by a state licensing board, or is the practice non-engineering and up to expert testimony to establish a duty of care. Where does the expert testimony come from, and who is equipped to function as the expert? The outcome could be vastly different if the expert testimony is from a Technical Director rather than a structural engineer. I think that an important first step to mitigate this potentially catastrophic legal "grey area" is to create a unifying professional organization for Technical Directors and develop a clear code of ethics that is taught and certified. The creation of such a formal organization and the code of ethics that should be adopted would provide a level of liability insulation that could be the standard entertainment structural designers are measured against in litigation.

CONCLUSION

Over the course of this chapter I have presented the ethical models of related industries and information about professional liability in structural design all in support of an effort to organize Technical Directors and related occupations to set their own code of ethical practice. I recognize the challenges to this effort and the potential mindset that the lack of organization means that we can continue to operate in a “grey area” free of clear and demonstrated liability, but I think this will lead to a tragic outcome for some in the industry. Now is the time to embrace the opportunity to set professional standards for the industry, if not, standards will be set in a reactionary way after a tragedy. I know that there are many ethical and skilled practitioners in structural design for live entertainment, and I want those people to continue to be able to practice without doubts or fear of the ethical or litigious unknown.

Chapter 5: Conclusion

Over the course of this thesis I have presented an overview of the people, the practice, and the ethical environment of structural and mechanical design for live entertainment scenery. To present this information, I utilized quantitative and qualitative survey results to describe the people engaged in the profession, and used their words to illustrate thoughts about the structural design process. Additionally this information was placed in conversation with literature related to the field. This survey and research study is a step in the process of adding formal oversight to scenic structural and mechanical design.

Chapter Two told the numbers story of the people and companies represented in the survey results. Understanding the audience and members of the scenic structural community is the clear first step to making recommendations to unify the working practices of that community. The diversification of the job description for Technical Directors is part of the allure and interest for the position. Practitioners are always engaged in creative problem solving and exploration. Furthermore, Chapter Two utilized quantitative survey results to provide a cross section of the training, skills, and years of experience of practitioners in the industry. Further, Chapter Two provided demographic information about the companies that employ the scenic structural designers. As demonstrated in the chapter, the title of Technical Director is earned through employment.

Chapter Three described the practice of structural design for live entertainment. Through both quantitative and qualitative survey results, I documented structural design resources, responsibility, and support for design decisions. The process of structural and mechanical design for live entertainment has not been clearly analyzed in practice before this study. It is critical to understand and document the activity happening in the field before recommendations can be made to influence the process.

Armed with the information contained in Chapter Three, myself or other researchers can begin to expand on the "best practices" approach so widely utilized in the industry. Formalizing, documenting, and standardizing the transmission of "best practices" between practitioners will be an important part of my recommendations to the field. Resource collaboration, similar to the documentation in that chapter, is a critical element to the standardization process among practitioners.

Finally, Chapter Four explored the ethical and legal environment that exists for the profession of structural design for live entertainment. Through an analysis of the ethical models of related professions engaged in similar activities, I set the stage for a unified ethical code in entertainment structural design. Because the profession is not made up of certified Architects or Engineers, there is not currently an ethical practice requirement. Each practitioner sets their ethical code for their practice. The lack of unification or standardization means that the ethics map for entertainment structural design is very broad.

Further, Chapter Four explored the legal "grey area" that entertainment structural designers operate inside. Because of the nature and scale of the work being performed, an argument can be made that the practice is actually engineering. In that case there is a requirement to utilize a licensed Professional Engineer to review and stamp all drawings. This is not always the case though. As a "quasi-learned" profession, entertainment structural designers must adhere to a standard duty of care. In the event of a lawsuit, it will be up to the lawyers and the parties involved to decide who gives testimony about that duty of care. A TD compared to other TDs will be a different standard than a TD compared to an Engineer.

RECOMMENDATIONS

In the following section I present ideas about how to utilize the information presented in this thesis to move the field of structural and mechanical design for live entertainment forward. These recommendations have been developed through my research and consultation process with other professionals in architecture, engineering, commercial construction, and live entertainment. I have worked to develop the starting place in this thesis, now the real work of utilizing this research can begin.

Entertainment Structural and Mechanical Design Collective

I have presented examples of ethical standards created, applied, and enforced through professional organizations in related fields, and I have offered information about the potentially costly liability risks associated with the practice of structural and mechanical design. Technical Directors should formally organize into a collective that stipulates a unified code of ethics. Ethical practice is the one constant that can exist across all levels of live entertainment production. Technical standards for live entertainment are currently being set by several organizations. A unified ethical standard should be the entry point to the application of the technical standards. Technical standards require a proper understanding of factors for application, and a unified ethical code should guide the understanding of those factors. A certification for basic knowledge and skills, including a clear understanding of ethics and resources should be developed for early career Technical Direction candidates. There are many certification models that can be analyzed for a basis, but that is outside the scope of this thesis. The first step for this process is organization and drafting of ethical standards.

As mentioned previously, these ethical standards should be keyed with Cicero's Creed to "do no harm." Additionally, these ethical standards should dictate formal regulations for professional engineering consultation. It is no longer acceptable to operate in a best guess and "best practices" world. The scope of live entertainment scenic production has grown extensively over the course of my own career, and I believe that trend will continue as live entertainment competes with other forms of entertainment to attract audiences. The challenges that will be faced by the future structural designer for live entertainment need to be acknowledged now by the best minds in the industry, and those industry professionals need to set in place a model to protect the professional practice.

Whatever this future collective ends up becoming, it should be based on the AIA and ASCE model, which feature experienced professional practitioners setting the model standards for their own practice. These models are proven successful organizations. Practitioners wishing to pursue a career in structural design and construction management for live entertainment should be influenced by the collective to achieve a higher level of professionalism in practice. Most importantly, this collective should represent the diverse operations and people presented in Chapter Two, and this collective should get to work formally drafting the ethical standards for practice. The variations in the practice and work of different Technical Directors throughout the field is one of the most appealing aspects of the profession, and that aspect should be clearly represented in any professional organization.

