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INDUSTRY, ENGINEERING & MANAGEMENT SYSTEMS CONFERENCE

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It is with pleasure that we present to you the Proceedings of the 28th International Conference on Industry, Engineering and Management Systems (IEMS). The papers presented this year consistently represented high quality scholarship in the authors' respective fields. The papers covered a wide range of topics in the business and engineering disciplines, integrating concepts that further the mission of the IEMS Conference.

We present these Proceedings to you to enable your own thought leadership so that you may share your presentations and papers in the future at our IEMS conference.

These proceedings would not have been made possible without the valuable contributions of our Track Chairs and reviewers for the time and effort they spent reviewing the papers.

We look forward to seeing you virtually at IEMS 2022!

Warm Regards,

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CONSTRUCTION ESTIMATING CHALLENGES AFTER COVID 19 - THE EFFECT OF PRICE ESCALATION AND MATERIAL SHORTAGES ON CONSTRUCTION COST AND CONTRACT MANAGEMENT

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Abstract: The cost of building materials is imperative for determining the profitability and success of construction projects. This paper focuses on the effect of the COVID 19 pandemic on material prices and the availability of material. The input cost of materials and services utilized in construction rose by 27.4% from April 2020 to August 2021. Typically, the material and equipment costs could reach up to 50-60 percent of the construction project cost. Therefore, the increase in material prices and the availability of material pose a significant risk to contractors' ability to bid and execute projects. Prudent contractors must develop a plan to manage and mitigate the risk of material price escalation at the bidding phase, during contract negotiation, and during the built phase of the project. The researcher provides contractors with risk mitigation strategies at each phase of the project to manage and control price volatility.

Key Words: *Risk management, material prices, risk mitigation, project cost, price escalation, construction management, material availability.*

1. INTRODUCTION

The construction industry considers a project to be successful if it finishes on time, within budget, and with satisfactory quality. To stay within budget, contractors ought to manage and control material costs. The cost of building materials is imperative for determining the profitability and success of construction projects.

The construction industry institute (CII) argues that material costs can reach more than fifty percent of the value of the project (Meng et al., 2018). Therefore, the effective management of material costs could determine whether the project will be completed within budget (Polat and Arditi, 2005; Georgy and Basily, 2008). This paper focuses on the effect of the COVID 19 pandemic on material prices and the availability of material. The paper also proposes an alternative approach to mitigate the effect of material shortages and price escalations on the project.

Inherently, the research produced in this area focused on managing material procurements during the construction phase. Scholars presented various material purchase management models to help contractors manage and control the material procurement process during construction. An example of these models is the economic order quantity (EOC), which defines the ideal material quantities to reduce the company inventory costs (Son et al. 2021). Another model is construction logistics planning (CLP). CLP provides contractors with the procedure to optimize material cost and inventory constraints (Hsu et al., 2018). Also, the dynamic programming model (DPM) is presented to balance material price with levels of demand for contractors to make optimal purchase decisions (Kang et al., 2016).

However, current construction industry market conditions, due to COVID 19, dictate that contractors must start managing the material procurement process from the project's bidding phase. Traditionally,

procurement management entails assuring material quantities availability, acquiring quotes, and delivery times from suppliers. Conversely, currently, the process should include incorporating clauses in the contract between the owner and the contractor to protect the contractor from price increases. At the same time, the clauses must protect the owner from unnecessary additional costs due to change orders and potential litigations.

The effect of the COVID 19 pandemic on the supply chain is substantial. The pandemic is causing a supply chain bottleneck that is causing an increase in material prices and issues with the availability of material. Manufacturers and suppliers are not able to meet the higher demand for the material. Even if they do, they are faced with a record shipping backlog and a shortage of truck drivers. The pandemic caused some factories to operate on part capacity due to issues with raw material availability, factory laborers not showing up to work, and cargo ships waiting extended time at sea before being able to dock at ports to unload. Also, Ships are not being allowed in certain ports due to COVID 19 restrictions and cargo handling has slowed as COVID 19 has depleted dockworker ranks.

Consequently, material prices have risen significantly. According to the Associated General Contractors of America (AGC) construction inflation report (2021), the input cost of materials and services utilized in construction rose by 27.4% from April 2020 to August 2021. Conversely, bid prices only rose by 5.2% in the same period (Figure 1). Prices are expected to continue to increase. According to the AGC Data Digest (2021) stated that for October 2021, the year over year rate for steel increased by 134%, aluminum mill shapes increased by 35%, plastic construction products increased by 30%, gypsum board increased by 23%, and insulation material the rates increased by 19%.

Figure 2 shows the producer price index (PPI) for bid prices for non-residential buildings construction and selected inputs. As shown in the figures above, there is a difference between bid price increases and material costs increases for the stated period. Furthermore, it is typical for the cost squeeze on contractors to last two years or more. Figure 3 shows the difference between a year-over-year change in material costs versus the bid process between January 2006 and August 2021. The change went up to above 18% for the first time between 2020 and 2021.

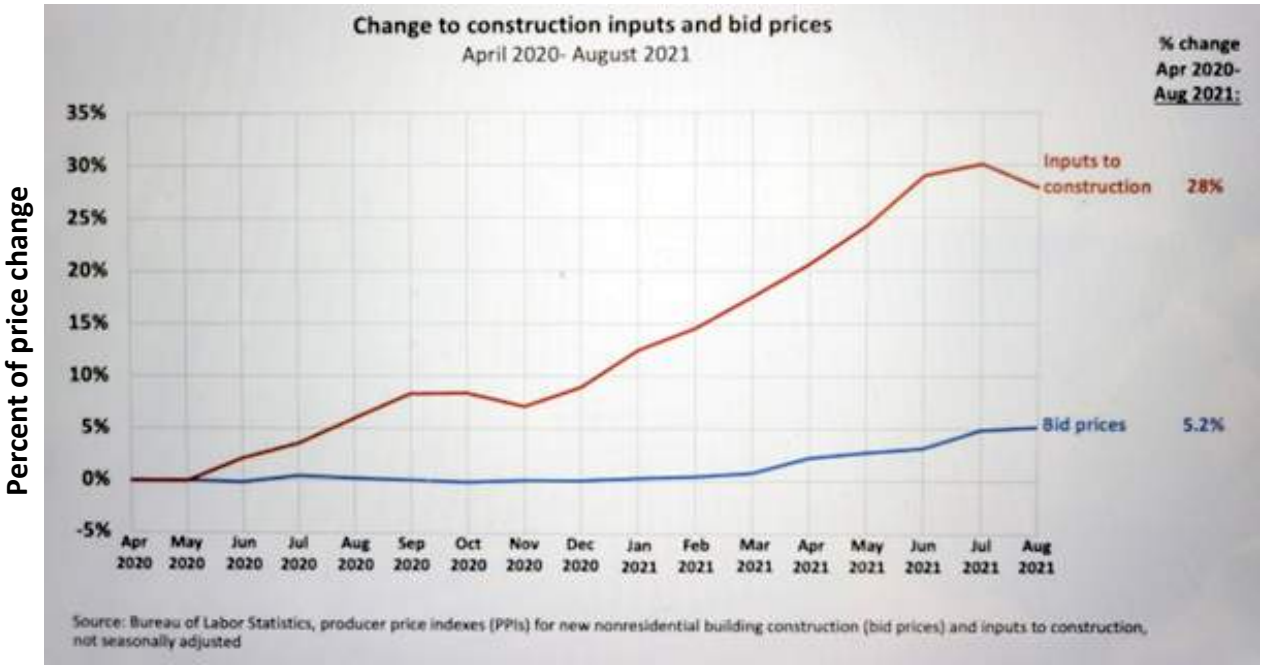

Figure 1 Change to construction inputs and bid prices from April 2020 to August 2021

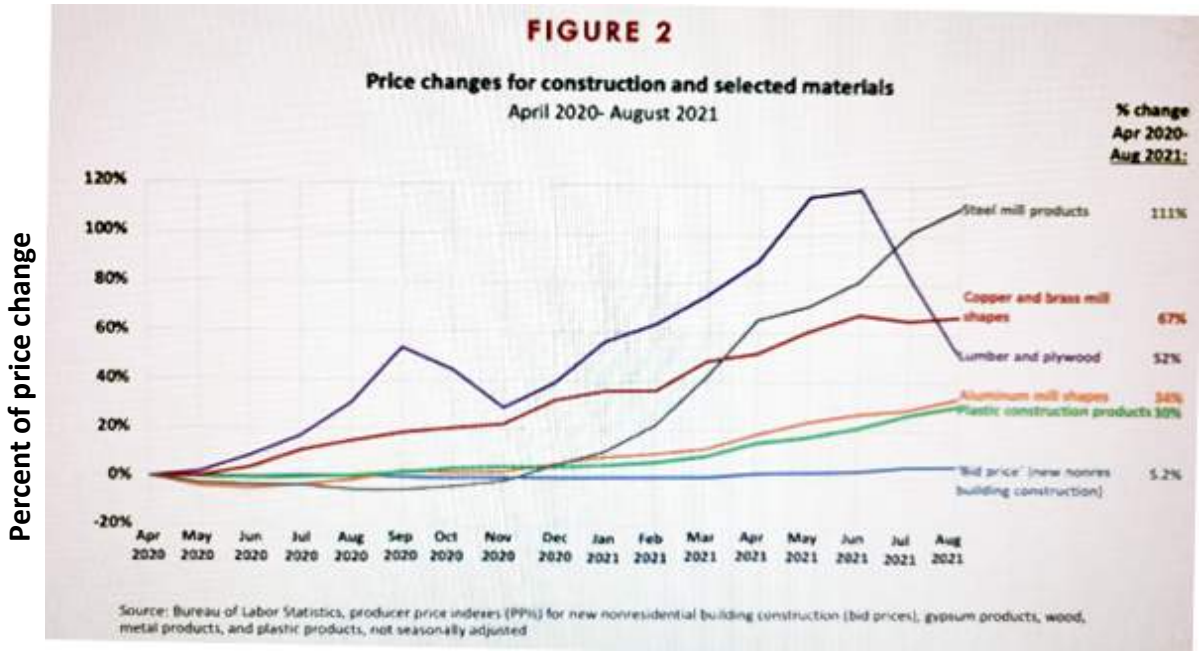

Figure 2 Change in the price for construction materials from April 2020 to August 2021

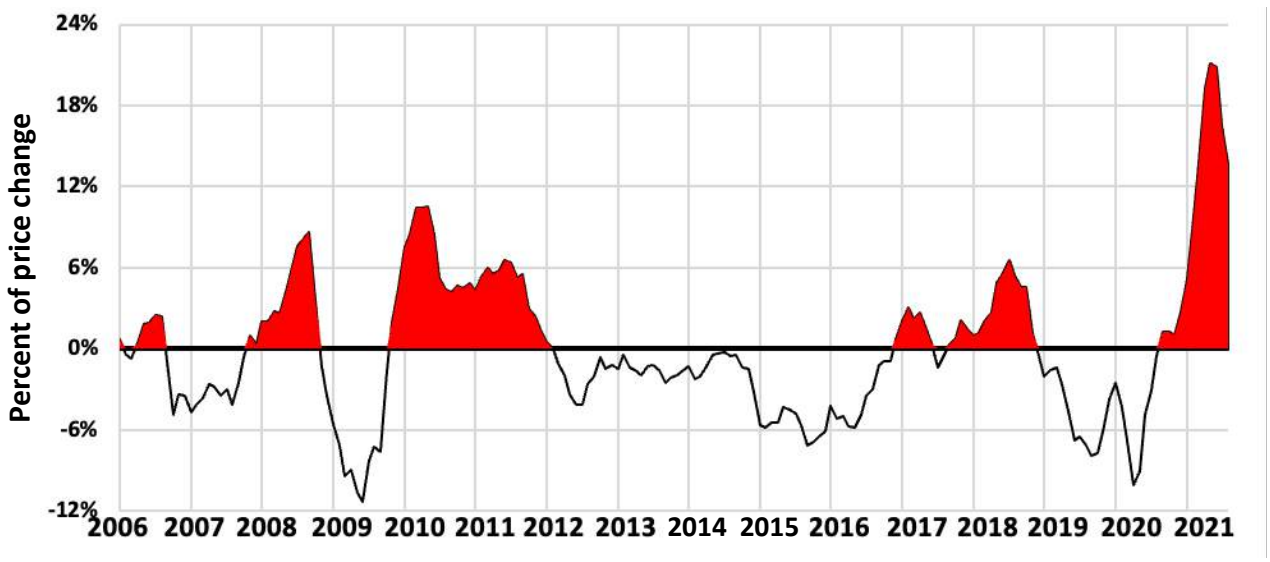

Figure 3 Producer price indexes for goods inputs to nonresidential construction (material costs) and new warehouse construction (bid prices). Source: Bureau of Labor Statistics

The aforesaid entails a burden on contractors to mitigate the effect of the material price increases on the project. According to the Federal Reserve open market committee report (2021), this situation could last for one year or more. The report also states the inflation rates are expected to keep rising for the next two years. Therefore**,** the contractor should develop an alternative approach to address price volatility to stay in the industry and avoid future conflicts with the owner.

This situation poses a significant risk to contractors' ability to bid and execute projects. However, the issue of material price fluctuation is not new to the construction industry. The inadequacy and inconsistency of the methods used in bidding projects and contract agreements constitute a major challenge to contractors (Golikova et al., 2019). Haddad (2007) posits that a risk-sharing approach

between the owner and the contractor could save a substantial amount on project price and reduce potential conflicts. Therefore, prudent contractors must develop alternative strategies to manage and mitigate the risk of material price escalation at the bidding phase, during contract negotiation, and during the built phase of the project

Therefore, this paper provides alternative approach strategies that can be implemented during the project's bidding phase, during contract negotiation, and for existing contracts.

2. BIDDING PHASE STRATEGY

At the bidding phase of the project, the contractor must talk to owners about alternative materials to be used in the project. The proposed material should be available, have more price consistency, and have better delivery time. Currently. it is very challenging to find an adequate alternative material with the aforesaid characteristics. However, the contractor should spare no effort to find and present to the owner with alternative materials.

The Contractor should also utilize cost indices to account for price escalations. Cost indices such as Turner Cost Index (TCI), Building Cost Index (BCI), and Construction Cost Index (CCI) can be used as a basis to calculate cost escalation when the material is needed for the project. In addition, the contractor must start negotiating material prices with suppliers and manufacturers at an early stage of the bidding phase to lock in prices and mitigate the risk of any price increase. Given the current supply chain issues, suppliers and manufacturers may be hesitant to lock in prices early in the project.

In this case, the contractor should use its negotiation skills to reach a mutual ground that the suppliers can agree to. For example, the contractor can limit the supplier's right to increase prices to the contractor's right to increase prices to the owner. Conversely, the contractor can negotiate with the supplier to limit the increase in material prices to a fixed amount. Thus, controlling the amount of exposure to changes in price.

Laos, the alternative approach requires contractors to add bid contingency that accounts for potential price escalation to the bid price. Contractors should factor in winning the bid versus losing money on the job. Contractors should also reduce the validity time of the bid. The expiration date on the bid must be shortened due to price volatility, shortage of material, and delivery time challenges.

3. CONTRACT NEGOTIATION STRATEGY

Contract negotiation is a very critical step for the success of the project. The contractor must ensure that the owner and the designer are willing to cooperate to mitigate the risk of material availability, price, and delivery. During the contract negotiation, the contractor must discuss the following with the owner:

- The stage of design. Design must be complete to start with material purchases as early as possible
- The impact of any potential design changes on the project
- The effect of changes to material selection on the project

Furthermore, the contractor must start presenting alternative material that will aid the project to finish on time with a low risk of price volatility. The contractor is expected to discuss the project delivery method. The contractor should avoid lump-sum contracts as these typically assign the risk of material price escalation to the contractors. Hence, the contractors bear the risk of any financial impact arising from fluctuations in material prices. This author recommends the contractor include a material price escalation clause when signing any new project regardless of the delivery method of the project.

A Material Price Escalation Clause

The ConsensusDocs contract form provides a material price escalation amendment, the ConsensusDocs 200.1, which aims to protect owners and contractors against price volatility. The amendment should list the material that is expected to have price changes during the project execution phase. Also, it should include a baseline price for each material. For these materials, the amendment includes a clause to adjust the contract price in the event of a decrease in the baseline price. Hence, the owner has the right to decrease project costs accordingly. Conversely, in the event of an increase in the baseline price, the contracting parties need to agree on the percentages to be added to the contract price.

Furthermore, Haddad (2019) argues that identifying risks at an early stage of the project and establishing a control mechanism to alleviate their impact on completing the project will improve controlling project costs and reduce project uncertainties. The contractor needs to identify the price escalation risk to the owner and include a clause in the contract to mitigate its risk.

4. EXISTING CONTRACTS

For existing contracts that have no Material Price Escalation Clause, contractors may be able to find relief from material price escalation through existing contract provisions or equitable principles. For instance, contractors may use the following contract clauses to alleviate the effect of material price escalations:

- Contract documents allow for an equitable adjustment for additional costs or time needed resulting from any change in law, including increased taxes, enacted after the date of the Agreement
- Force Majeure
- Mutual Mistake
- Commercial Impracticability

However, the research in this field argues that this approach constitutes a challenge to the contractor to prepare and convince the owner of his claim.

5. AN ALTERNATIVE APPROACH

Based on the aforesaid, the researcher provides the following alternative approach for risk management of material price unpredictability in today's market after COVID 19.

The contracting parties must agree on the list of the risky material to be included in the contract. the contractor must provide a baseline price for these materials to be reviewed and approved by the owner. Then the contracting parties should agree on the following:

- Reward to the owner in case material prices drop. Typically, the owner is rewarded the full amount saved due to the decrease in the price.
- In case of the material price increases, the contract clause should state the amount or percentage the owner will accept. For instance, the clause can state that the contractor will assume up to five percent of the price increase. Further, any increase beyond the five percent is the owner's responsibility.

Alternatively, the owner may decide to assume this risk. Therefore, the owner provides all or part of the listed material to the project. The contracting parties should agree on the owner's allocation of risks. In such an event, the owner should base payments to the contractor on the actual costs incurred plus 10% for overhead and profit.

In all cases, the contractor must include a clause in the contract to exculpate itself from any project delays liability due to the said material's late delivery to the site. Finally, utilizing the alternative approach

to material risk management and applying proper procurement methods and strategies enhances the opportunity for the contractor to mitigate the risk of material price fluctuation.

6. RECOMMENDATIONS FOR FUTURE STUDIES

For future studies, the researcher recommends Studies that are aimed to determine owners' willingness to assume the costs of identified materials. The contracting parties must recognize the cost benefits associated with assuming risks. This provides them with the knowledge necessary to make an informed decision on what risks he/she should assume and what risks he/she should shift to the other party.

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IMPROVING THE OUTCOME OF SIX-SIGMA PROJECTS WITH COST ENGINEERING APPROACHES

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Abstract: The objective of this literature review is to expand upon the research associated with relationship between the use of cost engineering approaches and six-sigma project success when designing or redesigning products in the manufacturing industry. The objectives of this literature review are two-fold. First, is to analyze contextual peer-reviewed literature pertaining to the impact of using cost engineering methods and practitioners in six-sigma projects focused on new or redesigned products. Second, to identify the causes and factors for six-sigma and related methodologies failures focused on product design and redesign. As a result of this literature review this research aims to provide a cursory look at discovering research gaps that could be addressed further.

Key Words: *Six-Sigma, cost engineering, product design.*

1. INTRODUCTION

"Every system is perfectly designed to get the result that it does," this is a quote from W. Edwards Deming describing the premise that intended and unintended consequences are both designed into our systems. With this concept in mind and understanding that as engineering principles have advanced, so too has the demand for higher quality products for less cost. One method for companies to meet the demand for delivering quality products at competitive prices is to begin with the end in mind. Companies need to understand where they want to position themselves in their market. They can adopt the stance of quick, low-cost, poor-quality products that can be sold cheaply in volume with little concern for their reputation and potential for loss of market share (Albliwi, Antony, & Lim, 2015; Antony, 2011; Imam, 2012). Or they may choose to produce products that are superior in quality but at a very high cost. This too could pose negative consequences as their market base may be too small to sustain a business with this model. Most companies will choose to produce products that are high enough in quality to meet the price point for their targeted customer base. As such, clearly there needs to be a method that a company can deploy that addresses the cost of designing and producing a product without sacrificing quality.

Six-sigma has been a proven approach for process improvement since the late 1980's. But process improvement applies to existing products and processes. The need for a design-based improvement methodology ushered in the six-sigma variant design for six-sigma among other approaches that focused on designing in characteristics such as cost, manufacturability, assembly, reliability, sustainment and others (Schenkelberg, 2016). These methods have also proven to be highly effective when successfully deployed, but research indicates alarmingly high failure rates. This creates somewhat of a paradox with six-sigma methodologies being very successful in some situations but can have staggeringly high failure rates in most other situations. Research is replete with studies as to critical success and failure factors for six-sigma projects, but in product design where design of six sigma (DFSS) is the primary tool, there is not much research indicating the root causes behind project failures. Interestingly, cost engineering is a field that is covered extensively by researchers and has shown that the successful utilization of cost engineering methods and the use of skilled practitioners can result in increased cost savings, customer

satisfaction as well as process efficiency (Domanski, 2020; Shermon, 2017). Again, there is little in the way of research discussing cost engineering approaches when designing new products using DFSS or similar six-sigma methodologies.

2. BACKGROUND

2.1. Lean, Six-Sigma, Lean Six-Sigma, Design for Six-Sigma and Design for Excellence

The mid-1980's ushered in the start of six-sigma. Rather than concern for focusing on the various types of waste that lean was proven to be effective, six-sigma focused on process improvements that removed defects from the final product. But, like lean, six-sigma was only effective with senior management support as well as numerous other critical success factors. Often coupled with six-sigma, lean six-sigma was popularized in the early 2000's as two complimentary methods that both could be implemented together but with different goals. Bhaskar pointed out that Lean management in isolation cannot remove variation from a process while Six Sigma by itself cannot remove many of waste from a process (Bhaskar, 2020).

Even with Six Sigma producing massive bottom-line impact in manufacturing, design, finance, healthcare and many other areas and was clearly a methodology that was here to stay, but there were some things missing that would enable it to have even greater impact (Antony, Snee, & Hoerl, 2017). DMAIC was the approach behind six sigma and is a proven method for improving existing products and services to significant levels, but the overall performance of the product or service may be limited by its initial design. Honeywell, in the early 2000's, had successfully applied Six Sigma to design new projects but there was not an existing process to use as a guide. At the same time GE was seeing the same limitations and began building on the foundation of six sigma creating the Define-Measure-Analyze-Design-Verify (DMADV) approach which is still the primary approach used today. This new six Sigma variant would be called Design for Six Sigma (DFSS) (Antony et al., 2017). Design for Six Sigma (DFSS) quickly became the natural choice of an approach for a company to use for the design or redesign of new products. An often-quoted rule of thumb in the world of design is that 20% of costs can be affected by improving the efficiency of a design process but 80% of costs are locked in during the design process itself (Mandelbaum, Hermes, Parker, & Williams, 2012).

Design for Six Sigma and Design for Excellence (DfX) are both sub-topics under six-sigma but focus on product and process design and redesign rather than the improvement of existing products processes. DfX considers many aspects of part design and manufacturing including concepts around parts modularity and re-use (variant reduction), alternate manufacturing processes, weight optimization, manufacturability (DfM), assembly (DfA), quality (DfQ), materials selection and substitution and supplier parts management (Schenkelberg, 2016). The most important aspect of designing with cost in mind is quality. All three concepts work together to create a balance of quality products and a cost that delivers value to a customer. Quality as well as cost must be part of every discussion to maintain the desired expected value.

2.2. Project Failure

For the family of six-sigma methods, success factors as well as failure factors are important topics. The top success and failure factors only vary slightly on most researchers lists. A particularly relevant finding from of Antony's study on critical success factors shows significant failure rates for LSS projects with the highest termination rates in the measure and analyze phases using DMAIC or DMADV (Antony, Lizarelli, & Machado Fernandes, 2020). Both measure and analyze requires commitments from many departmental areas from within the company. Often personnel with specialized skills are needed to carry out critical data analysis as part of the measure and analysis phases. A critical success factor requires having the proper skillsets for the task and adding additional black and green belts can slow performance improvement efforts. Managers who are unsure how to recruit skilled subject matter experts too often utilize black belts to remedy all problems (Guarraia, 2008). Product cost estimation is clearly not the responsibility for one department. For example, Purchasing will sometimes chase only supplier costs and

not communicate with Engineering during early in the design phase. Engineering departments do not understand cost structure and how to optimize cost with cost engineering approaches - they only work on design. Similarly purchasing departments can't recognize cost reduction ideas that won't degrade the design as illustrated in Figure 1 below. Collaboration and utilization of proper skillset is a critical factor for success (Antony & Banuelas, 2002; Sreedharan V, Sunder M, & R, 2018).

Figure 1 Skillset as a Critical Success Factor

Senior management's lack of commitment and support is an obvious reason for most performance initiatives to fail. However, the question of why senior management would not commit or support a six-sigma initiative has not been fully resolved in literature. Two other significant failure factors are lack of complementary skills among project teams as well as having adequately skilled team members. These are two similar but slightly different factors. Selecting team members is a critical step in aligning personnel skills for the project so that the team has the skillsets required perform all the tasks necessary for a successful project. Another critical failure factor is faulty selection of a process improvement methodology and associated tools/techniques (Antony et al., 2020). This is particularly noteworthy from the standpoint that even with all other factors deployed properly; poor tools/techniques may subvert the goals of the project through the acquisition of inaccurate data.

2.3. Cost Engineering

Cost engineering as defined by the Association for the Advancement of Cost Engineering (AACE) is "the application of scientific principles and techniques to problems of estimation; cost control; business planning and management science; profitability analysis; project management; and planning and scheduling." Dating back to the 1940's, demand for military equipment spiked creating shortages in labor, raw materials and parts for military equipment. Engineers and manufacturers quickly realized that original specification parts were not readily available, but equal or better-quality parts could be substituted at lower costs. This realization ushered in the principle of Value Engineering. Since that time many cost estimating tools have been developed and utilized to address various cost estimating concerns. Domanski notes in his book that cost engineering is really an umbrella of various cost estimating methods that comprise some the tools. His list includes target costing, cost estimating, should costing, cost modeling, marginal costing, activity-based costing, value analysis, value engineering, standard costing and TRIZ (Domanski, 2020). Figure 2 lists the processes that fall under the category of cost engineering methods that are allow cost engineers to model costs for estimating, cost control, cost forecasting, investment appraisal and risk analysis.

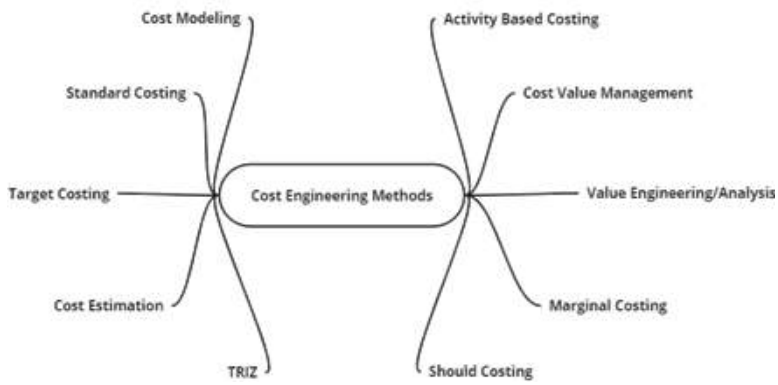

Figure 2 Cost Engineering Methods

Cost estimating uses predictive processes to determine costs of the resources that are required to fulfil the scope of the products final design and production. The ultimate goal of cost estimating is to minimize the uncertainty of the estimate while providing an expected cost that fails inside a derived probabilistic distribution (Creese, 2018). The often-quoted rule of thumb that 20% of costs can be affected by improving the efficiency of a design process yet 80% of costs are locked in during the design process itself. Consequently, improving the design early in the life cycle, when the design flexibility is highest, has far greater leverage (Mandelbaum et al., 2012). Figure 3 below, illustrates this notion of the positive impact of managing costs during the design phase rather than attempting to improve the situation after production begins (Yang & El-Haik, 2003).

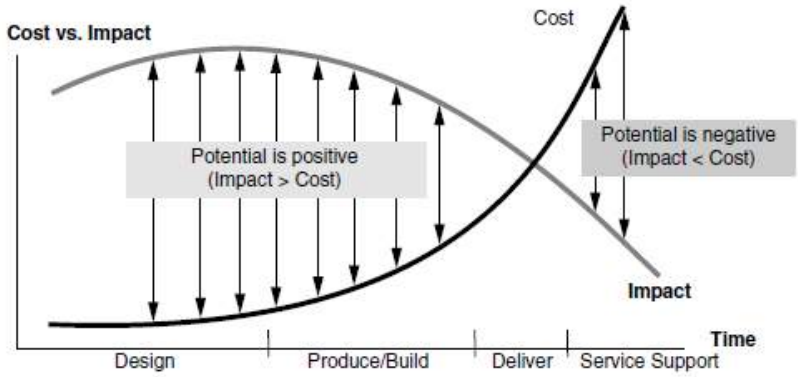

Figure 3 Impact of Cost during Design Product Life cycle. Source: (Yang & El-Haik, 2003)

Some of the basic costs that need to be determined as part of a new or redesign manufactured parts includes the following from Domanski's book:

- Manufacturing labor rates
- Raw materials
- Purchased components
- Floor space cost
- Machine costs
- Reference process times
- Machine setup
- Tooling and fixtures

It is very likely that many of these costs will need to be considered for various regions and countries

taking into consideration regulations for each (Domanski, 2020).

