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Involving Stakeholders at Early Stage of the Design Process to Improve Credit Points Allocation

Husam A. Alshareef, Krystal Vallejos, Patrick Aguilar, Dallas Leasure, Chance Trueblood

ABSTRACT

Several sustainable buildings (existing or new construction) that seek Leadership in Energy and Environmental Design (LEED) credentials tend to lack proactive plans at a very early stage of the project. stakeholders and decision-makers typically wait until the design phase begins to discuss LEED's categories (i.e. credit point allocations), which drains out the budget with a limited number of resources. This conventional method has a higher probability of reducing production and collaboration and also limits creativity and innovation. Therefore, this research is intended to evaluate the early preparation of eco-friendly buildings (e.g. the Technology Building at Colorado State University (CSU-P) as a case study) and examine practical applications to seek a LEED certification.

A collaborative iterative process approach was utilized by researching and evaluating ideas and conducting interviews with stakeholders and decision-makers. This process is undertaken to identify the most useful materials, items, ideas, and then weigh them against their pay-back periods. The purpose of this research was to integrate the iterative process into a high level of integrative process approach at an early stage of the project (Feasibility and Programming stage). The aim was to concentrate on the LEED categories that contribute more to the project in terms of point allocations without draining the project's budget at a very early stage of the project.

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2.0.0. Introduction

Since LEED (BD+C) rating system consists of seven categories according to the scorecard of New Construction and Major Renovation, this paper proposes the utilization of new ideas and materials that could be used for commercial buildings (e.g. educational building). These new ideas and materials help to accomplish synergy between credit category, system, and components that can be realized through the integrative process to achieve high levels of building performance, human well-being, and environmental benefits. Each LEED credit is assigned points based on its contribution toward addressing one or more of the LEED impact categories. The credit categories are composed of required and optional green building strategies. Required strategies are referred to as "pre-requisites." Optional strategies are referred to as "credits." To receive certification, projects must achieve all prerequisites and a minimum of 40 out of the available 110 points. Higher levels of certification are achieved by earning more points: LEED Certified is 40-49 points, LEED Silver is 50-59 points, LEED Gold 60-79 points, and LEED Platinum is 80 or more points. Proactive project teams typically target 3-4 more points than the minimum number of points necessary to achieve the targeted certification level. This is an effective risk management strategy since it is possible that a few credits may no longer be feasibly pursued during the design and construction phases of a project or that credits will be denied during the Green Business Certification Inc (GBCI) review.

Typically, educational buildings are built or renovated using conventional materials (e.g. concrete and steel), which are not useful in terms of minimizing the embodied energy and other impacts associated with the extraction, processing, transport, maintenance, and disposal of building materials (Alshareef 2018). Therefore, this paper shifts the focus toward more eco-friendly materials that are not typically utilized in commercial buildings. Not only these materials are feasible, efficient, and have a less negative impact on the environment, but also they achieve all prerequisites and credit points. As a result, stakeholders and decision-makers' participation at a very early stage of the project are highly recommended.

3.0.0. Methodology

The purpose of this case study is to explore different approaches to improve the efficiency of potentially newly renovated buildings (i.e. Technology Building at CSU-P). The paper collaborators began with a general observation of the Technology Building's needs with the LEED point system in mind. This approach is used because it produces generalized concepts and decisions based on a small number of observations. This is happened by iteratively meeting daily, weekly, and monthly to refine the objectives and goals and to find sustainable solutions. Also, several personal interviews were conducted with stakeholders and owner representatives to integrate their ideas and visions into this research and refine the overall processes. Furthermore, a high level of an integrative process was conducted through three phases of evaluations such as Discovery, Implementation, and Occupancy phases. For this research, data was collected mostly by interviewing construction faculty members, owner representatives, designers, general contractors, and the paper contributor personal observations. Afterward, all the collaborative approaches are examined against the LEED category sections concerning the prerequisites and credit conditions.

4.0.0. Case Study -Technology Building at CSU-Pueblo

4.1.0. Materials and Resources

4.1.1. Trash and Recycling Bins

This project will need an adequate number of dumpsters and recycling units to hold the amount of trash and any other type of material that is being removed while this building is under construction. For this project, the dumpster that should be used for the job is a 40-yard construction dumpster. A 40-yard dumpster typically includes a 5-6 tons or 10,000-12,000 pound weight limit, though weight limits vary by location and type of disposed of material. For the size of the building, there should be 4 dumpsters that are required to hold all the material that is to be removed. The size and number of dumpsters are prerequisites under the Materials and Resources category and no points are collected. A suitable location to store and sort all the materials that are being installed or being removed to reuse later on is a significant step in the construction process, which contributes to the prerequisites of the Construction and Demolition Waste Management Planning category. The best location to stage everything is going to be in the parking areas behind the Technology Building, parking lot S-1(Shown in Figure 1). This is the ideal location because it is large enough to store all of the building materials that are needed and it is convenient for trucks or equipment to enter and exit the job site. The authors recommend that the best location have everything staged for this project to be in the S-1 parking lot behind the Technology building. This gives the best location to have materials delivered and to have the dumpster placed in a good location that will make it easy to dispose of the waste that is being taken out of the building. And by making this location the designated area for staging, the Storage and Collection of Recyclables prerequisits can be achieved.

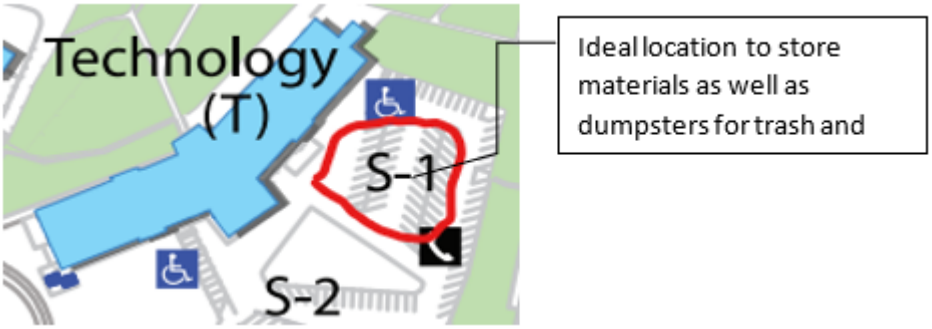

Figure 1: South S-1 Parking Lot, CSU-Pueblo Map

4.1.2. Exteriors

4.1.2.1. Exterior Insulation Finishing System (EIFS)

EIFS as an exterior provides insulation of an R-value of up to R20. It improves the energy efficiency of the building envelope and is environmentally friendly. EIFS helps to achieve partially Optimize Energy Performance credit (16 points). Unlike wood, siding, stucco and other siding materials, EIFS rarely need painting and are highly durable year-round, and they are even capable of withstanding powerful hurricanes. To move 25,000 square feet of material, EIFS requires 16 times fewer tractor trucks than bricks and 6 times less than stucco (Wasmi 2016). EIFS also support sustainable design practices such as achieving LEED Building Certifications. This material does great with managing air and moisture infiltration as well as condensation. EIFS has been proven to produce the smallest carbon footprint of all other claddings according to the National Institute of Standards and Technology (Shown in 2).

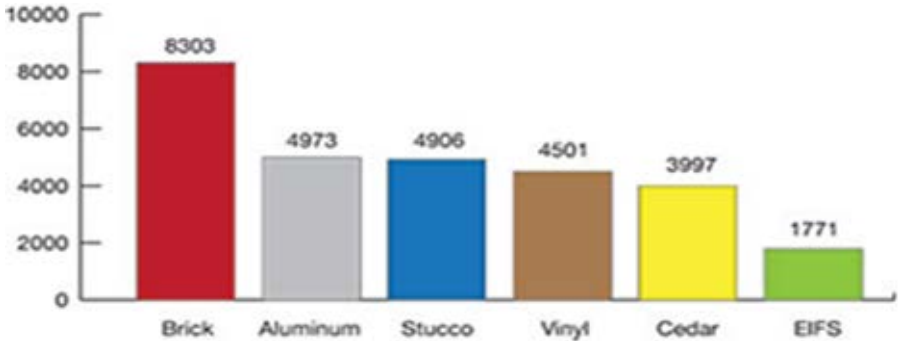

Figure 2: EIFS has a significantly smaller carbon footprint when compared to other materials.

All EIFS panels include a fluid-applied water-resistive barrier coating that is applied to the exterior face of the structure, and exterior insulation is adhesively attached using a notched trowel to provide vertical paths for water drainage. Next, a base coat, either acrylic or polymer-based cement material is applied to the top of the insulation then reinforced with glass fiber reinforcement mesh. The reinforcement mesh is embedded in the base coat material. The finish is a textured coat that's decorative and protective shown in Figure 3.

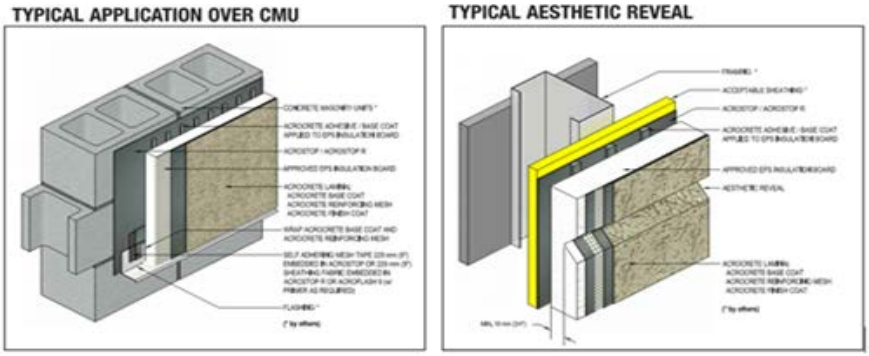

Figure 3: Two most common EIFS application on exteriors.

The main drawbacks with EIFS (Lstiburek 2007) are they need to be recoated every 10 years to maintain the system, and if not properly installed it can create problems that result in leakage. However, these installation problems can easily be avoided. A proper EIFS installation will shed water and be sealed at the windows and other wall penetrations so that leakage doesn't occur. Given the facts and information presented on EIFS, the authors recommend that the Technology Building chooses to use this highly efficient exterior system to achieve LEED certification for the Technology Building. With this suggestion, there is a rough estimate of the EIFS material cost (Canova 2013) compared to other commonly used materials (Shown in Table 1).

Exterior Options	Total Building Square Footage (ft^2)	Material Cost Per Footage ($)	Total Estimated Cost of Material ($)
EIFS	24,900	$16	$398,400
Stucco	24,900	$20	$498,000
Brick	24,900	$22	$547,800

Table 1: Total estimated cost of material using different exterior applications

By running takeoffs using Blue Beam (See Figure 4) the authors' were able to calculate the total area of the exterior which was then multiplied by the cost of material per square foot, which then gave the proposed total of $398,000 to use EIFS on the entire Technology Building. This price includes material transportation and labor costs.

Figure 4: Takeoffs of the exterior on Technology Building using BlueBeam

4.1.3. Windows

Smart Glass Technology is a glass or glazed window whose light transmission properties are altered when voltage, light, or heat is applied. When a small electrical current is applied to the ceramic layers coated on the glass, it causes lithium ions to change layers which causes the class to tint. Reversing this polarity causes the glass to clear. Simply turn a dial to apply a small amount of electricity to the glass, and it will absorb infrared light. Turn another dial, and the glass will go dark. (Shown in Figure 5 and Figure 6). The effects are substantial when using electrochromic (Lee 2007) windows. Being that the Technology Building is sitting on top of a hill overlooking Pueblo, it is the authors' recommendation to use such technology because of the long hours of sunlight the college receives throughout the year, especially during the long hot summers. While significant energy savings is a big reason to consider smart glass for the Technology building, it isn't the only benefit. Smart glass gives building occupants a connection to the natural outdoor environment by providing quality views without having to sacrifice any scenery. The openness the smart glass creates in an office environment promotes happiness, creativity, and communication, which are important aspects of good design and sustainable building. Other advantages of electrochromic windows are that it brings the heat load of the building down (Somani 2002). According to scientists at the US Department of Energy's National Renewable Energy Laboratory (NREL), windows like this could save up to 8 percent of a building's total energy consumption. These windows use only tiny amounts of electricity to

switch from dark to light which translates to huge net savings overall. With that said, HVAC systems can also be smaller, reducing overall capital expenses. Improved thermal comfort and a reduction of glare for the building occupants can be achieved.

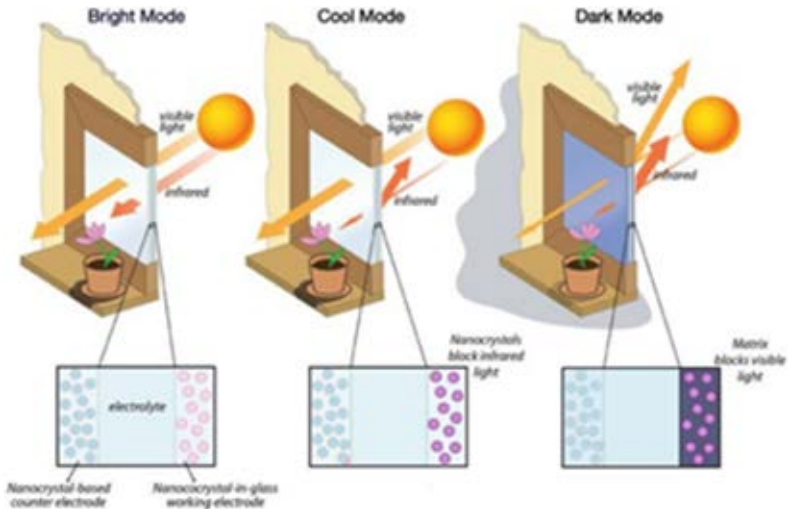

Figure 5: Smart Glass Technology effects on windows when the light transmission is altered

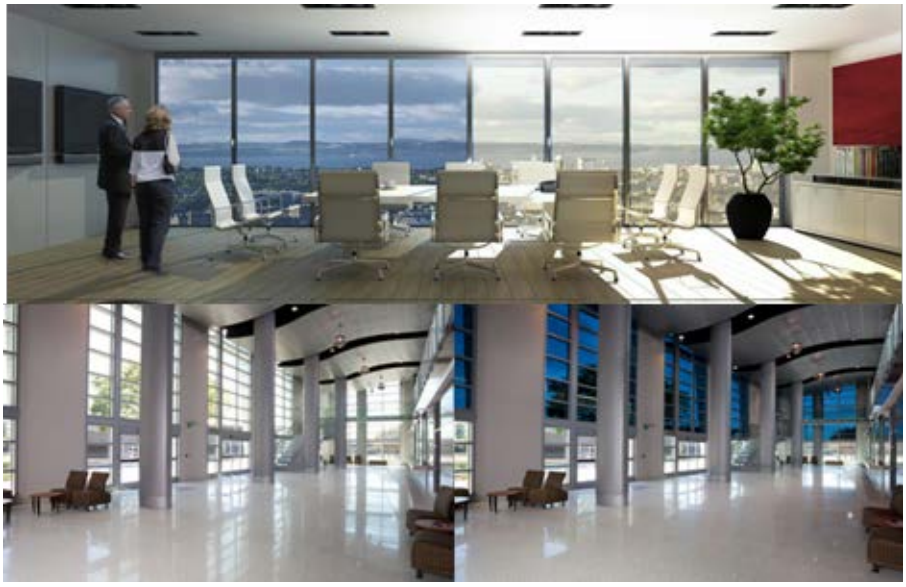

Figure 6: Before and after examples of Electrochromic Smart Glass in use

Smart glass was designed to maximize the use of natural daylight in buildings to improve the well-being of the people within. The use of smart glass on such a commercial project can help CSU-Pueblo achieve up to 37 LEED Certification Credits (Chart is shown in Figure 7). Part of those credits being one for innovative technology. By incorporating this design strategy that enhances daylight penetration with the use of smart windows, designers can additionally increase the number of occupants with exterior views. Adding smart windows and sidelights to openings built with this technology can help assist this project move forward in achieving this LEED Certification.

INTUS WINDOWS

LEED v4 SCORECHART

LEED Category	LEED Credit	Points
Energy & Atmosphere	Optimize Energy Performance	18
Materials & Resources	Building Product Disclosure & Optimization - Product Declaration	2
	Building Product Disclosure & Optimization - Material Ingredients	2
Indoor Environmental Quality	Enhanced Indoor Air Quality Strategies	3
	Indoor Air Quality Assessment	2
	Daylight	3
	Quality Views	1
	Acoustic Performance	1
Innovation	Innovation	5
Grand Total		Up to 37

* max LEED points available

Figure 7: LEED v4 Score Chart showing a total of 37 points applicable to the use of SmartGlass Technology.

4.2.0. Water Efficiency

4.2.1. Indoor Water Usage

The Technology building has four restrooms, two men and two women. In each woman's bathroom, there are four sinks and five toilets. In each men's bathroom, there are 4 sinks, 3 toilets and 3 urinals. There is a total of 16 sinks, 16 toilets, and 6 urinals. All plumbing fixtures should be WaterSense labeled or similar because WaterSense label is an EPA standard for water efficiency. The U.S. Green Building Council (USGBC), states the most often used fixtures are high-efficiency toilets and non-water urinals. If there are lower reduction needs of 20% to 30%, dual flush and high-efficiency urinals were most often selected. The fixtures to evaluate were selected out of the 2019 Wholesalers List Price Book. The toilet, urinal and faucet models selected are WETS-2002.1201 with Sloan ECOS 8111, WEUS-1000.1201 with SOLIS 8186, and EBF 615 respectively. The EBF 615 is a battery-operated model and is to be assessed with an electric hardwired model, ETF-80.

4.2.2. Outdoor Water Usage

Outdoor water reduction was considered with the methods of xeriscaping and little or no irrigation. Xeriscaping is an approach that includes efficient irrigation and native plant species to reduce outdoor water usage. Native plant species reduce outdoor water use because the species is already adapted to the climate, therefore there is no need to water the plants. Irrigation was approached by comparing drip irrigation with the conventional sprinkling system. Drip irrigation was considered because the system targets the roots of the vegetation directly and reduces the amount of runoff because over-spraying is avoided and it uses far less water than conventional sprinkler systems. A diagram of a drip irrigation system is shown in Figure 8 provided by WP Law (2016).

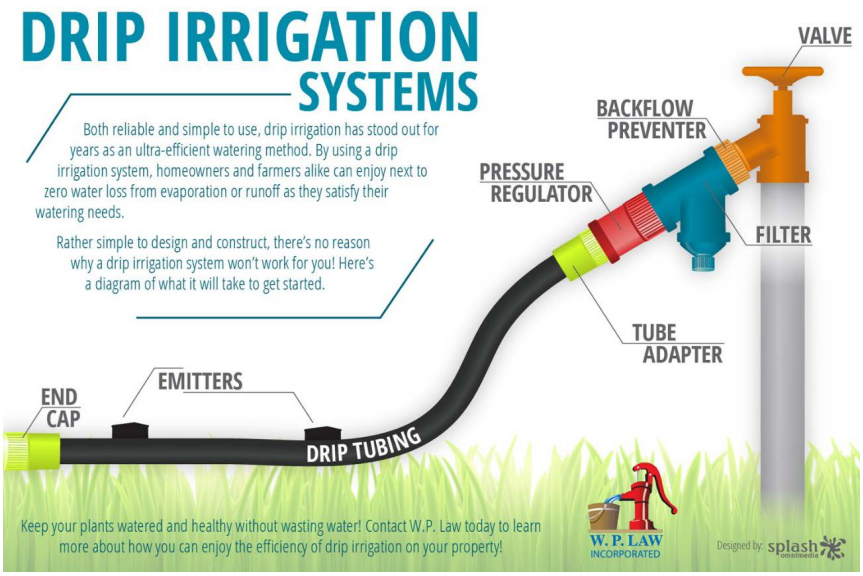

Figure 8: Drip Irrigation Systems, Diagram by WP Law, 2016

4.2.3. Water Usage

To reduce the amount of potable water, wastewater can be reused. The Technology Building does not have a system in place to reuse water. Treated wastewater can be used for toilet and urinal flushing. This will reduce the amount of potable water being used for purposes other than drinking. A type of wastewater treatment that was considered is the Living Machine. A living machine, according to Parsons Engineering Science (2001), will treat all wastewater so it can be used to flush toilets and urinals. If toilets and urinals are using reclaimed water to be flushed, that reduces the amount of water being used for purposes other than drinking. A diagram on Port of Portland's Living Machine is shown below in Figure 9, showing the indoor and outdoor cells.