Entertainment Engineering

I do not think that training a field of entertainment engineers is the best solution for the industry. In consultation with colleagues and professors in engineering, this does not seem like a feasible or necessary route because of the relative specialization requirement in entertainment compared with the amount of jobs. Utilizing subcontracted mechanical and structural engineering firms to either develop or simply review and approve structural design would shift some of the liability away from the practitioners in live entertainment. Further, the amount of potential jobs and need for an entertainment specific engineer would be limited. Especially when considering that the training necessary to be competent in both engineering and live entertainment production problem solving would be extensive. The job of the entertainment structural designer would be to illustrate and collaborate on creative design solutions that serve the aesthetic vision of the production, and the engineer could then consult and approve designs that are safe and secure.

There are a few engineering firms that currently have entertainment specific divisions, and some of the larger scenic and automation shops employ staff engineers. This is not a practical model for the diverse amount of live entertainment operations in the United States. A more practical model would be ethical practitioners that have some training in the work and language of engineering and construction management that can then define problems from scenic designs for review by third-party engineers. These engineers would then submit competitive bids on the structural work. This model would insure clear contractual obligations and liability assignment in addition to providing the "freedom" for TDs to ask for help. Further this model could facilitate development of an entertainment building code.

Entertainment Unified Building Code

Creation of a unified, entertainment-focused building code would move the conversation about informal “best practices” in structured directions. A unified building code would mean that there are standards that need to be met. This would help support professional practice in two key ways.

First, with a unified building code structural designers for live entertainment would have a basic resource that dictates key elements of design. I understand that every scenic design is different and the needs of production are always different, but there are common elements in almost every production. A compiled source of technical documentation and construction standards would insure key structural design consistencies between production operations. In this case, standard structural design and construction criteria could be met to insure a base level of structural stability in practice. Further, this code would be the basic jumping off point for structure and mechanics that do not adhere strictly to standards in the code. Scenic structural designers would be able to consult the code to know when and how to employ an engineer for design, approval, or both.

The second key benefit of a unified scenic building code would be the peace of mind that it would provide practitioners in the field of scenic structural design. No longer would structural designers for scenery have to hope that their designs were adequate or fully analyzed in-house. They would have a resource with basic standards and information to work with. Additionally, these structural designers would have a place to fall back in the event of an accident with structure or mechanics. The TD would have documentation that meets a code set by their industry peers and through consultation with engineers. The practitioner in question could be measured by the standard duty of care of their profession, rather than a "grey area" of duty of care.

OUTCOMES

The portal described at the beginning of this thesis safely made it through multiple installations, performances, and strikes. The areas of doubt that I experienced never materialized into anything more than personal worries. The structure was solid and lasted without issue, but even now with the classes that I have taken behind me, I am left with new doubts. Structurally the portal was sound enough for the life it lived, but was it designed appropriately in the eyes of an engineer? I had hoped after my course work at UT Austin to be able to approach these situations with complete confidence in my ability to design and analyze structures like that portal. I am now armed with a few more tools and the language to be able to talk about the analysis and design of structures, but I also have developed a new respect and appreciation for the specialization and ethics of engineering in practice.

I can feel confident in my structural design, but I have nothing to back up my confidence; I am neither an architect nor an engineer. In my practice now I am less concerned with the "why" questions I worried about earlier in my career. I know the resources to go to be able to answer the "why" questions and dispel any concerns I may have, but I am now even more concerned with the "what if" questions. What if that structure buckled when being installed or removed? What if a potential wind load was to affect the structure at a performance in the future? What if the structure became compromised in some way and fell during a performance? Who would be responsible in these situations? Even if I am not held solely responsible, what do I hold myself responsible for? These questions do not have as clear or simple answers as the "why" questions. These are the questions that I think need to be addressed in my own practice, and I assume in the practice of many of my colleagues. These all lead to the most important "what if" question in my mind. What if something catastrophic happens with my structural or mechanical design, and I could have done something to prevent it from happening? Regardless of any formal standard ever being created, that final question would haunt me and any other TD for which the standard duty of care for TDs would apply.

Appendix A: Survey

Consent to Participate in Internet Research

Identification of Investigator and Purpose of Study

You are invited to participate in a research study, entitled **"Creating Ethical Construction Standards for Entertainment Scenery."** The study is being conducted by **David Vieira (davevieira@utexas.edu) in the Department of Theatre and Dance** of The University of Texas at Austin, 300 E. 23rd Street Stop D3900, Austin, TX 78712-0362**, 512-471-5793.**

The purpose of this research study is to **examine structural and mechanical design standards for scenery and automation in live entertainment**. Your participation in the study will contribute to a better understanding of **professional practice.** You are free to contact the investigator at the above address and email to discuss the study. You must be at least 18 years old to participate.

If you agree to participate:

· The **online survey** will take approximately **20 minutes** of your time.

· You will complete a survey about scenic or automation construction practices and resources**.**

· You **will not** be compensated.

Risks/Benefits/Confidentiality of Data

The potential risk to the participants is **no greater than everyday life.** There will be no costs for participating. Participants will potentially benefit from being required to think critically about their own professional practice. The potential benefits for participants will vary from none to a small amount. If you provide an email address it **will** be kept during the data collection phase, separate from your survey responses, **for tracking purposes only**. A limited number of research team members will have access to the data during data collection. **After collection, identifying information will be stripped from the final dataset.** All data will be stored on a password protected website, and any identifying information will be stored on an encrypted spreadsheet.

Participation or Withdrawal

Your participation in this study is voluntary. You may decline to answer any question and you have the right to withdraw from participation at any time. Withdrawal will not affect your relationship with The University of Texas in anyway. If you do not want to participate either simply stop participating or close the browser window. If you do not want to receive any more reminders, you may email **davevieira@utexas.edu**.