2.4. Cost Engineering Practitioners

Should projects continually fail to meet their planned objectives, management will lose faith with six-sigma other methodologies such as DFSS or DfX. Antony et al. (2019) noted that one of the root causes for project failure is adequately skilled team members with specific skills and knowledge to support projects. This is a glaring omission from the literature given the description of a cost engineer as: "someone whose judgement and experience is used in the application of scientific principles and techniques to the areas of business planning and management science, profitability analysis, estimating, decision and risk management, cost control, planning, scheduling, and dispute resolution, etc. to support asset, project, program, and portfolio management" (AACE, 2022).

2.5. Product Cost Management Systems

Product Cost Management (PCM) systems are typically data sources that pull cost data into and integrated environment usually from PLM/PDM and ERP systems as well as materials, labor rate and manufacturing process libraries. Not a method itself, a PCM is a database of costs that are sourced from various locations that contain the most accurate date available. The use of a PCM system allows cost engineers the ability to respond quickly to the costs involved in ever-changing product designs (Ostroukh, Gusenitsa, Golubkova, & Yurchik, 2014). Given the training, experience and certifications appropriate to be a cost practitioner, it is easy to imagine that a Six-Sigma or DFSS team will have difficulty recruiting someone that can fulfil the cost estimating requirements to participate in a DMAIC, DMADV or other design methodology.

3. LITERATURE REVIEW

This literature review aims to provide a comprehensive background to discover research gaps that could be feasibly addressed by the proposed methodology by (Bacca, 2014; McLean et.al., 2013) and adapted to this literature review which follows the following flow:

Planning:

- Database selection
- Keyword selection
- Keywork modifiers
- Definition of inclusion and exclusion criteria of studies
- Definition categories for the analysis

Conduct the review:

- Study selection
- Data extraction (Content analysis method applied)
- Data synthesis
- Data coding

Reporting the review:

- Analysis of results
- Discussion of findings
- Trends
- Conclusions of the review

The following was the list of keywords selected:

- Six Sigma

- Design for Six Sigma and DFSS
- Cost Engineering
- Design Cost Methods (2012 – present)
- Six Sigma Project Failure (2012 – present)

The last decision to make prior to performing key word searches was to determine the date range for each keyword. Rather than arbitrarily setting a date range the researchers felt that some early background literature would be valuable in the following areas: Lean, Six Sigma, Lean Six Sigma, Design for Six Sigma, Design to Cost and Cost Engineering. As such, no starting date range was entered allowing the researcher to review materials from the beginnings of these topics to better understand the history and rationale. The starting date for Six Sigma Project Failure and Cost Management Systems were set to 2012 to provide more recent studies as part of this research. Lastly, this search only included articles that have been peer reviewed and available in English. All metadata from the search results were stored in the software package EndNote 20; a software package for storing, organizing and citing references. The systematic literature review process with document count as shown in Figure 4 below.

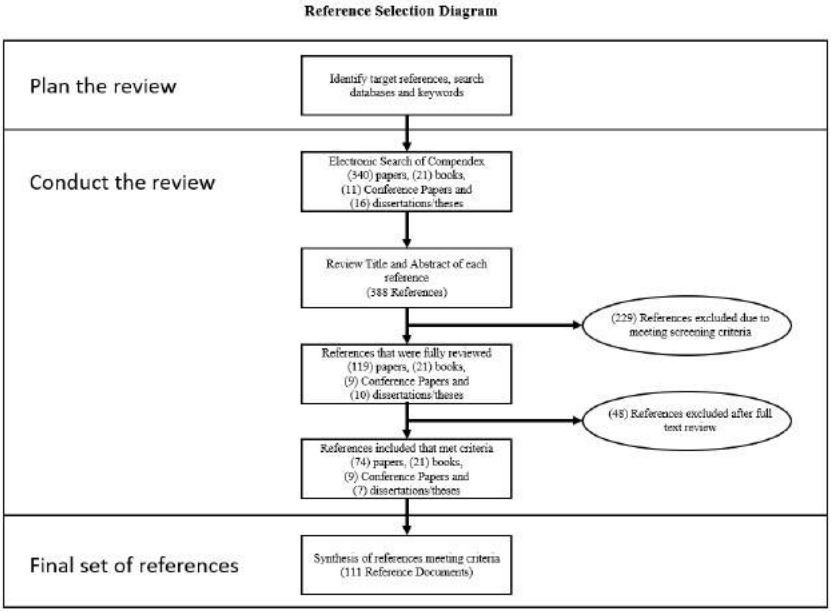

Figure 4 Literature Review Process with Document Count

The first search for papers focused on the history and relationship between six-sigma related methodologies. Starting with lean principles and its origins that date back many centuries but was popularized by Ford's moving assembly line process. Progressing to Toyota Production System (TPS) and Japan's market changing success after WWII. The concept of lean principles caught the attention of the U.S. to use to regain lost market share. But companies successful implementing lean principles quickly realized that that lean would only be successful if it were supported by senior management who understood that this would be a long-term commitment involving everyone in the organization. The mid-1980's ushered in the start of six-sigma. Rather than concern for focusing on the various types of waste that lean was proven to be effective, six-sigma focused on process improvements that removed defects from the final product. But, like lean, six-sigma was only effective with senior management support as well as numerous other success factors. Often coupled with six-sigma, lean six-sigma was popularized in the early 2000's as two complimentary methods that both could be implemented together but with different goals. Bhaskar (2020) pointed out that Lean management in isolation cannot remove variation from a process while Six Sigma by itself cannot remove many of waste from a process (Bhaskar, 2020).

Given this study focused on product design and redesign the search for papers shifted to include Design for Six Sigma and a Design for X. Both methods are sub-topics under six-sigma but focus on product and process design and redesign rather than the improvement of existing products processes. The findings from these papers are like six-sigma and lean six-sigma with regards to the need for strict adherence to the methodology as well as understanding and abiding by the critical success factors for a successful deployment.

The second search for papers focused on critical success and failure factors which are plentiful in the expected population of literature. The success factors as well as failure factors are very similar across the body of literature reviewed with the top factors only varying slightly based on the perspective of the targeted group. Revisiting the quote from Bain & Company which conducted a survey finding that 80 percent of 184 companies responding claimed that "Lean Six Sigma efforts are failing to drive the anticipated value" and 74 percent said, "they are not gaining the expected competitive edge because they haven't achieved their savings targets" (Guarraia, 2008). Additional studies found similarly high failure rates usually with a list of failure factors with little mention of the underlying cause. For this research study the concern is largely focused on failure factors for design based six-sigma methods. The failure factors discuss in DFSS and DfX papers were, again, high level factors that were general to six-sigma projects.

The third search was for papers on cost engineering methods, approaches, practitioners and cost database/product database systems. To frame this summary, it may be useful to repeat the Association for the Advancement of Cost Engineering's definition of cost engineering which was, "the application of scientific principles and techniques to problems of estimation; cost control; business planning and management science; profitability analysis; project management; and planning and scheduling." As expected, search databases were rich with cost engineering papers and the findings that were relevant to this research in that the researcher have studied the evolution of cost engineering principles from WWII with the advent of Value Engineering until today. Researchers discussed the need for cost estimation methods and tools for estimating costs and then subsequently controlling all the costs associated with the design and associated manufacturing of a product. Researchers note that is the pre-project estimate of the product cost that influences management to make go or no-go approval decisions for funding of a DFSS or DfX project. Should projects continually fail to meet their planned objectives, management will lose faith with six-sigma other methodologies such as DFSS or DfX. Not represented in the literature was any discussion of the use of a skilled, trained, certified Cost Engineer to augment the six-sigma resource team. Antony et al. (2019) noted that one of the root causes for project failure is adequately skilled team members with specific skills and knowledge to support projects. This is a glaring omission from the literature given the description of a cost engineer as: "someone whose judgement and experience is used in the application of scientific principles and techniques to the areas of business planning and management science, profitability analysis, estimating, decision and risk management, cost control, planning, scheduling, and dispute resolution, etc. to support asset, project, program, and portfolio management" (AACE, 2022).

The last set of key word searches was targeted at finding research on cost data, cost database and product cost management systems. Literature is very thin in this area with a few papers describing the concept of an integrated system using PLM/PDM and ERP systems which is the logical place for cost data to reside given that product BOM's are contained in these systems see Figure 5 below.

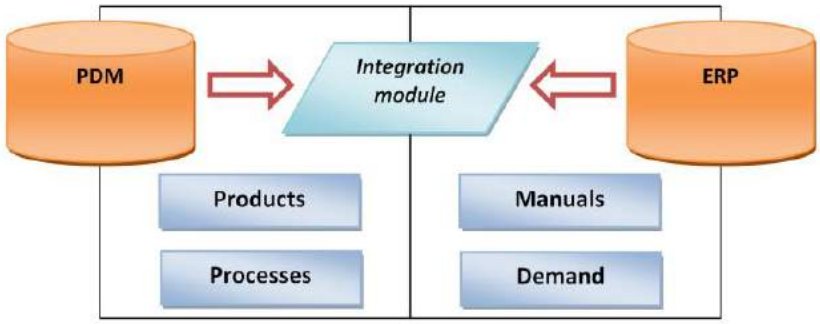

Figure 5 Integration Framework, PDM and ERP. Source: (Ostroukh et al., 2014)

As cost estimating requirements grew commercial software started to add libraries of material costs and machine processing costs as well as integrating PDM/PLM and ERP systems emerged creating what is called Product Cost Management (PCM) (Ostroukh et al., 2014). The first commercial tools specializing in manufacturing cost estimating appeared in the early 1980's. These tools had crude interfaces and required significant hours of training and expertise to use properly. As software technology advanced, so too did cost estimating software. The inclusion of a database to store part cost data allowed for somewhat easier retrieval began to appear in the marketplace allowing designers to understand the cost of their design was under over the target. As the 2000's progressed so did the technology and demand from various groups from within companies. Sourcing managers were asking for detailed should cost estimates as a tool for negotiating with suppliers and build to order shops and cost engineers were in desperate need of a system that was able to provide cost comparisons for many CAD models to understand the cost range of a particular design (Hiller, 2019).

A Product Cost Management System is not an accounting system; it is an integrated infrastructure that allows experts in various areas of design, engineering, manufacturing and sourcing to share cost data for the purpose of creating proposals ROI estimates as well as having a source that contains various manufacturing processes and their associated costs involved in designing and producing a product. A PCM system can provide very detailed analyses of costs for evaluating the total cost of production before the first part makes it to production. (aPriori, 2020).

4. CONCLUSION

Accurate cost estimates can provide a positive impact to the outcome of designed-based projects. The contribution of this literature review is to provide a look at some possible cost engineering approaches that may improve the success rate of six-sigma methodologies-based projects. DFSS and DfX product design projects are cost-oriented with costs emanating from many sources. Cost estimating methods are well documented and utilized in many industries and have clear value with improving estimates. Additionally, the use of a cost practitioner who has been trained, skilled and certified in cost engineering methods and practices can add often-lacking skills needed for developing cost models for quickly evolving designs. The last approach researched for this review is whether the utilization of an integrated Product Cost Management (PCM) system can provide a reliable and quick access to costs associated with the many factors that go into manufacturing new designed parts.

Research is sparse regarding the connection between six-sigma design related methods and cost engineering approaches. This gap provides research opportunities in the areas of building out a new framework for adding cost engineering approaches to six-sigma related methods to reduce the rate of project failures due to cost estimating inaccuracies.

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THE USAGE OF SMART GLASS TECHNOLOGY IN AIRPORTS TO REDUCE THE CARBON FOOTPRINT OF AVIATION FACILITIES

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Abstract: This study aims to increase awareness of a new solution for reducing the carbon footprint of airports. The use of Smart Glass technology in airports and other architectural design choices across the world mitigates the use of fossil fuels to help combat the transfer of heat and cold in buildings while bringing in a natural source of lighting in the infrastructure of buildings. The instrumental role Smart Glass technology can play in reducing energy poverty worldwide will make a massive difference in sustainability measures. In some way or form, every human in the world resides inside buildings that continue to use fossil fuels to provide comfort for people; with Smart Glass technology, we can be the new tomorrow of sustainability.

Key Words: *Architectural design, fossil fuels, sustainability, carbon footprint.*

1. INTRODUCTION

The study aims to ensure the future development of the aviation industry to pursue a more environmentally friendly and sustainable path of expansion. Implementing Smart Glass technologies inside airports and other structures will bolster the efforts of companies that are constantly in search of ways to cut down on the cost of operations. In addition to providing a sustainable environment, Smart Glass technology will also offer proper sunlight into terminals and other congregating areas inside airports.

In the world we live in today, we often find ourselves discussing the importance of energy and how to preserve it and improve the lifestyle of workers and travelers in airports. Many companies look forward to discovering renewable energy sources to reduce their carbon footprint, reduce their costs, and improve the environment. It is also imperative to have the employees and travelers feel welcomed and in an environment that is open to sunlight to make individuals feel at ease. Whether this concerns airports, many buildings currently have electrical lighting fixtures rather than built-in skylights or windows. Not receiving proper sunlight can negatively impact the health and productivity of workers and the positive feelings of passengers.

Over the past few years, we have begun implementing new ways to reduce energy usage by turning over to wind power, solar power, and even hydropower. The main issues we face with all three of these alternate sustainable energy obtaining methods are usually their costs. Wind, solar, and hydropower are costly to build, especially with all the planning and studies to place them around airports. Wind power does not work due to having obstacle clearance issues since planes have to land at runways. Solar energy has the issue of firstly conducting solar glare analysis. The glare analysis can throw away this idea if it causes problems in pilots' visions or aircraft control towers. However, another underlying issue is the availability of land to build solar panels. Airports already struggle with owning land around them and must deal with many problems. Lastly, hydropower requires a water source near an airport, and not

everywhere has access to the water point. Not only this but hydropower has been known to cause specific issues with the environment, such as hurting the population and habitats of certain animals, which is why it is not preferred. The alternative way I believe that airports can use sunlight to reduce costs in an environmentally friendly way is to use Smart Glass windows.

A study was done in the UK by Gupta, Howard, and Zahiri that shows the negative impacts in a work environment, such as health and sickness, can cause employers in the UK around £9 billion a year (2020). Improving workflow and passenger satisfaction in an airport can reduce the cost of employee issues, which can be introduced with the use of Smart Glass windows. It can also increase passengers' spending habits due to being in a better mood and feeling relaxed in the fresh atmosphere provided by Smart Glass implementations. The passengers will be under less stress as they navigate an airport that is better climate-controlled and naturally lighted. Allowing airports and other buildings to use Smart Glass windows or smart film could allow sunlight to enter without increasing or reducing the temperature inside these buildings. The presence of natural light will benefit workers and travelers and the entire ecosystem of the structure and surroundings. The technology will also help businesses by allowing them to save on operation costs. Spending will be cut down upon electrical aspects in structures, allowing for the mitigation of the business's carbon footprint. The main area that would positively affect the facility would be reducing the use of the HVAC system in the buildings.

2. BACKGROUND OF ENERGY POVERTY AND GOALS TO ADDRESS THESE ISSUES

The need to improve upon energy costs has been happening since the early 1970s. As stated by Rissman and Kennan in their study on the government's role in energy technology, "The OPEC oil embargo of 1973 was the initial impetus for the United States government to develop energy efficiency technologies" (2013, p. 2). The increase in oil prices has also driven the energy sector's expenses due to using non-renewable energy sources such as coal to produce electricity and oil to bring heat into buildings. The need to improve upon costs leads us to seek and find Low-e glass to find a way to cut down prices. In our present-day, people are now concerned about climate change and global warming. The push for the reduction of carbon footprint is greater than ever. Even airports have significant sustainability grants if they comply with a certain number of regulations to provide cleaner energy in their facilities. Thanks to the Federal Aviation Administration, programs such as Voluntary Airport Low Emissions Program (VALE) and Airport Improvement Program (AIP) always push airports to continue their improvements towards airport sustainability programs, AIP mainly provides airports that comply with sustainability management plans, grants, and funds to reduce airports' environmental impacts while VALE make sure airports comply with state issued air quality initiatives. (FAA, 2021).

The threats imposed by carbon emissions overall have increased the effects of global warming. The earth has been dealing with climate change problems for a few years now, and we are beginning to see those effects. Areas have experienced extreme heat, leading many to use their HVAC systems more frequently. In a research journal by Randazzo, Cian, and Mistry (2020), it is brought to attention that residents and businesses have a broader demand for electricity usage throughout the world. The rise in electricity usage is mainly due to the adaptation of air conditioning units.

Due to extreme heat, the problems of thermally cooling individuals' homes have risen. If companies want to run these cooling mechanisms, the user needs to run off electricity, which can be relatively expensive to obtain. In an attempt to cool homes and businesses, these applications' high prices and negative impacts can lead to energy poverty. Energy poverty described by Faiella and Lavecchia (2019) is "a complex and multidimensional problem, lying at the intersection between household income, energy costs and the energy efficiency of the housing stock" (p. 2). This means it can happen to anybody or business under the right conditions of poor energy management.

The global shift in climate change also brings colder weather to many countries and, as recently seen in the world, snow to places like Texas, which usually never see snow. Many places experience these extremely low temperatures, so they tend to crank up their thermostats. The use of heat in buildings

usually drives from furnaces and boilers to provide heat to the people. The ability to run these furnaces and boilers tends to increase our global warming as it is not the best choice for the environment. Lechner's book states, "Buildings use about 48 percent of all the energy consumed, with 40 percent for their operation and 8 percent for their construction. This energy is mostly derived from fossil sources that produce the carbon dioxide that is the main cause of global warming" (2014, p. 2). The importance here is to focus on sources that will eliminate the carbon footprint left behind by businesses and create a cost-effective way to run renewable energy sources.

This can work by introducing Smart Glass windows to the equation. Businesses can install skylights or windows with this technology to allow light into the building but limit the UV rays that cause heating. Implementing Smart Glass windows or smart films would be the best way to improve airport operations' cost reduction. Implementing Smart Glass windows will help the airport reduce its carbon footprint. The implementation of windows will allow the airport to allow sunlight into terminals, food courts, and shopping areas. Implementing the windows will also provide better control of interior temperatures, reducing the cost of HVAC. If air conditioning and heating are taken out of the airport's expenses, it will save money and allocate the budget to improve other weak areas.

2.1. The Goals of Smart Glass

The application of Smart Glass will reduce the energy usage of airports. Due to the glass's adjustability, the airport will use less heating and A/C components in their terminals. The glass will allow more UV rays inside through adjustments to keep heat inside while blocking out cold air with its double insulation system in lower temperature times of the year. In months when we see the high temperatures, the glass will block UV rays but allow natural light to come through. The airport will benefit from natural light without sacrificing to heat the facility only to waste energy cooling it back down.

Due to the glass' innate nature, it is not required to be powered by fossil fuels, like the HVAC system. It will also not be emitting greenhouse gasses to prevent further holes in the ozone layer. The glass will not use natural gas or furnaces to heat the area. Since there is no usage of fossil fuels, the glass will improve the airport's sustainability factors. As many of us are aviation experts, we are aware of AIP by the FAA. With Smart Glass technology installation, the airport will comply with AIP initiatives to create a sustainable airport. Doing so will allow the airport to receive grants and funding to allocate its annual budget to support other features the airport might lack. The money made here could improve SMS and other safety initiatives in the airport to improve the community's work and travel environment.

When Smart Glass technology is used at the airport, it will drastically improve its carbon footprint. It will take some time to kick in and show the reduction. However, more glass being installed in the airport will reduce the airport's usage of fossil fuels and other environmentally harmful energy sources. Even if the airport still uses some fossil fuels, a slight reduction will be beneficial. The initiative to reduce carbon footprint does not happen overnight but can be slowly adaptive to be more affordable and effective for the airport.

2.2. Flexibility of Options for Smart Glass Applications

The Smart Glass technology can be seen almost as a glass sandwich. The system is more intricate then having a glass layer that can allow UV rays in and block them. Many different materials are sandwiched between two separate layers of glass. Hillmer et al. (2021) presented to us in a fashion that explains how some of the science works behind it. The glass comprises a simple plane windowpane in a double insulation glazing window. The next crucial aspect of the glass has the mounting adapter that allows separation between the windowpane and the micromirrors. Lastly, the glass has the micromirror array module, which is the main element that will help differentiate unwanted sunlight and allow sunlight when the user desires it (Hillmer et al., 2021).

The micromirrors are nanostructured mirrors that adapt to day light's presence and detect human existence on the other end to allow sunlight in or deflect it accurately (Hillmer et al., 2021). The double insulation allows noble gasses to fill the gap, allowing the micromirrors' properties to react appropriately and adjust their movements based on the sunlight's presence. The micromirrors have a slight separation

known as the isolation layer. The layer allows for the transfer of negative and positive charges that adjust the micromirrors. Above the isolation layer, the photoresist layer that is baked in allows for undesired etching underneath this layer to ensure the micromirrors have a well-stable and fabricated area to be placed upon. The photoresist layer to ensure the stability of the micromirrors is also known as the FTO layer, allowing the electrode to flow through. The fourth primary layer in the installation will be a window frame that will hold all these parts together. Lastly, the job will end once the second layer of the windowpane is installed on top of the window frame (Hillmer et al., 2021). Once completed, the window will be ready to be installed into a spot to conduct its job. It allows the windows to heat a room and provide a natural light source. The application reduces the amount of heat transfer without lowering the room's brightness to still cut back on lighting costs.

Another type of glass that is much more readily available is low-emissivity windows. This type of Smart Glass is more straightforward than having a double insulated layer, thus costing less than its counterpart. Low-e windows are still insulated glass; however, they do not have as much layering as the micromirror example. In a study conducted by Rissman and Kennan (2013), they mentioned this glass's internal structure. They say, "low-e window uses two panes of glass, with a gap between them. A microscopically thin metal or metallic oxide coating is applied to one of the two inner surfaces (those facing the cavity between the panes). In higher-performance low-e windows, the air in the cavity is often replaced with an inert gas that has lower thermal conductivity than air (such as argon or krypton)" (Rissman & Kennan 2013, p. 2). The glass here is much simpler, which translates to less spending on the investment in the company's Smart Glass window application looking into the technology.

The applications that Low-e glass conducts are not very different from their counterparts (Rissman & Kennan 2013). They both do the same job, except that Low-e glass does not detect humans' presence in a room. The main advantage that is provided by Low-e glass is that it transmits the most visible light and blocks the most infrared radiation that causes heat inside airports. However, the application here might seem negative if individuals desire to heat an airport's interior since the inside of an airport is hotter than the outside during cold days. The glass uses the same application that keeps hot weather out during the summer but reverses the process to keep the airport's warm temperature during cold weather situations. Rissman and Kennan's (2013) study describes the process of heat staying indoors during cold climates and outdoor in hot climates, "This concept is known as transmittance, which is simply the percentage of radiation that passes through a material.11 A window will typically have different transmittance values for visible light and for heat" (p. 1).

2.3. Benefits

In conjunction with heat, the heat in buildings usually drives from furnaces and boilers to provide heat to the airport. The ability to run these furnaces and boilers tends to increase our global warming as it is not the best choice for the environment. Lechner (2014) stated in his book, "Buildings use about 48 percent of all the energy consumed, with 40 percent for their operation and 8 percent for their construction. This energy is mostly derived from fossil sources that produce the carbon dioxide that is the main cause of global warming" (p. 2). The importance here is to focus on sources that will eliminate the carbon footprint left behind by businesses and create a cost-effective way to run renewable energy sources. The implementation of windows will allow the airport to allow sunlight into terminals, food courts, shopping areas, and other locations. Implementing the windows will also provide better control of interior temperatures, allowing for reducing the cost of HVAC. If air conditioning and heating are taken out of the airport's expenses, it will save money and allocate the budget to improve other weak areas. One company that provides these Smart Glass installations is View. The company, View (2021), has already installed smart windows at San Francisco International Airport and has claimed that "View Smart Windows helped the SFO Terminal 1 Project realize $900k in savings, which is driven by a 25 CFM reduction in ventilation."

The service provided will allow the airport to have the glass installed into the airport. Once that is done, the airport will control the glass and change its levels to allow a certain amount of light to enter for different scenarios. The technology can be controlled through software such as Alexa and other control

assistance to allow instant modification of the environment. This feature will enable companies to save time by not worrying about adjusting the blinds to various lighting conditions during the day. Whether to clean and get rid of dirty bacteria on blinds or for maintenance, plastic blinds can be sun-bleached and eventually break. That said, the glass will help airports save money by continuously reducing UV rays during high temperatures to prevent heating in the terminal areas. This will have the benefit of airports running less AC. With the help of the glass technology, the airports will work their way into complying with more sustainability initiatives so they can receive AIP grants for keeping their airport eco-friendly. The data gathered from the United States Environmental Protection Agency (EPA) states, "Homeowners spend an estimated $73 billion or 29 percent of their total energy-related expenditures on space heating alone, whereas commercial buildings spend more than $27 billion or 15 percent annually" (EPA, 2021, para. 2). The data here shows an astronomical amount is spent on the commercial side and homeowners' expenses that can be mitigated with Smart Glass technology. Furthermore, Smart Windows leads to 95% overall occupant delight, 15 degrees cooler temperatures, 102% higher restaurant sales, and 83% longer gate dwell time (View, 2021). The occupant delight is vital because it introduces passenger dwell time in airports. The dwell time usually equates to passengers spending money in restaurants, vending machines, bars, and other amenities offered at airports. The cooler temperatures also provide a comfortable environment, making passengers more relaxed and less stressed, which helps individuals spend more money. As stated by Wong and Chan (2013), "The use of a photovoltaic smart glass system provides significant cost savings regarding heating, cooling, lighting, and overall energy bills. Smart glass represents a technology with a great deal of potential to reduce energy demand" (p. 2). The implementation of the Smart Glass technology provides the backbone for a new sustainable environment in airports and other architectures that will help shape the world's future in a more environmentally friendly way.

3. RESULTS

This section discusses the qualitative and quantitative research results. The qualitative research questions are as follows (1) Can it be possible to reduce the carbon footprint of airports and other buildings by implementing Smart Glass windows,2) Can the use of Smart Glass windows bring in enough sunlight to affect the moods of workers and travelers in the airports, and (3) What are the emotions and feelings of workers in terminals.

The quantitative research questions are as follows (4) Can the use of Smart Glass windows bring down the cost of spending on heating and cooling of a company, (5) Can the implementation of Smart Glass windows bring airports to achieve funding from AIP. These questions allow for an understanding of how the research can benefit companies and the planet by eliminating high operations costs and reducing carbon footprint.

Some questions revolve around the mood of workers and passengers. The process here shows that individuals are the key to income in the airport. The passengers are the ones who occupy and bring in cash to buy food, drinks, tickets, and other amenities offered at airports. On the other hand, the workers provide comfort and help passengers fulfill their desires. If the workers are not happy, they will reflect their moods upon passengers, thus losing profits for airports in the long term.

3.1. Interview/Survey Questions

Here are the questions asked to airport managers and other personnel to gather data on energy usage and implementations of Smart Glass technology. The survey questions are categorized by the qualitative and quantitative questions.

Qualitative

1. When you work in the airport, do you have the urge to go out and get fresh air and sunlight? Do you believe the implementation of smart windows/skylights would help with that?
2. What is your view on sustainability in airports?

3. If I were to tell you that sunlight can improve the moods of passengers and employees in the airport, would you be interested in installing smart glass windows/skylights?
4. How could the design of airports in the future improve upon sustainability acts?

Quantitative

1. What percentage of energy that is being used in an airport is sustainable?
2. How much do you think your airport spends on heating and cooling? Does your airport implement initiatives to reduce these costs?
3. What percentage of airports in the USA practice sustainable energy solutions?

4. CONCLUSION

This study aimed to increase awareness of a new solution for reducing the carbon footprint of airports. The study methodology utilized an interview design conducted with airport managers focusing on understanding the energy usage of airports. The results suggest environmental and financial benefits of Smart Glass for the Aviation Industry. The installation of Smart Glass technology will help airports save money on energy spending and reduce their carbon footprint. It will also provide a better environment for passengers and workers in the airport by providing natural sunlight without the UV rays that make the environment hot.

Three different future research studies were identified. The first study would be to perform environmental studies of Smart Glass to identify further the advantages gained by airports that have implemented technology. The second study would be to publish case studies of existing airports utilizing Smart Glass to spread further awareness of the benefits reaped by this technology. The third study would identify the barriers airports have in implementing this technology to further understand how to address these challenges. Overall, it is important to spread awareness of the benefits of Smart Glass in airports because it provides comfort to people while reducing the use of fossil fuels.

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EXAMINING MONTHLY AND ANNUAL LASER STRIKE REPORTS FROM 2010-2021

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Abstract: Laser strikes are becoming an increasing problem for the aviation industry, where the lives of both crews and passengers are at risk. The aim of this research was twofold: a) determine if there was a statistically significant difference in laser strike frequency by month and b) identify the trend in annual laser strike reports. This study examined the number of laser strikes reported to the FAA from January 2010 to September 2021. The data showed no statistically significant difference in frequency of laser strike reports between calendar months. The linear regression indicated an increasing annual trend of laser strike reports. The risk of a potential laser strike is approximately the same throughout the year regardless of the calendar month. There is a positive trend in laser strike reports from 2010 to 2021, which indicates that we need further research to help mitigate this risk.

Key Words: *Laser strikes, FAA laser reports, aviation safety*

1. INTRODUCTION

Lasers of all strengths and colors pose the threat of temporary blindness and permanent damage to the eye. Pilots, along with crewmembers or civilians, are at risk for a laser strike incident whether the strike is intentional or accidental. The Federal Aviation Administration (FAA) has established a voluntary laser incident database that collects laser strike reports and publishes the data publicly. The FAA has published advisory circulars regarding laser strike encounters and regulations that establish critical flight zones around airports where lasers are prohibited. Lasers create a safety hazard to the aviation industry as it can result in pilot blindness, and aircraft aborting landings (Nakagawara & Montgomery, 2004). Due to the safety risk associated with laser strikes, a better understanding of their frequency is necessary.

