Evaluation of Theory and Practices for Assessing Local Environmental Impacts in Construction Projects

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Abstract
An Environmental Impact Assessment (EIA) is a planning and decision-making tool utilized to assess the potential effects of construction projects on the environment. Environmental aspects are categorized into nine domains, one of which is local issues. This category encompasses noise, vibration, dust, odor, visual appearance impacts, etc. Risks of construction activities on human health, wildlife habitats, and the environment can be reduced by the early identification of the environmental issues, their sources, and receptors, along with the implementation of mitigation measures. This paper seeks to evaluate the current theories and practices employed in assessing local issues within construction projects, considering the main aspects of local impact assessment. Standardized protocols for comprehensively analyzing local issues in construction projects are lacking, while research works focus on developing sophisticated management strategies and simulation techniques to predict and mitigate local issues. Therefore, there is a need for practical and user-friendly impact simulation tools that allow full environmental assessments, such as four-dimensional Building Information Modeling (4D BIM) platforms and techniques.

Keywords: Environmental impact assessment, local issues, BIM, construction projects

1 Introduction
The construction sector is a major global source of environmental pollution, with significant direct and indirect impacts on the environment. An Environmental Impact Assessment (EIA) is a planning and decision-making tool utilized to assess the potential positive and negative effects of proposed construction projects on the environment. EIA adheres to internationally recognized standards and norms to identify, forecast, assess, and mitigate adverse environmental impacts to levels deemed acceptable (Ismaeel & Lotfy 2023). Eco-Management and Audit Scheme (EMAS) categorizes environmental aspects into nine domains, including air emissions; water emissions; waste generation; use and contamination of land; resource consumption; local issues; transport issues; effects on biodiversity; and incidents, accidents, and potential emergency situations (European Commission 2001). Construction-related local issues encompass a variety of environmental risks. Monterrubio et al (2020) examined local residents' perceptions of sociocultural and environmental effects of the New Mexico City airport construction project, noting adverse actions such as land clearing, land grabbing, relocating people, disturbances of everyday life, traffic congestion, population growth, and crime. They also identified several environmental risks, including noise and dust pollution, potential water table reduction, archaeological harm, mine overexploitation, deforestation, increased urban floods and temperatures, and harm to local bird species.

The major environmental risks of the construction projects should be precisely identified to enhance the effectiveness of environmental management systems. Zolfagharian et al (2012) investigated the frequency and severity of the most common environmental impacts across the construction of residential buildings in Malaysia. A risk matrix was utilized to rank various risks in order of importance, and it was found that 'transportation resource', 'noise pollution', and 'dust generation with construction machinery' are the most significant environmental impacts respectively. Araújo et al (2020) conducted a comprehensive review of more than 2,600 papers, and found that some environmental aspects are not thoroughly investigated and few published articles have focused on soil contamination-modification, noise pollution, and vibrations, corresponding to 1.09%, 0.12%, and 0.00% of the total analyzed. Due to the importance of the identification and assessment of the local environmental issues including noise, vibration, dust, and odor in the construction projects and the limited research works about these impacts, the focus of this paper is on the recognition of the main aspects associated with local issues that should be considered in environmental impact assessments. To effectively manage the severe environmental impacts on their surroundings, it is necessary to identify and assess the sources of these impacts, the affected receptors, and to consider mitigation measures based on the construction company's procedures and available guidelines.

Current approaches for managing local issues face several limitations that hinder their effectiveness. A notable absence of standardized protocols and procedures exists for conducting thorough noise, vibration, odor, and dust analyses in the construction industry. This lack of established norms contributes to uncertainties and inconsistencies in assessing and addressing these environmental concerns pre-emptively. On the other hand, Ismaeel & Lotfy (2023) highlighted that the primary issues with the EIA process stem from its isolation during various project stages, the intricate nature of EIA procedures, and the insufficient skills and competencies of practitioners. Consequently, the research posited that leveraging Building Information Modeling (BIM) technologies could address many of the challenges linked to the EIA. Additionally, there are not enough research works scrutinizing the causes of local issues occurrences in construction projects, and their severe physical and mental impacts on the workers, local communities, and wildlife habitats.

