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Homebuilder Activities and Knowledge of Tree Preservation during Construction: Comparison of Practitioners in Rural and Urban Locations

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Abstract: Preservation of existing trees is one of the few tools available to communities seeking to maintain or increase tree canopy coverage. This study compared the knowledge and activities of builders in an urban locale with a strict tree preservation ordinance and rigorous enforcement against a rural locale with no tree preservation ordinance. Overall, there were more similarities than differences between the two groups though some of those differences are very important. Urban builders and rural builders scored a very similar average of correct responses on questions testing their knowledge: 63% and 65%, respectively. The major difference between urban and rural appears to be in activities as dictated by ordinance. Urban builders were more likely to consult tree preservation experts and use tree fence to create tree protection zones. The successful tree preservation outcomes in the urban community are likely a direct result of ordinance requirements and enforcement by the City Forester, not builders' knowledge or their conscious decisions.

Keywords: home building; development; questionnaire; tree ordinance; urban development; urban forestry; urban trees

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1. Introduction

Humans' desire to live in a wooded environment is deeply rooted as a place attachment [1–4]. Developing a home in a wooded environment often involves a suite of individuals and groups making decisions about tree preservation: homeowners or residents (especially in the case of demolishing and redeveloping existing homes on properties [5]); municipal governments who pass ordinances regulating trees on private properties and/or construction and building activities [6]; and, of course, the home builders or developers making design decisions and engaging in physical construction activities on the property [7]. The knowledge, skills, and abilities of builders to successfully preserve trees vary [1,7,8]. Since, in the U.S., builders are the only party engaging in the actual construction of a home and making physical alterations to the landscape, understanding the strengths, limitations, and gaps in tree preservation knowledge of builders has a direct impact on post-construction tree health and survival outcomes [9].

Trees provide a suite of services to society that affect the sustainability and livability of the built environment [10–12]. Across the urban landscape, impervious surfaces, air quality, and urban heat island issues are pronounced, and the canopy cover of urban trees and forested areas provide significant benefits: an estimated $18.3 billion dollars in economic value are provided just from air pollution removal, building energy use savings, carbon

sequestered, and avoided emissions alone in the US [13]. In urban and suburban residential areas, trees may exist singly along streets or in yards, while groups of trees or "woods" create larger patches of canopy cover in backyards or across adjacent treed properties. The loss of trees as a result of development and construction results in a loss of potential rainfall interception, air pollution removal, shade and temperature mitigation, and energy conservation [14]. Because 75% of all canopy cover in cities is on residential and vacant lands [13], the loss of trees due to unregulated residential construction and redevelopment can be especially impactful to communities both ecologically and socially.

Various rules and regulations have been created at national to local levels to regulate development and construction activities near trees [6,14–18]. The temporal development of regulations was predicated on the removal of trees either during construction or their later decline and death as a result of construction processes [6,19]. Typically, a local ordinance becomes the foundation for guiding the rules of the game for construction in wooded locations [20]. Hauer and Peterson [21] found tree ordinances are widely prevalent; 89% of people in the USA live in a community that has one. Ordinances that regulate the construction process are less common, but 54% of US residents live in places that required tree preservation of some form [18,21]. This trend in municipal tree regulations is relatively modern, with only 11–14% of people living in municipalities in the 1970′s and 1980′s having tree ordinances [18]. Tree preservation ordinances tend to be more common in rapidly developing communities [20]. The effectiveness of these ordinances to reduce tree loss varies [18,22–26]. The mechanisms to promote retention or replacement of removed trees can take the approach of regulations, education, or incentives [27].

Delineating a tree protection zone (TPZ) is a common strategy to retain trees during construction, especially during the rapid redevelopment currently underway in many US urban and suburban communities. A TPZ is an area around an existing tree(s) in which certain activities (e.g., storing materials or equipment, driving heavy machinery) are prohibited or limited to prevent or minimize negative impacts to trees [28]. The size of the TPZ to ideally protect tree health and promote survival varies based on tree species, size, health, and maturity, but also must commonly accommodate the realities of construction activity. The critical root zone (CRZ) is the minimum radius of roots that are biologically essential for tree health and structural stability [28]. The CRZ is often used in determining an adequate TPZ and can be codified in local regulations using tree diameter to calculate a distance from the trunk of the tree as a guide of how far to stay away (e.g., X feet or meters away per diameter- inch/cm of trunk) to avoid branch, stem, root, and soil damage. When implemented correctly, tree protection can lead to no difference in tree survival and condition between trees in construction zones and those outside of construction activities [9].

Regardless of institutionalized approaches to promote tree retention during construction, people involved with construction on-the-ground are key actors with tree survival or death. The perceptions of homebuilders of trees and construction has been investigated in a few locales [1,7,8,29]. For example, O'Herrin et al. [8] found home builder knowledge of basic tree biology increased over 25 years for some factors (e.g., heavy equipment can damage roots, soil fill over roots can hinder gas exchange, compaction is more severe in wet soils); however, there was no net overall change in knowledge between the time period with ~55% giving the correct response to tree biology questions. Despot and Gerhold [7] found builder knowledge of factors that might damage trees and practices to best preserve trees was lower than that of arborists. Interestingly, builders were unlikely to consult with professional arborists to develop and implement tree preservation plans [8,30]. The cost associated with tree preservation [7] and site constraints [30] are factors given for not attempting to preserve trees.

The aim of this paper was to ascertain the builders' knowledge and perceptions of trees and construction. We investigated the following questions:

1. What is the builder frequency of redevelopment on wooded lots?
2. What activities typify construction near trees on wooded lots?