The purpose of this study was to a) examine if there is a difference between the frequency of reported laser strikes on aircraft from 2010 to 2021 based on the month of the year, and b) analyze the annual trend of laser strike reports. The laser strikes that are reported by crewmembers, air traffic control, and the public are collected by the Federal Aviation Administration (FAA) in the Laser Incidents Database (FAA, 2021); this study utilized all data from January 1, 2010 to September 30, 2021 to calculate the monthly frequency of laser incidents and the annual laser strike report frequency.

The importance of this study was to determine the calendar months that laser strikes occur most frequently in the United States of America, and the annual trend in laser strike reports. Laser strikes can cause significant injury to crewmembers and anyone onboard the aircraft (Cole, 2011). The results from this study may allow for further safety practices and crewmember awareness to be implemented for the given month, or for the future years.

2. LITERATURE REVIEW

2.1 Definition of Laser Strike Problem

The L.A.S.E.R. or "Light Amplification by Stimulated Emission of Radiation" (Harrington & Wigle, 2004) was first used approximately 60 years ago. As the name suggests, the light is amplified into a narrow beam. This became an important tool for many industries because of its wide range of uses "from photocopiers to antimissile defense systems" (Harrington & Wigle, 2004, para. 2). However, this is not always the case. Laser strikes are becoming a large problem for the aviation industry with an increasing number of laser strikes being reported to the FAA (Schmid & Stanton, 2018). Hawaii observed an increased number of laser strikes reported around Christmas of 2010 (Cole, 2011). Additionally, the FAA (2021) has reported an increase in laser strikes every calendar year. In fact, even with fewer airborne aircraft in 2020 due to the pandemic, the FAA (2021) noted an increase in laser strikes from the previous year. This does not only affect commercial aviation. It also affects general aviation, military aviation, and all other aviation types (Harrington & Wigle, 2004). There are records of laser strikes occurring for over three decades (Carroll & Richards, 2018). However, only in the previous two decades was it noted as an increasing problem (Carroll & Richards, 2018). Therefore, data is limited, and this study will utilize the results from January 2010 to September 2021.

According to Nontapot and Rujirat (2018), this increasing trend of laser strikes occurs because of the availability and accessibility of lasers, which have a wide range of uses for both work and recreation. One common usage includes inside of the classroom (Nontapot & Rujirat, 2018). Educators and lecturers may find this tool important to keep their audience focused on their current topic or a focal area on a PowerPoint slide. However, it is not uncommon to see these devices being used by the younger, untrained population (Nontapot & Rujirat, 2018). In this scenario, it may be used as a toy or for entertainment purposes such as party laser devices or pet entertainment.

Lasers can be categorized in different ways. First, there are several different colors of lasers. Each color may have a different power output and may pose more or less threat to pilots and the flying public. Generally, red, green, blue, and violet lasers are predominantly seen in use and reported today (Reddix et al., 2019). Reddix et al. (2019) reported different power output for different colors of laser. They concluded that the output varies by more than just its color, evaluating red, blue, and three different wavelengths of green. The blue laser recorded the highest output and veiling glare, and it produced the shortest wavelength. However, after interpreting the chart, no direct relationship between the wavelengths and power output or veiling glare was observed.

Lasers are also classified from one to four with a risk of incapacitation for any class above one (Schmid & Stanton, 2018). Therefore, many lasers that exist can be harmful to pilots. According to Harrington and Wigle (2004), wavelength, energy, aperture size, divergence, continuous or pulsed emission all contribute to the strength and class of a laser. Thus, even the lower strength or class lasers, which are more readily available, can be harmful to flight crews.

2.2 Threats of Lasers

Each type of laser produces a different level of threat for a pilot or anyone that may be impacted by laser usage in the United States. A high-intensity laser incident that shines upon a human eye can cause temporary blindness and possibly permanent damage to the eye. These two different impacts on the human eye are categorized into dazzle and damage (Freeman & Williamson, 2020). Murphy (2009) categorized laser incidents into three levels of effect on the human eye: distraction, glare, and temporary flash blindness. The high-intensity light from a laser can damage the retina, causing temporary or permanent blindness. Murphy (2009) found that the glare and flash blindness levels of lasers resulted in an aborted landing rate of 20-25%, with an impact level of more than 50% during the approach. Lasers are a significant threat to human eyes as they can cause permanent damage to the retina or temporary blindness that restricts the eye's ability to focus on the outside light.

The threat of a laser strike to a pilot or an occupant onboard an aircraft depends on different light

factors. Murphy (2009) specified strength of the laser, beam divergence, laser wavelength, color, and whether the laser is pulsed or continuous as important factors. Bright, low divergence, green-yellowish colored lasers were found to create the greatest threat to pilots (Murphy, 2009, p. 5-6). Another factor that impacts the threat of a laser incident is whether it occurs during nighttime or daytime (Murphy, 2009, p. 6, Nakagawara et al., 2004). During nighttime or low light conditions, the rods and cones in the eye are adjusted to the low-light conditions, which causes a greater impact to the eyes from a laser strike (Murphy, 2009, p. 6, Nakagawara et al., 2004). Laser incidents have been proven to be distracting to pilots at low altitudes, including critical phases of flight such as takeoff and landing (Nakagawara et al., 2004). In 2004, Nakagawara et al. found that a laser strike with strengths between 0.5 uW/cm2 and 50 uW/cm2 resulted in 75% of the pilots suffering from glare, flash blindness, and afterimages (Nakagawara et al., 2004). Of the 75% that were impacted by the laser strike in the simulator, eight executed missed approaches, and one handed over the controls to the co-pilot. The simulator was accepted to replicate the cockpit environment in the aircraft, although it is important to take into account that the simulator may have had different humidity, temperature, clouds impact on laser, and the laser electronically created and displayed through the simulator visual system (there was no actual laser being used in the simulator), meaning that actual lasers may have different impacts. These studies indicate that laser strikes result in missed approaches and aborted landings, all due to the temporary blindness of lasers.

Causes of laser incidents vary from personal lasers that can be bought online to lasers that are used for entertainment at outdoor venues (Murphy, 2009). Public-used lasers are available for purchase with different intensities (brightness) and colors. Common lasers have approximately 1 W of power, which is within the danger range for impacting the human eye (Nontapot & Rujirat, 2018). Laser incidents with aircraft can be executed on purpose by an individual with an underlying goal or accidentally by a source (Murphy, 2009). The trend of the increasing number of lasers being accessible to the public poses a threat to pilots in the cockpit whether the strikes are purposeful or not (Murphy, 2009, Nakagawara et al., 2004). Lasers that have dangerous levels of power are readily available to the public for purchase, which poses a threat to pilots.

2.3 Measures Already in Place to Prevent Laser Strikes

The number of laser incidents have increased for a variety of reasons, one being how inexpensive it is to purchase lasers online. The FAA established airspace zones protected around airports and other sensitive areas that protected aircraft from exposure to a laser. Nakagawara et al. (2004) evaluated pilot's performance while they encountered laser illuminations during final approach above the laser free zone (Nakagawara et al., 2004). This study included definitions for Critical Flight Zone, Sensitive Flight Zone, Laser Free Zone, and Normal Flight Zone. The Critical Flight Zone covers 10NM and has an emission power limit of 5µW/cm² established. The Sensitive Flight Zone covers everything outside the critical zone and has an emission power limit of 100 µW/cm² established. The Laser Free zone covers everything in the vicinity of the airport and has an emission power limit of 50µW/cm² established. The Normal Flight Zone covers all navigable airspace and has an emission power limit of 2.5 mW/ cm² (Nakagawara et al., 2004). Nakagawara et al. (2010) mentioned that because of the frequency of laser strikes, the Advisory Circular 70-2 was published in 2005 (Nakagawara et al., 2010). After its issuance in 2005, the reports for incidents were more reliable at the time of their submission, and they were more detailed (Nakagawara et al., 2010, p.4). This document was later updated to Advisory Circular 70-2A, which was published in 2013 and provided information on the FAA's measures taken for laser strikes. AC 70-2A also provided counter-tactics for aircrew, such as avoiding direct eye contact and shielding eyes during the presence of a laser strike (Burress Jr., 2017). The AC 70-1A provided sufficient information regarding laser strikes, including why is it important to notify the FAA about incidents, who should file the incidents, where to submit the reports, what information should be included, and what the FAA will do with the information (FAA, 2018). After any unauthorized laser illumination events, pilots are required to report by radio to ATC and fill out the "FAA Laser Beam Exposure Questionnaire" upon arrival at their destination. The FAA Laser Beam Exposure Questionnaire is an instrument for collecting data regarding laser incidents (FAA, 2018). ATC should report any incidents to the Domestic Events Network. The public should email

the FAA to report an incident, including name, contact information, date, time, and location (FAA, 2018, Nakagawara et al., 2010). The FAA Modernization and Reform Act enacted on February 14th, 2012 makes laser strikes a crime:

Section 311 amended Title 18 of the United States Code (18 USC), Chapter 2, § 39, by adding § 39A, which makes it a Federal crime to aim a laser pointer at an aircraft. The crime is punishable by a fine up to $250,000 and five years' imprisonment. (FAA, 2016, para. 2)

The FAA has taken steps necessary to attempt to reduce the number of laser incidents, as they know the danger these impose to safety.

Previous research suggested there was an increasing trend in laser strikes, and one claimed more strikes closer to winter holidays. The threat for pilots has also increased as lasers are capable of causing permanent and temporary damage based on the different light factors (FAA, 2021, Murphy, 2009, Nakagawara et al., 2010, Reddix et al., 2019). As the accessibility of lasers is increasing to the public (Nakagawara et al., 2004), the resultant laser incident occurrences are likely to increase. The FAA states that "pointing a laser is a federal crime" (FAA, 2021, para. 2), and although this may not end laser strikes completely, the FAA has taken this step to reduce the number of laser strikes. However, it is necessary to continue to research the relationship between the number of laser incidents reported and trends in laser strikes over time so that aviation professionals have current information on the hazards.

3. METHODS

The research used an ex post facto design to examine the relationship between the number of laser strikes reported to the FAA from 2010 to 2021 and the frequency for each calendar month and the annual trend in reports. The reports in the FAA database are reported by crewmembers, air traffic control, and the public (FAA, 2021). The names of reporting individuals have been de-identified. Laser incident data between January 1, 2010, and September 30, 2021, in the United States was exported from the FAA (2021) Laser Incident Database to an Excel file.

The dataset retrieved from the FAA (2021) Laser Incident Database was limited to the laser incident and the date it occurred. When downloaded, the data was separated by year; we combined the data into one sheet for 2010 to 2021. The monthly laser strike report frequency was calculated for each month from the first day to the last day. The annual laser strike reports were calculated by summing reports for all 12 months from the first day of the year to the last day of the year that data was available for each year from January 1, 2010 to September 30, 2021. For 2021, the total reports were multiplied by 1.33 because reports for October through December were not yet released. This result was used as the annual laser strike total for the purpose of determining the yearly trend.

The descriptive and inferential statistics were calculated on the entire dataset for each month. Excel was used to calculate the descriptive statistics; inferential statistics were calculated by exporting the dataset to R studio v 1.4. A one-way analysis of variance (ANOVA) was used to determine the difference in laser strikes by month.

4. RESULTS

The data utilized contained 64,558 individual laser strike reports. This included all reports submitted to the FAA in the period ranging from January 1, 2010, to September 30, 2021 (FAA, 2021). Data from the last three months of 2021 did not exist or had not yet been released. These laser strikes were reported by pilots who had been flying a variety of aircraft ranging from piston aircraft as small as a Cessna C-150, to much larger jets such as an Airbus A380. The data also showed the strikes reported at different altitudes and all states in the U.S.

Descriptive statistics for laser strike reports by month are shown in Table 1 and Figure 1. The overall monthly mean was 458 laser strikes. However, there were as few as 117 laser strikes reported in March of 2010, and as many as 946 in December of 2015, resulting in a total range of 829 laser strikes per month and a standard deviation of 185. There were no modes observed for any month. The ANOVA

found no significant effect of month on laser strike reports, $F(11, 129) = 1.45$, $p = .16$. Eta squared was 0.11, which indicated a medium effect size.

The trend in laser strike reports over time was also examined. Figure 2 shows a positive trend over time with increasing numbers of laser strikes reported. The linear regression had a slope of 466.02 and an intercept of negative 933,706 ($R^2 = 0.72$), illustrating the increasing trend in laser strikes.

Table 1 Descriptive statistics for monthly Laser strike reports for 2010 - 2021

Statistics	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Mean	437	371	436	396	380	399	477	496	518	515	550	538	458
Median	463	374	480	356	357	407	466	486	495	519	468	608	424
Max	673	617	775	743	796	758	817	768	893	775	892	946	117
Min	148	117	159	217	191	194	288	361	328	321	238	214	946
Range	525	500	616	526	605	564	529	427	565	454	654	732	829
Std. Dev.	173	156	177	161	160	151	159	142	192	178	252	257	185

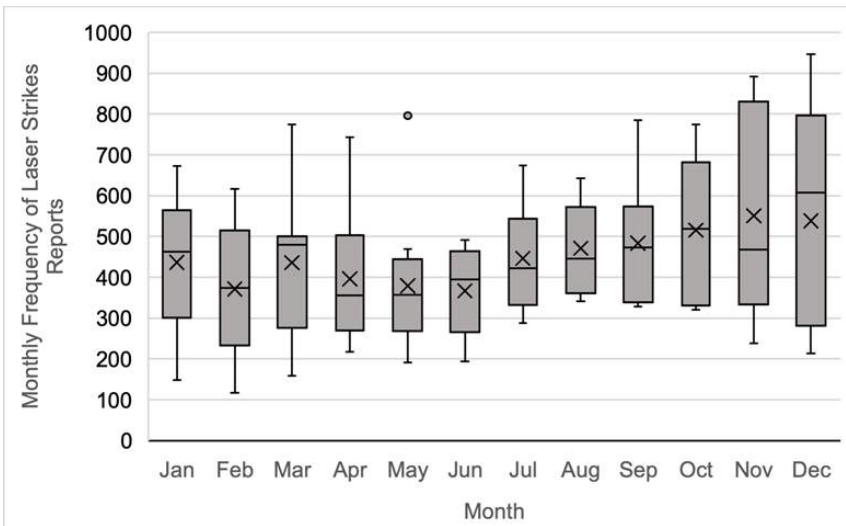

Figure 1 Laser strike reports by month for 2010 to 2021

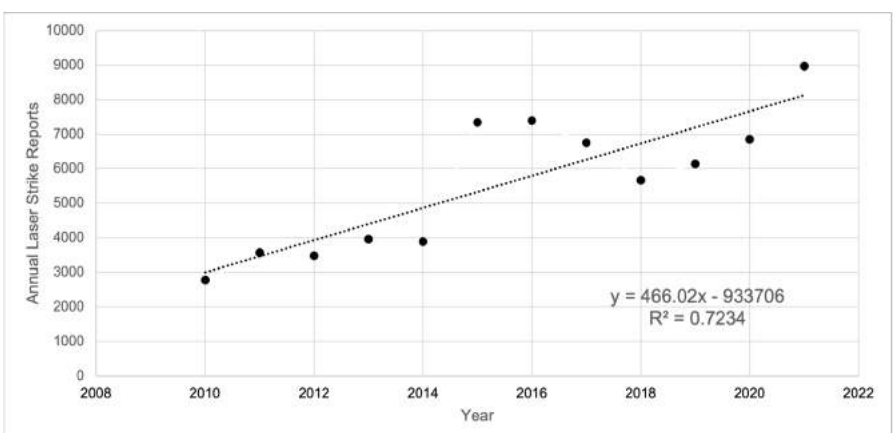

Figure 2 Annual laser strike reports by year

5. DISCUSSION

The goal of this study was to a) investigate if the monthly frequency of laser strikes varies between calendar months from 2010 to 2021, and b) to identify if there is a trend in annual laser strike reports from 2010 to 2021. The first aim examined whether the monthly frequency of reported laser strikes varies between calendar months from 2010 to 2021. The ANOVA found that the number of reported laser strikes in the United States on aircraft from 2010 to 2021 did not differ between calendar months; thus, the data did not support the hypothesis.

The aim of this study was to identify if there is an annual trend in laser strike reports from 2010 to 2021. The hypothesis was that there would be an increasing trend from 2010 to 2021, which was supported by the linear regression calculated (Figure 2). The linear regression has a positive slope indicating that there are approximately 466 more laser strikes each year. The goodness of fit ($R^2 = 0.72$) indicated that 72% of the variance in strikes is explained by the year.

One limitation of our study was the non-existence of results from October 2021 to December 2021. Therefore, to accommodate for this, the total count for 2021 reported until the end of September was multiplied by 1.33. This estimation was used to represent the total count for 2021. Laser strike reports to the FAA do not include all laser strikes that may be encountered by aircraft because the reporting is voluntary. Some airlines require laser strikes to be reported, while other carriers or general aviation aircraft are not required to submit a report. Those who are not required to report the laser strike may not report a laser incident, which limits the number of reports in the database and variety of report sources. That said, the FAA (2021) database is government maintained and the best available data.

This study examined the difference between the frequency of reported laser strikes on aircraft from 2010 to 2021 based on the month of the year, and the annual trend in total laser strike reports from 2010 to 2021. The data indicated that there is no difference in the frequency of laser strike reports and the calendar month. The linear regression showed an increasing trend for number of laser strike reports from 2010 to 2021. The aviation industry can use the data collected in this study to reinforce that pilots and crew members need to be aware of laser strikes during every flight, regardless of the month the flight is taking place. In addition, the aviation industry should be aware of the increasing trend in annual laser strike reports. Other research may be conducted on protective measures/technology that can be installed in aircraft to mitigate the possible damage by a laser on the crew. From the data analyzed in this study, the aviation industry can conduct future research by collecting and analyzing laser strike report data to identify possible trends in laser strikes' geographical positions or type of source the reports are coming from. Further research is required on laser strikes because lasers pose a significant threat to pilots and passengers, and with the laser strike reports annual trend increasing, proactive measures are a necessity for the aviation industry regarding laser strikes.

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ASSESSING THE USABILITY OF A DESKTOP SIMULATOR FOR TRAINING INSTRUMENT FLIGHT RULES (IFR) PROCEDURES

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Abstract: The aviation industry has used simulator training devices as an inexpensive and safe alternative to flight training for decades. Many different simulation types have been developed, with varying quality levels in fidelity and realism. The study aim is to evaluate the the usability of the RedBird JAY desktop simulator for training Instrument Flight Rules (IFR) procedures. Spradley's (2016) domain analysis is used to identify common themes in the participant's responses. Twelve pilots, holding an FAA private pilot certificate and instrument rating as a minimum and with mixed prior simulator experience, operated a Redbird JAY flight simulator configured with the Cessna 172 using standard analog instruments with a separate horizontal situation indicator (HIS) and Garmin G1000 integrated flight instrument system. Each participant was given three scenarios, consisting of approximately five minutes of flying in identical conditions for all participants. The results and future research areas are discussed in this paper.

Key Words: *Simulators, flight training,*

1. INTRODUCTION

The aviation industry has used simulator training devices as an inexpensive and safe alternative to flight training for decades. Many different simulation types have been developed, with varying quality levels in fidelity and realism. This study aims to evaluate the the usability of the RedBird JAY desktop simulator for training Instrument Flight Rules (IFR) procedures. The RedBird JAY simulator is a relatively affordable option for pilots wishing to practice flight procedures.

The RedBird JAY simulator is a relatively affordable option for pilots wishing to practice flight procedures. For the simulator to be useful, it must be usable for pilots. The unlimited practice it provides will only be useful if the pilots operating the simulator understand it and deem it realistic enough to be helpful. This study will help determine whether or not the JAY simulator is a useful tool for pilot IFR operations.

2. LITERATURE REVIEW

The Flight simulators can be useful tools for flight instruction if properly used; however, they are not perfect like all tools. Fassel et al. (2019) studied the usability of a flight simulator with 23 collegiate aviation students. Participants were asked to perform five tasks in random order and report the difficulty experienced while conducting the task. Although the participants generally reported through the post-

survey System Usability Scale that the simulator was easy to operate and understand, an artifact of the study became evident in confusion over control buttons.

Forrest (1999) conducted a similar usability study with six certificated flight instructors operating a Personal Computer Aviation Training Device (PCATD). Participants provided a cognitive walkthrough and answered a post-survey heuristic questionnaire. Areas of concern included spasmodic control feedback and complaints about the small size of buttons and switches.

Spradley's (2016) domain analysis is useful in determining common themes and conjectures from domains, cover terms, and included terms from participant's responses. Each conjecture is then further defined into child nodes as included terms and cover terms to be in alignment with Spradley's domain analysis. Each of the conjecture has a cover term, but every conjecture does not have a corresponding included term. Palmquist (2018) identified advantages and disadvantages of using a content analysis. Advantagest include that the analysis directly views communication, provides historical and cultural insights, and allows categories and relationships to emerge from the coding of participant responses. Disadvantages include this method being time consuming, errors could occur if the researchers are too liberal in drawing influences or relationships, and is difficult to automate.

3. METHODOLOGY

The usability study documentation was developed and submitted to the Institutional Review Board (IRB). Once IRB approval was authorized, participants were recruited. The partipants consisted of twelve pilots, holding an FAA private pilot certificate and instrument rating as a minimum and with mixed prior simulator experience. During the study, the participants operated a Redbird JAY flight simulator configured with the Cessna 172 using standard analog instruments with a separate horizontal situation indicator (HIS) and Garmin G1000 integrated flight instrument system. Each participant was provided with three scenarios, each consisting of approximately five minutes of flying.

The first scenario consisted of five minutes of free-flight in Visual Flight Rules (VFR) conditions with the aircraft configured with analog gauges, allowing the participant to familiarize themselves with the simulator. The scenarios were initiated from Melbourne International Airport (KMLB) runway 09R, with participants requested not to crash the aircraft intentionally. In the second scenario, the participants were tasked with flying a straight-in ILS approach to KLMB runway 09R (33' MSL) to a full stop with the aircraft configured for analog gauges. Each scenario was initiated with the aircraft airborne at 1950' MSL in IMC conditions 7 NM from the runway, with a cloud base of 800' AGL. The aircraft was configured before initiating the flight for the approach, aligned with the localizer and glideslope, and an optional short explanation of the instruments for participants unfamiliar with the analog setup. The third scenario was identical to scenario two but with the aircraft configured with the Garmin G1000 instead of analog instruments.

The study data was analyzed and the descriptive statistics and the results from using Spradley's (2016) domain analysis are discussed in the results section. The domain analysis was useful in determining common themes and conjectures from domains, cover terms, and included terms from participant's responses from the three open-ended responses on the most liked and least liked aspects of the simulator and improvement recommendations using desktop simulators for aviation instrument training.

4. RESULTS

This section discusses the study results. The first part of this sections discusses the descriptive statistics. The second part of this section identifies the common themes from using Spradley's (2016) Domain Analysis.

4.1 Descriptive Statistics

4.1.1 Realism

The results from the first study question highlighted that the most common answer for "How realistic was the simulated flight compared to actual flight?" was somewhat realistic. Seven out of the 12 participants chose that the simulator portrayed a somewhat realistic flight compared to an actual flight. The mean was calculated as 3.58, and the variance was 0.74 with a standard deviation of 0.86.

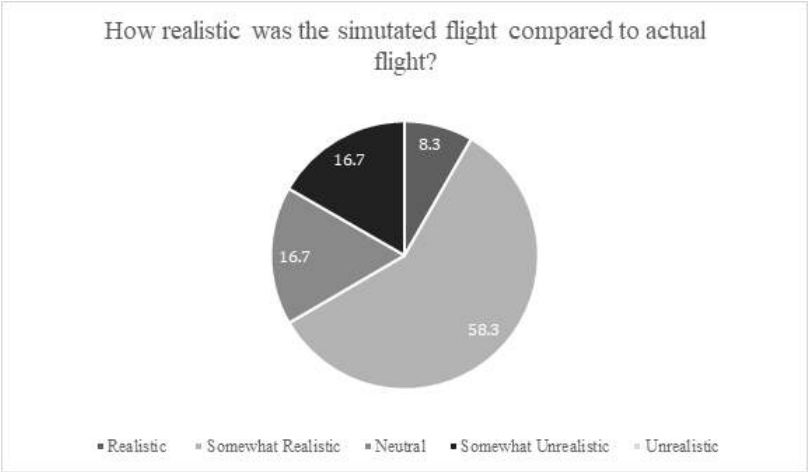

Figure 1 Realism of Simulator

4.1.2 Similarity to Other Training Simulators

Most participants selected that they strongly agreed or just agreed with the statement that "Depending on your experience, this simulator performs similarly to other training simulators." Four out of 12 participants selected that they *strongly agreed*, with five participants selected that they *agreed* with the statement. Therefore, there was a total of 75% of the participants that *agreed*. Also, the mean was calculated as 3.75, with a high variance of 1.69 and standard deviation of 1.30.

4.1.3 Maneuverability

The participants' views on the maneuverability component of the simulator differed. There was a mix of answers when the participants were asked, "how easy was it to maneuver this simulator?" Out of the 12 participants, 66.6% of the responses stated that the simulator was *easy* and *moderate* on the scale of how easy it was to maneuver. This is directly related to the mean calculated. The mean of 3.50 shows that there was a direct split between the answers *easy* and *moderate*. In addition, other descriptive statistics include the variance of 0.92 and the standard deviation of 0.96.

4.1.4 Beneficial

Similar to when the answers were analyzed for how similar the simulator is compared to other training simulators, the results from the question regarding how beneficial the simulator is varied in responses. Based on the range from *non-beneficial* to *very beneficial*, the participants were asked to score "how beneficial do you believe this simulator is?" The mean was 3.33, which correlates with the answer closest to *moderately beneficial*. The variance and standard deviation both suggest the widespread of answers due to both of these being high. The variance calculated was 1.72, and the standard deviation was 1.31.

4.1.5 Clarity

Based on the results of the question "how clear are the instructions to fly the simulator," most participants found it to be very clear. All 12 of the participants were asked this question on the unclear to very clear scale, and all the participants selected either *very clear* (11 participants) or *clear* (one survey respondent). The mean of the results was 4.92, which correlates directly to the answer, *very clear*. The variance and standard deviation were very low due to most participants selecting that the instructions to fly the simulator were *very clear*. The variance was 0.08, and the standard deviation of 0.28.

4.1.6 Comparing Approaches

When participants were asked, "Which approach was the easiest?" all 12 participants selected that the ILS with glass display was the easiest. Descriptive statistics were not needed to express the results from this question because 100% of the participants' answers were toward the ILS approach with the glass cockpit display.

4.1.7 Effectiveness for IFR Training and Pilot Practice

There are two questions that asked participants about the effectiveness of the simulator for IFR training or IFR pilot practice. For the IFR training question, a Likert scale of *ineffective* to *very effective* was used. No participants selected that it would be *very effective*, but 66.6% of the responses were either *effective* (four participants) or *moderately effective* (four participants). The descriptive statistics include the mean, 2.83, a variance of 1.14, and the standard deviation of 1.07. Both the standard deviation and variance were high due to the widespread responses.

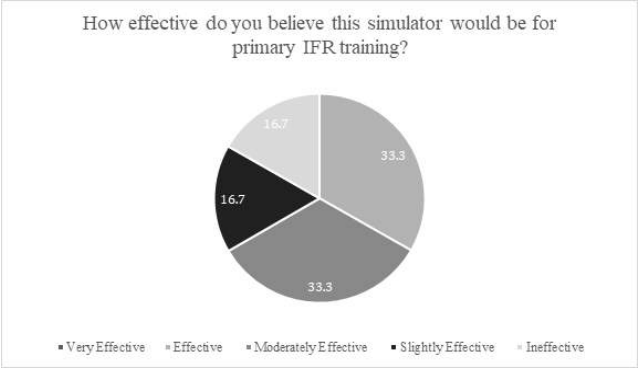

Figure 2 Effectiveness for Primary IFR Training

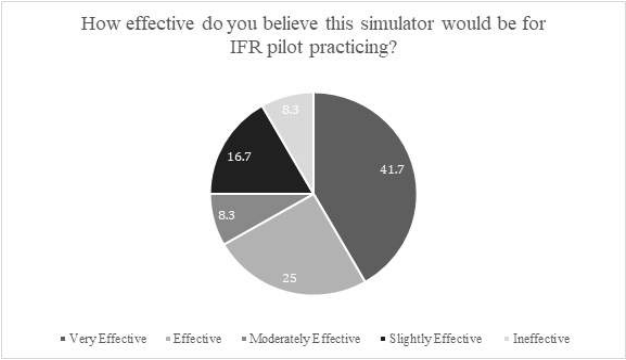

Figure 3 Effectiveness of Simulator for IFR Pilot Practice

Additionally, when participants were asked the same question but with the simulator's purpose being useful for IFR pilot practice rather than training, 41.7% of participants selected that it would be very effective (five participants). Due to many participants having different views on the simulator, its effectiveness differed with partcipants' responses. The mean was calculated as 3.75 with the standard deviation of 1.36 and the variance to be 1.85. The standard deviation and variance are high due to the participants' selection varying based on the simulator being effective.

4.2 Domain Analysis

Three open-ended responses were included in the questionnaire to gather information on the most liked and least liked aspects of the simulator and improvement recommendations. A summary of participant responses following Spradley's (2016) Domain Analysis is discussed regarding using desktop simulators for aviation instrument training. Domain 1, most liked aspects of displays, is summarized in Table 1. The most liked aspects included flight instruments sensitive to small corrections and ease of use operating the simulator. The cover terms *Instrument Representation* and *Ease of Use* were applied with included terms being *Realism* and *Flight Instruments*. For example, participant 4 (P4) reported "it does a good job for teaching small corrections for IFR," P5 stated "the instruments looked and felt realistic," and P7 reported "familiarity with G1000."

