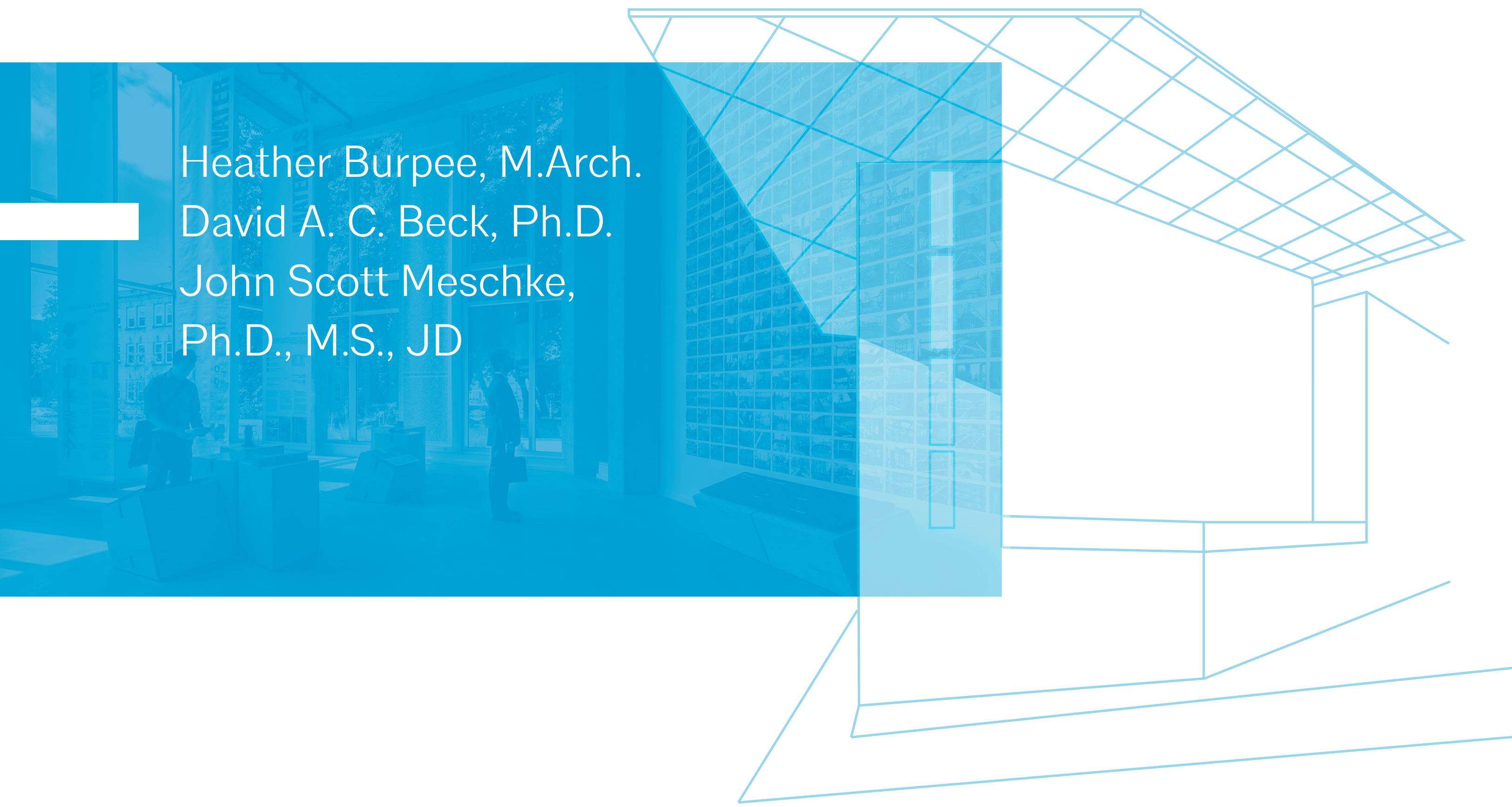
HEALTH IMPACTS OF GREEN BUILDINGS



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Introduction & Background

The built environment impacts health in multiple dimensions, from large infrastructure to the microscopic molecules and organisms that are not seen or perceived in daily life. At the building scale, how a building's features are built and used can have a direct impact on occupants' health and well-being. For example, using the stairs rather an elevator results in greater physical activity that translates to weight loss or reduced weight gain.[1] The increased stair use also results in reduced energy consumption by the building elevators, yielding a potential indirect effect on global health by lessening greenhouse gas emissions associated with the structure. Indoor environmental qualities (IEQ), such as access to natural light, views, and fresh air, have been shown to increase positive perceptions of work environments and also relate to increased human performance and productivity.[2,3]

