WINTER
2021

JOURNAL OF MANAGEMENT & ENGINEERING INTEGRATION

AIEMS
VOL 14
NO 2

ISSN: 1939-7984

JOURNAL OF MANAGEMENT AND ENGINEERING INTEGRATION

Scope: The Journal of Management and Engineering Integration (JMEI) is a double-blind refereed journal dedicated to exploring the nexus of management and engineering issues of the day. JMEI publishes two issues per year, one in the Summer and another in Winter. The Journal's scope is to provide a forum where engineering and management professionals can share and exchange their ideas for the collaboration and integration of Management and Engineering research and publications. The journal will aim on targeting publications and research that emphasizes the integrative nature of business, management, computers and engineering within a global context.

Editorial Review Board

Reviewers

The Journal Editorial Team would like to thank the reviewers for their time and effort. The comments that we received were very constructive and detailed. They have been very helpful in our effort to continue to produce a top-quality journal. Your participation and timely response are very important for the success in providing a distinguished outlet for original articles.

Edwin Sawan, Ph.D., P.E.
Editor-in-Chief

Abdulaziz Abdulaziz
Sue Abdinnour
Mohammed Ali
Abdelhakim Al Turk
Gordon Arbogast
Muhammad Attar
Mehmet Barut
Enkhsaikhan Boldsaikhan
Deborah S. Carstens
Tristan Davison
Andrzej Gapinski
Ed Hernandez
Xiaochun (Steven) Jiang
Mohammad Kanan
Chris Kluse
Jingyun Li
Huitian Lu
Adam Lynch
Roger Merriman
Narasimha Nagaiah (Raju)
Sherisse Pierre
Dennis Ridley
Lauren Schumacher
Brooke Wheeler
Xun Xu
Bayram Yildirim

Table of Contents

Everybody Wins When More Women are in the Transportation Industry

*Kristie Drawe, Behbood Zoghi
Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX 77843
**kristiedrawe@gmail.com; zoghi@tamu.edu*

Abstract

The objective of this paper is to provide an analysis and evaluation of the current workplace landscape on gender equity, culture and support, career advancement opportunities, perceptions on gender demographics, and how they relate to company success and a more user-friendly transportation system. The main method of analysis compared responses collected from transportation professionals and university students with an interest in transportation. While the survey responses show that both professionals and students recognize that organizations would benefit from a more equitable workplace and that my additional literature review demonstrates the positive return on investment of a more equitable workspace, the data shows women feel that gender equity has not been achieved and that opportunities are not the same regardless of gender, while fewer men feel the same way. On the contrary, more male students than female students recognize that both employees and the organization would benefit from an increased percentage of women in the workplace.

This study concludes that organizations in the transportation industry would benefit from the following initiatives:

1. Providing opportunities for training and/or information sessions on how to recognize gender bias and how to avoid it in the workplace.
2. Evaluating and standardizing pay.
3. Considering flexible work options.
4. Reviewing the organization's recruiting strategies.

1. Introduction

According to a recent study, women represent only 15% of the transportation industry workforce (Godfrey & Bertini, 2019). It has been widely known and somewhat accepted as a cultural norm that most transportation industry jobs are filled with men. The Transportation Research Board (TRB), one of seven program units of the National Academies of Sciences, Engineering, and Medicine, is interested in this topic's findings. Amid the Third Women's Issues in Transportation conference hosted by the TRB, the issue was raised that planning has not been done to examine if opportunities are created in a gender-neutral or unbiased style for women to pursue careers

in transportation. Furthermore, less attention may have been paid to women workers' needs in the ergonomics of their work environment that they are expected to drive or work in makes these jobs less attractive, such as a more flexible work accommodation. This discussion took place during the conference in 2007, and the research has not been done as of today. News highlights in recent years have shown, more than ever, a defining global movement for equity and justice that is bending the arc for history to a turning point of reconciliation and rejuvenation. An increased representation of women in the transportation industry, especially as decision-makers, can positively improve many of the rider's experiences. This study, "Everybody Wins when More Women are in the Transportation Industry" examines constraints in the US public transportation system that make it exceptionally challenging for women to be active members of the professional community and the perceptions and attitudes of women and men on gender equity. Equity is defined as the quality of being fair and impartial, while equality is the state of being equal.

The study's proposed outcome identifies barriers to be removed to increase the talent pool and offers recommendations that allow more women the opportunities and vested interest to pursue a career in the transportation industry. What will it take to attract more women to careers in transportation and ensure that they thrive equitably with their male counterparts? This study focuses research on two groups:

a) Professional working men and women who are currently employed in the transportation industry.

b) Male and female university students who are currently pursuing an engineering degree with a transportation program at the undergraduate or graduate level or graduated students who have not entered the workforce.

1.1. The perception of transportation culture

The transportation industry has historically been male-dominated regardless of the type of transportation: planes, trains, or cars. During the 2018 Transforming Transportation conference hosted by the World Bank and the World Resources, the group examined the gender dimensions of transport. It publicly recognized that transport is not gender-neutral for the first time (Carvajal & Alam, 2018). Most women are afraid of being harassed in public spaces while using public transportation. Female participation in the transportation industry as operators, engineers, conductors, and leaders remains low. While the percentage of women who receive an engineering degree from universities remains steady, the percentage of women who choose a career in the transportation industry remains low. A recent study has shown that roughly 25% of women have actively avoided jobs that are perceived as “men only” (Intelligent Transport, 2019) including construction, bus driving, and politics. How were these perceptions formed? Who made the rule that men should drive taxis and women should be nurses? In certain countries globally, such as Saudi Arabia, the prohibition that did not allow women to drive cars was recently lifted in June 2018 (Sant, 2018). A quick images search on Google pulled up a mixture of men and women as bus drivers with the keyword “bus drivers.” However, with keywords such as “light rail driver” or “truck driver”, women are seen few and far between. Could transit agencies be a part of the problem that they are trying to solve? Is there enough female representation shown in advertising and social media? What is the social stigma, and are there gender stereotypes being represented in the photos online, on banners, or in magazines?

1.2. What is a man's role in winning more women?

While the gender gap is evident in the transportation industry, finding a male role model who advocates for this issue is rare as finding hen's teeth. The voices for this issue and the conversations occur within female networks instead of everyone's engagement. When more men than women represent decision-makers, men can also take place as stakeholders who are loudly and visibly creating a narrative around gender equity. A meticulous, cyclical, and ongoing movement around advocacy are the best fuel for change by:

1. Acknowledge that biases exist
2. Show solidarity
3. Challenge gender favoritism or masculinity in the workforce
4. Help transform power dynamics

To obtain the full potential of everyone, gender bias must be acknowledged, recognized, and eventually removed, and equity must be realized. Denying human support based on gender denies the economic, scientific, and value growth of humanity.

1.3. Value-added with gender inclusivity

An article from Forbes estimated that reaching full gender equality is 217 years away (Roy et al., 2018). Although women make up 46% of the labor workforce, statistics show that 94% of Fortune 500 companies' CEOs are male. Yet companies that have recognized the return on investment in gender diversity perform better than companies that do not. A Deloitte report (Pellegrino et al., 2011) entitled "The Gender Dividend: Making the Business Case for Investing in Women" outlines this business case to integrate women in both the workplace and as consumers and to reap the benefits from the dual-focused business model. Why is gender diversity not reached despite the significant business benefits?

This paper aims to identify drivers that both encourage and discourage women in the transportation workforce to understand both the realities of our current workforce and determine strategies to bring more diversity into the future. Through expanding women's opportunities, socioeconomic outcomes are improved, and accelerated economic growth is achieved. Organizations recognize that their competitive advantage lies within their employees, therefore, the emphasis to attract, engage, develop, and retain the best assets will be the differentiator between best and average. As the transportation industry is rapidly evolving and changing, a central focus should be placed on recognizing the gender gap and correcting the biases and barriers that exist in the workplace. Everybody wins when more women are in the transportation industry.

2. Methodology

Since the research is looking to understand the current state of the environment within professional organizations and the attitudes and perceptions of engineering students, the participants from a selective pool were chosen.

The first group of participants is professionals: working men and women who are currently employed in the transportation industry. To gather information related to the current attitudes and perceptions of men and women in the transportation industry, and their feedback on gender diversity, a survey was distributed with the assistance of transportation industry organizations that have a large number of members, participants, and other interested parties. The research team posted on social media and reached out to their professional contacts. Detailed survey responses of 161 participants were gathered

for the survey for professionals and 21 survey responses were gathered for the survey for students, totaling 182 responses. Out of the 161 responses from the survey for professionals, 58 responses (36%) identified themselves as male and 102 responses (63%) identified themselves as female, 1 respondent (1%) preferred not to say. Out of the 21 responses from the survey for students, 10 responses (48%) identified themselves as male, and 11 responses (52%) identified themselves as female. Due to confidentiality, name, location, and the organization of the survey participants were not collected.

The demographics of the professionals at levels within their workplace are as follow: 36% of respondents are individual contributor (no direct reports). 32% of respondents are managers. 17% of respondents are directors. 15% of respondents are executives. Their years of experience are as follows: 21% of respondents have 5 or fewer years of experience. 36% have more than 5 years and 15 years or fewer years of experience. 23% have more than 15 years and 25 years or fewer years of experience. 22% have identified themselves to have more than 25 years of experience.

The demographics of the students are as follows: 29% of respondents are undergraduate students. 38% of respondents are graduate students with equal to less than two years and have not graduated. 19% of respondents are graduate students with more than 2 years of graduate school and have not graduated. 14% of students have received their master's degree or above and have graduated. The survey question does not include a question on the job type or the organization of the respondent due to confidentiality. However, a wide audience was reached, and it is likely that respondents from the professional group are from the following: transit system (public and private), consultant, and government.

3. Analysis

This section presents the analysis from the survey conducted. The following groups were studied and compared:

Group 1: professionals (male and female) vs students (male and female)
Group 2: male professionals vs female professionals
Group 3: male students vs female students
Group 4: professionals (male and female, 25+ years of experience) vs professionals (male and female, ≤5 years)
Group 5: students with internship experience, and with no internship experience.

From this study, common elements emerged, within the study's research aim, that are broken up into the following topics: gender equity, workplace barrier, origin of gender inequity, organization support, social improvements, and future growth.

3.1. How close are we to gender equity?

"Gender equality is not only a fundamental human right but a necessary foundation for a peaceful, prosperous and sustainable world" (United Nations, n.d.). Achieving gender equity and empower all women and girls is one of the United Nation's 17 goals for sustainable development. One target is to end discrimination against women and to ensure full participation in leadership and decision-making.

This study asked 161 professionals two questions on gender equity at the workplace. Interestingly, the results showed that more men felt that gender equity is achieved in their workplace when Group 2 analysis was conducted. In question 1 (Table 1), 44.8% of the male respondents thought men and women are treated equitably, while 36.3% of women feel the same way. In question 10 (Table 2), when both professionals men and women were asked if opportunities are the same or different for advancement for men versus women, three-quarters of all male respondents (72.4%) felt that opportunities are the same.

In contrast, a little over half of the female respondents (56.9%) answered that opportunities are the same for males and females.

Table 1. Question 1 responses between female and male professionals

[Question 1] In your current role, do you feel that men and women are treated equitably (compensation, job advancement, fairness, etc.)?		
	Group 2	
	Female (professionals)	Male (professionals)
Yes	36.3%	44.8%
Sometimes	38.4%	37.9%
No	25.5%	17.3%

Table 2. Question 10 responses Between female and male professionals

[Question 10] In your organization, do you feel that women have more, fewer, or the same opportunities to advance professionally as men?		
	Group 2	
	Female (professionals)	Male (professionals)
Women have more opportunities than men	2.9%	6.9%
Women and men have the same opportunities	56.9%	72.4%
Women have fewer opportunities than men	40.2%	20.7%

3.2. Barriers at the workplace

The professional respondents were asked if there are any physical barriers or work environments that make it less suitable for women. Both parties within Group 2 responded similarly to question 15 (Table 4), where the total sum of the "agree" and "disagree" answers are the same for men versus women. It appears that most men and women (over 50% for both groups) feel that there are no concerns with work requirements or work environments that make it less suitable for women. In comparison, roughly 27% of respondents feel concerns about the work requirements or environment that make it less suitable for women.

Barriers at the workplace could include many tangible and intangible things, such as work-life balance, equal pay, culture, fear of failure, and others. Overall, almost 8 times as many females (13.7%) as males (1.7%) strongly agreed to barriers for women to advance (Table 3).

Table 3. Question 9 Responses between female and male professionals

[Question 9] How much do you agree/disagree with the following statement: There are barriers to women's professional success at my organization.		
	Group 2	
	Female (professionals)	Male (professionals)
Strongly Agree	13.7%	1.7%
Agree	32.4%	29.3%
Neutral	24.5%	34.5%
Disagree	23.5%	20.7%
Strongly Disagree	5.9%	13.8%

Table 4. Question 15 Responses between female and male professionals

[Question 15] How much do you agree/disagree with the following statement: There are concerns with my work requirements and/or work environment that makes it less suitable for women.		
	Group 2	
	Female (professionals)	Male (professionals)
Strongly Agree	8.8%	5.2%
Agree	19.6%	22.4%
Neutral	13.7%	12.1%
Disagree	37.3%	29.3%
Strongly Disagree	20.6%	31.0%

3.3. But wait, students had expectations of gender inequity?

The study results indicated a similar result for gender equity perception from the students before they even entered the workplace, as with professionals. The results of Group 1 comparison between professionals and students are shown in Table 5-7 below.

Table 5. Question 1 responses between professionals and students

[Question 1] In your current role, do you feel that men and women are treated equitably (compensation, job advancement, fairness, etc.)?		
	Group 1	
	Professionals	Students
Yes	39.8%	42.9%
Sometimes	37.9%	42.9%
No	22.4%	14.3%

Table 6. Question 9 responses between professionals and students

[Question 9] How much do you agree/disagree with the following statement: There are barriers to women's professional success at my organization.		
	Group 1	
	Professionals	Students
Strongly Agree	9.3%	9.5%
Agree	31.1%	47.9%
Neutral	28.0%	28.6%
Disagree	22.4%	9.4%
Strongly Disagree	9.3%	4.8%

Table 7. Question 10 responses between students with internship experience, and with no internship experience

[Question 10] Do you foresee women having more, fewer, or the same opportunities to advance professionally as men?		
	Group 5	
	No (No internship experience)	Yes (I have internship experience)
Women have more opportunities than men	0%	9.5%
Women and men have the same opportunities	10%	23.8%
Women have fewer opportunities than men	28.6%	19%

3.4. Are we doing enough? (How effective are organizations in achieving diversity?)

When the participants were asked if their organization is doing enough to increase gender diversity, the statistics answered by the female and male participants were almost flipped. The percentage of female professionals who answered that their organization should be doing more to achieve diversity is almost the same as the percentage of male participants who answered that their organization should continue its current progress (Table 8).

Table 8. Question 7A responses between female and male professionals

[Question 7a] Do you think your organization should be doing more to increase gender diversity, doing less, or is the amount of effort currently being used sufficient?		
	Group 2	
	Female Professionals	Male Professionals
Doing more	59.8%	39.7%
Doing the same	40.2%	58.6%
Doing less	0%	1.7%

Table 9. Question 8 examines professionals who want to see more gender equity programs and are willing to participate in this program

[Question 8] If your organization offers an optional program that encourages gender equity or support for women which meets weekly for 1 hour, would you join?			
	Doing more	Doing the same	Doing less
Yes	81%	48%	0%
No	19%	52%	100%

While the vast majority (81%) of all respondents who believe that their organization should be doing more indicated that they would join, half of the participants who answered doing the same would join, and the other half would not join (Table 9).

3.5. Can we see a positive trend in gender equity?

What is the difference of opinion when Group 4 is examined? Is there a difference between the professionals with 25+ years of experience and the newbies who are brand-new to the work culture (≤5 years). Interestingly, the numbers are very similar between professionals with many years of experience

and those who just entered the workforce.

Table 10. Question 1 responses between professionals with more than 25 years of experience, and professionals with 5 years or less of experience

[Question 1] In your current role, do you feel that men and women are treated equitably (compensation, job advancement, fairness, etc.)?		
	Group 4	
	Professionals (≤5 years)	Professionals 25+ years
Yes	20.6%	21.4%
Sometimes	29.4%	37.1%
No	50.0%	41.4%

Question 1 (Table 10) is combined with question 19. Question 19 asks, "What would most effectively encourage gender equity in your organization?" Over 100 (62%) men and women participants answered the optional question on how gender equity can be done in their organization.