Table 1 Domain 1 Analysis

Domain 1	Cover Term	Included Term	Conjectures
Most Liked Aspects of Displays	Instrument Representativeness	Realism	1.1. Flight controls similar to actual aircraft
			1.2. Realistic instruments provided familiarity
	Ease of Use	Flight instruments	1.3. Responsive to small corrections
			1.4. Simple to operate

Domain 2, least liked aspects of displays, is summarized in Table 2. The cover term was *Controls* and the included terms were *Tactile* and *Performance.* Responses include P3 stating that the "yolk is extremely hard to control. Much harder than the actual aircraft. Rudder pedals extremely touchy," P4 stated "control inputs had to be a lot smaller than the actual aircraft," P6 stated that "the rudder was way too sensitive and the steam gauges seemed to have a slight lag," and P8 stated that "the instruments didn't always turn smoothly in the steam gauge cockpit, they seemed to lag a bit."

Table 2 Domain 2 Analysis

Domain 2	Cover Term	Included Term	Conjectures
Least Liked Aspects of Displays	Controls	Tactile	2.1. Inaccurate control feedback
			2.2. Difficulty moving controls precisely
		Performance	2.3. Analog instrument lag
			2.4. Improve control feedback
			2.5. Physical buttons and switches

Domain 3, simulator improvements, is displayed in Table 3. When asked for simulator improvement suggestions, participants noted limited tactility. The cover term is *Tactile* and the included term is *Usability*. P7 suggested "being able to manipulate switches and knobs easier," P11 suggested "being able to access more buttons," P12 stated "less responsive control inputs," and P3 suggested "adjusting yoke and rudder control."

Table 3 Domain 3 Analysis

Domain 3	Cover Term	Included Term	Conjectures
Simulator Improvements	Tactile	Usability	3.1. Easy to manipulate controls
			3.2. Accessiblity
			3.3. Adjustability

5. CONCLUSION

The study findings suggests that the RedBird Jay simulator is usable for instrument flight training. The simulator screen reacts to small movements necessary for approach flying and would be useful in teaching pilots the importance of small adjustments. Areas of improvement are related to the physical hardware associated with the simulator. Adjustments to the yolk and rudder pedals would be advised to ensure the deflection of such controls is as similar as possible to the actual aircraft. The inclusion of physical buttons and switches would also provide pilots the opportunity to build procedure muscle memory.

Future research studies consist of conducting a survey, recruitment of pilots, and having participants share their perceptions on the importance of simulator characteristics for the purposes of training and practice. Another future research area is to test different simulator displays, RedBird and others, to gather data on what pilots need most from virtual training. Furthermore, a study could be conducted to measure the transfer of training from simulated training to real-world performance through the use of different simulators and displays to analyze pilot performance with regards to those different simulators and displays.

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TEACHING TRENDS IN DATA, TECHNOLOGY, AND SOCIETY – FINDING A NEW BALANCE

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Abstract: In the Fall of 2020, a First-Year Seminar that discussed various trends in the applications of data and technology to society was taught at Stetson University for the first time. It covered exciting trends in data analytics in identity theft, marketing, fraud detection, and accounting. Data visualization of large data sets was explored. The course also covered aspects of ethics related to data privacy and data governance, especially social media and medical records. Companies such as Cambridge Analytica and their ability to use personal data to target specific ads at small groups of individuals and the ensuing impact on voters were investigated. Machine learning and its potential to automate processes previously only able to be performed by humans and its potential to disrupt various job markets were considered. The implications of data usage in generative adversarial networks and the application to "deep fakes" were also explored. This class was also taught in a modified form in the Fall of 2021.

This paper will briefly discuss some of the topics covered in those classes. Additionally, the ongoing process of developing the course, along with lessons learned related to student engagement, an "overcorrection" between the first and second time teaching the classes, along with a plan to attempt a "flipped classroom" structure next fall to improve student engagement will be discussed.

Key Words: *First-Year Seminar; Trends in Data; Deep Fakes; Cambridge Analytica*

1. INTRODUCTION

In the Fall of 2020, a First-Year Seminar entitled "Data, Technology and Society," which discussed trends in the applications of data and technology to society, was taught at Stetson University for the first time. The course was divided into three main areas, which allowed the students to explore the basics of data, some applications of data, and how personal data was used.

The course covered the basics of data analysis and visualization trends in data analytics in a variety of fields. Basic tools of data analysis, including some concepts in statistics, data visualization, and Excel, were explored to allow students to better appreciate some of the later material in the course. The students were also required to read and write about an old classic book, "How to lie with Statistics."

The course progressed into some applications of data that are used throughout the world today. Students reflected on aspects of machine learning and the automation of processes that were previously thought to reside entirely in the domain of human abilities.

The course moved into issues related to personal data, including identity theft and microtargeted advertisements. The Cambridge Analytica scandal was a topic that received very positive feedback from the students. The book "Social Physics" by Alexander Pentland was also read and discussed.

Changes have been made to various aspects of this course in the two times that it has been taught. Reflection on what has been effective and engaging to students has been made, as has much consideration to future directions for the next time this course will be taught.

2. BACKGROUND ON FIRST-YEAR SEMINARS AT STETSON UNIVERSITY

First-Year Seminars at Stetson University were developed to fulfill a number of goals, including introducing students to university life and resources through a course on an exciting topic that requires the students to think critically, interpret primary sources, and communicate both in written and oral form. The class includes a significant writing component, in-class and online discussions, mentorship with individual meetings throughout the semester, and a final project that includes a presentation.

3. DATA AND DEEP FAKES

The instructor participated in a group discussion some years prior to the first presentation of the class in which three images were displayed. Two pictures were researchers, and one was an artificially generated image of a face using a generative adversarial network. The participants in the discussion then chose which picture they thought was fake. About one-third of the participants chose each of the three pictures. To introduce one application of data that had significant implications for our society, the instructor created a set of 10 images using the site thispersondoesnotexit.com which used StyleGAN2 developed by Kerras et al. (2019), and put them on a PowerPoint slide to display for the class. The students were told the story of the three images and then were asked to determine which if any of the images were fake. The students also were unable to determine which of the images were fake and were surprised to find out that all of them were generated using an algorithm that used the data from many images to create new faces. The students were then asked to reflect on the implications of deep fake technology to society in a written essay.

4. THE CAMBRIDGE ANALYTICA SCANDAL

One of the most popular topics in the personal data section of the class was the Cambridge Analytica scandal. After having discussed some of the basics of online personal data and issues with identity theft previously, the class discussed the alleged misuse of data by the marketing firm Cambridge Analytica. The students were able to watch statements from the CEO, Alexander Nix, from just before the 2016 US election. They then watched media coverage from when the scandal broke in 2018, followed by an interview by Christopher Wylie. They then were able to watch a rebuttal in an interview with Nix after the alleged data misuse was public knowledge. The students were then encouraged to research the topic further and reflect on issues related to how personal data online was used to micro-target niche groups and potentially influence voters' decisions. The student responses varied greatly on their opinions as to whether the data was properly acquired and used ethically in their reflection essays.

5. REFLECTIONS ON CLASS FORMAT AND FUTURE DIRECTIONS

With the advent of COVID-19, and the precautions that were taken, the Fall 2020 version of the course was taught in a hybrid format but with a more typical lecture style than had been initially planned. Student engagement was challenging as half of the class was watching online on a typical day. During that semester, students seemed to give more positive feedback on the days that had some online videos related to the course material, with the students sent off to research related material after the presentation.

The Fall 2021 course version spent more time with the students independently researching topics after the class lecture material. This could be seen as somewhat of an overcorrection to the initial presentation of the material. Unfortunately, since the student would often be more focused on the independent research aspect, the in-class material was "tuned out" by some. While encouraging their independent research was a good thing, their inability to tie the class material to their writing was sometimes evident.

In Fall 2022, the instructor is hoping to create a set of videos that the students would be required to watch before attending class (a flipped-classroom approach). Then a "Think-Pair-Share" activity where the students pair up, discuss the material briefly in pairs, then have the small groups of students present

the material to the larger group. The instructor hopes that this form of classwork will encourage the student to think more deeply about the material before they then move on to independently researching the topic they would be writing about that day. The instructor also hopes that this will give the students more of a balance between the learning material and the graded activities.

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SOLAR DECATHLON DESIGN CHALLENGE: A COLLABORATIVE STUDENT-COMMUNITY ENGAGEMENT PROJECT

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Abstract: To prepare our students for their chosen careers, it is important to provide opportunities that integrate their past studies and apply these through civic engagement. The Solar Decathlon competition sponsored by the U.S. Department of Energy (DOE) can be such a platform that challenges student teams to become involved with their community and apply their knowledge and design highly efficient and innovative buildings. According to the DOE, the Solar Decathlon competition provides participating students with unique training that prepares them for the clean energy workforce; educates students and the public about the latest technologies and materials in energy-efficient design, smart building solutions, and demonstrates to the public the comfort and savings of buildings that combine energy-efficient construction and innovative designs including onsite renewable energy production. Considering the dual benefits of this program, the Engineering Technology final year students at Fitchburg State University have participated in the Solar Decathlon Design Challenge. Under the supervision of faculty, students in coordination with local authorities selected a downtown urban property for redevelopment following the guidelines of the Solar Decathlon project competition. This paper presents the importance and challenges of this type of collaborative community engaged project to enhance the learning opportunities for undergraduate students. Moreover, it highlights the benefits of this type of real-world project in capstone course curricula.

Key Words: *Civic engagement, Solar Decathlon, classroom learning, education.*

1. INTRODUCTION

There is a frequently asked question, "does the traditional university classroom learning and education process of lecturing professors, passive note takers and anxious examinees develop the skill set that graduating professionals need?" (Holt et al., 2012). Most academicians and professionals agree that the traditional academic environment does not provide practical skills and exposure to the real-world problems that are meaningful and engaging to the students to become effective professionals upon graduation (Bernold, 2005; Holt et al., 2012). They must "balance technical solutions with social, cultural, environmental, economic, and sustainability concerns, in an environment that features multidisciplinary peer interaction and mentoring" (Fiori & Songer, 2009). Participating in the Department of Energy (DOE) Solar Decathlon program is a real-world learning environment that cannot be replicated in the classroom (Grose, 2009). The students and faculty involved were challenged beyond what they would have experienced in the classroom setting and what they learned could not be replicated in the traditional university learning environment (Holt et al., 2012). The ultimate beneficiaries from the outcomes of this type of program are university entity (especially students and faculty), industry, and community. Therefore, it is worth taking bringing all entities on board as partners during the execution of the project.

The partnerships among universities, communities, and organizations connect faculty and students

with communities and organizations and also provide a common platform for concerned stakeholders to share knowledge, learn by serving communities, integrate community serve-learning models into the academic curriculum, and provide an innovative pedagogical approach to realizing higher education's civic responsibilities (Driscoll et al., 1996). These partnerships ultimately improve the quality and productivity of instruction as well as address community problems (Bringle, Games, & Malloy, 1999; Bringle, Hatcher, & Games, 1997; Driscoll et al., 1996; Edgerton, 1995, Nicotera et al., 2011).

This paper explains a framework to conduct a Faculty-Students-Community Engaged (FSCE) project. A FSCE project provides a common platform for all stakeholders (such as faculty, students, community representatives, local industry, professional organizations, and city officials) to identify existing issues in a community or city (Mani & Chenot, 2020). FSCE projects also create dual opportunities for students in both learning and community service. This research not only contributes to the body of knowledge but also develops a foundation for designing a systematic strategy for the effective implementation of a FSCE project. In addition, this paper presents a case study that shows the feasibility of the proposed framework and also shows how Fitchburg State faculty and students contributed to the welfare of the city. Moreover, this paper explores and presents how to integrate learning outcomes from the Solar Decathlon project into a program's curriculum.

2. BACKGROUND OF PROJECT SITE

Fitchburg, with a current population of about 41,000, was first incorporated in 1764. Because of its location along the Nashua River and access to early water power, it grew as part of this country's early industrial revolution and even more rapidly after the 1830s when the railroad connected it with the rest of the country. As manufacturing expanded, Fitchburg grew and integrated many waves of immigrant workers and their families.

During the mid-to-latter part of the 20th Century, the city's industrial base gradually moved away and suburbanization and shopping malls progressively devalued the city's once vibrant urban Main Street. The most recent structure located at 510 Main Street was the Johnsonia Hotel block built in 1898. It was a mixed-use building with retail and offices on the first two levels, hotel rooms on floors 3rd and 4th and an elegant restaurant dining room at the top level. More recently, the building was converted to condominiums maintaining its business/residential mix, but it was unfortunately destroyed by fire in 2011.

Today, the City of Fitchburg is working to revitalize its once vibrant downtown. At the same time, the Commonwealth of Massachusetts is facing a housing crisis, and, in particular, affordable housing. Recently, Fitchburg was again connected by commuter rail to the east and North Station in Boston. To help alleviate the housing shortage and create livable, walkable, energy-conscience communities, the state has designated Fitchburg along with other cities on the commuter rail network as Gateway Cities. This designation provides additional planning assistance, grants and funding avenues for Gateway Cities to succeed adding planning tools to achieve thriving, mixed-use, walkable cities. These include the City's downtown zoning Smart Growth mixed-use overlay district, the Massachusetts Transformative Transit-Oriented Development (TTOD) initiative, and the Transformative Development Initiative (TDI) with grants and planning assistance. These initiatives and planning tools are in place and drive the development of 510 Main Street.

2.1 Solar Decathlon

The Solar Decathlon Design Challenge is annual competition organized by U.S. Department of Energy (DOE), first began in 2014. In this competition, the selected teams design the energy-efficient, architecturally appealing, engineering excellence with innovation, and affordable solar-powered homes as per given guidelines (DOE, 2020). U.S. Department of Energy (DOE) states that "the Solar Decathlon Design Challenge continues to build a global community of current and future professionals dedicated to providing solutions to complex problems related to climate change, affordability, and environmental justice through building design." This competition provided an opportunity to demonstrate and educate participants that these types of solar-powered homes can be affordable as well as energy-efficient.

Fitchburg State University (FSU) was selected as one of the finalist teams from around the globe to participate in the Solar Decathlon Design Challenge 2021, held remotely because of Covid-19 pandemic. The building described in this paper was designed by the students of FSU for this competition with the help of faculty from the Engineering Technology Department.

Teams entering the Design Challenge must select from seven allowable building types (divisions) to create their design (DOE, 2020), such as (i) Suburban Single-Family Housing, (ii) Urban Single-Family Housing, (iii) Attached Housing, (iv) Retail Building, (v) Office Building, (vi) Elementary School, and (vii) Mixed-Use Multifamily Building. Buildings in this completion were judged based on 10 factors (contests) which are: Architecture, Engineering, Market Analysis, Durability and Resilience, Embodied Environmental Impact, Integrated Performance, Occupant Experience, Comfort and Environmental Quality, Energy Performance, and Presentation (DOE, 2020).

The value of competitions, such as the Solar Decathlon is that they engage students in authentic and complex learning activities relevant to their degrees (Cooper et al., 2014). Barth et al. (2007) indicated how difficult it is to develop key competencies for sustainable development as this requires the opportunity for both formal and informal learning in an interdisciplinary environment where students can develop self-responsibility. Kos and de Souza (2014) outlined how the Solar Decathlon competition has provided an invaluable vehicle to engage the public, industry, and academia in promoting excellence in renewable energy and sustainable buildings teaching and research. By linking research activities in solar power, sustainable housing, energy modeling etc. with learning activities and practical outcomes, the Solar Decathlon provides a great opportunity to create a multi-disciplinary research-teaching nexus (Cooper et al., 2014).

3. RESEARCH FRAMEWORK

Authors have developed a research framework to conduct Faculty-Students-Community Engaged (FSCE) projects as shown in Figure 1 (Mani and Chenot, 2020). This is a generalized framework which can be updated based upon project requirements.

Through the case study on the Solar Decathlon project, this paper explains how the FSCE framework is compatible for students-community engaged project and how multiple stakeholders are interlinked for the sustainable development of the city. The concerned stakeholders for this specific project are faculty, students, community representatives, utility company representatives, and Solar Decathlon Design Challenge project review team. Through extensive discussion, investigation and design, effective plans and strategies are then prepared for implementation toward sustainable redevelopment in the city. The collected information, detailed plans, strategies, and outcomes from the project are recorded and shared among all concerned parties for review and adaptation.

For this Solar Decathlon Design Challenge, the students reimagined the site of the former Johnsonia Building, a hotel-turned-apartment complex that was demolished after a fire in 2011. The team collected project specific information from various sources, such as City officials and community representatives. In designing a new structure for the location, the students considered a mixed-use, multifamily development that would serve Fitchburg's ethnically diverse population with retail and commercial space that also provided affordable housing. The design accomplished this while adhering to the net zero energy footprint (wherein energy used by the building is offset by what is produced on-site) through maximizing daylight, capturing solar energy, and geothermal heating and cooling systems.

Upon completion or during the working process, achieved learning outcomes are further integrated and adopted into the relevant course curriculum for future students. The learning outcomes from this project are incorporated for the Engineering Technology Capstone curriculum.

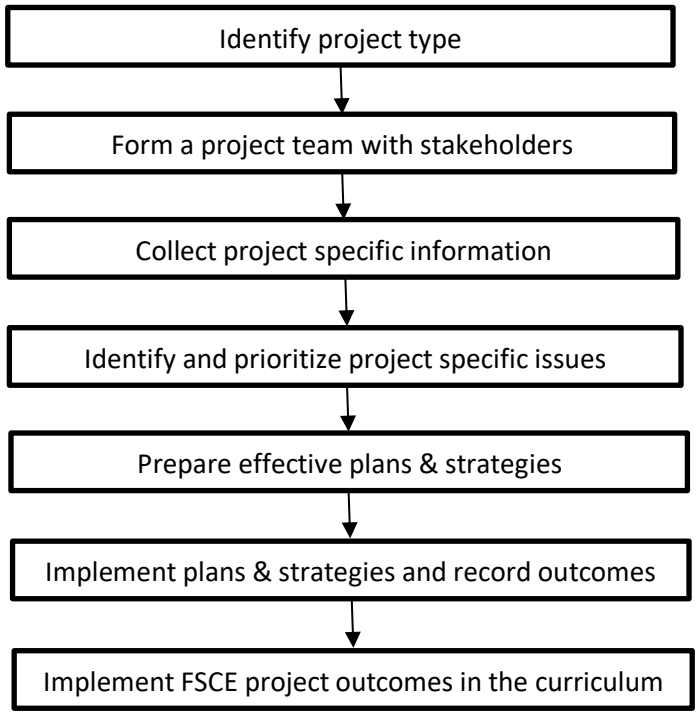

Figure 1 Research framework (Adapted from Mani and Chenot, 2020)

4. CASE STUDY

After discussion with concerned parties, the Johnsonia Hotel building block (located at 510 main street, Fitchburg, MA) was selected for the case study. Built in 1898, this building was a mixed-use with retail and offices on the first two levels, hotel rooms on floors 3 and 4 and an elegant restaurant dining room at the top level as shown in Figure 2. But it was destroyed by fire in 2011. The land coverage is just over 15,000 sf and is adjacent to an underutilized five-level municipal parking garage.

The site is located within one block from a second public parking structure and is within easy walking distance to the commuter rail/intermodal center, the Fitchburg Public Library, City Hall, a post office branch, a soon-to-be revived live theater building, several churches, a mosque, and Monument Park and Riverfront Park. Also close by, are the Fitchburg Art Museum, the Longsjo Middle School, and Fitchburg State University. The property has great potential to contribute positively to the City's Smart Growth development and again becoming a rich urban experience for all. This planning has paid off as downtown Fitchburg is beginning to re-find its urban advantage. Two new restaurants and a brewery have recently opened, and older mill and school buildings are being transformed for new uses.

The target market is for equitable business and housing opportunities for today's Fitchburg citizens and new arrivals who thrive on urban convenience and community. Fitchburg, as with most communities, is represented by a new mix of ethnicities and age groups. This project will add density and diversity of people and activities to this community rich with heritage.

Under the guidance of Prof. D. Keith Chenot and Dr. Nirajan Mani, nine Engineering Technology Capstone and four Construction Management Capstone students were involved in this project. Construction Management Capstone students were responsible for estimating and life cycle assessment and Engineering Technology Capstone students were responsible for architecture design, market analysis,

energy, and others. Industry experts from Unitil Electric Company were also invited for presentations and sharing their working experiences in various aspects of the project.

Figure 2 Johnsonia Hotel Block

5. RESULTS & DISCUSSION

The project addresses the following goals of the Solar Decathlon project requirements.

5.1 Architecture

This project adds to the convenience and quality of urban living. Retail and commercial services at street level are highly visible on this prominent downtown corner. Upper level apartments are configured to maximize views and daylighting. Units are designed to be affordable and designed for modern households, such as space for work-at-home. Internal corridors and stairways will have daylighting and quality materials to celebrate socialization, physical activity, and reduce reliance on the elevator. Rooftop and terrace gardens will provide areas for outdoor living. A mid-level connector to the adjacent municipal parking structure will provide easy and secure access to reserved tenant parking, including additional EV charging for the structure.

5.2 Engineering

The structural systems will utilize low carbon reinforced concrete at the base and carbon-sequestering mass timber and other framing systems above. The building envelope will be designed to highly regulate thermal transmission, manage moisture migration, be durable, and integrate with the building design. Heating and cooling will be first through natural ventilation with operable glazing and then with advanced heat pump technology evaluating both geothermal and air systems. Mechanical ventilation will be through heat and moisture transfer systems linked to CO_2 and occupancy monitoring. Plumbing will feature low-flow fixtures and hot water systems using heat recovery and heat pump technology. Roof and terrace rain water collection will be stored and distributed for water closet flushing and rooftop garden irrigation.

5.3 Market Analysis

Demand for affordable and equitable housing and small business development in Massachusetts is high, particularly in commuter rail hubs like Fitchburg. To meet this demand, State and City funded incentive programs have been developed geared toward livable cities, affordable housing, and local commerce. This type of development is encouraged by the City's recent Smart Growth zoning mixed-use overlay district, and through other state incentive programs.

5.4 Durability and Resilience

Fitchburg's varying climate conditions mandate an integrated design approach to selecting materials and designing systems that function both passively and are resiliently.

5.5 Embodied Environmental Impact

The project is focused on abating its life cycle environmental impact by selecting materials that minimize extraction, that favor renewable or low embedded energy and that, where possible, are locally sourced. The project's location utilized the city's existing urban infrastructure, and encourages walkable low energy connections to shopping, services, and mass transportation all reducing the project's environmental impact.

5.6 Integrated Performance

The project's location and proposed uses are integrated to enhance the diversity and benefits of urban living. The building's integrated design approach creates a highly functional result that minimizes energy use through passive design and sound engineering principles to maintain comfort while minimizing energy consumption and environmental degradation.

5.7 Occupant Experience

The project's downtown location allows easy walking access for all. Ground level retail/commercial spaces have high visibility, daylighting, rear service access, and efficient, low energy HVAC systems. Upper level apartments will be designed to maximize daylighting and natural ventilation. The units will have functional layouts reflecting today's modern living, efficient low energy, low cost environmental systems, appliances, and lighting. Rooftop and Level 2 courtyard spaces are dedicated for outdoor living and garden plots for tenants.

5.8 Comfort and Environmental Quality

Daylighting, sound control between units, monitored ERV air quality, efficient heat pump technology, and shared terrace and rooftop green space add to occupants' comfort.

5.9 Energy Performance

Performance to achieve EUI goals will be evaluated using energy modeling software. Energy goals will also be compared with Massachusetts's newly proposed Mass Zero-Energy Code, one of the nation's most energy conscience regulations. Clean PV energy generation is minimized with the reduced footprint of the proposed design's upper levels, but this project will (i) in partnership with the city, investigate adding a large PV array over the adjacent 5-level municipal parking garage and share the produced energy with each building and provide EV charging stations, and (ii) purchase off-site renewable to replace nonrenewable energy sources.

5.10 Presentation

Students presented their complete project work to the judge panel and audience virtually because of Covid-19 pandemic. They explained their proposed design drawings (preliminary proposed drawing as shown in Figure 3), estimated costs, and timeline to complete the project in their report. Their performance was evaluated by the judge panel and awarded certificate of participation to them.

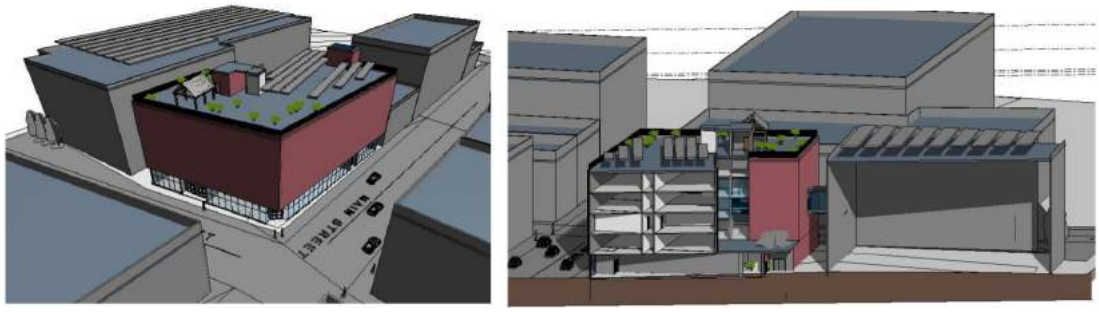

Figure 3 Proposed Design of the Johnsonia Hotel Project

6. CONCLUSIONS

This paper shows how the project team introduced the Solar Decathlon Design Challenge Competition and linked as a faculty-students-community engaged project and integrated its learning outcomes into the program curriculum. The faculty-students-community engaged project helps to build a strong relationship between Fitchburg State University, Fitchburg city officials, residents and community, and concerned stakeholders. This project also helps the urban planner and concerned authorities to plan and execute effective strategies for the development of Fitchburg city. Because of this type of project, students will realize their responsibility towards their community. This type of project can be a foundation and common learning platform for students who want to do real project for their senior level projects, such as capstone courses.

7. ACKNOWLEDGEMENTS

Authors acknowledge the assistance of all undergraduate students who were actively involved in the project and express their special gratitude to the city officials, community representatives, and organizations involved in the project. Without their support, this case study would not have been possible.

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TEACHER EXTERNSHIP PROGRAM: AN OPPORTUNITY FOR EDUCATORS TO BUILD A RELATIONSHIP WITH INDUSTRIES

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Abstract: It is a tremendous responsibility of teachers to prepare students for the future workforce by exposing them and providing necessary skills as per current demand of industry. It can be challenging for teachers who receive licensure through a traditional teacher preparation program and have not been exposed to the skills used in the industry. Considering this fact, the Massachusetts Department of Elementary and Secondary Education (MA-DESE) allocated funding for the Perkins teacher externship program that offers a common platform for the professional development of high school teachers by connecting the classroom to the workplace. Through a competitive process, Fitchburg State University was selected to manage and administer the externship program in year 2018. This paper reports the challenges, benefits, and the outcomes of the Perkins teacher summer externship program managed by a team of faculty members of Fitchburg State University. In year 2018, 66 quality lesson plans were submitted by the selected high school academic and career and technical teachers. These lesson plans have been recorded and are available in the "Contextual Learning Portal" to interested teachers who wish to complement and enhance their curriculum. It also helps to educators to formulate effective teaching strategies to achieve maximum outcomes and also assists them in designing and implementing classroom activities, projects, and work-based learning opportunities that will add relevance and meaning to students' classroom learning with the first-hand exposure. This program also provides the opportunity for educators to build a relationship with companies. Moreover, this paper presents benefits of the externship program not only for teachers but also for the externship hosting companies.

Key Words: *Education, leadership, workforce, technology.*

1. INTRODUCTION

Industries are transformed or being transformed with the development of technology. There is a high demand of skilled workforce with recent knowledge of technology and skills. It is a tremendous responsibility of teachers to prepare students for the future workforce by exposing them and providing necessary skills as per current demand of industry. It can be challenging for teachers who receive licensure through a traditional teacher preparation program and have not been exposed to the skills used in the industry (Bowen, 2016). Therefore, teachers must constantly update their own knowledge and skills about current workplace practices, requirements, and tools by gaining an "on the ground" understanding of economic and career trends that will affect their students (Career Academy Support Network, 2010). To keep up to date, various types of workplace experiences are adopted based upon requirements and target group, such as student internships, teacher externships, job shadowing, informational interviewing, and service learning. Among them, teacher externships provide a peer-to-peer learning environment to teachers (CASN, 2010). The duration of externship may range from a day of job shadowing to longer period depending upon objectives of externship. Some project-based externships can last as long as a full summer.

Considering this fact, Fitchburg State University organized and administered a teacher externship summer program funded by Massachusetts Department of Elementary and Secondary Education (DESE) in 2018. The Perkins Teacher Externship Summer program offers a common platform for professional development of high school teachers by connecting the classroom to the workplace. According to Career Academy Support Network (CASN) (2010), externship programs provide actual field experience in which teachers spend time in a workplace to learn through direct experience about current technology, trends, required skills, opportunities, and challenges in industry related to their field of study in order to enrich and strengthen their teaching and bring relevance to student learning. Teacher externships offer a professional development experience that is often transformative for educators and their students (CASN, 2010). The externship experience helps teachers connect classroom content with students' future career interests and helps students develop both the academic and technical skills required in the world they are preparing to enter. It provides educators with the exposure to answer questions about real-world application and also helps to prepare students for their future careers and improve educational experiences (STEM Advisory Council, 2011).

This paper reviews the literatures depicting various types of externship programs and their significant role in the preparation of educational strategy. Author presents the methodology adopted to conduct the Perkins Teacher Externship Summer program and its benefits and outcomes. In addition, this study investigates the extent to which the phenomenon of teacher externship can be used as an initiative for creating long-lasting and strong collaborations between institutions of higher education and organizations/industries. The finding of this research not only contributes to the body of knowledge but also develops a foundation for designing the systematic strategy for effective externship program and addresses the lack of policy or strategy to resolve the skilled and techno-savvy workforce shortage issues.