3. What are the tree removal amount and tree structural elements associated with removal decisions?
4. What is the level of builder knowledge of tree biology and soils?
5. What is the importance of activities associated with tree removal and preservation?
6. What are their preference attitudes for altering natural areas and the environment?

This study was further designed to contrast builder activities and knowledge between those who practice building homes in a rural area and those from an urban locale.

2. Methods

2.1. Study Locations

This study was conducted in two locations. The first is Highland Park, IL, USA (42.1817° N, 87.8003° W), a suburb about 25 miles north of Chicago, IL, which had a regional population of 9.5 million. The City of Highland Park had a 2019 population of 29,515 residents across a 12.27 mi2 area (31.79 km^2) [31]. As of 2019, Highland Park (HP) residents had a median household income of $147,962, a median home value of $575,800, and 83% percent of residents owned their own homes [31]. By contrast, the U.S. median household income in 2020 was $67,521 [31] and the median home sales price in 2020 was $329,000 [31]. The population identified as 90.7% White, 7.9% Latino, 2.9% Asian, 0.8% Black, 2.7% two or more races, and 0.1% Native American or Alaskan Native [31]. HP had 49% tree canopy cover across the entire city (59.1% canopy in residential areas that comprise 51.53% of all land use) in the most recently available analysis [32]. Forest type in HP is a remnant *Quercus* spp. & *Carya* spp. (oak-hickory) woodland with poor natural regeneration due to deer over-browsing and competition from invasive buckthorn (*Rhamnus cathartica* L.), which is prevalent in the understory.

Study results were further compared against results from a study in Portage County, WI (44.4736° N, 89.4742° W) by O'Herrin et al. (2016). The much less dense rural county had a population ~70,000 in an 800.78 mi2 area (2074 km^2) and was anchored by the city of Stevens Point (population ~25,000 in 18.53 mi2 area (48 km^2) in the center of the county). Portage County (PC) residents had a median household income of $58,853, a median home value of $168,100, and 69% owned their own home [31]. The county's population identified as 93.8% White, 3.4% Latino, 3.1% Asian, 1.0% Black, 1.5% two or more races, and 0.5% Native American or Alaskan Native [31]. Communities in the PC region had an ~28% tree canopy cover [33]. Forest type in PC varies by site conditions, however the predominate construction areas occur in glacial influenced soils with *Pinus* spp., *Quercus* spp., and *Acer* spp. trees.

2.2. Participant Selection and Questionnaire Design

Participants selected for this study were a part of previous studies for both locations. The HP participants were selected from a study testing a tree preservation ordinance for its effectiveness in protecting trees on residential properties that underwent redevelopment, which is where an original home was either partially or entirely demolished and a new, usually larger, home was constructed in its place [6]. All residential builders that constructed homes in that study (n = 35) and all builders who currently held construction permits in the city (n = 188) were included as participants. The two builder group lists were merged and duplicates were removed, resulting in a total of 184 home builders being contacted. The PC participants came from a member list of the Golden Sands Home Builders Association builder group (n = 49).

The survey was designed to explore the existing knowledge, perceptions, and practices of builders regarding tree preservation on residential properties during and after redevelopment occurs. Note that author K. O'Herrin was City Forester of HP during research design and data collection. The HP survey was approved by DePaul University's Institutional Review Board (IRB, #JV011720CSH) and included 41 questions (Supplementary Materials). The PC survey (#HBKP07) was approved by the UWSP IRB and included 42 questions [8]. Most questions in the HP survey (See Supplementary Materials) were

adopted from O'Herrin et al. [8] and Vander Weit et al. [1]. In brief, these questions ascertained builder activities (e.g., tree removal decisions, construction approaches), knowledge about basic tree biology and soils, and the builder's assessment of buyer preferences for development characteristics. Some questions were updated to reflect current knowledge and practices surrounding tree care during construction (and after a beta review from tree experts). The HP survey also included two sets of questions adapted from Milfont et al. [34] designed to create two indices or scales of environmental attitudes of study participants: (1) respondent enjoyment of nature, and (2) altering natural areas for human usage. Questions about builder decisions around tree removal or preservation and environmental attitudes utilized a Likert scale, where respondents were asked to assess their level of importance or agreement for survey items on a 5-point scale (1 = very unimportant or strongly disagree; 3 = neutral; 5 = very important or strongly agree).

2.3. Data Collection Approach

Surveys were sent following the Dillman [35] method: 4 mailings were sent by US Postal Service mail beginning on 9 April 2020 (this time period coincided with the beginning of the COVID-19 pandemic, but we do not think this is likely to have influenced the survey response rate or builders' answers significantly). All questionnaires included a unique identifier used to track participant responses and to target reminder postcards and duplicate questionnaires to non-respondents accordingly. The first mailed item was a letter informing the homebuilder they could expect to receive a questionnaire in the mail soon. The second mailed item was a packet containing a cover letter explaining the research study, the questionnaire itself, and a self-addressed and postage-paid envelope for returning the questionnaire. The third mailed item was a postcard reminding any non-responding homebuilder they had received the questionnaire in the mail and requesting the homebuilder contact the researchers if they required a replacement questionnaire. The fourth mailed item, as necessary, was a replacement questionnaire to homebuilders who had not yet responded. All mailings also included a URL link and option to respond to the survey online via the Qualtrics survey platform (as licensed for institutional use to DePaul University). All surveys returned by standard mail were entered into Qualtrics in preparation for analysis. A total of 25 builders (14%) completed the HP questionnaire. Comparatively, 27 builders (55%) responded to the PC survey. Delivery of the PC survey was similar as above and described in detail in O'Herrin et al. [8].