At the microscopic level, the health and IEQ of buildings are directly impacted by the resident microbiome, the collective living micro-organisms such as bacteria and fungi.[4] Moreover, the actors at varying scales do not act independently—macroscopic design decisions have strong relationships with microscopic effectors. For example, a building with closed, inoperable windows relies on the use of HVAC (heating, ventilation, and air conditioning) systems for temperature control. These systems are known to act as aggregators, breeding grounds, and dissemination vectors for microbial pathogens such as Legionella pneumophila that causes Legionnaires' disease.[5]

In light of the complex interaction between various health-related impacts of the built environment, this research team has taken a multi-disciplinary approach and includes a team of a research architect, a public health environmental scientist, and a data analytics expert.

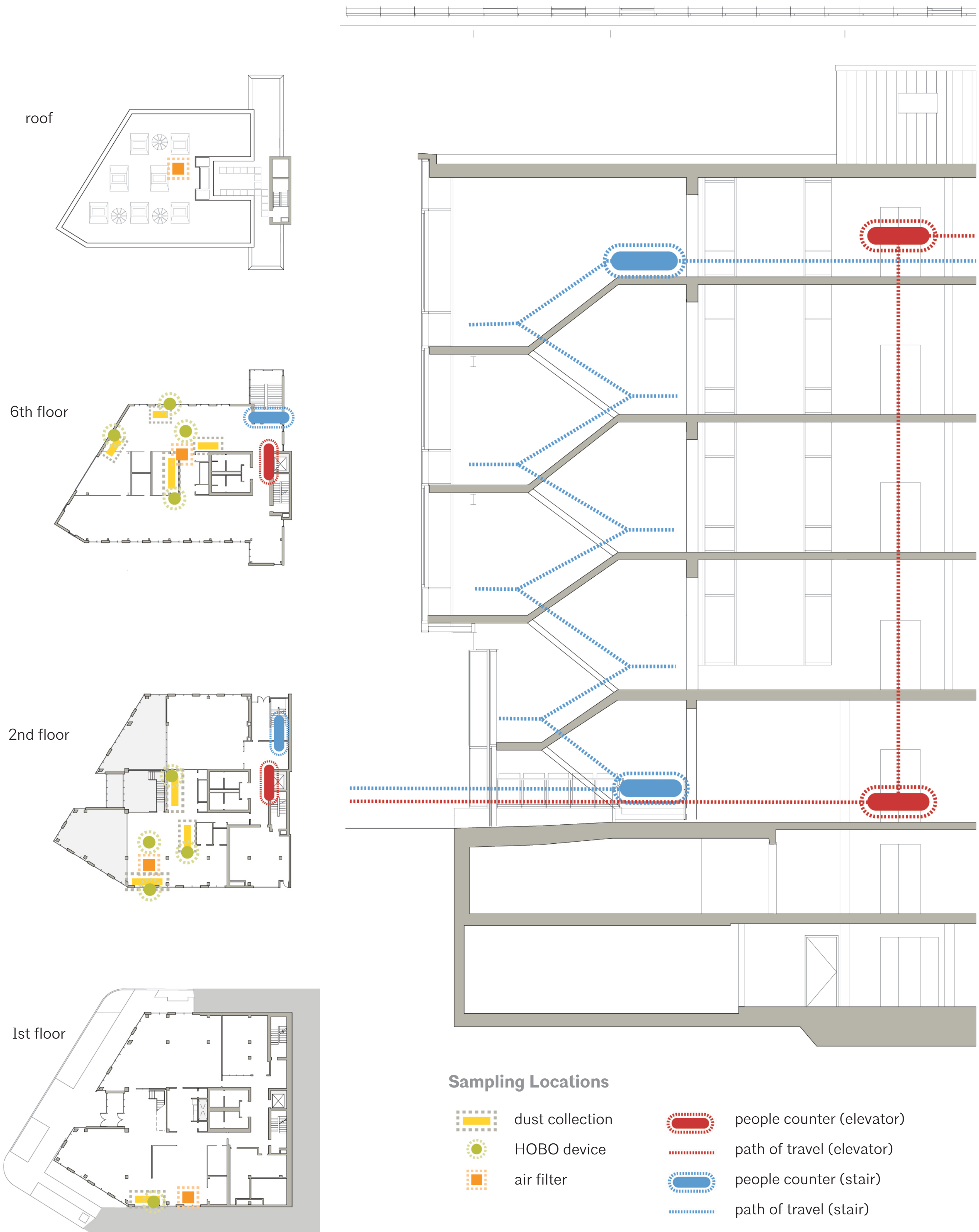
This team has used the Bullitt Center as a pilot project to develop and implement methodologies for collecting data. These data include testing how the building impacts **1) physical activity** and **2) indoor environmental quality**, including the microbiome. To this end, the team has:

- Measured stair and elevator use
- Collected numerous empirical measurements of light, temperature, humidity, and moisture content of the building
- Surveyed building occupants related to well-being, physical activity, and their perceptions of the indoor environmental quality of the building
- Collected dust and air samples to quantify and characterize microbial populations.

These data were collected in both the Bullitt Center over the first nine months of occupancy as well as in two office spaces immediately prior to the move to the Bullitt Center.

This paper outlines the relevant background information, active design and indoor environmental quality studies, and shares preliminary findings. The methodologies for the team's investigations are detailed, as well as preliminary analysis of the data resulting from these studies. The combination of building characteristics, empirical data collection, and occupant perception provides a platform for analyzing the health attributes of this and other buildings. If positive connections emerge, the evidence

FIGURE 1. Sampling locations at the Bullitt Center



will help make the case for more green buildings, and may help improve future policies and decision making in order to develop new, healthier, buildings.

The Bullitt Center as a Site

The Bullitt Center was chosen as the primary site for this study. The building is a 6-story, 52,000 sq. ft. commercial office building in Seattle, Washington, and is the nation's first urban mid-rise commercial project to be on track to meet the Living Building Challenge, the most rigorous benchmark of sustainability in the built environment. As such, it was noted as the "most sustainable building in the world" by World Architecture News in 2013.[6] This building is ambitious by many measures and is a leader in building design that aims at many of the desired outcomes for design and health projects, including promoting alternate transportation choices, encouraging physical activity, reducing air pollution, and supporting natural environments. This building is on track to demonstrate net-zero energy use, have all its water needs provided by harvested rainwater, eliminate onsite parking and maximize transportation via other modes. The building is over 80 percent naturally daylit, naturally ventilated, and excludes 362 toxic "Red List" materials. Its essential components are built to last 250 years.

Figure 1 shows diagrammatic plans and a section of the Bullitt Center. Locations of data collection are noted on the plan and described in greater detail in the following sections. These include air and dust sampling; light, temperature and relative humidity monitoring; and patterns of use for the stairs and elevator.

Physical Activity

Background

The built environment's effect on physical activity is a developing area of study. Health design experts state that "although some evidence suggests that using specific features of buildings and their immediate surroundings such as stairs can have meaningful impact on health, the influences of the physical environment on physical activity at the building and site scale are not yet clear."[12] At an infrastructure level, how people move around cities, whether by car, bus, bicycle, or foot has been shown to affect physical health.

Similarly, at the building scale, small daily choices may positively impact health, such as the decision to take the stairs versus elevators or escalators.[13] Two minutes of additional stair-climbing per day would result in a weight loss of over one pound per year and would stave off the one pound per year weight gain that the average American incurs.[14] This suggests that building-related opportunities for everyday activity may have a tremendous positive impact on building occupants' health.