2. BACKGROUND

In today's globalized and technological fast changing world, it is important to update curriculum with the recent development to prepare students with the required up-to-date knowledge and skills as per current industry demand. As many teachers have earned teaching licenses through traditional methods, it may be challenging tasks for teachers to increase student engagement in activities that help prepare them for the future workforce if they do not know how industry is currently using different processes to solve technological problems (Ignite, 2017). Considering such a learning gap, the idea of externship program for teachers was developed to provide opportunity to work and learn in the industry environment so that they can bring valuable knowledge back to the classroom (Barrett & Usselman, 2005, Bowen 2015).

Typically, a teacher externship program is referred to "a summer work experience in an environment that engages the teacher in engineering or design-based activities in order to gain a practical understanding of how industry uses current tools, processes, and resources to solve technological challenges" (Bowen & Shume, 2018). There are many teacher externship programs being implemented in national and regional levels. The National Science Foundation's Scientific Work Experience Programs for Teacher (SWEPT) and Research Experiences for Teacher (RET) are two popular externally funded programs for teachers to gain industry and research experiences (Bowen & Shume, 2018). Ignite program (previously called as the Industry Initiatives for Science and Math Education Program) was initiated in 1985 to place teachers into industry positions in STEM-related fields for 8-weeks summer work experiences in California. After completion of on-site experiences, the participated teachers were required to produce an Education Transfer Plan for integrating the knowledge gained through the work experience into the classroom (Ignite, 2017). Since 1991, the Georgia Institute of Technology sponsored Georgia Intern Fellowships for Teachers (GIFT) program and placed on average more than 75 teachers per year in university and industry settings to gain practical knowledge about current industry practices (CEISMC, 2017). In collaboration with university faculty, local economic development corporations, education cooperatives, and business in the upper Midwest region, the Educators in Industry: K-12 Externship program was initiated in 2011 to provide opportunity to in-service teachers to experience how corporations were using the engineering

design process (EDP) and 21st century skills to solve technological challenges (Bowen & Shume, 2018).

Studies shows that externship programs were successfully conducted not only for engineering and technology sectors but also health sectors and others, such as pediatric externship program (Patel et al., 2012); externship program on clinical education (Adamczyk & Mozlin, 2013); externship program on nursing (Balsam & Reuter, 2018); externship program related to law education (Jordan, 2016); STEM education externship (Choi & Linton, 2020). Fitchburg State University administered the Perkins Teacher Summer Externship program for academic and vocational programs. This program is a common platform for professional development of high school teachers in Massachusetts. The objective of this program is to provide actual field experience in which teachers spend time in a workplace to learn through direct experience about current technology, trends, required skills, opportunities, and challenges in industry related to their field of study in order to enrich and strengthen their teaching and bring relevance to student learning (CASN, 2010).

3. METHODOLOGY

Administering a valuable teacher externship program is a challenging job as it requires thorough knowledge of processes, detailed information, and collaborations with concerned parties. For this, author of this paper who is one of the members of the Fitchburg State University externship team, conducted extensive literature reviews to find if there are sufficient research conducted on externship related topics. The primary goal of the literature reviews was to establish an effective mechanism and to create necessary documents and forms so that the Perkins Teacher Summer Externship program could successfully organize and achieve targeted benefits for participated teachers and DESE. Based on working experiences in this project, author developed an externship program flow chart. Author also investigated the extent to which the phenomenon of teacher externships can be used as an initiative for creating long-lasting and strong collaborations between institutions of higher education, public organizations, and private organizations in Massachusetts.

3.1 Define Externship Program

Figure 1 shows the flow chart – a methodology of the Perkins Teacher Externship program. Considering the potential benefits from the externship, the Massachusetts Department of Elementary and Secondary Education (DESE) decided to start summer externship program for high school teachers in 2018. The DESE selected Fitchburg State University's (FSU) proposal to administer the Perkins Teacher Externship Program from competitive approach based upon technical and administrative competence. After discussion, the DESE and FSU team defined the scope, working procedure, and outcomes of externship program.

3.2 Coordinate with Concerned Parties

Major concerned parties for this program are DESE, Fitchburg State University (FSU) project team members, Regional MassHire Workforce Boards, selected teachers for externship, and employers (companies who provide externship sites for teacher externs). The DESE provided the grant to Fitchburg State University for stipends to participating teacher externs and for project management. The DESE also coordinated with the Fitchburg State University Externship Program management/instructional team and regional MassHire Workforce Boards. The DESE actively monitored the work progress and also participated externship related programs organized by Fitchburg State University.

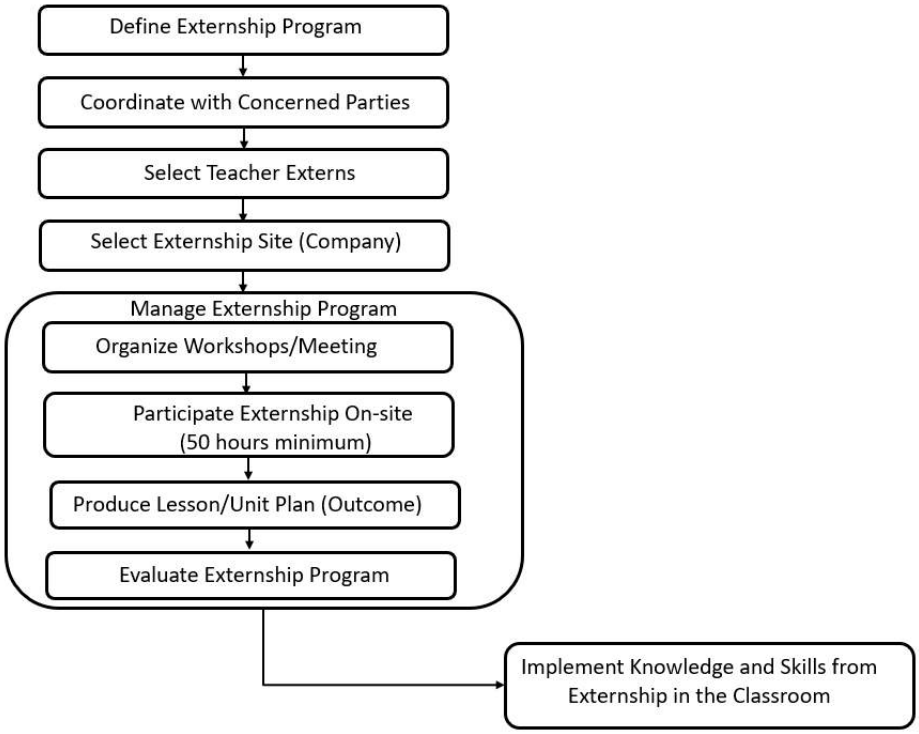

Figure 1 Externship Program Flow Chart

3.3 Select Teacher Externs and Externship Site

Twelve regional MassHire Workforce Boards were represented in the program from across the State of Massachusetts. Each Board selected two to four high school teachers based upon their regional prioritized selection criteria. The Regional MassHire Workforce Board was responsible for the externship site selection based on selected teachers' career field and related to courses they taught. For example, teachers who used to teach health careers and health technology, they did their externship in hospitals or medical center.

3.4 Manage Externship Program

The FSU externship team was responsible for managing and administering the externship program. The management team consisted of three full-time faculty (Dr. James Alicata, Dr. Wayne Whitfield, and Dr. Nirajan Mani) and one Adjunct faculty (Andrew Patenaude) from the Engineering Technology Department. The management team offered three one-day externship meetings. First meeting was for orientation program to provide information regarding externship program to participating teachers, such as overview of the project, externship site visits, administrative process, available resources, expected outcomes, and implementation of knowledge and skills obtained from externship in their classroom settings. A zoom webinar was conducted as a second meeting to inform participating teachers about upcoming meetings, additional information regarding assessment instruments, and assignments. During discussion session in the third follow-up meetings, teacher externs shared their project experiences with others and worked cooperatively developing their lesson plans.

This externship program was to provide a valuable professional development opportunity for teachers who support academic and technical integration for students. This experience enabled teachers to participate in new and emerging technologies, ensuring rigor and relevance in their curricula and instructional teaching methods. The extern teachers were responsible to actively participate workshops held at FSU; learn during approved 50 hours (minimum) externship and submit a lesson plan. Extern teachers were given the opportunity to earn additional graduate credit by preparing additional lesson plan.

The site supervisor at externship employer site provided necessary site-specific information, acted as resources to teachers in the development of their lesson plans, and monitored and evaluated each individual extern based upon their successful experience with the program.

3.5 Implement Knowledge and Skills

All lesson plans submitted by externs were reviewed and approved by the FSU team and posted on the Contextual Learning Portal for future references. All externs were encouraged to use these lesson plans for teaching in their classrooms and to share their externship experiences with others.

4. RESULTS AND DISCUSSION

A total of 66 lesson plans were received from participants. After thoroughly reviewing all lesson plans, these lesson plans were classified into different clusters, such as Academics (Math), Academic (English), Agricultural and Natural Resources, Art and Communications Services, Business and Consumer Services, Education, Health Services, Hospitality and Tourism, Information Technology Services, and Manufacturing, Engineering and Technology. The selected reflections were posted in the Contextual Learning Portal (http://contextuallearningportal.org/).

Many teachers were visited individually through an on-site interview or an online interview. During these interviews, discussions were held with the supervisor at the externship site in addition to the participated extern. The responsibilities assigned to the teacher were discussed as well as the individual strengths of each teacher. The specific details were made available on a general basis, respecting individual corporate trademarks and product confidentiality agreements between the teacher and the employer. Specific skills that teachers brought to their employer were identified and general job demands, such as measuring, calibrating and familiarity with specific commercial software were recognized. A minimal review of individual career and technical education curriculum and strands were discussed at the meetings. Many employers ranked employability skills as the highest priority. This was the case in many organizations where specific technical skills were considered secondary to employees demonstrating consistent attendance, and attention to details of work assigned to them. Many teachers provided a specific service for their employers which were reflected in their lesson plans.

All of the employers recognized the value that teachers held in communicating the opportunities that are available through their organizations to their students when they return to their schools. Employers were interested in developing a pathway to encourage and recruit future employees and saw the teacher as a conduit in this process. The employers recognized the value of education providing skills, such as problem–solving and application of academic subjects in a real work situation. Employers were also interested in a foundation level of skills where they could enhance and build upon to meet the specific needs of their organization. Several employers stated that an employee with a willingness and aptitude to learn and a positive attitude could advance to the highest levels within their organization. Several employers were impressed with the level of expertise and skills learned by high school students and made a conscious effort to consider recruiting high school seniors as summer interns to fill positions recently offered to college sophomore students.

5. CONCLUSIONS

Externship program provides actual field experience and provides opportunity to learn through direct experience about current technology, trends, required skills, opportunities, and challenges in industry related to their field of study in order to enrich and strengthen their teaching and bring relevance to student learning. It provides the opportunity for establishing strong ties between industry personnel and educators. Employers or companies were interested in developing a pathway to encourage and recruit future employees and saw the teachers as a conduit in this process.

Perkins Teacher Externship funded by the Massachusetts Department of Elementary and Secondary

Education (DESE) and administered by Fitchburg State University was successfully completed. In year 2018, total 66 lesson plans were submitted by fifty high school academic and career & technical teachers. These lesson plans were reviewed by a team of faculty members of Fitchburg State University in accordance to externship guideline set by the team. The selected externship lesson plans are available in the "Contextual Learning Portal" (http://contextuallearningportal.org/) to interested teachers who wish to complement and enhance their curriculum.

The initial goal of this program was to identify the specific skills needed for different levels of employment in the organizations offering externship for high school teachers. It was our belief that students could enter the company at different levels or positions based upon the skills required to perform each position. Through this program study, we learned that the economic demand for a trained workforce is so great that companies will take the responsibility of providing training and advancement for positions they are interested in filling. Several employers identified a new model or paradigm for an employee to advance in their career. Historically, employees would attend post-secondary educational institutions and receive associate, bachelor, and graduate degrees prior to seeking employment based on the application of the skills and knowledge learned. It was brought to our attention that with the advances in technology and distance learning an employer could and would be willing to guide and sponsor an individual's training and advancement while they maintained employment at their company. As employees are progressing in their degree programs or skills measured by a license become completed, employees would become eligible for advancement in their organizations. Upon completion or progress made in programs, employees would be able to move from support positions to technical positions to management and eventually executive positions within the same company.

6. ACKNOWLEDGEMENTS

Author acknowledges the assistance of all DESE staffs, Fitchburg State staffs, and faculty team members who were actively involved in this project and expresses special gratitude to the regional MassHire Boards, participated high schools and teachers, and employers involved in the project. Without their support, this project would not have been possible.

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EXECUTIVE INNOVATION

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Abstract: One recent quote for the role of CEOs and other C-Suite executives on the innovation of a firm is: "Innovation executives are not expected to be the innovators, but the great ones can facilitate ideation processes effectively to generate great ideas" (Soloman, 2005). This paper explores the role of CEO/Top Executive participation in innovation in modern business. At the turn of the 20th century, there were many great inventors who also became successful businessmen. They founded and played key management roles in firms that created the backbone in the infrastructure and business growth of the country. Thomas Edison (GE), Alexander Graham Bell (AT&T) and the Wright Brothers (Aircraft) are just a few that come to mind. However, as the 20th century wore on, America's big business organizations became more bureaucratic with CEOs and executives leaving entrepreneurship and innovation primarily to their R&D divisions (e.g., Bell Labs and RCA Labs) and to outside organizations that could be acquired if necessary. However, recent trends indicate that this may be changing. This paper looks at today's state of innovation and examines the current role of innovation as it pertains to CEO and Top Executives.

This subject of CEO/Executive innovation is approached with a view of: (1) examining if the spirit of innovation is alive at the CEO level; and (2) if it is, determining if today's CEOs/Executives are contributing to innovation in U.S. major firms. A literature review addresses some of the authors and academicians who have contributed current major ideas concerning innovation. Joel Barker is a futurist who has spent his career focusing on paradigm shifts and innovation. A famous MIT professor, Clayton Christensen, was another who developed and documented key ideas in innovation that are now mainstream e.g., the theory of disruptive innovation. Lastly, most graduate books on Business Strategy address innovation in a separate chapter and describe the latest ways that a firm can embrace innovation to be successful.

Much insight into this topic was gained by examining a recent Forbes list of Executive Innovators (Forbes 2019). At the top of the Forbes list are found some common names of U.S. CEOs and Executives. Quite a few have recently displayed a healthy penchant toward reaping the benefits of innovation. Included in the list were: Sundar Pichai at Alphabet (Google); Jeff Bezos at Amazon; and Elon Musk at Tesla. Three major recent CEOs who epitomized the best in the successful harnessing of innovation over the past 30 years are also discussed in some detail: Steve Jobs (computers and other related fields), Edward Whitacre (Telecommunications) and E. Hunter Harrison (Railroads). While examining these leading CEO/Executives, deregulation in the United States economy was identified to be a potential important construct that may well have influenced positively the changing role of modern CEOs and top Executives in innovation.

It is concluded that all innovation does not necessarily have to be driven by intrapreneurs within a firm or acquired from outside a firm. In fact, CEOs are more active today in driving innovation than at any time since the earliest 20th century. It appears that innovation at the CEO/Executive level has been revived and is far from being defunct!! Future CEO and Top Executive position hires should be examined with innovation in mind. At a minimum criterion for selecting a new CEO or Top Executive needs to include how well they have delivered innovation in their past executive assignments, as well as what ideas they have for generating innovation in their new job.

Recommendations are also made as how to further research this topic to provide definitive factors that are driving innovation at the CEO and Executive levels today. Such research on innovation should not be limited to just technological innovations, but needs to be expanded to include innovations in such functional areas of business as marketing, operations, procurement, R&D etc. Lastly, future research could also be undertaken in innovation using techniques such as data analytics. A data-centric technique could be employed which would focus on using machine learning algorithms to identify themes that are driving the recent upsurge in CEO and Executive innovation.

Keywords: *Innovation; Disruptive versus Incremental Innovation; Precision Scheduling Railroading; Data Analytics*

1. BACKGROUND

It has been observed that innovation is the life blood of a nation. Over the past 200 years innovation by United States inventors has been a major reason that America has been successful in establishing a vibrant and powerful national economy. Fulton's steamboat, Eli Whitney's Cotton Gin, Cyrus McCormick's Reaper, Otis's Elevator, Samuel Colt's revolvers, Goodyear's Vulacanization of rubber, Samuel Morse's telegraph were just a few of the major inventions by Americans in the early-to-mid 1800s. In the late 1800s and early 1900s a major industrial nation arose on the heels of the inventions of Alexander Graham Bell, Thomas Edison, Nikola Tesla, the Wright Brothers, and a host of other entrepreneurial innovators. What was unique about many of these late 19th Century innovators was that they did not only invent new and useful things, but they then made major contributions to society by commercializing their inventions as Executives of firms they helped to create. By going into business, they laid the groundwork for major industries that would make their company's products available to millions of people world-wide. Alexander Graham Bell invented the telephone and then was the President of Bell Telephone Company (1877) and later in 1884 the new AT&T (Alexander Graham Bell, Wikipedia). In 1878 Thomas Edison invented the light bulb and then the Edison Electric Light Company. He had many other patents involving electricity and played a major role in the formation of General Electric in the early 1900s (Thomas Edison, Wikipedia). In 1880 George Eastman invented the first commercially available camera and founded Eastman Camera Company (later Eastman Kodak) (Ball, 2013). Ford developed the large-scale assembly line in the early 1900s to mass produce his Model T cars at a price that could be sold to the middle class (Webb, 2021). The Wright Brother invented the airplane and established the Wright Company in 1909 (Wright Brothers, Wikipedia). Although not inventors per se, numerous other American entrepreneurs capitalized on the boom in technology and innovation in the late 1800s to build the modern infrastructure of the nation i.e. Vanderbilt (Railroads). Carnegie (Steel), Rockefeller (Oil), Westinghause (electrification of America with Alternating Current), and lastly J.P. Morgan, the great banker who financed many of the great infrastructure projects in the early 1900s (History Channel, 2019).

In the 20th century the United States had many new products and innovations. However, most of the inventions from this century were made by entrepreneurs who have not served as Presidents (or the more modern term Chief Executive Officer or CEO) of firms that have acquired such inventions. The Radio Corporation of America (RCA) is a good example. David Sarnoff was the major executive of RCA from 1920-1969, but was not an inventor. He was a Russian immigrant who made his reputation by operating a Marconi radio that took the distress call from the Titanic in 1912 and directed the RMS Carpathia to pick up survivors. Later as President of RCA, he adopted the inventions of Lee de Forest (the Father of Radio), Philo Farnsworth (first real commercial Black & White TV), and John Baird (Color TV) to make RCA the premier communications company in the world starting around 1940 (Dreher, 1977). As illustrated by Sarnoff, a shift occurred by the mid-20th Century with most new inventions being made by scientists and engineers employed in an organic R&D organization of the parent firm (e.g., RCA Sarnoff labs and AT&T's Bell Lab) or outside the big firms by enterprising entrepreneurs. The time when inventors were establishing new businesses and transforming them into major Fortune 500 firms had seeming receded into the distant past. However, events over the past 30 years may lead one to question that premise. The major thesis of this paper is that CEOs and top executives today may well be playing key roles in innovation.

2. LITERATURE REVIEW

The important role of innovation in success has been echoed by many who have studied it. In the Journal of Strategic Leadership, Gary Oster was only one researcher who acknowledged this sentiment. In 2009 he stated: "In perilous economic times, fresh ideas and innovation are the lifeblood of every corporation" and by extension every nation (Oster, 2009).

Another recent quote on innovation is: "Executives are not expected to be the innovators, but the

great ones can facilitate ideation processes effectively to generate great ideas" (Soloman, 2005). This section reviews some of the recent major authors and academicians who have contributed current important ideas on innovation. Joel Barker is a futurist who has spent his career focusing on paradigm shifts. Clayton Christensen, an MIT professor, is another who has developed and documented key ideas in innovation that are now mainstream e.g., the theory of disruptive innovation. Lastly, most graduate books on Business Strategy address innovation in a chapter and describe the latest ways a firm can embrace innovation to be successful.

Joel Barker was the first person to popularize the concept of paradigm shifts as it pertains to innovation in the modern corporate world. He began his work in 1975 and he observed that discovering new paradigms is at the heart of innovation. He stated that paradigm shifts were the most profound changes that occur in the world (Barker, 1992). He defines a paradigm shift as a new approach to a process or system that does two things: (1) defines the boundaries; and (2) helps in solving problems. Paradigms can be in very common areas (like washing dishes) to complex ones (changes in governments). These can occur in a multitude of major areas e.g., technological, social, environmental, economic, political etc. (Ibid).

Some major paradigm shifts that have occurred in the past 40 years include: the shift from vacuum tubes to solid-state electronics and then to integrated circuits; mechanical (Swiss) watches to Quartz Crystal (Japanese) Watches, Birth of the Internet, and the advent of both cell phones and the Iphone; Rachel Carson was cited by him, as well as the Fall of the Soviet Union (Barker, 1992). Carson's book *Silent Spring* created a paradigm shift and triggered the environmental movement (Carson, 1962). In the quest for new innovation, Barker advanced his famous "Impossibility Question" to be asked to all employees in a firm that are involved with a process or new product i.e. "What is impossible to do today, but if it could be done would result in a fundamentally change your organization for the better?" (Barker, 1993).

For an innovation to take place, two protagonists are needed – the paradigm shifter and the paradigm pioneer. In paradigm parlance the shifter is the inventor of the new device or processes. A good example of this was Wernher Von Braun. He was instrumental in Germany's V-2 rocket success in World War II. After the war he was recruited by the United States and moved to Redstone Arsenal in Huntsville, Alabama (Neufeld, 2007). He was then appointed the Director of Development Operations in the newly created Army Ballistic Missile Agency (ABMA). In that role he was instrumental in developing the innovations in technology that would be used in the US Space Program that became prominent in the 1960s. He and his ABMA team were transferred to NASA in the new NASA Marshall Space Center in Huntsville in 1958. As Director, he pioneered the development of the SATURN V rockets to carry heavy payloads into space. These were used along with other of his ground-breaking innovations (e.g., the lunar orbit rendezvous concept) to enable six teams of astronauts to reach the surface of the moon later in the decade (Ward, 2005)).

Barker's paradigm pioneer is the person that sees that the paradigm is shifting and puts all their resources and personal attention into commercializing the shift. A good example of the latter is Bill Gates. When the computer world was shifting from mainframes (the old paradigm) to smaller computer servers, Gates was able to recognize the fundamental shift and devote all his attention and resources to help bring the new computer world into being with DOS and Windows (Barker, 1993). Other recent paradigm pioneers include Elon Musk (in Electric Vehicles) and a person we will discuss in some detail later in this paper- Edward Whitacre.

The late Clayton Christensen was the Kim B. Clark Professor at Harvard Business School, the author of seven books, a five-time recipient of the McKinsey Award for Harvard Business Review's best article, and the cofounder of four companies, including the innovation consulting firm Innosight (Google Book Review, 2011). Also, in 2011 he published the now classic book on Innovation entitled *The Innovator's Dilemma* (Christensen, 2011). In 2011 he was named the world's most influential business thinker in a bi-annual ranking conducted by Thinkers50- the Oscars of Management Thought (Thinkers50, 2021). Professor Christensen introduced the now famous "Theory of Disruptive Innovation" in 2015. (MIT Sloan Management Review, Spring 2015). Focusing on "disruptive

technology," Christensen showed why most companies miss out on new waves of innovation. Whether in electronics or retailing, a successful company with established products will get pushed aside unless managers know when to abandon traditional business practices. Using the lessons of successes and failures from leading companies, *The Innovator's Dilemma* presents a set of rules for capitalizing on the phenomenon of disruptive innovation. In this revolutionary bestseller, innovation expert Clayton M. Christensen says outstanding companies can do everything right and still lose their market leadership—or worse, disappear altogether. And not only does he prove what he says, but he tells others how to avoid a similar fate (Ibid). Numerous examples of disruptive technologies have been identified by Christensen and other researchers. These include the transition from vacuum tubes to solid state electronics in the 1960s, Toyota's entry into the North American car market in the 1980s, and later Kodak's loss of the camera market, and Amazon creating a Kindle to spur the sale of books by moving to electronic delivery from paper copy. It should be noted that there is a close relationship between the terms of disruptive technology and paradigm shifts. In reality a disruptive technology normally enables a paradigm shift to create a new product. As previously mentioned, paradigm shifts are a more general term that also embraces changes in process, systems and/or broader issues.

Modern textbooks used in MBA programs normally have an entire chapter on innovation. In that chapter they discuss several key concepts that have become central to the study of innovation. First, they draw a distinction between inventions and innovation. Specifically, inventions are the creation of new products while innovation is the inventions and then commercialization of these new products i.e., inventions by themselves are valuable, but unless they can be made useful by society they do not qualify as innovations. Secondly, entrepreneurs are individuals who create new innovations outside of established firms, while intrapreneurs create innovations within firms. Entrepreneurs normally do so by raising money from friends and family and using that capital to invent something new, often a new prototype. However, to be able to scale up to make more improved products and to market their invention, they need capital. This is normally obtained from Venture Capitalists (the VCs) who are looking to invest their money into a promising venture. It is at this point that it becomes an innovation if it becomes commercially viable. In the case of a successful product, the original investors then often employ an Investment Bank to do an Initial Public Offering (IPO) that results in a new business that allows the Inventor, VCs and/or other investors to recover their investment by cashing out of the venture (Hitt, Ireland, and Hoskisson, 2019).

In the case of innovations that are created within the firm, that process is called Internal Corporate Venturing. There are two major ways that this can occur- in a strategic context or in a structural context. In the first case, the firm resorts to autonomous strategic behavior. This occurs in firms that encourage their employees to innovate on their own, but do not directly support a specific innovation that is occurring in their firm or are even aware of the activity going on to create it (Ibid). An example was in INTEL in the early 80s. At the time the lead author of this paper was in the Pentagon on the Army Staff when INTEL was lobbying DOD for support in their chip manufacturing. Japanese firms were then receiving generous governmental support in their chip manufacture process, creating a less than level playing field. They were then able to cut prices and dump RAM, DRAM and ROM chips in the United States. INTEL purported to the Pentagon that if this continued, they would soon be forced out of the chip making business. They claimed the upshot would be that the United States would then become totally dependent on off-shore chips for its many weapons, communications, and other Defense mission essential systems. The Reagan Administration did not support INTEL's views and they were left on their own to figure out a way to survive. Fortunately, they had in their firm some intrapreneurial scientists in their organic R&D organization who had just invented processor chips. The timing was perfect for INTEL to make a strategic shift from memory chips to processor chips. Thus, their chips found a home in the first personal computers (PCs) - the famous X286 chip. As PCs in the early 1980s were in their embryonic stage, it did not produce much revenue at first. However, when PCs exploded on the scene, these chips (along with follow-on X386, X486, Pentiums etc.) became the major revenue source for INTEL and a boon to the Defense Department and the country.

The second way firms can stimulate innovation is by a structural context called induced strategic

behavior. In this way a firm plays an active role by providing funds to a specific R&D sub-organization within the firm. This is often called a "Skunk Works" (Rich and Janos, 1994). The scientists and engineers then are fully employed in using these funds to wisely create a new product. Two good examples of this were the creation of the Stealth Fighter (SR-71) and the Arpanet. In 1975, engineers at Lockheed Skunk Works found that an aircraft made with faceted surfaces could have a very low radar signature because the surfaces would radiate almost all of the radar energy away from the receiver (Ibid). In the case of the ARPANET, it was the forerunner of the modern-day INTERNET (Abbate, 2000). The ARPANET was effectively a "Skunk Works" in the Department of Defense's (DOD) Defense Advanced Research Projects Agency (DARPA). DARPA was established by President Eisenhower in 1958 in response to the Soviet launching of Sputnik 1 in 1957. By collaborating with academia, industry, and government partners, DARPA was tasked to formulate and execute research and development projects to expand the frontiers of technology and science, often beyond immediate U.S. military requirements (Eisenhower, 2008). The ARPANET was conceived by DARPA in the 1960s when packet-switching first became available. In 1990, the ARPANET was decommissioned and its technology went mainstream into the commercial world (DARPA, Wikipedia). Tim Berners-Lee and his colleagues at CERN developed hypertext markup language (HTML) and the uniform resource locator (URL), giving birth to the first incarnation of the World Wide Web (Berners-Lee, 2010).