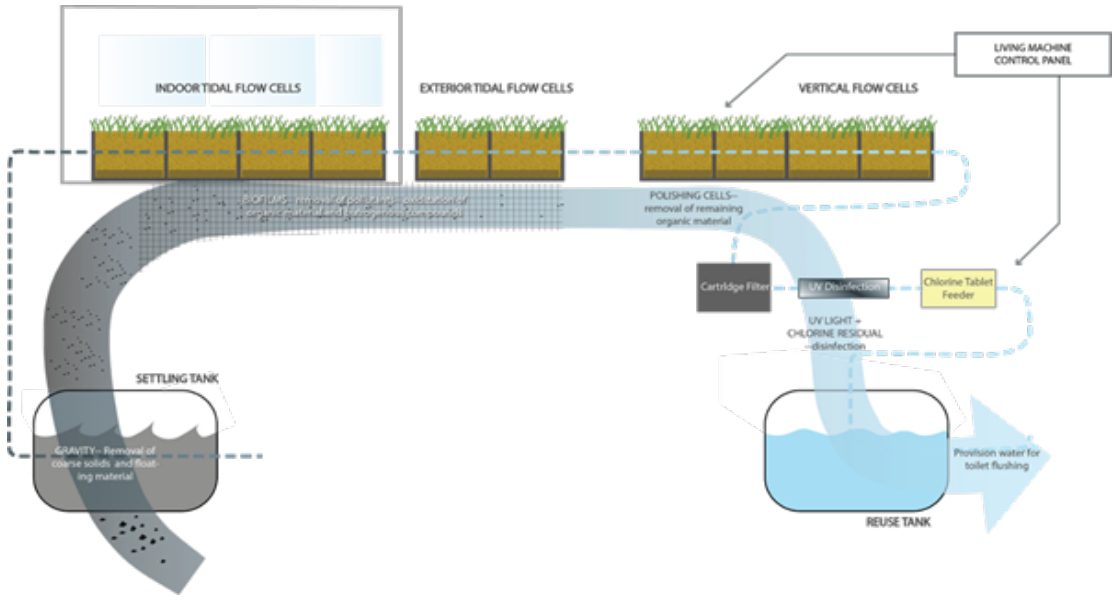

Figure 9: Port of Portland's Living Machine Diagram by Yidan, Tamara, and Pure, 2016

The U.S. EPA compared a living machine to a conventional wastewater system. The Present Worth Comparison Of "Living Machines" and Conventional Systems table shows the cost of living machines with and without a greenhouse to a conventional wastewater system depending on the gallons used per day. Table 2 shows the Living Machine without a greenhouse costs less than the Living Machine with a greenhouse and a Conventional system. The unit gpd is gallons per day. The table also shows the price of different gpd.

Process	40,000 gpd	80,000 gpd	1 million gpd
"Living Machine" with greenhouse	$1,077,777[1]	$1,710,280[1]	$10,457,542[2]
"Living Machine" without greenhouse	$985,391	$1,570,246	$9,232,257
Conventional System	$1,207,036[1]	$1,903,751[1]	$8,579,978[2]

(1) Cost difference is less than 20 percent
(2) Cost difference is greater than 20 percent

Source: U.S. EPA, 2001.

Table 2: Present Worth Comparison of "Living Machine" and Conventional Systems by U.S. EPA, 2001

The EPA states the Living Machine can treat wastewaters many needs to BOD5, TSS, and more. Also, the Living Machine is aesthetically pleasing. The Port of Portland Headquarters has a Living Machine which is indoors and outdoors. Figure 10 shows a living machine can be aesthetically pleasing indoor and outdoor. The EPA also states the disadvantages to having the Living Machine are it only removes about 50 percent of influent phosphorus and it requires a greenhouse for reliable operation in cold weather of more temperate climates.

Figure 10: Exterior (Left) and Interior (Right) Flow Cells from Port of Portland Case Study, 2013

4.4.0. Indoor Environmental Quality

Intelligent controllers provide solutions for building automation as well as creating a healthy environment. BAS's also fulfill indoor environmental quality credits because the system design usually includes economizers to implement outdoor air supply. Because LEED is a certification above the bare minimum (in this case being ASHRAE standards), things such as timers and CO2 sensors can be tuned to keep air filtered, thereby eliminating the possibility of sick building syndrome. Lighting is another area of the building that contributes greatly to occupancy health, it also contributes greatly to power consumption. In fact, LEED cited lighting power as the largest electricity consumer in commercial buildings (LEED GA v4.1). Remedies to excessive power consumption in buildings result in addressable light controls, changes to color temperature, and regulated daylight.

5.0.0. Findings

5.1. Battery vs. Electric

Touchless faucets are useful for conserving water. Because the water shuts off automatically, this can dramatically cut down on water waste and reduce the risk of sink overflow caused by the faucet being left on. Some benefits to the electric hardwired faucet are that sensor taps would pour 10L to 15L per minute, while the other type would not use more than 6L. This practice can benefit the environment more if the power comes from a renewable source and if further restraints are made

in the system to control the outflow of water. A disadvantage to the electric operation is that if the building loses power, it can cause the faucets to stop working. Battery-powered faucets are beneficial because both are the same as the electric in every way in saving water consumption and efficiency. Another disadvantage to the battery-powered is that batteries are replaceable often. The battery-powered is good because if the power happens to go out the faucets will continue to work. The most common one used for buildings like this is the electric type. The electric faucet is the most commonly used because both are easy to install and there is hardly any maintenance required. Even though each option is useful the electric faucet is the best option for the job. Therefore the EBF 615 battery powered is not considered, instead, the ETF-80 hardwired model will be considered.

5.2. Water Efficiency

5.2.1. Indoor Water

The Water Resource category will affect the overall use of potable water in the Technology Building. The authors' final decision on water efficiency for indoor use is to use efficient fixtures for the toilets, urinals, and faucets. The total number of fixtures are shown in *Table 3*. The total number of fixtures were found by counting each fixture and recorded in a spreadsheet.

	Men	Women	Total
Number of Bathrooms:	2	2	4
# of Sinks:	4	4	16
# of Toilets:	3	5	16
# of Urinals:	3	0	6

Table 3: Number of Fixtures, table made in Excel

The cost of the fixtures based on the list price is shown in Table 4. The total cost for all fixtures is found by multiplying the total amount of each fixture by the List Price found in the Wholesalers List Price Book.

Efficiency	Model	List Price:	Cost for all fixtures
1.6/1.1 gpf	WETS-2002.1201 w/ Sloan ECOS 8111	$817.15	$13,074.40
0.125 gpf	WEUS-1000.1201 w/SOLIS® 8186	$958.95	$5,753.70
0.35 GPM	ETF-80	$ 752.65	$12,042.40
		Total	$30,870.50

Table 4: List Cost of Fixtures made in Excel Spreadsheet

5.2.2. Outdoor Water

The decision on outdoor water use is to focus on more efficient irrigation and landscaping by using native plants, and drip-irrigation to avoid excessive use from runoff. The EPA has a study on the types of irrigation, which states that a conventional sprinkler system has an initial cost, low and high, of $1,540.00 and $2,240.00 respectively. The total annual costs over its low lifespan of 20 years and high lifespan of 12 years are $1,371.73 and $1,408.93 respectively. A sub-surface drip irrigation system has an initial cost, low and high, of $1,707.00 and $2,029.89 respectively. The total annual costs over its low lifespan of 25 years and high lifespan of 20 years are $445.95 and $504.77 respectively.

The drip irrigation system may have a greater initial cost however over its lifetime there is a lowercost annual cost which makes the drip irrigation system's total cost cheaper than the conventional sprinkler system. The data and results are shown in Table 5. The Initial Cost, Annual Cost over Lifetime, and Life Time are from the EPA case study.

	Conventional Sprinkler System		Drip Irrigation System	
	Low	High	Low	High
Initial Cost	$1,540.00	$2,240.00	$1,707.00	$2,029.89
Annual Cost over lifetime	$1,371.73	$1,408.93	$445.95	$504.77
Life Time (year)	20	12	25	20
Total Cost	$28,974.60	$19,147.16	$12,855.75	$12,125.29

Table 5: Irrigation Comparison made in Excel Spreadsheet

5.2.3. Water Usage

The final decision for the Water Resource category is to use The Living Machine to reduce the amount of potable water consumption by using reclaimed wastewater for flushing toilets and urinals. Based on the Port of Portland Headquarters' case study on the Living Machine, the system capacity is 5,000 gpd of a 200,000 square foot headquarters building. The area of the Technology Building which is about 29,600 square foot was found by using the website Mapdevelopers' area finder (See Figure 16). By comparing the Port of Portland's system capacity and size of the building to the Technology Building, a living machine of similar criteria will support the size of the Technology building with ease. If the price of a 40,000 gpd system is $1,077,777, the worth of the Living Machine for the technology building could be less than the worth of a Living Machine with a greenhouse.

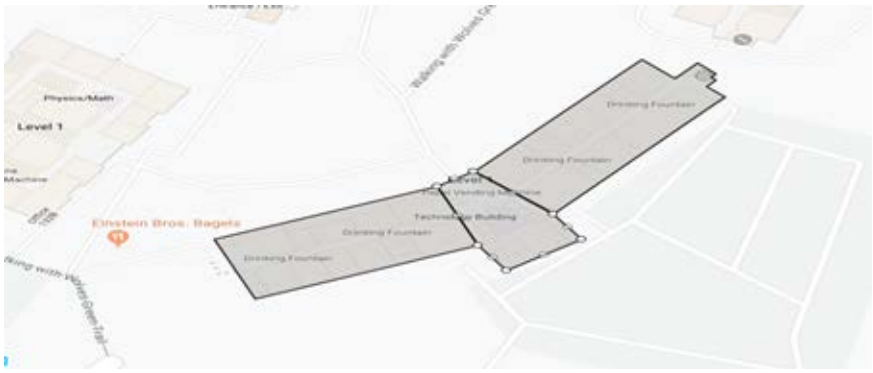

Figure 16: Technology outline from mapdevelopers.com

A Living Machine needs a greenhouse when the climate is too cold, which is why the Technology Building should install a Living Machine similar to the Port of Portland Headquarters interior and exterior Living Machine. Having the fragile part of the Living Machine inside of the building removes the need for a greenhouse.

6.0.0. Conclusion

This research considered synergy at a very early stage of projects (i.e. Feasibility and This research considered synergy at a very early stage of projects (i.e. Feasibility and Programming stage) to encourage stakeholders and decision-makers involvements to have a more collaborative environment with fewer budget constraints. Typically, changes at this stage are expected and have fewer impacts on the budget; more so, participants are more resilient to new ideas. Therefore, this research studied new ideas and materials that are rarely utilized in commercial buildings (i.e. educational buildings) to develop more eco-friendly and sustainable buildings. The effort will lead to transforming the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life.

The research is used to gain a better insight into the possibilities for improvement of the Technology Building at CSU-Pueblo as an educational case study building. It was approached to produce generalized concepts and conclusions by gathering documents and reports for the most useful materials, items, and ideas to compare them to their pay-back periods. The LEED categories were the vehicle to drive the research study to evaluate the tradeoff of materials against credit points while considering the project's budget at an early stage. Furthermore, multiple iterative processes were incorporated into a high level of integrative process to refine the outcome and collaborate with subject matter experts. This approach helped to provide a more efficient methodology and eliminated unnecessary overlaps and inefficiency.

7.0.0. References

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LEED Process Assessments and Efficiency Improvements for Renovated Buildings

Husam A. Alshareef, Anthony Clark, Alexander Milyard, Hamern Robert, Brian Hund

ABSTRACT

The Library and Academic Resources Center (LARC) at Colorado State University – Pueblo (CSU-P) was renovated in 2011. During this time, the building was awarded Leadership in Energy and Environmental Design (LEED) Platinum. This is the highest award for a sustainable building granted by the United States Green Building Council (USGBC). This building was evaluated under the LEED version 2.2 Building and New Construction standard. The LARC building is studied and evaluated in this research as a case study. All three LEED phases were evaluated during this case study: discovery, implementation, and occupancy. The purpose of this case study is to assess the LEED process used during the first evaluation and propose any necessary improvements to increase the efficiency of the building. The secondary purpose was to determine if the building could achieve a lower LEED award without compromising efficiency. This study was conducted by interviewing campus LEED professionals, observing LEED literature in the LARC building, and utilizing publicly available information. Our analysis results in a proposal that increases the LEED score to 57 out of 69 points for an award of LEED Platinum. The infrastructure proposed in this paper could lead to an increased LEED score for all buildings on campus.

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1.0 Introduction

This report provides a comprehensive study and analysis of the Colorado State University - Pueblo LARC building. The study focuses on the way in which the building was certified as a LEED Platinum project. Aspects in the LEED process range from the physical materials used during the project, to environmental quality during construction and during the occupancy of the building after completion (Wasmi 2016). LEED certification also looks at the interior and exterior of the structure, such as indoor environmental quality, energy and atmosphere, and water efficiency; all of these topics where investigated throughout the duration of the case study. After the initial findings, it was found that the LARC building - even with a Platinum rating - could attain a handful of other LEED credits by using different methods and/or materials to increase the sustainability and efficiency of the building.

2.0 Methodology

This case study followed a three stage or phase methodology that tried to emulate the actual process in which a LEED project is developed and implemented. The first phase of our investigative methodology is the discovery phase. At this time in the study, the investigative team does not yet know what different means the builders used to achieve certification in LEED. In the discovery phase, the investigative team's goal was to begin to understand the project as a whole and then slowly break the scope of the project up into smaller components. These smaller components then became focal points for the rest of the case study. After understanding the focal points of the project, the discovery began to analyze the way in which the project achieved their LEED Platinum certification. Due to the fact that this case study is based around an existing building, the different systems, means, and methods used to reach said certification were relatively easy to find and understand. The last part of the discovery phase was to locate certain LEED credits that were not awards to the LARC building and possible reasons why they were not achieved. It was also in this part of the discovery phase in which the investigators could begin to plan for the next part of the phasing, the implementation phase. During the implementation phase of the study, the investigators were to use the information found in the discovery phase and find areas that the LARC building could improve on and possibly earn more credits toward their certification. Such areas include sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. Each LEED accredited area was investigated in depth during the implementation phase in order to produce a better solution to the problems that the LARC could face based on their existing certification. This phase of the case study helped immensely due to the fact that it narrowed the focus of the investigation down to a few key concepts that could be improved on. It also allowed the investigators the chance to further research the different methods used to mitigate certain problems that other LEED projects had faced. The last phase of the methodology was the occupancy phase. This phase took the different methods recommended in the implementation phase and discussed whether or not these methods would be beneficial to the LARC building. This phase looked at the cost of each introduced method, what each method requires, both positive and negative aspects of each, and the rate of return on investment if there is any at all. This final phase provided the best results for recommendations to be made at the end of the case study.

3.0 Case Study - LARC Building at CSU-Pueblo

The LARC project achieved LEED Platinum certification with version 2.2 The renovation was considered a major renovation because the building's acoustics, exterior aesthetics, day lighting and overall Mechanical, Electrical, and Plumbing systems (MEP) were improved. The H.W. Houston was the general contractor for the renovation of the Library and Academic Resource Center (LARC) project. The architect firm was Bennett Wagner and Grody. The total square footage of the building was 125,800.

There are many alternatives to the LEED building design that do exist according to the Harvard Energy and Facilities committee. Throughout this research, it was discovered that it is no secret that creating an energy efficient building is quite a desirable goal. Building green saves on energy and waste costs and limits the negative impact on the environment (Alshareef 2018). There are a lot of alternatives that are available and would need to be considered before committing to an endeavor such as this.

The initial investment in becoming LEED certified can be quite significant. It was discovered that this needs to be kept in consideration. Becoming LEED certified is not only a complicated process, it's expensive. There is a flat registration fee ranging from $1,200 for the basic certification to $3,250 for silver, gold, and platinum certification, which is just for the precertification review. There are also additional costs, depending on the size of the building, and these costs can reach up to $27,500 for buildings with more than 500,000 square feet. Moreover, the things that must be changed in an existing structure to achieve the certification can cost hundreds of thousands of dollars. It was discovered that there is not only a large monetary investment involved, but that there is also a significant time investment to achieve LEED certification. Further, and upon becoming LEED certified, there is an investment in maintenance as well.

3.1 Water Efficiency

There are two alternatives that CSU-P should consider in order to increase water efficiency on campus: non-potable water usage or xeriscaping. These two ideas are not mutually exclusive; however, the cost to integrate a non-potable water irrigation system would be very high. Therefore, xeriscaping should be reduced if a non-potable system is installed.

Federal Energy Management program defines Xeriscaping as a landscape design practice that reduces or eliminates the need for irrigation. This is done by drastically reducing the surface area of the vegetative landscape. Often rocks or mulch are used, along with drought-tolerant plants. The main advantages to xeriscaping are that it greatly reduces water consumption, and it reduces maintenance and usage costs. However, grass is iconic on a college campus because it provides an environment in which students can come together. Therefore, a campus with a rock and mulch landscape may not be appealing to students.

Non-potable water is water that is not safe for human consumption, but it can still be used for other purposes. Non-potable water is highly effective for irrigation because it is cheaper than potable water, and vegetation can survive on it. There are three main ways of receiving non-potable water on campus: reclaimed water from a waste treatment facility, pumping the water directly from a water source, or collecting the water from a runoff on campus.

The James R. Dilorio Water Reclamation Facility treats waste water in the city of Pueblo. After the water is treated, it is pumped directly into the Arkansas River. This water could be used more efficiently if it was used for irrigation. Unfortunately, the waste treatment facility is nearly 3.5 miles from the CSU-P campus, as seen in Figure 1, and it would be very expensive to construct the pipe necessary to transport the water. Additionally, many businesses and residents would be impacted from the construction process.

Fountain Creek is approximately one mile from campus, and 1.25 miles from the LARC building, shown in Figure 2. Non-potable water could be pumped directly from Fountain creek; however, water rights would need to be obtained in order to do this. Although, it would be cheaper to construct the infrastructure necessary to pump water from Fountain Creek than from the water reclamation facility. A third option would be to construct a basin on the CSU-P campus that collects runoff. However, since CSU-P is on a hill, the basin would only get runoff from the campus itself. It is unlikely that the runoff from campus would be able to supply the entire campus's irrigation needs.