Contacts

If you have any questions about the study or need to update your email address contact the researcher **David Vieira** at **davevieira@utexas.edu.** This study has been processed by the Office of Research Support and the study number is **[2013-05-0051].**

Questions about your rights as a research participant.

If you have questions about your rights or are dissatisfied at any time with any part of this study, you can contact, anonymously if you wish, the Office of Research Support by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Thanks!

By checking "I agree" you agree to participate in the following survey.

□ I agree

Q1- How many years have you worked as a professional in scenic construction or automation for live entertainment?

□ 0-2 Years (1)
□ 2-5 Years (2)
□ 5-10 Years (3)
□ 10-20 Years (4)
□ 20+ Years (5)

Q2- What level of education have you completed?

□ HS Diploma (1)
□ Some college (2)
□ Associates Degree (3)
□ Bachelor Degree (4)
□ Some graduate school (5)
□ Masters Degree or beyond (6)

Q3- If you have a degree or degrees, what are they?

Q4- What are your current job responsibilities, including any responsibilities not related to scenic structure? (Check all that apply)

□ Development of structural design for productions (1)
□ Development of drafting for construction (2)
□ Direct supervision of scenic construction (3)
□ Fabrication of automation elements (4)
□ Budget management (5)
□ Schedule management (6)
□ Construction of scenery (7)
□ Painting or finish of scenery (8)
□ Construction of props (9)
□ Advising Students (10)
□ Other (please list) (11) ____________________
□ Managing Venue (12)
□ Venue Maintenance (13)

Q5- What type of live entertainment organization do you work for?

□ Professional Regional Theatre (1)
□ Community Theatre (2)
□ Educational Theatre (High School or younger) (3)
□ Educational Theatre (University or College) (4)
□ Opera House (5)
□ Dance Company (6)
□ Broadway or West End (7)
□ Las Vegas or Cirque du Soleil shows (8)
□ Commercial shop (9)
□ Other (please list) (10) ____________________

Q6- (Optional) What company do you work for?

Q7- What is an average budget per production for scenery materials including any automation or mechanical components? (In dollars)

- □ 0-500 (1)
- □ 500-1,000 (2)
- □ 1,000-2,500 (3)
- □ 2,500-5,000 (4)
- □ 5,000-10,000 (5)
- □ 10,000-20,000 (6)
- □ 20,000-40,000 (7)
- □ 40,000-75,000 (8)
- □ 75,000+ (9)

Q8- On average, how many new productions does your company create annually?

- □ 1-2 (1)
- □ 2-5 (2)
- □ 5-10 (3)
- □ 10-20 (4)
- □ 20+ (5)

Q9- From acceptance of final design to 1st preview, how long is a typical structural design and construction period for your company?

- □ 1- 4 weeks (1)
- □ 4- 8 weeks (2)
- □ 2- 4 months (3)
- □ 4- 6 months (4)
- □ 6 months- 1 year (5)
- □ 1- 2 years (6)
- □ 2+ years (7)

Q10- On average, how long is the life span of a set constructed by your company from construction completion to strike?

- □ Less than 1 week (1)
- □ 1-3 weeks (2)
- □ 3-6 weeks (3)
- □ 6 weeks- 3 months (4)
- □ 3-6 months (5)
- □ 6 months- 1 year (6)
- □ 1 year+ (7)

Q11- Where are sets for your company constructed?

□ In-house scene shop (1)
□ External or shared scene shop (2)
□ Contracted commercial scene shop (3)
□ In the venue where the performance will take place (4)
□ Commercial construction company (5)
□ Other (please explain) (6) ____________________

Q12- How often are the following materials utilized in scenic construction or automation fabrication at your company?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Very Often (6)
Dimensional Lumber (1x4, 2x4, etc.) (1)	❍	❍	❍	❍	❍
Engineered wood products (Plywood, OSB, MDF, etc.) (2)	❍	❍	❍	❍	❍
Pre-engineered wood trusses (3)	❍	❍	❍	❍	❍
Steel tubing or pipe (4)	❍	❍	❍	❍	❍
Heavy structural steel (I-beam, Channel, etc.) (5)	❍	❍	❍	❍	❍
White bead foam (EPS) (6)	❍	❍	❍	❍	❍
Extruded Polystyrene Foam (XPS or Blue Foam) (7)	❍	❍	❍	❍	❍
Ultra High Molecular Weight Plastic (UHMW) (8)	❍	❍	❍	❍	❍
Polycarbonate (lexan, etc.)	❍	❍	❍	❍	❍

Aluminum (10)	❍	❍	❍	❍	❍
Steel wire rope (11)	❍	❍	❍	❍	❍
Fibrous or synthetic rope (12)	❍	❍	❍	❍	❍

Q13- Are there any complicating conditions that scenic or automation elements at your company have to endure? (Check any that apply)

□ Transportation by car or truck to performance venue from construction venue (1)
□ Running in a repertory situation (2)
□ Construction, storage, or performance is outdoors (3)
□ Long-term storage (4)
□ Limitations due to size of doorways or other barriers between site of construction and
□ performance venue (5)
□ Other (please list) (6) ____________________

Q14- Does your company require any of the following certifications of any employees?

□ ETCP Rigging Certification (1)
□ ETCP Electrical Certification (2)
□ AWS Welding Certification (3)
□ Fluid Power Society Certification (4)
□ Other (please specify) (5) ____________________
□ none of these (6)

Q15- Does your company provide any incentives for employees to have any of the following certifications?

□ ETCP Rigging Certification (1)
□ ETCP Electrical Certification (2)
□ AWS Welding Certification (3)
□ Fluid Power Society Certification (4)
□ Other (please specify) (5) ____________________
□ none of these (6)

Q16- At your company, who is responsible for making structural or mechanical design decisions?

Q17- How often do you use the following resources when creating structural or mechanical design?