The research cited above illustrate examples of where much of the innovation was coming from in the United States in the post-World War II period (1945- 1983). The lead author of this paper spent over 30 years in the telecommunications industry (as an engineer, principal scientist, and with his last two assignments as the Chief Engineer of the Defense Communications Agency and later as Vice President of Systems Technology at Pacific Bell. In his many roles he had first-hand knowledge of the major innovations (and also failures of innovation) in the telecommunications industry. He was intimately aware of the following: AT&T had Bell Labs; RCA had the RCA Sarnoff Labs; IBM had IBM Labs; Xerox had Xerox Palo Alto Research Center (PARC); and INTEL had the scientific intrapreneurs in their organic R&D arm. In the same post-World War II timeframe most of the major firms mentioned were being run by CEOs and Executives who were primarily strategic managers and not closely involved with innovation. As a result, innovation was often overlooked and stagnated. Two classic examples of this lack of foresight and resulting failure to support innovation were:

a. AT&T- Bell Labs led the world each year in the number of filed patents throughout much of the 1960s and 1970s. However, the AT&T CEOs and top management allowed very few of these to go into production. As AT&T had a "natural monopoly" at the time and were making good profits, they did not have the incentive to see much change in telecommunications. At the time we all found humorous that there were consumer outcries to replace the black phone on the wall in our homes in the 1960s. Finally, AT&T gave in and gave us what- a white phone!!! Years later when deregulation broke up the stranglehold that AT&T had on telecom, there were a variety of new phones e.g., different colors, Princess Phones etc. Such a lack of innovation led to huge consequences with AT&T's subsequent demise. Congress intervened by deregulating telecommunications in the "Great Divestiture of 1984". This was a seismic event in the telecommunications industry. As a giant U.S., corporation, AT&T was at the top of the Fortune 500 list of U.S. corporations before the breakup. After the divestiture, AT&T was carved up into primarily seven Baby Bells and AT&T Long-Lines (with the R&D arm "Bellcore" replacing Bell Labs). All eight of these firms were still ranked in the top 50 of the Forbes Fortune 500 largest US corporations (Coll, 1986), a testament to the impact of this huge economic event (Coll, 1986).
b. Xerox- Another well-known example of retarded innovation occurred in the 1970s at Xerox. Xerox PARC had developed many of the innovations that would one day fire the Internet Revolution e.g., the mouse, the first Graphical User Interface, the Laser Printer and Ethernet to name just a few. When these were presented to the Xerox top management and Board of Directors, inventions such as the mouse were rejected for production. When the outsider Steve

Jobs contacted Xerox top management and asked permission to experiment with several of these innovations, Xerox management foolishly acceded to his requests. The PARC scientists and engineers were totally flummoxed. The result gave Jobs at Apple a running head-start as he copied much of Xerox's innovative work in his first computers and systems. (Pirates of Silicon Valley, wikipedia.org).

3. INNOVATION AND DEREGULATION

The Great Divestiture of AT&T in the 1980s had further, major world-wide impact. Most foreign industrialized countries had over the years copied the United States' approach to telecommunication. Each of these countries had one major telecommunications firm that provided telephone and other communications service for internal communications e.g., British Telecom in England, French Telecom in France, Nippon in Japan, Deutsche Bundespost in Germany etc. Virtually all deplored the break-up of the sacred AT&T and expressed grave reservations about the eventual consequences of the chaos that would be wrought. Most were later amazed when the deregulation of AT&T worked. For starters many of the scientists and engineers who had been stymied in operationalizing their patents were motivated to shortly depart their previously parent organizations and start their own major firms e.g., Larry Ellison left Ampex and started ORACLE; five previous IBM engineers founded SAP; Jack Shemer from Xerox helped found TERADATA etc.

In the 1980s and 1990s deregulation occurred in virtually most of the major industries in the United States. This included deregulation in such major industries as telecommunications, finance, banking, the airlines, railroads, natural gas and trucking. When major innovations began to appear in all these industries, the major industrialized countries that had been critical of deregulation soon followed suit. (Wilson, 1998). The rapid acceleration of innovation, especially in the industries dependent on technology, appear to have benefited from deregulation. In support of the major thesis of this paper, innovation appears to have been assisted greatly and may have been a virtual byproduct of deregulation. Many highly qualified and motivated engineers and scientists were released into the marketplace where they founded numerous start-ups and new firms. Heretofore, such innovation brainpower had not been present in the US economy. Working with major technological universities such as MIT and the California Institute of Technology, these newly released scientists and engineers inspired an entire new crop of entrepreneurs to join in and participate in the innovation revolution.

An excellent snapshot of innovation today in the United States today was created by Forbes Magazine. It was a listing of the top fifty innovators listed with their industry. Updated in 2019 (Forbes, 2019) the list provides the following information:

a. The top ten CEOs and Executives who have been recently active in innovation in their firms is quite insightful. In order they are: Jeff Bezos at #1 (Amazon); Elon Musk (Tesla); Mark Zuckerberg (Facebook); Reed Hastings (Netflix); Sataya Nadella (Microsoft); Shantanu Naragen (Adobe); Tim Cook (Apple); Larry Page and Sergey Brin (Alphabet/Google). Note that most firms here are technological in nature.
b. Well over 25 of the top 50 CEOs were from firms that also made their mark in technology and are very active in innovation. A partial listing of these firms is Intuit, Boston Scientific, BioMarin Pharmaceutical, Abbott Laboratories, NVIDIA, Medtronic, Texas Instruments, Electronic Arts, Stryker, Electronic Arts, Activision Blizzard, AbbVie Inc., Lab Corp, Education Lifesciences, and Henry Schein (Ibid).

4. MODERN DAY INNOVATORS

This section discusses the careers of several recent innovative CEOs who made major contributions to their industries with their innovations. These three major CEOs epitomize some of the best in the successful harnessing of innovation and are discussed in some detail: The are in order: Steve Jobs (computers and other related fields), Edward Whitacre (Telecommunications) and E. Hunter Harrison

(Railroads).

Steve Jobs- Steve Jobs is probably the best known of the three modern day executive innovators. He co-founded Apple Computer in 1976 with his partner Steve Wozniak. As new start-up entrepreneurs, they succeeded in building a successful firm with innovations such as the Apple 1, Apple 2, and Macintosh computers (Isaacson, 2011). He resigned in 1985 and next founded a second successful computer company- NeXT Computer. NeXT computers were used by several computer innovators such as Tim Berners Lee. Berners Lee used a NEXT operating system to invent Web Sites in 1994. Web Sites was one of the most important innovations that triggered the Internet Revolution in the late 1990s (Berners Lee, 2010).

Jobs returned to rescue a foundering, near bankrupt Apple in 1997. From 1997 to 2011 he was prolific in making major strides with very significant innovations. Just mentioning a few includes the following: primary inventor or co-inventor of 346 United States patents or patent applications related to a range of technologies; various computers, operating systems, portable devices to user interfaces, speakers, keyboards, power adapters, staircases, clasps, sleeves, lanyards and packages. He also initiated a "Think different" advertising campaign which led to the Apple Store, App Store, iMac, iPad, iPod, iPhone, iTunes, and iTunes Stores. In 2001, the original Mac OS was replaced with a completely new Mac OS X (now known as the MacOS). This was based on NeXT's NeXTSTEP platform, giving the new Operating System a modern Unix-based foundation for the first time. What was significant in virtually all of this innovation is that Jobs used his CEO position to directly involve himself with all aspects of innovation which included product design, production, and creative marketing (Isaacson, 2011).

Edward Whitacre- Ed Whitacre completely revamped U.S. telecommunications with dramatic, innovative initiatives that transformed a deregulated industry into a completely new model. His technological innovations were a major part of this transformation. Whitacre was a seasoned veteran in AT&T when the Telecommunications Reform Act of 1984 was passed. As mentioned, this Act completely ended the century-old monopoly of AT&T, also known as “Ma Bell”. In 1988 Whitacre became the CEO of Southwestern Bell (SWB) in Texas. SWB was one of the seven “Baby Bells that the Telecomm Act had created from the former AT&T. They were given a temporary monopoly for short-range communications in the Southwestern part of the United States e.g., Texas and Oklahoma. The other Baby Bells were Pacific Bell (California and Nevada), NYNEX (Northeastern US), Bell Atlantic (in middle US Eastern States), Bell South, Ameritech (Mid-West) and US West. The remainder of the old AT&T was renamed AT&T Long Lines and had retained the long-distance communications links that tied the entire nation-wide system together. Subsequent to the break-up, the government had advised that a second round of deregulation would be forthcoming that would remove the monopolies from the Baby Bells over short-range communications (Wilson, 1998).

Pacific Bell decided to get ahead of the power curve on this next projected government deregulation action. In 1995 California was the biggest state in the union and economically the seventh largest economy in the world. It is now the 5th largest economy today just behind Germany (https://en.wikipedia.org> Economy of California). The strategists at Pacific Bell decided to take a series of actions in the early 1990s to ensure that they could compete with other telecommunications firms that might be attempting to take market share from them in California. As the technological environment was shifting rapidly from analog to digital, PacBell decided to commit over $3 billion to: (a) digitize their telecom infrastructure i.e., replacing the copper wires in the ground with fiber optics; and (b) digitize their old analog switches and other central office equipment with digital technology. Unfortunately, the large expenditures hit Pac Bell’s capital financial structure much harder that they had anticipated. It was an existential moment for PacBell and it was deemed essential to downsize the firm from some 160,000 workers to approximately 55,000 employees. This was done in three successive downsizing waves in the 1992-1994 timeframe and seriously impaired PacBell’s operations. It was at this point that Ed Whitacre came calling. Enjoying a huge capital war chest at SWB, he proposed a merger between PacBell with his SWB firm. Having the had the upper hand with ample capital, Whitacre adroitly had succeeded in transforming this merger into a successful acquisition. When the

smoke cleared in 1997 there was only one CEO (Whitacre) left, all three PacBell Executive VPs had been removed and twenty-two of the previously twenty-four PacBell Vice Presidents were gone (the lead author of this paper included). In addition, Whitacre retained some of the best engineers and information systems engineering personnel in the now defunct PacBell. As an example, Ross Ireland had always been recognized as the top communications Engineer in the country and was one of the VPs who was retained. Whitacre had successfully engineered a successful take-over of PacBell and had California securely under his telecom control (Whitacre, 2013).

Thereafter, Whitacre used this successful innovative formula to enlarge his telecommunications empire. In 1998 he acquired Southern New England Telephone (SNET), followed in 1999 by Baby Bell Ameritech and then Comcast. It took him a few years to digest all of these acquisitions, but he then moved decisively in the mid 2000s with the same formula to acquire both large Bell South and Cingular Wireless. In 2005 he put the cherry on the top by acquiring the remaining piece he needed - AT&T Long Lines. He renamed the new company "AT&T", thereby being able to recapture the goodwill that "Ma Bell" had long enjoyed. His new AT&T was now the largest telecommunications company in the world. It also was the largest provider of mobile telephone services in the U.S. As of 2020, AT&T was back to being ranked 9th on the Fortune 500 rankings of the largest United States corporations (https://fortune.com/fortune500/2020/).

Whitacre employed innovation in the way he brilliantly assembled AT&T. He also demonstrated technological innovation by systematically acquiring the best available technological talent in the telecommunications industry and harnessing it effectively throughout his newly created telecom empire. Led by the best engineers and some of the best IT personnel in the country, he was able to gain access to the best technical ideas in the industry. He took a personal interest in many of the technological issues at the time and adroitly worked with and empowered this talent to innovate many new and creative telecom solutions to propel AT&T to the top of his industry (Whitacre, 2013).

Whitacre's actions did not go unnoticed in the industry. When he had started his acquisitions in 1996, the "Baby Bell" Bell Atlantic was watching his every move and began to copy his strategic initiatives and formula. Bell Atlantic acquired NYNEX in the late 1990s, followed up by GTE, TracFone Wireless and some other firms. They renamed their firm Verizon in 2000. Thus, the old AT&T had been restructured in sixteen years into two telecom giants- AT&T and Verizon. Whitacre had to appear before a Congressional committee in 2007, but with two huge firms to compete, as well as a number of smaller firms (e.g., US West which had morphed into Quest), apparently the goals of the government to deregulate telecommunications were satisfied. Along the way Whitacre had outwitted a large number of very smart telecommunications executives to achieve his goal of getting as close to domination in the industry as the country would allow. His actions were reminiscent of Rockefeller (Standard Oil) and the other titans of industry in the late 1890s (Carnegie in Steel; Vanderbilt in Railroads) putting together monopolies, soon to be broken up by Teddy Roosevelt and governmental actions (Ibid)

E. Hunter Harrison- E. Hunter Harrison started work as an oil man and safety inspector in a St. Louis-San Francisco (Frisco) Railway yard. He was later promoted to railroad operator at Frisco, and moved consistently up in the railroad business. He was promoted within Burlington Northern after they purchased Frisco. Harrison was promoted eighteen times in his first decade with Frisco, proving his passion for the job. He learned early in his career that financial performance could be improved in railroads by adding cars to a train, driving trains faster, and eliminating unneeded stops. At one point early on as a laborer, he was stopped by a third-generation railroad worker managing a key terminal. It was operating at full capacity, but the manager wanted more. Harrison, through his unique viewpoints, saw enough capacity, but advised the terminal manager that the cars weren't being loaded rapidly enough. He showed how this could be achieved, opening extra capacity up immediately (Green, 2018).

Harrison had a knack for understanding the intricacies of railroad operations and developing efficient procedures. As current Canadian Pacific CEO and a former colleague of Harrison at Illinois Central, Keith Kreel pointed out that Harrison's approach was "so simple and so common sense based, they were brilliant. He understood the nuts and bolts of the business well enough to go against the status quo. He was swimming against the stream. Everyone said what he was doing was wrong and

to go forward required a whole lot of risks" (Schleier, 2018}. Kreel noted that Harrison proved throughout his career that swimming against the stream was the right way to make a railway company run more efficiently and increase financial performance (Ibid).

Harrison didn't spend long in the yards, but joked later in life that he learned more there about railroading in those brief years than he ever did in his 50 years of management. Often crediting rail workers with understanding the operations of a railway company more than anyone else, he often leaned on his early experiences when building his precision scheduled railroading platform. That was where he learned how yards direct lines. Over the years, he built out his precision railroading system concepts based on these insights. Although eventually promoted up to Vice President of Transportation, Harrison left Burlington Northern in 1989 to join Illinois Central (IC). He worked in multiple executive positions until being named CEO in 1993, staying in the position until 1998. When Harrison joined as Chief Transportation Officer at IC, their operating ratio was 98%, or in layman's terms, it cost IC 98 cents to make a dollar. By the time Harrison left IC and it was purchased by Canadian National, Harrison had dropped their operating ratio to 62.3%. Later at Canadian Pacific, he entered with operating ratios at 80%. By the time he left the company in 2016, their operating ratio was at an extraordinary 58.6%. Nobody in the rail industry had such a positive effect on rail companies since the rail systems had been modernized around the turn of the century (Ibid).

At every step in his work, he deciphered how inefficient operations could slow trains to a crawl, and then the quickest way to get product to the customer. Harrison ran into opposition from customers, unions (and seemingly everyone in between) as he worked to change how his railways operated. Although his operational model dramatically improved a railways financial performance, it didn't often sit well with customers who were often opposed to the way he operated. Early in Harrison's career, customers controlled the railways because trucking offered them a cheap alternative and customized scheduling. Trains then didn't have scheduling, so customers had no idea when their orders would arrive at the destination. Rail companies kept rates low to compensate and keep their clients. Harrison didn't agree with that model and changed it quickly with every company he took over, even if it meant losing customers in the short-term. While at Illinois Central (IC), he met with a customer worth around $100 million a year in business, or about 17% of its total revenue. The customer believed prices were high and demanded a steep cut in prices, arguing that rail service was a commodity. Harrison reacted by simply packing up his briefcase and walking out of the meeting. Harrison lost the customer. However, two years later the customer begged to come back after it had tankers sitting on a siding for over three months that their new rail company was unable to move. To describe his leadership to others during these bumps, he said he simply led from the pulpit. He knew what was right for the railways and what would be most efficient and cost effective for the customers in the end. Although often vilified for his harsh leadership tactics and crass treatment of railway employees and customers spanning his four stints as CEO, he was also one of the most celebrated CEOs for the stunning turnarounds he performed. He was named Railroader of the Year, the industry's most prestigious award, in 2002 and 2015 by *Railway Age,* CEO of the year by *Globe and Mail* in 2007, Railroad Innovator of the year in 2009 by *Progressive Railroading,* CEO of the Year by *Morningstar in* 2013, Executive of the Year by *Supply Chain Dive* in 2017, and many others. He was actively recruited by investors before joining his last two railways, as they understood what Harrison's leadership and operational innovation could mean to the companies in which they had a large stake. When his name was merely announced by a CSX investor stating he wanted Harrison to join the company, stock price soared over 20% in a single day. CSX later put together a $300 million package to bring him onboard (Ibid).

One of the biggest aspects of Harrison's success, as arguably the leading railroad pioneer of the last century, is that he didn't just drive change, he drove foundational innovation that changed the course of large companies. Any effective CEO could have taken the reins of these railroads and cut costs through worker reductions and making train operations more efficient through longer trains and better scheduling. Harrison's model is considered innovative not just because he made such changes, but because he also changed the core way the railways transported goods using his PSR railroading model.

He was shrewd enough in the process to drive the type of change in the firm's culture to support all his efforts. Since the modern railway was first built, companies had employed the traditional hub-and-spoke model to transport goods. Although a solid model for decades, Harrison believed it: (a) caused multi-day delays to shipping goods to the customers; (b) led to over-busy and inefficient large rail yards that companies spent billions to make more efficient and (c) operated on a model that other industries had already proved could be improved. As another innovator (Herb Kelleher) had proved at Southwest Airlines, a point-to-point system could not only work, but it could be extremely profitable. Harrison used this point-to-point model as a basis for the innovation he led across four major railroad companies. The system was so proven that CSX continued its implementation after Harrison's death. Union Pacific Railroad has since followed suit, hoping to recognize the same benefits that Harrison's previous companies did enjoy (Schleier, 2018).

5. CONCLUSIONS

A comprehensive review over the past 125 years reveals that participation by CEOs and Executives in innovation has varied greatly. In the early 1900s executives were very active. However, as the 20th century progressed, executive activity in innovation dwindled significantly This was evident as the larger firms employed major R&D subordinate organizations such as internal laboratories, Skunk Works and intrapreneurs. However, more recently there are numerous examples of CEOS and other executives that have been much more involved in the innovation process. Steve Jobs, Edward Whitacre, and E. Hunter Harrison were cited in some detail, but the list also includes many familiar names such as Sundar Pichai (Google/Alphabet); Jeff Bezos (Amazon) and Elon Musk (Tesla). In fact, there are many examples today of CEOs that are much more engaged in the innovation process. In short, CEO/Executive innovation today seems to have been resurrected in many different industries.

As innovation is vital to the growth of American industry, it should not be left entirely to intrapreneurs, entrepreneurs, internal R&D organizations, new start-ups and acquisitions. Executives need to play a more decisive role. In the future criteria for selecting CEOs could include how well they delivered innovation in their past industries and executive assignments, as well as how they intend to promote innovation in their new roles.

6. RECOMMENDATIONS

Due to the diversity of industries, CEO/Executive innovation can take different forms. It should not be limited to just technological innovations, but needs to be expanded to include innovations in such functional areas as marketing, operations, procurement, R&D etc. For example. Whitacre's innovations showed how innovation can be accomplished in the area of organizational structuring and design. In any event, future research could also be taken in innovation to specifically determine how CEOs and Executives can best foster innovation in their respective industries.

Also, techniques such as data analytics would be useful in performing future research in innovation. A data analytics study could be set up to employ text mining and use a data-centric (versus a problem centric) methodology. Machine learning algorithms could then be used to convert unstructured data into structured data using natural language processing (NLP). This technique is useful for identifying themes, as well as theory building and modeling. Such a study could identify a variety of themes such as (a) definitive evidence of how much CEO and Executive participation in innovation ebbed and then flowed over the past 125 years; (b) exactly what constructs are driving the recent upsurge in increased CEO and Executive innovation; and (c) how increased innovation by CEOs and Executives could pay dividends in other functional areas of business besides technology.

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DESIGN, MANUFACTURABILITY, AND SUSTAINABILITY ANALYSIS OF AN HCCI COMBUSTION ENGINE UTILIZING GASOLINE AND RENEWABLE FUELS

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Abstract: The global quest for new forms of energy is constantly growing. Extensive research is conducted to test and analyze new blends of fuels to meet these requirements. Due to the concern about the continued availability of fossil fuels, such as crude oil and natural gas, it has become a worldwide quest to face these challenges with renewable forms of fuels and new approaches to internal combustion (IC) engine designs. The IC engine has established a robust utility in various sectors, such as transportation, agriculture, aerospace, defense, and other small power plants, to name a few. However, not all conventional IC engines have the capability to operate on multiple types of fuels. Blended fuels have proven to have slight lower power outputs with increased CO and CO2 emissions; however, yielding a lower fuel consumption is also a factor. In order to eliminate some of the major fuel issues, we have designed, developed and manufactured homologous charge compression ignition (HCCI) engine system. The benefit of this successful HCCI engine is that it can operate without a spark plug or direct injection while operating on regular gasoline. To prove this, various experiments have been conducted with different engine designs and fuels. This paper will explore the superiority of the HCCI engines over the traditional spark ignition, direct ingestion, and compression engines. These HCCI engines have successfully passed testing on different fuels such as gasoline, rubbing alcohol, and blended E10 gasoline. Because of the high engine performance and efficient burning, low particulate emissions (micro and nanoparticles) are expected from these studies.

Key Words: *IC Engines, Alternative Fuels, HCCI Engines, Emissions.*

1. INTRODUCTION

1.1 General Background

Internal combustion engines are the most frequently utilized and widely deployed power- generation systems in use today. Gasoline engines, diesel engines, gas turbine engines, and rocket propulsion systems are examples of these IC Engine systems. In these engine designs, the reactants of combustion, the fuels and oxidizers, and combustion products serve as the working fluid (source of power). The propulsion energy is obtained from the heat released in the combustion process. The combustion process occurs within the closed engine system, which is a part of the thermodynamic cycle. In contrast to an external combustion engine, which uses a separate combustor to burn the fuel, internal combustion (IC) engine releases the chemical energy of the fuel inside the engine and uses it directly for mechanical work.

The CI engine was conceived and constructed during the early 18th century. It had a significant influence on society and is regarded as one of the most important innovations of the 18th century (Benson & Whitehouse, 2013) as it is considered to be the primary propulsion method for equipment manufacturers (OEMs) (Davani, 2019). Earlier attempts to design an IC engine by Christian Huygens, a Dutch physicist, in 1680 fueled by gun powder were regarded impractical (Benson & Whitehouse, 2013). Later in 1807, Isaac De Rivaz invented an IC engine that utilized a mixture of oxygen and hydrogen as a fuel to power his cart (Benson & Whitehouse, 2013).

Although the design was unsuccessful, it was used as a foundation by other scientists. The IC has served as the basis for the successful developments of a wide range of commercial systems. The most beneficial sector is the transportation industry, enabling the developments and improvements in aircraft, trucks, automobile, and train propelling systems. Since the 1800s, the reciprocating IC engine elements designs, such as the piston, block, crankshaft valves, and connecting rod, have remained constant (Benson & Whitehouse, 2013). The primary distinctions between a modern IC engine and one manufactured years ago are thermal efficiency and the levels of emissions.

The global quest for new forms of energy is constantly growing. The automotive industry is one of the leading industries in the emission of greater greenhouse gas (GHG) (Davani, 2019). Extensive research is conducted to test and analyze new blends of fuels and engine designs to reduce carbon emissions. Due to concern about the continued availability of fossil fuels, such as crude oil and natural gas, it has become a worldwide quest to face these challenges with renewable forms of fuels and new approaches to the IC engine designs.

1.2 Progress in Combustion Engines

Internal Combustion Engines: Many scientists have tried to develop and improve the IC engines. However, Jean Etienne Lenoir, in 1960, patented the first commercial IC engine (Forrest, 2019). During that time, the engine was made of only one cylinder and was characterized by overheating. Nevertheless, it powered the vehicle for 2 miles per hour. It was a massive step in the design since Lenoir proved that the IC engine could run continuously. By the year 1879, Nikolaus Otto created a more efficient four-stroke engine (Forrest, 2019). In the same year, Clerk Dugald developed a two-cycle IC engine ("Two-Stroke Cycle Diesel Engine," 2016). The IC engine has established a robust utility in various sectors, such as transportation, agriculture, aerospace, and other small power plants, to name a few. However, not all conventional IC engines have the capability to operate on multiple types of fuels. Blended fuels have proven lower power outputs as well slight increase in CO and CO_2 emissions; however, yielding a lower fuel consumption is also a factor. Clerk's design employed a separate cylinder that served as a pump to transfer the fuel-air mixture to the compression cylinder. Later in 1899, the design was simplified by John Day to a two-cycle engine that is widely used in today's automobile ("Two-Stroke Cycle Diesel Engine," 2016).

Several configurations have been developed to improve the IC engine performance, for instance, the V engine configuration. In this design, the pistons are arranged to appear like a "V" to reduce the overall length and weight as opposed to the straight arrangement. The V engine design was developed by Wilhelm Maybach and Gottlieb Daimler in 1888 (Johnson, 2014). The V engine designs include V4, V6, V8, V10, and V12. The number after V represents the number of cylinders. Inline engine configuration (straight) has all cylinders lighted in one row (Wilson, 1995). The design is characterized by simplicity (Johnson, 2014). However, the engine length can longer and bulky. In the flat design, the cylinders are located on the opposite sides of the crankshaft. The flat design was first used by Karl Benz in 1897. This has advantageous since it offers a shorter engine length and allows air cooling. Finally, in the radial design, the cylinders are arranged radially around the crankcase. This engine design is mainly used in aircraft and gas turbines.

***Spark Ignition Engines*:** Spark ignition engines are also referred to as petrol or gasoline engines. These types of engines utilize the four-stroke Otto cycle (Breeze, 2018). The four stages are illustrated in Figure 1.

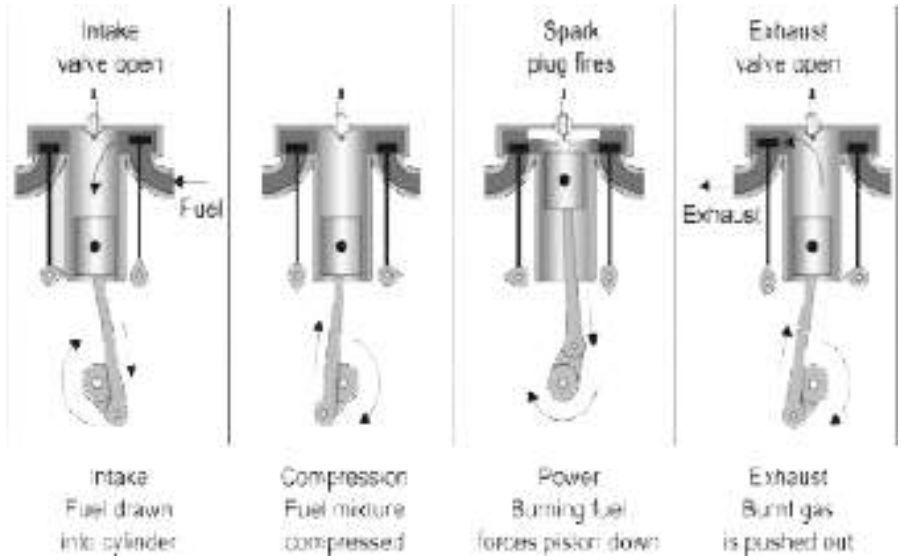

Figure 1 Four-stroke engine stages (Breeze, 2018)

According to Foster and Hermann (2003), the universal spark-ignition engine uses low flammability fuels that include liquified petroleum gas (LPG), gasoline, methanol, Liquified Natural Gas (LNG) and hydrogen (Naber & Johnson, 2014). The combustion process is initiated by the spark plug in these spark-ignition engines (Davani, 2019). These engines were an improvement from an earlier engine that utilized hot tube ignition. The hot tube was an invention of Gottlieb Daimler in 1884 to power his car (Merrygold, N.D.). Before starting a vehicle, two platinum tubes beside the engine were heated to red hot. The tube extended to the combustion chamber. During the compression stroke, the fuel mixture was pushed along the tube to the red- hot spot where the ignition takes place. Unfortunately, the ignition process was faced with inaccuracy which necessitated Bosch to develop the magneto, which became the source of power to the spark plug (Naber, & Johnson, 2014; Merrygold, N.D.).

The thermal efficiency of the spark-ignition engine is significantly dependent on the compression ratio (Davani, 2019). However, it considerably suffers engine knocks (spontaneous fuel ignition due to lower octane number). Fuel additives suppress the engine knock effect, such as lead, tetramethyl, tetraethyl, and many other compounds being researched (Bhatia, 2014). However, the elements like lead have been found to be harmful to the environment, making fuels with the additive quite impractical (Bhatia, 2014). The spark-ignition engine runs on a combination of air and atomized fuel generated by fuel injection into frequently used induction pipe, popular combustion chamber, or the classical carburetor (Foster and Hermann 2003). The ignition process, basically by an electric spark, is dictated by the correct quantity of oxygen and fuel (close to being stoichiometrically correct) (Foster and Hermann, 2003). For petrol fuel, a one kilogram of fuel will require 14.5 kilograms of air (λ=1). Since the fuel-air ratio is always kept near to stoichiometry under all conditions (pressure and temperature) within the combustion cylinder, output control can only be achieved by varying air density, accomplished mainly by intake air throttling (Foster and Hermann, 2003). Although the spark ignition engines run smoothly, they are limited to low efficiency at partial loading due to energy losses in air throttling (Auer, 1982). They are also disadvantaged by engine knocks, inaccurate fuel-air mixture ratio, location of spark plugs, and many other factors (Auer, 1982).

***Direct Injection Engines*:** Direct injection engines differed from the convention spark- ignition engines in how the fuel is delivered into the combustion chamber. The fuel is directly squirted into the combustion cylinder with the assistance of high precision management computer systems when the chamber is hottest. Bosch designed the direct injection concept in 1951 to increase the IC engine efficiency. The engine design was to allow reduced emissions and low fuel consumption. As Parker (2021) illustrates, the fuel-air mixture significantly determines the engine performance, emission levels, and fuel efficiency. The direct-injection engine uses a fuel-air mixture with a high amount of air compared to the fuel (lean mixture). The lean mixture constitutes 40 parts of air for every part of fuel (40:1), allowing a conservative combustion process.

According to Yi (2010), a direct injection engine operates efficiently in various modes. It uses a stratified air-fuel ratio at partial loads and lower speeds, whereas at full loads and higher speeds, it uses a 'homogeneous' ratio (Yi, 2010). As a result, the engine is characterized by reduced pumping losses, higher thermal efficiency due to high compression ratio, and lower heat losses through cylinder walls since the fuel is injected at lower temperatures. However, this type of IC engine has a high maintenance cost due to its complexity; it requires high-quality fuel, expensive design components, and problem diagnosis can be complex.