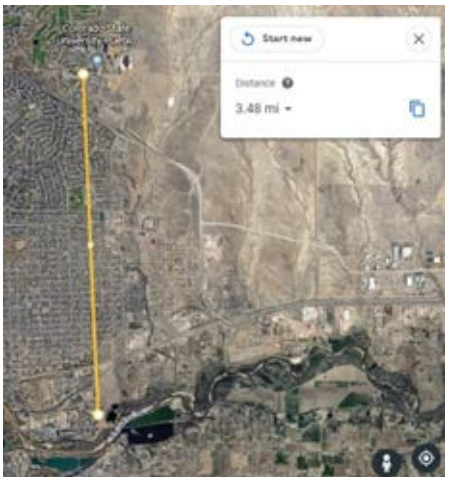

Figure 1 – Distance from Water Reclamation facility to CSU-P

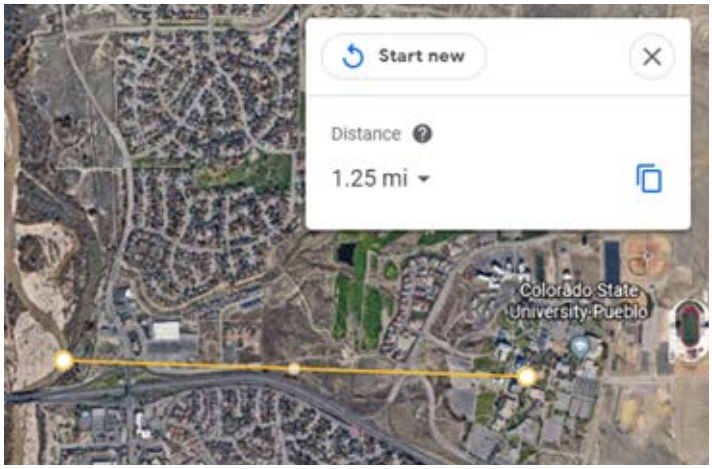

Figure 2 – Distance from Fountain Creek to CSU-P

3.2 Energy & Atmosphere

The LARC received 1 credit for optimizing energy performance. This credit was achieved through the use of high-performance lighting, T5HO lamps, LED accent lighting, a combination of arches and light-colored ceilings, high performance glazing, daylight harvesting controls, active beams, passive beams, modern HVAC technologies, and highly efficient condensing boilers.

High-performance lighting provided warm and comfortable lighting very efficiently. The primary overhead lighting utilized T5HO lamps. The combination of arches and light-colored ceilings, with the type of lighting fixtures that shines the light up as well as down, provided evenly dispersed, diffused lighting that furnish less glare for computer screens. LED accent lighting provided new shapes of lighting. High performance glazing allowed for larger areas of glass, while preventing unwanted heat from entering or desired heat from escaping from the building. Daylight harvesting controls used photocells to monitor the amount of ambient light and dim the lighting to appropriate levels when sufficient daylight exists. The active beams used high velocity air to induce warm room air to move through chilled coils. Passive beams rely on the natural flow of warm air rising and cool air falling to silently cool the space. The modern HVAC technologies achieved 43.5% energy savings. This was achieved through the use of chilled beams, radiant heated slabs, and the displacement of air systems. The highly efficient condensing boilers produced hot water more efficiently than traditional boilers.

3.3 Indoor Environmental Quality

The LARC building achieved a score of 10 out of 15 possible credits (reference Table 1) in Indoor Environmental Quality. The credits that the project did not receive were air delivery monitoring, controllability of systems for both heating and lighting, and daylight and views. An initial alternative was to allow the controllability of heating and lighting throughout the layout of the building. This was proven to have more of a negative impact on the efficiency of the building due to the function of the building. The LARC building operates as a classroom and learning environment, a study area, and a lounge or social area. Giving controllability of climate and lighting systems would provide no financial benefit, and giving control to the occupants in the building is not cost effective due to the fact that the occupants do not reside in the building on a regular basis, meaning climate and lighting systems would be left in operation without the need for either; consequently affecting the efficiency of the building. Air delivery monitoring is a credit that is easily achievable on almost any project in today's industry, it is a matter of whether it is going to be necessary or not depending on the functions and location of the building. Air delivery monitoring can provide feedback to the climate system inside of a building. This in turn can improve the efficiency of the HVAC system in the building so that the system is not in use when it does not need to be. With daylight and views, the LARC building is an area where this use of natural lighting could be extremely useful, both for economic reasons and social reasons. This is one aspect of the project where the investigation is deciding to make improvements and attempt to achieve the two credits associated with daylight and views. Some positive points to make about daylight and views are as follows:

- Lower energy costs (HVAC)
- When controlled, natural lighting generates hardly any heat at all
- Overall energy savings can range from 15 to 40 percent
- Can have a positive impact on productivity and satisfaction of occupants

Negative points of daylight and views:

- Significant initial investment

- If not planned properly, using natural lighting can result in undesirable heat gains in the building
- Direct sunlight penetration in classrooms and offices often produce unpleasant glares

If planned and designed properly, a new daylight and views system could be beneficial to the LARC building, as well as providing two more credits to the overall LEED score applied to the building.

Table 1 Indoor Environmental Quality LEED Credits (scorecard of LARC building)

Indoor Environmental Quality				
		Max	Obtained	Proposed
Prereq 1	**Minimum IAQ Performance**	Required	Required	Required
Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required	Required	Required
Credit 1	**Outdoor Air Delivery Monitoring**	1	0	1
Credit 2	**Increased Ventilation**	1	1	1
Credit 3.1	**Construction IAQ Management Plan**, During Construction	1	1	1
Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1	1	1
Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1	1	1
Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1	1	1
Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1	1	1
Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1	1	1
Credit 5	**Indoor Chemical & Pollutant Source Control**	1	1	1
Credit 6.1	**Controllability of Systems**, Lighting	1	0	0
Credit 6.2	**Controllability of Systems**, Thermal Comfort	1	0	0
Credit 7.1	**Thermal Comfort**, Design	1	1	1
Credit 7.2	**Thermal Comfort**, Verification	1	1	1
Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1	0	1
Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1	0	1
		15	10	13

4.0 Findings

It was further discovered by the investigators that in order for this building to strive closer to becoming a zero-point energy building, there would be many additional costs involved to achieve this. Specifically, the investigators had looked closely at incorporating a green, living roof to the building. It was therefore discovered that this could and would very likely cut down on the costs to supply food for this building's occupants. However, there is a significant financial investment the investigators found to implement this. The investigators did find that the overall level of self-sustainability could be improved with additional financial investment toward this goal.

4.1 Sustainable Sites

This first category of LEED Certification prerequisites has to do with the specific location and piece of land that the project is to be built on. It was discovered that these credits specifically deal with protecting the natural habitat in the area, keeping the open spaces open, dealing with the rainwater the best way possible, and keeping the heat island effect and light pollution down to a minimum.

Site Assessment:

This credit is worth 1 point. In order to earn this credit, project teams must perform and document a site assessment of the project location, including the following topics: topography, hydrology, climate, vegetation, soils, human use, and human health effects. The assessment should discuss how the topics above influence the design, as well as any of the topics that were not addressed in the design.

Protect or Restore Habitat:

This credit is worth 1-2 points. The project must preserve and protect at least 40% of the greenfield (undeveloped) area on the project site, if such an area exists. In addition, the project must restore 30% of the site to natural habitat using native and adapted plant species (worth 2 credits) or provide financial support to an organization accredited by the Land Trust Alliance (worth 1

credit). The habitat restoration should include both soil and vegetation, and vegetated roofs can be counted in certain circumstances.

Open Space:

This credit is worth 1 point. The project must provide open space equal to 30% of the total site area. At least 25% of that open space must be vegetated or have overhead vegetation. Turf grass areas do not count as vegetated areas. Open spaces must be designed for one or more of the following uses: social gathering, gardening, physical activity, or natural habitat that includes elements for human interaction. Vegetated roofs can be counted in certain circumstances.

Rainwater Management:

This credit is worth 1-3 points. This credit asks the project team to design a rainwater management system that handles the water falling on the site in a way that is similar to the native state of the site. Depending on how much water the system is capable of handling, 1-3 points are possible. The capacity of the system is measured by what percentage of local or regional rain events could be handled by the system. If the system can handle 95% of the events, then it can earn 2 points, and 3 points for handling 98%. Or, as an alternate way of calculating the credit, if the system can handle 100% of the increase in runoff that occurs as the result of the development of the site from its natural state, then the project can earn 3 points.

Heat Island Reduction:

This credit is worth 1-2 points. Heat islands occur in areas where hardscape surfaces (such as parking lots and sidewalks) hold heat and reflect it back, raising the temperature of the surrounding environment. This change in temperature can affect weather patterns in the local area. To avoid this, projects receive credit for using roofing materials with a high solar reflectance, reducing the number of hard surfaces, shading project areas with trees and other foliage, placing parking lots under cover, and using open paver systems.

Light Pollution Reduction:

This credit is worth 1 point. Projects must reduce the amount of up-lighting used for exterior lighting, avoid pollution of light into adjoining sites, and control light levels outside the building to meet certain standards. This requires a photometric plan, which shows the level of light in all areas of the site. The design team must take measurements to confirm that the built condition meets the requirements for this credit.

4.2 Water Efficiency

Table 2, below, shows the points available in the water efficiency category. This table is a modified version of the 2013 LEED scorecard for the LARC. Five points can be obtained in this category, and CSU-P obtained three points. The research contributors believe that CSU-P should consider pursuing the "Water Efficient Landscaping" credit. In order to do this, a considerable investment would need to be made to bring non-potable water to the campus or removing irrigation altogether throughout the entire footprint of the LARC building.

Table 2 Water Efficiency LEED Credits (scorecard of LARC building)

Water Efficiency				
		Max	Obtained	Proposed
Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1	1	1
Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1	0	1
Credit 2	**Innovative Wastewater Technologies**	1	0	0
Credit 3.1	**Water Use Reduction**, 20% Reduction	1	1	1
Credit 3.2	**Water Use Reduction**, 30% Reduction	1	1	1
		5	3	4

Xeriscaping has a much cheaper total cost than installing non-potable water, but studies show that a grass environment is more appealing to humans. A xeriscaped environment may be detrimental in the recruiting efforts of the university; therefore, it is the recommendation of the research contributors that CSU-P investigates the feasibility of bringing non-potable water to campus. Bringing non-potable water to campus would have a high upfront cost; however, the pipe network has a lifespan of 50-70 years. Once the infrastructure is in place it could be used for every facility on campus. This would give every structure on campus the water efficient landscaping credit. Additionally, it would considerably reduce irrigation costs and reduce the campuses potable water consumption.

4.3 Energy & Atmosphere

The alternate energy that could be used in the LARC building is a geothermal system. The benefits of a geothermal system can be configured to accommodate the amount of property used. A geothermal system can be configured to a horizontal or vertical, open or closed loop system. Horizontal loop systems have lower installation cost, but they require a plot of land sufficient for 3-5 trenches: 130 to 160 feet long and 12 to 20 feet apart. Water or antifreeze circulated through the pipes collects heat for heating in the winter and dumps heat for air conditioning in warm months. A vertical loop system has a higher installation cost, about $1500.00 per 12,000 BTU's (British Thermal Units). This system is ideal for smaller properties. Vertical loop systems are where several holes are drilled, each between 50-400 feet deep, and several pipes are installed. Water is then circulated through the pipes that collect heat for heating in the winter and dumps heat for air conditioning in warm months. The other benefits of this system are that they have a quiet operation, resulting in less noise pollution. Geothermal systems are more efficient than ordinary heating and air conditioning units because the systems deliver more energy than they use. A geothermal system will offer a more precise distribution of cooled or heated air, year-round, so there would be less hot and cold spots in the building. Geothermal technology is more reliable than most air conditioning units and heat pumps, and they typically require less maintenance than other heating and cooling units.

Heat pump pipes even have warranties of between 25 and 50 years, while the pump can usually last for at least 20 years. This also requires less space for hardware as opposed to conventional systems. This system is more environmentally friendly because geothermal systems don't emit carbon dioxide or other greenhouse gases that are considered contributors to environmental air pollution. This system is highly efficient because geothermal heat pump systems use 25% to 50% less electricity than conventional systems for heating or cooling, and with their flexible design, they can be adjusted to different situations, requiring less space for hardware as opposed to conventional systems.

4.4 Material & Resources

The LARC received 16.4 credits in the material and resources category. These credits varied from building reuse, recycled content, low-emitting material, and for certified wood. The reason the LARC received 1.2 credits for building reuse was because it maintained 95% of the precast structure and cladding system. The exception was where panels were removed to allow for the expanded exterior glazing which added more natural lighting. The reason the LARC received 4.2 credits for recycled content was because 20% of the building content was re-used. These materials varied from carpet, countertops, solar shades, and ceiling tiles. The reason the LARC received 4 credits for low-emitting material was because materials that have low-VOC (volatile organic compounds) content were used. These materials were adhesives, sealant, paints, coatings, and carpet systems. Composite woods and Agri fiber were selected to contain no urea-formaldehyde. The reason the LARC received 7 credits for certified wood was because the wood that was selected were FSC (Forest Stewardship Council) certified.

4.5 Indoor Environmental Quality

This investigations recommendation for improved Indoor Environmental Quality is to enhance the daylight and views in the LARC building. This comes as a recommendation due to its ability to save on energy and improve the social dynamic inside the building. Both of these focal points become more important based on the overall use of the building. The LARC is utilized as a classroom building, study area, and social/gathering area all at the same time. When natural daylight can improve productivity and satisfaction in these types of environments, the reason for this change is justified with the social improvement that it can have. The energy savings is more complicated. In order for the improved daylighting and views to be cost effective, it would be this investigations recommendation to perform a design study before construction and/or improvements commenced. Such studies can be in the form of a Building Information Modeling (BIM) model, and when coupled with a specific location and time of year, the design team can resolve to the best solution possible.

5.0 Conclusion

Using the seven LEED (BD+C) rating system's categories, this report analyzed comprehensively the existing Platinum certification of an educational building (i.e. the LARC building at Colorado State University-Pueblo). This investigation was able to improve the overall score of the LEED accreditation by five points with respect to the budget. The intent of all explanations and recommendations is to ensure the betterment of the operation and sustainability of the LARC building, as well as to improve the building's LEED accreditation. The infrastructure proposed in this paper could lead to an increased LEED score for all buildings on campus (i.e. CSU-P), so this research serves as a vehicle for future investigation in this regard.

6.0 References

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Measured Versus Predicted Dynamic Modulus of Asphalt Concrete Used in Colorado

Tingting Hu, Md R Islam, Sylvester A. Kalevela

ABSTRACT

The dynamic modulus (E*) of Asphalt Concrete (AC) is the primary material property used in asphalt pavement design. However, the testing of dynamic modulus of AC is very expensive considering time, equipment and skills. This is why, instead of conducting the testing, the available regression equations in the literature are very often used to determine the dynamic modulus of AC. This research evaluated the mostly used regression equation (known as the viscosity based Witczak model) for 105 asphalt mixtures used in Colorado. The dynamic modulus of AC is predicted using the viscosity based Witczak model and is compared with the measured dynamic modulus. Results show that the predicted dynamic modulus correlated well with the measured dynamic modulus. Hence, the viscosity based Witczak model can be used reasonably in case of no test data is available.

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Introduction

Asphalt Concrete (AC) is a viscoelastic material. Viscoelasticity of a material is the property that exhibit both viscous and elastic characteristics when subjected to deformation. In purely elastic materials, stress and strain are in phase. In viscous materials, there is a phase difference between stress and strain. A 90° phase lag is observed for the strain in purely viscous material (Figure 1). In viscoelastic materials, the behavior is somewhere in between that of purely elastic and purely viscous materials, exhibiting some phase lag less than that for purely viscous materials. Upon applying (σ), the resulting cyclic strain (ε) can be expressed as:

$$\varepsilon = \varepsilon_o \sin(\omega t + \phi) \tag{1}$$

where ε_o is the strain amplitude, ω is the frequency of strain oscillation, t is time, and ϕ is phase lag between stress and strain. The applied stress (σ) can be expressed as:

$$\sigma = \sigma_o \sin \omega t \tag{2}$$

where σ_o is the stress amplitude.

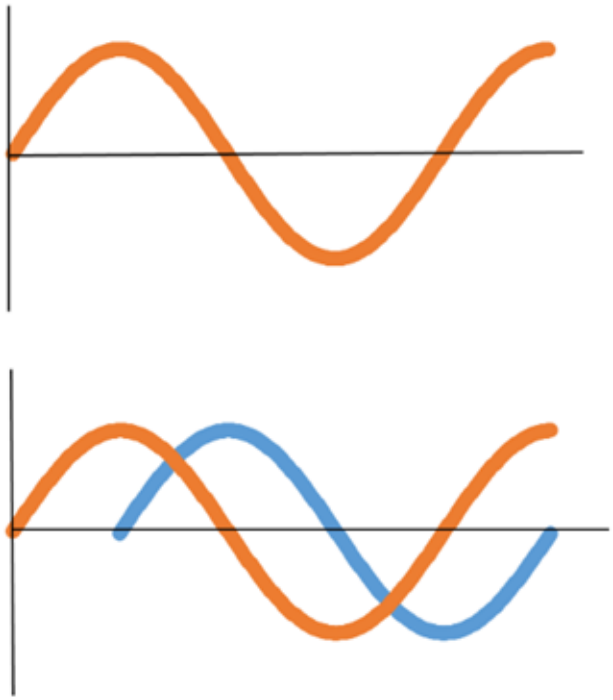

Figure 1 Stress-strain behaviours of elastic and viscoelastic materials.

The storage modulus measures the stored energy representing the elastic portion of the response. The loss modulus represents the viscous response measuring the energy dissipated as heat. The storage modulus (E') and the loss modulus (E'') can be mathematically expressed by Eq. (3) and Eq. (4) respectively.

$$E' = \frac{\sigma_o}{\varepsilon_o} \cos \phi \tag{3}$$

$$E'' = \frac{\sigma_o}{\varepsilon_o} \sin \phi \tag{4}$$

The ϕ-value can be defined as shown in Eq. (5).

$$\phi = \tan^{-1}\left(\frac{E''}{E'}\right) \tag{5}$$

The dynamic modulus (E*) is then expressed as:

$$E^* = E' + iE'' \tag{6}$$

The absolute value of this complex modulus is thus:

$$|E^*| = \sqrt{(E')^2 + (E'')^2} = \sqrt{\left(\frac{\sigma_0}{\varepsilon_0}\right)^2 \left(\sin^2\delta + \cos^2\delta\right)} = \frac{\sigma_0}{\varepsilon_0} \tag{7}$$

where $|E^*|$ is the dynamic modulus, σo is the peak dynamic stress and εo is the peak recoverable axial strain. Thus, the |E*| is defined mathematically as the ratio of σo and εo.The ϕ-value can also be determined as:

$$\varphi = 2\pi\omega\Delta t \tag{8}$$

where, ϕ is the phase angle in radian, ω is the frequency in Hz, and Δt is the time lag between stress and strain in seconds.