2.4. Data Analysis

Study results were tabulated descriptively as frequency counts and means. Differences in responses between this study and O'Herrin et al. [8] were evaluated using two methods. A test comparing two binomial proportions was used for comparing builders' assessment of buyers' site preferences, builder activities, and builder knowledge. A Mann–Whitney U test was used to compare Likert scale questions measuring importance [36]. Significance for tests was set at $\alpha \leq 0.05$ as evidence to reject a null hypothesis of no differences between HP and PC builder survey responses. Marginal significance was interpreted for probabilities between an $\alpha > 0.05$ and ≤ 0.10. Scores on the index of environmental attitudes were developed using the means of respondent Likert scores, with Chronbach's alpha reported. All data analysis used SPSS version 27 (released 2020, IBM Corp. Armonk, NY, USA).

3. Results and Discussion

3.1. Builder Demographics

Builders in HP had a mean of 27 years of experience building homes (median 30 years). Most builders (71%) were aged 55 or older and 83% were working full-time. Education levels of builders varied: 17% had a high school diploma, 4% had a trade or technical degree, 50% had a bachelor's degree, 25% had a master's degree, and 4% had some type of professional degree (MD, JD, DDS, etc.). Builders had a wide range of total pre-tax household income with 14% earning $50,000–99,999, 19% earning $100,000–149,999, 29%

earning $150,000–199,999, 10% earning $200,000–249,999, and 29% earning $250,000 or more. Builder demographics from the PC study were not ascertained.

Most builders worked frequently (46%) or occasionally (42%) in HP, with a few (12%) responding that they rarely worked in the city. Few builders (4%) responded that they typically only build homes on speculation (building without a specific homeowner or buyer secured), while 44% responded they typically only build custom homes and 52% responded that they engage in both. Building homes on speculation is much more common in new subdivisions [37]. HP was completely subdivided and parceled out decades ago and is now undergoing almost exclusively redevelopment (single houses being demolished to make room for a new house on the same footprint).

3.2. Builder Preferences for Nature and the Environment

Environmental attitude scales are used to discern human behavior towards an environmental problem [38]. We adopted two different index measurements of environmental attitudes from Milfont et al. [34]. The 'Enjoyment of Nature' scale measured "the belief that enjoying time in nature is pleasant and preferred to spending time in urban areas, versus belief that enjoying time in nature is dull, boring and not enjoyable, and not preferred over spending time in urban areas" [34]. HP builders scored a mean of 4.12 on a scale of 1 to 5 where 1 is a low level of enjoyment, 3 a neutral feeling, and 5 suggests a high level of enjoyment of nature (Chronbach's alpha 0.953).

The 'Altering Nature' scale measured "the belief that humans should and do have the right to change or alter nature and remake the environment as they wish to satisfy human goals and objectives, versus belief that nature and the natural environment should be preserved in its original and pristine state and should not be altered in any way by human activity or intervention" [34]. HP builders scored a mean of 3.18 on a scale of 1 to 5 where 1 is a high level of discomfort, 3 a neutral feeling, and 5 a high level of comfort toward altering nature (Chronbach's alpha 0.886).

3.3. Builders' Assessments of Buyer Preferences and Tree Survival

In a national survey of builders, Despot and Gerhold [7] found that an overwhelming majority of builders agreed that clients will pay a premium for trees to be preserved on-site. Therefore, in our surveys, we asked builders for their assessment of buyers' preferences with respect to tree and site characteristics.

3.3.1. Tree Removal Preference

When asked if certain sized trees are removed, HP builders responded affirmatively in more than twice the proportion than PC builders (Table 1). But of those responding yes, PC builders then indicated that they remove trees in all three size classes at much higher levels than HP builders. O'Herrin et al. [8] interpreted this as a 'preference' held by PC builders, since there is no ordinance dictating what size can or cannot be removed. However, there is such regulatory intervention in HP where a permit is required to remove trees 8 in (20 cm) diameter at breast height or greater.

Builders in both HP and PC showed a propensity to remove small trees instead of large trees. This may be directly influenced by buyers as HP builders reported that buyers express a preference for certain tree sizes at a statistically similar rate to PC builders, and in both cases preferred (over 50%) large-diameter trees ($\geq$10 in (25 cm) be left on site far more than medium or small trees.

Table 1. Characterization of development of woodlots into residential lots and buyer preferences in Highland Park, IL (n = 24) and Portage County, WI (n = 27).

Buyer Site Preferences	Percent (%) Yes		Relative Difference	Z-Score	p-Value
	Portage County	Highland Park			
Are certain sized trees removed?	22.2	54.2	32.0 [z]	−2.224	0.026
If yes, small size 2.0 to 3.9 in (5.0 to 9.9 cm)	100	29.2	−70.8 [z]	5.354	<0.001
If yes, medium size 4.0 to 9.9 in (10 to 25 cm)	83.3	20.8	−62.5 [z]	4.469	<0.001
If yes, large size ≥ 10 in (25 cm)	33.3	8.3	−25.0 [z]	2.168	0.030
Are certain types of species removed?	25.9	22.7	−3.2	0.266	0.791
Buyers express preference for type (species) left on lot	66.7	41.7	−25.0 [y]	1.791	0.073
Buyers express preference for certain tree size left on lot	40.7	58.3	17.6	−1.255	0.210
If yes, small size 2.0 to 3.9 in (5.0 to 9.9 cm)	0	4.2	4.2	−1.076	0.282
If yes, medium size 4.0 to 9.9 in (10 to 25 cm)	27.3	16.7	−10.6	0.908	0.364
If yes, large size ≥ 10 in (25 cm)	72.7	54.2	−18.5	1.374	0.170
Buyers' preference for site following development					
Site left as natural as possible	14.8	21.7	6.9	−0.640	0.523
A partially landscaped and partially natural site	81.5	60.9	−20.6	1.632	0.103
A totally landscaped lot	3.7	17.4	13.7	−1.617	0.106
Buyers' complaints received by builders					
Dead trees	25.9	33.3	7.4	−0.579	0.563
Portions of trees dying	22.2	29.2	7.0	−0.573	0.567
Scars on trees	18.5	12.5	−6.0	0.588	0.556
Exposed roots	18.5	4.2	−14.3	1.582	0.114
Cut roots	11.1	4.2	−6.9	0.914	0.361
Windthrown trees	3.7	8.3	4.6	−0.698	0.486
None	63.0	66.7	3.7	−0.276	0.783

