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Communication

Beyond Design: The Importance of Construction and Post-Construction Phases in Green Developments

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Abstract: Green developments are becoming a popular land use planning concept that attempts to accommodate growth while minimizing impacts on natural resources. Various policies encourage conservation designs that usually translate into the clustering of homes and the conservation of some percentage of open space. However, the success of a design is determined by what happens during the construction and post-construction phases of a subdivision project. These two phases are often ignored in land use planning and given only minimal attention by built environment professionals. As a result, green developments may not be functioning as originally intended. This essay discusses the importance of construction and post-construction and a way forward to create functional, sustainable communities. Construction activities and decisions, such as impacts from earthwork machines, improper protection of conserved open spaces and trees, the choice of plants used for yards and common areas, and the storage of construction material all can lead to severe impacts on natural areas both within and surrounding a development site. During post-construction, a variety of improper management practices by homeowners can compromise the sustainability of a development. Developers and associated environmental consultant teams could implement approaches that would engage contractors and residents, such as environmental construction covenants and the installment of a neighborhood, environmental education program. To increase the adoption of relevant construction and post-construction practices, appropriate policies need to be created. However, the shift will only occur once the planning and built environment community acknowledges that design is only the first step towards sustainability. Academic design studios and continuing education courses can help with this culture shift by including construction and post-construction considerations within their curriculum.

Keywords: green infrastructure; smart growth; conservation subdivision; land use sustainability; green developments

1. Introduction

In urban communities, green developments are becoming a popular concept as a way to accommodate growth while minimizing impacts on natural resources. While many variations of this concept can be found world-wide, green development goals typically include habitat conservation, energy and water conservation, walkability, and the reduction of vehicular miles. To achieve these goals, attention must be paid to the three phases of a new development: design, construction, and post-construction. The design phase is where the juxtaposition of built lots, roads, and open space (if any) are placed on paper and submitted for approval through local authorities. Once approved, construction phase is where a host of contractors and sub-contractors take what is on paper and build homes, lots, and transportation routes. Post-construction phase is where people move into their homes, managing their properties and neighborhoods. In creating green communities, land use planning practices typically focus most on the design phase whereas the construction and post-construction phases are neglected. However, the long-term functionality of a green development is primarily dependent, as I will argue, on what happens during the construction and post-construction phases. Even the best design is doomed to fail if these two latter phases are not addressed. In this essay, I will (1) outline the importance of construction and post-construction phases and how each impact sustainability, and (2) suggest construction and post-construction strategies that will help insure that green communities function as originally intended.

2. Critical Factors during Construction and Post-Construction Phases

The original intent of a design can fail in the short- or long-term depending on how a particular design was installed and how it was managed. For example, clustered developments or conservation subdivisions is a popular design concept championed by the landscape architecture community [1,2]. One goal for these conservation subdivisions is to conserve natural habitat by clustering built areas and setting aside open space. Typically, some percentage of the development is conserved open space and values can range from 20% to 50% or more [3]. Much discussion occurs during the design phase of where the open space is located and how much is conserved. The design is important as it creates the framework for the subdivision; where built lots and open space are located will influence impacts on natural resources, such as wildlife populations [4]. From my experiences with green developments, once this design is drawn out on paper, very little effort or oversight is extended to the construction and post-construction phases. However, what occurs during the construction and post-construction phases can literally destroy the biological integrity of conserved areas and compromise any conservation goal, such as the conservation of biodiversity or wildlife habitat.

During construction, contractors and sub-contractors are hired to sculpt the land and install transportation systems and built lots throughout the subdivision. Heavy machinery, such as earthwork

machines, is used to raise and lower grades to meet local building regulations. The whole construction process impacts not only the construction areas, but surrounding lands as well. For example, clearing areas for homes and roads disturbs the land and there is a danger of stormwater runoff carrying sediments into nearby protected wetlands. Sediment concentrations coming from construction are often 10 to 20 times greater than runoff from agricultural land and 1,000 to 2,000 times greater than forested areas [5]. Thus, a couple hours of discharge from a construction site can contribute to a waterbody a large amount of sediments, organic nutrients, and other pollutants. Increased amount of sediments entering a waterbody has a range of detrimental impacts from fish kills, reduced invertebrate diversity, and decreased primary production [6]. Often, regulations stipulate that silt fences are installed to prevent sediment loading on waterbodies. However, without due diligence by contractors and construction site supervisors, silt fences deteriorate and fail to trap sediment during construction. Improper silt fence construction and maintenance can result in huge sediment loading in nearby conserved wetlands. If these "blowouts" occur often enough, the water quality may become compromised for decades to come. All the original effort to conserve wetlands has effectively been for naught because of improper construction management of sediment control measures.