The $|E^*|$ of AC depends on many mix factors: aggregate, binder, air void, etc. Few empirical based $|E^*|$ models are available in the literature addressing these factors to determine the stiffness of AC such as viscosity (η) based Witczak model (also called Witczak's I-37A Prediction Model), shear modulus based Witczak model, and Hirsch model (Islam et al. 2019 and Rahman et al. 2019). The viscosity based Witczak model is the primary $|E^*|$ prediction model in the recently developed AASHTOWare pavement Mechanistic-Empirical (ME) design software (AASHTO 2015). The viscosity based Witczak model, presented in Eq. (9), uses η of binder as the main input parameter to capture the effect of binders, aggregate gradation, temperature and air void (AASHTO 2015).

$$\begin{aligned}\log|E^*| = {} & 3.750063 + 0.02932\,\rho_{200} - 0.001767\,(\rho_{200})^2 - 0.002841\,\rho_4 \\ & - 0.058097\,V_a - 0.802208\left(\frac{V_{beff}}{V_{beff} + V_a}\right) \\ & + \frac{3.871977 - 0.0021\,\rho_4 + 0.003958\,\rho_{\mathbf{8}} - 0.000017(\rho_{\mathbf{8}})^2 + 0.00547\,\rho_{\mathbf{34}}}{1 + e^{(-0.603313 - 0.313351\log(f_r) - 0.393532\log(\eta))}}\end{aligned} \tag{9}$$

Eq. (9) can be presented similar to the sigmoid function mentioned below:

$$\log(|E^*|) = \delta + \frac{\alpha}{1 + e^{\beta + \gamma\log(f_r)}} \tag{10}$$

where

$$\delta = 3.750063 + 0.02932\ \rho_{200} - 0.001767\ (\rho_{200})^2 - 0.002841\ \rho_4 - 0.058097\ V_a - 0.802208\left(\frac{V_{beff}}{V_{beff} + V_a}\right)$$

$$\alpha = 3.871977 - 0.0021\ \rho_4 + 0.003958\ \rho_{38} - 0.000017(\rho_{38})^2 + 0.00547\ \rho_{34}$$

$$\beta = -0.603313 - 0.393532\ \log(\eta)$$

$$\gamma = -0.313351$$

$$f_r = a(T) * f$$

$$\log f_r = \log f + \log[a(T)]$$

$$\log f_r = \log f + c(\log\eta - \log\eta_{T_r})$$

$$c = 1.255882$$

|E*| = dynamic modulus, psi
ρ34 = cumulative % retained on the ¾ in sieve
ρ38 = cumulative % retained on the 3/8 in sieve
ρ4 = cumulative % retained on the No. 4 sieve
ρ200 = % passing through the No. 200 sieve
η = viscosity of binder at the temperature of interest, 106 Poise
ηTr = viscosity at the reference temperature, 106 Poise
Vbeff = effective binder content, % by volume
Va = air void content, %
fr = reduced frequency at the reference temperature, Hz
f = frequency at a given temperature of interest, Hz
a(T) = shift factor as a function of temperature
T = temperature of interest, °F

Literature Review

The performance of η-based Witczak model for predicting |E*| of AC was evaluated by several researchers. Clyne et al. (2003), Christensen et al. (2003), Tran and Hall (2005), and Mohammad et al. (2005) reported the η-based Witczak model produces slightly less value. On the other hand, Birgisson et al. (2005) found an over prediction of |E*| value by the η-based Witczak model. Kim et al. (2005) reported that the η-based Witczak equation predicts better at low temperature. Dongré et al. (2005) implemented the η-based Witczak model for original, Rolling Thin Film Oven (RTFO) and Pressure Aging Vessel (PAV) aged binder. It was reported that the η-based Witczak model produces unreasonable estimates for modulus below 700 MPa (100,000 psi) and underpredicts measured |E*| for air void and binder content higher than the mix design. They also recommended to improve the η-based Witczak model by revising the coefficients of volumetric variables, such as the percentage of voids in mineral aggregate (VMA), the percentage of voids filled with asphalt (VFA), AC percentage, and Va. Robins (2009) studied four different mix types were incorporated in the investigation including Superpave mixes (super), stone matrix asphalt mixes (SMA), and a rich bottom layer (RBL). Research finding from different studies are summarized in Table 1. It shows that the η-based Witczak model sometimes predicts lower, sometimes larger and very few times reasonable dynamic modulus compared to the measured values. Therefore, research is needed to find out a solid answer or find an appropriate answer for Colorado's mixes. This is why, this study is motivated to evaluate the η-based Witczak model for Colorado's mixes.

Table 1. Summary of the Performances of the Predictive Models

References	Brief Description	Performance
Rahman et al. (2016)	Tested 21 SP mixtures in New Mexico	Under-predicts
Weldegiorgis (2014)	Tested 5 SP mixtures in New Mexico	Under-predicts
Robbins (2009)	Studied Alabama's SP, SMA, RBL mixtures	Scattered
Clyne et al. (2003)	Four different asphalt mixtures from the Mn/ROAD site were studied	Under-predicts
Mohammad et al. (2005)	Studied asphalt mixtures used in Louisiana	Under-predicts
Tran and Hall (2005)	Studied asphalt mixtures used in Arkansas	Under-predicts
Birgisson et al. (2005)	28 common mixtures in Florida were tested	Reasonable
Dongre et al. (2005)	Five pavement construction sites across the US were studied	Reasonable
Yousefdoost et al. (2013)	28 different Australian mixtures were tested	Under-predicts
Mateosa and Soaresb (2015)	Eight Spanish mixtures were tested	Reasonable
Biligiri and Way (2014)	A total of 2834 test sections from Arizona were used	Under-predicts
Ceylan et al. (2009)	205 unaged mixtures were used from NCHRP 9–19 project.	Under-predicts
Gedafa et al. (2010)	Nine SP mixtures were tested from Kansas	Scattered
Georgouli et al. (2016)	15 mixtures from Greece were tested	Reasonable
Hou et al. (2016)	Asphalt mixtures used in China were studied.	Scattered
Khattab et al. (2014)	25 different HMA mixtures in Saudi Arabia were studied.	More Reasonable
Li et al. (2013)	3 different mixtures of China were studied.	Under-predicts

Results and Analysis

The measured dynamic modulus data is also plotted with the Witczak's I-37A Prediction Model (viscosity-based model) which is widely used in the PMED software for level 2 or Level 3 analysis. The comparison is plotted in Figure 4. It shows that the predicted -dynamic modulus values are well correlated with the measured data.

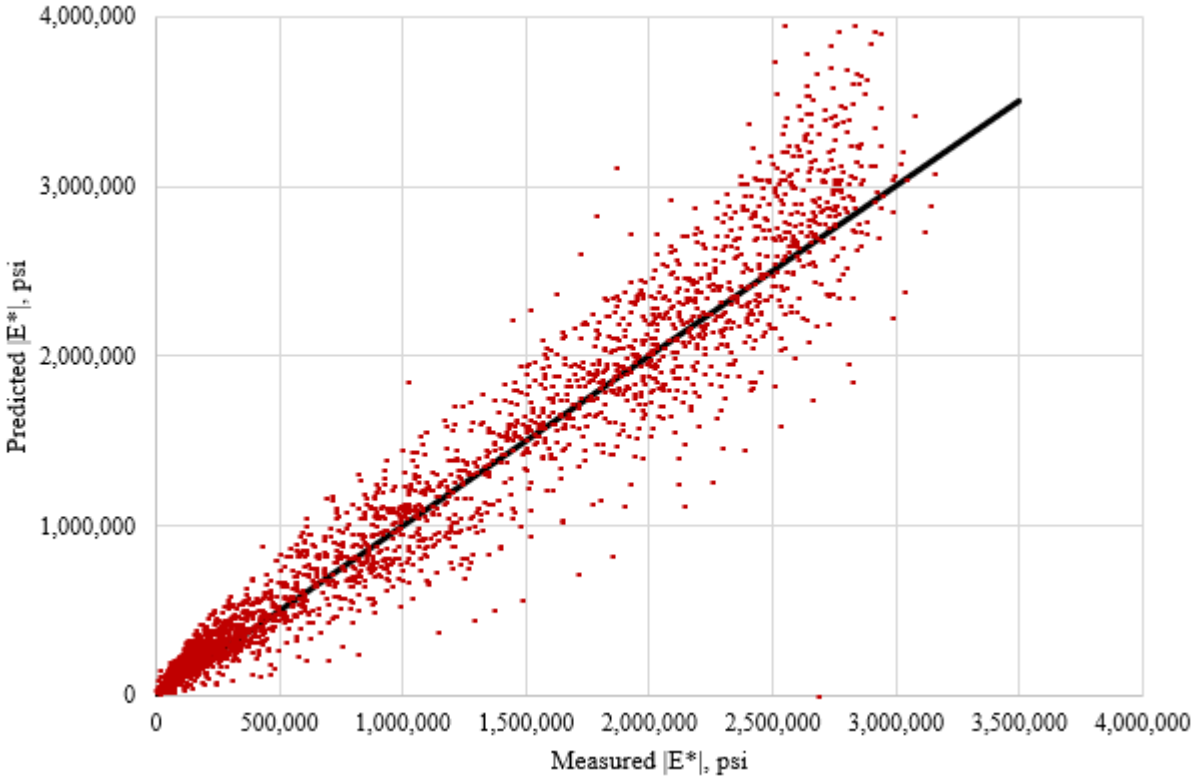

Figure 4. I-37A Model-Predicted dynamic modulus with the measured values

Conclusions

This study found that the predicted dynamic modulus using the viscosity based Witczak model is well correlated with the measured dynamic modulus of mixes used in Colorado.

Acknowledgements

The Colorado State University-Pueblo (CSU-Pueblo) research team appreciates the research funding by the CDOT. It would like to express its sincere gratitude and appreciation to Jay Goldbaum, Michael Stanford, Dr. Aziz Khan, Melody Perkins, Keith Uren, Vincent Battista, Skip Outcalt, Bill Schiebel and Roberto E. DeDios from the CDOT.

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Six Lessons to Healthier Eating in Middle Schools Students: Investigating a Change in Knowledge and Behavior

Guadalupe Gutierrez Miranda

El Rio: A Student Research Journal. Vol. 3, No. 1 (2018), pp. 29-35.

Introduction

The definition of nutrition, according to Weaver-Hightower (2010), is the process of taking in food and using it for growth, metabolism, and repair. Nutritional stages are ingestion, digestion, absorption, transport, assimilation, and excretion. Freijer, et al. (2019) state that nutrition is about eating a healthy and balanced diet. Food and drink can provide the energy and nutrients people need to be healthy and active. Understanding nutritional terms enhances and encourages better food choices. Nutrition is significantly more complicated than simply food intake. Nutrition consists of a proper balance of carbohydrates, fats, proteins, vitamins, minerals, and water.

Teaching nutrition to children is important as it can help them make better decisions when eating. Proper nutritional choices can reduce the chances of diabetes, heart problems, obesity, cancer, strokes, and cardiovascular disease in adulthood (Dietary Guidelines, 2015). The knowledge of nutrition that children obtain early in life may help them make better decisions that can influence their adult years forming their choices early in their lives. Learning to like different foods and willingness to try different foods at a young age, as well as learning to eat fruits and vegetables instead of junk food, could reduce the risk for chronic disease. Better health for future generations can happen, and teaching children healthy nutritional habits at a young age can contribute to the change. Schools are in a unique position to provide students with knowledge and skills concerning healthy nutrition and disease prevention.

The 2015-2020 Dietary Guidelines for Americans recommends that people aged 2 years or older follow a healthy eating pattern that includes a variety of fruits and vegetables, whole grains, fat-free and low-fat dairy products, a variety of protein foods and some oils. The guidelines also recommend that people limit calories from sold fats and added sugars as well as reduce sodium intake (US HHS, 2015). Although these recommendations are in place, many children do not follow them (Bauer, Yang & Austin, 2004). Between 2001 and 2010, the consumption of sugary beverages accounted for 10% of total caloric intake (Mesirow & Welsh, 2015). Between 2003 and 2010 data showed that most youth do not meet the minimum fruit and vegetable intake recommendations (Drewnowski & Rehm, 2015). In addition, calories from added sugars and solid fats contributed to 40% of the caloric intake of children and half of these calories came from soda, fruit drinks, dairy desserts, desserts, pizza and whole milk (Reedy & Krebs-Smith, (2010).

Considering the benefits of teaching children about nutrition, it is concerning that nutrition isn't a required subject in all school systems. Even though it has been proven that there are benefits to teaching kids about nutrition, the educational system generally doesn't prioritize requiring courses on nutrition or providing funding for nutrition courses. Students attending traditional schools in the U.S. receive less than eight hours of nutrition education each school year (Results, 2014). In addition, the percentage of schools that required instruction on nutrition decreased from 84.6% to 74.1% between 2000 and 2014 (Results, 2014). The educational system tries to fit nutrition or other health-related curriculum into alternative classes such as physical education. However, that strategy takes time out of the schedule that allows for physical activity. Another option would be to teach nutrition during the same time allotted for breakfast that is provided by the school or incorporated into other appropriate subjects such as Science and Math (Murimi et al., 2018).

Much food served in schools does not have high nutritional value and may teach children that fast food is a good option. For example, pizza is one of the most prevalent foods being served in schools. About 26% of all U.S school districts serve fast food pizza to students (Weaver-Hightower, 2011). Children are learning visually what should be on a plate and many schools do not provide fresh healthy foods. School-aged children are not usually allotted a great deal of time for meals. Most meals last between only 25 and 35 minutes with some of that time spent standing in line to receive food. As a result, many children are forced to eat quickly and do not focus on what they're eating. However, some attempts have been made to increase the variety and quality of food available to students. For example many school districts provide breakfast programs for students. Since implementing breakfast programs, Yao, Liu, & Zhou (2019) found that students who eat breakfast have better grades and focus more in school.

While many attempts have been made to increase the number of schools that teach nutrition, knowledge and programs may not be maintained or properly managed. Crawford (2011) found that children are eating at minimum sufficient or excessive food calories based on the recommended federal government dietary guidelines of America. Although children are getting enough caloric intake, it has been found that children from the age of 5 to 18 eat approximately 720-950 empty calories a day Crawford (2011). Federal government dietary guidelines are helpful but are not being taught or maintained in all school districts and research shows that most children do not eat the daily nutritional requirements to assure healthy growth (US HHS, 2015; Krebs-Smith, Guenther, & Subar, 2010, Reedy & Krebs-Smith, 2010). Huynh et al. (2015) conducted a study demonstrating that slowed growth doesn't have to be permanent, with kids as old as three and four years successfully catching up through nutritional intervention and dietary counseling.

In this study, six nutrition classes were taught at a local middle school in Pueblo, Colorado, to increase nutrition knowledge and influence nutritional behavior in middle school students.

Hypothesis

The students at Roncelli STEM Academy will improve their nutrition knowledge and improve their nutrition behavior scores after being taught six nutrition lessons.

Methods

The samples consisted of 51 students from Roncelli STEM that were enrolled in a physical education class. The experimental group of students (N=25) were taught six lessons that came from HealthSmart Digital, Nutrition and Physical Health Curriculum. Health Smart is a comprehensive health education program that is built on research and best practices to meet the characteristic of effective health education curricula from the Centers for Disease Control (CDC). It meets national standards and is based on the knowledge and skills expectation in the CDC Curriculum Analysis Tool (ETR.org, 2019). These six lessons included: what is nutrition, assisting my eating habits, reading food labels, healthy snacks, eating healthier, eating healthier at fast-food restaurants, and assisting physical activity. The lessons were delivered twice a week. The lessons followed the curriculum fully and maintained the integrity of the curriculum. The lessons were presented in a PowerPoint format. All the activity sheets from the curriculums were used with the students. A matched controlled group of 25 students who did not received the lessons was chosen from the same school. The experimental and control groups were chosen at random.

Both groups were given a nutrition knowledge pre-test, before any lessons were completed and post-test, after the lessons were completed. The students were also given a nutrition behavior pre-test and post-test at the same time as the knowledge test. The knowledge pre-test and post-test asked students to list the MyPlate U.S. Government recommendations for food groups and serving recommendations, to develop a healthy meal plan for Breakfast, Lunch and Dinner, as well as questions concerning the benefits of eating breakfast and three healthy snacks. The behavioral pre-test and post-test asked students to recall their nutritional behavior in the past month regarding how many times they had eaten fast food, how may unhealthy snacks they had eaten daily, how many sugary drinks they had consumed daily, how many servings of fruit and vegetables they had consumed daily, and how many times they had eaten while engaging in television or video games.

The first meeting day, the students took the pre-test for nutrition knowledge and behavior. The second meeting day, students were provided the first lesson, this continued until the sixth lesson was given. After the six lessons, on the last meeting day, the students were given the post-test for nutrition knowledge and behavior. When taking the pre-test and post-test, students were separated and provided no assistance beyond instruction for the assessment. The experimental and control groups took the pre-test and post-test in the same way in the same general time period.

After the lessons were completed, the students' data was put into Excel where paired samples t-tests were analyzed from their pre- and post-test results on both the behavior and nutrition assessments. The outcome of the t-test evaluation determined whether the lessons helped students improve their nutritional behavior and knowledge concerning nutrition. Finally, a one-way ANOVA test was performed to evaluate the differences in the control versus the experimental sample that received the lessons.

Result

There was no significant difference from pre-test to post-test in the experimental (p=.14) or control group (p=.47) for nutritional behaviors as found through matched t-tests. When analyzing the knowledge score through a matched t-test, both the experimental group (p<.0001) and the control group (.0189) showed a significant increase in nutritional knowledge from the pre-test to the post-test. A one-way ANOVA test on nutrition knowledge pre-test to post-test in both the control and experimental groups revealed that the control group had a significantly higher knowledge score at the pre-test (.0465) showing that the control group had more knowledge coming into the pre-test than those who received the lessons. A second one-way ANOVA revealed that there was no significant difference pre-test to post-test on the nutrition behavior in the control group when compared to the experimental group.

Table 1.
t-test outcomes for knowledge pre-test to post-test

	Pre-Knowledge Experimental Group	Post-Knowledge Experimental Group	Pre-Knowledge Control Group	Post-Knowledge Control Group
Mean	13.2	25.6	17.1	21.3
P value	<.0001		.0189	

Table 2.
t-test outcome for nutrition behavior pre-test to post-test

	Pre-Behavior Experimental Group	Post-Behavior Experimental Group	Pre-Behavior Control Group	Post-Behavior Control Group
Mean	83.8	67.13	94.3	93.6
P value	.1412		.4735	

Table 3.
One-way ANOVA Knowledge Difference Between Experimental to Control Groups
ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1890.449	3	630.1497	16.7047	1.23E-08	2.710647
Within Groups	3244.169	86	37.7229			
Total	5134.618	89				

Table 4.
One-way ANOVA Behavioral Difference Between Experimental to Control Groups
ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7780.153	3	2593.384	0.893221	0.448206	2.713227
Within Groups	243886.1	84	2903.406			
Total	251666.3	87				

Discussion

When examining the children's behavior data, neither the students that received the lessons nor the control group had a significant change in their nutritional behavior. Although, when looking at the students' scores individually, it was found that many of the students in the experimental group individually increased their consumption of fruit and vegetables and decreased their intake of junk food. This may have been influenced by the lessons or by other factors.

The knowledge data revealed a significant increase in both the experimental and control groups. The difference for the students that were taught the six lessons of nutrition was greater than the control group. The one-way ANOVA for the knowledge score data showed that the control group had a higher knowledge score before the experiment when compared with the experimental group. The groups were randomly chosen and unfortunately the two groups were not matched for nutritional knowledge at pre-test, which may have affected the outcomes. Although the students that were in the control group had more knowledge than those that received the lessons, it is important to note that these two groups came from the same school. It is possible that some crossover of information occurred between those students that received lessons and some of those that did not receive lessons through friends or other discussions. To improve the study, it would be important to have a control group from a completely different school.
Another limitation of the study was the small size of the groups. The limited number of subjects may have also skewed the data. One additional confounding factor was the short timing of the lessons and the possible influence of culture and/or nutritional habits of the student's family.