[z] Significant at $p \leq 0.05$ level. [y] Significant at $p \leq 0.10$ level.

When asked if certain species are targeted for removal, no difference was found. Species listed by HP builders were those "as required by the forester", "invasives such as buckthorn (*Rhamnus cathartica* L.)", "predominantly invasives", and "scrub trees, do not know the names." Far fewer HP builders reported that buyers express a preference for certain species of tree to be left on the lot than PC builders (Table 1). This is likely a result of the difference between the land clearing occurring on previously undeveloped woodlots in PC being viewed as a "blank canvas," as opposed to redevelopment of existing homes on heavily-treed properties coupled with a strict tree ordinance in HP greatly limiting buyers' choices on tree removal. At the time of the study, no community had a tree preservation ordinance in PC [14].

3.3.2. Landscaping

HP builders reported fewer buyers who prefer a partially landscaped and partially natural site following development at a lower rate than PC builders/buyers (Table 1). HP buyers also reported far more buyers who prefer a totally landscaped lot compared to PC builders/buyers.

3.3.3. Buyer Complaints

Buyers' complaints received by builders were reported by both HP and PC builders at very similar rates (Table 1). Approximately two-thirds of builders from both locations reporting no complaints were received at all about trees. Of those HP builders that did indicate receiving complaints about trees, the most common were concerning entire dead trees or portions of trees dying.

3.3.4. Tree Death

When asked how often trees die from construction activities during or post-construction, PC builders reported trees die rarely (11%), occasionally (56%), or often (33%), but never very often (0%). Answering the same question on tree death, with a modified question response, HP builders were even more optimistic about tree survival. They thought tree death never occurs (55%), or less than half of the time (46%), while no HP builders thought trees die more than half the time (0%) or always (0%). It appears HP builders are greatly unaware of actual tree death outcomes, because Pike et al. [6] used a content analysis of construction plans and visited 96 construction sites in Highland Park to reveal 92% of those construction sites studied lost at least one tree 8 in diameter or greater.

3.4. Preconstruction Plan Development and Refinement

The development of plans and their refinement ideally happens before construction occurs near trees [39]. An initial step is developing a plan. The plan is then reviewed for compliance with ordinances and further expert opinion on tree tolerance to the plan as designed. Redesign might be needed and may undergo negotiations with city officials, the builder, and possibly the home buyer/owner.

3.4.1. Design Considerations

Decisions that ultimately lead to good or bad tree outcomes begin in the design process, during which builders may consult not only with existing property owners or consider potential buyers, but also negotiate with the local municipal authorities to make sure building and site designs meet local regulations, including building codes and applicable tree ordinances. In our survey, we asked about any modifications made specifically in consideration of potential tree damage during the design phase and the relative positioning of hardscape elements (foundations, driveways, and sidewalks) with respect to trees.

Only 37% of PC builders said the location of the new home's footprint on the lot was frequently moved to avoid tree damage, while 59% responded seldom (59%) or never (4%). However, HP builders indicated that the placement of the following was altered to avoid tree damage: foundation/house (75%), garage (71%), driveway (71%), sidewalk (63%), and utilities (83%).

A third of HP builders reported placing foundations within 10 ft (3 m) of trees, while only a small fraction of PC builders reported the same (Table 2). PC builders were likely removing trees preemptively rather than digging foundations so close to trees. Preemptive removal occurs in HP as well, which may be why Pike et al. (2021) found no correlation between proximity to newly developed foundation and observed tree condition or mortality in that study of tree preservation success in HP. (Note that Pike et al. [6] only studied trees that were intended to be preserved and were unable to catalogue trees that the City Forester allowed to be removed preemptively.) A distance of 10 ft or less may not leave enough space for heavy equipment to operate between the preserved tree and the edge of the new foundation, and builders generally prefer a site with no such obstacles. However, the City Forester in HP sometimes requires trees to be preserved this close to both existing and new foundations (see next section below "3.4.2 Negotiations . . . ").

Interestingly, more than three-quarters of HP builders reported consulting tree experts (e.g., foresters, arborists, or other tree specialists) while creating development plans for residential construction, which is nearly four times greater than PC builders. This is likely because the HP ordinance requires them to submit a full tree site plan with an inventory to apply for building permits. The ordinance does not stipulate this be prepared by a certified arborist or similar; however, these plans are usually very accurate and are also field-verified by the City Forester (see next section).

Table 2. Percentage of builders who indicated the following questions typify their activities when building residential homes on wooded lots in Highland Park, IL (n = 24) and Portage County, WI (n = 27).