Here is some of the feedback:

- *"Many times, women are part of the team, sometimes the leader sometimes not, but generally the leader is the recognized person, so I think a more team recognition would be appreciated and would show the true value of women contributing regularly"* (Female, ≤5 years of experience) (Answered: "Yes" to question 1)
- *"Increase tuition reimbursement amount for employees to obtain more advanced degrees based on needs of organization"* (Male, ≤5 years of experience) (Answered: "Yes" to question 1)
- "*Offer 30 hour/week full-time positions to parents. That way fathers can have a larger part in taking care of their children and mothers in the fields have more time with their families. That may make it less likely for women to leave the field to raise their families.*" (Female, ≤5 years of experience) (Answered: "Sometimes" to question 1)
- *"Continue finding leadership opportunities for women"* (Male, 25+ years of experience) (Answered: "Sometimes" to question 1)
- *"Honest dialogue."* (Female, over 25+ years of experience) (Answered: "Sometimes" to question 1)
- "*A cultural shift in our society away from male-dominated ways of doing things.*" (Female, ≤5 years of experience) (Answered: "No" to question 1) *"I think we need to care about gender equity, including persons who do not identify with the traditional male/female gender, as much as we care about racial equity. I also believe it is important to care about equity issues relative to age and disability, which are often not discussed in equity training or equity initiatives.*" (Answered: "No" to question 1)

Common trends in the selected answers above and all responses brought up ideas such as increasing work-life balance flexibility, pay gap statistics, promotion and selection of women in executive-level positions, and placing more women in management roles.

3.6. How will an improvement of gender equity change our organization or the world in which we live?

Many participants understand that gender equity is based on specific actions and statistics, but the entire goal is dedicated to gender parity. Most females and males agree that an increase of women in the workplace makes business sense because of its investment return. The participants' data show that not everyone believes that this culture of inclusivity is smart for the business. More female participants believe that a higher percentage of women should be included than male participants (Table 11).

Table 11. Question 14 responses between female and male professionals

[Question 14a] How much do you agree/disagree with the following statement: If your organization increases the percentage of women at work and creates a workplace culture that supports both men and women equitably, both employees and the organization will benefit.		
	Group 2	
	Female Professionals	Male Professionals
Strongly Agree	64.7%	48.3%
Agree	22.5%	27.6%
Neutral	10.8%	19%
Disagree	2%	1.7%
Strongly Disagree	0%	3.4%

In contrast, the student group all agreed that the return of investment is related to company diversity, and more male students strongly agreed than female students (Table 12).

Table 12. Question 9 responses between female and male students

[Question 14a] How much do you agree/disagree with the following statement: If your organization increases the percentage of women at work and creates a workplace culture that supports both men and women equitably, both employees and the organization will benefit.		
	Group 3	
	Female Students	Male Students
Strongly Agree	72.7%	90.0%
Agree	27.3%	10.0%
Neutral	0%	0%
Disagree	0%	0%
Strongly Disagree	0%	0%

Here are some of the comments by students:

- *"Toxic masculinity hurts men too. By not supporting women in industry, you lose half the talent that could be making advancements. Gender representation also leads to variety in ideas"* (Female, graduate student ≤2 years)
- *"Good ideas are a byproduct of collaboration between individuals with different backgrounds."* (Male, undergraduate student)
- *"Increasing diversity in a workplace, especially one that is involved in providing transportation services, will always be a benefit because it brings in more diverse viewpoints and understanding of how people travel and what barriers they face"* (Female, graduate student 2+ years)

There have been many studies on how women and men travel, these studies include identifying travel patterns, and the associated impacts (Whitton, 2019). Of the female professionals, most agreed that a more inclusive passenger-friendly system will be created if women's representation increases and most men fall in the range of disagreeing to strongly agree. Conversely, most both female and male students see a relationship between an inclusive transportation system and women's representation. However, a much higher percentage of male students felt neutral vs female students (Table 13).

Table 13. Question 14A and 16A responses between female and male professionals

[Question 16a] How much do you agree/disagree with the following statement: If a greater percentage of women were in transportation careers, women's needs and travel patterns would be better represented in how transportation systems are designed, creating a more inclusive and passenger-friendly transportation system.		
	Group 2	
	Female Professionals	Male Professionals
Strongly Agree	43.1%	24.1%
Agree	31.4%	36.2%
Neutral	20.6%	20.7%
Disagree	3.9%	13.8%
Strongly Disagree	1%	5.2%
[Question 16a] – Same as question for professionals above		
	Group 3	
	Female Students	Male Students
Strongly Agree	63.6%	30.0%
Agree	36.4%	40.0%
Neutral	0%	30.0%
Disagree	0%	0%
Strongly Disagree	0%	0%

Here are some of the comments by students:

- *"It is not just more women, but a diversity of women using the modes of transportation. i.e. if you don't ride a bus, you may not have the awareness that lighting, shelter, safety, and comfort are necessary for women and mothers."* (Female, >15 to 25 years) (Answered "Agree" to Question 16a)
- *"It is not rational to think that transportation systems represent any particular gender. The irrationality of this makes me think of describing a "woman travel pattern" as possibly: 1) by color code (pink as an example); 2) travel venues to kid care (not all women have children); 3) slower lanes (if women tend to be more cautious drivers); and 4) direct access to beauty-related shopping and shoe stores."* (Female, ≤5 years) (Answered "Neutral" to Question 16a)
- *"We don't sit around designing new transportation systems. We implement projects based on specs from customers. A track circuit doesn't care if a train is full of men, women, or puppies - it just checks to see if a train is present and sends the information along."* (Male, >5 to 15 years) (Answered "Strongly Disagree" to Question 16a)
- *"Same answer as 14b... things that are known in the literature, for example, that women tend to take more "chained" trips, more trips during the workday, etc. while public transit systems are generally designed to operate best during commute times"* (Female, graduate student 2+ years) (Answered "Strongly Agree" to Question 16a)

The difference in perception of males and females is significant to the conclusion. If males believe that the environment is equitable and the majority of the leadership are males there will be less motivation to do more or change, thus the status quo remains.

4. ROI

As the benefits to having more women are high for both the organization and the customers and the cost to recruit and retain female employees is comparatively low, the return on investment is particularly interesting.

Indeed, numerous studies show that a homogenous workforce limits the potential of the collective capabilities of the group. Diversity breeds success. A 2015 McKinsey report estimated that closing the gender labor gap could add as much as $28 trillion, or 26%, to the annual global GDP by 2025. This is based on a "full-potential" scenario where women participate in the economy identically to men (McKinsey & Company, 2015). A 2019 Bloomberg article shows that diversity boosts the share price of listed companies. Annual returns for businesses with a higher percentage of women were higher than firms that are the least diverse (Telling, 2019), and an NRP study shows that gender diversity in the very top ranks of companies leads to a better chance that the company will outperform the industry (Talbot, 2019). Additionally, a PWC study shows that female directors are performing better at reaching corporate goals beyond financial goals such as increasing diversity and inclusion, lowering employee attrition, and lowering environmental impacts (PricewaterhouseCoopers, n.d.). Furthermore, a study from Morgan Stanley has identified five factors that can potentially explain why gender diversity leads to outperformance: higher employee satisfaction, more innovation, appealing to a broader customer base, lower reputational risk, and better recruiting (Trager, 2019). Women leaders have different traits than male leaders. Those traits amongst women CEOs include risk-taking, resilience, agility, and managing teamwork among their employees (Ellingrud, 2019)

While it is hard to find data showing that hiring and including women have negatively affected the company culture and performance, and most studies point to a clear positive return on investment, some companies and leaders do too little to attract, recruit and retain women.

5. Recommendations and conclusion

The cost to attract, recruit and retain more women is minimal. The return of investment to the business entity and the value that it will bring to the employees and its customers is highly beneficial. Proven by the statistics and the real-life experiences of the survey participants, the disparity between the experiences of women and men based on gender is evident. In a world of self-driving cars, artificial intelligence, and smart devices, unequal treatment or perception based on gender is still prevalent and ubiquitous.

Although from the survey responses there are no concerns with work requirements or the work environment that makes it less suitable for women, both the professionals and the student participants feel that there are barriers to women's professional success. The study confirmed that organizations should be doing more to increase gender diversity. Furthermore, most participants feel that both employees and the organization will benefit, and a more inclusive and passenger-friendly transportation system will result from an increased percentage of women as well as being in positions of greater influence in the transportation industry workforce. Future research is being planned to include a question to examine if job type would impact respondents' answers to the survey questions.

It is recommended that companies start from the top-level executives to lead a focused effort on a robust recruitment strategy, conduct more organizational lead discussions regarding and greater awareness of gender biases and the advantages of an inclusive work environment, and promote and embraces a culture of equity in every sense and at all levels of the enterprise. As many survey participants have pointed out, flexible work options that allow employees to work from home, and additional options for taking time off (paid or unpaid). Organizations should evaluate and standardize pay and examine

recruiting strategies from the inside out. A focused effort to recruit, develop, retain, and advance women's strategy or plan should be developed and executed at the top company level.

While cultural change, has taken place even to the point of the introduction of state laws, to advance equitable gender representation, women are still extremely underrepresented in many industries holding leadership positions. Imagine a world where the decision-makers around the room are equally represented and one type of voice is not drowned out by the other. In the transportation industry where the women's representation is low, an increase of input and work from women will impact communities. Positive change will lead to progress toward greater community equity. In the end, this paper is about women, but it is not exclusively for women. This is not only a men's issue as much as it is a women's issue, but a human rights issue that impacts both women and men. Gender diversity is the inclusion of all genders, and not one gender being dominant over another. Inclusion can broaden perspectives to drive better decision-making.

Fueled by the energy and the intellect of many like-minded women and men dedicated to creating greater equity, the best way to predict the future is to create it today. May this decade be the emergence of a major confluence: the overwhelming power of a sustainable collective future of our society over the individual.

References

Carvajal, K. G., & Alam, M. M. (2018). Transport is not gender-neutral. World Bank Blogs. Retrieved October 10, 2020, from https://blogs.worldbank.org/transport/transport-not-gender-neutral

Ellingrud, K. (2019). How Women Leaders Change Company Dynamic. Forbes. Retrieved March 19, 2021, from https://www.forbes.com/sites/kweilinellingrud/2019/01/30/how-women-leaders-change-company-dynamics/?sh=411ff6754733

Godfrey, J., & Bertini, M. R. L. (2019). Attracting and Retaining Women in the Transportation Industry (No. WP 19-01). Retrieved October 20, 2020, from https://transweb.sjsu.edu/sites/default/files/1893-Godfrey-Attract-Retain-Women-Transportation.pdf

Intelligent Transport (2019). Women actively avoid careers perceived as 'men only'. Retrieved October 10, 2020, from https://www.intelligenttransport.com/transport-news/76523/women-work-choices-gender-equality/

McKinsey & Company (2015). The Power of Parity: How Advancing Women's Equality Can Add $12 Trillion to Global Growth. Retrieved March 17, 2020, from https://www.mckinsey.com/featured-insights/employment-and-growth/how-advancing-womens-equality-can-add-12-trillion-to-global-growth

Pellegrino, G., D'Amato, S., & Weisberg, A. (2011). The Gender Divided: Making the Business Case for Investing in Women. Deloitte. Retrieved October 10, 2020, from https://www2.deloitte.com/content/dam/Deloitte/ru/Documents/public-sector/gender-dividend-en.pdf

PricewaterhouseCoopers. (n.d.) Holding the Centre. PwC. Retrieved March 19, 2021, from https://www.pwc.com/us/en/services/governance-insights-center/library/gender-diverse-boards-esg.html

Roy, K., Kimmel, M., & Johnson, S. (2018), The Importance of Male Voices in the Gender Equity Narrative. Forbes. Retrieved October 10, 2020, from https://www.forbes.com/sites/ellevate/2018/05/09/the-importance-of-male-voices-in-the-gender-equity-narrative/?sh=663d91f129c1

Sant, S. V. (2018), Saudi Arabia Lifts Ban On Female Drivers. NPR. Retrieved October 10, 2020, from https://www.npr.org/2018/06/24/622990978/saudi-arabia-lifts-ban-on-women-drivers

Talbot, P. (2019). Investors May Prefer Companies with More Women in the Workforce. NPR. Retrieved March 19, 2021, from https://www.npr.org/2019/09/20/762056390/investors-may-prefer-companies-with-more-women-in-the-workforce

Telling, O. (2019). Companies That Employ Most Women Get Best Returns. Bloomberg.com. Retrieved March 19, 2021, from https://www.bloomberg.com/news/articles/2019-08-14/need-alpha-companies-that-employ-most-women-get-best-returns

Trager, L. (2019). Why Gender Diversity May Lead to Better Returns for Investors. Morgan Stanley. Retrieved March 19, 2021, from https://www.morganstanley.com/access/gender-diversity

United Nations, Gender equality and women's empowerment – United Nations Sustainable Development (n.d.). Retrieved February 20, 2021, from https://www.un.org/sustainabledevelopment/gender-equality/

Whitton, E. (2019). To build a better transit system for all, start by understanding how women travel. Greater Washington. Retrieved March 20, 2021, from https://ggwash.org/view/74441/we-need-to-understand-how-women-travel-so-we-can-have-a-better-transit-system-for-everyone

Appendix A: Terms and Definitions

Bias: prejudice in favor of or against one thing, person, or group compared with another, usually in a way considered to be unfair.
Diversity: the practice or quality of including or involving people from a range of different social and ethnic backgrounds and of different genders, sexual orientations, etc.
Equity: the quality of being fair and impartial.
Equality: the state of being equal, especially in status, rights, and opportunities.
Inclusion: the achievement of a work environment in which all individuals are treated fairly and respectfully, have equal access to opportunities and resources, and can contribute fully to the organization's success.

Appendix B: Survey Links (closed – for reference only)

Information Sheet: https://forms.gle/CFsoLF8G2dKBfqQu6
Survey for Professionals: https://forms.gle/yc1q1hQEuXsEaqt2A
Survey for Students: https://forms.gle/zS5m7EsLKbMBtM677

Utilizing Marine Engineering Technology Departmental Assets

*Kevin Winn, Stephen Thompson, Behbood Zoghi
Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX 77843
**winkk@tamug.edu; swthompson@tamu.edu; zoghi@tamu.edu*

Abstract

The Marine Engineering Technology (MARR) Department at a land grant university in Galveston has a great number of experimental equipment, testing devices, scientific instruments, and electrical/mechanical power machines that are worth thousands of dollars. Due to the missing parts and technical literature, there is a lack of training and support when it comes to properly using the MARR assets. As a result, they are not being fully utilized for educating the future generation of engineers and the intended research work. Given the information from the physical inventory, the MARR faculty and students, the gathered data are analyzed and interpreted by using the Inventory Stratification Method. Based on our findings, the MARR Department needs to reduce the idling assets and invest the savings in the more useful assets. The analysis also shows a favorable (9.8%) increase in Gross Margin/Department Fund.

1. Introduction

The laboratories and training spaces used by students and faculty members in the MARR department include Fluid Mechanics Lab, Materials Lab, Machine Shop Lab, Electrical Power Lab, Electronics & Automation Lab, Materials Research Lab, Advanced Research Electronics Lab, Steam/Diesel/Welding Lab, and Diesel/Steam Engine Simulator Lab ("Department of Marine," 2020). Some of the assets that have been acquired for instructional and research purposes in the labs are very costly purchases for the department. These assets are idle for a significant amount of time due to missing parts, absence of technical literature, the lack of training and support for using them, and off-campus long-term loans. Furthermore, some of the assets simply disappeared from their originally reported locations after being misplaced during use, repair, and maintenance or as a result of being stolen. Consequently, those assets have ended up in the lost-and-found section of the annual reports ("Financial Management," 2020). The objective of this project is to minimize the Marine Engineering Department's wasted resources and boost the utilization of departmental assets to their full potential to achieve an improved work scheduling efficiency and significant cost-savings.

2. Problem statement and proposal

The problem for managing MARR departmental assets has two dimensions. One aspect is to set up a system to get the department resources into the hands of MARR instructors to fully utilize them. The second aspect is to safeguard MARR assets while managing the departmental inventories effectively and efficiently. The current impact of the problem will be measured in two steps.

The first measure is to compare the assets' values vs. frequency of their use, based on different teaching laboratories and research interests. The challenge for this first step is to figure out how often

each asset is used and who are the users of those assets in the different laboratories. As the department has three traditional semesters (Spring, Summer, and Fall) for offering engineering courses, some assets are used in two to three semesters every year, but some are in the alternate semester per the academic year. In addition, some assets are used two to three times a week per semester, but some, once or twice a month per semester.

The second measure is to seek the Return on Investment (ROI) by comparing expenses and benefits, including quantitative and qualitative values in the above areas. The challenge for this second step is to find out the benefits of using the various assets in the different technical laboratories. Since the MARR department laboratories are used for neither profit-making nor production purposes, the quantitative value will be measured by counting the aggregate usage of individual assets in an academic year as an appropriate measure. In terms of measuring the qualitative value of using the various assets, there will be a survey question and comment section that the researcher will use to seek feedback from potential respondents. Therefore, applicable data collection will be accomplished by sending out surveys to the MARR faculty and students with a list of closed or multiple-choice questions about who uses which assets, where, and how often. The gathered data will then be analyzed and interpreted by using the Inventory Stratification Method/ABC Classification Procedure, which is a widely used practice in inventory management among various industries (Harris & Natarajarathinam, 2017; Hmida et al., 2014) but not many in marine technology. The process involves organizing inventory items into a set of categories to optimize the institution's working capital and ranking asset items based on their profitability (Olsen et al., 2018).