Conclusion

The results can conclude that nutritional behavior did not significantly change after six nutrition lessons in a group of middle school students, although some individual students did show beneficial behavioral changes. The results also concluded that nutrition knowledge did significantly increase in the group after the six nutrition lessons. This study also demonstrated that teaching knowledge lessons alone will not necessarily translate into behavioral change.

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Variations of Flow Number of Asphalt Concrete Due to Human Effects

Katherine Widjaja, Md Rashadul Islam, Sylvester A. Kalevela

ABSTRACT

Flow number (N) of Asphalt Concrete (AC) is an important property relating the number of load repetition an AC material can sustain without having any permanent deformation on it. This property is determined in laboratory using very sophisticated equipment. This study shows the flow number of a mix can vary from contractor to contractor and so on; to study the flow number of the AC specimens that are determined. Then, the results are analyzed. The results show that the same mix may have statistically different flow numbers for the same contractor. The same mix may have statistically different flow numbers for different contractors. The mix with same mix factors might have statistically different flow numbers.

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1.0 Introduction

The flow number (N) is the number of load cycles at which tertiary flow begins or permanent damage occurs in material. Tertiary flow can be differentiated from secondary flow by a marked departure from the linear relationship between cumulative strain and number of cycles in the secondary zone (Islam et al. 2019). It is assumed that in tertiary flow, the specimen's volume remain the constant. The N-value is important as it can be correlated with rutting potential of flexible pavement. The final evaluation is an evaluation of the rutting resistance of the mixture using the flow number test defined by the American Association of State Highway, and Transportation Officials (AASHTO) TP 79 (AASHTO TP 79 2015) using the Asphalt Mixture Performance Tester (AMPT). The test is conducted at the 'high' pavement temperature calculated by the LTPP Bind 3.1 software program for a specific project location. An unconfined flow number test with a repeated deviatoric stress of 87 psi (600 kPa) and a contact deviatoric stress of 4.4 psi (30 kPa) is used in this study. The test is conducted on specimens that are short-term conditioned for two hours at the compaction temperature to simulate the binder absorption and stiffening that occurs during construction.

In the flow number test, the permanent strain at each cycle is measured, while a constant deviator stress is applied at each load cycle on the test sample (Figure 1). Permanent deformation of asphalt pavements has three stages (Biligiri and Way 2013):

a. Primary or initial consolidation
b. Secondary, and
c. Tertiary or shear deformation

Figure 1 shows the three stages of permanent deformation. The N-value is taken as the loading cycle, at which the tertiary stage begins following the secondary stage. Justification for selection of N-value criteria is determined using the Francken model, which is discussed below.

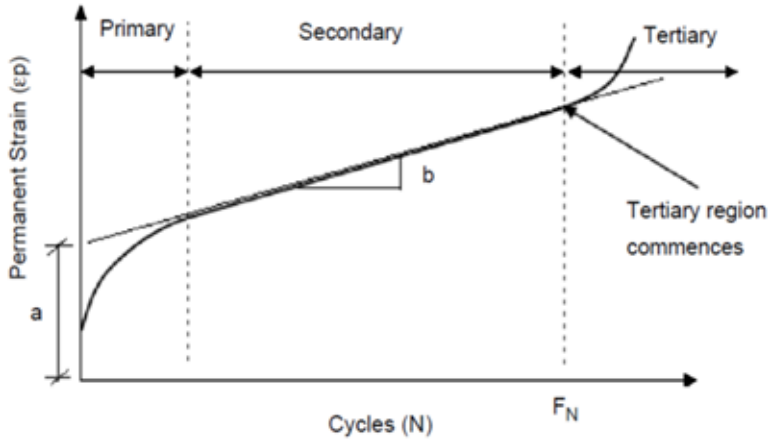

Figure 1. Relationship between Permanent Strain and Load Cycles (Biligiri and Way 2013)

The current study used testing conditions and criteria for N testing described in AASHTO TP 79 (AASHTO TP 79 2015) for unconfined tests. The recommended test temperature, determined by LTPP Bind Version 3.1 software, is the average design high pavement temperature at 50% reliability for cities in Colorado. Tests are conducted at a temperature of 55 °C with an average deviator stress of 600 kPa and a minimum (contact) axial stress of 30 kPa. For conditioning, samples are kept in a conditioning chamber at the testing temperature for 12 hours prior to testing.

2. Results and Analysis

2.1 Same Mix by Same Contractor

To investigate the variation of flow number by a single contractor for the same mix, the mix SX(100) PG 64-28 is randomly selected (Table 1). SX(100) means the number of gyration is 100 when the mix was produced/designed. PG 64-28 is the type of asphalt binder used. The paving contractor is APC Southern (APC), with the binder material provided by Suncor, and aggregate provided by Valardi. Different numbers such as 19655 P20 14, 19655 P21 14, etc. are mix identification number.

Table 1. Generic Information of 19655 Mix

19655 P20 14	19655 P21 14	19655 P23 14	19655 P24 14	19655 P28 14	19655 P37 14	19655 P48 14	19655 P87 14	
Contractor	APC	APC	APC	APC	APC	APC	APC	APC
Refinery	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor
Pit	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi
Date	July 2014	July 2014	July 2014	July 2014	July 2014	Aug 2014	Sep 2014	Oct 2014

The N-values vary from 120 to 531 with an average value of 261, and standard deviation of 125, as shown in Figure 2. To determine whether this data is statistically significant or not, a one-sample t-test are conducted. The t-test requires the data to be normally distributed. Three normality tests (Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk) are conducted, and all of them showed the data is normal. The t-test showed the 95% Confidence Interval (CI) boundaries to be 150 and 372, with the mean value of 261. This means all the mixes, except for 19655 P21 14 and 19655 P87 14, are statistically the same. Therefore, a conclusion can be made that the same mix may have statistically different flow numbers for the same contractor.

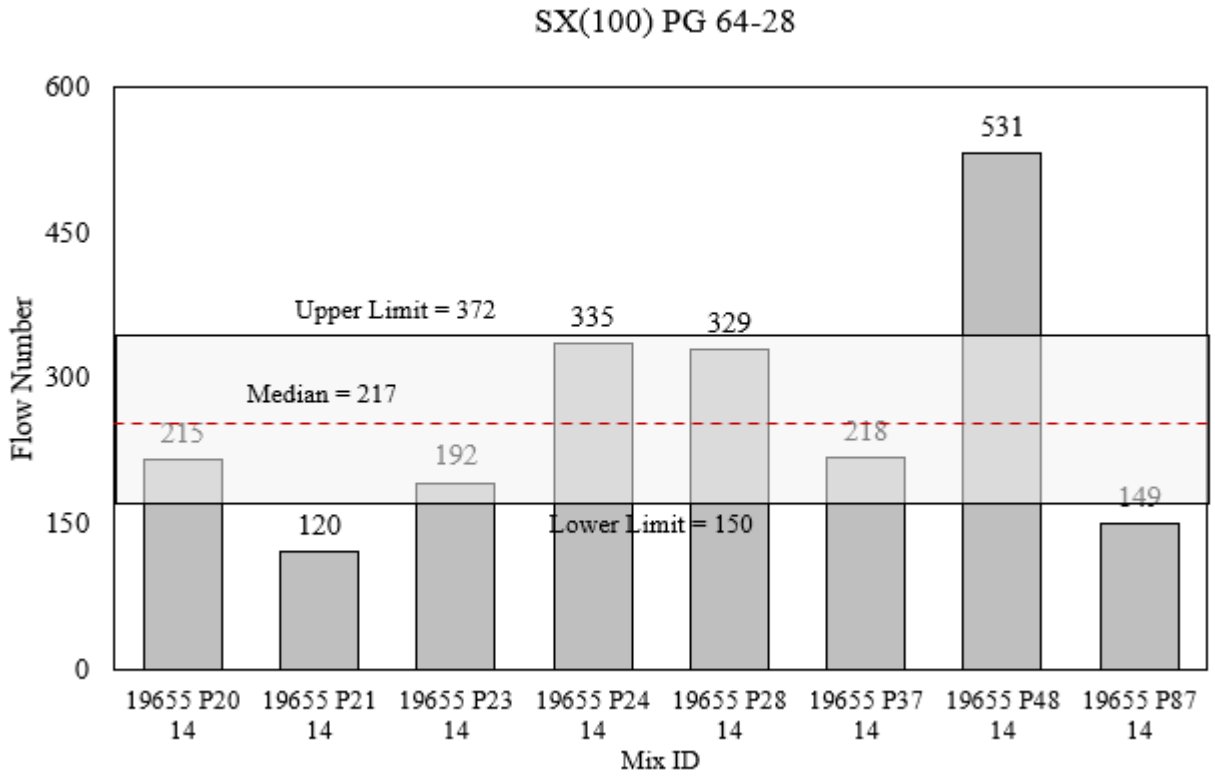

Figure 2. Flow Number of Eight Specimens of SX(100) PG 64-28 Mix

2.2 Same Mix by Different Contractors

To investigate the difference in flow number for the same mix prepared by different contractors, SX(100) PG 76-28 mix has been selected. The average flow numbers from four contractors, 19128, 18842, 19458, and 19677, are presented in Figure 3.

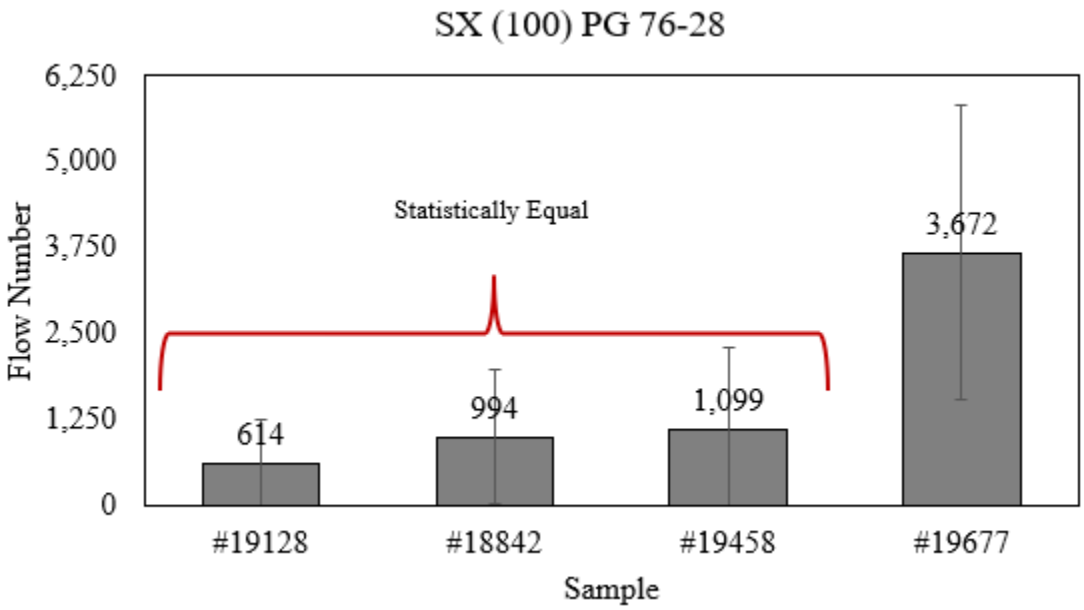

Figure 3. Flow Number of a Mix by Different Contractors

Normality tests (Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk), show only projects #18842 and #19677 to be normal. The pairwise-comparisons test result shows mixes, 19128, 18842, and 19458 are statistically the same (Table 2). Therefore, a conclusion can be made that the same mix may have statistically different flow numbers for different contractors.

Table 2. Pairwise Comparisons using t-tests to Determine Whether Statistically Different

	19128	18842	19458
18842	Equal	-	-
19458	Equal	Equal	-
19677	Different	Different	Different

2.3 Flow Numbers of a Mix

To evaluate the flow number of a mix with different mix factors, the mix SX(100) PG 76-28 has been selected. The flow numbers for SX(100) PG 76-28 mix by different contractors are presented in Figure 4. The graph shows that the flow number of this mix varies from 82 to 6,343, with an average number of 1,578, median of 810 and a standard deviation of 1,837. As per AASHTO, a mix is considered good for traffic greater than 30 million ESALs if it has a flow number greater than 740. Although the average flow number is 1,482, nearly half of the samples had a flow number less than 740. Therefore, it is very difficult to conclude whether this mix is considered good for traffic greater than 30 million ESALs. Comparing this result with the previous binders, the flow number increases with an increase in high-temperature grade of the binder. A similar observation are found for the SX(75) mix. Normality tests Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk did not show sufficient evidence of the data to be normal. The t-test showed the 95% CI boundaries to be 893 and 2,262. Out of 33 specimens, only 7 specimens are within the 95% CI boundaries.

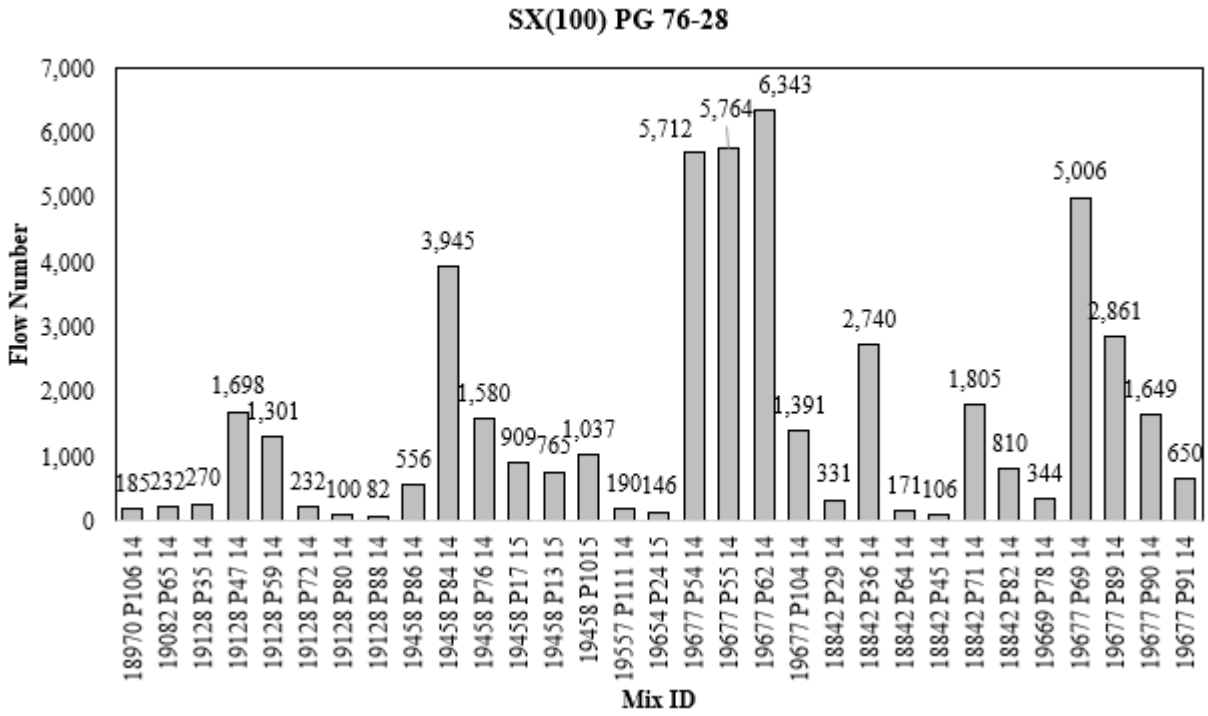

Figure 4. Flow Numbers for SX(100) PG 76-28 Mix

As listed in Table 3, there are seven mixes whose mix factors are the same, but their flow numbers are not statistically the same. To clarify, the mixes by Kiewit, Martin Marietta, or Simon Construction have similar mix factors in every category, but the flow numbers are statistically different. Table 4 also shows that mixes with different properties have statistically the same flow numbers.

Table 3. Generic Information of SX(100) PG 76-28 Mix

	Paving Contractor	Binder Supplier	Region	Date	Vbe (%)	Va	VMA (%)	VFA (%)	AC (%)	Pit
18842 P29 14	Kiewit Construction	Suncor	2	7/2014	12.61	6.68	18.1	64.3	6.30	Tezak / Fountain / I-25 Millings
18842 P36 14	Kiewit Construction	Suncor	2	8/2014	14.32	4.56	15.8	72.5	6.30	Parkdale/ Tezak
18842 P45 14	Tezak	Suncor	2	8/2014	12.53	6.93	18.2	62.2	5.20	Tezak / Fountain / I-25 Millings
18842 P64 14	Kiewit Construction	Suncor	2	9/2014	12.53	6.85	18.2	62.4	6.30	Tezak / Fountain / I-25 Millings

18842 P71 14	Kiewit Construction	Suncor	2	10/2014	15.23	4.88	18.5	73.5	6.30	Parkdale/ Tezak
18842 P82 14	Kiewit Construction	Suncor	2	10/2014	12.53	6.93	18.3	62.3	5.20	Tezak / Fountain / I-25 Millings
18970 P106 14	APC Southern	Suncor	5	11/2014	12.72	5.60	18.2	67.4	6.12	King Pit
19082 P65 14	ACA Buena Vista	Suncor	5	3/2015	13.84	6.85	18.8	63.2	5.70	Avery Pit, ACA Buena Vista
19128 P35 14	Martin Marietta	Suncor	2	8/2014	10.96	6.32	17.1	62.5	5.60	Evans
19128 P47 14	Evans	Suncor	2	8/2014	10.90	6.82	17.6	61.4	5.60	Evans
19128 P59 14	Martin Marietta	Suncor	2	9/2014	10.90	6.82	17.6	60.9	5.60	Evans
19128 P72 14	Martin Marietta	Suncor	2	9/2014	10.00	6.82	17.9	60.2	5.10	Evans
19128 P80 14	Martin Marietta	Suncor	2	10/2014	10.00	6.82	17.6	60.7	5.10	Evans/slate
19128 P88 14	Martin Marietta	Suncor	2	10/2014	10.82	6.83	17.6	61.6	5.60	Evans/slate
19458 P10 15	Simon Construction	Suncor	4	5/2015	9.90	5.30	16.8	61.5	5.05	Granite Canyon, Julesburg, Sedgwick
19458 P13 15	Simon Construction	Suncor	4	6/2015	9.47	5.30	16.5	61.7	4.96	Granite Canyon, Julesburg, Sedgwick
19458 P17 15	Simon Construction	Suncor	4	6/2015	9.55	5.30	16.1	60.7	4.93	Granite Canyon, Julesburg, Sedgwick
19458 P20 15	Simon Construction	Suncor	4	6/2015	10.32	4.40	16.6	60.0	5.30	Granite Canyon, Julesburg, Sedgwick
19458 P76 14	Simon Construction	Suncor	4	6/2015	11.57	6.43	17.3	62.6	5.20	Granite Canyon, Julesburg, Sedgwick

19458 P79 14	Simon Construction	Suncor	4	7/2015	11.57	6.80	17.6	61.4	5.20	Granite Canyon, Julesburg, Sedgwick
19458 P84 14	Simon Construction	Suncor	4	9/2015	11.57	6.75	17.6	61.2	5.20	Granite Canyon, Julesburg, Sedgwick
19458 P86 14	Simon Construction	Suncor	4	10/2015	11.57	6.78	17.6	61.3	5.20	Granite Canyon, Julesburg, Sedgwick
19557 P111 14	A&S Construction	Suncor	2	11/2014	11.71	5.00	17.7	64.6	5.38	Tezak/ Transit Mix
19654 P24 15	Martin Marietta	Suncor	2	7/2015	10.31	5.00	17.6	60.6	5.25	Evans/slate
19669 P78 14	A&S Construction	Suncor	2	10/2014	10.72	6.93	17.7	61.0	5.40	Rocky Ford South/La Junta
19677 P54 14	Elam Construction	Suncor	3	1/2015	10.25	5.18	14.9	65.4	5.50	23 Road
19677 P55 14	Elam Construction	Suncor	3	1/2015	10.54	5.04	15.1	66.6	5.50	23 Road
19677 P62 14	Elam Construction	Suncor	3	2/2015	10.69	5.00	15.2	66.5	5.50	23 Road
19677 P69 14	Elam Construction	Suncor	3	5/2015	11.71	4.43	15.6	71.7	5.50	23 Road
19677 P89 14	Elam Construction	Suncor	3	10/2015	10.69	6.83	16.8	58.9	5.50	23 Road
19677 P90 14	Elam Construction	Suncor	3	10/2015	11.71	5.98	17.0	64.6	5.50	23 Road
19677 P91 14	Elam Construction	Suncor	3	11/2015	11.71	5.88	16.9	65.3	5.50	23 Road
19677 P104 14	Elam Construction	Suncor	3	11/2014	11.02	5.88	18.6	57.6	5.74	23 Road

Note: Green highlighted mixes produce statistically the same flow number.