In addition, conservation subdivisions will have identified (for preservation) large trees and vegetative buffers on the site to promote biodiversity conservation. However, these areas may or may not be properly marked and protected from heavy construction vehicles. In particular, trees and their root systems are extremely vulnerable to construction activity. Vehicles that run over the root zone cause soil compaction, reducing the ability of tree roots to absorb essential nutrients and water. Around 80% of soil compaction occurs in the first pass of a vehicle across the soil [7]. Fencing that is placed around the trunk of the tree is not adequate as tree will often die in the near future because of soil compaction within the root zone [8,9]. The roots underneath the drip line (the outer edge of the leafy canopy) should be protected by a sturdy fence. Even with this fencing system, 50% or more of the roots will be impacted by construction. The single best factor that will help ensure the survival of a protected tree is irrigation. Stressed trees need plenty of water during the construction process; this means watering each tree to a soil depth of 30 cm about 2–3 times per week [8].

Other construction factors affect tree survival. Lowering or raising the soil grade around trees (particularly in the tree root zone) even a few centimeters can effectively kill the tree. Lowering the grade a few centimeters removes important root mass and raising the grade a few centimeters smothers the roots and prevent oxygen from reaching them. Dumping fill near a tree and paving over the soil limits the ability of roots to acquire oxygen and other essential nutrients. How construction debris and chemicals are discarded is also important; construction debris can be toxic or can change soil pH due to leeching of chemicals into the ground. There should be designated zones for the storage of construction materials, away from any trees meant to be preserved.

With regards to large patches of natural habitat, construction activities can compromise the integrity of these areas as well. Construction vehicles and construction materials placed within conservation areas can, as mentioned above, compact the soil and change soil chemistry. Even the placement of utilities through heavily forested sites can impact a large number of roots. The best solution (and most cost effective) is to lay the utilities beneath the roads in the subdivision. A number of landscape construction practices can help to retain soils in their original state [9].

Another critical issue during construction is how land clearing creates conditions where invasive exotic plants can gain a foothold. Many invasive plants are adapted to disturbance and when native vegetation has been removed, invasives are typically the first to spread into an area [10]. Of note, earthwork machines, which are transported from other construction sites, may carry invasive plant seeds and propagules to the construction areas. For example, the invasive plant Fennel (*Foeniculum vulgare*) was brought into Dunedin, New Zealand on machinery used to build the southern motorway (Colin Meurk, personal communication). Once invasive plants gain access to a construction area, they can spread into conserved natural areas and displace native plants, ultimately impacting native plant and animal communities and ecosystem services. A monoculture of exotic plants reduces biodiversity and inhibits even ecosystem services, such as the ability of forested patches to sequester carbon [11]. If careful monitoring and removal of invasive plants does not occur during construction, natural areas are compromised and become dysfunctional patches of open space.

The aforementioned issues during the construction phase are important, but let's say for argument's sake, that everything was done correctly during construction (and the design phase). The conservation subdivision can still fail depending on what happens during the post-construction phase. This is because a multitude of homeowners now manage the homes, yards, and shared areas within a community; cumulatively, these individual decisions can have huge impacts on conserved open space and surrounding natural areas. There must be consistent, appropriate management of both built and conserved areas. However, evidence suggests that homeowners, even within green developments, do not understand the function of conserved natural areas and are not aware of appropriate management practices to maintain environmental features within yards and homes. One study in Florida found that residents of a conservation subdivision did not differ or scored lower on several questions about environmental knowledge, attitudes, and behaviors than residents of "conventional" subdivisions [12]. In another study, new homebuyers of conservation subdivisions and conventional communities showed little difference in terms of environmental knowledge, attitudes, and behavior—and overall measures were quite low for all respondents, regardless of community type [13]. Thus, green developments may not be attracting or encouraging environmentally sensitive residents, and in the absence of an environmental education program to engage residents, a community may resort to environmentally insensitive behaviors and are unable to manage environmental features [14]. Without homeowner involvement, natural areas often retain little to no wildlife value [3]. The list of inappropriate behaviors can be quite extensive and they include:

1. Excessive irrigation—Watering excessively can cause multiple problems. First, it can draw down local groundwater supply and cause nearby wetlands to dry up. Also, overwatering can cause an increase in leaching and large amounts of pollutants would enter nearby streams, lakes, and wetlands.
2. Excessive fertilization and pesticide use—Combined with overwatering, excessive amounts of nutrients and pesticides would enter waterbodies, causing a decline in water quality.