3. Methodology

3.1. Research design

The definition of engineering asset management (EAM) involves a broad range of disciplines and processes covering the life-cycle stages of establishing, operating, and retiring physical assets. The EAM definition includes a balanced manner to satisfy a set of constraints imposed by business strategy, economy, the integrity of operation and maintenance, and regulatory compliance. It is implicit from the definition that there is a value chain for managing physical assets, but aligning utilization and management towards the stakeholders' desired performance is a critical challenge (Amadi-Echendu, 2004).

According to El-Akruti et al. (2013), the organizations have acknowledged significant shortfalls in their strategy realization due to the asset performance for a long time. Some new strategies have failed due to inadequacy in the activities that are required to properly manage the physical assets. In addition, inadequate feasibility studies have contributed to the inconsistency between the strategic goals and the asset management system (El-Akruti et al., 2013). As we aim to utilize the MARR departmental assets to their full potential, we list all valuable assets the department has and identify how many times those assets are being used empirically, and then conduct a quantitative analysis to find out the optimum results to use them effectively. This method is appropriate for this study which focuses on gaining an understanding of the objective experience of the end-users, an area in which little research has been done.

3.2. Participants

The sample population will consist of the MARR faculty members and students from the Marine Engineering Technology Program. The sample will include five faculty members, four student technicians

that are in their junior year of academic studies, and three senior students that are graduating soon. The researcher picks five faculty members, representing the different engineering disciplines as they are the principal investigator for the different laboratories related to their teaching area and expertise. Although four student technicians are juniors, they mainly work with the laboratory coordinator and faculty members for the operation and maintenance of most MARR department assets in the engineering laboratories. Since the survey criteria of this research are to cover the three semesters in any calendar or academic year, the three senior students from the MARR program will have full knowledge of what engineering assets they have used in the respective laboratories.

3.3. Instruments

For the Quantitative data collection method, we sent out Surveys with a list of closed or multiple-choice questions about who uses which assets, where, and how often for the different assets in the different locations that the MARR department has. As an example, some survey details of the MARR department's laboratories related to the subject area of marine engineering technology courses and asset items are described in Table 1.

TABLE 1. Sample asset usage data for three semesters per academic/calendar year*

Lab Name/Rm.	Description	Manufacturer	Model	Family	Spring	Summer	Fall
Machine Shop #180, PMEC	Engine Lathe	Lion	C400 TM	Machining	1	0	1
Machine Shop	Milling Machine	Star Tax	2V Vertical	Machining	1	0	1
Machine Shop	3-Axis CNC MillPower	Bridgeport/Acu-Rite	Series1/J I1 30A8	Machining	0	1	0
Machine Shop	Drill Press	Enco	105-1117	Drilling	1	1	1
Machine Shop	Radial Drill Press	ROLLO Industries	R3	Drilling	1	0	1
Machine Shop	Shear, Break &Roll Equip.	Enco	130-4000	Sheet Metal Fab.	0	1	0
Machine Shop	Bandsaw, Horizontal	Kalamazo	13AW	Metal Sawing	1	1	1
Machine Shop	Bandsaw, Vertical	JET	VBS-1610	Metal Sawing	1	0	1
Machine Shop	Surface Grinder	Enco	93612	Precision Grinding	0	1	0
Machine Shop	Bench Grinder	JET	JBG-6A	Grinding	1	0	1
Machine Shop	Pedestal Grinder	US Electrical Tool	10wg	Grinding	1	0	1

(*Enter the asset usage by the semester as "0" for NO, or "1" for YES)

3.4. Procedure

First, the researcher conducts a physical inventory for the MARR departmental assets that are used for teaching purposes in the engineering laboratories. The physical search of the departmental assets consists of the engineering asset items that are on and off the inventory records, including the donated items. Then, the whole inventory is tabulated by the name and location of the engineering laboratory with the needed information to easily identify the assets related to the respective engineering disciplines. Some of the assets share the same description, manufacturer, and model, so those assets are listed as a single entity to track the usage per school semester. For example, there are six engine lathes

in Machine Shop, but it is listed as a single entity no matter which one of the engine lathes is used by the respondent. The codes of survey questions are added next to each entity to find out the historical usage of assets for three school semesters only in a calendar/ academic year no matter what year the asset is used. After adding the questionnaire, the survey is sent out to the potential respondents via email or in-person to collect the data.

3.5. Data analysis plan

The gathered data will then be analyzed and interpreted by using the Inventory Stratification method, which is the value chain analysis. The process of Inventory Stratification involves classifying inventory items based on predetermined factors related to an organization's business needs and objectives. The process has a focus on organizing inventory items into a set of categories to optimize the use of the MARR department's assets. With this value chain analysis, the researcher can identify those activities where the department can quickly optimize effort, eliminate waste, and increase the benefit of using the assets. As the data from the survey questionnaire will be categorized and coded, the researcher will pay attention to patterns that may develop an appropriate inventory management strategy or conduct additional analysis, such as SWOT analysis if needed. Analyzing activities also gives insights into elements that bring greater value to the end-users.

3.6. Risk management process

To supplement the overall asset management of MARR assets, the researcher conducts the identification and assessment of asset risks in this project. According to Carl March, five risks mainly contribute to an organization's failure to optimally manage their assets: not knowing what the organization has; over-and-under maintenance; sub-standard operation; inappropriate risk management; and sub-optimized asset management systems (March, 2020). In this project, there is a risk that the whole inventory list is not 100 percent completed due to the off-the-record departmental inventories. This risk is associated with some assets on temporary loans from outside sources and ongoing unclaimed assets or gift items left by the internal and external stakeholders. Another risk is the continuation of proper operation and maintenance for all the assets in the different laboratories because some assets are idling for a significant amount of time due to the missing parts, the lack of training and support on using them, and the unavailability of teaching subjects related to the certain assets. The above-mentioned risks will be further reviewed and mitigated after analyzing the data with Inventory Stratification.

During the data collection process, there is a risk for tracking the usage number of all individual assets in the different laboratory locations for a calendar/academic year. This risk is associated with the respondents' human errors because the survey format has a total of "84" inventory items, scattered in "9" laboratories and some respondents may underestimate or overestimate the usage over a year or so. There is also another risk associated with few assumptions in the data analysis for implementing the Inventory Stratification Method and making the decisions for the inventory policy by the organization. As risk management is a decisive part of this or any project, accounting for risks and having an accountable party with a mitigation strategy will decrease the likelihood of a risk negatively affecting the project. To quantify the risk priority, the risks are then scored on the Probability and Impact Matrix (Shenoy, 2021).

Risk evaluation score (Low/Medium/High)											
Probability	**1**	0.1	*0.2*	*0.3*	0.4	0.5	0.6	0.7	0.8	0.9	1
	0.9	0.09	*0.18*	*0.27*	*0.36*	0.45	0.54	0.63	0.72	0.81	0.9
	0.8	0.08	0.16	*0.24*	*0.32*	0.4	0.48	0.56	0.64	0.72	0.8
	0.7	0.07	0.14	*0.21*	*0.28*	*0.35*	0.42	0.49	0.56	0.63	0.7
	0.6	0.06	0.12	*0.18*	*0.24*	*0.3*	*0.36*	0.42	0.48	0.54	0.6
	0.5	0.05	0.1	0.15	*0.2*	*0.25*	*0.3*	*0.35*	0.4	0.45	0.5
	0.4	0.04	0.08	0.12	0.16	*0.2*	*0.24*	*0.28*	*0.32*	*0.36*	0.4
	0.3	0.03	0.06	0.09	0.12	0.15	*0.18*	*0.21*	*0.24*	*0.27*	*0.3*
	0.2	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	*0.18*	*0.2*
	0.1	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
		0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
		Impact									

Figure 1. Probability and impact matrix (Risk level assessment)

Table 2. Risk register

Risk ID	Risk Details	Probability	Impact	Probability Impact Score	Risk Level	Accountability	Mitigation Strategy
1	Tracking issues on Usage of all assets in 9 laboratories	0.5	0.9	0.45	High	The users of lab facilities	Keep electronic tally counters/ logbooks on useful assets
2	Lack of proper Operation & Maintenance for all assets	0.3	0.8	0.24	Medium	Lab Directors & Lab Coordinator	Provide training, budget & labor to use valuable assets
3	Cut-off points on assets' ABC Classification with Usages	0.2	0.9	0.18	Medium	Department Head/ Organization Management	Review Inventory Policy, manage current/ future needs of assets
4	Assumption of Financials: Revenue, Assets, Operation & Maintenance	0.2	0.9	0.18	Medium	Department Head/ Organization Management	Review policy on Lab fees, Asset valuation & Budget allocation
5	Tracking problems with the locations of all assets	0.3	0.5	0.15	Low	Accountable Property Officer (APO), or Alt-APO	Annual Physical Inventory/ use Bluetooth Low Energy (BLE) tags & software
6	Prioritizing needs of assets with ABC Classification	0.1	0.9	0.09	Low	Lab Directors & Lab Coordinator	Feedback on appropriate Usage with Multiplier
7	The whole inventory list is not 100% completed	0.1	0.2	0.02	Low	APO/ Department Head, or Alt-APO	Communicate often with stakeholders and Physical Inventory
	(Risk register with mitigation strategies)						

The standard of Low, Medium, and High is used and the severity of each risk is defined as follows. A high impact risk is scored at greater than or equal to 0.4, medium at greater than or equal to 0.18 but

less than 0.4, and low at anything less than 0.18. All of these values are scored on the Probability and Impact Matrix in Figure 1. Once scored, all risks will be logged in the Risk Register. The Risk Register will have the score of each risk, the severity, the accountable party, and their mitigation strategy if the risk occurs as described in Table 2.

4. Data analysis and return on investment (ROI)

4.1. ABC classification procedure

The below-mentioned steps are taken to follow ABC Classification Procedure as described in Figure 2 and Figure 3.

Step 1. Calculate the total value (Usage) for each inventoried Stock Keeping Units (SKUs), as their value can be represented as cost, sales volume, profit, bin hits, etc.

Step 2. Sort the values of SKUs (bin hits/ Usage) in decreasing order of value as the most valuable items appear on the top of the sorted list.

Step 3. Calculate the percent value, % of the total number of Usage, SKUs, and the respective cumulative values.

Step 4. Determine cut-off points to classify SKUs into classes (A, B, C, or D) so that: type A items are considered highly valuable; type B items are considered moderately valuable; type C items are considered marginally valuable; and type D items are considered idling as described in Table 3.

Step 5. Validate if cut-off points are suitable, repeating Step 4 until a practical classification is achieved. Focus on items at the boundaries and update periodically when values at cut-off points change significantly (Leon, 2020, September 6).

4.2. Demand variability effect on inventory policy

According to Leon (2020, September 20), it is useful to measure the demand variability as the ratio of the standard deviation and the average. This ratio is known as the coefficient of variability (Cv) and is estimated by dividing the sample standard deviation by the sample mean. The Cv represents the relative magnitude of the standard deviation with respect to the average demand. With the given demand data for a product, it is straightforward to calculate the demand's average, standard deviation, and coefficient of variability. By using a spreadsheet software, the MARR inventories are sorted based on the frequency of usage/ demand and classified into Low (L), Moderate (M), and High variability (H). The cut-off points given in Table 3 are typical and should be adjusted as required. Products with low Cv are easy to manage due to their reliable demand forecasts. For these products, inventory policies can be based mainly on estimated demand. Products with moderate Cv require more sophisticated management models that explicitly use both the demand's average and the standard deviation in their calculations. Products with high Cv should not be forecasted because the forecast error may be too large to be useful in practice and the inventory policies must be based on rapid response rather than forecasted demand values.

LAB. NAME/ Location	DESCRIPTION	MANUFACTURER	MODEL	FAMILY	SPRING	SUMMER	FALL	TOTAL	SKU	ESTD. COST
Machine Shop, #179 PMEC	Engine Lathe	Lion	C400TM	Machining	8	0	4	12	M001	$24,500
Machine Shop	Milling Machine	Star Tax	2V, Vertical	Machining	8	0	3	11	M002	$6,800
Machine Shop	3-Axis MillPower CNC Mill	Bridgeport/Acu-Rite	Series1/HJ130A8-44S	Machining	2	0	0	2	M003	$34,311
Machine Shop	Drill Press	Enco	105-1117	Drilling	7	0	3	10	M004	$3,800
Machine Shop	Radial Drill Press	ROLLO Industries	R3	Drilling	7	0	2	9	M005	$10,795
Machine Shop	Shear,Break & Roll Equipment	Enco	130-4000	Sheet Metal Fabrication	4	0	2	6	M006	$1,600
Machine Shop	Bandsaw, Horizontal	Kalamazo	13AW	Metal Sawing	7	0	4	11	M007	$5,050
Machine Shop	Bandsaw, Vertical	JET	Vbs-1610	Metal Sawing	4	0	2	6	M008	$4,400
Machine Shop	Surface Grinder	Enco	93612	Precision Grinding	6	0	4	10	M009	$3,300
Machine Shop	Bench Grinder	JET	JBG-6A	Grinding	6	0	5	11	M010	$400
Machine Shop	Pedestal Grinder	US Electrical Tool	10WG	Grinding	6	0	4	10	M011	$2,500
Welding Shop, #180 PMEC	Shielded Metal Arc (Stick) Welder	Miller	Dialarc 250	Welding	5	0	5	10	W001	$3,500
Welding Shop	Gas Metal Arc (MIG) Welder	Miller	Millermatic 250 CV	Welding	0	0	2	2	W002	$3,300
Welding Shop	Gas Tungsten Arc (TIG) Welder	Miller	Econotig CC	Welding	0	0	2	2	W003	$3,300
Welding Shop	Plasma Cutting Machine	Thermal Dynamics	Cutmaster 52	Metal Cutting	2	0	4	6	W004	$2,121
Welding Shop	Gas Cutting Machine, Track Torch	Koike	IK-92 PUMA	Metal Cutting	3	0	6	9	W005	$2,900
Welding Shop	Oxy-acetylene Cutting Equipment	Victor	Journeyman 350	Metal Cutting	4	0	6	10	W006	$1,100
Welding Shop	Guided Bend Test Equipment	Walker	93616, 15 Ton Capacity	Weld Testing	3	0	4	7	W007	$3,000
Diesel & Shop Storage, #183 PMEC	Diesel Engine	Wartsila	W8L20	Diesel Generator	5	0	0	5	D001	$500,000
Diesel & Shop Storage	Diesel Engine	Cummins	150 DGFA	Diesel Generator	2	0	1	3	D002	$33,000
Diesel & Shop Storage	Gas Furnace	MIFCO	B-160	Metal Casting	1	0	0	1	D003	$5,922
Diesel & Shop Storage	Diesel Doctor Portable Analyzer	Icon Research	Doctor DK-20	Diesel Engine Monitoring	4	0	0	4	D004	$7,200
Diesel & Shop Storage	Internal Combustion Engine	MEGATECH	DG-1/ MARK.III	Dynamometer/ Generator	1	0	0	1	D005	$8,415
Diesel & Shop Storage	ROV Kit	SeaPerch	Version 2015	Remotely Operated Vehicle	2	0	0	2	D006	$179
Diesel & Shop Storage	Gas Turbine Engine	Rolls-Royce Allison	250-C	Gas Powered Engine	1	0	2	3	D007	$30,000
Diesel & Shop Storage	Gas Emission Analyzer	E Instruments	E8500-4	Emission Test	2	0	1	3	D008	$7,122
Diesel & Shop Storage	Open-Cup Flash Point Tester	Huanyu/ Cleveland	SYD-3565	Lube Oil Analysis	1	0	1	2	D009	$750
Diesel & Shop Storage	Oil Analysis Onboard Test Kit	ExxonMobil	Signum	Lube Oil Analysis	2	0	1	3	D010	$3,000
Materials Lab, #157 PMEC	TRINOCULAR MICROSCOPE	OLYMPUS	BX51M/U-TR30-2	Trinocular Observation	2	1	2	5	MS001	$11,918