3. Conclusions

The following conclusions can be made from the study:

- The same mix may have statistically different flow numbers for the same contractor.
- The same mix may have statistically different flow numbers for different contractors.
- Mix with same mix factors might have statistically different flow numbers.

Acknowledgements

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Natural History of Shortgrass Prairie Plant Species at The Pueblo Chemical Depot 2018-2019

Cody Allyn Back, Kevin Healey, Sean Kyle Staples, Elizabeth K. Peterson, Brian Vanden Heuvel

ABSTRACT

Undisturbed shortgrass prairie is a rich, diverse ecosystem that is becoming endangered due to disturbance by humans in the Midwest. We surveyed the effects of droughts and heavy precipitation years to analyze the plant composition on an undisturbed shortgrass prairie ecosystem located on the Pueblo Chemical Depot. We found that during drought years, there are few species of plants capable of growing, all plants were perennials, and there were few invasive species of plants. When comparing the floral compositions between a wet year and a dry year we found that wet years have higher diversity, more invasive species, more annual plants, and that most drought-year plants were not found again during the wet year. Our results demonstrate that drought years select for native perennial plants, wet years create more possibilities for annuals and invasive plants, and drought-year plants are most likely outcompeted by other plants during wet years.

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Introduction

Shortgrass prairie is a native ecosystem in North America located east of the Rocky Mountains in the central part of the United States (Samson, 1996). Fires and heavy grazing by ungulates and small mammals (e.g. bison and prairie dogs) are natural processes in shortgrass prairie ecosystems (Samson, 1996). Thus, plants in shortgrass prairies have evolved with regular cycles of fire and grazing and tend to be highly resilient, perennial plants, such as Bouteloua gracilis, Buchlöe dactyloides, Yucca glauca, and prickly pear cactus (Dickinson, 1976).

Our study site is located on a 23,000-acre military installation, the U.S. Army Pueblo Chemical Depot, located east of Pueblo, CO (Rondeau, 2013). The Pueblo Chemical Depot is in the center of three different types of floristic zones (see Fig. 1) (Cronquist,1982), including the Rocky Mountain zone, North American Shortgrass Prairie zone, and the Chihuahuan Desert zone. Each zone has very different compositions of plants; for example, the Rocky Mountain zone contains mainly trees, shrubs, and a few types of grasses, while the Chihuahuan Desert zone contains mostly cacti and prickly shrubs (Huenneke, 2001). Previous surveys at the Pueblo Chemical Depot has shown, that plant compositions from each zone at the Pueblo Chemical Depot follow the same pattern (Rondeau, 2013). The objectives of this study are to survey the plants located on shortgrass prairie at the Pueblo Chemical Depot. The results of this study will contribute to conservation of critically endangered grassland habitat and show that the habitat at the Pueblo Chemical Depot is unique in that it is a melting pot of North American floristic zones.

Methods

Location: This survey was conducted at the U.S. Army Pueblo Chemical Depot located in southeastern Colorado (Pueblo, Colorado). The habitat at the Pueblo Chemical Depot is either grassland, riparian or semidesert shrubland (Andrews and Righter 1992), with shortgrass prairie vegetative communities in grassland areas (Rondeau, 2013). We did not survey plants in the riparian woodland, northern sandhill prairie, greasewood shrub, or wetland on the Pueblo Chemical Depot (Rondeau, 2013).

Sampling: All surveys were conducted in the month of June 2018 and 2019. Southeastern Colorado suffered a severe drought during the summer of 2018, causing little diversity and density of plant growth (Weather Underground, 2020). 2019 proved to be a wetter year and was a more productive year for plants at the study site. To catalog the plants at the Pueblo Chemical Depot, we used the Modified Whittaker Plot method (Stohlgren, 1995) in 12 plots during 2018 and 14 in 2019.

In brief, Modified Whittaker Plots are 10x25 meter rectangular plots used for surveying plants (Stohlgren, 1995). Modified Whittaker Plots have 13 subplots within the 10 x 25 meter plot, with 10 subplots occupying 0.25 x 1 meters (for a total of 2.5 meters) located on the perimeter of the plot to maximize efficiency of sampling and used to gather data on plant composition. Three subplots, which add up to 30 meters, are used for finding plants that were not found within the other subplots.

Identification: We collected a sample for each plant species, pressed the sample in a plant press, and then identified it by using Ells (2012). We then used the USDA PLANTS database to find the floristic zone and growth habit of every plant (USDA, 2020). In this study we used North American shortgrass prairie, Chihuahuan desert, and Rocky Mountain floristic zones for reference.

Results

Annual precipitation in Pueblo, Colorado was lower in 2018 than 2019 by approximately 6 inches (see Fig. 2). In 2018 we found 6 total families of plants and in 2019 we found 20 total families of plants (see Tables 1 and 2). In 2018, we found a total of nine plant species including one invasive species and eight native species; all species found undergo the perennial growth habit. In 2019, we found 46 total plant species including six invasive species and 40 native species. There was a total of 24 perennial growth habit plants and 22 total annual growth habit plants. All invasive species found were annual plants (see Table 2). In 2019, we found only 5 similar plants that were found in 2018, which is over half of the total number of plants found in 2018 (see Fig. 2).

Discussion

In 2018, a major drought occurred in the shortgrass prairie located on the Pueblo Chemical Depot that decreased the number of plants surveyed and plant diversity (Weather Underground, 2020). All plants surveyed in 2018 were perennial i.e. plants that live for more than two years and invest growth in the roots and/or secondary growth to maintain life when undergoing drought, fires, grazing, or nutrient unavailability (Ehrlinger, 1985). This may be because perennial plants prefer not to exhaust their nutrient stores in creating flowering organs during drought events, instead investing their growth into organs that are important to staying alive for when flowering is beneficial rather than detrimental (Iwasa, 1989).

All plants surveyed in 2018 are native species, except one invasive species (Bromus inermis), and are native to harsh climates, such as those in shortgrass prairies (Otfinowski, 2007). Bromus inermis is an invasive perennial plant that can be found in areas with animal grazers, such as prairie dogs in shortgrass prairies.

In 2019, Southeastern Colorado experienced a higher amount of precipitation, with a total of 13.13 inches of rainfall during this year at the Pueblo Chemical Depot (Weather Underground, 2020). As a result, there was a higher amount of plant growth on the Pueblo Chemical Depot shortgrass prairie (Rondeau, 2013). The floral community completely shifted, due to the rain, from only perennials in 2018 to almost half of the species found being annuals in 2019. This is most likely due to the higher amounts of precipitation, which allowed annual plants to grow (Ehleringer, 1985). In addition, all invasive plants found in 2019 were annuals, likely because they rely on rainfall rather than being adapted to drought conditions.

One plant found in 2018 but not 2019 was Astragalus inflexus; this plant, when in full bloom, has a very conspicuous purple flower allowing it to be seen from even far away. A. inflexus is also a very small, herbaceous plant that is adapted to drought conditions (REFS). Given the high number of other plants, they may have outcompeted this species.

In 2019, we did not find Bromus inermis, a very turfy, drought-resistant plant. This plant was introduced to the United States from Eurasia for use as a pasture grass for livestock; it's used to high amounts of grazing and it undergoes the perennial growth habit by forming large clumps of populations that typically outcompete other plants (Otfinowski, 2007). We speculate that due to the large amount of rainfall during 2019, that most of the clumps of B. inermis populations were choked out by the new annuals outcompeting other plants. We also hypothesize that if another drought were to occur, we will see less of the annual plants and more of the perennial plants, perhaps even the same species found in 2018 during the drought.

The Pueblo Chemical Depot has a wide array of plants from many different floristic zones such as Bouteloua gracilis, which is native to the shortgrass prairie floristic zone, to the large species of cactus, Cylindropuntia imbricata (commonly called tree cholla), which is native to the Chihuahuan desert floristic zone. These plants are all native to different floristic zones in North America and were found at the Pueblo Chemical Depot, indicating that this military installation is a sort of "melting pot" of floristic zones. To achieve a better model for the types of plants on the shortgrass prairie of the Pueblo Chemical Depot, we could also conduct surveys at different times of the year to see what conditions certain plants grow under and the times of year they bloom or sprout. There is still much to be studied about this wonderfully diverse location with it being in the center of multiple floristic zones.

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Figures

Figure 1.

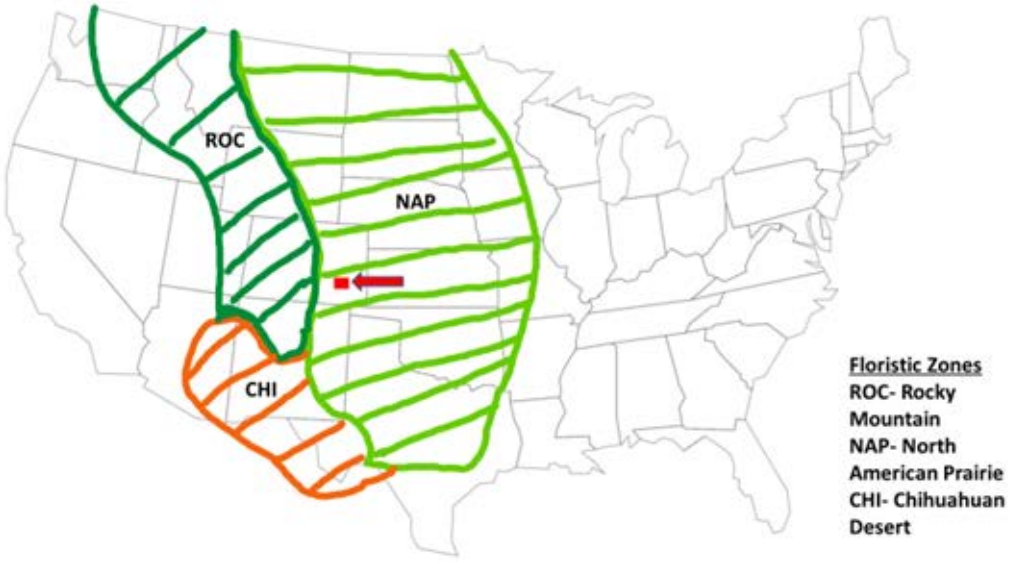

Figure 1. The floristic zones of South and the central United States, including Rocky Mountain (ROC), North American Prairie (NAP) and Chihuahuan Desert (CHI). The arrow indicates the general location of the study site, the U.S. Army Pueblo Chemical Depot, in Pueblo Colorado.

Figure 2.

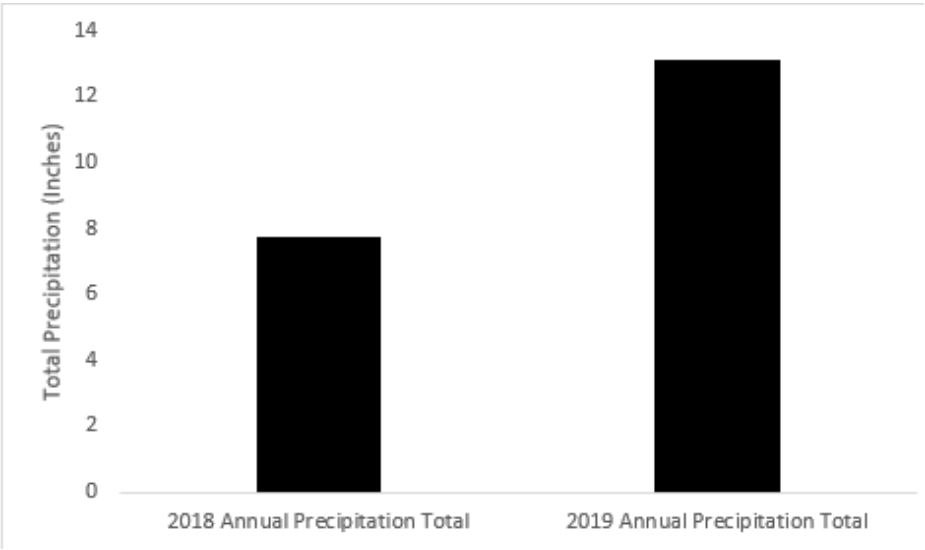

Figure 2. The total amount of precipitation in Pueblo, Colorado, during 2018 and 2019.

Figure 3.

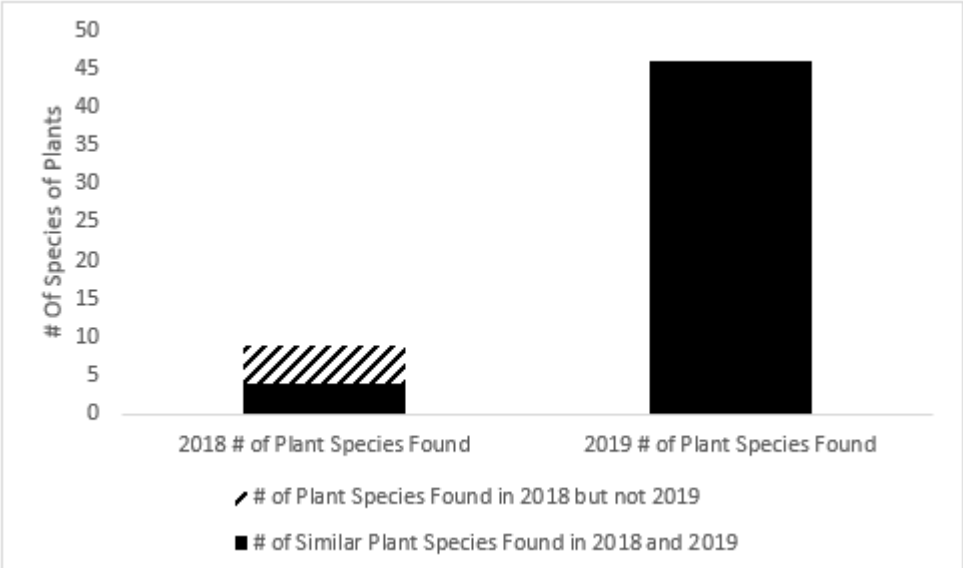

Figure 3. The total number of plant species found in 2018 and 2019. There were 9 plant species found in 2018 and 46 plant species found in 2019. Five species of plants were found in 2018 but not found in 2019.

Table 1.

Family	**Genus**	**Species**	**Floristic Zone**	**Growth Habit**
Agavaceae				
	Yucca	*glauca*	C,N,R	Perennial
Asteraceae				
	Ericameria	*nauseosa*	C,N,R	Perennial
	Grindelia	*squarrossa*	C,N,R	Perennial
Boraginaceae				
	Cryptantha	*crassisepala*	C,N,R	Perennial
Fabaceae				
	Astragalus	*inflexus*	N,R	Perennial
Poaceae				
	Aristida	*longiseta*	C,N,R	Perennial
	Bromus	*inermis*	Invasive	Perennial
	Buchlöe	*dactyloides*	C,N,R	Perennial
Polygonaceae				
	Eriogonum	*effusum*	C,N,R	Perennial

Table 1. The plant species and families found on the Pueblo Chemical Depot in 2018. There was one invasive plant found. All but one species of plant found were native to the three floristic zones described, Astragalus inflexus has not been known to be native to the Chihuahuan floristic zone. All plants found undergo the perennial growth habit. Floristic zones C,N,R stand for Chihuahuan zone, North American Prairie zone, and Rocky mountain zone, respectively.

Table 2.

Family	**Genus**	**Species**	**Floristic Zone**	**Growth Habit**
Apiaceae				
	*lomatium**			
Asteraceae				
	Chrysothamnus	*viscidiflorus*	C,N,R	Perennial
	Cirsium	*vulgare*	Invasive	Annual
	Conyza	*canadensis*	C,N,R	Annual
	Ericameria	*nauseosa*	C,N,R	Perennial
	Erigeron	*divergens*	C,N,R	Annual
	Gaillardia	*aristata*	C,N,R	Perennial
	Helianthus	*annuus*	C,N,R	Annual
	Lactuca	*serriola*	Invasive	Annual
	Machaeranthera	*pinnatifida*	C,N,R	Perennial
	Machaeranthera	*tanacetifolia*	C,N,R	Annual
	Pectis	*angustifolia*	C,N,R	Annual
	Stephanomeria	*pauciflora*	C,N,R	Perennial
	Zinnia	*grandiflora*	C,N,R	Perennial
Boraginaceae				
	Cryptantha	*crassisepala*	C,N,R	Perennial
Brassicaceae				
	Brassica	*nigra*	C,N,R	Annual
	Descurainia	*pinnata*	C,N,R	Annual
	Lepidium	*ramosissimum*	C,N,R	Annual
Cactaceae				
	Cylindropuntia	*imbricata*	C,N,R	Perennial
	Opuntia	*macrorhiza*	C,N,R	Perennial
Chenopodiaceae				
	Chenopodium	*album*	Invasive	Annual
	Kochia	*iranica*	Invasive	Annual
	Salsola	*collina*	Invasive	Annual
Commelinaceae				
	Tradescantia	*occidentalis*	C,N,R	Perennial
Cucurbitaceae				
	Cucurbita	*foetidessima*	C,N,R	Perennial

Euphorbiaceae				
	Croton	*texensis*	C,N,R	Annual
	Euphorbia	*maculata*	C,N,R	Annual
Fabaceae				Annual
	Psoralea	*argophylla*	C,N,R	Perennial
	Psoralea	*tenuiflora*	C,N,R	Perennial
	Sophora	*nuttalliana*	C,N,R	Perennial
Malvaceae				
	Sphaeralcea	*coccinea*	C,N,R	Perennial
Nyctaginaceae				
	Abronia	*fragrans*	C,N,R	Perennial
	Tripterocalyx	*micranthus*	C,N,R	Annual
Onagraceae				
	Gaura	*coccinea*	C,N,R	Perennial
	Oenothera	*albicaulis*	C,N,R	Annual
Plantaginaceae				
	Plantago	*patagonica*	C,N,R	Annual
Poaceae				
	Aristada	*purpurea*	C,N,R	Perennial
	Bouteloua	*gracilis*	C,N,R	Perennial
	Buchlöe	*dactyloides*	C,N,R	Perennial
	Sitanion	*hystrix*	C,N,R	Perennial
Polemoniaceae				
	Phlox	*longifolia*	C,N,R	Perennial
Portulaceae				
	Portulaca	*oleracea*	Invasive	Annual
Solanaceae				
	Quincula	*lobata*	C,N,R	Perennial
	Solanum	*rostratum*	C,N,R	Annual
	Solanum	*triflorum*	C,N,R	Annual
Verbenaceae				
	Verbena	*ambrosifolia*	C,N,R	Perennial

Table 2. This table represents the plant species and families found on the Pueblo Chemical Depot in 2019. There were 46 total plants found, 6 invasive, 40 native, and 20 total families. Every plant native to North America fell under the three floristic zones described. There was a total of 24 perennial growth habit plants and 9 total annual growth habit plants, all invasive species found were annual plants. Floristic zones C,N,R stand for Chihuahuan zone, North American Prairie zone, and Rocky mountain zone, respectively.