3. Spread of invasive plants and animals—How homeowners manage their pets and decisions made on landscaping can have dramatic consequences for conserved natural areas. For example, free roaming cats can kill a surprising number of birds, lizards, and frogs. Released pets, such as Burmese pythons (*Python molurus bivittatus*), have caused extensive ecosystem problems (e.g., the Florida Everglades). If a homeowner purchased and installed an invasive-exotic plant (e.g., Coral Ardesia *Ardisia crenata*), this plant would spread into natural areas and outcompete native vegetation.
4. Replace native landscaping with exotics—Uninformed homeowners could replace natives with exotics and this would not only reduce biodiversity, but may increase the use of fertilizers, pesticides, and irrigation.
5. Improper management of Low Impact Development (LID) features—A range of LID features need to be properly maintained by homeowners. Permeable pavements need to be annually vacuumed, swales and rain gardens should not be filled in, and cars and other vehicles should not park on swales. The above examples would cause soils to lose their permeability and water would not percolate into the ground.
6. All-terrain vehicles (ATVs) and foot traffic enter conserved areas—If people and ATVs are not kept on designated trails, they can disrupt wildlife populations and destroy native vegetation.
7. Underground seepage from septic tanks—In rural areas, if septic tanks and field lines are not properly maintained, they can cause increased nutrient loading on nearby waterbodies.
8. Feeding wildlife and other human/wildlife conflicts—If people feed wildlife, wildlife species lose their fear of humans and become a nuisance. Feeding alligators, raccoons, and squirrels can cause these animals to become aggressive. This especially is a problem with alligators as their threat can be lethal.
9. Conflicts with natural area management practices—For example, many natural habitats (e.g., longleaf pine uplands) need prescribed fire. If homeowners were not supportive of prescribed burns, the natural areas would revert to something other than what was intended.

3. A Way Forward

Overall, to make a green development work, more attention to detail must occur during the construction and post-construction phases. It is especially important to take into account the installation and maintenance in both the built lots and the conserved natural areas. Yet, plain inertia within public and private sectors is often a huge barrier to overcome. Development has gone down a conventional path for decades and it will be difficult to shift peoples' attitudes in adopting green construction and post-construction strategies. To create change or at least the conditions to foster change, planners/policymakers and developers can play a pivotal role.

Planners/policymakers can create the enabling conditions to increase the uptake and implementation of sustainable development practices. Unfortunately, particularly with regards to open space conservation, most of the policy effort is concentrated on the design phase with only token attention for the construction and post-construction phases [15]. Developers (and associated built

environment professionals) should be encouraged or required to adopt sustainable practices during construction and to prepare viable long-term management and education programs for the post-construction phase. A planner's toolbox includes regulatory policies (*i.e.*, "sticks") or more incentive-based policies (*i.e.*, "carrots"). Depending on the local political/social/economic climate, carrots may be the first step with regulations to be adopted later. Because it is voluntary, incentive-based policies are a popular policy strategy as it usually meets little resistance. Incentives are typically financial and include such measures as housing density bonuses, judicious use of conservation easements [16], permit breaks, and fast-tracking permits. However, care needs to be taken when crafting an incentive-based policy. Many incentive-based policies have failed or have had very limited impact [17]. Failure occurs due to three factors. First, policies are developed without the involvement of important stakeholders and the incentives are not viewed as true incentives for the affected parties. Often, there is a perception that green practices only add costs to a project with very little financial benefits; thus, the incentives are not regarded as sufficient enough to overcome the financial burden of implementing a green practice. However, green practices can provide a financial benefit, such as homes in green neighborhoods sell more quickly than those in conventional neighborhoods [18]. Second, incentive-based policies are implemented without marketing or education plans. As a result, policies just sit on the books because the private sector is not aware of them. Finally, some incentive-based policies are developed without the government determining whether inter-department agencies have the capacity to implement these new policies. For example, a fast-tracking incentive to encourage Low Impact Development (LID) practices could have been crafted by planners without the knowledge of this by regulators (e.g., city engineers). When the first developer submits a development plan, he or she could get rejected by regulators because they are not comfortable approving a project that contains practices that do not fit with current engineering standards. In this case, regulators must work in conjunction with planners to formulate unique policies. To potentially have some impact, incentive-based policies should address the above three factors. In addition, green development projects should be monitored over time to determine whether an incentive-based policy actually had the desired effect. This critical feedback will help determine the "true effect" of a policy and whether it should be continued or changed in some manner.