Activity	Percent (%) Yes		Relative Difference	Z-Score	p-Value
	Portage County	Highland Park			
Foundations placed within 0 to 10 ft of trees	7.4	33.3	25.9 [z]	−2.326	0.020
Driveways placed within 0 to 10 ft of trees	63.0	41.7	−21.3	1.521	0.128
Sidewalks placed within 0 to 10 ft of trees	59.3	50.0	−9.3	0.666	0.505
Heavy equipment passing near base of tree	70.4	45.8	−24.6 [y]	1.782	0.075
Removal of trees	92.6	83.3	−9.3	1.028	0.304
Pruning of trees	59.3	83.3	24.0 [y]	−1.878	0.061
Trees or shrubs planted	40.7	75.0	34.3 [z]	−2.468	0.014
Lowering of the grade	40.7	37.5	−3.2	0.234	0.815
Raising of grade (fill)	92.6	45.8	−46.8 [z]	3.661	<0.001
Root pruning	7.4	62.5	55.1 [z]	−4.167	<0.001
Providing irrigation as needed	18.5	33.3	14.8	−1.211	0.226
Consult tree expert while creating development plans	22.2	79.2	57.0 [z]	−3.973	<0.001
Trenching for underground utilities	96.3	NA	NA	NA	NA
Boring for underground utilities	NA	87.5	NA	NA	NA

Note: NA = Not applicable, as the question was not asked that year. [z] Significant at $p \leq 0.05$ level. [y] Significant at $p \leq 0.10$ level.

3.4.2. Negotiations to Meet Tree Protection Ordinance

One major difference between the two locations that may explain the greater consideration of trees during the design process and subsequent less impactful building practices is the codified tree protection ordinance in HP [6]. (Recall no tree protection ordinance existed in PC at the time of the study.) The HP Tree Preservation Ordinance specifies that the City Forester shall not issue the tree removal permits necessary for building unless they find "all reasonable efforts have been undertaken in the architectural layout and design of the proposed development to preserve existing " . . . trees 8-inch diameter or greater . . . " [40]. This includes modifying the placement of foundations, driveways, sidewalks, and utilities; prescribing construction means and methods; and protecting the critical root zone with tree fence and other best management practices. Admittedly, "all reasonable efforts" is subjective and often a negotiating point with the HP City Forester, who has a great deal of authority to enforce tree protection activities. The aim is not to prevent development, but rather to enable development to occur in a way that trees are preserved. This functionally translates into a need to negotiate with builders. The City of Milwaukee has likewise developed a program that allows construction near street trees that involved contractors in developing a tree preservation program with no differences in tree survival or health between trees in construction and non-construction zones [9].

During redevelopment in HP, builders usually reuse existing foundation footprints, however they also often choose to excavate to expand that footprint, often approaching the maximum building size allowed per building ordinance. Additionally, existing detached garages are often demolished and replaced with attached two-, three-, or four-car garages, both increasing the footprint of the garage and relocating that footprint on the lot. This puts at risk any existing trees that were previously a biologically safe distance away from the old foundation.

Driveways can have major impacts on trees and frequently come up as a point of contention between the City Forester and builders. Codified limits on impervious surface in HP are relatively weak and rarely limit driveway expansion, despite recent increases in localized flooding events [41–44] and the acceleration of destructive erosion in the community's ecologically sensitive ravines [45,46]. Whereas the foundation of a home is viewed as sacred and often given priority over trees, driveways are viewed as both consumable and plastic, and must accommodate trees. Architects and designers may

propose flipping the driveway from one side of the lot to the other based on placement of the attached garage, which in turn is influenced by the layout and design of the entire home (especially garage proximity to the kitchen). Flipping the driveway often encroaches on existing trees in the front yard, or even City-owned street trees, and is not necessarily permitted. Other current trends in HP include installing a new half-circle driveway which connects to the street at two points, or a side-loading garage because garage doors facing the street is viewed as aesthetically inferior. Either luxury requires excavation to greatly expand the driveway, putting existing trees at risk of root loss, as well as long-term risk of potential decreased oxygen and water from increased impervious coverage. For these reasons, the City Forester frequently refuses to permit these types of driveway expansions based on proximity to existing trees. Alternatively, the Forester may require that builders use a combination of excavation techniques that limit root damage (e.g., root pruning and hand digging) coupled with plant health care to mitigate the negative effects of root loss (e.g., mulch, compost, supplemental water, deep root injection, Cambistat growth regulator treatment). Perhaps due to these negotiations, Pike et al. [6] found that the tree survival rate in HP increased as percent impervious surface decreased. Other researchers have observed similar relationships: Just et al. [47] found impervious surface decreased tree condition, and Elmes et al. [48] found impervious surface increased tree mortality.

3.5. Builder Activities during Construction

Construction activities varied between the two locations (Table 2). Some tree-damaging practices were reported with lower incidence in HP than PC, possibly due to ordinance restrictions (e.g., heavy equipment use near trees).

3.5.1. Tree Removal and Planting

HP builders reported trees being pruned as part of building activities more than builders in PC (Table 2). No difference was found in the reported frequency of tree removal activities. Whereas not quite half of PC builders responded that they plant trees and shrubs as part of development, three quarters of HP builders do so; this is likely due to HP ordinance requiring replacement trees to mitigate for tree removal. No ordinance requires this in PC, however, subdivision covenants in PC may require tree planting in some cases [14]. Per HP's Tree Preservation Ordinance, replacement tree plantings are required for any trees removed during development, with the ratio of replacement trees dependent on the preservation status (size, species) of the trees removed, ranging from 2:1 to 4:1 [40].