***Compression Ignition Engines*:** Breeze (2018) argues that the Compression Ignition (CI) engine is stronger and more efficient than ignition engines. The CI (or sometimes the diesel engines) uses a higher compression ratio than SI engines to heat and ignite the fuel-air mixture. According to Davani (2019), the CI engines depend on the combination of stratified charge (SI) and compression ratio to create ignition. Usually, the fuel used is diesel which much denser than gasoline. Only air and residual exhaust gases (EGR) are sucked into the combustion chamber in CI engines. The air mixture is compressed and fuel-injected when the compression stroke approaches TDC. The already heated air mixture causes the fuel to auto-ignite to produce power. Since the CI is based on autoignition, the run-on higher compression ratio ranges between 16 to 20 (Naber & Johnson, 2014).

2. EXPERIMENTAL PROCEDURE

In this study, to eliminate some of the major fuel, power and emission issues, we have designed, developed and manufactured a homogeneous charge compression ignition (HCCI) engine system. The HCCI incorporates the characteristics of both SI and CI to increase its capabilities and efficiency (Davani, 2019). The major advantages of both SI and CI engines are expected to be delivered by engines that operate unthrottled at modest loads with a homogeneous charge (Riley, 2018). Rather than employing an electrical spark for ignition, the HCCI engine design injects fuel during the intake stroke where the compression increases the fuel mixture's density and temperature until it spontaneously ignites (Riley, 2018). This compression combustion process produces a flameless, low-temperature auto-ignition that is fundamentally more efficient, with less fuel than in a typical SI engine. In addition, SI engines use air more efficiently than diesel engines under partial loads. Therefore, it is critical to harvest the benefits of gasoline engine performance with CI engine advantages to achieve enhanced fuel efficiency and specific power outputs over the load range. Working in a meager air-fuel ratio, the HCCI can provide light-load engine performance without throttling; an event referred to as lean combustion.

The Nautilus GEN 2 engine is designed based on the HCCI system and utilizes characteristics from a spark ignited engine as well as a compression ignition engine. The redesign in the piston and cylinder head make it possible to achieve homogeneous charge compression ignition. Prior to machining the redesignation and cylinder head, a laser 3D printer was used to manufacture the finalized parts. This cost-effective method served its purpose in mitigating errors that could have otherwise been overseen. Figure 2 shows the 3D printed Nautilus GEN 2 piston and cylinder head.

Figure 2 Laser 3D Printed Piston and Cylinder Head (Davani, 2019)

3. DESIGN, MANUFACTURING AND TESTING

Various experiments have been done around the world with different engine designs ranging from gasoline to diesel engines. According to Davani (2019), there are presently no HCCI engine prototypes on the market that has been produced. The notion of HCCI has the potential to revolutionize the notion of the IC engine and enable it to maintain its global appeal of low carbon emission (Davani, 2019), as shown in Figure 3.

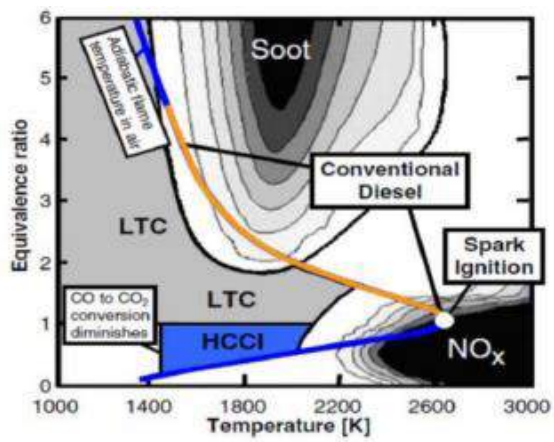

Figure 3 The link between temperature and air-fuel ratio and soot and NOx emissions in SI, LTC, and HCCI engines (Davani, 2019)

Nautilus team has taken a huge step in designing an HCCI engine (Nautilus Gen II) that can greatly harvest most power from the fuel through two power stroke stages (primary and secondary power stroke) while cutting down levels of emissions. The engine design is capable of operating on multiple fuels depending on the applicability. However, at this design stage, gasoline E-30 and E-80 are preferred due to their higher energy value and higher burning rate (Riley, 2018). In addition, the engine's piston design plays a bigger role in the improved power efficiency, as shown Figure 4.

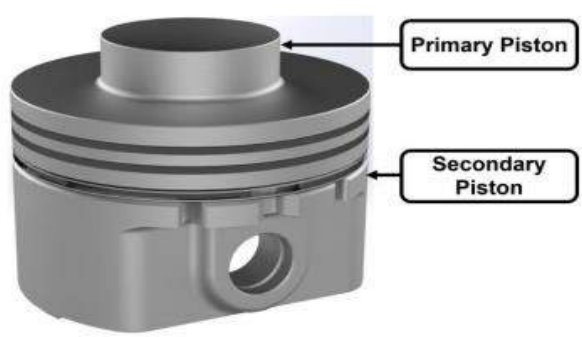

Figure 4 Nautilus GEN II piston design (Davani, 2019)

The piston is redesigned to allow multiphasic combustion, which involves primary force- controlled and secondary forced-controlled complete combustion (Davani, 2019). The piston material proposed is titanium due to its durability, lightweight, and resistance to corrosion at elevated temperatures. Also, the engine's cylinder head is configured to incorporate the piston, and the 2 staged power strokes. According to Davani (2019), the Nautilus GEN II engine's primary combustion chamber (PCC) is positioned dead center to the piston. The secondary combustion area in the cylinder head was redesigned for the improved dynamic flow of the premixed air-fuel mixture across the valves into the secondary combustion chamber (SCC), as shown Figure 5. In addition, the ability of the mixture to flow through the chamber is improved by increasing the capacity in the cylinder head (Davani, 2019).

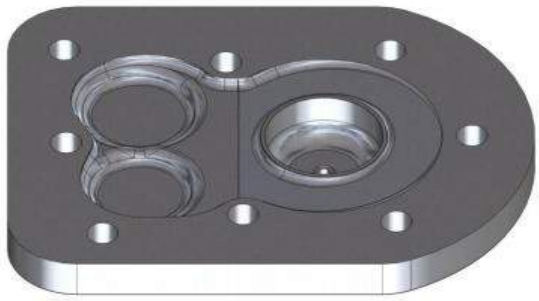

Figure 5 Nautilus GEN II cylinder head (Davani, 2019)

Aluminum is used to make the cylinder head. The primary combustion chamber of the cylinder head, on the other hand, accepts the installation of a cooper puck to improve thermal insulation for the main auto-ignition (Davani, 2019). As seen, the copper topping of the main combustion also houses a miniature Radio-Controlled (RC) glow plug (Davani, 2019). The glow plug assists in preheating the primary combustion chamber head for primary combustion to occur. Figure 6 displays the primary combustion chamber with cooper glow plug in the middle, while Figure 7 shows the cylinder head piston assembly of Nautilus GEN II engine (Davani, 2019).

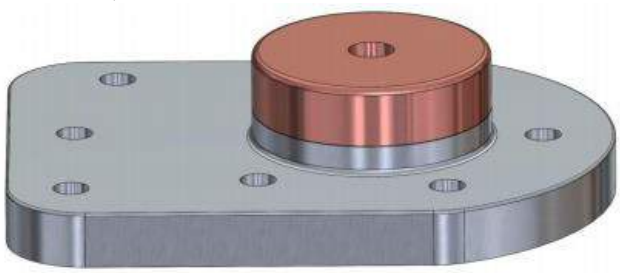

Figure 6 Primary combustion chamber with cooper glow plug in the middle. (Davani, 2019)

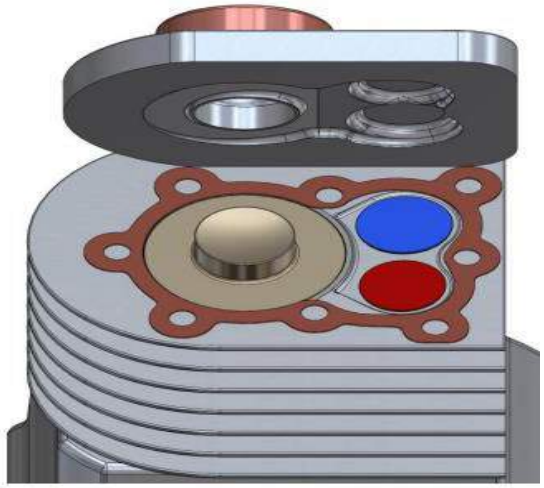

Figure 7 Cylinder head piston assembly of Nautilus GEN II engine. (Davani, 2019)

The Nautilus GEN III engine, which is being developed by Nautilus engineers, is a four- stroke, six-cycle dynamic multiphasic combustion engine III is designed for automotive applications since it can operate at a variety of loads and RPM ranges. With the inclusion of port injection and throttle body injection, it is now feasible to consume several fuels simultaneously. Figure 8 shows the Nautilus GEN III engine design for improved performance in terms of power, torque and gas and particulate emissions (Davani, 2019).

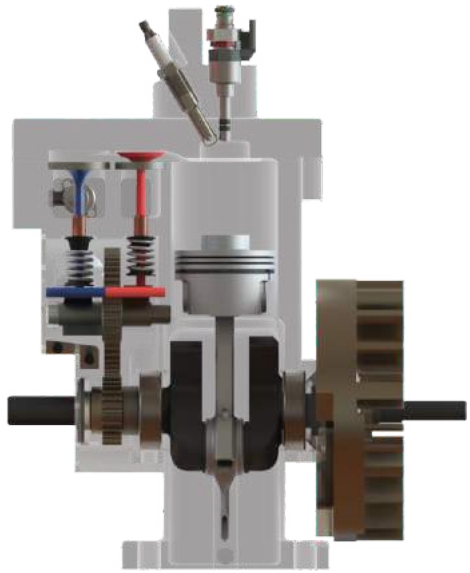

Figure 8 Nautilus GEN III engine design (Davani, 2019)

The new HCCI engine system was tested at Wichita State University for its capabilities. This system does not have a spark plug since the fuels of different kinds (rubbing alcohol, gasoline, and octanol) were preheated before injecting into the newly designed engine system. The test results showed that engine performance, rpm, power and torque of the HCCI system were considerably increased (20-40%) while the gas emissions (CO_2, CO, SO_2, NOx, and HC) were drastically reduced (approximately 10-20%). Owing to the high engine performance and efficient burning of the system, low particulate emissions (micro and nanoparticles) are expected from these studies.

As a comparison, some studies have been conducted on improving the CI engine to avoid wear and tear of moving parts using nanomaterial known as nanoflakes (NASA, 2020). This material has two sides, smooth and sticky sides. The sticky side is drawn to areas of friction in the moving parts, for instance, the cylinder bore. The sticky side adheres to them, leaving the smooth side facing out. This process is repeated over and over, building up layers of nanoparticles until a rough or worn-out spot is completely repaired, similar to filling in a roadway pothole (NASA, 2020). The technology has been tested over a range of temperatures, and the results are promising for the transport industry. The technology will further reduce the emissions and leakages produced by worn-out engine parts and improve the IC engine performance (Moradiya, 2019); however, the new HCCI engine system provided substantially higher engine performance. In the future, more experiments will be conducted in this field.

4. CONCLUSIONS

The A new HCCI engine system (Nautilus GEN II) was successfully designed, manufactured and tested. This prototype uses a 2-Stage combustion method to control HCCI and operate with different blended and unblended fuel types. The introduction of a fully atomized mixture of fuel and air in the combustion chamber allows the complete burn of fuel eliminating the chance for engine knock. After testing the three fuels, it is certain that the Nautilus GEN II prototype is fully operable without the aid of a spark plug for the SI system. It was observed that the flameless combustion engine was able to run on much lower peak temperatures during the testing period compared to conventional SI and CI engines. With the elimination of a flame front caused by a spark plug, lowering operating temperatures are possible, resulting very low production of CO and CO_2 gases. The NOx production did not surpass 40 PPM in any of the experiments. This study will open new avenues for the future designs of the internal combustion engine system with high performance and low emissions.

5. ACKNOWLEDGMENT

The authors gratefully acknowledge the Wichita State University for the technical support of the project.

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CYCLIC FINITE ELEMENT ANALYSIS OF TI-6AI-4V TITANIUM SPECIMEN

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Abstract: In this paper, finite element simulations of TI-6AI-4V titanium cylindrical dog-bone specimens subject to sinusoidal loading mimicking specimens loaded in an MTS axial fatigue testing machine are presented. The geometry was modeled according to ASTM E466 standards, and the specimens were modeled using second order tetrahedral elements. The load was applied axially, and symmetry constrains were imposed on three surfaces. A static load was first applied axially, and the results were used in the durability fatigue and life analysis application of Siemens NX. A strength-life plot was created for the specimen. The simulations are performed to help determine how best the finite element methodology (FEM) can be used to guide experimental cyclic testing for surface treated specimens.

Key Words*: Ti-6AI-4V Titanium, durability, cyclic analysis, finite element analysis, FEM, FE*

1. INTRODUCTION

Medical implants are subject to highly variable and cyclic loads and need to last a long time as replacement requires surgeries. As such, implants are commonly made from titanium Ti-6Al-4V because of its high strength and corrosion resistance. Still, Ti-6Al-4V is not perfect and to optimize the implants, further understanding of the material is needed. While Ti-6Al-4V is corrosion resistant, it still contributes to implant failure (Antunes and Oliveira, 2015). Because the surface roughness is a contributing factor to corrosion fatigue behavior (Zhang and wang, 2022), one way to improve the material is to change its surface characteristics though coating or shot peening (blasting the surface with a stream of objects (Campbell,1971)). In determining if and how this improves the cyclic characteristics of the material both experimental and computational studies are being conducted. The computational study is performed using finite element analysis (FEA) and the technique will be verified by the experimental analysis. The FEA will allow researchers and implant designers the tools to analyze the cyclic behavior of the material subjected to specific shapes and loads, which is difficult and expensive to do experimentally. This paper presents the first stages of developing such a FE model. A dog-bone shaped Ti-6Al-4V specimen is subjected to cyclic load and the cyclic behavior of the material is presented though an S-N curve. Next stages of the research will include surface treatment and comparisons to experimental data.

2. METHODOLOGY

The methodology applied consisted of developing a Computer-Aided Design (CAD) model of a dog-bone specimen, reducing it to an 1/8 volume to allow for symmetry, and then preparing the model for finite element analysis by applying a mesh, material, boundary conditions, and loads. The finite element model was then solved first using static analysis and then cyclic analysis.

3. CAD MODEL PREPARATION

A dog-bone specimen was modeled using the CAD application of Siemens NX. The dimensions followed recommendations of ASTM specification E466 (ASTM,2021), as shown in Figure 1. To allow for symmetry conditions during finite element analysis, the CAD model was cut along three symmetrical planes resulting in the 1/8 model geometry shown in Figure 2.

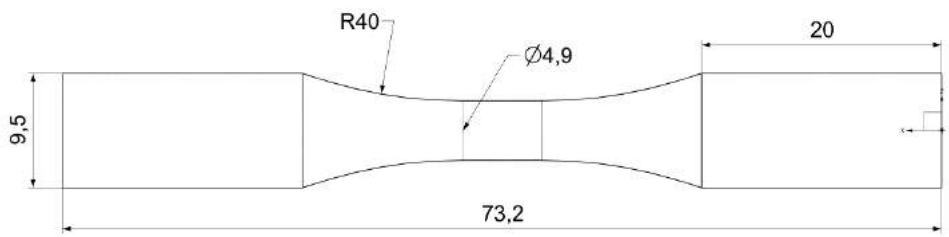

Figure 1 Dog-bone shaped specimen with dimensions (mm)

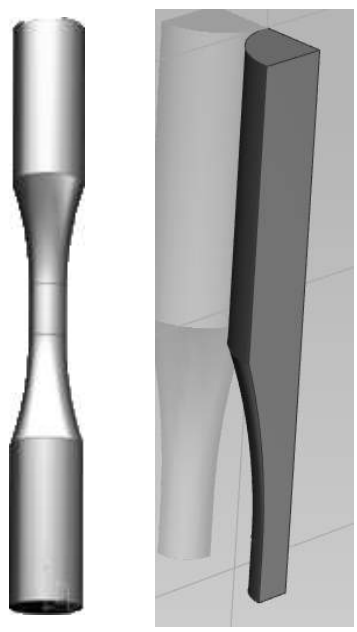

Figure 2 CAD model before and after modifying for symmetry boundary conditions

4. MATERIAL AND MESH

NX Siemens was used in conducting the finite element modeling and analysis of the specimen. The Ti-6AI-4V titanium was modeled using the following properties (Antunes and Oliveira, 2015): Young's Modulus of Elasticity of 12.1GPa, Poisson's ratio of 0.34, a Yield Strength of 805kPa and an Ultimate Tensile Strength of 845MPa.

Second order tetrahedral elements (CTETRA (10)) were used in modeling 1/8th of the dog-bone specimen. The mesh consisted of 3165 elements and 5735 total nodes. An h-refinement method was applied to the mesh to ensure convergence. The number of elements vs. von Mises Stress are reported in Table 1 which shows that the stress changed less than 2% as the mesh was refined from 223 to 3165 elements. While it can be argued that the coarser mesh could have been successfully used, the finer mesh of 3165 elements was used as the time to solve the model was insignificant.

Table 1 H- Refinement method

Number of Elements	223	373	567	709	827	870	1471	1666	3165
Von Mises Stress (MPa)	218.62	217.75	216.62	216.19	215.73	215.68	215.66	215.32	215.22

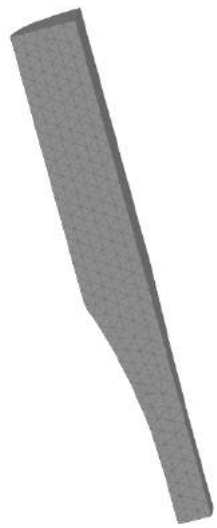

Figure 3 Meshed Model

5. BOUNDARY CONDITIONS AND LOAD APPLICATION

To better control the symmetrical behavior of the model during finite element analysis symmetry conditions were applied to three planes and resulted in a 1/8th of the original object being modeled and analyzed. Boundary conditions were applied to restrict motion across the planes of symmetry. The CTETRA (10) element only has three linear degrees of freedom, and as such the constraints were applied to all nodes on the planes of symmetry and hindered motion perpendicular to the symmetry planes.

The load was applied to simulate the load that would be applied to a physical specimen in a Material Test System (MTS 858 MiniBionix). The FE load application was slightly modified from the physical application in that it was applied to the flat circular surface rather than though a grip on the cylindrical surface. Because the area of interest (waist of the specimen) is far from the location of load application, this simplification is not expected to significantly alter the results at the location of interest. The load was applied in the axial direction of the specimen.

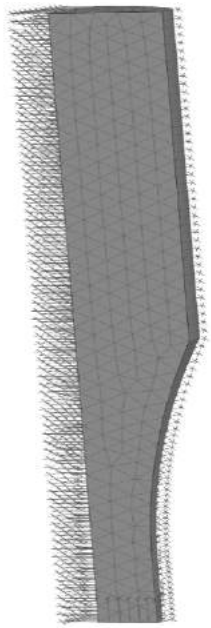

Figure 4 Applied constraints on one of the symmetry planes

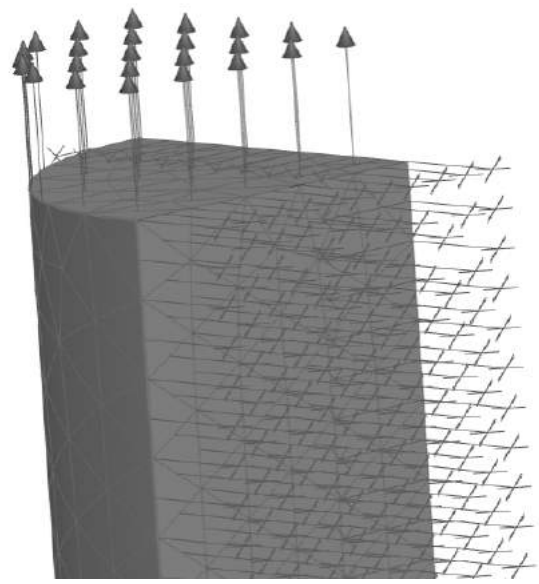

Figure 5 Applied loading conditions

An arbitrary load magnitude of 1000 N was first applied to the specimen. Because the analysis was linear in nature, the maximum allowable load for static analysis could be calculated by linearly scaling the results from the arbitrary load using Equation 1.

Maximum allowable load=Applied load x (Ultimate Tensile Strength /Maximum von Mises Stress from arbitrary load) Equation 1

6. STATIC ANALYSIS

The static analysis was performed to determine the maximum allowable load for one cycle so that those results could be used for cyclic, or durability analysis. From the linear scaling in Equation 1, the maximum load was calculated to be 3983 N.

7. DURABILITY ANALYSIS

NX Siemens Durability application was used in determining the number of cycles that can be applied to the specimen for various loads, allowing the creation of a strength-life (S-N) diagram. For this analysis, the loading pattern was set to Full Unit Cycles to best replicate how the specimen will be tested in the MTS machine.

As seen in Figure 7, the stress criterion was set to Ultimate Strength, the stress type to von Mises stress, cycles to failure were used for the design life criterion, and stress life (high cycle fatigue) was used for the fatigue life criterion.

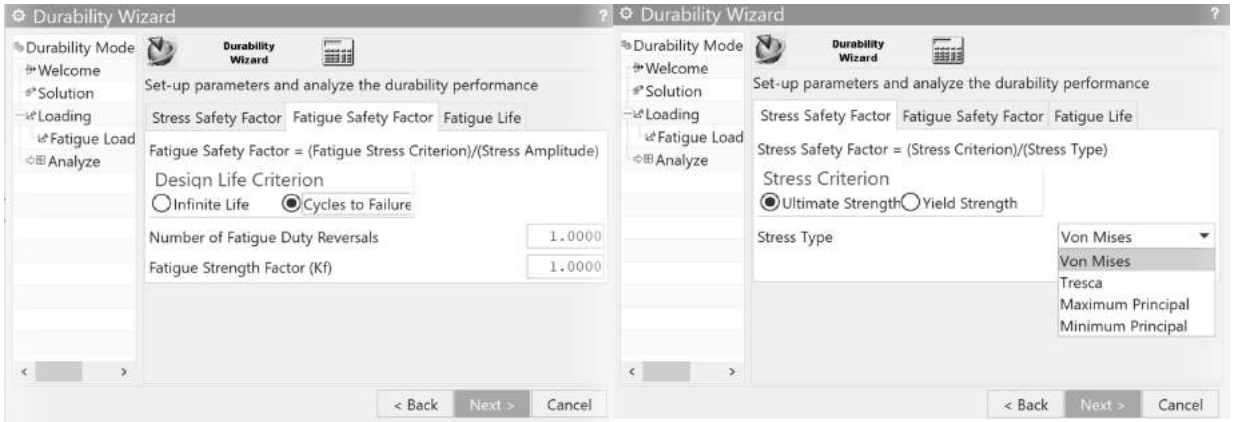

Figure 6 Durability parameters selection

8. RESULTS AND CONCLUSIONS

For the static analysis, the material behaves linearly and the maximum allowable force that could be applied was calculated to be 3983 N based on results from an arbitrary load application and the material's ultimate tensile strength of 845MPa. Figure 6 shows the von Mises stresses resulting from the arbitrary and maximum allowable load. As expected, the results have the same distribution.

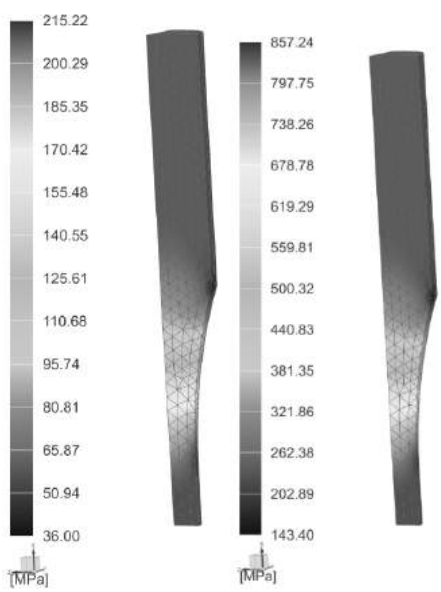

Figure 7 Von Mises stress results from arbitrary load (left) and maximum allowable load (right)

For the durability analysis, the number of cycles to failure were computed for various loads ranging from 100% of the maximum static load applied (3983N) to 25% of the load applied (996N), which was determined to be the infinite life of the model at 100 million cycles. The load was reduced in 3% increments from the 100% load. The resulting data is plotted on the strength-life (S-N) curve shown in Figure 8.

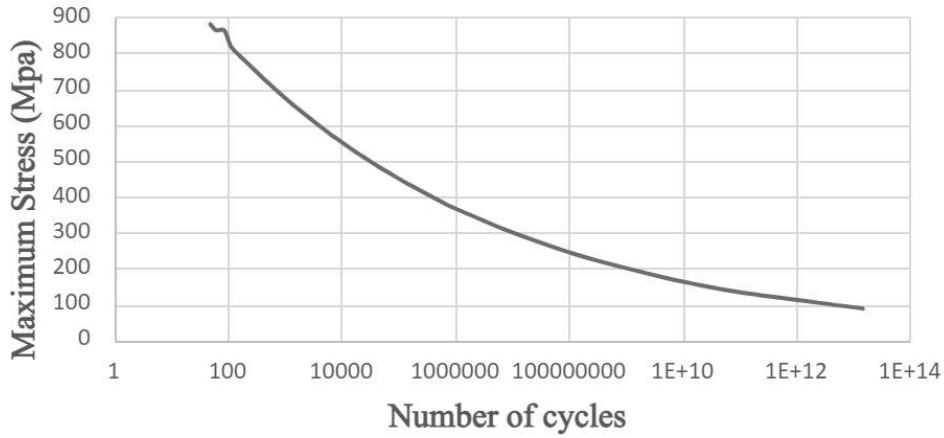

Figure 8 S-N curve made from Durability Simulation

The number of cycles computed for one of the cyclic analysis is shown in Figure 9. The gage length of the specimen fails at significantly fewer cycles than the grip section, supporting the validity of the simplification of load application.

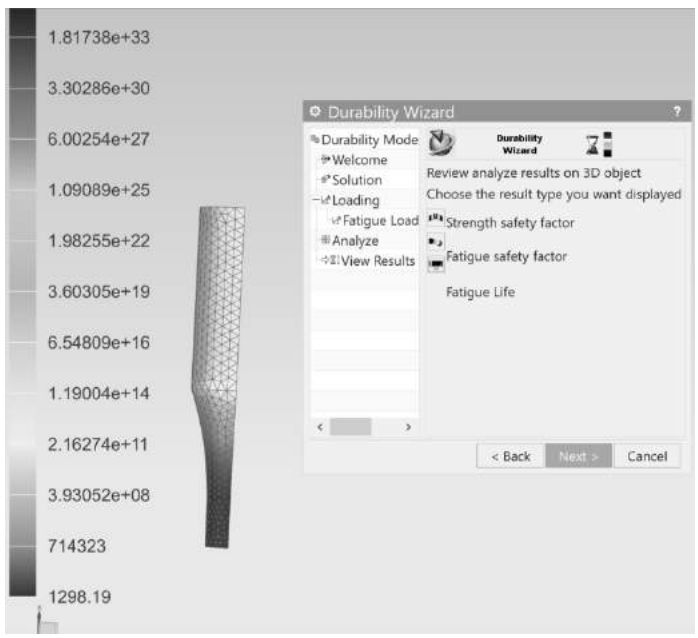

Figure 9 Cycles to failure during durability analysis

To continue to improve implants it is vital that the behavior of the material is well understood and that it continues to be optimized for the human body environment and load applications. The presented FE analysis is the first step in developing a FE model that can be used for cyclic analysis of various implants. Improvements of the model will be to model a different surface finish and then later to apply the material to geometries of implants and various loading scenarios.

9. ACKNOWLEDGMENTS

We are grateful to the Auld and White Foundation for their support of this project.

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MARKETING CHALLENGES FOR THE NEXT GENERATION OF NUCLEAR POWER:

HAS DEREGULATION ELIMINATED THE NUCLEAR OPTION?

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Abstract: The purchase of a nuclear plant relies on bank financing and lenders emphasize the quality of the nuclear plant's projected income stream to repay the financing. This is why all previous nuclear plant financings relied on the monopoly status of the purchaser with its legislatively anointed captive market to ensure an adequate income stream.

Today, due to deregulation, electric utilities can't own regulated power plants in two-thirds of the country. In these states, electricity is generated and sold on a competitive basis by Independent Power Producers, end-use customers are free to choose their electric suppliers, and state regulators no longer ensure cost coverage of the nuclear-related risks.

However, policymakers at last year's United Nations COP26 and other environmental forums touted nuclear power as a solution to climate change because it doesn't produce greenhouse gases. Missing is a discussion and analysis of the impact of this deregulation (and its loss of a guaranteed revenue stream) on the ability to obtain financing and, in turn, on the potential size of this market. Thus, deregulation may have eliminated nuclear power as an option to fight climate change. This presentation builds on earlier research by proposing an analysis of survey data regarding two post-deregulation risk factors (long-term price certainty and long-term output quantity certainty) versus the likelihood to obtain financing.