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Very Often (6)	N/A (7)
The Backstage Handbook, Carter (1)	❍	❍	❍	❍	❍	❍
Pocket Ref, Glover (2)	❍	❍	❍	❍	❍	❍
Structural Design for the Stage, Holden (3)	❍	❍	❍	❍	❍	❍
Mechanical Design for the Stage, Hendrickson (4)	❍	❍	❍	❍	❍	❍
Technical Design Solutions for the Theatre, Sammler (5)	❍	❍	❍	❍	❍	❍
Scene Technology, Arnold (6)	❍	❍	❍	❍	❍	❍
Control Systems for Live Entertainment, Huntington (7)	❍	❍	❍	❍	❍	❍
Stagecraft Fundamentals, Carver (8)	❍	❍	❍	❍	❍	❍
Stock Scenery Construction: A Handbook, Raoul (9)	❍	❍	❍	❍	❍	❍
Statics: Engineering Mechanics, Fowler (10)	❍	❍	❍	❍	❍	❍
The Architects Studio	❍	❍	❍	❍	❍	❍

Companion, Allen (11)						
Electromechanics, Harter (12)	❍	❍	❍	❍	❍	❍
McMaster Carr Catalog (13)	❍	❍	❍	❍	❍	❍
Other Manufacturer Catalog (14)	❍	❍	❍	❍	❍	❍
Website (please list) (15)	❍	❍	❍	❍	❍	❍
Other (16)	❍	❍	❍	❍	❍	❍

Q18- Are there any other resources that you use when creating structural or mechanical design

Q19- What, if any, structural design supporting paperwork do you produce?

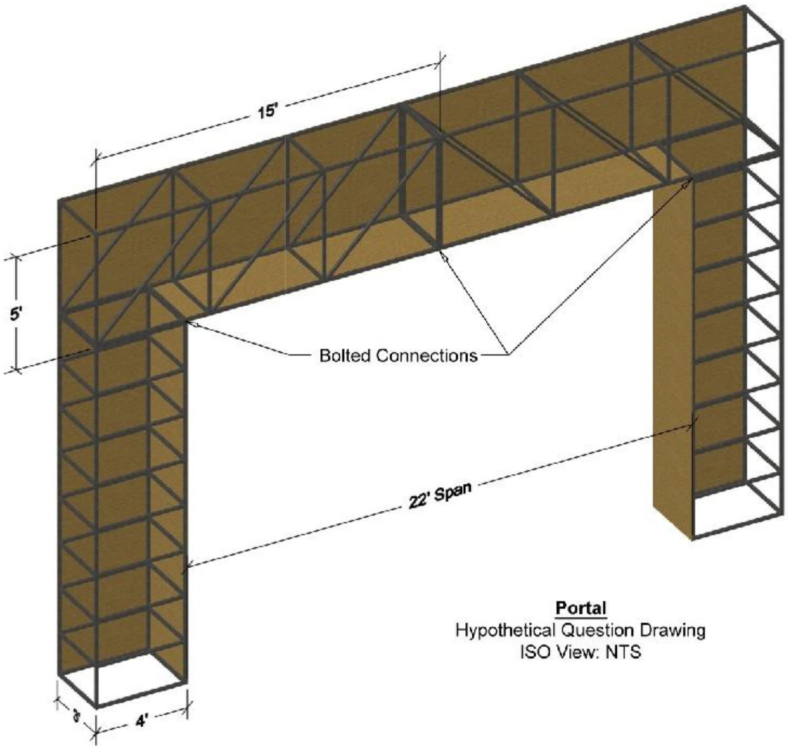
Q20- How often do you consult an engineer for scenic or mechanical elements to be constructed by your company?

- □ Never (1)
- □ Rarely (2)
- □ Sometimes (3)
- □ Most of the Time (4)
- □ Always (5)

Q21- Other than Safety, which one of these factors influences your structural design decision making the most?

- □ Money (1)
- □ Schedule constraints (2)
- □ Availability of materials or resources (3)
- □ Technical expertise (4)
- □ Other (5) ____________________

Structural Design Hypothetical Situation



Q22- In the service of a show, Mike was asked to draft the structure for a portal (shown above). This portal consisted of two towers framed with steel and a header truss framed with steel. The towers had a footprint of 3'-0"x 4'-0" and the top of the tower was at +16'-0". The header had cross sectional dimensions of 5'-0" tall x 3'-0" deep and was made in two 15'-0" sections for a total length of 30'-0". The towers were at opposite ends of the header which created a span of 22'-0". The header was covered on the bottom and the front with ¼" lauan skin and black velour.

In the process of creating the drawings for this piece, Mike became very interested in the complicating factors around this structure. It would need to be assembled and disassembled as part of the run of the season. Also, the unit would be exposed to the elements, including wind and rain, as part of its running and storage life. Further, this piece would need to be packed into a truck at the end of the season for long-term storage or potential travel to a different theatre.

Mike asked a few questions of his colleagues about the structural needs of the piece, and about other structures that had been created at the theatre that served a similar structural purpose. With advice about framing material and basic statics analysis of similar trusses, Mike drafted the structural design for the towers and the header. The towers and header were constructed and installed, and the show ran without any problems at all. However, Mike was unsure he had a complete understanding of the forces involved in the problem.

Do you feel like this is a realistic situation?

□ Yes (1)
□ No (2)

Q23- If "Yes", why? OR If "No", why not?

Q24- As a professional, what advice would you have given Mike to help him feel more comfortable about the structure of the portal?

Q25- Would you be willing to be contacted for a follow-up interview based on your survey responses?