Figure 2. ABC classification procedure step 1

ANNUAL USAGE	SKU	ESTD. COST	% USAGE	CUM. % USAGE	CLASS	% SKUs	CUM. % # SKUs	AVG. USAGE	STD. DEV.	Cv	Variability
13	ES001	$3,551	3.0%	3%	A	1.2%	1.2%	4.33	3.06	0.71	M
13	ES002	$650	3.0%	6%	A	1.2%	2.4%	4.33	3.06	0.71	M
13	ES005	$1,052	3.0%	9%	A	1.2%	3.6%	4.33	3.06	0.71	M
13	ES006	$129	3.0%	12%	A	1.2%	4.8%	4.33	3.06	0.71	M
12	M001	$24,500	2.8%	15%	A	1.2%	6.0%	4.00	4.00	1.00	M
12	ES003	$199	2.8%	18%	A	1.2%	7.1%	4.00	3.00	0.75	M
12	ES004	$1,999	2.8%	21%	A	1.2%	8.3%	4.00	3.00	0.75	M
11	M002	$6,800	2.6%	23%	A	1.2%	9.5%	3.67	4.04	1.10	M
11	M007	$5,050	2.6%	26%	A	1.2%	10.7%	3.67	3.51	0.96	M
11	M010	$400	2.6%	28%	A	1.2%	11.9%	3.67	3.21	0.88	M
11	E009	$100	2.6%	31%	A	1.2%	13.1%	3.67	1.53	0.42	L
11	E010	$200	2.6%	33%	A	1.2%	14.3%	3.67	1.53	0.42	L
10	M004	$3,800	2.3%	36%	A	1.2%	15.5%	3.33	3.51	1.05	M
10	M009	$3,300	2.3%	38%	A	1.2%	16.7%	3.33	3.06	0.92	M
10	M011	$2,500	2.3%	40%	A	1.2%	17.9%	3.33	3.06	0.92	M
10	W001	$3,500	2.3%	43%	A	1.2%	19.0%	3.33	2.89	0.87	M
10	W006	$1,100	2.3%	45%	A	1.2%	20.2%	3.33	3.06	0.92	M
9	M005	$10,795	2.1%	47%	A	1.2%	21.4%	3.00	3.61	1.20	M
9	W005	$2,900	2.1%	49%	A	1.2%	22.6%	3.00	3.00	1.00	M
9	E001	$9,570	2.1%	51%	A	1.2%	23.8%	3.00	1.73	0.58	L
9	E002	$10,535	2.1%	53%	A	1.2%	25.0%	3.00	1.73	0.58	L
9	E004	$8,794	2.1%	55%	A	1.2%	26.2%	3.00	1.73	0.58	L
9	E005	$1,013	2.1%	58%	A	1.2%	27.4%	3.00	1.73	0.58	L
9	E006	$4,115	2.1%	60%	A	1.2%	28.6%	3.00	1.73	0.58	L
8	E013	$23,326	1.9%	62%	A	1.2%	29.8%	2.67	1.53	0.57	L
8	F001	$28,773	1.9%	63%	A	1.2%	31.0%	2.67	1.53	0.57	L
8	F004	$9,000	1.9%	65%	A	1.2%	32.1%	2.67	2.08	0.78	M
7	W007	$3,000	1.6%	67%	A	1.2%	33.3%	2.33	2.08	0.89	M
7	E003	$3,100	1.6%	69%	A	1.2%	34.5%	2.33	2.08	0.89	M
7	E011	$200	1.6%	70%	A	1.2%	35.7%	2.33	1.15	0.49	L
6	M006	$1,600	1.4%	72%	B	1.2%	36.9%	2.00	2.00	1.00	M

Figure 3. ABC classification procedure step 2-4

Table 3. ABC Classification (Current Status)

Type A :	> 6 hits	70% of total usages and 35.7% of total SKUs (AVG. USAGE >2)
Type B :	3 to 6 hits	24% of total usages and 29.8% of total SKUs (AVG. USAGE: 1 to 2)
Type C :	< 3 hits	6% of total usages and 17.9% of total SKUs (AVG. USAGE <1)
Type D :	Idling	0% of total usages and 16.7% of total SKUs

(Inventory policy decision "Assumption" made by the organization)

4.3. ROI on current v. proposed inventory strategy

As described in Figure 4, the Usage of inventory items is sorted out from A to D by type, together with the cost of individual items as Asset Value. To proceed to the tabulated Current Inventory Status, the researcher makes decisions/assumptions on financials & budget allocations and uses standard financial formulas to address Gross Margin Return On Inventory Investment (GMROII). As described in Figure 5, the GMROII is 1.8% for the current situation, which is a measure of the current return on inventory assets in the MARR department with the status quo. To improve GMROII, the proposed strategies are to (1) Eliminate 50% of D-type Inventories and (2) Invest all inventory savings in A-type Inventories. The solutions for the above strategies are taken in two steps: Step 1 is to update the inventory (Asset Value) for Type D & A items. Step 2 is to update the key performance indicators (KPIs); the #SKU, Hits, Revenue, and COGS are supposed to be adjusted proportionally for the change in the inventory. The proportional adjustments for Type B & C items are zero and the associated KPIs (#SKU, Hits, Revenue & COGS) remain the same as the current inventory status. After completing the above two steps, the GMROII is changed to 2.0% (as an improvement from the current return of 1.8%) with "no" percent change in the total inventory/asset value.

MARR INVENTORY STRATIFICATION

Usage & Asset value by Classification

A (Usage)	A (SKU)	A (COSTS)	B (Usage)	B (SKU)	B (COSTS)	C (Usage)	C (SKU)	C (COSTS)	D (Usage)	D (SKU)	D (COSTS)
13	ES001	$3,551	6	M006	$1,600	2	M003	$34,311	0	EA001	$2,500
13	ES002	$650	6	M008	$4,400	2	W002	$3,300	0	EA002	$3,046
13	ES005	$1,052	6	W004	$2,121	2	W003	$3,300	0	EA003	$3,655
13	ES006	$129	6	E012	$1,600	2	D006	$179	0	EA004	$2,834
12	M001	$24,500	6	ESA001	$10,828	2	D009	$750	0	EA005	$7,645
12	ES003	$199	6	ESA002	$67,266	2	MS002	$5,364	0	EA006	$1,600
12	ES004	$1,999	5	D001	$500,000	2	MS004	$1,500	0	EA007	$2,000
11	M002	$6,800	5	MS001	$11,918	2	MS009	$16,600	0	EA008	$900
11	M007	$5,050	5	ESA003	$9,013	2	MS011	$1,000	0	EA009	$900
11	M010	$400	4	D004	$7,200	2	F005	$5,387	0	E007	$21,293
11	E009	$100	4	MS012	$5,500	1	D003	$5,922	0	E008	$18,982
11	E010	$200	4	MS013	$4,000	1	D005	$8,415	0	F002	$22,195
10	M004	$3,800	4	F007	$8,500	1	MS005	$2,500	0	F003	$18,045
10	M009	$3,300	3	D002	$33,000	1	MS006	$3,500	0	F008	$16,706
10	M011	$2,500	3	D007	$30,000	1	F010	$17,190	0	14	$122,301
10	W001	$3,500	3	D008	$7,122	25	15	$109,218			
10	W006	$1,100	3	D010	$3,000						
9	M005	$10,795	3	MS003	$1,200						
9	W005	$2,900	3	MS007	$5,718						
9	E001	$9,570	3	MS008	$3,000						
9	E002	$10,535	3	MS010	$11,230						
9	E004	$8,794	3	F006	$21,959						
9	E005	$1,013	3	F009	$8,342						
9	E006	$4,115	3	F011	$2,995						
8	E013	$23,326	3	F012	$7,499						
8	F001	$28,773	103	25	$769,011						
8	F004	$9,000									
7	W007	$3,000									
7	E003	$3,100									
7	E011	$200									
301	30	$173,951									

Decisions/ Assumptions on financials & budget allocation

% Mark-up on Asset Value (Inventory) for using MARR Asset

Classification	(Revenue)	(COGS)
A	**6%**	**3%**
B	**4%**	**2%**
C	**2%**	**1%**
D	**0%**	**0.4%**

Gross Margin (GM)=Revenue-COGS

COGS=Cost Of Goods Sold

GMROII(%)=100*GM/ Inventory

Gross Margin Return on Inventory Investment (GMROII)

is a measure of return on inventory assets (or)

how effective the organization uses its inventory.

Figure 4. Inventory Stratification (Current situation)

Current Situation							
Classification	**#SKUs**	**Usages (Hits)**	**(Revenue) Lab fees**	**Oper. & Maint. Costs**	**Asset Value (Inventory)**	**(Gross Margin) Dept. Fund**	**GMROII**
A	30	301	$10,437.06	$5,218.53	$173,951.00	$5,218.53	
B	25	103	$30,760.42	$15,380.21	$769,010.50	$15,380.21	
C	15	25	$2,184.36	$1,092.18	$109,218.00	$1,092.18	
D	14	0	$0.00	$489.20	$122,301.00	-$489.20	
TOTAL	*84*	*429*	*$43,381.84*	*$22,180.12*	*$1,174,480.50*	*$21,201.72*	*1.8%*
Inventory Strategy							
1. Eliminate 50% of D-type Inv. I(D)					**-50%**		
2. Invest all inventory savings in A-type Inv. I(A)					**100%**		
Solution							
Step.1.Update Inventories							
Inv. Difference D^ =	50% I(D)	-$61,150.50					
Inv. Update I'(D)=	I(D)+D^	$61,150.50					
Inv. Difference A^=	100% D^	$61,150.50					
Inv. Update I'(A)=	I(A)+A^	$235,101.50					
Step.2.Update KPIs (Key Performance Indicators)							
(Assume KPIs (**#SKU, Hits, Revenue & COGS**) are adjusted proportionally for the change in Inventory)							
Proportional adjust. p(A)=	[I'(A)-I(A)]/I(A)				0.35	(35% increase)	
Proportional adjust. p(D)=	[I'(D)-I(D)]/I(D)				-0.5	(50% reduction)	
Proportional adjust. p(B)=					0	(no change)	
Proportional adjust. p(C)=					0	(no change)	
KPI Update KPI'(A)=	KPI(A) [1+p(A)]						
#SKU'(A)=	SKU(A) [1+P(A)]				41	(example)	
Results							
Classification	**#SKUs**	**Usages (Hits)**	**(Revenue) Lab fees**	**(COGS) Oper. & Maint. Costs**	**Asset Value (Inventory)**	**(Gross Margin) Dept. Fund**	**GMROII**
A	41	407	$14,106.09	$7,053.05	$235,101.50	$7,053.05	
B	25	103	$ 30,760.42	$15,380.21	$ 769,010.50	$15,380.21	
C	15	25	$ 2,184.36	$ 1,092.18	$ 109,218.00	$1,092.18	
D	7	0	0	$244.60	$61,150.50	-$244.60	
TOTAL	*88*	*535*	*$47,050.87*	*$23,770.04*	*$1,174,480.50*	*$23,280.83*	*2.0%*
% Change	4.2%	24.7%	8.5%	7.2%	0.0%	9.8%	
KPI % Change=	(KPI'-KPI)/KPI						
#SKU % Change =	(SKU'-SKU)/SKU				4.2%	(example)	

Figure 5. Inventory Stratification (Proposed strategy)

5. Recommendation and conclusion

Based on our findings from the data analysis, the MARR Department needs to reduce the number of idling assets (Type D items) and invest the savings in the more useful assets (Type A items) to increase the revenue. For this project, the source of revenue is lab fees – a charge in an amount to generally cover the cost of laboratory materials and supplies used by a student. The Lab fees are authorized by Texas Education Code Section 54.501(a) and are limited to $2 to $30 per course (U. T. System Office of Academic Affairs, 2020). As the revenue in this analysis is based on the percentage mark-up of assets' values (inventories), the MARR department needs to review them to meet the guidelines from school management. For example, the value of a Wartsila diesel engine is assumed as one-half million dollars, though its listed value is one million dollars by the donor/equipment manufacturer, and the value of Cummins diesel engine is assumed as $33,000.00 for the cost of refurbishment. This analysis illustrates that the ABC Inventory Classification Method is suitable to manage the MARR departmental inventories. With the use of Inventory Stratification, our implementation strategies for managing the departmental inventories are to eliminate 50% of D-type Inventories and invest the savings in A-type Inventories. The detailed explanations for choosing these strategies are described below.

A (9.8%) increase in Gross Margin (GM)/Department Fund is a noticeable improvement for a non-profit organization with some idling assets. Such an increase in GM is obtained despite a relative increase (7.2%) in Operation & Maintenance costs (Cost of Goods Sold). GM improvements are possible because of the better allocation of inventory assets. GM improvements are achieved because of a significant (24.7%) increase in Usages (Hits) with a few numbers (4.2%) increase in Stock Keeping Units (SKUs); i.e., more useful inventory assets mean more gross margin. Notice that Gross Margin Return on Inventory Investment (GMROII) has improved from (1.8%) to (2.0%), suggesting the importance of Inventory Management by implementing better inventory strategies. This analysis also illustrates GMROII as a good Key Performance Indicator (KPI) for inventory management on how effectively the organization uses its inventory.

6. References

Amadi-Echendu, J. E. (2004, October). *Managing assets is a paradigm shift from maintenance.* IEEE International engineering management conference, Singapore. Retrieved October 15, 2020, from https://ieeexplore.ieee.org/document/1408874

Department of Marine Engineering Technology, Texas A&M University at Galveston. Training & Research. Retrieved September 7, 2020, from https://www.tamug.edu/marr/research/

El-Akruti, O. K., Dwight, R., & Zhang, T. (2013). The strategic role of engineering asset management. *International Journal of Production Economics, 146*(1), 227-239.

Financial Management Operations, Texas A&M University. Property Management. Retrieved September 9, 2020, from https://fmo.tamu.edu/property/

Guidelines for Assessing Course Fees, Lab Fees, College and Program Fees and Differential Tuition: U. T. System Office of Academic Affairs. (March, 2020). Retrieved October 14, 2021, from https://www.utsystem.edu/sites/default/files/sites/ut-online-consortium/Guidelines%20on%20Course%20%20Lab%20Fees%20Major%20Fees%20and%20Differential%20Tuition_Final.pdf

Harris, C., & Natarajarathinam, M. (2017). Optimising packaged gas inventory placement at welding supply distributors. *International Journal of Business Excellence*, *12*(2), 193-213.

Hmida, J. B., Parekh, S., & Lee, J. (2014). Integrated inventory ranking system for oilfield equipment industry. *Journal of Industrial Engineering and Management*, *7*(1), 115-136.

Leon, V. (2020, September). Class Lecture, Inventory Management-ABC Classification. TCMT_634_M3T018-021, College of Engineering, Texas A&M University. Retrieved September 6, 2020, from course website.

Leon, V. (2020, September). Class Lecture, Demand Characteristics: Magnitude Variability. TCMT_634_M3T025, College of Engineering, Texas A&M University. Retrieved September 20, 2020, from course website.

March, C. *The five biggest risks to effective asset management.* Life Cycle Engineering. Retrieved October 18, 2020, from https://www.reliableplant.com/Articles/Print/27771

Olsen, K. W., Gopal, G., & Calleja, J. Q. (2018, April 24). *Inventory stratification optimizes results.* SCM NOW Magazine. Retrieved September 8, 2020, from https://www.apics.org/apics-for-individuals/apics-magazine-home/magazine-detail-page/2018/04/24/inventory-stratification-optimizes-results#

Shenoy, S. Sample Probability and Impact Matrix: Analyzing Risks Qualitatively. PM Exam SmartNotes. Retrieved January 1, 2021, from https://www.pmexamsmartnotes.com/perform-qualitative-risk-analysis/

The Pandemic Lockdown Impact on Employees in Saudi Arabia

Ali M. Qawarish
Ahmed A. Bakhsh
Department of Industrial Engineering, King Abdulaziz University, Jeddah, Saudi Arabia
aqawarish@stu.kau.edu.sa; aabakhsh@kau.edu.sa

Abstract

Once COVID-19 lockdown was activated in most countries, people had started to suffer the consequences, among those were employees who are considered one of the important society segments as an engine of economic growth during the pandemic. In this regard, this study employs structural equation modeling (SEM) to determine the impact of COVID-19 lockdown on private sector-employees in Saudi Arabia based on a sample targeting the lockdown period using a survey consisting of three main domains to be measured: physical, psychological, and financial. The correlations between the study variables are within the acceptable range. Confirmatory Factor Analysis (CFA) was conducted using AMOS software to validate each domain construct. The results provide support for the hypothesized model with significant internal consistency reliability for each domain. The estimated model reveals that the lockdown exerted a considerable influence on various aspects of employees' life which therefore may impact their performance in their organizations later. The findings can help guide decision-makers within the business community regarding internal customers' needs and also help governments gain a better understanding of citizens' emotions, issues and, interests during critical times.

1. Introduction

At any time, the world is susceptible to crises that could impact individuals and communities. An impact is likely to go beyond the measure, hitting people in their direct life causing undesirable changes. In fact, through the ages, people suffer from crises along with their negative consequences. Pandemics usually influence the community in different dimensions and change life and patterns of behavior, which entails conducting research, particularly for changes that can cause negative consequences.

Employees are one of the effective segments of society as they participate in the promotion of development, with their efforts considered as the engine of economic growth. Hence, it is important to address any problems that may impede their progress during crises.

As the Covid-19 pandemic spread and had deteriorated, few organizations were barely able to cope with the crisis or to have the flexibility for new economic updates. Not only organizations were struggling to survive, but also employees were severely suffering the consequences of being part of the organizations' system. The organizations' management response to the Covid-19 pandemic and the actions taken under pressure were both influenced by employees. That is to say, employees got impacted by governmental actions in general and organizations' decisions in particular.

