relevant information to determine success or failure for a new or already established program: *Cost*, *Operability* and *Penetrability*.

Cost: While LEED requires trained and experienced personal (that is not usually available in the Colombian market), EDGE and the "do it yourself" proposal, can involve stakeholders (such as the project manager, ordinary designers and even the owner) with minimum level of training. This is one of the causes for the reduce cost in EDGE. Moreover, when the costs associated with both certifications were analyzed (Since September 2017, the cost for EDGE is fixed in local currency. In October 2017, certification for a commercial building costs USD9.970 (IFC, 2017) (according to exchange rate of that month). The minimum cost allowed for LEED is USD9.920 (USGBC, 2017) but its price will increase per square feet. Taking reference exclusively to the table costs for registration and design and construction certifications posted in the EDGE official websites, the costs of EDGE were between 45%-55% of those for LEED in projects of similar type and size (IFC, 2017). It is vital to mention here that this study does not aim to compare the two standards, and the numbers are only presented to provide an overview for the readers who may not be familiar with EDGE. The comparison between the two certificates, given the different scope and strategy of the two programs, may not be easily possible; and even if possible, the comparison must be made among the "return-on-investment" for buildings certified under each program.

Operability: Review of the literature and interviews with specialists indicate that LEED is not a basic/user-friendly tool to be used without enough training. Application of LEED, on the other hand, requires preparation, and a long-term dedication to obtain the results expected by the certifications. Yudelson states that the future rating certification systems for design, construction and operation, must be founded on three principal features: being smart, simple and sustainable. It means being easily accessible with a technology easy applicable and comprehensible such that no special training is required for the use of the tool or system (Yudelson, 2016). Exploring EDGE software shows that it is not too difficult to understand the philosophy, learn the method and work with the software and its different tabs. The "do-it-yourself" proposal should stimulate the knowledge spreading and the direct involvement for the team and authorities inside the projects, in the achievement of the certification.

Penetrability: The adoption of a new rating certification program will be highly influenced by the two previous features. Providing tools with a user-friendly nature on the one hand, and increasing the level of awareness among high-level policy-makers and project-level decision-makers on the other hand, may lead to a higher acceptation level from the users. Support from the government will be a key factor; the involvement of the entities in charge of regulations for the building sector and construction standards can pave the way for and promote adoption of new rating systems in emerging markets.

Structure of the survey

The survey questionnaire was developed through an analysis of EDGE (software and the documentations), adapted for the Colombian case, and arranged in three different dimensions according to the selected subject matter for each one. The target participants were selected among the LEED and EDGE auditors/specialized professionals, certification clients/users and civil servants in entities in charge of regulation or support of this type of programs in the government (all having experience in the local Colombian market). The entire group of interviewees had the domain knowledge (and experience) about LEED and some of them also had experience with applying EDGE in the Colombian market. As a result, two versions of questionnaires were prepared and the participants were directed to each, based on their level of familiarity with EDGE. The initial part of both versions (questions 1 through 21) included statements about LEED. While the second part (questions 22 through 38) was asking about EDGE in the first version; in the second version, it was providing general statements (regarding the promises that EDGE gives), without naming the name of EDGE.

Two of the first EDGE and LEED auditors as well as representatives from CCCS were initially contacted and the survey was disseminated trough their databases. Finally, a total of 17 responses was received, out of which, eleven filled the LEED-EDGE version, and six filled the version without direct reference to EDGE. In order to be able to aggregate and analyze the results quantitatively, Likert scale was used with seven choices: Strongly/Moderately/Slightly agree, Strongly/Moderately/Slightly disagree, and I do not know. No open questions were provided. The definition of the categories for the set of questions will stem from this analysis and the previous content of the document.

RESULTS, DISCUSSION & CONCLUDING REMARKS

1. Cost – Majority of the participants in our study believed that the cost of LEED certificate is too high and increases proportionally with the budget and complexity of the construction projects. They believed that such a high cost is a main barrier for adoption of this certificate in construction projects within Colombian construction market. When it came to EDGE, among the experts who were familiar with this tool, there was not a clear agreement on its affordability; only 45% believed that EDGE is affordable for "any type" of projects and about the same portion believed that the EDGE costs still fairly increase in proportion with the project budget.