3.5.2. Grade Changes and Other Major Site Alterations

Raising the grade was far more common in PC than HP, but interestingly there was no difference in the reported prevalence of grade lowering. One possible explanation for this is different geologies and topographies in the two study areas: builders in PC raise the grade for lots in poorly drained soils to build homes above seasonally high-water tables. Trucking in fill soil to a new home site would be standard practice in PC to achieve drainage and grading that directs water away from the foundation of the new home. In HP, this work would have already been accomplished during construction of the original house, though adjustments would be needed if the new footprint is larger in size; drainage and grading are strictly regulated by the City to prevent unnecessary grade changes within the root zone of preserved trees, but also to prevent major changes to localized flooding (diverting water onto a neighboring property).

The method of utilities installation is dramatically different between study locations: Whereas 96% of PC builders reported trenching for underground utilities, 88% of HP builders reported directional boring for underground utilities. The HP Tree Preservation Ordinance specifically allows the City Forester to require boring instead of trenching where they believe trenching would impact trees. Boring has become very common in the region around HP and utility companies anecdotally report a preference for boring over trenching

most of the time in dense residential situations as it successfully avoids conflict with other infrastructure and homeowners more often than trenching/excavation. The City Forester is also increasingly requiring the use of hydrovac excavation where existing utilities need to be accessed within the CRZ of protected trees. Despot and Gerhold [7] reported that 64% of builders avoided trenching through root zones and 13% used boring under trees. Even though boring equipment is becoming rather common, this is not the case in PC even for wooded lot construction [8].

3.5.3. Activities in the Critical Root Zone (CRZ)

Just under half of HP builders reported that heavy equipment passes near the base of trees, while almost three-quarters of PC builders reported the same (Table 2). Further, in HP, when heavy equipment does pass near trees (i.e., within the CRZ), City code ensures it is done in a controlled and planned way. The HP tree protection ordinance defines the CRZ as 1 ft (0.30 m) radius per 1 inch (2.54 cm) diameter at breast height, and the tree protection zone (TPZ) as an area protected by tree fence in size up to the full CRZ, as determined by the City Forester. In practice, TPZs on tight residential lots must frequently accommodate heavy equipment traffic within the CRZ. Again, as with many activities during the site design phase, the TPZ is often a point of negotiation between builders and the City Forester based on site conditions and proposed design, and the TPZ is often not the full CRZ even on heritage trees (highest priority for preservation per ordinance).

Wherever the TPZ is less than the full CRZ, the Tree Preservation Ordinance allows the City Forester to dictate means and methods, such as requiring wood chips or boards to create a path for heavy equipment within the CRZ. This compromise accommodates both protection of the CRZ and the use of heavy equipment. Over half (59%) of HP builders reported always using wood chips or boards (plywood), 9% more than half the time, 5% about half the time, 9% less than half the time, and only 18% never. On the other hand, only 19% of PC builders reported using wood chips or boards. Despot and Gerhold [7] found only 0.1% of builders reported using geotextile fabric and wood chips to protect tree roots, despite 56% of respondents being aware of the practice; this low usage may have been due to the added requirement of geotextile fabric where wood chips alone would suffice.

HP builders were eight times more likely to root prune than PC builders. Root pruning is a proactive step to minimize root severing from excavation [39,49,50]. Root pruning is frequently required in conjunction with hand-digging as a condition of permits, as opposed to digging with heavy equipment which rips and tears roots indiscriminately.

3.6. Importance of Tree Preservation Activities

In addition to asking about the actual practices engaged in during construction on sites, we also surveyed builders to rate the importance of 11 specific tree preservation activities, which are commonly part of Best Management Practices for construction near trees [39]. Overall, builders in HP rated tree preservation activities as significantly more important than PC, both overall and on nine of the eleven individual items (Table 3). On a scale of 1 to 5 from very unimportant (1) to very important (5), the 11-question mean importance index score for HP builders was 4.2 (“important”) while PC builders felt more neutral about these activities (Table 3). The activity with the greatest relative difference was the importance of consulting with tree preservation experts, which HP builders rated on average as “important” (4.1) and PC builders rated between “not important” and “neutral” (2.5). This finding contrasts with past studies [7,30] that found builders were less likely to involve tree preservation experts. Identification of tree location in proximity to construction activities was the highest rated activity by both PC and HP builders, although HP builders rated tree location as even more important than PC builders did. The reason for this is likely a result of numerous factors, including that HP developed tree preservation requirements in 1991. The redevelopment occurring in HP also does not involve land-clearing as would be required when building a new home on a previously undeveloped woodlot in the rural-like PC locale. Compared to PC builders, HP builders rank with greater importance

inventories for tree size and condition, creating a TPZ, identifying vehicle movements, identifying tree care needs, and moving the building footprint based on tree susceptibility to construction activities.

Table 3. Importance rating of tree preservation activities during building on wooded lots by builders in Highland Park, IL and Portage County, WI. Each item was rated on a scale of 1 to 5 from very unimportant (1) to very important (5). Results of a Mann–Whitney U test show differences in mean score between Highland Park, IL and Portage County, WI. Items listed in descending order of importance as rated by builders in Highland Park.