On March 2, 2020, the first Covid-19 case was confirmed in Saudi Arabia and this figure jumped to 2400 by April 5, 2020. About a quarter of the population experienced severe to moderate psychological impact (Alrashed et al., 2020). The Saudi government announced that about $32 billion would go for the private sector as an economic relief in reaction to the impact of Covid-19. However, the government had to raise the Value Added Tax (VAT) by 10%, aiming to lessen the budget shortage (Parveen, 2020).

1.1. Problem statement

The scope of this research is on private-sector male employees in Saudi Arabia. To investigate the pandemic lockdown effect on their quality of life, a hypothesis is proposed as follows:

H1: Covid-19 pandemic Lockdown negatively impacted the quality of employees' life.

2. Literature review

On March 11, 2020, the world health organization (WHO) declared the Covid-19 pandemic as a global pandemic. The virus had spread rapidly throughout the world. Exact diagnoses could not be made and the ambiguity in virus seemed to be a great mystery to scientists. In addition, the increment of newly infected cases raised a great uncertainty about when the pandemic is going to end. The elderly and children were more susceptible to infections of Covid-19, more than half of the earliest reported infected cases were having a median age of 56, not to mention that thousands of cases passed away (Sohrabi et al., 2020). In the light of this tragic event, i.e., control and lives losing, containing the situation was a must. Hence, most governments around the world implemented lockdowns. Such action was taken under the pressure to avoid aggravating the situation and to escape the potential consequences.

However, once the lockdown was activated, people had started to suffer the consequences of those decisions taken by authorities. For this reason, several researchers have striven to investigate the numerous negative effects of the Covid-19 pandemic on human health and the world economy. The following sub-sections will shed light on what elements are impacted by crises in particular domains.

2.1. Physical domain

Evidence from previous studies demonstrated that seven items got impacted by crises and pandemics. A study revealed that as petrol prices increase, people tend to stay at home and enjoy their physical activities. Hence, it can be argued that during similar crises (such as covid-19), a change may occur to an individual's *mobility*. Obviously, for a happy life, car driving must be supported since it helps in building up social networks (Prakash et al., 2020).

The fourth leading cause of death is *physical inactivity* (Kohl et al., 2012). The lockdown caused a reduction in physical activity levels. About one-third of respondents felt lazy and less energized in UAE during the lockdown (Cheikh Ismail et al., 2020). Nevertheless, people of both sexes were spending extra time in *housework* during the lockdown, particularly for those with children (Del Boca et al., 2020).

Some people felt less satisfied with themselves during the lockdown, investigation revealed that it was attributed to spending less time in *self-care* which also results in feeling sexually less attractive (Dewitte et al., 2020). Another study found an indirect significant relationship between personal hygiene and self-esteem (Umoiyoho et al., 2011). Many participants said they had sleep disturbances, their *sleep quality* had become poorer, and they *gained weight* during the lockdown (Cheikh Ismail et al., 2020).

2.2. Financial domain

The pandemic caused a rise in the unemployment rate and thus a *reduction in the income* for those on the job (Dang & Viet Nguyen, 2020). Some economists investigated the economic crisis's impact on workers, respondents stated that they face *limited promotion* prospects (Bispinck et al., 2010).

The *desire for more money* is likely to lower well-being (Diener & Biswas-Diener, 2002). Those with less money orientation are likely to have higher emotional intelligence and the ability to handle challenges (Engelberg & Sjöberg, 2006). *Financial difficulties* lead to stress, depression, and anxiety (Richardson et al., 2017) and could force individuals to *draw on past savings* (Utting et al., 2012).

2.3. Psychological domain

Overthinking affects performance and causes unhappiness and other negative psychological effects (Lyubomirsky, 2007). An investigation in China revealed that about 80% of the public spent at least one hour a day thinking about the pandemic, about one-third of Chinese expressed *anxiety* amid Covid-19 lockdown (Huang & Zhao, 2021). Some people in the UK including younger adults, students, and women expressed high levels of *loneliness* during the lockdown period (Bu et al., 2020). A study in Canada was conducted to discover how pandemic health anxiety affects the employees where one of the participants reported a high level of frustration with feelings of helplessness and *loss of control* (Trougakos et al., 2020). Arslan and others examined the relationship between *pessimism* and the psychological problems of Covid-19. Results indicate that a high level of pessimism is related to a high level of psychological inflexibility. It was recommended that lower pessimism is likely to help the public to cope with the pandemic stress and to deal with psychological problems (Arslan et al., 2020).

2.4. Quality of life domain

Quality of life can be determined by three factors: life satisfaction, happiness, and absence of ill-being. Individuals who experience ill-being, including anxiety or depression may not experience subjective well-being or good QoL (Argyle, 1996; Sirgy, 2012).

Considering the literature discussed above, it can be seen that crises generally affect people in several dimensions. It is worth studying those dimensions comprehensively to investigate the covid-19 pandemic effect and to see the overall impact on the quality of life, particularly for employees as the scope of the study. This could help address the effect or at least mitigate it when further similar crises occur. The method used in this study is discussed in detail in the next section.

3. Methodology

A questionnaire was used to collect data for this study. Questions were formed and categorized based on the literature review. Each question was formulated attempting to measure a specific variable, to make it easy for participants, the questionnaire was followed a 4-point Likert scale. A group of certain variables constitutes a factor. A proposed model was constructed as illustrated in Figure 1. Confirmatory Factor Analysis (CFA) was used to validate each factor before implementing structural equation modeling (SEM) for the hypothesized model. AMOS software was used for analysis.

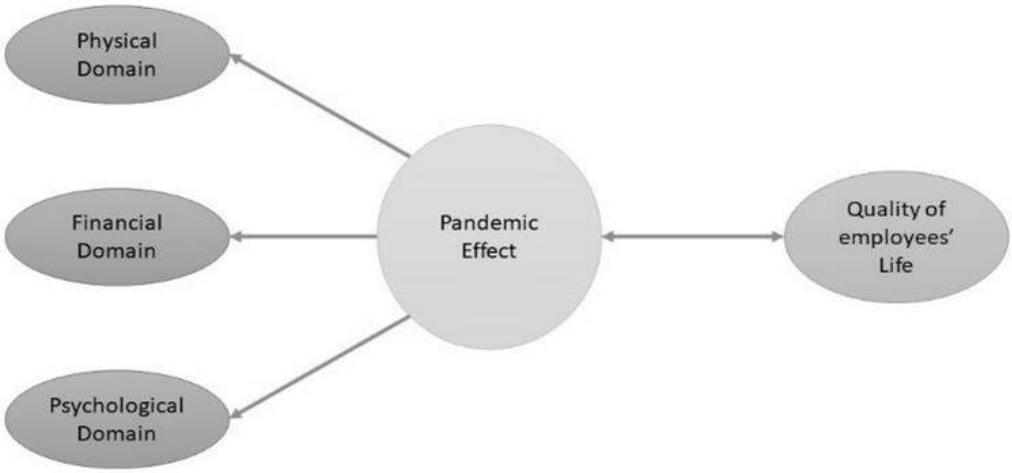

Figure 1**. The proposed model**

3.1. Study variables

Table 1 indicates the study variables and their description:

Table 1. Study variables

Domain	Symbol	Variable description	Domain	Symbol	Variable description
Physical	Ph1	Getting around	Psychological	Ps1	Overthinking
	Ph2	Daily activities		Ps2	Anxiety
	Ph3	Housework burden		Ps3	Loneliness
	Ph4	Energy and vitality		Ps4	Pessimism
	Ph5	Personal care and appearance		Ps5	Loss of control
	Ph6	Sleep quality	Financial	Fi1	Income reduction
	Ph7	Weight gain		Fi2	Job/Promotion opportunity
QoL	Q1T	Life satisfaction		Fi3	Money chase
	Q2T	Happiness		Fi4	Financial difficulties
	Q3T	Overall QoL		Fi5	Savings abandon

3.2. Sample size

A sample size of at least 200 is required in any SEM model to minimize bias for estimates of parameters as well as standard errors to an acceptable level (Boomsma & Hoogland, 2001). The data collected in this study was only 265 respondents, but it was decreased to 234 after eliminating invalid and incomplete responses.

3.3. Statistical measures

To assure model adequacy, several measures were considered. Correlation values should be higher than 0.05 but less than 0.85 to avoid multicollinearity, a correlation value of 0.85 or higher flags a collinearity problem (Kline, 1998). Cronbach's alpha reliability value of 0.70 and above indicates adequacy (Hair et al., 2016). For CFA, a value of at least 0.5 for each factor loading estimate should be secured to assure adequacy in SEM (Hoyle, 2014; Schumacker & Lomax, 2010). Several fit indexes and measures in SEM are commonly used to evaluate the overall model fit. To evaluate each mode in this study, some common measures and indexes were specified, those commonly reported in academia by researchers, such as Chi-square test (χ^2), Chi-square to degree of freedom ratio (χ^2/df), the root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), the Tucker–Lewis index (TLI), goodness-of-fit index (GFI), and comparative fit index (CFI). The fit criteria for each measure will be illustrated in the result section, they are taken from the references (Hoyle, 2014; Schumacker & Lomax, 2010).

4. Results and discussion

4.1. Demographic data

Of the participants, 38% were aged between 19 and 32, 33% were between 33 and 45 and 29% were between 46 and 59. In terms of education, nearly half of the respondents held a bachelor's degree while the other half had either a high school or a master's degree. Participants were from various geographical areas since the sample was randomly chosen. Figure 2 shows the age, educational level, and geographical location of participants.

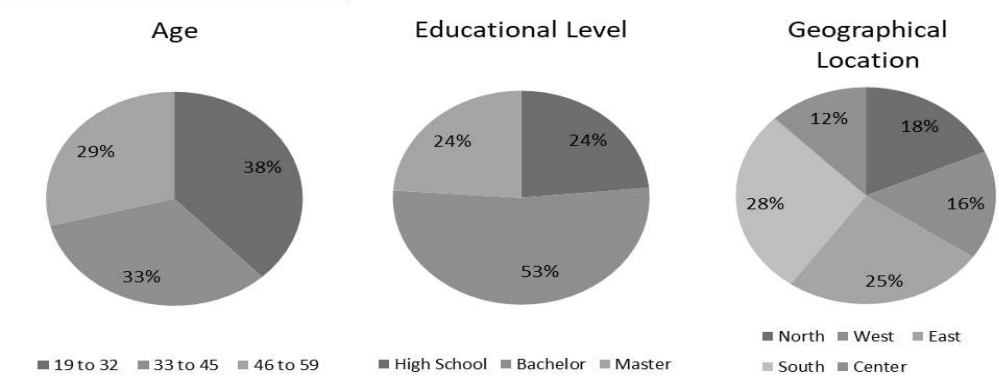

Figure 2. Demographic data

4.2. Correlations and multicollinearity

Using Spearman's rho method, a correlation matrix was drawn for each variable in this research, all correlations were within the acceptable range, i.e. higher than 0.05 to be significant and less than 0.80 to avoid multicollinearity, except Fi4 and Fi5 as they were correlated by 0.84, also Ph7 had a lower correlation with other variables, thus it was recommended to remove Fi5 and Ph7.

4.3. Common bias method

If one factor explains no more than 50% of the variance among variables, it can be said that common bias is not a concern (Podsakoff et al., 2003). Harman's method was conducted in this study, indicating that the first factor explains only 26% of the variance among variables, thus no common bias is present.

4.4. Confirmatory factor analysis (CFA)

After conducting CFA, it was necessary to eliminate some variables although this was already done during the correlation check stage. Table 2 indicates the standardized factor loading for each indicator and Cronbach's alpha (α) for each factor in both initial and modified models.

Table 2. Standardized factor loading and reliability values for initial and modified models

Factor	Indicator	Initial	Modified	Factor	Indicator	Initial	Modified
Physical	Ph1	.40	Deleted	Financial	Fi1	.83	.76
	Ph2	.61	.60		Fi2	.61	.71
	Ph3	.46	Deleted		Fi3	.52	.51
	Ph4	.64	.65		Fi4	.85	.93
	Ph5	.65	.66		Fi5	Deleted	Deleted
	Ph6	.56	.56		Reliability (α)	.801	.801
	Ph7	Deleted	Deleted	Psychological	Ps1	.67	.77
	Reliability (α)	.723	.705		Ps2	.86	.75
QoL	Q1T	.72			Ps3	.58	.68
	Q2T	.94			Ps4	.36	Deleted
	Q3T	.58			Ps5	.38	Deleted
	Reliability (α)	.785			Reliability (α)	.709	.705

4.5. Hypothesized SEM model

To construct the Hypothesized model, an SEM model was considered including all study elements. The lockdown effect factor, as a latent factor, was conceptualized by three latent factors addressed earlier in this study which were physical, financial, and psychological domain factors. Furthermore, the lockdown effect factor was linked with the QoL factor to discover the correlation between them. The model is illustrated in Figure 3.

For the lockdown effect factor, CFA was performed to evaluate the factor loadings of each of the three specified domains as well as their critical ratios to discover whether a specified domain factor is significant or not. Running the model with a focus on the lockdown effect factor revealed that all standardized factor loading values for the three factors were sufficient, i.e. higher than 0.5 as illustrated in Figure 3.

Moreover, it was recommended to examine modification indices that are suggested by AMOS which could improve the model fit, and attempting to apply it if possible. Hence, the model is deemed to be adequate as illustrated in Figure 3.

Table 3 shows the goodness-of-fit measurement for the SEM model. The overall result illustrates that the model had adequate goodness-of-fit measures.

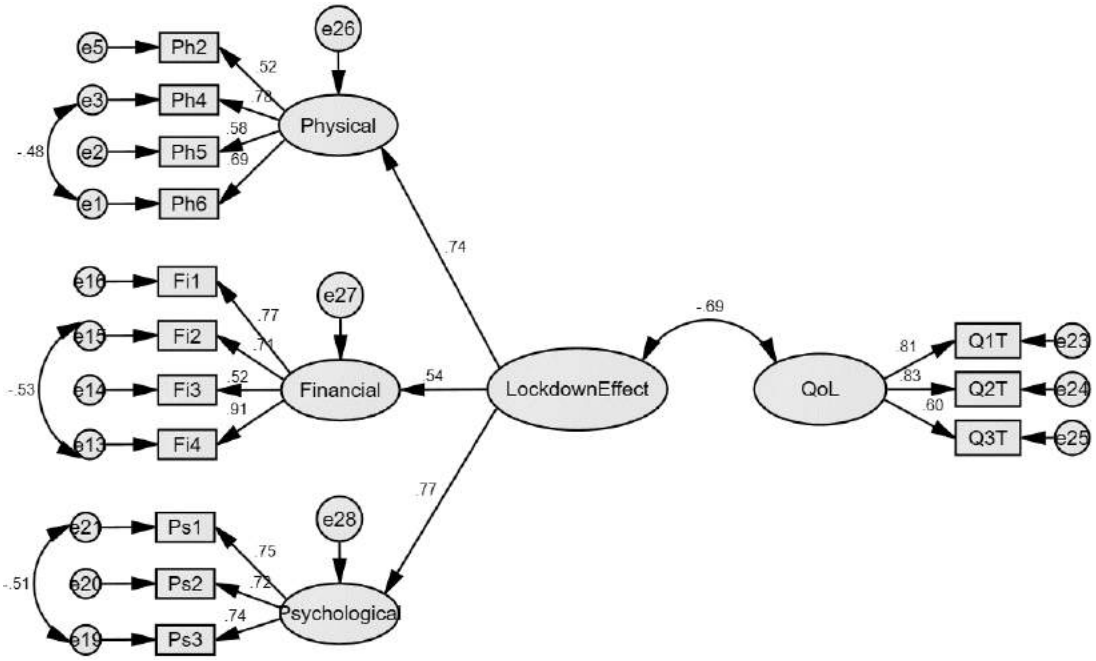

Figure 3. The Conceptualized SEM model and its output

Turning to the crucial point, the lockdown effect factor had a great covariance with the QoL factor. Covariance represents the directional relationship between two items. In this study, the covariance between the lockdown effect and QoL was -0.69, indicating that as the lockdown effect increases, the QoL decreases. This latter point confirms the hypothesis of this research which was:

H_1: Covid-19 pandemic Lockdown negatively impacted the quality of employees' life.

Therefore, based on the finding of this study, it was obvious that Covid-19 negatively impacted the quality of employees' life.

Table 3. The goodness of fit measures for the SEM model

Index	Fit Criteria	The model measure
Chi-Square statistic (X^2)	Low	98.047
Degrees of Freedom	>= 0	70
P-value	> 0.05	.015
Chi- Square statistic/df	<= 4	1.401
standardized root mean square residual (SRMR)	< 0.05-0.08	.048
Tucker-Lewis index (TLI)	> 0.95	.965
Comparative fit index (CFI)	> 0.95	.973
Goodness of fit index (GFI)	> 0.95	.945
Root mean square error of approx. (RMSEA)	< 0.05-0.08	.041
Probability (p- close)	> 0.05	.761

5. Conclusion and recommendations

When considering the Covid-19 pandemic, it comes to mind the lockdown, which was the main scope of this study. While recent studies have attempted to measure the lockdown effect considering only one dimension, to the best of our knowledge, this is the first study that investigates several significant factors comprehensively and integrating them into the covid-19 pandemic effect aiming to see the overall impact on the quality of employees' life.