Transformation and Fate of the Pharmaceutical Carbamazepine as a Model For Pharmaceuticals and Personal Care Products (PPCPS) in Agricultural and Aquatic Environments

Cody Shreffler, Travis Zuniga

ABSTRACT

It is well documented that pharmaceuticals and personal care products (PPCPs) are incompletely removed during the treatment of wastewater. Treated wastewater and sewage sludge generated during wastewater treatment represent two sources leading to PPCPs to become persistent in both agriculture and aquatic environments. With PPCPs becoming more persistent in these environments, it is important to understand the fate and transformation of these compounds. In this review, we will focus on the pharmaceutical compound carbamazepine (CBZ) as a model for PPCPs as environmental contaminants. CBZ is commonly detected in both agriculture and aquatic environments, but there remains a lack of understanding in its fate and transformation. There is also a paucity of information around the risk factors involved with the fate and transformation of PPCPs, such as toxicity and endocrine disruption. Future research will be aimed toward understanding the toxicological potential of PPCPs and transformation products (TPs).

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Introduction

Pharmaceuticals belong to a class of active compounds widely used in human and veterinary medicine, agriculture and aquaculture purposes. Due to the purpose of these pharmaceuticals, they are designed to remain stable in the harsh conditions of human and animal bodies, making them difficult to remove during wastewater treatment[1]. The anticonvulsant medication carbamazepine and its transformation product, carbamazepine-10,11-epoxide, are relatively stable compounds that are recalcitrant in many environmental niches and thus pose a problem to wastewater treatment and environments impacted by wastewater end products[2]. The potential for adverse risk in the environment by pharmaceutically active compounds and trace organic compounds has long been known, but the extent has yet to be adequately investigated[3]. In many parts of the world, the unregulated use of antibiotics in livestock breeding and aquaculture is much greater than regulated human use, and thus contributes to the presence of antibiotics in surface-, ground- and wastewater systems. Only a few effects have been described for pharmaceutically active compounds, such as bioaccumulation, endocrine disruption, certain kinds of diseases, acquisition of antibiotic-resistance genes in bacteria and changes to microbial populations or biomagnification[4]. Largely, however, the full extent and depth of PPCPs on local flora and fauna as well as the effects that this accumulation has on the health of each ecosystem as a whole remains obscure.

» *CBZ Transformation Pathways*

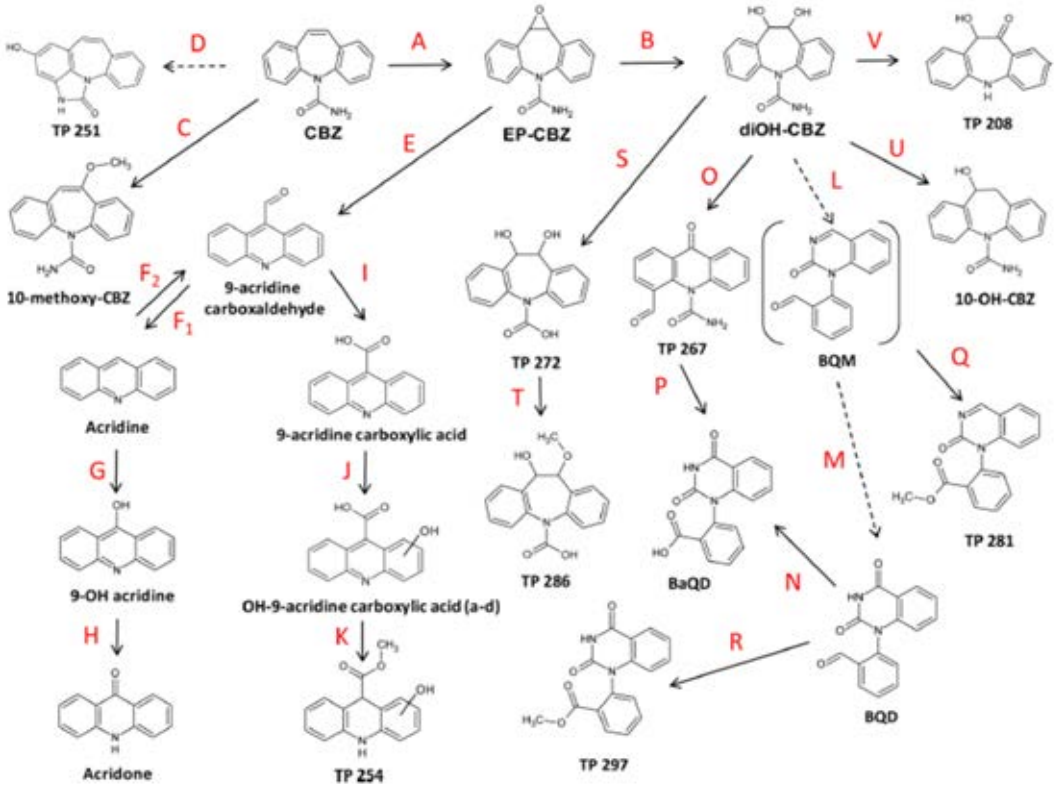

Figure 1: CBZ Transformation Pathways

Carbamazepine and its transformation product, carbamazepine-10,11–epoxide, are pharmaceutically active compounds that contribute to this growing environmental concern. As presented in Figure 1, CBZ can undergo many transformation processes, with the most common occurring in the conversion of CBZ to CBZ-10,11-epoxide (EP-CBZ) in humans and other biota. This can result in the conversion of EP-CBZ to acridine—a DNA intercalating substance—threatening multiple trophic levels of biota in both aquatic and terrestrial ecosystems[5]. The medication is regularly prescribed for the treatment of chronic conditions such as bipolar disorder, epileptic disorders, and certain depressive disorders which, in part, accounts for the large accruement of CBZ and EP-CBZ in wastewater systems across the globe[4]. The medication's molecular composition consists of a tri-heterocyclic aromatic ring structure containing a heteroatom nitrogen. The presence of aromatic structures in this substance confers on it properties related to aromaticity, electrophilic substitution reaction, and resonance stabilization. This means that the medication has reduced bioavailability in the environment resulting in steady accumulation and eventual steady-state concentrations in many niches[6].

» Input and Impact on Freshwater Organisms

PPCPs are detected in the environment at trace concentrations that range from below ng/L to μg/L and typical concentrations in treated wastewater and biosolids range from ng/L to μg/L and μg/kg to mg/kg respectively[8]. The prescription pharmaceutical carbamazepine has been measured in reclaimed wastewater and biosolids destined for land application with average concentrations of 93.6 ng/L and 66.4 μg/kg respectively[9].

CBZ is one of the most frequently detected PPCPs in aquatic environments[10]. While it has been recently shown to cause acute and chronic toxicity in a variety of non-target aquatic organisms, the full extent of the pharmaceutical's effects remain largely unilluminated. *Chen et al.*[11] discusses the acute exposure of CBZ and chronic effects of the drug on populations of *Daphnia similis.* This species of freshwater crustacean native to Lake Taihu, China is regularly subjected to CBZ concentrations ranging from .[24] to 8.74 ng/L. At concentrations higher than 6.25 μg/L, the CBZ seemed to inhibit the release of chitobiase and thus reduced the molting of D. *similis*. While this concentration is significantly greater than those reported in Lake Taihu, the study underlines how PPCPs like CBZ interact with non-target biological systems in unpredictable and demonstrably adverse ways. The study also demonstrated that chronic exposure to CBZ at concentrations of 0.03, 0.3, 3, and 30 μg/L over the course of 21 days reduced the size of broods, average amount of offspring per brood, as well as the mean number of broods per female. The detection rate of CBZ in Lake Taihu, Nanjing, and Yangtze River were all found to be 100%, with the latter containing concentrations as high as 1090 ng/L. While this study was largely focused on populations of D. *similis* in Lake Taihu, the detection rate for CBZ in other populations of organisms in Lake Taihu such as common carp (*Cyprinus carpio*), yellow catfish (*Pelteobagrus fulvidraco*), and crucian carp (*Carassius auratus*) were all found to be at or significantly near 32%8. The waterways of China serve as a model and similar CBZ accumulation and interactions with local biota can be observed in water systems around the globe12,14. In Nigeria, only an alarming 23.4% of respondents reported disposing of their unused medication in complete compliance with the national guidelines[13]. In countries like Germany, negligent disposal can result in the accumulation of PPCPs like CBZ at detection rates well over 1500 ng/L in surface water and STP effluent[14]. While a variety of exposure experiments have been conducted on many different populations of organisms, even a sequestered model like the organisms of Lake Taihu demonstrate the inadequacy of our understanding. In a variety of complex ecosystems across the globe, we understand comparatively little about how CBZ and other PPCPs affect individual organisms. The same is true of the emergent effects of CBZ on the interconnected trophic levels of each ecosystem as a whole, many of which end in the eventual accumulation of these compounds into the human ecosystem.

» *Input and Impact on Terrestrial Organisms*

Treated wastewater and sewage sludge (biosolids), two main products of wastewater treatment plants, are frequently applied to the agro-ecosystem. Incomplete removal and/or degradation of PPCPs in wastewater treatment plants is well documented and thus PPCPs are ubiquitous in treated wastewater effluents and biosolids[26]. Once in the agro-ecosystem, PPCPs may undergo several fate-determining steps such as, adsorption, desorption, transport, degradation, transformation, and uptake by plants which in turn can introduce PPCPs into the food chain and lead to potential human exposure[1]. Uptake of CBZ by root and fruit vegetables has been confirmed numerous transformation products (TPs) and carrot cell cultures along different vegetables grown under field conditions have also determined several TPs[15]. Metabolism of organic contaminants in plants is comparable to the liver and can be divided into 3 separate phases. Xenobiotics undergo processes such as oxidation, reduction, and hydrolysis during the first metabolism phase. This usually results in compounds commonly more reactive than the respective parent compound due to the introduction of functional groups. During the second metabolism phase, further conjugation of the reactive compounds occurs. This conjugation process usually increases the hydrophobicity. Increasing the hydrophobicity leads to the third metabolism phase which is detoxification and compartmentation[16].

Pathways, Types of Exposure, and Effects on Aquatic and Terrestrial Wildlife

» *Pathways and Exposure*

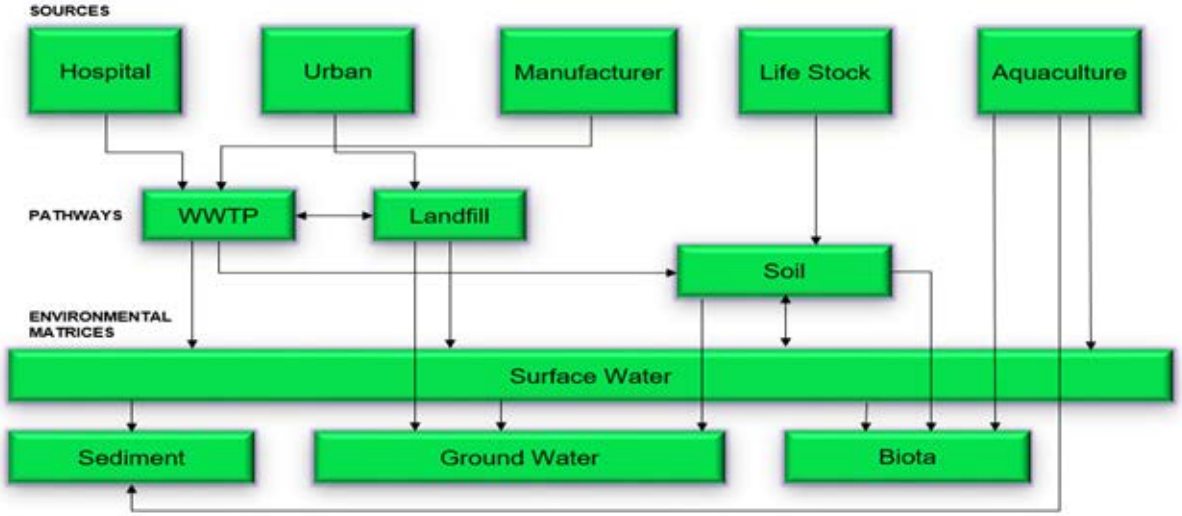

Figure 2: PPCP pathways through the human ecosystem into WWTP and the environment.

CBZ, and subsequently its TPs, find their way into wastewater systems and landfills chiefly through the municipal waste stream, and from there into the surface waters or ground waters through discharge of treated wastewater and as leachate from landfills[15-16]. The chemical properties of CBZ and many of its TPs make it difficult to remove through conventional methods of wastewater treatment. Coupled with the sheer volume of pharmaceuticals being released into water systems, gives these compounds virtually ubiquitous access to reservoirs of surface- and groundwater18. It is estimated that 50 to 150 g of CBZ is consumed per year in industrialized countries[19]. These estimations were based on prescribing data. Several studies have been conducted to characterize the method of disposal to determine how much of CBZ may be entering landfills and wastewater systems directly from individual households[15-18]. A study in the UK found that 63.2% of 400 households reported disposing of their pharmaceuticals with the rest of their household waste while only 21.8% returned their unused medication to a pharmacy and 11.5% reported disposing of them in a toilet or sink. A similar study conducted in Germany reported that of the nearly 16,000 tons of pharmaceuticals disposed of by Medicaid, 60-80% were disposed of in toilets or alongside household waste as well[14]. These statistics underline a disquieting pattern of systematic negligence among both the inadequately informed populaces and the agencies that have a responsibility to educate them.

» *Effects within Terrestrial and Aquatic Agricultural Systems*

Pharmaceuticals, which are well characterized for human toxicity, are entering the environment and many have significant enough lifetimes to potentially impact non-target organisms[18]. When non-target organisms are exposed to pharmaceuticals like CBZ there is potential for negative effects on exposed individuals. Many TPs of pharmaceuticals are also biologically active and may elicit toxic effects in non-target organisms. Organisms that have been chronically exposed to contaminants may develop increased tolerance or resistance in comparison to non-exposed individuals, but with associated costs, such as oxidative damage[19]. Ecosystems are filled with plant and animal relationships in which herbivores depend on primary producers to survive. There can be negative effects within entire ecosystems if these relationships are interrupted, either by one species not being available to the other or by xenobiotic substances entering the environment and disrupting naturally occurring phenomena[20]. This relationship extends to the health of an agricultural system as well. PPCPs like CBZ are able to accumulate, due to their recalcitrance, in wastewater which is used to irrigate farmland. From there it enters surface waters, which is a drinking water source for livestock or humans, or is indirectly used in large aquaculture environments for the raising of salmon or other fish stock[21]. A study conducted by Hampel et al. in 2013 indicated that, when exposed to concentrations of CBZ approaching 7.85 μg/L over the course of 5 days, populations of Atlantic salmon's expression of mRNA sequences shifted, with the highest changes being in the expression of pituitary hormones' encoding features like somatolactin, prolactin, and somatropin[21]. The results indicated that even relatively low concentrations of CBZ seem to have an effect on brain physiology—targeting similar processes in humans. What's more, the excited gene expression pathways were all associated with mRNA sequences that indicate a high degree of stress in Atlantic salmon. These types of large-scale and chronic exposures to populations of organisms that we depend on for sustenance and livelihood could potentially result in total collapse if

left unchecked. Further research needs be conducted in order to assess the vulnerability of agricultural systems to PPCP exposure, not only in populations of domesticated or raised fauna, but in the maintenance of crops as well.

Human Effects and Risk Assessment

» *Chemical Risk of CBZ and TPs*

Multiple studies have shown that human metabolites (HMs) and TPs can exhibit higher toxicity than the respective parent compound[20]. Carbamazepine is heavily metabolized in the human body and more than 30 metabolites, which are excreted via urine and feces, have been identified. Among these 30 are reactive metabolites, such as arene oxide[21], 9-acridine carboxaldehyde[22] CBZ 10,11-epoxide[23], an iminoquinone metabolite (CBZ-IQ), and an o-quinone metabolite (CBZ-quinone)[24], all of which contribute to the idiosyncratic toxicity associated with CBZ[25]. Indirectly, CBZ and its related TPs may pose a risk to the stability of agricultural systems worldwide. This could potentially result in the acute loss of crops or livestock as well as create degenerative trends in population sizes, representing millions of dollars in property loss and potential food shortages.

Analytical Techniques and Challenges

» *Analytical Techniques, Tools, and Challenges*

Pressurized liquid extraction (PLE) along with Ultra-High Performance Liquid Chromatography coupled with a triple quadruple mass spec (UHPLC/MS/MS) has proven to be a dependable source for the analysis of PPCPs and known TPs. While certainly not the only technique, the utilization of HPLC and mass spectrometry represents just one of the tools being utilized for monitoring PPCPs like CBZ and its TPs[29]. Over the past 25 years many new, highly selective, and robust analytical devices have surfaced and allowed for a greater resolution between parent compounds and their TPs. Peak separation challenges during sample analysis can play a part in analyte detection as TPs can show peak overlap as well as have the same molecular mass as other TPs or the parent compound. Methods involving Orbitrap MS, time of flight (TOF) MS detectors, and increased quadrupole application, such as in a triple-quadrupole system, have allowed for the quantification of even smaller concentrations of pharmaceuticals present in the environment. The coupling of novel sample-extraction methodology has also allowed for the probing of previously problematic environmental matrices like biosolids, landfill leachate, various soils, sewage sludge, and biological tissues. However, even with the advent of modern methodology and technology, the extent of PPCPs and their influence alongside other environmental stressors remains elusive. Considerably less is known about how individual PPCPs interact with multiple facets of an environment as well as how they influence the effects of other PPCPs or TPs that may be existing alongside them. Many of the methods being employed to monitor and identify PPCPs, alongside their TPs, follow similar myopic trends. Furthermore, there is even woefully less known about how the interaction between individual PPCPs may affect other emergent patterns of interaction, such as the accumulation of PPCPs within the trophic cascade, or when framed with effects of acute and chronic conditions after exposure. Additionally, identifying TPs without previously characterized standards has proven to be one of the most difficult aspects of monitoring PPCPs in the environment as well as in understanding the extent to which the compounds morph and engage with biological systems over time.