This paper aims to evaluate the key factors required to be considered for the assessment of local environmental impacts in construction projects with attention to the theoretical and practical perspectives. Following the introduction, the second section reviews research works identifying the primary sources, receptors, and mitigation measures concerning noise, vibration, dust, and odor in construction projects, alongside presenting relevant guidelines and standards regarding these impacts. The following sections summarize the important aspects and factors related to the identification and assessment of local issues, incorporating insights from both theoretical points of view and real-world case studies. The fifth section is dedicated to a brief discussion and the final section contains the conclusions and future prospects.

2 Related works

2.1 Important factors in the evaluation of noise, vibration, dust, and odor

The effects of noise, unlike other contaminants, may not be immediately apparent; however, its accumulation can lead to significant physical issues like hearing loss and auditory problems, as well as psychological and social deterioration (Fernández et al 2009). The level and impact of noise generated during construction can vary based on several factors, including the specific activities being carried out, the type and condition of equipment utilized, and the surrounding environmental conditions, as noted by Gannoruwa & Ruwanpura (2007). According to the findings of Ballesteros et al (2010), construction phases such as excavation, framework and wall construction, and brickwork are associated with high levels of noise emission. They noted that excavation ranks as the loudest phase due to its direct association with the machinery employed, and this stage exhibits a significant variation in noise levels emitted. Heavy equipment stands out as the main source of noise emission during construction (Albertini et al 2023). Lee et al (2019) examined annoying construction stages and found the demolition stage tops the list as the most annoying, succeeded by the foundation, earthwork, and concrete framing stages. Figure 1 shows that the equipment deemed most bothersome varies with each construction phase; for example, the breaker, pile driver, and hammer compactor are considered the most disruptive machines during the demolition, foundation, and earthwork stages, respectively (Lee et al 2019). Aguilar-Aguilera et al (2020) pointed out that noise not only impacts the health of workers and those living close to construction sites but also causes occupational disturbances and environmental disruptions. To mitigate construction noise, Albertini et al (2023) have suggested replacing older, noisy equipment with newer, electric, or specially designed low-noise machinery and benefitting from both active and passive sound barriers, such as delaying the demolition of structures or preserving trees to mitigate sound spread. They also recommended scheduling adjustments to prevent high-noise activities from occurring simultaneously, effectively reducing overall noise levels.

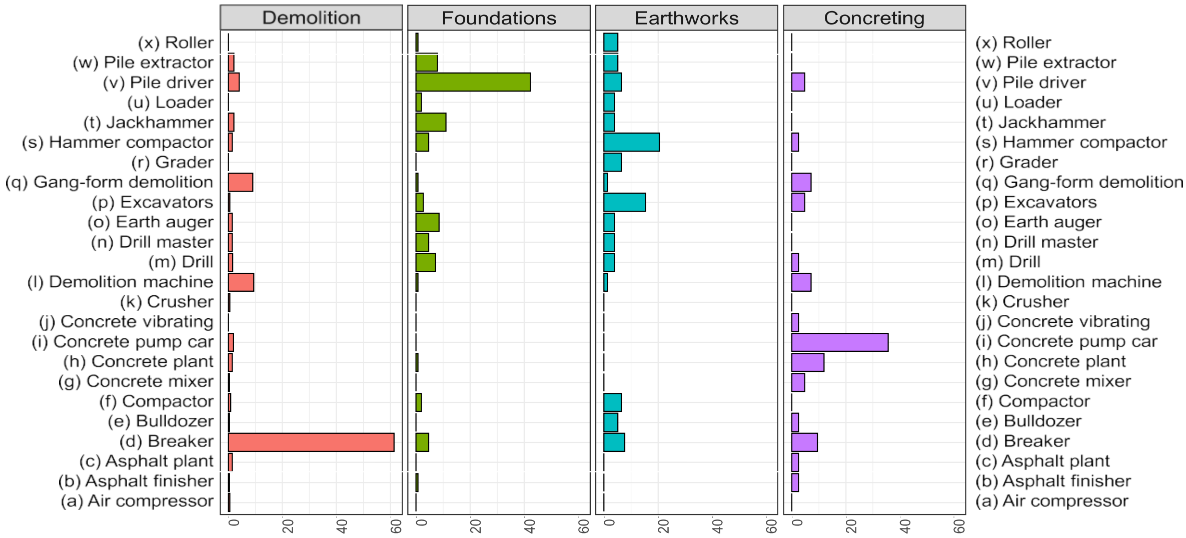

Figure 1. Percentage of each annoying construction machine at various construction stages (Lee et al 2019)