Employees got impacted by the lockdown in their personal life as proved by the findings of this study. This finding certainly confirms the earliest imposed hypothesis. Moreover, the result of this study was consistent with the previous literature studies on the same field.

A point to be noticed through this study is that employees probably were pushed beyond their powers of endurance during the lockdown. Organizations should take serious heed of the effects on employees as they are being the internal customers.

Understanding of organizational environment can be improved by considering the effects of crises on employees. One of the basic tenets of safety is that employees cannot withstand severe impact during crises unless management pays attention to critical factors.

In any situation in which crises' serious issues are not well-addressed within the organization, employees tend to be the weakest link in the chain in terms of safety commitment or expectation. Given this, organizational management should broaden the range of caring for employees, not only at the macro level but also down to the individual level, i.e. the employee's personal life level. Bearing in mind that management often turns a blind eye to what happens with employees outside the workplace thinking that this has nothing to do with their business.

6. Limitations and future work

As is the case with the majority of studies, the findings of this research, however, are subject to some limitations. First, the employees were of different organizations and with various jobs, unknown how many hours they worked from home or office. This was out of the researchers' control and due to data access limitations. Thus, the authors advise interested researchers who can access extensive data to address this limitation.

Also, it should be noted that the study variables and the model were constructed based on the

literature review and the authors' assessment of the situation. It seems probable that some variables or factors were omitted. Thus, the authors recommend interested researchers explore new elements and factors such as social domain. Managers and relevant authorities may use this study for future reference as a starting point to evaluate the effect of further similar crises.

7. References

Alrashed, S., Min-Allah, N., Saxena, A., Ali, I., & Mehmood, R. (2020). Impact of lockdowns on the spread of COVID-19 in Saudi Arabia. *Informatics in Medicine Unlocked, 20*, 100420.

Argyle, M. (1996). Subjective well-being. *In pursuit of the quality of life*, 18-45.

Arslan, G., Yildirim, M., Tanhan, A., Bulus, M., & Allen, K. A. (2020, Jun 4). Coronavirus Stress, Optimism-Pessimism, Psychological Inflexibility, and Psychological Health: Psychometric Properties of the Coronavirus Stress Measure. *International Journal of Mental Health and Addiction*, 1-17. https://doi.org/10.1007/s11469-020-00337-6

Bispinck, R., Dribbusch, H., & Öz, F. (2010). Impact of the economic crisis on employees.

Boomsma, A., & Hoogland, J. J. (2001). The robustness of LISREL modeling revisited. *Structural equation models: Present and future. A Festschrift in honor of Karl Jöreskog, 2*(3), 139-168.

Bu, F., Steptoe, A., & Fancourt, D. (2020, Nov). Loneliness during a strict lockdown: Trajectories and predictors during the COVID-19 pandemic in 38,217 United Kingdom adults. *Soc Sci Med, 265*, 113521. https://doi.org/10.1016/j.socscimed.2020.113521

Cheikh Ismail, L., Osaili, T. M., Mohamad, M. N., Al Marzouqi, A., Jarrar, A. H., Abu Jamous, D. O., Magriplis, E., Ali, H. I., Al Sabbah, H., Hasan, H., AlMarzooqi, L. M. R., Stojanovska, L., Hashim, M., Shaker Obaid, R. R., Saleh, S. T., & Al Dhaheri, A. S. (2020, Oct 29). Eating Habits and Lifestyle during COVID-19 Lockdown in the United Arab Emirates: A Cross-Sectional Study. *Nutrients, 12*(11). https://doi.org/10.3390/nu12113314

Dang, H.-A. H., & Viet Nguyen, C. (2020). Gender inequality during the COVID-19 pandemic: Income, expenditure, savings, and job loss. *World Development*. https://doi.org/10.1016/j.worlddev.2020.105296

Del Boca, D., Oggero, N., Profeta, P., & Rossi, M. (2020, Sep 6). Women's and men's work, housework and childcare, before and during COVID-19. *Rev Econ Househ*, 1-17. https://doi.org/10.1007/s11150-020-09502-1

Dewitte, M., Otten, C., & Walker, L. (2020, Oct). Making love in the time of corona - considering relationships in lockdown. *Nat Rev Urol, 17*(10), 547-553. https://doi.org/10.1038/s41585-020-0365-1

Diener, E., & Biswas-Diener, R. (2002, 2002/02/01). Will Money Increase Subjective Well-Being? *Social indicators research, 57*(2), 119-169. https://doi.org/10.1023/A:1014411319119

Engelberg, E., & Sjöberg, L. (2006). Money attitudes and emotional intelligence. *Journal of Applied Social Psychology, 36*(8), 2027-2047.

Hair, J., Anderson, R., Black, B., & Babin, B. (2016). *Multivariate Data Analysis*. Pearson Education. https://books.google.com.sa/books?id=LKOSAgAAQBAJ

Hoyle, R. H. (2014). *Handbook of Structural Equation Modeling*. Guilford Publications. https://books.google.com.sa/books?id=4s7SAgAAQBAJ

Huang, Y., & Zhao, N. (2021, Jan). Mental health burden for the public affected by the COVID-19 outbreak in China: Who will be the high-risk group? *Psychol Health Med, 26*(1), 23-34. https://doi.org/10.1080/13548506.2020.1754438

Kline, R. B. (1998). *Principles and Practice of Structural Equation Modeling*. Guilford Publications. https://books.google.com.sa/books?id=a1NvQgAACAAJ

Kohl, H. W., Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., & Kahlmeier, S. (2012). The pandemic of physical inactivity: global action for public health. *The Lancet, 380*(9838), 294-305. https://doi.org/10.1016/s0140-6736(12)60898-8

Lyubomirsky, S. (2007). *The How of Happiness: A New Approach to Getting the Life You Want*. Penguin Publishing Group. https://books.google.com.sa/books?id=Ivf-_LufHmwC

Parveen, M. (2020). Challenges Faced by Pandemic Covid 19 Crisis: A Case Study in Saudi Arabia. *Challenge, 63*(6), 349-364.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003, Oct). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J Appl Psychol, 88*(5), 879-903. https://doi.org/10.1037/0021-9010.88.5.879

Prakash, K., Awaworyi Churchill, S., & Smyth, R. (2020). Petrol prices and subjective wellbeing. *Energy Economics, 90*. https://doi.org/10.1016/j.eneco.2020.104867

Richardson, T., Elliott, P., Roberts, R., & Jansen, M. (2017, Apr). A Longitudinal Study of Financial Difficulties and Mental Health in a National Sample of British Undergraduate Students. *Community Ment Health J, 53*(3), 344-352. https://doi.org/10.1007/s10597-016-0052-0

Schumacker, R. E., & Lomax, R. G. (2010). *A Beginner's Guide to Structural Equation Modeling: Third Edition*. Taylor & Francis. https://books.google.co.uk/books?id=30KkFDyUvEoC

Sirgy, M. J. (2012). *The Psychology of Quality of Life: Hedonic Well-Being, Life Satisfaction, and Eudaimonia*. Springer Netherlands. https://books.google.com.sa/books?id=tTSGbDAAKGkC

Sohrabi, C., Alsafi, Z., O'Neill, N., Khan, M., Kerwan, A., Al-Jabir, A., Iosifidis, C., & Agha, R. (2020, Apr). World Health Organization declares global emergency: A review of the 2019 novel coronavirus (COVID-19). *Int J Surg, 76*, 71-76. https://doi.org/10.1016/j.ijsu.2020.02.034

Trougakos, J. P., Chawla, N., & McCarthy, J. M. (2020, Nov). Working in a pandemic: Exploring the impact of COVID-19 health anxiety on work, family, and health outcomes. *Journal of Applied Psychology, 105*(11), 1234-1245. https://doi.org/10.1037/apl0000739

Umoiyoho, A. J., Inyang-Etoh, E. C., Abah, G. M., Abasiattai, A. M., & Akaiso, O. E. (2011). Quality of life following successful repair of vesicovaginal fistula in Nigeria. *Rural and remote health, 11*(3), 102.

Utting, P., Razavi, S., & Buchholz, R. V. (2012). *The Global Crisis and Transformative Social Change*. Palgrave Macmillan. https://books.google.com.sa/books?id=fPGCUj0jh5sC

3D Printed Nanocomposite Parts for Improved Dental Recovery of Decayed Teeth

Lateefah Miller
Muhammad Mustafizur Rahman
*Ramazan Asmatulu
Department of Mechanical Engineering
Wichita State University, 1845 Fairmount, Wichita, KS 67260, USA
**ramazan.asmatulu@wichita.edu; fareal1@gmail.com, muhammad.rahman@wichita.edu*

Abstract

Bone regeneration and tooth recovery processes have been gaining much popularity and becoming a feasible process worldwide. This process is also called bone scaffolding and grafting where grafted bones are surgically placed to the section of the bone/tooth for repair. Recently, the 3D printing technology has been a great interest in research on bone and tissue repair with the use of 3D printed parts; however, research in dental repair has seen very little interest. In the U.S., adults have an average number of 3.28 decayed or missing permanent teeth and 13.65 decayed and missing permanent surfaces. Meanwhile, dental costs are a significant barrier to adults aged 20-64 maintaining good oral and dental health. Most healthcare plans will cover all basic dental exams, but typically only pay up to half of the cost of major procedures such as crowns and inlays. This research is focused on creating a means of producing permanent dental repairs using the 3D printing process. The 3D printed parts include biodegradable polymers, hydroxyapatite particles, and mechanical testing parts. It is expected that this process will drastically lower costs compared to the conventional tooth recovery processes by limiting the dental operations and dentist visits.

1. Introduction

A Tooth is a calcified small and whitish structure in the jaws of many vertebrates and one of the major parts of the organs. Teeth are composed of enamel, dentin, pulp, and periodontium. Although the dentistry field has been around for a long time, there has been no real advancement in the regeneration of lost dentin minerals caused by tooth decay and other reasons. It has a critical role in the digestive system by breaking down solid food. Losing teeth is very detrimental for both women and men, which is mainly caused by accidents, injuries, or diseases, including tooth decay, dental avulsion, mineral deficiency, and gum diseases (Hughes, 2016a; Hughes et al., 2016b; Asmatulu et al., 2015). According to the most recent annual estimates from the US Center for Disease Control (CDC), among American adults aged 20-64 years, more than 90% had at least one cavity and 27% had untreated decay. Untreated decay leads to 13-14 decayed or missing permanent surfaces per person (Bowers, 2010; Crown(tooth), 2021) If a part of the tooth gets chipped or broken, a dentist can apply an artificial crown. Crowns are used to entirely cover a damaged tooth or cover an implant. Bridges are also used to cover a space if one or more teeth are missing. They are cemented to natural teeth or implants surrounding the space where the tooth once stood. Figure 1 shows the anatomy of tooth structure (Crown(tooth), 2021). Dental costs are a

significant barrier to adults maintaining good oral and dental health. African Americans, Hispanic, younger individuals, and those with lower incomes have more untreated decays. Also, pregnant, and elderly women are more vulnerable to tooth loss than normal adults. Figure 2 shows the common out-of-pocket dental costs (Bowers, 2010; Crown(tooth), 2021; Curtis & Watson, 2014).

In 2012, national dental expenditures were approximately $111 billion in the U.S.A. (Silk, 2014). Local dental clinics charge patients anywhere from $100 to $300 to fill decayed teeth. Dental crowns, which cover the top of teeth and essentially become the new tooth surface and can cost from $700 to $1,200, depending on the type of materials used: ceramic, metal mixtures, or gold. Dental bridges, which are imitation teeth that fill the gaps, cost $2,000 to $3,000, surgical tooth extractions cost $200 to $400 per tooth, and simple tooth extractions cost $100 to $200 per tooth (Dannan, 2009). With the cost of these procedures, there has been a need for new research to create permanent and inexpensive repairs to patients' teeth (Barquins & Shanahan, 1997).

Streptococcus mutans bacteria can absorb into the surface of the tooth and lives off the minerals in dentin. This causes the tooth to decay at a rate faster than the body can regenerate the lost minerals (Hughes, 2016a; Hughes et al., 2016b; Asmatulu et al., 2015). The primary ***risk factors*** for teeth decays include age, sex, family history, race, diet, geography, obesity, smoking, alcohol, lifestyle, and hormone level disorders (Curtis & Watson, 2014). The current method of patient tooth care may temporarily fix the problem but causes long-term damages. The durability and appearance of teeth are sometimes more important to people than their concern about tooth functionality.

The specific requirements of dental applications create a need for the unique merger of material and technology. Several materials, including ceramics, metals, polymers, composites, and nanomaterials are available today but only a few are viable alternatives for dental restorative procedures (Curtis & Watson, 2014). Many environmental and mechanical properties must be considered when looking into any dental repair material (Branco et al., 2019; Chun et al., 2014a; Chun et al., 2014b; Cramer et al., 2011; Denry & Holloway, 2010). The long-term effects have become more important than previously recognized. The toxicity effects had not been considered in the past and are shown to cause significant harm (Bowers, 2010).

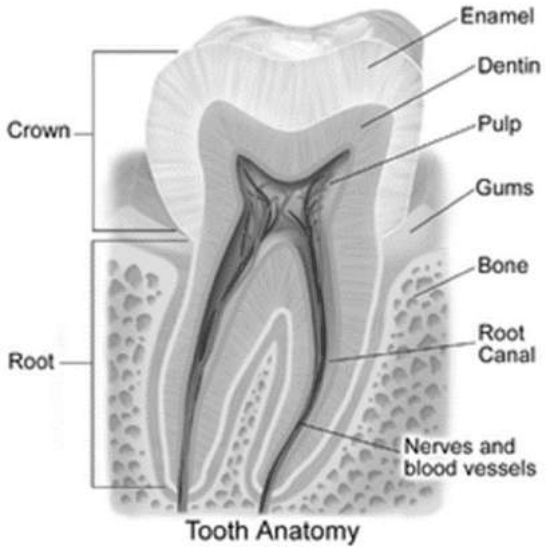

Figure 1: Anatomy of tooth structure (Hughes, 2016a; Hughes et al., 2016b)

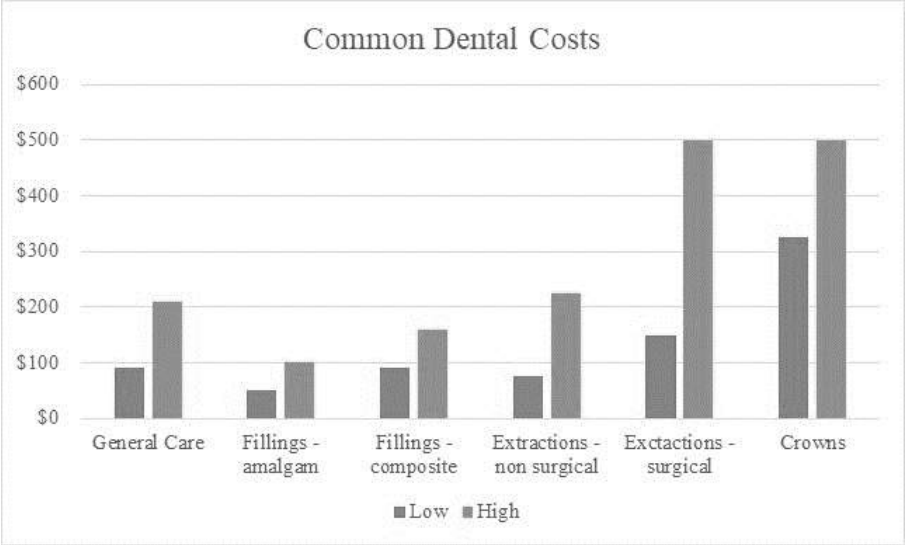

Figure 2: Common out of pocket dental costs

Additive manufacturing is a very useful step toward better dental restorative procedures. The ability to use x-ray scans to compile the 3D tooth customized to the patient is a very important aid. The availability of a wide range of materials of every type allows for enough experimentation to truly address the needs of the teeth and perform exhaustive toxicity studies (Bowers, 2010; Crown(tooth), 2021; Curtis & Watson, 2014). In the past, each "new" dental solution to get away from the practices of old times was only focused on how the mechanical properties were comparable. Decades would pass and the material would be widely used before the realization that they had massively negative health effects. With additive manufacturing, a wider range of materials can be developed and in large enough quantities to perform thorough analyses. With enough investment and research, perhaps the dental industry will soon see the same advancements that additive manufacturing brought to surgical preparation, bones, and prosthetics, and other areas of medicine (Curtis & Watson, 2014; Chun et al., 2014a; Denry & Holloway, 2010).

In the present study, 3D printed polylactic acid (PLA) parts were produced using the natural tooth extraction process, and the mechanical properties of the porous structures were determined for the decayed tooth recovery.