Success is ultimately contingent on whether developers and environmental consultants are engaged. Discerning developers should hire only consultants that are aware of appropriate construction and post-construction techniques. In turn, consultants should only hire trained and *engaged* contractors and sub-contractors. Having a team that understands the importance of construction and post-construction phases is probably the single, best factor that determines the long-term success of a project. Even with the best regulations and an admirable conservation ethic by the developer, what happens on a day-to-day basis during construction (and afterwards) has ramifications that stretch well into the future. To help train built environment professionals, academia and other instructional agencies can develop continuing education courses that address construction and post-construction issues. Most built environment professions require continuing education units (CEUs) to retain licenses, and these courses could be approved by various professional societies and made available for their members. University of Florida's Program for Resource Efficient Communities (PREC,

www.buildgreen.ufl.edu) has successfully administered a number of continuing education courses targeting built environment professionals.

While no exact formula has been tried and tested, I suggest below several key construction and post-construction practices. These practices should be implemented by the built environment professionals and supported by appropriate polices.

3.1. Construction

1. Reduction or elimination of turfgrass lawns. A number of native groundcovers and native shrubs and trees covers are available.
2. Utilization of stem wall construction for houses. Often, fill dirt is required to raise the grade of the lot to meet flood requirements. However, if one uses stem wall construction, only the footprint of the home is raised up the required amount to meet flooding standards. This way, the whole site does not need to be graded; the topsoil is conserved on a lot-by-lot basis.
3. Establishment of clearly marked construction site access and routes that coincide with eventual streets and roads. This will limit compaction of the soil to areas that will contain roadways for the subdivision.
4. Designation of parking and stockpiling sites for vehicles and building materials. One should limit and clearly mark these areas so contractors know where to park vehicles, to mix materials, and to store materials. In particular, riparian buffers should be off limits to vehicles and construction activities.
5. Avoidance of lowering or raising the grade around trees and natural areas as lowering the grade damages roots and raising the grade smothers them. Sturdy, protective fences must be installed at least around the dripline of trees.
6. Regular construction equipment checks for invasive-exotic material. Establishment of an effective monitoring system to identify and eradicate any invasives and also to clean machines before they enter a construction site.
7. Construction and *maintenance* of silt fences. All it takes is one blow out to impact nearby wetlands.
8. Development of environmental covenants and contracts for all contractors and subcontractors. In particular, contracts should clearly identify areas and landscape features that are protected; financial penalties should be listed for contractors that damage these areas. Even bonuses could be included where contractors do no damage to protected areas.

3.2. Post-Construction

1. Creation of strict Codes, Covenants, and Restrictions (CCRs) that address environmental practices and long-term management of yards, homes, and neighborhoods. These CCRs should describe environmental features installed on lots and shared spaces and appropriate measures to maintain these. An example of an environmental CCR can be found at http://edis.ifas.ufl.edu/uw248.

2. Development and installation of an on-site education program that includes educational kiosks along primary walkways and a Web site that provides detailed information about local environmental and conservation issues. An example can be found at www.wec.ufl.edu/extension/gc/harmony/. This type of education program can impact homeowner knowledge, attitudes, and behaviors [19].
3. Establishment of a homeowner association that includes a sub-group to oversee conservation issues associated with built and conserved areas.
4. Creation of a funding source to help with the management of natural areas. Funds can be collected from homeowner association dues, home sales (even resales), and the sale of large, natural areas to land trusts with some of the funds retained for management.
5. Hiring a landscaping company that understands environmental management techniques for shared common areas, such as stormwater retention ponds, forested areas, and riparian buffers.

In summary, to build functional green communities, design is important but construction and post-construction practices must be addressed. Any development plan must contain language that addresses the environmental and conservation features of both built and conserved natural areas and this plan must be formulated during the design phase. It is inadequate to set aside natural areas, for example, but have landscaped yards that consist primarily of exotic vegetation. To increase the ranks of built environment professionals that are aware of construction and post-construction issues, I suggest that academic departments, especially Planning and Landscape Architecture Departments, establish joint ventures and degrees with more environmental departments such as Wildlife, Biology, and Soils. Design studios could be co-taught and include instructional content that addresses design, construction, and post-construction phases. In lieu of academia, continuing education courses can address holistic construction practices where practitioners receive continuing education units (CEUs) for taking such courses. Ultimately, successful land use planning practices requires the engagement of practitioners. Academic and continuing education courses, which include specific construction and post-construction material, will help foster more holistic, green development projects.

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