Exposure to construction dust is most notably linked to chronic respiratory diseases and symptoms, as well as increasing the risk of cancer, respiratory infections, and potentially leading to death, based on morbidity assessments (Wang et al 2023). Some activities generate dust at construction sites, such as excavation, drilling, cut and fill operations, bulk material transportation, loading and unloading, concrete and mortar making, and open-air material storage (Dickerson 2016). Li et al (2019) collected and analyzed a total of 783 personal respirable samples and bulk samples from 33 construction sites and 16 contractors in Hong Kong. Research indicates that the highest levels of respirable dust exposure occur during cement mixing, concrete breaking, and demolition activities. Meanwhile, the processes of grinding and rock breaking are identified as having the highest levels of quartz exposure, a form of crystalline silica. Deurssen et al (2014) identified workers in various construction roles as the primary group exposed to construction dust, with the residents living nearby as the next most affected population. Dust generated by construction activities can have various impacts on its surroundings, including damage to neighboring property, cleanliness, poor visibility, and air pollution (Zuo et al 2017). As indicated by this study, various methods are employed to mitigate dust production, including water suppression, local exhaust ventilation, controlling stockpile heights, electric sweepers, and dust screens. While water suppression stands as one of the most favored and used approaches for controlling dust, the associated water wastage is considered environmentally detrimental.

Exposure to unpleasant odors can lead to a range of negative responses, such as headaches, irritation, and heightened psychological stress (Nicell 2009). The findings show a significant correlation between odor distribution and emotional mapping, with areas of positive emotions generally having a balanced presence of pleasant smells (Qin & Xuan 2023). Volatile Organic Compounds (VOCs) stand out among pollutants due to their associated odors and widespread presence. The focus of most research works is on the measurement and analysis of odors originating from indoor construction activities, landfills, and agricultural facilities. Liang (2020) measured indoor VOCs at eight indoor construction stages including gypsum plaster, wall paint, cupboards and cabinets, putty 1 & 2, wooden flooring, wallpaper, and doors and doorframes. Total VOC concentration and odor activity value were the highest during the "doors and doorframes" and "wooden flooring" stages. In addition, Qin & Xuan (2023) identified woodworking and paint as important sources of construction odors. Therefore, painters and carpenters are more likely to be exposed to high levels of VOCs compared to other construction workers. During their work, the risk of cancer accounts for 78.0% and 65.7% of the total risk for painters and carpenters, respectively (Liang 2020). Odor emissions are a frequent cause of complaints and significantly affect the quality of life for both humans and animals. To reduce the side effects of odor impact, different measures can be considered. Placing odor-absorbing devices in the direction of prevailing winds (Qin & Xuan 2023) and the use of chemical additives as an alternative to traditional treatment technologies like scrubbers and incinerators (McCrory & Hobbs 2001) can help to eliminate or reduce the spread of unpleasant smells

2.2 Current standards and guidelines

Standards, guidelines, and regulations are crucial for managing local environmental impacts by providing clear protocols and measures to mitigate disturbances, ensuring community well-being and ecosystem sustainability. The International Organization for Standardization (ISO) publishes various standards for the measurement and assessment of occupational exposure to local issues (ISO 2024). In addition, different countries establish their own specific guidelines and regulations for managing local issues. In the United States, the Occupational Safety and Health Administration (OSHA) has established noise exposure limits in construction sites through specific standards, such as 29 CFR 1926.52 (Occupational Noise Exposure) and 29 CFR 1926.101 (Hearing Protection), while also providing guidance on managing vibration (OSHA 2024). The European Union implements the Directive 2002/49/EC to manage noise pollution and the Directive 2002/44/EC on the minimum health and safety requirements regarding workers' exposure to risks arising from physical agents, vibration (European Commission 2002).