□ Yes (Please provide preferred contact email address. This information is stored separately from survey responses.) (1) ____________________
□ No (2)

Appendix B- Other Resources and Complete Hypothetical Situation Survey Answers

18. Are there any other resources that you use when creating structural or mechanical design?

Text Response
I often need to refer to Rigging texts in conjunction with structural design. The two texts I most often go to are "The Stage Rigging Handbook" by Jay Glerum, and "Entertainment Rigging" by Harry Donovan.
no. if it is a major item i might hire a certified engineer.
outsourcing of engineering calculations
Previous Experience
Steel Construction Manual, Textbook for Engineering Physics I (At UT Austin), iTunes U (Mechanics I by the Saylor Foundation)
Thomas Truss reference packet, Jay O' Glerum's Rigging Handbook
Diverse in house design team.
peers/colleagues; Yale tech briefs; some USITT papers collected over the years.
N/A
Steel Construction Manual, AISC; Machinery's Handbook, Industrial Press; Mechanical Engineering Design, Shigley and Mischke; Aluminum Design Manual, Aluminum Association; Entertainment Rigging, Donovan; Welding Codes D1.1 - D1.2 - D1.3, AWS; AISC 7-05 Minimum Design Loads . . .; International Building Code, NYC Building Code. Roarks Formulas, Many others.
Copy past practice Rigging materials from mfg.
no

Manufacturer spec's most often.
People I've worked with in the past
Cut sheets from manufacturers
Creative Conners systems - website and their technical support
Modern Steel Construction, AISC, Donovan's Rigging Guides, Rhino, Revit,
no
Self Generated Excel Spreadsheet, Beam Buddy iOS App.
None
Stage Rigging. Glerum
Holden's structures book is great for case formula. The steel reinforcement handbook is solid for my use. The Glerum rigging book is also a great resource
Machinery's Handbook, Technical Drawing 8th ed (Giesecke et al)
none
Other professionals
Lightning reference handbook
OSHA, Client specifications and standards, Local AHJ, NFPA
Refer to other master in the business
n/a
Mechanics of Materials, Beer & Johnson Vector Mechanics for Engineers, Beer & Johnson
Thomas register online Nook linear bearings Sew eurodrive Stock drive products
Grandfathered spreadsheets and data
Technical Director and Master Carpenter
too many to list; from vendors to part manufacturers to outside machine shops, waterjet,

lots of waterjet, colleagues many many colleagues
no
Other employees with relevant experience who actually will be the end user. This allows for a much more user friendly design.
just the resources that TAIT can provide to us
Grainger Catalog

Question 22: Mike asked a few questions of his colleagues about the structural needs of the piece, and about other structures that had been created at the theatre that served a similar structural purpose. With advice about framing material and basic statics analysis of similar trusses, Mike drafted the structural design for the towers and the header. The towers and header were constructed and installed, and the show ran without any problems at all. However, Mike was unsure he had a complete understanding of the forces involved in the problem.

Do you feel like this is a realistic situation?

If yes, why OR if no, why not?

1. In my past, I would have done exactly what Mike did. Now, I would at least consult with an engineer that deals with exterior structures and possibly pay to have the drawings reviewed and stamped approved. The other option would be to go with manufactured truss designed for this type of use rather than making it in house. I have learned that exterior forces can be incredibly significant and are beyond my knowledge, and with an audience involved, it isn't worth the risk.

2. i can see something like this built, i did some thing like this for a show that was installed in Sundance theater festival.

3. Because so much process and information is passed on empirically in this business, I find this to be very realistic. "When in doubt, build it stout" was a mantra I learned very early on in scenery construciton, and until one comes across a situation where the weight of "stout" becomes part of the "doubt" and one is responsible for the outcome, there is not much impetus to learn the structural math to calculate forces and stresses.

4. It is almost impossible to be 100% certain in these situations. Traditionally, this issue is handled by slightly over-designing a piece to account for unforeseen factors, which was likely the advice Mike was given. There comes a point in

the design process where things must move forward as best they can, even if the problem is not fully fleshed-out.

5. Mike was confident in the decisions and calculations he made, but continues to analyze the forces involved because he is probably not a licensed structural engineer and most likely wears many "hats" in his position. In my experience, it's not doubting your understanding of the forces you calculated but rather the forces you didn't plan on.

6. I feel that since our industry's building practices was derived from the principle of "best practices", we are often apt to instill this in structural design. This is how it has worked in the past, so we should be safe to do it again. I do not believe that either Mike or his colleagues did calculations to asses fatigue of the steel due to the repertory situation or the rain, or how much of a wind load the piece could withstand. As such, I do not believe they had a complete understanding of the forces surrounding the piece.

7. It is more common in smaller shops & regional theatres for newer A/TD's to "go with their gut" than to buckle down and do true engineering calcs. However, with a breadth of knowledge that exists in our industry the usual questions "hey...do you think this is a crazy idea?" among collegues is enough to create an environment where an idea can be nurtured safely and efficiently.

8. I often see ATD, TD types out of their depth in structural design situations in the NFP/academic world. It is my experience that it is infrequent that an engineered, or even analyzed approach is taken until you hit the for-profit shop world where liability and major financial losses are of paramount concern.

9. This structure is simple enough to design using static calculations and rules of thumb.

10. I, and I think most, technical directors are not trained as mechanical engineers. we rely on past practice, common sense and some mechanical mathematics learned and/or acquired. Being conscientious, we know that we don't know everything we need to know and are a bit unsure that we have a total grasp of the situation.

11. But I'm not sure why you are asking.

12. It sounds like a typical real-world way that fairly simple scenery is "engineered."

13. Many individuals in Mike's position learn from a "hands-on" approach and gain knowledge through experience and trial and error. They never really gain the academic knowledge of structural design.

14. I feel that often times young professionals are thrown into high libality situations (especially in summer stock) without knowing the full risks. Also, depending on the level of education, there may not be enough education for him to make accurate and informaed analysis of the natural elements and stresses to which the piece may be subjected.

15. People are asked to do things beyond their expertise all the time and they often do it.

16. We often build based on construction experience rather than engineering knowledge. It seems it is rare for Technical Theatre managers to have had any formal engineering training. I typically try to compensate by over-building to some degree.

17. This might be real at a small regional theatre, but not at a professional shop. If Mike does not understand what he is designing he has the duty to let his boss

know that he is out of his depth and should seek professional help. If the situation is one or two guys sitting around guessing at what the best solutions is, they should stop before they hurt someone.

18. Theaters in general often produce scenic structures based on the experience and opinions of senior staff whom generally have no engineering background.