2. Experiment

2.1 Materials

To examine the use of hydroxyapatite (HA) with additive manufacturing methods, raw materials had to be processed to achieve the resulting HA particles. Based on the most relevant research available, bovine teeth (bone growth media) were the most commonly used raw material from which the HA was extracted. HA was prepared by calcination (pyrolyzing) of the bovine teeth in a Thermodyne furnace for three hours at 800^{o}C. Once calcinated, only the HA as a chunky particle structure remains. The material is pulverized into a very fine consistency (approximately below 20 µm). This is achieved by mortar and pestle. Figure 3 reveals the extracted cow teeth, calcination of natural teeth in a Thermodyne Furnace, mortar grinder, and ground powder form.

Figure 3: Images showing a) extracted bovine teeth from a cow, b) calcination of natural teeth in a Thermodyne Furnace, c) mortar grinder and d) fine HA powder.

2.2 Fabricating PLA+HA filament

Using a magnetic stirrer with heat, PLA pellets were dissolved into dimethylformamide (DMF) solvent. The PLA was most successfully dissolved at a stir speed from 450 to 600 rpm at elevated temperatures. The HA was incorporated until the mixture was thoroughly combined. The mixture was slowly cooled so the added HA particles would not settle out from the PLA. As the PLA was liquefied, it had to be stirred with a glass rod to make sure that no material gathered around the outer edges of the beaker away from the magnetic stirrer. This insured that the PLA thoroughly dissolved and allowed the HA to be well distributed at high-speed mixing. Once the material was in pellets, it sat in an open container until the remaining DMF solvent evaporated out. The color would change from a dark grey to mostly white as the DMF evaporated. The weight was checked to be sure that it matched the PLA and HA only dry weight. HA powders were added to PLA in various quantities by weight: 0, 5, 10, 15, and 20%. Figure 4 shows the dissolved PLA, adding teeth powder into the PLA solution, evaporation of the mixture, and mixed PLA+HA particles.

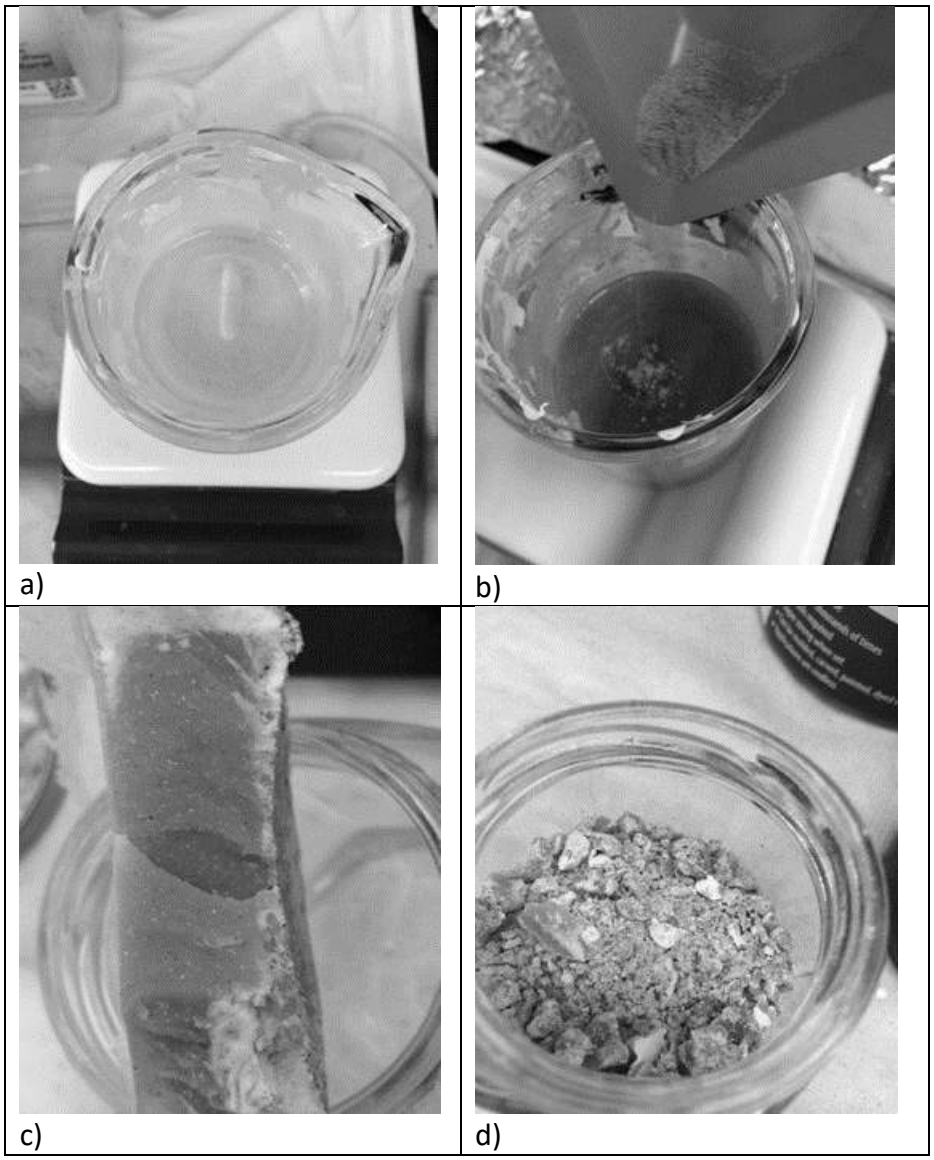

Figure 4: Images showing a) dissolved PLA, b) adding teeth powder into the PLA solution, c) evaporation of the mixture and d) mixed PLA+HA particles.

The pellets of PLA-HA were fed into a Wellzoom filament extruder. The extruder heats the pellets to melt (above 160 °C) and the material gets extruded out of the nozzle above the melting temperature. The extruded material has to be guided from the nozzle to the filament winder while it cools to form a 1.75 mm filament. Once the filament was produced, it was placed on the 3D printer as the source material. Figure 5 provides the images of the Wellzoom filament extruder and PLA-HA filament for 3D printing of porous parts. In addition to the filament and 3D printing processes, some of the samples were prepared using the solvent casting process for comparison.

Figure 5: Images showing the a) Wellzoom filament extruder and b) PLA-HA filament for 3D printing of porous parts.

2.3 3D Printing of scaffolds and compression testing

Using natural PLA filament and the PLA-HA filament, samples of scaffolds were printed on a Prusa MK3 3D printer. This printer is very practical to use in this type of research. The printer was equipped with a 0.6mm nozzle. PLA filament was loaded into the printer and samples were printed. The PLA-HA filament was then loaded into the printer and samples were printed. Scaffold samples that were printed were tested using MTS Criterion 45 Universal Testing Machine. Figure 6 shows the Prusa MK3 3D Printer, 3D printed PLA-HA porous parts for the decayed tooth recovery, while Figure 7 shows the compression tests on the samples.

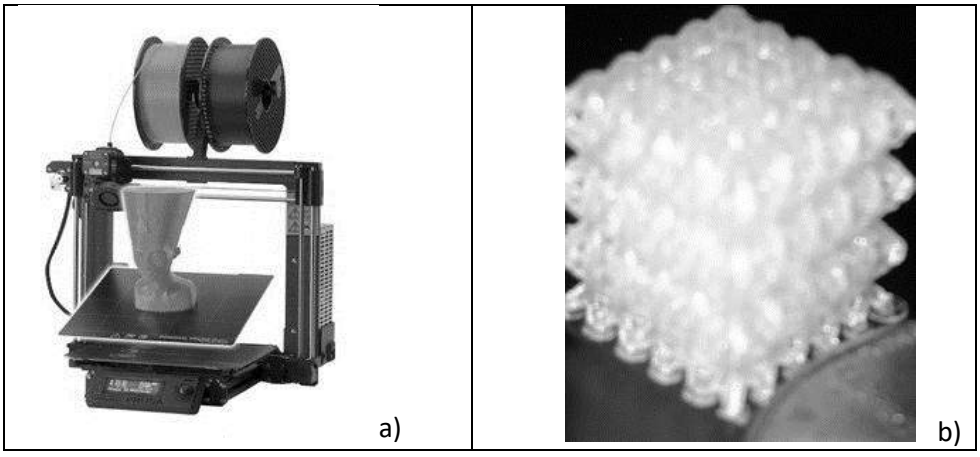

Figure 6: Images showing a) the Prusa MK3 3D Printer and b) 3D printed PLA-HA porous parts for the decayed tooth recovery

Figure 7: Images showing the compression test results of the prepared samples

3. Results and discussion

The porous scaffold samples that were 3D printed were tested using MTS Criterion 45 Universal Testing Machine. Each of the specimens was loaded under compression at a constant rate of 0.008 mm/s. The compression testing yielded the results for load versus time, peak load, peak stress, and modulus of elasticity. Modulus of Elasticity (or Young's Modulus) often referred to simply as the modulus, is the stress-strain relationship of material within the elastic region under tensile or compressive forces. The modulus of elasticity gives a material's resistance to deformation (Curtis & Watson, 2014). It can be used to predict the elongation or compression of an object as long as the stress is less than the yield strength of the material. The results of the compression tests for the 3D printed porous PLA scaffolds are given in Table 1. The average peak load, peak stress, and Elastic Modulus values of the printed PLA porous samples are 1760 N, 43.6 MPa, and 3551 MPa, respectively.

Table 1: Stress and Modulus of 3D printed porous PLA scaffold samples

PLA Samples					
Spcmn No.	Width mm	Thickness mm	Peak Load N	Peak Stress MPa	Modulus MPa
1	12.7	3.175	2070.59	51.4	3971.7
2	12.7	3.175	1877.02	46.6	2791.9
3	12.7	3.175	1169.35	29.0	3461.9
4	12.7	3.175	1755.23	43.5	3358.2
5	12.7	3.175	1927.42	47.8	4172.9
AVG	12.7	3.175	1759.92	43.6	3551.3

The same tests were conducted on the samples after adding HA particles into the PLA sample. The same MTS machine with the same testing conditions was used. Table 2 gives the preliminary results for the PLA with 10% HA. The test results indicated that the average peak load, peak stress, and Elastic Modulus values of the 3D printed porous PLA+HA samples were increased about 54.4%, 120.2%, and 19.5%, correspondingly. This revealed that adding HA particles into PLA significantly increased the mechanical properties of the samples, which may be beneficial for dental recovery purposes.

Recently, new investigators have been trying to develop new dental protection systems to protect the human teeth, including implants, tissue scaffolding, stem cell, artificial, ceramic, and composite teeth, new crowns, bridges, and so on (Silk, 2014; Dannan, 2009; Barquins & Shanahan, 1997). In some of these systems, antibacterial and cell-promoting drugs have been applied during dental operations. In our previous studies, solution cast parts and electrospun nanofibers incorporated with synthetic and natural bone minerals were produced for the regeneration of the missing bones in the human body (Hughes, 2016a; Hughes et al., 2016b; Asmatulu, 2015). The cytotoxicity studies showed that the viability of bone growth cells was between 70 and 100%, which will greatly promote the cell growth and remineralization of the bones. In addition, adding antibacterial agents into the electrospun nanofibers with the bone particles were substantially reduced the bacterial growth.

Overall, this study tries to create a new approach that can kill bacteria causing tooth decay, and then assist in the natural cycle of the tooth to regenerate lost minerals and dentin (Sultana, 2012). After the biological studies (mineralization with the bone growth bacteria), the compression and other mechanical, chemical, and biological properties of the recovered tooth will be drastically improved for real dental purposes.

Table 2: Stress and Modulus of 3D printed porous PLA+HA scaffold samples

PLA-HA Samples					
Spcmn No.	Width mm	Thickness mm	Peak Load N	Peak Stress MPa	Modulus MPa
1	5.2	6.2	9683.783	300.4	13281.91
2	5.1	5.3	920.632	34.1	1051.887
3	5.2	4	1202.268	57.8	1301.454
4	5	3.5	966.859	55.2	4323.657
5	5.3	4.7	815.572	32.7	1261.787
AVG	5.16	4.74	2717.8228	96.04	4244.139

4. Conclusions

This research set out with the goals of exploring the feasibility of 3D printing for low-cost dental applications. The natural teeth were extracted from the cow and calcined at 800 ^{o}C for 3 hours before adding into the PLA in DMF solvent. The test results showed that the average peak load, peak stress, and Elastic Modulus values of the printed PLA+HA porous samples were 2717.8 N, 96.0 MPa, and 4244.1 MPa, respectively. Adding HA particles (bone growth media) will likely enhance the recovery process of the decayed tooth. This study may open new possibilities to increase the tooth recovery processes and reduce dental costs through limiting dental operations and dentist visits.

5. Acknowledgment

The authors gratefully acknowledge the Wichita Medical Research and Education Foundation (WMREF) Collaborative Investigator-Initiated Research (CIIR) Program and Wichita State University for the financial and technical support of the project.

6. References

Asmatulu, R, Patrick, S, Ceylan, M, Ahmed, I, Yang, SY, and Nuraje, N. (2015). Antibacterial Polycaprolactone/Natural Hydroxyapatite Nanocomposite Fibers for Bone Scaffoldings. Journal of Bionanoscience, 9 (1-7).

Barquins, M, and Shanahan, ME. (1997). Effect of Surface Cavities on Static and Dynamic Adhesion to an Elastomer," International Journal of Adhesion and Adhesives, 17(4):313-317.

Bowers, MC, Forensic Dental Evidence: An Investigator's Handbook, 2nd Edition, Elsevier, Tokyo, 2010.

Branco AC, Silva R, Serro AP, Polido M, Pina CG (2019, March). Subtractive vs additive manufacturing in the production of zirconia pieces for dental applications. Annals of Medicine (51), 100-100.

Chun KJ, Choi HH and Lee JY (2014a). Comparative study of mechanical properties of dental restorative materials and dental hard tissues in compressive loads. Journal of Dental Biomechanics. Volume 5: 1–6. DOI: 10.1177/175873601455524.

Chun KJ, Choi HH and Lee JY (2014b). Comparison of mechanical property and role between enamel and dentin in the human teeth. J Dent Biomech 2014; 5. DOI: 10.1177/1758736014520809.

Cramer NB, Stansbury JW, Bowman CN (2011). Recent Advances and Developments in Composite Dental Restorative Materials. Journal of Dental Research, 90(4):402-416.

Curtis, RV, and Watson, TF, Dental Biomaterials: Imaging, Testing, and Modeling, Woodhead Publishing, Cambridge, England, 2014.

Dannan, A. (2009). Dental-derived Stem Cells and whole Tooth Regeneration: An Overview," J Clin. Med Res Journal of Clinical Medicine Research, doi:10.4021/jocmr2009.03.1230.

Denry, I. and Holloway, JA (2010). Ceramics for dental applications: a review. Materials. 3: 351- 368.

https://en.wikipedia.org/wiki/Crown_(tooth), accessed on March 18, 2021.

Hughes, SH. (2016a). Electrospun PCL Nanofibers Incorporated with Natural and Synthetic Calcium Hydroxyapatite Particles for Human Tooth Regeneration. M.S. Thesis, Wichita State University.

Hughes, SM., Pham, A, Nguyen, KH, and Asmatulu, R. (2016b). Training Undergraduate Engineering Students on Biodegradable PCL Nanofibers through Electrospinning Process. Transactions on Techniques in STEM Education, 1: 19-25.

Silk, H. (2014). Diseases of the Mouth," Primary Care: Clinics in Office Practice, 41(1): 75-90.

Sultana, N., Biodegradable Polymer-Based Scaffolds for Bone Tissue Engineering, Springer, New York, 2012.

Examining Part 141 Flight Training: Flight Hours and Days to Instrument Rating

Brooke Wheeler
Jessica Mumfrey
Drew Dolan
College of Aeronautics, Florida Institute of Technology
bwheeler@fit.edu; jmumfrey2017@my.fit.edu; ddolan2017@my.fit.edu

Abstract

Understanding the efficiency of flight training in collegiate programs is essential as Part 141 training aims to create safe pilots with lower training times. The purpose of this study was to determine whether there is a relationship between the total flight hours and the total calendar days it takes to complete the FAA Part 141 instrument flight training course. We used a correlational design to analyze the relationship between the variables; the records used were those who had enrolled in the instrument course and successfully passed the instrument check ride. Examining the Part 141 flight school records at a collegiate program, we found a medium, positive correlation between total calendar days in the course and flight hours to instrument rating.

1. Introduction

Part 141 flight training is the FAA approved, accelerated, professional pilot training. Collegiate flight schools aim to produce qualified pilots in minimal flight time, which also necessitates an emphasis on safety and effectiveness of training. This requires continual assessment of both safety (e.g., Wheeler et al., 2019b, 2020a) as well as understanding student performance and training in order to iteratively improve programs. The strong safety culture of this collegiate program is indicative of the commitment to both safety and iterative improvement (Wheeler et al., 2019a), including regular assessment of the training programs. Prior research on initial flight training examined the relationship between flight time and length of course for the Part 141 Private Pilot's license course and found a strong positive correlation for initial Part 141 training (Wheeler et al., 2020b). Although previously documented in initial, *ab initio* flight training for private pilots, this relationship has not been examined in the upper level flight courses.