Furthermore, it's essential to monitor dust to maintain it at the recommended exposure levels of 0.1mg/m3 or below (Zuo et al 2017). The Environmental Protection Agency in Victoria, Australia regulates and outlines the relevant dust regulations for construction projects (EPA 2024). The Health and Safety Executive (HSE) in the United Kingdom proposed Construction Dust: Inspection and Enforcement Guidance in 2014 and provided detailed suggestions on controlling construction dust (HSE 2014). Additionally, some countries and regions have developed regulations to manage environmental odors, which can be applied to construction activities. In response to increased complaints about air pollution and offensive odors from industrialization and urban growth, Japan enacted the Offensive Odor Control Law (OOCL) in 1972 to regulate odors from business activities (Government of Japan 2003).

3 Theoretical evaluation of local environmental impacts

Assessing the environmental impacts of construction projects requires a thorough consideration of multiple aspects and dimensions to ensure exhaustive environmental management. This section synthesizes findings from a comprehensive literature review, focusing on essential requirements and factors for evaluating local environmental impacts of construction activities, specifically noise, vibration, dust, and odor.

3.1 Key elements for the assessment of local environmental issues

It is crucial to consider several key factors affecting the EIA process of construction projects, as discussed in this section. The type and function of a construction project, whether infrastructure-related, commercial, residential, or other, significantly influences its environmental footprint. Infrastructure projects, for example, encompass a wide range of endeavors, such as roads, bridges, and utilities, each with distinct environmental considerations compared to commercial or residential buildings. The project's scale, the material used, and the construction techniques employed also contribute to varying levels of environmental impacts. In addition, the project's location, whether situated within a densely populated urban area or outside city limits, further complicates environmental assessments. Projects in congested urban environments face unique challenges, including noise pollution and air quality concerns, necessitating specialized mitigation strategies. Conversely, construction projects in remote or rural areas might affect natural habitats or agricultural land, requiring a different set of considerations for minimizing environmental harm. Furthermore, the availability of environmental guidelines and standards at both the national and local levels is crucial. Some regions might have well-established environmental regulations and standards tailored to their unique ecosystems and urban development patterns. In cases where local guidelines are lacking or insufficient, global standards can provide a benchmark for environmental performance and sustainability. However, the effectiveness of these standards often hinges on their adaptability to the local context and the political and economic will for enforcement. The country's developmental status where the project is located also affects the environmental assessment process. Developed countries often have more stringent environmental regulations, advanced technological resources, and greater public awareness, which can facilitate the provision of comprehensive environmental impact assessments. In contrast, developing countries may struggle with limited resources, less stringent regulations, and other priorities that can impact the thoroughness and implementation of environmental protective measures.

3.2 Identifying sources, receptors, and mitigation measures of local issues

Drawing from a broad spectrum of scholarly works, this section presents the important aspects that need to be considered in the assessment of local environmental concerns. Figure 2 presents a flowchart that maps out the relationships between the sources of local impacts, affected receptors, and mitigation measures put in place to address them. A foundational step in addressing environmental issues involves the early identification of all existing environmental risks unique to each project, along with pinpointing the related sources of each impact.

The subsequent critical consideration in evaluating local issues revolves around the analysis of the receptors affected by these impacts. In the dynamic environment of a construction site, the activities undertaken, and the operation of equipment generate environmental side effects that can significantly impact the workers, surrounding community, and wildlife habitats. Among the environmental challenges, local issues stand out as primary concerns due to their potential to affect both human well-being and the ecosystem. On-site construction workers are the most directly exposed to noise, vibration, dust, and odor, making them primary receptors. Residents and people living near construction sites are also directly affected by local impacts which can disrupt their daily life and comfort, and potentially cause health problems. Educational institutions such as schools and universities near construction sites also experience disruptions, affecting the concentration and learning of students. In addition, healthcare facilities and hospitals nearby can face challenges in providing appropriate care, affecting patients' comfort and recovery. Last but not least, local issues can adversely affect wildlife habitats and animals near construction projects, disrupting feeding patterns and breeding behaviors. It is imperative to evaluate the severity and frequency of the impacts on each receptor and prioritize the sensitive receptors. Identifying the environmental risks, their sources, and receptors are crucial initial steps, which must be followed by the proposal of mitigation measures. Additionally, it's essential to consider the cost-effectiveness of these measures, ensuring they are economically viable. Equally important is considering the perspectives of the stakeholders and the public concerns. Table 1 compiles the primary sources of noise, vibration, dust, and odor in construction sites and explains the corresponding preventive measures.