Most of our participants, even the ones unfamiliar with EDGE, were aware of availability of other energy efficiency certification (or programs) in the market, at a lower cost of implementation than LEED. The interesting observation in this regard, was that around 20% of those who were familiar with EDGE, still disagreed with availability of a replacement for LEED at a lower cost. This may indicate that such experts do not consider EDGE as a replacement for LEED in Colombian construction market, which in turn, can be due to the limitations of EDGE. Majority of our participants believed that LEED is by far the most popular energy efficiency program in the commercial construction in Colombia. However, half of our participants (and most of the ones who were unfamiliar with EDGE) believed that due to the high costs, in some projects, although the LEED-suggested process is followed, the team avoids payment to grant the certificate.

2. Operability –Among those experts who were familiar with both LEED and EDGE, a rough majority (of 55%) believed that EDGE is a strong tool to popularize the use of energy certification in Colombian construction sector. All participants in this study described LEED as a dynamic tool that adapts well to various projects, regardless of specific requirements of the project. While an absolute majority of the participants believed that LEED is a suitable tool for large-scale projects (budgeting above $100,000), when it came to the smaller projects (under $1,000), half of the expert disagreed with the applicability and suitability of LEED. This observation can be justified given that the cost per square feet in small projects is generally high (due to the fixed overhead standard costs of the certificate). All participants agreed on the need for certification tools in Colombian market to cover energy efficiency evaluation of such small projects.

A great majority of the participants believed in the positive role of LEED in sharing project information among the project team (which is not achieved by adoption of EDGE). 65% of our participants claimed that LEED is a user-friendly tool, even for the first-time users, however, about the same portion (not exactly the same individuals though) believed that there are other alternatives that are easier to implement. Those participants were a clear majority (82%) among the experts who were familiar with EDGE. When the experts who had worked with EDGE were questioned whether there are other energy efficiency certifications which are easier to use than EDGE, only about 27% gave positive answer. About the same portion said they are not aware of such tools, and 46% believed that such a tool may not exist. Majority of those who were not familiar with EDGE, mentioned that Colombian market does not offer any sustainability certificate program easier to apply than LEED; but most of them emphasized the need for such a certification program. About 75% of the experts who had worked with EDGE, believed that it is easy to use, and slightly above half of them believed that almost any person in the project can use EDGE with minimum training.

Regarding the comprehensiveness of LEED, the majority explained version 4 of LEED as a truly new and revolutionary way of certifying buildings, and believed the 21 categories offered by it competently cover most of the building types in the Colombian market and are enough for the purpose of certification. At the same time, about one third of experts who had worked with LEED V4, mentioned that in spite of advertisements, this version has not simplified nor streamlined the process of certification. On the other hand, while 55% of the experts who had worked with EDGE believed that its five major pillars are enough for calculation of energy/material consumption and saving; the majority of them (around 64%) argued that the four tabs (design, energy, water and materials) do not suffice for a good assessment of the project. Even those who were not familiar with EDGE, when provided with the list of five pillars and the four tabs; while agreeing on efficiency of the five pillars, considered the four tabs insufficient for certification purposes. Our study showed that most Colombian experts who have worked with EDGE consider the 20%-20%-20% objective as an attractive goal (which may stimulate the adoption). Even those who were not familiar with EDGE, were supportive of such an idea. A clear majority of experts who work with EDGE in Colombian market, suggested that providing the base case key assumptions for more than 350 cities around the world, as well as announcing the list of (more than 130) developing countries as the main scope of application, will help to increase the adoption of EDGE, particularly in developing countries such as Colombia.

3. Penetrability – We asked our participants to compare the trend of increase in penetration of LEED over time, in Colombian market versus the US market. We questioned them about the reasons for lack of increase in penetration within the specific market of Colombia. High cost of the certification; and complexity of the process, involving extra activities/calling for hiring and training more personnel were voted for, respectively as the top two reasons. While closely half of the experts blamed the lack of LEED penetration increase on inadequacy of advertising and lack of brand recognition in Columbia, the other (comparatively smaller) half disagreed with this item being a major cause. More than $3/4^{th}$ of all experts in this study (including half of those who were unfamiliar with EDGE) believed no other program or certificate for energy efficiency has the chance of reaching more penetrability and popularity than LEED.