Methodology & Results

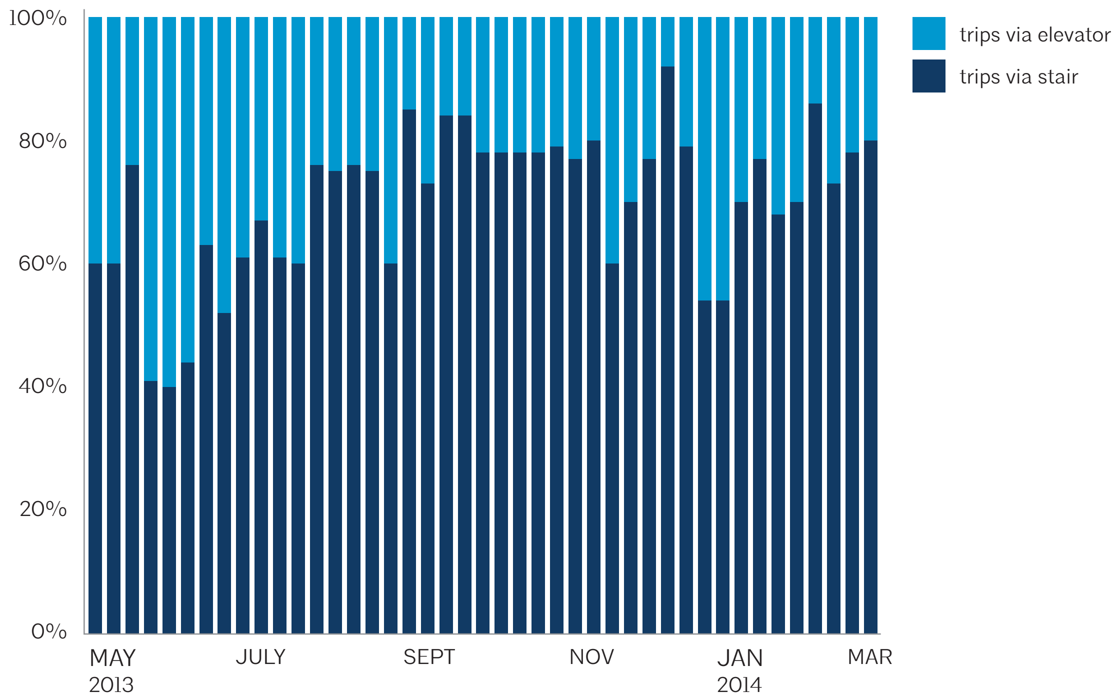
TRACKING PHYSICAL ACTIVITY The research team sought to track occupant movement within the building. The research team aimed to track movement inside the building at a fine grain, within 6 feet, in order to understand patterns of building use as well as occupant physical activity. At the time of the study, however, this level of detail was not realistic to obtain. This is a case where appropriate technology to understand the way in which people use and move through the building has not reached a mature enough point of development. While systems exist for tracking building occupancy, they 1) are prohibitively expensive, 2) require a vast array of hardware, 3) do not have the precision to accurately assess occupancy patterns, or 4) require user input or involvement at a prohibitive level. As technology for tracking patterns of movement indoors progresses, the resulting information will be valuable for understanding how occupants move through different spaces in buildings, and to what degree occupants are active throught the day as a result of building design. This data also can play a part in designing dynamically controlled building systems, such as HVAC and lighting, that relate to real-time occupancy.

Although comprehensive occupant tracking was not possible, the team applied a secondary approach for tracking occupants' use of the stairs and elevator. A major design feature of the Bullitt Center is a central staircase, the "irresistible stair," that is physically located adjacent to the main entrance. The elevator is tucked away in a less conspicuous location. The goal of the prominent stair location is both to save energy on elevator use, and also to promote physical activity through individual locomotion.

This team's question was: Is the "irresistible" stair really irresistible, and as such, how often is the stair being used as compared to the elevator? Counters that track movement in two directions were placed at the bottom and top of the stair as well as at the bottom and top of the elevator. Weekly readings were taken of how many people had gone up and down the stairs, as well as how many up and down the elevator. Preliminary data show the irresistible stair is used for 70% of the trips from the main 2nd floor entry to the 6th floor. These data can be seen in Figure 2. Similarly, 75% of trips initiated at the 2nd floor entry are via the stairs, showing a strong choice to take the stairs compared to the elevator. These data indicate a very favorable outcome when compared to other studies, including one that reports ascents via the stairs between 17–23% on average over a typical day in a commercial office building.[15]

FIGURE 2. Modes of arrival to the 6th floor by week

Comparison between stair and elevator use to the top floor of the Bullitt Center. On average, 70% of trips were made via the stair, indicating that the active design intentions are succeeding.



Indoor Environmental Quality

Background

The quality of the indoor environment in offices, schools, and other workplaces is important not only for workers' comfort and productivity,[7] but also for their health. At the building scale, IEQ is affected by aspects such as access to light and view, temperature, humidity, ventilation, acoustics, air quality, material toxins, dust, and the microbial environment.

Many factors affect IEQ and are broad ranging from building form and design to materials selection to building operation. For example, a building's form and orientation affect the amount of natural light that occupants have in their work environments. Windows enable views to the outside, and depending on the building design, allow for natural ventilation through operable windows rather than solely relying on HVAC systems for fresh air. Temperature and humidity are affected by the source of ventilation air and façade design where thermal comfort can vary depending on shading, window quality, and access to the perimeter. Air quality can vary significantly and can be affected by activities within the building, such as dust from construction or renovation, use of cleaning supplies or pesticides, ozone from electronic equipment (copiers, etc.), and carbon monoxide and other noxious chemicals from combustion heating. Additionally the building materials themselves may affect indoor air quality, with small amounts of chemicals being released from buildings and finishing materials (e.g. benzene, formaldehyde, phthalates, flame retardants, PCB). Further, a building's microbiome can affect human health through exposure to the organisms themselves (causing allergies and infections, for example) or their by-products (e.g. endotoxin).