19. It makes perfect sense for someone in scenic construction to be presented with a problem they haven't run into before. It is also common for someone to engineer something but not completely understand it because they had a short time to build it.

20. I would say yes with some caveats. The whole structure should be braced for the wind and or have cuts to allow air to pass through. There need to be specifics on number, grade and placement of bolts.The attachment method of the luan also needs to be included as well as backpainting.

21. Unfortunately, I don't really feel like I can answer this question without more information. We need some background on Ballasts/counterweight, guy wires, assembly method, what the surroundings are like, etc. How is it attached to the floor? What wall thickness is it build from? What is the self-weight of the header? Will the wood surfaces get rained on directly? I don't have experience building for outdoors, so I'd be worried about wind in a very big way. If this were freestanding indoors, I'd say that 3' of US-DS depth is too narrow, unless it has bracing, or a good attachment to the floor...

22. Typical of the situations I see that there is short term needs to design and construct something in time for the current production without considering other ways of doing things based on a complete understanding of how else the item may be built better. In this case, I think full drawings and even asking the questions was more than happens all too often.

23. In the theatre, we often build by the motto "When in doubt, build it stout, out of things you know about." We often overbuild things just to be safe since "more" is often seen as better when it comes to structures. Also, many people have not had proper structural engineering instruction. The things we build are not subject to things like wind/rain/snow loading if we are indoors, so the rigorous formulas and tables that conventional structural engineers use don't apply or aren't necessary. I think, many TDs also go with their "gut feeling" and past experience when doing technical design more often than not.

24. seems a standard outdoor false proscenium

25. Answer depends on size/weight of components. This structure is quite possible, easily so, but information is incomplete. You basically have quite deep trusses stabilized laterally in an adequate manner. Why is the relatively heavy luaun required to back the relatively heavy velour? What grade bolts connect the units? While this it is possible to imagine a structure that would support the load, what about during erection? Apparently, the venue is outdoors. Any structure above for chain motors, etc? If one reads Modern Steel Construction issues, one might see that the real issue is not in the staic but in the assembly, before all elements are added in support. This is an unrealistic scenario. It is rather obvious that, while the investigator might have had some training in structural design for the stage, that training was sadly incomplete.

26. No, without doing any calculations the design is structurally flawed and does not take into account wind and rain stresses affecting structure.

27. This is a fairly typical case scenario. We are often requested to build a false portal.

28. Many times people are limited by time and just simply ask others who have been around, "What have you done in the past?" While this is a way to prevent from having to reinvent the wheel, just because something has been done before, doesn't mean it was safe. Too often, this process is used.

29. The loading condition (including the span) is not very large given the ovarall dimensions of the scenery (in particular the depth of the header).

30. Often times people are asked to draft something without a thurough understanding of how the forces work on the structure. Even though the piece may never have a problem, it is possible that without the proper analysis of materials, the piece could weaken overtime and become a danger to actors or talent, as well as technicians who handle the piece.

31. 14 feet of unsupported scenery. Granted that you are splitting the weight on to uprights the thought still comes to mind. Whats going to keep the deflection out of that header and how could i make this actor safe.

32. Firstly, that's not an Isometric view. Oblique, maybe. In my experience, a structure this simple isn't going to be MIke's main concern - he'll have bigger things to worry about. The only part of this unit that isn't going to be intuitive to anyone qualified to draft it is the wind loading situation. Rather than delve into an engineering solution (provide a big enough weight of floor connection at the bottom to make it stable - now you have to figure out how big/how heavy is acceptable) he's much more likely to just tie the top to architecture or adjacent units that brace it US-DS. Another spot he could conceivably be worried are the free span - but 5' of depth is plenty. Even 1x1x16ga tube would probably hold that, but 1.5x.15.16ga - no question.) THe final not super-obvious consideration is the bolted connection in the middle of the span. Any technical designer I

know is likely to just beef up the number of bolts (maybe even members) in that joint, until they are confident it's way more than enough (because that's a lot faster than trying to do the math and worrying if the math was right.) Since there is very good access for making those bolted connections, there is no need to skimp. If he's worried about the stiffness of the unit in terms of the strength of the space frames, he's likely to resolve those worries when he sees the finished unit and can feel how rigid it is ass it gets moved around and installed. Basically, this unit is too simple and too routine to have much engineering to worry about.

33. Consistently in our industry folks are asked to create objects which may be outside of their comfort zone. That comfort zone may be of time, materials, structural design, building methods etc.

34. It is typical for people to trust that their co workers are right, and move on due to time than taking the time to learn theory.

35. This sort of scenery is used all the time in outdoor theater.

36. People put up a lot of "portals" so I could easily see this as a challenge he would face.

37. The only problems I had were with the covering materials. Lauan and velour have never been great outdoor choices in my past. See that they never last in even I high humidity area. Other then that it looks like a great frame for reparative use.

38. sounds like he had some questions such as, was lauan the velour the best option for something outside exposed to elements for an entire season?

39. I like how header rests on legs. Would like to know how steel size and guage was determined for each element

40. What type of materials were being used, or applied? Seismic activity, wind load considerations, etc....

41. Steel for this structure would be way too heavy and there is products readily available in the market to create that exact structure which is pre engineered.

42. Sadly, I think that this happens all of the time. Structural designs are created very often - thankfully less nowadays - without any real structural design. I feel that this is a realistic situation as I have seen it happen several times. I don't, however, believe that this is an acceptable way to do it. I hope that's what you were asking...

43. Mike sounds like someone who works at the regional theatre level. It seems very plausible that someone there could create a piece of scenery like this based on prior experiences (his own, and those of his co-workers) without having done the full structural analysis required to analyze all of the forces. Also, the general dimensions of the piece seem plausible for the situation described and they also describe a piece of scenery likely to be structurally stable.

44. Absolutely. From experience I have seen this happen after having a structure go through an FEA. The FEA revealed areas that were over stressed, but not dangerous. But through some simple design changes, those stresses could be removed.