We asked the experts who were familiar with EDGE, regarding the aspects to be focused on, in order to increase the penetration of EDGE in developing countries (such as Colombia). The results were respectively: ease of the access and user-friendliness; promoting the brand recognition; and the low cost compared to other alternatives (the same three parameters were emphasized by those experts who were unfamiliar with EDGE, as requirements for adoption of any new certification program). They also strongly emphasized on the role of IFC collaboration with the private sector, as a crucial success factor for EDGE. More than 90% of the participants emphasized on the role of local and national government, and regulation requirements for increasing penetration of building energy efficiency certifications in the Colombian market. At the same time, around 65% of the experts participating in this study believed that Colombia is ready for institutionalizing a certificate program of its own, similar to LEED. When it came to EDGE, about 55% of the experts (who were familiar with EDGE), believed that Colombia is prepared to institutionalize EDGE as a certification program. Among the expert who had never worked with EDGE, a larger majority (among 85%) believed that Colombia is prepared for a program with promises such as those given by EDGE.

If successfully realizing its goals, EDGE can identify itself as an important tool to fill the lack of fund for adopting traditional certifications in developing countries. However, as the results of this study shows, EDGE must not be considered as a “replacement” of the existing standards (such as LEED). It is worthwhile to emphasize once again, that in the comparison of EDGE and LEED costs, it is important to differentiate aspects as the expected revenue obtained from application of each, resources required and the brand recognition gained through years of application. However, the (comparatively) lower investment and training required, can provide a promising overview for adoption of EDGE within Colombian market.

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Methodology to Measure Real-Time PM 2.5 Levels in Equipment Cabins

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Abstract

The Construction industry is one of the most hazardous industries in the U.S. Construction workers, on a daily basis, are exposed to numerous risks while performing a range of activities involving construction, alteration, and/or repair. Dust and diesel exhaust emissions from construction equipment are considered harmful to the workers in the long run. Several studies have highlighted the ill-effects of constant exposure to diesel fumes and dust, but without directly relating the conditions at a construction site. A variety of construction activities generate tons of $PM_{2.5}$ and other dust particles which are suspended to the atmosphere. These particles pose a threat to the environment and humans alike. The method that is currently in practice measures the amount of exhaust gases released by the construction equipment and not the amount of dust and emissions the equipment operators are constantly exposed to. This paper presents a novel methodology to measure $PM_{2.5}$ concentration levels inside the operator cabin of construction equipment. The concentrations of $PM_{2.5}$ were measured using an aerosol monitor, TSI DustTrak II 8530. The measuring device was placed (1) inside the operator cabin while collecting data from an excavator; and (2) inside the DustTrak II 8535 enclosure while collecting data from an open, cabinless dozer. DustTrak II 8530. The results of this study can be used to develop studies to determine the exposure of equipment to diesel exhaust emissions.

Introduction

The construction sector is one of the fastest growing sectors in the US market (Forbes 2017). The construction industry utilizes massive amount of energy, in various forms, to construct residential, commercial and infrastructural projects and subsequently producing massive amounts of waste, while deteriorating the quality of air. According to the UK Green Building Council (UKGBC), the construction sector uses more than 400 million tons of material a year, many of which has an adverse impact on the environment (Willmott-Dixon Report 2010). Most construction activities involve the use of heavy nonroad equipment that are known to generate dust and emissions such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulate matter (PM). These emissions impact worker health and reduce the quality of the surroundings as well as the working environment (CEQA 2012). Based on a report by the National Toxicology Program of the Department of Health and Human Services, continuous exposure to diesel exhaust is believed to be cancerous to humans and animals (NTP 2000, NIOSH 2016). In addition, according to a report prepared by the Willmott Dixon Group, construction activities are responsible for nearly 23% of air pollution. The report also states that almost half of the gases responsible for climate change are a result of construction activities (Willmott-Dixon Report 2010).