Tree Preservation Activity	Portage County		Highland Park		Relative Difference	Z-Score	*p*-Value
	Mean	SD	Mean	SD			
Identification of tree location in proximity to construction activities	4.19	0.895	4.64	0.492	0.45 [y]	−1.708	0.088
Inventorying tree size	3.15	1.134	4.43	0.662	1.28 [z]	−4.114	<0.001
Creating tree protection zones based on the critical root zone	3.38	1.023	4.39	0.656	1.01 [z]	−3.547	<0.001
Assessment of tree condition	3.85	0.989	4.35	0.775	0.50 [z]	−1.977	0.048
Identification of vehicle access movement locations outside of a tree protection zone	3.56	1.086	4.14	1.037	0.58 [z]	−1.980	0.048
Inventorying tree species	3.26	1.163	4.13	1.100	0.87 [z]	−2.810	0.005
Consulting with tree preservation experts	2.52	1.122	4.09	0.949	1.57 [z]	−4.418	<0.001
Determining trees suitable for preservation	3.69	0.928	4.09	0.733	0.40	−1.391	0.164
Identifying tree care needs	3.27	0.919	3.91	0.996	0.64 [z]	−2.378	0.017
Moving proposed house and road locations based on tree susceptibility to construction activities	3.15	1.027	3.86	0.854	0.71 [z]	−2.335	0.020
Creating tree protection zones based on tree species tolerance to construction	3.31	1.011	3.71	1.056	0.40	−1.269	0.205
Overall Average	*3.39*	*1.027*	*4.16*	*0.846*	*0.76*[z]	*−3.789*	*<0.001*

[z] Significant at $p \leq 0.05$ level. [y] Significant at $p \leq 0.10$ level.

3.7. Builder Knowledge

No difference was found between HP and PC for overall builder tree knowledge in the average percent of questions correct: both scored an approximate two-thirds correct responses on questions testing their tree biology and soils knowledge (Table 4).

3.7.1. Soils

Excepting the relationship between soil texture and compaction, HP builders had relatively strong soils knowledge basis, scoring above 80% correct on 3 of 4 soil knowledge items (Table 4). However, HP builder soil knowledge scores were consistently lower than PC builders, with 3 out of 4 soil items being significantly lower for HP than PC. For instance, 86% of HP builders knew that soil compaction becomes most severe when soil is wet, which was significantly lower than the universal soil compaction knowledge of PC builders.

Highland Park is dominated by clay soils, which are highly susceptible to compaction. The soils in PC vary from sandy to clay soils with more development occurring in the sandy soil locations [8]. Pike et al. [6] found mean soil compaction in HP sites did not exceed the literature-based thresholds for restricted root growth. That study also found that on sites where construction activities were unrestricted, the soils were significantly more compacted than soils within the TPZ protected by tree fence [6]. Compaction due to

construction activities has been commonly reported in areas that did not take precaution to avoid or minimize soil compaction [51].

Table 4. Percent of builders responding correctly to questions of arboricultural knowledge and effects of construction activities on the development site in Highland Park, IL (n = 18 to 24) and Portage County, WI (n = 19 to 27).

Knowledge Area	Percent (%) Correct		Relative Diff.	Z-Score	p-Value
	Portage County	Highland Park			
Proper arrangement of soil texture and compaction	21.7	14.2	−7.5	0.645	0.519
Proper arrangement of soil texture per air and water movement	100	83.3	−16.7 [z]	2.036	0.042
Compaction is most severe when the soil is wet	100	86.4	−13.6 [z]	1.978	0.048
Cement wastewater can increase soil alkalinity	92.6	73.9	−18.7 [y]	1.798	0.072
Fill over existing soil level will hinder air and water exchange	96.3	87.5	−8.8	1.167	0.243
Heavy equipment will injure exposed and underground roots	92.6	91.7	−0.9	0.119	0.905
Pruning to compensate for root loss	69.2	72.7	3.5	−0.268	0.789
Lateral extent of tree roots	70.4	86.9	16.5	−1.404	0.161
Depth of tree roots	42.3	52.2	9.9	−0.692	0.488
When pruning it is best to cut to the branch collar	37.0	37.5	0.5	−0.037	0.970
Grass around the base of trees can be detrimental	26.9	50.0	23.1	−1.681	0.093
Effect of mulch on trees is preferred to grass	61.5	54.2	−7.3	0.522	0.601
Native undergrowth and leaf litter removal detrimental to tree	37.0	30.4	−6.6	0.491	0.623
Overall Average	65.3	62.7	−2.6	0.193	0.847

[z] Significant at $p \leq 0.05$ level. [y] Significant at $p \leq 0.10$ level.

3.7.2. Roots and Root Damage

Both HP and PC builders have a high-level understanding of the potential negative effects that fill soil and heavy equipment can have on a tree root system, but they have a poor understanding of root systems beyond that (Table 4). In both locations, builders overwhelmingly correctly indicated that fill over existing soil levels will hinder the exchange of water and air between tree roots and soil (Table 4). Over 90% of builders in both locations correctly indicated that heavy equipment passing near trees can injure both underground roots as well as exposed roots. No difference was found between the 87% of HP builders who correctly indicated that tree roots generally extend laterally away from the tree trunk at least to the edge of canopy, compared to the 70% in PC responding the same. Just over half of HP builders correctly believed that tree root systems are most prevalent in the upper few feet of soil and similar to the proportion in PC. Under a third of builders in both locations believed it wise to prune a tree to compensate for root loss. Pruning tree branches to compensate for root loss is generally a practice not supported by research [52].

3.7.3. Pruning

Pruning knowledge was low and consistent between PC to HP builders (Table 4). Less than 20% of HP and PC builders said they cut flush to the trunk—the incorrect approach. Just over a third of both HP and PC builders said they prune to the branch collar, which is proper pruning technique.