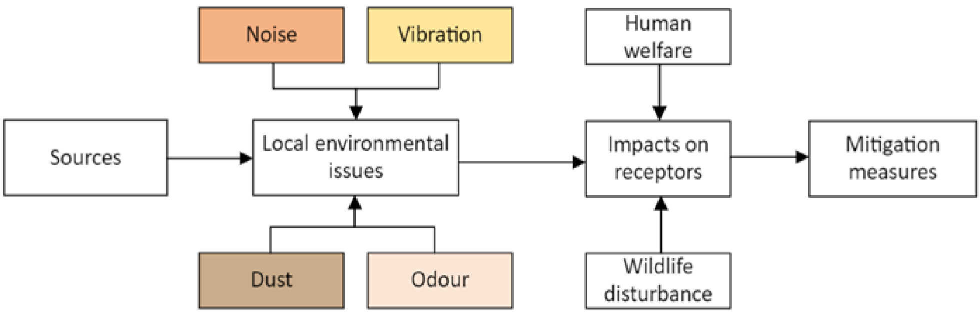

Figure 2. Flowchart of the key factors in the assessment of local environmental issues

Table 1. The sources and mitigation strategies related to local environmental impacts

Local issues	Sources	Mitigation measures
Noise & Vibration	- The operation of heavy equipment, such as loaders and excavators - The usage of power tools, such as drills, saws, and jackhammers - Demolition activities and the use of demolition machines - Construction activities like welding and concrete pouring - Loading and unloading of materials	- Erecting temporary or permanent sound barriers - The use of low-noise or electric equipment - Regularly maintenance checks of equipment - The usage of Personal Protective Equipment (PPE) like earmuffs by workers - Modifying scheduling to prevent overlapping of high-noise activities - The use of vibration-damping mats or pads under heavy equipment to reduce the transmission of vibrations into the ground
Dust	- Earthwork activities, such as excavating and grading - Demolition of buildings - Transportation, loading up, and unloading of bulk materials - On-site concrete mixing - Cutting and drilling of materials like concrete and stone - The movement of heavy equipment on unpaved roads - Land clearing and removal of vegetation and topsoil	- Providing workers with appropriate PPE, such as respirators and safety goggles - Placement of physical barriers like fences - Planting or maintaining existing vegetation as natural dust barriers - Applying chemical dust suppressants - Regularly maintaining equipment - Limiting equipment speeds on unpaved roads - Regularly spraying water - Covering stockpiles of soil and sand with tarps - Planning and modifying construction activities
Odor	- Production of hot paving asphalt - The usage of materials, such as paints, sealants, and adhesives - Decomposing construction waste, such as wood and vegetation - Construction and repair work on sewage systems and septic tanks - Construction on contaminated Sites	- Providing adequate ventilation while working with volatile substances - The usage of low-odor materials - Effective waste management and regular disposal of waste materials - The use of odor suppressants like biological oxidation - Strategic storage of chemicals - Planting trees and vegetation to reduce odor

4 Practical evaluation through case studies

Following the theoretical overview, several construction projects in different countries are examined and compared according to the key factors discussed in the previous sections, as presented in Table 2. This analysis delves into real-world applications, observing how foundational principles are implemented in practice. The Vietnamese-German University (VGU) construction project is located in Binh Duong Province, Vietnam covering a total area of 50.5 hectares (Nguyen 2015). This ambitious endeavor was executed in two phases and included the construction of approximately 50 buildings and various facilities to support academic and administrative functions. The dust control measures implemented in the VGU project, such as water spraying and covering stockpiles, are practical applications rooted in the established dust management principles discussed in Section 3.2.