Construction activities generate fugitive dust and particulate matter in many ways. Equipment exhaust, equipment travel, and working on unpaved surfaces result in the presence of particulate dust in the environment. A recent report published in the Portland Business Journal conducted by Oregon Environmental Council showed that approximately 460 individuals die prematurely each year due to continuous exposure to diesel exhaust resulting in health issues related to brain, heart and lungs (Portland Business Journal 2016). Different pollutants emitted by the diesel engines affect the health of workers in more ways than one. For instance, according to the Office of Environmental Health Hazard Assessment (OEHHA), long-term exposure to diesel exhaust is one of the most common causes of cancer. The report estimates that constant inhalation of diesel exhaust is the cause for about 70% of cancer risk that an average Californian faces (OEHHA 2016). Another study by Fang et al. (2013) found that constant exposure and inhalation of particulate matter is globally responsible for nearly 3% of cardiopulmonary and almost 5% of lung cancer fatalities. This is backed by a study conducted by Jarvholm et al. (2003) on heavy equipment operators and truck drivers in Sweden. The study involved several craftsmen such as carpenters and electricians along with the general population and truck drivers. The study reported that the rate of lung cancer was higher among truck drivers and heavy equipment operators than all the other participants of the study. In addition, the International Agency for Research on Cancer (IARC) considers diesel exhaust to be a probable human carcinogen (IARC 2012). This was confirmed by a study conducted by Mauderly et al. (1992), which concluded that exposure to diesel exhaust led to cancer due to possible cell mutation and DNA damage. In addition to this, the California EPA estimates that constant inhalation of diesel exhaust is accountable for about 70% of all cancer risk from air pollution in California (OEHHA 2003b).

Previous Works

Emissions from mobile sources are generally estimated and predicted by the EPA and other public organizations using the EPA Nonroad Model and the California Air Resources Board offroad model. These models are used to estimate the levels of emissions based on tests done on the respective engine dynamometers (EPA 2004). These models, however, do not provide real world emission data. To determine real world emissions produced by nonroad construction equipment, several studies use portable emission measurement systems (PEMS). The use of PEMS is also backed by the EPA. PEMS are devices, connected to the exhaust of onroad and nonroad equipment, to measure the various exhaust gases. A group of researchers have used PEMS to create a modal-based model to measure and predict real time emission data from construction equipment (Abolhasani et al., 2008, Frey et al., 2010, Heidari et al., 2015, Rasdorf et al., 2010). The PEMS device is placed inside a safety cage on the construction equipment, while the PEMS sensors are attached to the engine to collect several engine data. In addition to this, a probe is installed inside the tailpipe of the construction equipment to sample the exhaust emissions. This setup helps researchers obtain a real time emissions data of various exhaust gases such as NO_x, PM, CO_2, CO, O_2 and NO. The researchers used these exhaust data and the engine data to develop a model to predict emission rates from various construction equipment.

The methods mentioned above, however, measure the amount of exhaust gases released by the construction equipment and not the amount of gases the equipment operators are constantly exposed to. Additionally, the method to setup the devices is tedious and time-consuming. A research conducted by Frey et al. (2007), shows that the majority of the components had to be pre-installed a day prior to the day of data collection. The PEMS also had to be installed in a steel or metal cage and placed on the equipment as shown in Figure 1. this setup would hinder the productivity of the equipment operators, thereby impacting the study process, while affecting the concerned construction project.

Figure 1: PEMS mounted on a nonroad equipment (Google 2017a)

The objective of this paper is to present a novel idea to measure the amount of exhaust gases and dust equipment operators are exposed to while seated in their equipment cabins.

Methodology

The methodology section provides a brief overview of the different entities involved in the data collection process. The methodology section sheds light on the location and scope of the construction project in question, the sensor used to measure the particulate matter produced by the activities and the equipment at the project, the different construction equipment involved in the construction project, and the method used to collect data.

Selection of Construction Project

The present study was conducted in Corvallis, a city with a population of 55,298 in Central Western Oregon. This region of Oregon has a subtropical climate with an average temperature of 52.65° F, and experiencing an average annual rainfall of 42.76 inches (U.S. Climate Data 2017). The construction project is located on the Western fringe of the city, within the campus limits of Oregon State University.