45. Most scenery is built by instinct

46. This seems like a realistic situation for a large outdoor repertory theatre. I would be concerned about the header being built in two pieces though, especially with the repeated assembly and disassembly throughout the season.

47. Seems that wind was not considered i would expect the truss design to have chords changing directions rather than being parallel Missing knowledge of the rigging

48. Yes this seems like it would be a realistic situation and solution, but no it does not seem to be the best solution. Also is there any use of guying points to counteract wind load on the installed portal? Luan in an outdoor situation is not going to hold up well no matter how well sealed and will fail before long. As well, steel will rust. A better solution would be Aluminum with only a fabric cover with a means to allow stretching or easy removal/replacement of the cover. The legs of the portal should have diagonal braces as well.

49. This sort of thing happens all the time, all over the industry. Someone with little or no structural design experience is asked to design or build something beyond their expertise, then they must cross their fingers that it's welded well enough, or at least overbuilt enough to handle the stresses.

50. i don't think it's uncommon for a drafter to be asked to make decisions for elements like this. I think Mike intended the best for this piece, for this show and for the longevity of the piece, but I question if mike has the expertise to make final decisions for construction based on his uncertainty of understanding of the forces involved. Simply put, this is both a simple piece that many people build every year, but it has the potential to be a very serious danger if the risk is not properly assessed and the forces are not understood.

Question 24: As a professional, what advice would you have given Mike to help him feel more comfortable about the structure of the portal?

1. i build a portal like this for the musical […]. it was a outdoor performance space on the ski slopes. i built it out of 1.5" alum. sq. tube. and added guy wires to make sure it did not blow over.

2. For this relatively simple header truss I think we might just sit down with Holden/Sammler and figure out the stresses.

3. Work to recognize when a concern is based on fact or feeling; if there is some information that you do not have, but need to make a circumspect decision, by all means find it or scrap the idea if you cannot, but an amorphous, niggling doubt should not haunt you. Seek advice from people who have done it before, see how they succeeded (or failed) and use that experience to inform your decisions.

4. I would consult a structural engineer for specific projects that are more complicated or that include intricate design constraints.

5. The only person technically "qualified" to asses the structure of the portal would be a licensed engineer. Consider what they do for a moment. They asses buildings, houses, bridges, etc., making sure it can last for 20+ years through disastrous (with a distinction to be made as disastrous being earthquake, tornado, etc.) weather, and including propogation of uncertainties with every calculation they make. In this situation, you are calculating a 22' span constructed with (in the scope of an engineers perspective) lightweight yet resilient material. The scenery realistically needs to only be able to support mild wind and rain (any weather more severe and there would be an evacuation of the audience and additional personnel, and if it breaks, it breaks with no one around it). As for the repertory abuse, the piece would see abuse in the amount of a few hundred times at worst. Consider how many times an engineer would calculate stress, for example

the shocks on your car. They probably saw more abuse on the way into work than the scenery will every see. Also consider the inspiration for your structural design, trusses. I have seen trusses with a much smaller section modulus that have been rated for this span in addition to being rated for more weight. With all this said, your "best practices" method is perfectly adequate for scenery built on such a small scale.

6. Consult established reference materials/ piers in the industry.

7. Hire a consulting engineer, a staff structural designer, or pursue structural design training to better make decisions as to what is comfortably within your depth. If you do not know, don't do it. Advanced modeling and FEA software in trained and responsible hands can often help draw clear and clean lines in this regard. As scenery construction becomes increasingly complex it is necessary that we broaden the scope of our industry's expertise. Many scenic solutions are now beyond the depth of the standard curriculum TD type training programs. We must otherwise equip ourselves to make responsible decisions.

8. It is healthy to feel unsure. So I think he has the right attitude. That is what will lead to more training and more experience

9. refer him to someone with the mechanical design experience; suggest some safety methods (picking to grid or higher structure if possible or stronger anchor methods).

10. He should do a systematic review of the required load cases. For outdoor scenery wind is likely to control. You did not mention any connection analysis, either between the parts of the portal or between the portal an the theater, again these are likely to be areas of concern. Flame Retardancy and corrosion control have structural impact, how were they integrated.

11. I'd want to know alot more about the weather issues and what facility this unit is planned for before answering that question.

12. I would advise looking further into the weather resistant aspects of the unit. Proper fastening and adhesives could be of significant importance for the luaun,

13. Study Structural Design for the Stage and consult with industry colleages.

14. I would advise consulting the management of the company and push for their to be outside analysis of a structure that he were not comfortable. However, this is very much a catch-22 in our industry. This often makes producers and managers respond "why did we hire this guy." There must be a mutual understanding of what is and is not expected as far as engineering.

15. One obvious point is with regards to wind and rain. Once those factors are involved I would have reccommended the designs be signed off on by a structural engineer. I would also be concerned that the loads are being transfered correctly from the center of the span to the towers. The diagonals should be check for the proper orientation.

16. If he was uncomfortable spec-ing the portal himself after consulting with fellow professionals, he should have consulted an engineer.

17. Get the right education to do what he is doing.

18. If in doubt consult a professional engineer. It is cheaper to have a structure analyzed than to pay for an accident.

19. He had gone to all the correct sources for help

20. In addition to looking deeper into the design, Mike needs to have a high wind plan and a specific wind speed that will ingage the high wind plan. Also Mike needs to look at weight of the velour when wet.

21. I think the most important piece of advice for Mike is to not build anything that he doesn't feel 100% confident in. Seek out people with more experience to help evaluate your designs. Hire professional engineering support when needed. Work as a team, not alone. The head carpenter, riggers and technical department all need to be comfortable with everything, or it doesn't happen.

22. Consider how it will be anchored and used. Seek out drawings from other theatres in similar situations to understand how and what they did to build this peice.

23. I would give him some books on structures, and encouraged him to do some more research on truss loading.

24. Take an adequate course in Structural Design for the Stage from a competent practitioner. Otherwise, contact a qualified engineer. Remember the staging that, improperly installed although to supplier's specs, killed so many recently? If you don't know, don't go.