One of the environmental issues associated with the Grand Trunk Road improvement project was the generation of noise and vibration (LEA 2001). The focus of this project was on upgrading the road segment spanning from Agra to Barwa Adda in India. The project encompassed widening a 422.80-kilometer stretch of highway by constructing a new 2-lane carriageway with paved shoulders, alongside reinforcing the existing carriageway through extensive rehabilitation measures. The noise mitigation strategies used in this project align with the theoretical approaches discussed earlier. For instance, the erection of physical barriers and regular equipment maintenance are practical applications of the recommended measures for noise control. On the other hand, the Guangxi Laibin project located in Laibin City, China faced odor issues due to its various components, including building and upgrading dikes, constructing a flood control dam, and establishing a stormwater and sewage pipeline network in the old urban area (Research Academy of Guangxi 2012). The use of odor suppressants spraying and closed transport vehicles reflects the recommended strategies for controlling odor, as detailed in Section 3.2.

Through this comparative study, the section seeks to bridge the gap between theory and practice, showcasing tangible outcomes and lessons learned from diverse project scenarios. These case studies and many executed projects illustrate how real-world projects effectively apply theoretical principles through conventional assessment methods. However, these conventional environmental assessments have not benefited from advanced tools like 4D BIM technologies for a comprehensive analysis of environmental impacts. As a result, their precision may not match that of projects employing cutting-edge approaches, underscoring the potential for more accurate and comprehensive environmental assessments with advanced simulation and analysis tools. On the other hand, construction projects often deal with several environmental impacts simultaneously. Drawing from various case studies, it is common for such projects to address both air and noise pollution concurrently. This often arises during the operation of heavy construction equipment on-site, which not only serves as a primary source of noise pollution but also significantly contributes to dust generation. Accordingly, the quantity, location, movements, and specifications of all equipment available at construction sites should be precisely analyzed before the construction phase (Amrollahibuki 2019).

5 Discussion

A key challenge for environmental impact assessment is the scarcity of protocols and guidelines designed specifically to tackle noise, vibration, dust, and odor in construction projects, as most existing standards broadly target local impacts across industries without distinction. However, the construction industry is distinct in its methods, materials, and equipment used, which necessitates a more tailored procedure. Effective EIA should also consider specific factors related to each construction project, such as the type, scale, and location of the project to ensure comprehensive and proactive environmental management.

Furthermore, while several studies have focused on predicting and mitigating local environmental issues through sophisticated management approaches and simulation techniques, there is a demand for more practical and accessible simulation approaches and tools. In this context, BIM emerges as a reliable and viable solution, despite limited research proposing effective strategies to analyze local issues using BIM. It includes various dimensions for different purposes. While 6D BIM focuses on sustainability and long-term performance, 4D BIM integrates time into construction processes for real-time analysis of immediate local impacts. 4D BIM aligns with Level 2, suitable for managing construction activities, whereas 6D BIM is associated with higher levels of BIM implementation for comprehensive lifecycle management. Therefore, this paper focuses on 4D BIM for its ability to analyze immediate local impacts during the planning phase. Additionally, 4D enables visualizing, simulating, and scheduling the spatiotemporal changes in the sources and receptors of environmental impacts. It allows comprehensive local impact assessment covering various dimensions not feasible through 2D, 3D, and conventional methods. Based on the severity and extent of the impacts, mitigation measures can be proposed, and several alternatives can be suggested and analyzed through the BIM tools. Architecture, Engineering, and Construction (AEC) team members and other stakeholders can collaborate more efficiently and select the most environmentally friendly approach to conduct their projects. The assessment findings in 4D BIM can also be made accessible to the public, fostering collaboration and community involvement, as its intuitive interface enables users to visualize the realistic effects of construction projects (Boton 2018). Due to the lack of specialized methods and approaches for assessing environmental issues through advanced technologies in a practical manner, construction companies might not fully recognize the potential of BIM tools to mitigate environmental problems. This oversight often becomes evident in the project execution, where many construction projects encounter environmental challenges that were not thoroughly anticipated during the design phase, leading to severe consequences for workers, residents, and society.