Gaps in Research and Future Research

It is imperative that our knowledge of the extent of risks posed by PPCPs, like CBZ, be encompassing and detailed. The application of informatics is essential to the understanding of these complex systems involving the nexus of PPCPs, environmental systems, and the human ecosystem. Additionally, TPs and their associated pathways pose risks to the environment and may be underestimated in their involvement with perpetuating contamination by existing in forms that can participate in reversible conjugation pathways back into their parent compound[30]. One of these is the TP of CBZ, Acridine, a known DNA intercalating agent. There are many TPs that have yet to be identified and even more still that may possess mechanisms of interaction with non-target organisms. TPs represent another hurdle that wastewater treatment plants must be aware of and treat for as well. Many of the TPs of CBZ have exhibited similar stability and recalcitrance as their parent molecule. This means that future research should be geared toward the identification of unknown TPs as well as assessing the dangers that both known and unknown TPs might pose to both terrestrial and aquatic environments. Furthermore, additional research assessing the specific risks that CBZ and its TPs have to endemic wildlife should be extensive in its range of survey as well as hierarchical. How PPCPs move through the trophic cascade of an environment, both horizontally between organisms of a similar trophic level and vertically, through predation, remains largely unelucidated. Without this plethora of information, devising efficient and effective removal techniques remains challenging.

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1. Figure 1: CBZ Transformation Pathway; Environ. Sci. Technol. 2015, 49, 20, 12351-12362 Publication Date: September 29, 2015 https://doi.org/10.1021/acs.est.5b02222

2. Figure 2: Pathways Outline; PPCP pathways through the human ecosystem into WWTP and the environment.

Justice for All: John Rawls Theory of Justice and the Green New Deal

Emma Sommer

ABSTRACT

The Green New Deal (HR 109/SR 59) is calling for a quick change in United States environmental and economic/social policy, with focus on the effects of climate change. By applying John Rawls' theory of justice, precisely the original position and the two principles of justice to the proposed change in policy, this paper finds that the resolutions would support the ultimate goal of justice. With uncertainty about one's place in society, changes towards equality and an environment with cleaner air, water, and land are in everyone's favor. As justice is equal to fairness, the current state of regulations on the economy and the environment are unjust. They are benefiting the energy industry, while hurting low-income families who have to deal with the effects. Guided by Rawls theory, the U.S. approach to these issues would have to change drastically, and the Green New Deal is a version of that.

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I. Introduction

The "New Green Deal" is concerned with America's most prominent modern-day issues of climate change and inequality. It is a pair of congressional resolutions consisting out of the House resolution 109 and Senate resolution 59 that were introduced and sponsored by Representative Alexandria Ocasio-Cortez from the Democratic party. These resolutions were introduced because of increasing effects of climate change on the planet as well as future predictions on the extent of these effects. They are calling for a quick change in United States environmental and social policy. The US has 20% of the global greenhouse gas emissions and the greatest income equality in the United States since the 1920s (Ocasio-Cortez, 2019). Right now, the Environmental Protection Agency (EPA) is responsible by creating regulations for emissions with legal authorization through the Clean Air Act (United Sates Environmental Protection Agency). As HR 109 clearly states out that the regulations are insufficient at this point in time, it seeks to set higher goals for the EPA including "net-zero greenhouse gas emissions" (Ocasio-Cortez, 2019).

John Rawls introduced political philosophy that can be applied to achieve justice in society in his book, A Theory of Justice in 1971. It is a guideline for just decisions that go beyond utilitarian ideas. His theory of justice includes the two principles of justice, the original position, and the veil of ignorance. These concepts can be easily used to determine if legislation, decisions or systems are just under his perception. In this paper they will be used to decide whether current legislation is serving that ultimate goal of a just society and if steps towards a more sustainable future like "The Green New Deal" can be justified under his idea of justice. After describing the core objective of the Green New Deal, the paper will outline the essentials of Rawls' theory on justice. It will then use his theory to make an argument for AOC's proposed legislative change and the direction the resolution is aspiring.

II. The Green New Deal

The goal of the Green New Deal is the reduction of greenhouse gas emission and the dissolving of social problems like economic inequality and racial injustice as well as creating new jobs in the clean energy industry (Friedman, 2019). It includes investments in clean-energy technology, infrastructure, transportation, and research, and calls for an economic transformation. The large investments made by the plan are suggested to be paid by introducing carbon and emission taxes as well as a 70% marginal tax on incomes over $10 million.

In detail the proposal explains a duty:

- To achieve net-zero greenhouse gas emissions through a fair and just transition for all communities and workers.
- To create millions of good, high-wage jobs and ensure prosperity and economic security for all people of the United States.
- To invest in the infrastructure and industry of the United States to sustainably meet the challenges of the 21st century.
- To secure for all people of the United States for generations to come- clean air and water; climate and community resiliency; healthy food; access to nature; and a sustainable environment.
- To promote justice and equity by stopping current, preventing future, repairing historic oppression of indigenous peoples—including communities of color, migrant communities, deindustrialized communities, depopulated rural communities, the poor, low-income workers, women, the elderly, the unhoused, people with disabilities, and youth (referred to in this resolution as "frontline and vulnerable communities").

These goals are to be accomplished by:

- Repairing and upgrading the infrastructure in the United States.
- Meeting 100 percent of the power demand in the United States through clean, renewable, and zero-emission energy sources.
- Overhauling transportation systems in the United States to remove pollution and greenhouse gas emissions from the transportation sector as much as is technologically feasible.
- Providing resources, training, and high-quality education—including higher education—to all people of the United States, with a focus on frontline and vulnerable communities, so that all people of the United States may be full and equal participants in the Green New Deal mobilization.
- Directing investments to spur economic development, deepen and diversify industry and business in local and regional economies, and build wealth and community ownership. While also prioritizing high-quality job creation and economic, social, and environmental benefits in frontline and vulnerable communities, and deindustrialized communities that may otherwise struggle with the transition away from greenhouse gas intensive industries.
- Providing all people of the United States with- high-quality health care; affordable, safe, and adequate housing;

economic security; and clean water, clean air, healthy and affordable food, and access to nature (Ocasio-Cortez, 2019).

The name of the resolution is inspired by the "New Deal" by President Franklin Roosevelt, which introduced a huge reform of the economy, social programs and taxation during the Great Depression. Major parts of it are also guided by reports from the United Nations (Janes, 2019).

There are two different sides on the issue of climate change, as well as the resolution itself. In the United States, they are broadly represented by the Democratic and Republican party with few exceptions. Much of this divide is caused by the increasing party polarization in the US as representatives from different parties will not support each other's proposals and legislation.

First of all, there are arguments that go against the existence of climate change, and therefore the necessity of a change in legislation. President Trump is the most prominent member of that part of the debate. He rejects the existence of climate change as a whole and is the force behind the United States leaving the Paris agreement in 2017 (Thomas Reuters Foundation).

But there is other criticism about the resolution, especially linked to the huge investment of the government. In times of a rising deficit, some argue there is no room for more costs. Right now, the deficit of the United States is around 1060 billion dollars (Amandeo, 2020). Also, a united Congress and Senate would be needed to pass actual legislation because of the polarization, and the House is currently controlled by the democratic party, while the Senate has a republican majority. Adding to that the resolution would affect many jobs in the Midwest that are viewed as politically critical in terms of Democratic support and that might lower the support from democratic representatives. (Janes, 2019). Experts also believe that 0% carbon emissions in 10 years, which is what the Green New Deal calls for, would be "socio-politically infeasible", even though it is technically possible. (Rizzo, 2019).

But there is another, more positive side to this. A poll by Yale University found out that 81% of Americans actually do support a change in legislation in order to transition into a more sustainable future (Leiserowitz, 2018). As well as more liberal politicians and climate advocates have voiced their support for the proposal. The idea to act against climate change has gotten bipartisan support and the resolution opened up a debate about the issue in the whole country. (Janes, 2019). In both chambers of the Congress the "Climate Solution Caucus", a congressional group founded to develop legislation on climate change, has members of both parties. In the group legislators try to overcome polarization and work together on a solution for warming temperatures worldwide. An article by the Guardian even calls climate-change-deniers the "minority" in the Republican party (Milman, 2017).

The resolution starts by pointing out all the effects of climate change like increasing wildfires and rising sea levels and continues to name impacts of climate change in the future like mass migration (Ocasio-Cortez, 2019).These effects of climate change as well as rising social and economic inequality are threatening the stability of the United States and are causing huge economic impacts. Wildfires, polar vortexes and hurricanes are creating huge amounts of costs for the government as they destroying the lives and cities of many Americans. The government has to pay for protective measures, rescue missions, and to rebuild the cities after the chaos. As the United States is a leading representative in terms of economy and western values, it should act as a leader and take steps towards a more sustainable future. The inequality, poverty and racial injustice in the United States today does not match its status as a first nation country, and it needs to be addressed. These issues are real and even though the resolution is somewhat vague, it is important to open up a debate about these topics and start working on solutions.

III. Rawls theory of justice

John Rawls is an American philosopher that introduced a theory of justice that can be used within judge legislation and ensure the fairness of such. In is a theoretical framework which can be applied to various decision-making processes in order to determine if the proposed policies or changes in legislation would be considered just and favorable for society.

His idea is "to set up a fair procedure so that any principle agreed to will be just" (Rawls, 118). Everyone who is concerned with a decision and needs a way to test if the decision will be just can use his principle. This can be especially useful for legislators or people that work in the government and make decisions that impact a society. His theory is based on a thought experiment.That is called the "Original Position" and it is an external viewpoint; meaning that one imagines she is crafting a new political system from the outside. One has to put herself behind the veil of ignorance in order to achieve that viewpoint. That means that one has to ignore her own personal characteristics and biases when judging a principle. Rawls says to achieve that "we must nullify the effects of specific contingencies" (Rawls, 118). Her decisions should be made as if one have no particular knowledge of her own circumstances, such as gender, race, particular talents or disabilities; age, social status, particular conception of what makes for a good life, or the particular state of the society in which one lives. However that person would "know the general facts about human history" that are needed to make such a decision such as "principles of economic theory", "laws of human psychology" or any other "general facts [that might] affect the choice of the principles of justice"(Rawls, 119). With these circumstances Rawls argues that decisions can be made rational and fair. People would choose principles of justice that do not benefit one certain social class but were fair to everyone. No one has any of the particular knowledge about themselves that he or she could use to develop principles that favor his or her own particular

circumstances and "no one is in a position to tailor principles to his advantage" (Rawls, 16). There is no self-interest in choosing those principles, because no one knows if they are choosing principles that would make their lives harder (Rawls, 16).

Following the original position Rawls argues that people would choose two basic principles of justice to guide them. They can be used to "assign[..] rights and duties in the basic institutions of society and [..] define the appropriate distribution of benefits and burdens" within society" (Rawls, 4). The first one is the guarantee of liberties that are basic, equal and secure "with a similar scheme of liberties for others" (Rawls, 53). The second one is the difference principle, which talks about social and economic inequality. They are only justified if "they are both reasonable and expected to be in everyone's advantage and attached to positions and offices open to all" (Rawls, 53). The summary is that inequality is only justified if the worse off are still benefiting from the distribution of property. This means that all distribution of property must still be in the advantage of the people on the bottom that have the least amount of property. If a policy results in inequality and the lower end of society suffers more than it would before as an outcome the policy is not just. Rawls interpret "justice as fairness" and if the policy to judge is not fair to the people that struggle the most, it is not justifiable under Rawls' philosophy (Rawls, 10).

IV. Circumstances in the United States today

In the United States, today, there is a huge divide in the population in terms of economic opportunities, influence in politics, and exposure to pollutants. The Green New Deal addresses a variety of topics including energy production, the environment, and economic disadvantages. To apply Rawls theory of justice on the Green New Deal it is important to understand the circumstances in the United States that would be influenced by a legislative change in line with the Green New Deal. As the Green New Deal covers many different topics in one broad resolution this paper will use energy production and their ability to influence politics as well as results of economic inequality as an example.

Current legislation definitely benefits energy producers that use nonrenewable energy sources. In 2017, 77.6% of the U.S. energy came from petroleum, natural gas, and coal, which are all nonrenewable (US Energy Information Administration, 2018). The production of electricity through these means have negative impact on air quality, water quality, and the environment as a whole. Politicians are benefiting from getting financing and donations from corporations that produce the nonrenewable energy. In the 2016 election circle, the coal mining industry contributed a total of 13,751,235 US$ to politicians and parties and 97% of that money went to Republican recipients. In 2019 to 2020, Donald Trump as an individual received 282,009 US$ for his campaign (Center for Responsive Politics). The industry itself had a total revenue of 29.6 billion US$ in 2019, with profits falling in the recent years (IBIS world).

And that is the money spent and earned by the coal industry. There are more industries that influence the policy outcome today by lobbying. State governments create legislation that makes it easier and cheaper to extract raw materials and politicians receive campaign contributions. This shows how much power these industries have over policy decisions. Their energy production has been proven to contribute majorly to the pollution of the environment but there has been little change in restrictions in order to prevent further pollution. The newest president Donald Trump specifically supports subventions for the dying coal sector and has given less attention to investments in renewable energy sources like the ones mentioned in the Green New Deal. But who are the ones that are penalized by the impact of the energy production? Lower-class citizens that cannot afford to move when water and air quality is low and threatening their health. The quality of the air is proven to have negative health impacts. For example, in the Bronx, a part of New York City with lower income classes represented, the air quality is linked to higher rates of children's asthma in the area. Because of high poverty rates the people living in the area cannot leave and are forced to breath the polluted air (Ocasio-Cortez, 2019). This is also due to the widening gap between social classes today. Ocasio-Cortez mentions in the resolution that income equality is at its highest point since the 1920s. The Gini-Index which measures income inequality in all countries around the world comes to the same conclusion. In recent years it has gone up and income inequality has been worsening every year in the United States (Chappell, 2019).

V. Justice applied to Green New Deal

The theory of justice that Rawls introduced can be used to evaluate the proposed changes of the Green New Deal and the effects on the condition of the United States today.

Section IV illustrated the power that energy corporations have in influencing energy policy. The Green New Deal proposes a change in energy policy with more focus on renewable energy sources. The ultimate goal here is to achieve "net-zero greenhouse gas emissions", which cannot be met with energy production through coal burning (Ocasio-Cortez, 2019). Going into the original position, one would choose legislation that would eliminate pollution and serve the interest of more than just the energy sector. Removing one's biases and personal viewpoint from judging the current energy production sector the amount of power these

corporations have would be perceived as unjust. Few individuals benefit economically from the current state of energy production while many others have to live with the pollution they are creating. The Green New Deal proposes changes into a more sustainable future with no pollution. Without having knowledge about one's position in the society this legislation would be supported with the Rawlsian viewpoint. With this thought experiment no one would know if they would be the heads of these companies that economically benefit from the pollution or the children in the Bronx that suffer. Therefore, legislation in line with Rawls original position would actively support the switch to more renewable energy sources that do not pollute the air and water as much and try to limit the power of energy producers that pollute. The support for stricter legislation with penalties, more effort into clean energy and extreme reduction of carbon emissions would be high in all parts of society to ensure good living conditions all throughout the US. The Green New Deal tries to achieve exactly that by putting equality in terms of education, healthcare, access to a clean environment, economic opportunity, and efficient and clean transportation systems as a priority. No matter where in society one would find herself the legislative changes that would result in line with the Green New Deal would improve one's situation. An energy sector that is not reliant on finite resources and is not polluting the environment is a change that can be perceived as just and fair under Rawlsian political philosophy.

As Ocasio-Cortez mentions in her resolution that the income inequality is at its highest point since the 1920s. Applying the difference principle of Rawls the social issues and the disadvantage of certain racial and social groups, she picks on would not be justified. The Green New Deal proposes investments in high-quality education, creation and access to high-quality jobs for marginalized communities, and support for low-income families. These proposed directions in economic and social policy would improve the current circumstances in the United States. On basis of the original position a change in economic policies that would ensure more equality and redistribution of property would be just. A tax on billionaires of 70% in order to finance the economic transformation, investment in infrastructure, and clean energy would be justifiable, because everyone would benefit from it. No matter what place you have in society, a better transportation system, cleaner air and water as well as economic development would benefit you. Keeping the current system of inequality alive and not investing in creating better economic opportunities to improve the Gini-index would against Rawlsian philosophy. Keeping this system alive would only be justified under Rawls if the worse off were still in a better position than with a policy change. But the Green New Deal is especially directed at these groups and aims at improving their living conditions and opportunities in Americas society. Therefore it would be unjust to maintain the current economic system because, firstly, through the original position, one might end up in one of the marginalized communities. Second of all, it violates the difference principle.

VI. Discussion

Jan Kunnas comes to the same result in his application of Rawls theory of justice to warming climate. In his paper he examines the economic growth of Finland over the last decades. He finds that the expansion of Finland economy, like all other developed countries, are correlated to increase in carbon dioxide emissions. In comparison to the rest of the world, developed nations are building up an ecological debt because they are overusing their environmental space. With rising carbon emissions, the effects of climate change become more intense as the average world temperature is increasing. Many experts believe that this will lead to rising sea levels depending on how high the average world temperature is. A country that would suffer extremely under this raise would be Bangladesh that produces only 0.06% of global emissions. Rising sea levels would overflow up to 20% of its landmass as a result of climate change. The future generation of the poorest countries would be the ones carrying the burdens of climate warming not the developed nations like Finland. Jan Kunnas argues that, under the principle of justice by Rawls policy, change must happen. Under the original positions no one would gamble with the fact that they could be one of Bangladesh's future generations suffering from these effects. Therefore, governments of the developed world must change their direction away from achieving economic growth and more towards a just future. It is important to notice here that Kunnas is applying the original position across generations because one doesn't know if she is in our generation or the next generation. This paper applies it within generations since one doesn't know whether she would be in the 1% or a poor person in the Bronx, one in the original position would want a green new deal policy to ensure clean air and a limit to income inequality. The same conclusion is drawn because of that uncertainty of where one might end up the new policies created should all go towards protecting the environment and placing that goal above others, including economic success (Kunnas, 2012).

The results of Kunnas matter to this paper because sustainability and pollution is an international issue. Even though the Green New Deal is a domestic policy the implementation of investments in more sustainable energy production for example have international relevance. If the United States moves towards a more sustainable future it serves as an inspiration to the rest of the world. His paper also shows how the theory of justice is universally applicable for domestic, international, and across generation policies. It can be applied to a variety of topics and countries. In his paper the focus lays on judging the current state of the world

with special detail to Finland. This paper takes a look at current circumstances in the United States as well as judging a resolution that is aimed at changing these circumstances.

VII. Conclusion

By adopting the Rawlsian original position to judge the proposed legislative directions of the Green New Deal one can identify them as being just. When one's biases and personal attachments are removed from deciding if policies in line with the Green New Deal should be implemented, it is possible to make an uninfluenced judgement. This paper finds that by using Rawls theory of justice one would argue for a policy change when looking at current circumstances in the United States. Following the original position new legislation within the frameworks of the Green New Deal would help reduce pollution and move towards a more sustainable future. Without knowing one's spot in society everyone would want an environment that is clean and an economy that benefits the most people as possible. No one would agree to give corporations that much power over the policies concerning for example energy production. The Green New Deals proposed move towards zero net emissions and investments in clean energy production would be in line with Rawls perception of a just legislative change.

Adding to that the direction of the resolution is important and should be further explored. The Green New Deal offers a future that includes everyone and helps to create support for those that need it. Taxing billionaires and taxing companies that produce too much emissions is justifiable. These few people have to contribute to society and have to be part of the solutions. At a certain point of wealth, you have enough money and it is impossible to spend it all. That's the point where you have to give back to communities that are marginalized and have disadvantages. This especially applies to companies that earn their money from industries that pollute the environment with their practices. Polluting the environment, no matter if it's the air or water is always wrong even if you believe that climate change is a hoax, and the government has to enforce laws that protect it for a future where our children's children can still live in. That is the basic principle of sustainability and even if it is not possible to fully relieve the environment from economic burdens, it should always be the goal.

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