25. My advice would be that Mike not design the portal as it reads that he is not prepared to do so.

26. If he doesn't have the knowledge or experience to do a structural analysis, I would recommend that he seek out an structural engineer to ensure the framing material, truss design and bolt connections meet the loading conditions. Was the welding done by a qualified welder?

27. I would have pulled out my "Structural Design for the Stage" book and told him, "Lets sit down and do the mat to make sure what you have come up with is safe." Also, make sure you are using rated hardware and "C-H-I-N-A" is not a rating.

28. My biggest concern would be how the pieces are handled during the load-in, specifically the location of the pick points for raising the header into position. I would

also encourage Mike to do a careful analysis of the wieght of each of the pieces before attempting to load-in the portal.

29. Look up the structural tolerances of the materials that are used to build the unit, and then assess the forces that will be exterted on the piece. If concerns still exist, respectfully take your findings to the technical director and explain your feelings.

30. No matter the scope of work or size of a set piece, I'm always going to take extra precautions when it comes to over head structures. Weather it be the use of thicker gauge steel, calling out the welds on each member or bolt size(always rated hardware). Make sure you are creating scenery with materials that would be allowable for that particular circumstance.. And if you don't know how to, do the research or reach out to someone who may know. Also think about where the set piece would be on stage. What other scenery interacts with it, does it move, could it be mounted to the deck or the architecture or the room? These question will help guide you in making materials decisions for any piece if scenery...

31. Build it. Try to push it over (parallelogram it.) Still worried? If you are worried, you could always add diagonals to the columns. Don't forget to backpaint because steel rusts in the rain. The first way it fails isn't going to be something your structures book covers - as the humidity changes, the lauan is going to start coming off of the steel, because the luaun expands significantly with humidity and steel keeps its same shape pretty darn consistently.

32. Think through the processes this scenic element will be undergoing, is there a plan for all of them? How will the header get up? Are rig points possible? Are the components of this unit easily lifted by 2 or by 10? Is lauan resilient enough for this task? How windy is it in this area, what is the calculated wind force? What are the risks

if this fails, how might it fail? If you are doing something far outside of your comfort zone and experience seek input from those who could give appropriate input.

33. There are multiple points of failure vs just two or three. If something were to happen it is designed in such a way that the system could support itself for a temporary period.

34. If you're worried about wind can you attach cable in multiple directions or use sistering of other materials to add rigidity.

35. When in doubt build it stout.

36. I would have just asked that he checked the numbers to see if the span was with in my comfort zone.

37. I would discuss how the portal would be standing and what rigging points could be made.

38. If going outside, a drive by an engineer would be good. Wind loads are difficult for them to calculate, much less 'us'

39. Find out all possible conditions, mentioned above. Verify with Structural Engineer.

40. Just rent a premade kit instead.

41. I would say that you should not build or install anything that you do not feel good about. Engineers are getting less expensive these days and I would say that he should send his designs to an engineer for review and approval. Then, he would know that the design was either good or not. The other advice would be to take some classes and learn about statics and structures.

42. Don't ever be afraid to ask others for help or seek out additional information if you are at all unsure, and don't stop until you are confident that you

understand the problem and have correctly analyzed it. Then, show your work to a trusted friend/colleague to see if you missed anything. Always verify, never assume anything. If any part of your work makes you uncomfortable or reluctant to show to someone else, you haven't done all of your due diligence. Safety is an obligation not to be taken lightly. Design wise: -Make sure that all of your bolted connections on this piece use the same size hardware (for speed of assembly - it limits the number of tools the tech's need). -Make sure your drawings specify what the weld of each joint is to be, and make sure your welders understand what the drawings are telling them. -The diagonals of your header piece are inverted. They should be "down" at the center seam, not "up". -Each of your four pieces (2 towers, 2 headers) should ideally have at least one piece that runs diagonally "through the middle" of the piece - for example the towers should have a piece going from the DSL chord to the USR chord. -The vertical towers should have diagonal bracing in them going both SL/SR and US/DS. -The vertical towers probably do not need as many horizontal chords - these are just adding weight and about half of them could probably be removed. -All four of the pieces should have lifting tabs welded into them, to facilitate installation (Especially since 3/4 of the main chords are covered by decorative scenery). These could be as simple as 1/4" Plate with a hole in them for a shackle, welded to the frame of the truss. These should be at the bottom of each piece, so that the piece is lifted in compression, not tension. -When assembled, this piece should be safetied off to the grid so that it can't topple over. This potentially could be the same chain motors/ropes used to hoist the piece into the air. -Be sure to use rated hardware and specify the hardware to be used for assembly on your drawings. -Consider anchoring the structure to the deck, if possible. -Consider skinning the US and Offstage sides of the towers so that people won't be tempted to climb on them, hang on them etc. (perhaps just the lower 8', etc.) -The vertical chords of the header should align with the perimeter of the towers. This is done correctly at the offstage side of the towers, but incorrectly at the onstage side of the towers. At the onstage side of the towers, the vertical chords of the header appear to be about 1' onstage of the vertical chords of the tower. Instead of effectively transferring load to the tower, it is creating a massive stress concentration in the lower horizontal cords of the header truss. The vertical chords of the tower should be moved offstage 1' (along with the diagonal bracing) so that they are directly above the vertical chords of the tower.

43. Have the unit analyzed by an engineer. Even better have them run an FEA.

44. Consult a more experienced entertainment structure designer as opposed to neighborly advice.

45. I would have told him to consult with someone posessing an education in structural engineering.

46. consideration of 'the elements' that the portal is exposed to is important. if the structure and it's connection to the facility are adequate to withstand all of the potential forces involved, then he should feel confident. that can only be assessed thru some risk assessment and engineering. not knowing the entire situation, i can't say if that can be back-of-the-envelope, or if it needs to be more intensive. But if he does not understand the potential forces or the potential risk, then he should find a reasonable, qualified engineer to help make those assessments.

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