Methodology & Results

A systems approach to studying the microbiome and other IEQ factors was undertaken to help correlate both building occupant's perceptions of their work environments, physical measurements of the indoor environment, and sampling of the building's airborne and surface microbiome. These data were collected for the first nine months of occupancy at the Bullitt Center as well at two office environments prior to the move to the new building.

DUST AND AIR SAMPLES TESTING THE BUILDING'S LONGITUDINAL MICROBIOME

While this aspect of the study is still underway, a major accomplishment has been the development of methodologies for collecting and analyzing air and dust sampling. A total of 86 dust and air samples have been collected on six occasions spanning a nine month time period at the Bullitt Center, and one pre-move sampling was collected in two prior office locations. The protocol for analyzing the air and surface microbiological samples was developed and it was determined that a sampling cycle of 65 days was ideal for collecting sufficient material for analysis.

When DNA sequencing is complete, the team will analyze the resulting data to determine the quantity and type of the microbiological population in various sampling sites at the Bullitt center. It is hypothesized that the microbiome will appear more similar to the exterior environment than the human environment and will gain maturity from the first sample to the last sample, eight months after the building was occupied. This result is expected to be unique to buildings that have operable windows and do not rely exclusively on mechanical ventilation systems for fresh air. Others' work hypothesizes that a microbiome more similar to the exterior environment is healthier since it is wider-ranging and has fewer pathogenic characteristics.[8]

TEMPERATURE, RELATIVE HUMIDITY, AND LIGHT

Onset HOBO data loggers have been placed in the building in locations that correspond to the microbiome air and dust sampling locations. Temperature, relative humidity, and light levels have been recorded for the duration of the study, starting in April 2013. Readings are at 10 minute intervals and will be used to relate environmental factors to both microbiome data as well as survey respondent results where appropriate.

SURVEY DATA

Three peer reviewed questionnaires were selected and compiled to survey the Bullitt Center's occupants. These questionnaires have been used by other researchers in various capacities, making it possible to analyze the survey data internally as well as to compare the results of this study to other studies that have been conducted and reported in the literature, as listed below:

- Ed Deiner's "Satisfaction With Life Scale," is designed to measure global cognitive judgments of satisfaction with one's life.[9]
- The International Physical Activity Questionnaire helps measure the physical activity in populations of people in work-related, transportation-related, and leisure-related activities.[10]
- Occupant Indoor Environmental Quality Survey, developed by the Center for Built Environment at UC Berkeley, is designed to objectively gauge which building services and design features are or are not working, and helps to determine occupants' satisfaction with the indoor environmental qualities of the building, as well as their workspaces and workplace productivity.[11]

The compiled surveys were distributed a total of three times. The first surveys were distributed in February 2013 to employees of two organizations prior to their move to the new building. The second and third surveys were conducted in June 2013 and October 2013, and were distributed to occupants of the Bullitt Center. The first round of surveys had a 100% response rate (n=16), the second round 77% responded (n=24), and the third 64% responded (n=25).

Analysis of the survey results is currently underway. The team is evaluating the changes between pre-move versus post-move, as well as whether there is a difference between the June and October survey results. Emerging analysis shows a variety of interesting findings, including a shift in occupants' transportation-related physical activity before and after their move to the Bullitt Center. The trend shows a 12% decrease in time traveled via car, a 65% increase in time spent using public transportation, and a 58% increase in time biking. Such results are indicative of healthier transportation choices, and provide evidence in favor of the building's siting as it relates to public transit and active modes of transportation.

Emerging Insights

The most significant accomplishment of this work is the development of a protocol for studying the health-related impacts of building design. This kind of research and analysis is vital, especially using this team's multi-disciplinary approach. Thus, creating a methodology and developing a case study at the Bullitt Center facilitates the work of both this team and other teams to replicate this kind of research, which will enable a greater body of research related to the health impacts of the built environment at the building scale.

As more analysis is completed, further discoveries regarding the health impacts of the Bullitt Center will certainly emerge and may help the Bullitt Center become a greater catalyst for change, as well as inspiring future studies of health-related considerations in buildings' design.

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