The construction project involved the demolition and the reconstruction of Peavy Hall, College of Forestry at Oregon State University as shown in Figures 2 and 3. The overall square footage for the project is 114,000, with 80,000 square feet being designated to the building that will replace the existing Peavy Hall and 18,000 square feet for the Advanced Wood Products Laboratory. The study presented here was conducted during the demolition and excavation phases. In the first half of the study, excavators were used to tear down the existing slabs and the retaining walls along the perimeter of the site, while in the latter phase, excavators were used for structural excavation and backfilling while a dozer was used to push the soil post-excavation.

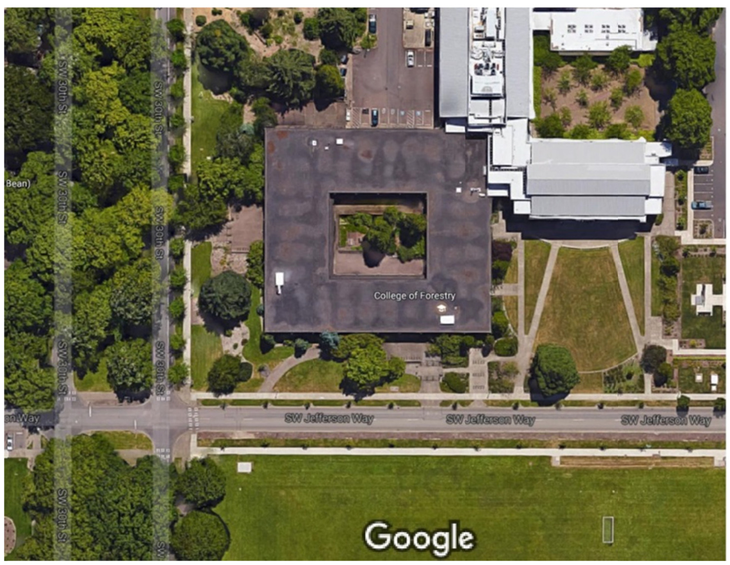

Figure 2: Peavy Hall (Google 2017b)

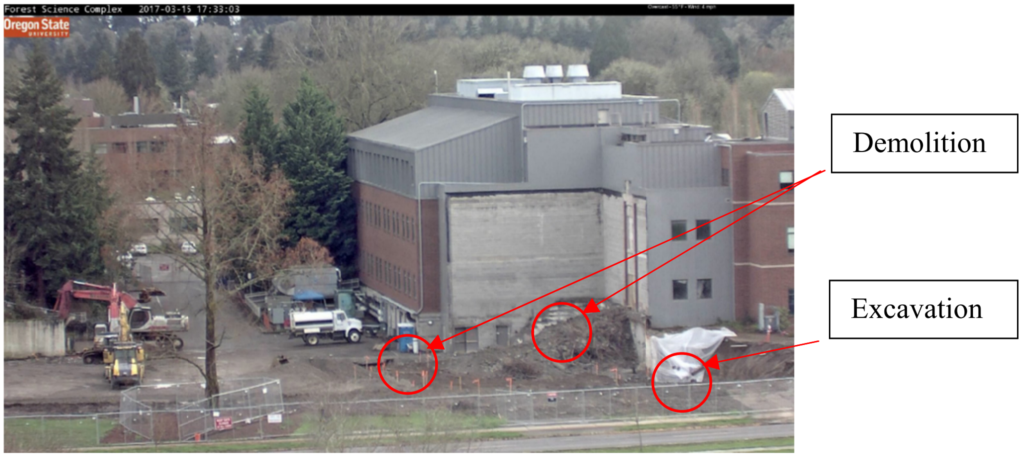

Figure 3: Site Plan (OSU Webcams 2017)

Construction Equipment Studied

Data was collected during the demolition and excavation phases. During these phases, there were three different equipment present on the project site. Excavator 1 was an Isuzu Link-Belt 370LX excavator and it was assigned to the demolition phase, while Excavator 2, a Komatsu PC228USLC excavator, was solely involved in the excavation phase, with cutting and backfilling forming the majority of its scope of work. Excavator 1 and 2, as seen in Figures 4 and 5 respectively, have an enclosed operator cabin. These enclosed operator cabins are designed and engineered to provide operators with a comfortable, healthy and safe working environment. Meanwhile, the dozer, a Komatsu D41P is a crawler tractor with a blade on the front does not have an enclosed operator cabin, as shown in Figure 6.

Figure 4: Excavator 1