1.1 Purpose and Significance

The purpose of this study was to determine whether there is a relationship between the total flight hours and the total calendar days it takes to complete the FAA Part 141 instrument rating flight course at a collegiate program in Florida. Total flight hours were calculated by adding simulation hours and aircraft hours from the de-identified student flight records. The total calendar days in the course were measured using the course start date and date of the successful check ride. The research question for

this study was "how do calendar days correlate with the total flight hours obtained during the instrument flight training course?" We expected to see a positive correlation between flight hours and days in the instrument course.

In addition to providing data on the number of flight hours logged for the instrument course and the number of days from the start of the instrument course to completion, this study improved our understanding of the relationship between flight time and how long instrument training takes students. Part 141 training is highly standardized with the aim of offering flight students pursuing a professional goal safe, quality instruction with minimal flight time. Thus, it is important to regularly evaluate student performance and understand length of training time in the various flight courses as well as other factors related to training. This study provides an analysis for the instrument rating course. This may be used to improve the efficiency of the Part 141 instrument flight training program and ensure that there are not any delays in training proficiency.

The results apply to the instrument rating flight course at the collegiate Part 141 flight program in Florida that provided data. However, the results are likely generalizable beyond the accessible population to instrument training at all collegiate Part 141 flight schools in the United States. All Part 141 flight training schools have similar syllabi, include the same airman certification standards, and have been approved by the Federal Aviation Association (FAA). The student populations of collegiate flight schools also share many demographic characteristics, including a high male to female ratio and students in the college age range of 18-23 years old.

1.2 Flight student training and performance

In flight training, student performance is essentially a student's ability to reliably retain the information and skills they are taught. The FAA recognizes both ground training, primarily knowledge tested with a multiple-choice exam, and application of skills that are assessed in a final check ride to receive the certificate or rating. In order to maximize student learning and success, research is necessary to understand both the knowledge and application parts of pilot training.

In instrument training, simulator training is key to effectiveness. Improved simulators can be used to provide a more realistic experience to student training. Myers et al. (2018) evaluated the efficiency of training by the general fidelity of simulators. When training in a simulator that more effectively resembles the actual aircraft, including advanced technologies, it is easier to understand new concepts and to practice old ones. The quality of simulators affects the amount of knowledge that transfers over to real experiences. However, while an emergency training procedure can be done perfectly in a simulation, when it comes to real-life situations, pilots may not make certain decisions because there may be a real life-or-death decision to make, as opposed to the simulation where they know there will not be any harm done if they make a mistake. This can lead to pilots overthinking a situation and ignoring the most obvious and easiest solutions (Myers, et al., 2018). Thus, while simulators are effective training tools, they lack the immediacy of risk associated with aircraft training.

Simulators are a cost effective and reliable method for flight training, with the added benefit that a simulator lesson never has to be cancelled due to weather. The availability of simulators with correct weather conditions makes them an ideal option (Kozuba & Bondaruk, 2014), particularly for training in

the instrument rating course. This can benefit students by helping to increase regularity of training during this stage. A substantial portion of instrument training may be completed in simulators because the weather is not always appropriate for logging instrument aircraft time, and simulators are considered realistic approximations for training to fly in instrument conditions. Thus, for this study, total flight hours included both simulator and aircraft time.

Many other variables play into flight student success and performance. Chaparro and colleagues (2021) performed a hierarchical multi-variate regression of 19 predictors to determine indicators for flight student persistence in their undergraduate program and eventual success. Age, flight training costs, course load, academic success in flight courses, and instructor changes were all significant contributing factors (Chaparro et al., 2021). Flight time is directly related to costs, and this is a key variable to continue studying at a finer scale to better understand the impact on progress in particular courses.

Student learning can also be directly impacted by other factors, including fatigue, which is both common and critical to assess in flight training from a safety perspective. Fatigue directly impacts effectiveness of flight lessons through a negative relationship with retaining information. Fatigue can be controlled by taking short breaks during ground lessons or taking a moment to analyze your situation during a flight. Additionally, instructors can assist by helping to identify fatigue in their students (Mendonca et al., 2019), thus improving awareness and minimizing the negative impacts on retention and performance in flight training. Similarly, Williams and Shapiro also noted that fatigue is increased when student schedules have multiple courses back to back (Williams & Shapiro, 2018).

1.3 Frequency of Training

In fields as varied as education, sports, music, and flight training, we recognize the importance of regular training and practice in success. In the field of accounting, Mohrweis (2000) compared the performance of students who met more frequently- three days a week for 50 minutes- to those who met less frequently- two days a week for 75 minutes. After controlling for academic aptitude (GPA), which was a significant factor, there was no significant difference in the student performance based on frequency of class meeting (Mohrweis, 2020). However, both of these groups met regularly over the same semester length. Similarly, in flight training, we expect regular lessons, either two or three times a week, to help a student to maintain and build their skills with a regular progression.

On the other hand, Geltner and Logan (2001) found that student success and grades were higher in shorter terms (both six and eight weeks) than the traditional 16-week academic term. This demonstrates an inverse relationship between student success and length of the academic course; grades are lower in the longer courses. This indicates that condensed course durations promote student success. Williams and Shapiro (2018) conducted a large-scale study of student outcomes at the Air Force Academy and concluded that student outcomes do improve with repetition. This implies that regular, more frequent training does positively relate to student performance.

Particularly in instrument training, there is anecdotal evidence that students who do not fly regularly have lower confidence in their skillset prior to their check ride. Even though students whose instructors sign off that they are prepared for their instrument check ride typically have the skills to successfully

complete the rating, these students feel more confident in their performance when the check-ride is in a very short timeframe after their last lesson (Dr. Isaac Silver, personal communication, June 29, 2021). Repetition is always key when learning a new skill or refining skills because repetition helps with muscle memory, thus regular training is important to student success. With flying, it is also very important to stay current with ratings and endorsements. Taking a break from training can disrupt the flow of the learning process, and then a student must go backward to repeat lessons to refresh their skills.

In the initial stages of flight training, studies have documented a relationship between flight time and length of the course. Caligan (2012) found a significant relationship between flight time to solo, which is the first major benchmark in private pilot training, and the total flight time to receive a private license. However, he did not find support for the flight time to solo predicting the success of the first check ride. Additionally, the ability to predict time to license improved with frequency of training (Caligan, 2012). This means that at the private pilot level scheduling flight lessons more frequently led to more predictable training times overall. Wheeler et al. (2020b) found a positive relationship between duration of the private course and efficiency, or total flight time (r = .52, p < .001). For the private course, it is clear that more regular training over a shorter course duration translates to lower overall flight times in the course. However, we have not yet studied this relationship at the instrument level.

2. Methods

This study used a correlation analysis with existing, archival flight records to examine the relationship between total flight hours and the number of calendar days to completion of a Part 141 instrument flight course. Prior to the study, we applied for and received an IRB exemption (20-022). To ensure privacy and maintain the anonymity of the of data, all identifying information was removed from the dataset prior to release to the researchers. Additionally, results will only be presented in aggregate. The deidentified flight records were provided by a Part 141 collegiate flight program for all students who enrolled in and successfully completed their check ride for the instrument rating under the current, FAA approved training course outline (TCO). This ensured that all students had the same requirements for the course including lessons, and ground, simulator, and flight time, in this case 35 hours (FITA, 2018).

Total flight hours in the course were calculated as the sum of the dual flight instruction (N.B., there was no solo flight time for this course) and the simulator flight time. The course calendar days were calculated with an Excel formula from the start date and date of the successful check-ride. Descriptive statistics were calculated using Excel. A Pearson's product moment correlation and a linear regression were calculated in R Studio version 1.2.5001.

3. Results

The deidentified data file included a total of 76 flight records, for all Part 141 students who enrolled in and successfully completed the course under the current TCO. Thus, the data includes a census of the accessible population of collegiate Part 141 flight students who completed the instrument course at the flight school. However, because the data was de-identified, we can only say that the sample is likely representative of Part 141 collegiate students, typically in the 18-23 year old age range and with more males than females in the sample.

Preliminary analysis identified four outliers, three of which were outliers on both the calendar days in the course and the total flight hours. In Part 141 training, there are minimum time requirements, which means that there are lower bounds for the variables; all identified outliers were more than two standard deviations above the mean for at least one of the variables of interest, hours and days. The four outliers were excluded from further analyses in order to meet the assumptions for a Pearson's correlation. The remaining 72 student records were used in the analyses. Other assumptions for a correlation were met. Two other variables were provided and included in the descriptive analysis: FAA knowledge test score and the number of unit attempts (i.e., the number of lessons, including repeated lessons).

Figure 1 shows a scatter plot of the total flight time in the instrument course by the days in the course. Although there is a weak, positive trend. The descriptive statistics for lesson attempts, knowledge test score, days, and hours are presented in Table 1. The FAA knowledge test scores ranged from 70 (FAA minimum passing grade) to 98, and the mean, mode, and median were all close to 85. Calendar days in the course had the largest variability with a minimum of 60 days (approximately two months) and a maximum of 397 (well over a year). The other variables all had reasonably small ranges and standard deviations. The average flight time (49.52 hrs) was larger than the median (46.65 hrs).

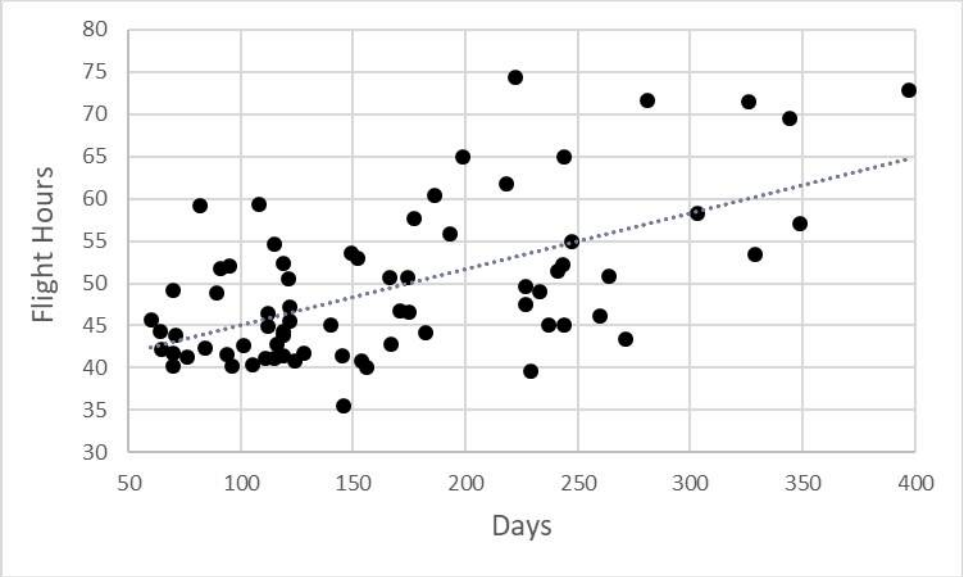

Figure 1. Total Flight Hours vs. Calendar Days in Instrument Course.

Table 1. Descriptive statistics for Part 141 Instrument Flight Course.

	Mean	Mode	Median	Minimum	Maximum	Standard Dev.
Attempts	48	41	45	38	76	8.4
Grade	84	85	85	70	98	6.9
Days	167	119	148	60	397	80.2
Hours	50	65	47	36	74	9.0

Statistics for lesson attempts, FAA knowledge test grade, calendar days in the course, and total flight hours (aircraft time plus simulator time).

The Pearson's product-moment correlation indicated a statistically significant positive relationship between calendar days and flight time in the instrument course ($r(70) = 0.59$, $p < .001$). The results of the linear regression showed that days in course was a significant predictor of total flight hours in the instrument course ($F(1,70) = 37.43$, $p < .001$, $R^2 = .35$). Both the slope (0.07) and intercept (38.45) of the model were significant ($p < .001$). This demonstrated that although days in course only explained 35 percent of the variance in the flight hours this is a statistically significant predictor.

4. Discussion

The deidentified flight records included all Part 141 collegiate flight records for students who successfully completed the course. Although we did not receive any demographic information, including all records ensures that this sample is representative of the accessible population. Exclusion of the four records that were outliers brought the data into compliance with all assumptions for the correlational analysis.

The majority of the records were clustered towards the lower end of the distribution (Figure 1). This is as expected because the FAA has minimum flight hours specified for the instrument course, which forms a lower bound on flight time. Likewise, instructors typically schedule during student flight blocks and only one lesson a day, which puts a minimum on the number of days that the course could be completed in. Ideally, students who are training regularly and efficiently would complete the course in a minimum time, both flight time and calendar days.

The data supported our hypothesis that there would be a positive correlation between total flight hours and calendar days in a Part 141 instrument rating flight course ($r(70) = 0.59$, $p < .001$). The relationship was significant and moderately strong. These results align with prior work on the Private Pilot License course, which found a strong positive relationship between these variables (Wheeler et al., 2020b). Although the relationship is moderate for the instrument course, the relationship does hold in the more advanced instrument course.

The linear regression indicated a significant linear relationship between the variables. Calendar days in the course only explained 35 percent of the variance in the flight hours. Thus, the model fit is low, but the length of the course was a statistically significant predictor. Predicting flight training is notoriously challenging because there are so many variables that impact students, such as lessons cancelled for weather, illness, financial delays, changing instructors when the instructor leaves for a job with the airlines, maintenance issues with an aircraft, a break in training (e.g., leaving over the summer semester), and student motivation. Accounting for 35 percent of the variance in flight training time in a course with only one variable indicates that the length of course is important.

This research confirmed a positive relationship between calendar days in the instrument course and total flight time required to complete the rating. Therefore, flight students are recommended to train regularly and proceed through the course as shorter course duration is related to lower total flight times, and therefore lower flight training costs. This analysis should be repeated in the single- engine commercial, multi-engine commercial, and certified flight instructor courses to determine whether this relationship is present in later flight training. Additionally, studies should replicate this in other Part 141

flight schools for comparison.

5. References

Caligan Jr., R.J. (2012). Time to Solo as a Predictor of Performance in Civilian Flight Training. *The International Journal of Aviation Psychology*, *22*:1, 30-40. DOI: 10.1080/10508414.2012.635124

Chaparro, M., Sharma, V., Carroll, M., Mehta, R., Wheeler, B., & Dayiaglo, B. (2021, May 19). *Predicting Pilot-in-training Success and Persistence in a Private South Eastern United States University.* International Symposium on Aviation Psychology.

FITA, 2018. *Instrument Rating Course Airplane [FAA Part 141 Syllabus].* FIT Aviation, L.L.C. Florida Institute of Technology.

Geltner, P., & Logan, R. (2001). *The Influence of Term Length on Student Success*. RR-2001.4.1.0 Santa Monica College, CA.

Kozuba, J., & Bondaruk, A. (2014). Flight Simulator as an Essential Device Supporting the Process of Shaping Pilot's Situational Awareness. *Proceedings of the Scientific Conference AFASES*, 1, 41–60.

Mendonca MR, F. A., Keller, J., & Lu, C. (2019). Fatigue identification and management in flight training: An investigation of collegiate aviation pilots. *International Journal of Aviation, Aeronautics, and Aerospace*, *6*(5), 13. https://doi.org/10.15394/ijaaa.2019.1365

Mohrweis, L. C. (2000). *Is learning impacted by how often a class meets? Some empirical evidence*. Working paper series--00-05.

Myers, P., Starr, A., & Mullins, K. (2018). Flight Simulator Fidelity, Training Transfer, and the Role of Instructors in Optimizing Learning. *International Journal of Aviation, Aeronautics, and Aerospace,* 1. https://doi.org/10.15394/ijaaa.2018.1203

Wheeler, B., Cambata, C., Alyamani, G., Fox, G., & Silver, I. (2019a). Safety culture at a collegiate flight school. *Journal of Management & Engineering Integration, 12*(2), 94-98.

Wheeler, B.E., Golcher Ardic, E., Wertin, R., Fox, G., & I.M. Silver. (2019b). Operational Incident and Mishap Reports by Phase of Flight. *Journal of Management and Engineering Integration*. *12*(2), 105-111.

Wheeler, B.E., Redden, K., Bonilla, D., Fox, G., & Silver, I. (2020a). OMIR Event Type and Frequency at a Collegiate Flight Program. *Journal of Management and Engineering Integration. 13*(1), 104-110.

Wheeler, B.E., Risso, A., Albrecht, T., Mehta, R., & Silver, I. (2020b). *Duration and Efficiency of Private Pilot Training*. University Aviation Association Virtual Conference.

Williams, K. M., & Shapiro, T. M. (2018). Academic achievement across the day: Evidence from randomized class schedules. *Economics of Education Review*, *67*, 158-170.

WINTER
2021

AIEMS VOL 14 NO 2

AIEMS

AIEMS is committed to furthering the integration between business management, engineering, & industry. Our objective is to promote research, collaboration, & practice in these multidisciplinary areas. AIEMS seeks to encourage local, national, & international communication & networking via conferences & publications open to those in both academia & industry. We strive to advance professional interaction & lifelong learning via human & technological resources, and to influence and promote the recruitment and retention of young faculty and industralists.