Table 2. Evaluation of several construction projects based on the key environmental factors

Case study 1: Vietnamese - German University (VGU) Construction Project (Nguyen 2015) **Local issue:** Dust	
Sources:	- Land excavation activities and operation of machines including excavator and bulldozer - Transport of materials like soil and sand (15-ton truck) - Unloading and storage of materials and excavated soil
Mitigation measures:	- The contractor shall implement dust suppression measures (e.g., using water spraying vehicles to water roads, covering material stockpiles, etc.) - Material loads shall be suitably covered and secured during transportation to prevent the scattering of soil, sand, materials, or dust - The contractor shall implement a special dust control program for surrounding residential areas - Exposed soil and material stockpiles must be shielded from wind erosion, taking into account prevailing wind directions and nearby sensitive receptors
Case study 2: Grand Trunk Road Improvement Project (LEA 2001) **Local issues:** Noise & vibration	
Sources:	- The operation of equipment for the excavation activities - The activity of crushing plants and asphalt production plants - Using machines for grading the site and the construction of structures - Loading, transportation, and unloading of materials - Traffic noise
Mitigation measures:	- The erection of physical barriers in the form of walls and screens besides the Provision of vegetative barriers - Structural modifications at the receptor locations, such as the provision of double-glazing - Regular maintenance of vehicles and equipment - Earthen berms between the highway and the receptor - The usage of PPE by workers - Adjustable schedules and rearrangement of the sensitive locations
Case study 3: Guangxi Laibin Water Environment Project (Research Academy of Guangxi 2012) **Local issue:** Odor	
Sources:	- Dredging operations to remove sediment from the riverbed - Transportation and disposal of the sludge produced by the building of river-course treatment components
Mitigation measures:	- Dry sludge and other waste shall be transported to the waste landfill site of Laibin. If can not be transported right away, the sludge is better to be put in straw sacks - The sludge should be transported with closed transport vehicles to avoid splash and the lime should be sprayed into the sludge pool to control odor - Planting trees around the pump house to reduce odor - Temporary dumping areas should be located away from roads or separated by small drainage ditches to prevent sewage from overflowing onto roads during rainy days

6 Conclusion

This paper aims to identify and evaluate the primary facets that need to be considered in the analysis of local risks, focusing on noise, vibration, dust, and odor. During the planning phase of construction projects, meticulous analysis of impact sources, receptors, and mitigation measures is imperative, given that identifying the related sources is just the initial step. It's equally essential to precisely specify the receptors these issues affect, as the ramifications of local environmental impacts are wide-ranging, influencing humans, animals, vegetation, and structures alike. Hence, conducting a thorough assessment to understand the consequences of each impact on its environment becomes paramount, and mitigation measures should be proposed with meticulous attention to the severity and extent of the issue. The analysis of local risks in theoretical evaluations and executed construction projects within this paper reveals that certain construction activities, such as earthwork; concrete cutting and drilling; transportation, loading, and unloading of materials; and demolition operations, generate significant noise and dust pollution. Additionally, some specific equipment like excavators, demolition machines, and bulldozers, are common sources of noise, vibration, and dust pollution on construction sites. Recognizing that some construction activities and equipment commonly contribute to local environmental issues, it is crucial to focus on managing these factors during the planning phase. To mitigate environmental adverse effects on construction sites, appropriate scheduling and planning, utilizing PPE for workers, and implementing natural barriers through planting or maintaining existing vegetation covers effectively reduce the side effects of noise, vibration, dust, and odor.

In this paper, key factors for the evaluation of local environmental impacts, along with the sources, receptors, and mitigation measures as the important facets of local impact assessment are scrutinized from both theoretical and practical points of view. The findings are discussed along with the crucial role of BIM for EIA improvement, although there are not adequate research works considering BIM as a solution for mitigating adverse consequences of local impacts despite its magnificent advantages. There are areas of research that can be taken into consideration in future work. There is a need for comprehensive research on the capabilities of 4D BIM in EIA advancement, as it can be integrated with local environmental assessment to fully identify sources and analyze the impacts of local risks on their receptors.

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