Key Words: *Deregulation, cost-of-service regulation, economic efficiency, power plant financing, nuclear power, public policy*

1. INTRODUCTION

The construction of a nuclear power plant is a major financial commitment. The most recent data on actual construction costs for a 1,000 MW nuclear power plant exceeds ten billion dollars (King, 2017). Long-term financing is relied upon to pay for most of the construction costs and twenty-year financing terms are common (IAEA, 2017; Harmon & Reynolds, 2003; Joyner, 2013; Wealer et al., 2021). Lenders place great weight on the quality of the projected income stream of the nuclear plant to repay the loans (Harmon & Reynolds, 2003; IAEA, 2014; IAEA, 2017). This explains why all previous nuclear power plant financings have relied on the monopoly status of a purchasing utility, with its legislatively anointed captive market, to provide an income stream sufficient to ensure debt coverage, as well as cover nuclear-related risks to the satisfaction of the lenders.

Today, due to electricity deregulation, electric utilities are not permitted to own regulated power plants in about two-thirds of the U.S. market where electricity is generated and sold on a competitive basis by non-utility Independent Power Producers (IPPs) and state regulators no longer ensure cost coverage of the nuclear-related risks (Ward, 2011; White, 1996). Moreover, in many states, end-use customers are

able to choose their electricity suppliers (Ward, 2011; White, 1996). However, policymakers at the 2021 United Nations 26th meeting of the Conference of Parties (COP26) and other environmental forums began to establish nuclear power as a solution to climate change because it doesn't produce greenhouse gases (GHG). Overlooked by the policymakers in these environmental discussions, is any consideration and/or analysis of the impact of this electricity deregulation on the ability of nuclear plants to obtain the financing needed for construction and, in turn, on the potential number of nuclear power plants that could help fight climate change.

This paper fills a gap in the literature by: 1) establishing the case that the deregulation of the electric industry has likely eliminated nuclear power as an option to fight climate change in most of the United States, and 2) proposing an analysis that will quantify the impact of this deregulation (specifically the loss of a guaranteed revenue stream) on the ability to obtain the financing needed for construction.

The argument herein is constructed, sequentially and layer by layer, on the technical, economic, regulatory, and marketing issues that systematically build on each other to support the position that deregulation has removed the requisite underlying credit to support the financing of a nuclear plant. This paper builds on an earlier work (Dansky, 1994) by incorporating several decades of newer technical, financial, regulatory, and market information and by proposing an analysis of survey data regarding two post-deregulation risk factors (long-term price certainty and long-term output quantity certainty) versus the likelihood to obtain financing.

Topics of discussion proceed in the following manner:

1. The environmental push behind the many recent news articles promoting nuclear power as a means to reduce GHG.
2. The economic and technical issues as well as the financial risk issues that impose constraints unique to the financing of nuclear power.
3. The ramifications of significant regulatory changes within the electric industry ("deregulation") that affects economic, technical, and financial risk constraints in such a way as to make it very difficult, if not impossible, to obtain the needed financing.
4. The inability to obtain financing impacts the market viability of nuclear power in the United States.

The resulting clash between two conflicting government policies: The Promotion of Economic Efficiency versus the Promotion of Energy Diversity and the impact on jobs creation.

2. CONCEPTUAL DEVELOPMENT

2.1. Climate Change May Open a Window of Opportunity

Many believe that global climate change is a serious threat to the environment and is primarily caused by man-made GHG (Tollefson, 2021). During the past several decades, international attention to this problem has been growing. Between 1992 and 2021, four United Nations (UN) climate agreements were signed, including the Framework Convention, the Kyoto Protocol, the Paris Agreement, and the recent COP26 Agreement (Almer, 2016; Dimitrov, 2016; Tollefson, 2021). Over time, the number of countries signing these agreements has grown, and the quantity reductions for greenhouse gases have become more stringent.

Multiple greenhouse gases are identified by the UN as the cause of climate change, but CO_2 is identified as the largest contributor (Jaforullah & King, 2015; York and McGee, 2017). The largest share of manmade CO_2 (about 87%) comes from the combustion of fossil fuels (Jaforullah and King, 2015; York and McGee, 2017). Of this, the majority of fossil fuel combustion occurs within the internal combustion engines used for transportation and within the combustion turbines and steam boilers used for electric power generation. With respect to transportation, oil is the primary fossil fuel that is consumed, and with respect to electric power generation, coal and natural gas are the primary fossil fuels consumed. Therefore, to meet the CO_2 reductions set forth in the UN agreements, existing electric generation fueled by coal and natural gas needs to be replaced with some other technology that is climate-friendly.

Being climate-friendly does not necessarily translate to "renewables" since many renewable fuels produce GHG. For example, biomass such as wood waste, landfill methane, and farmed algae all contain carbon and thus are unsuitable for reducing CO_2. The challenge, therefore, is to find electric generation technologies that do not emit GHG. Moreover, to add to the challenge, these GHG-free technologies must also be reliable (PJM, 2021) and economic (Zhongyang, 2022).

Since 1990, the installed capacity of nuclear power in the U.S. has declined as retirements of existing plants exceeded the construction of new plants. Many announced new units were canceled and only one location (having two units) started construction within the last three decades. However, the above concern for global climate change has opened a window of opportunity for the construction of new nuclear power plants in the U.S., because nuclear power does not emit GHG. Policymakers at last year's United Nations COP26 conference and other environmental forums have declared nuclear power as one solution to climate change. The European Union has recently announced it will re-label nuclear power as a 'green' energy source and a component of its strategy to meet climate and energy targets for 2030 under the European Green Deal (Gillet, 2022) as well as its COP26 goals. Not surprisingly, since last year's COP26 agreement, there has been a resurgence of news articles promoting nuclear power as a means to reduce GHG.

2.2. Economic and Technical Issues Create Financing Implications

Nuclear power isn't the only technology that could be used to reduce GHG. There are a number of carbon-free electric generation technologies such as geothermal, hydroelectric, tidal, wind, and solar. Each of these has certain limitations and, as such, no one technology appears to have the overall advantage. Geothermal power is limited to locations where the earth's tectonic plates meet, creating fissures in the earth's crust enabling the hot gases to be accessed (Muther, 2022). Tidal power is also limited to certain feasible locations, and also suffers due to its distance to load centers (Wu et al, 2016).

Hydroelectric plants are also limited to specific locations and cause high environmental impact (Cudmore, 2011) such as the effect on existing flora and fauna when a river is transformed into a lake. No new large hydroelectric plants have been able to secure the requisite permits from the Federal Energy Regulatory Commission and the U.S. Environmental Protection Agency for several decades and several hydroelectric plants have recently been taken out of service and decommissioned to re-establish fish migration and spawning (USSD, 2015).

Wind power is limited to locations where the wind is constant (Cudmore, 2011). Also problematic are the protests of visual pollution due to the size and quantity of the wind turbines, and because it's not 'energy dense', the required large number of wind turbines creates land use issues. Solar power has limitations from inclement weather, cannot generate power at night, and suffers from efficiency losses the further its location from the equator (Cudmore, 2011). It also is not 'energy dense' which creates land use issues. Nuclear power has many technical and political issues (Cudmore, 2011) primarily linked to radiation. However, the European Union's re-labeling of nuclear as a 'green' energy source and incorporating it into its strategy to meet its climate targets might act as a precedent for the U.S.

Imposed as a further constraint, those power plants technologies that have a high fixed capital cost (a high per kW cost) and a low variable cost (a low per kWh cost) are only economical serving the baseload demand (the level of demand that is present around the clock). Nuclear power is one of these.

The above characteristic of nuclear power has important financing implications. In order to be cost-competitive, it is necessary that nuclear plants be operated at a high-capacity factor, where capacity factor is defined as the actual annual output in kWh divided by the annual potential output in kWh. Capacity factors of 90+ percent, i.e., baseload operation, are critical if nuclear power is to be cost-competitive. In other words, using the equation for average fixed costs: $AFC = FC/Q$, where FC is the annualized fixed capital costs of the power plant, and Q is the annual output of the power plant (Mankiw, 2015; McConnell et al, 2021), it is, therefore, important to maintain a high Q to keep AFC down because nuclear plant fixed costs are high (EIA, 2017; King, 2017). By operating as a baseload unit, the high fixed costs of a nuclear plant can be allocated over a greater quantity of kilowatt-hours to minimize AFC.

This also means that nuclear plants cannot be dispatchable (IAEA, 2009), that is, to increase and

decrease output during the course of a day to meet changes in electric demand. They can't be used as an intermediate or peaking unit (IAEA, 2009), because this would lower Q and, in turn, increase AFC.

The conundrum is that the price (P) of the generated power must be low enough to ensure that the plant will be called on (dispatch) to sell a high quantity (Q) of the plant's output, and thus be a baseload unit, yet the total revenue (TR = P x Q) must be large enough to cover all costs, including the plant's high capital costs. This is a tight operating window and the nuclear plant must be able to satisfy this constraint over the plant's life despite changes in competing technologies, regulations, and customer demand. The banks that lend money to the owners of the nuclear plant to finance its construction seek to have this operating risk minimized.

2.3. Project Risks That Affect Financing

All aspects of any new power project have risks, whether technical, engineering, social, political, or regulatory. These risks all have the potential to impact a project's long-term profitability, and thus a potential impact on the bank lenders. As such, "all risk is financial risk" (IAEA, 2017: p.11). The key, then, to obtaining financing is to provide the lenders with enough assurance ("belts and suspenders") that the forecasted revenues will always be sufficient to meet the risk-return requirements of the lenders (IAEA, 2017).

The first major long-term risk that gives lenders concern is long-term price certainty. To reduce this risk the power plant must sell its output at a price that is high enough to cover both its fixed and variable costs. A long-term concern is the presence or innovation of competing technologies that are able to sell electricity at a lower price and push the nuclear plant out of the market (Harmon and Reynolds, 2003; IAEA, 2014; IAEA, 2017).

The second major risk is long-term output quantity risk. On one hand, this can come about because the plant is unable to generate power at full output for technical reasons (e.g., the need for many nuclear plants to plug leaking steam generator tubes, which reduces output). However, this risk can also come about because a lower costing competing technology can push the nuclear plant "up the dispatch curve" and block it from being a baseload plant (and thus reduce Q). This will result in a shortfall of total revenue (Harmon and Reynolds, 2003; IAEA, 2014; IAEA, 2017), and in turn, affect the ability to make payments to the lenders.

The lenders are also concerned about the risks of cost uncertainty (IAEA, 2017; Joyner, 2013). Construction cost overruns translate into increased annual fixed costs, affect debt coverage ratios, and impact debt ratings (Wealer et al, 2021; Ziegler and Dansky, 1982). All nuclear plants constructed in the U.S. to date experienced significant construction cost overruns, sometimes doubling and tripling the initial cost projections (Frye, 2008). The Shoreham nuclear plant experienced a quintupling in cost before being terminated (Ross and Staw, 1993). Thus, the history of nuclear power is that cost overruns are more common than not and this affects the degree of risk as seen by the lenders.

Construction schedule delays affect cash flow, affect the start of debt repayment, and increase the interest on the debt during construction (Wealer et al, 2021). Referred to as Allowance for Funds Used During Construction, or AFUDC, this is the accrued interest on the loans during construction that is capitalized and converted into a fixed cost to be repaid with interest to the lenders (Wealer et al, 2021; Ziegler and Dansky, 1982). Given the 8–12-year construction schedule for a nuclear plant, it is common that the compounding interest of AFUDC doubles the cost of a nuclear plant (Ziegler and Dansky, 1982).

Another major risk of concern to lenders is the cost and availability of insurance. Commercial insurance companies have not been willing to insure nuclear risk, and as such, the federal government instituted, under the Price Anderson Act, federal insurance guarantees limiting the risk exposure of nuclear plant owners and their insurers (Fishman, 2018; Kolomitz, 2016). Congress has extended the Price Anderson Act several times (Fishman, 2018; Kolomitz, 2016), but it is unknown if they will continue to extend this protection, or if they will extend it to non-utility IPPs.

Finally, there is the risk associated with the cost of decommissioning and decontaminating a nuclear power plant at the end of its useful life, and the cost and availability of spent fuel storage (Bems et al, 2015; IAEA, 1997). A permanent solution for spent fuel storage has yet to be approved in the U.S. due to

political considerations and is thus difficult to quantify. Together, each of these poses a significant risk to the lenders, which in the past have been addressed to the lenders' satisfaction under a regulated monopoly utility cost-of-service framework (Grantham, 2017; Harmon and Reynolds, 2003). Under this framework, known as the "sovereign method of financing" (IAEA, 2014), the government assumes the revenue and cost risks or it sets forth regulations that require these risks to be assumed by captive customers.

Specifically, in the United States, these long-established cost-of-service regulations go back to the Supreme Court decision in Hope Natural Gas v. Federal Power Commission (FPC) and established the "used and useful" doctrine for regulated monopoly utilities (Brown, 1944; Cabot, 1929). Under this doctrine, if a power plant (or any utility asset) has been determined by the appropriate regulatory body to be used and useful, then the prudently incurred costs, including cost overruns, schedule delays, and interest during construction, plus a reasonable rate of return, shall be included in the electric rates charged to customers (Brown, 1944; Cabot, 1929). Moreover, the utility's retail customers situated within the geographic boundaries of the utility's service territory are captive—they can't switch electric providers no matter how high the electric rates that have been approved by the regulators. These captive customers provided the ultimate credit support for the utility's construction plans. Thus, under a regulated monopoly utility framework, the revenue and cost risks, *such as ensuring baseload operation to maintain a high Q and lower AFC*, were reduced to a point sufficient to satisfy the lenders.

This regulatory framework supported the construction of 91.5 GW of nuclear capacity in the U.S. during the 1960-1990 timeframe (Kumar, 2021). In round numbers, this is about 90 nuclear units. Very little was started after 1990 (only Vogtle Units 3 and 4 which are now under construction) (Kumar, 2021). Some of this post-1990 drought may be attributable to the 1978 Three Mile Island, 1986 Chernobyl, and 2011 Fukashima nuclear accidents, some of it may be attributable to newer lower-costing generation technologies (EIA, 2017), and some of it may be due to significant regulatory changes within the electric industry ("deregulation") affecting the ability to obtain the needed financing, which is the primary focus of this paper.

Despite the post-1990 nuclear construction drought in the U.S., many other countries continued to construct nuclear plants (Kumar, 2021). The sovereign method of financing also holds true for the rest of the world; in some countries, the government agreed to assume the revenue and cost risks, and in others, it passed the risks on to captive customers (IAEA, 2014; IAEA, 2017). No nuclear power plant has successfully secured financing anywhere in the world without some form of the sovereign method (IAEA, 2014; IAEA, 2017). Other forms of credit support have been explored (IAEA, 2014) but none have successfully resulted in the financing of a nuclear plant. These other forms of financing, including project financing and balance sheet financing, are used routinely to finance coal, natural gas, wind, and solar projects, all of which have different risk profiles from nuclear plants (Dansky, 1994; IAEA, 2014; IAEA, 2017).

2.4. Electric Deregulation Eliminated Cost-Of-Service Rate Regulation

The above "used and useful" regulatory framework served the participants of the electricity industry well from 1920 to 1970 when there was a long-term general decrease in electricity rates largely due to technology improvements in fossil-fuel steam-generation thermal efficiency (Isser, 2003). In the 1970s, however, inflationary pressures began to drive up electricity prices, the Clean Air Act imposed additional costs on fossil-fired plants, and the OPEC oil embargoes in 1973 and 1978 impacted oil prices (Isser, 2003). In addition, cost overruns on the roughly 90 nuclear units, which occurred under the monopoly utility cost-of-service regulations noted previously, put upward pressure on electricity prices. The term "rate shock" was coined at this time, due to the increase in rates caused by high nuclear plant costs, and was indicative of the widespread concern of the public (Barber, 1986; EUN, 1984).

Simultaneous with this increase in nuclear plant costs, new technology became available, primarily in the form of natural gas combined-cycle units. This new technology had several advantages: lower capital costs, efficient heat rates at smaller scales, modularity of design and construction, load-following dispatch capability, and a risk profile that did not depend on cost-of-service regulation to secure financing (Dansky, 1994; EIA, 2017; Olkhovski et al., 2021).

The combination of increasing electricity prices and the availability of smaller-scale new technology captured the attention of economists that had witnessed and/or participated in the deregulation of the airline, package delivery, and trucking industries. To many economists (including one of the authors of this paper), the risks of regulatory failure, as specifically observed in the lack of economic incentives to curb power plant cost overruns, were greater than the risks of any market failure that might arise from a market that was oligopolistic and not fully competitive, or arise from an oligopolistic market that had significant, but different, regulatory impositions (Isser, 2003). This resulted in a concerted push to deregulate the electric power industry, and these efforts were primarily aimed at dissolving the long-standing vertical integration of generation, distribution, and retail sales.

Congress responded to this push with the Public Utility Regulatory Policies Act of 1978 (PURPA); the first in a series of federal actions to encourage competition and increase economic efficiencies in the electric generation market (Joskow, 1989; White, 1996). PURPA directed state regulators to determine state-specific rules for electricity pricing based on marginal cost prices. See Dansky (1987) for a summary of several marginal cost price formats that emerged from several state hearings.

Other legislation followed to further encourage competition including the Energy Policy Act of 1992 (EPA) which made changes to both the Public Utility Holding Company Act of 1935 (PUHCA) and the Federal Power Act of 1935 (FPA) (Flores-Espino et al., 2016). After the passage of PURPA and the EPA, most states enacted legislation to deregulate both the generation of electricity and the retail sales of electricity (Dansky, 1994). The Federal Energy Regulatory Commission (FERC) then issued orders 888 and 1000 to further promote economic efficiencies arising from competition in electric markets by providing open access to electric transmission lines (Isser, 2003).

Arising from this string of legal and regulatory changes was a restructured electricity market serving most of the United States. In this restructured market, electric utilities were required to divest their electric generating assets. Most electric plants are now developed, owned, and operated by non-utility IPPs, and in approximately two-thirds of the U.S. market, these IPPs sell their electricity into a competitive wholesale "electric grid" as a commodity using prices provided by the IPP to the grid operator the day prior (Ward, 2011; White, 1996). Thus, prices change daily and there is no price certainty.

Cost-of-service regulations are not available to these IPPs. They make use of project financing and balance sheet financing the same as other competitive businesses in other markets. They survive, or not, on their ability to make a return on investment in a competitive market the same as other competitive businesses in other markets. In short, the goal of economists several decades ago to deregulate and restructure the electric generation market, and bring economic efficiencies through competition, has largely succeeded. Numerous studies (Csereklyei & Stern, 2018; Fabrizio et al., 2007; GAO, 2002; Lei et al., 2017; Musco, 2017; Switzer & Straub, 2005) have shown that deregulation led to increases in operating performance and plant efficiency, as well as lower electricity prices to customers. Whether this deregulated environment can be habitable to new nuclear power plants is unknown.

2.5. Impact of Deregulation on New Nuclear Power Plants

Today, the regulatory structure affecting the construction of new power plants is divided. In two-thirds of the U.S., the role of the regulated utility is now limited to distributing the electricity generated by the non-utility IPPs (Ward, 2011; White, 1996). In the other one-third of the country, regulated utilities can continue to own regulated electric power plants because these states never enacted the federal regulations to deregulate (Electric Choice, 2021; Flores-Espino et al., 2016) due to countervailing political pressures.

Consequently, in two-thirds of the United States: a) there are competitive wholesale and retail electricity markets (White, 1996), b) there are no regulated monopolies for the generation of electricity (Flores-Espino et al., 2016), c) the previously captive retail customers are now free to choose their electric suppliers (Flores-Espino et al., 2016), and d) the revenue and cost certainty that the lenders previously relied upon via the "used and useful" doctrine have been eliminated (Dansky, 2002; Ward, 2011). While nuclear power remains potentially financeable in the one-third of the U.S. market that remains regulated, the underlying basis for the financing of nuclear plants (the sovereign method of financing) has been

removed in two-thirds of the market (Dansky, 1994). This lack of long-term revenue and cost certainty in two-thirds of the U.S. market suggests that nuclear power plants are unlikely to obtain financing within most of the U.S. market (Dansky, 1994). It is this two-thirds of the market that is the focus of this paper.

2.6. Implications

Policymakers at the 2021 COP26 meeting and other recent environmental forums have offered nuclear power as one solution to climate change, however, none of them have publicly recognized the likely inability to secure financing in most of the U.S. as an impediment to meeting GHG reductions. The "real obstacle [to building a nuclear plant] isn't the Sierra Club but the … analysts on Wall Street" (Aston, 2006:1). Standard & Poor's Rating Service stated that any electric utility that pursued a new nuclear plant would have its credit rating negatively impacted (Frye, 2008). The CEO of a large electric utility with prior nuclear experience stated the credit rating agencies "would assuredly drop your bonds to junk status" (Frye, 2008:351), and Moody's Investors Service dropped the bond rating of SCANA (the parent company of a utility) when the company announced it was considering construction of a new nuclear power plant (Frye, 2008).

While this is suggestive of a financing problem, it is hardly conclusive. More analysis is needed. To that end, this paper fills a gap in the literature by: 1) establishing the case that the deregulation of the electric industry has likely eliminated nuclear power as an option to fight climate change in most of the United States, and 2) proposing an analysis that will quantify the impact of this deregulation (such as the loss of a guaranteed revenue stream) on the ability to obtain financing and, in turn, on the potential size of this market.

2.6.1 Conflicting Public Policy of Economic Efficiency Vs Energy Diversity

If the results of this proposed analysis suggest that the financing of nuclear power in deregulated jurisdictions is not feasible, we are then presented with a clash of conflicting public policies. On one hand, the government has promoted economic efficiency whenever possible, including but not limited to the deregulation of the airline, trucking, package shipping, natural gas, and electric industries. It has busted trusts and pried apart monopolies since the 1890 passage of the Sherman Ant-Trust Act in the name of increased competition. In that vein, the 'invisible guiding hand' of competitive markets should decide what type of GHG-free generation should be built.

On the other hand, the government has promoted energy diversity, and expended billions of dollars in energy R&D, as a means to reduce market risk and enhance energy security (National Research Council, 2007). From this perspective, if nuclear power is unable to obtain financing in a competitive market, the government could carve out a protected regulated niche (a non-compete market set-aside) for nuclear power even though it would be at the expense of economic efficiency with ratepayers taking on the revenue and cost risks. But there may not be a need to carve out a protected niche for nuclear power to promote energy diversity since there are other existing GHG-free generating sources previously discussed including wind, solar, hydro, tidal, and geothermal, and other possibilities on the horizon such as hydrogen-fueled combustion. However, another important issue distinct from GHG reduction emerges from this discussion – the impact on jobs.

Each GW of nuclear power (the size of a typical nuclear plant) creates several thousands more middle-class construction jobs over a longer period of time than the alternatives (DOE, 2022; NEI, 2022). For example, there are presently 9,000 construction workers at the under-construction Vogtle nuclear plant (DOE, 2022) which is expected to take ten years to construct (King, 2017). In contrast, a wind or solar project of the same GW size would create between 500 and 800 construction jobs over a three-year period (Wyoming, 2019). Thus, there is a significant difference in the creation of construction jobs between nuclear and other technologies.

This back-and-forth between Promoting Economic Efficiency vs. Promoting Energy Diversity then filters down to one question: Is it in the public interest -- a concept recognized as rife with complex and diverse multiple definitions (Dadashpoor & Sheydayi, 2021) -- to have electric customers pay more for

electricity (i.e., remove competition and reinstate cost-of-service regulation to make nuclear financeable) to create more construction jobs? Elected officials would be able to create these jobs via an indirect tax on the public (higher electric rates) that would be off the government's budget and hidden from budget analysts. This approach to funding government-supported programs is not uncommon due to electricity's inelasticity of demand (Mankiw, 2015; McConnell et al., 2021). For example, taxes and surcharges that fund government programs account for 25-30% of one utility's bills in New York (Sanderson, 2014) and the State of New Jersey mandates a Societal Benefits Charge on every electric bill to fund efficiency grants and loans, renewable power subsidies, education, and assistance to low-income electric users (NJPRO, 2010). Thus, intentionally increasing electric rates to fund more construction jobs is not without precedent.

While timely and salient, this sidebar into deregulation's impact on power plant construction jobs will be the focus of future research. Given that establishing the availability of financing is a requisite first step, the primary focus of this paper is the impact of deregulation on nuclear plant financing to which we now return.

2.7. Propositions

P1: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term price certainty (i.e., the price per kWh received by the nuclear plant will remain high enough to cover fixed and variable expenses including debt coverage).

P2: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term output quantity certainty (i.e., the price per kWh charged by the plant will remain low enough to ensure baseload operation (high Q to maintain low AFC)).

P3: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term revenue certainty (i.e., the price per kWh times the output quantity will remain sufficient to cover fixed and variable expenses including debt coverage).

3. PROPOSED METHODOLOGY

3.1. Design and Sample

The research methodology entails a survey questionnaire from a population of 30 lending bank executives. A priori, a larger sample size would be preferred, but there are only several dozen banks in the world that provide financing for power plants in the U.S. Because of the complex and very specific nature of power plant financing, it is necessary that the data be collected from those bank executives that previously financed electric generation projects, are familiar with electricity deregulation, and are familiar with the financing risks of the electric industry so as to reduce sampling error (Bansal, 2017). Moreover, the use of multiple responses from co-workers at the same bank, who usually work together in a small team on each power plant financing, may affect the independence of each data point. Thus, this study faces a data collection challenge which is addressed below.

The sample population noted above is expected to be sufficient to provide statistical significance on a t-test, but it may not be sufficient for multivariate regression analysis. Second, it is possible that there will be a strong correlation between the two independent variables, price and quantity. In a post-deregulation environment, the daily price submitted by the power plant owner to the grid operator determines where the plant falls on the dispatch curve, and thus, the quantity sold may be a function of price. If there is a strong correlation, then a multivariate analysis may not be warranted. Therefore, the survey questions will be designed to enable a switch from multivariate regression analysis to a paired one-tailed t-test if necessary. The proposed analysis addresses a specific real-world application that should be useful to financial lenders, power plant owners, manufacturers and constructors of nuclear plants, and government policymakers and represents a market that may reasonably reach a hundred billion dollars.

3.2. Manipulated Variables

Each respondent will view four scenarios that manipulate the perceived certainty of the nuclear power plant revenues (price and quantity) across conditions and measure their willingness to provide financing, as depicted below. This scenario-based experimental design is widely accepted (e.g., Grewal et al. 2008; Baranishyn, et al., 2010)

Table 1 Experimental Conditions

No price certainty/No quantity certainty	Price certainty/No quantity certainty
No Price certainty/Quantity certainty	Price certainty/ Quantity certainty

To that end, each respondent will answer a series of questions that are identical in all respects except for a change in the certainty of each independent variable (long-term price certainty (X_1) and long-term output quantity certainty (X_2). The dependent variable will be the banker's willingness to finance a nuclear plant under each scenario. Manipulation checks for X_1 and X_2 will be utilized along with X_1X_2 as this represents revenue. Within each scenario, other factors will be held constant, identical in all matters that materially impact the revenue and cost of a power plant, including the size of the nuclear power plant, technology, design, construction method, location, permitting, and environmental matters, (IAEA, 2009; IAEA, 2017; Ziegler & Dansky, 1982). Thus, the four scenarios have identical risk profiles except that they vary in their revenue (price and/or output quantity) certainty. Scenario #1 presents the base case with low price risk and low output quantity risk. Scenario #2 presents controlled output quantity, with an unknown price (high price certainty risk). Scenario #3, presents controlled price with an unknown quantity (high output quantity certainty risk). Scenario #4, presents uncontrolled price and output quantity (high price certainty risk and high output quantity certainty risk).

Scenario #1 reflects the "sovereign method of financing" and, as previously discussed, this scenario supported the financing of every nuclear plant presently constructed. Meanwhile, scenarios #2-4 reflect actual non-nuclear IPP projects that have successfully obtained financing. Thus, the above manipulations in the survey questions possess ecological validity.

Responses to the various scenarios will be scored on a 7-point Likert scale ranging from "Not Willing" to "Willing". The data will be used to determine a two-variable regression analysis of the form:

$$\mathbf{y = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 + e}$$

Each regression coefficient is a slope estimate. With more than one independent variable, the slopes refer to the expected change in y when x makes a unit change while keeping all other variables constant (ceteris paribus). Therefore, b1 is the change in y given a unit change in x1 while holding x2 constant, and b2 is the change in y given a unit change in x2 while holding x1 constant.

If a two-variable regression analysis cannot be performed due to the data problems noted above, the data will be analyzed using a paired one-tailed t-test to determine if statistically significant differences exist between the pre-and post-deregulation scenarios (certainty and no certainty, respectively) for both independent variables individually.

Here, survey responses for each paired question are anticipated to form two normal distributions with the mean of the "post-deregulation" (no certainty) scenario resting leftward of the "pre-deregulation" (certainty) mean. That is, the anticipated results will show a reduction in the likelihood of a bank providing nuclear plant financing in the post-deregulation environment. It can also be interpreted as a comparison of the likelihood of a bank providing nuclear plant financing within those states that deregulated their electricity markets versus those states that continue to use monopoly utility cost-of-service regulation.

4. STUDY LIMITATIONS

Scenarios by their nature require respondents to imagine how they would react to stimuli that has been presented in a controlled format and therefore real-life reactions may have more variability. However, this also provides a more challenging context to find support for our propositions, while raising internal

validity and control through the clean (isolation) manipulation of our independent variables. Also, the proposed analysis investigates the risks associated with revenue certainty and is therefore limited in that it does not address the risks associated with cost certainty.

5. FUTURE ANALYSES

Due to the limitation noted above regarding cost certainty, future analyses are proposed to analyze the willingness of banks to provide financing as a function of Construction Cost Overruns, Construction Schedule Delays, Interest During Construction/AFUDC, Decommissioning and Spent Fuel Storage, and Insurance/Price Anderson Act availability. Furthermore, two Canadian provinces (Alberta and Ontario), as well as Great Britain, have deregulated their electricity markets along lines generally similar to the U.S. Future analyses can be extended to include these markets, with attention paid to regional specifics.

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