3.7.4. Tree-Understory Relationships

In both locations approximately one-third of builders in HP and PC correctly indicated that removal of native understory vegetation and leaf litter may be detrimental to tree health. In HP, 31% said it would have no effect and 39% said removal would benefit the tree, and these were similar percentages to PC (33% and 30% respectively).

Builders were asked about placement of grass and mulch around trees. In HP 50% responded correctly that grass around the base of trees tends to be detrimental (Table 4), while 21% said grass would have no effect on the tree, and 13% said it would tend to benefit the tree. A significantly lower percentage of PC builders responded correctly on this grass question. Just over half of HP builders correctly indicated that mulch around the base of a tree is preferable to grass, which was similar to the percentage of PC respondents who answered correctly (Table 4). In HP 25% thought mulch was only cosmetic and 13% thought mulch could be detrimental to tree health.

Removing understory vegetation is unregulated in HP. After the home is constructed, the tree protection fence is removed to allow for final grading and "restoration," which refers to installation of grass sod. As the footprint of the new home is often larger than the home being replaced, this pushes the yard back on the lot; areas that were previously native understory and leaf litter are removed and replaced with turf, including within the CRZ of protected trees.

3.7.5. Interest in Continuing Education

Interest in education on tree preservation during construction was mixed. Only 46% of respondents indicated they would be interested in attending a workshop on tree preservation and construction in HP. This was consistent with findings from O'Herrin et al. [8]: PC builders either did not know if they wanted to attend (41%) or were not interested (22%). Of the 17 builders in HP responding to the question about how much time would they be willing to spend at such a workshop, 71% indicated two hours, with much less enthusiasm (29%) for a four hour or longer workshop. PC respondents with interest or unsure about attending were most interested in a two-hour (48%) or four-hour (48%) workshop. Despite the aesthetic and property value that trees can bring to residential properties (cf. [53]), less than half of builders in both locations indicate interest in improving their knowledge of techniques and best practices that that could help them preserve large trees in their developments.

3.8. Limitations

This study used the self-reported activities, beliefs, and perceptions of respondents. It is possible that the builders have bias in responses. The sample size in this study, while sufficient to identify statistical differences in many cases, may under-report some differences between the study locations in some cases. As while differences between the two sites exists for tree ordinance codification, we do not know if neighborhood norms affect homeowner and builder practices. Pike et al. [6] was a comprehensive examination of tree preservation success in HP, and not having a similar understanding of tree preservation outcomes in PC—that is, the impact of builder practices on the trees themselves—is a further limitation of this study.

4. Implications

Preservation of existing trees is one of the few tools available to communities seeking to maintain or increase canopy coverage. This study compared the knowledge and practices of builders in one urban locale with a strict tree preservation ordinance and rigorous enforcement (Highland Park, Illinois) against another rural locale with no tree preservation ordinance (Portage County, Wisconsin). Overall, our findings provide applicable outcomes for applied practice, future research, and the urban forestry community as a whole. We bullet point these take-home points below.

4.1. Applied Practice

1. Overall, there were more similarities than differences between the two groups, though some of those differences are very important. HP builders and PC builders scored a very similar average of correct responses on questions testing their knowledge, yet these scores were not "passing grades": 63% correct for HP and 65% for PC builders are letter grades of either 'D-' or 'F' in an academic sense. There is significant room for improvement here both in knowledge and practice, yet less than half of builders at both locales were interested in continuing education. The challenge for tree preservation advocates remains how to engage builders to build knowledge and skills around the impact of construction on trees.
2. The major difference between HP and PC appears to be in activities as dictated by ordinance in HP, compared to the unregulated PC builders. These activities especially include those in the design phase: HP builders report frequently moving foundations, driveways, sidewalks, and utilities to minimize tree damage—often in consultation with the City Forester—and also report more frequently consulting a tree expert during the planning phase.
3. The successful tree preservation outcomes found in HP by Pike et al. [6] is likely a direct result of ordinance requirements and oversight by the City Forester, not builder knowledge or their conscious decisions. Communities likely need to regulate the removal of trees during construction in order to achieve positive tree survival outcomes. Illinois is a Home-Rule state, which means municipalities such as HP are empowered to exercise any power and perform any function pertaining to its government and affairs including regulation to protect public health, safety, and welfare. By contrast, most U.S. states empower municipalities to a lesser degree, and so ability to pass local laws that regulate tree preservation during construction will vary. Additionally, a rising trend in some states is to craft state laws that preempt and obstruct local tree preservation laws [18,54,55].

4.2. Future Research and Scientific Literature

1. This study and Pike et al. [6] increase our understanding of the interplay between builders' knowledge of trees, soils, building, and tree preservation practices; the activities undertaken during construction; and tree outcomes, ultimately proving the effectiveness of tree preservation ordinances.
2. This research can and should be repeated, using the same survey instrument. Many cities have comprehensive building and tree permit records and could collect data from builders as in this survey and perform a 10 or 20 year follow up on tree outcomes (as in Pike et al. [6]). Many cities spend significant time on enforcing tree preservation ordinances, so this is a very important question—how effective are tree preservation ordinances?
3. This research was a collaboration between a municipal government and a university, with funding from a non-governmental organization. We encourage more of this cross-sector research.

4.3. Urban Forestry as a Whole

1. By excluding construction impacts and avoiding land alteration within required TPZs, tree preservation can also protect pervious soil structure and native plant communities, even during redevelopment. This further increases the realized value of tree preservation laws by amplifying benefits such as stormwater mitigation and retaining ecological richness.
2. This study and Pike et al. [6] highlight the importance of adopting tree preservation laws as a foundational principle of any city's efforts to improve their sustainability and resiliency.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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