Imagining Future Cities:
Aesthetic Design Guidelines for Small Cells

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Draft as of September 26, 2019

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I. INTRODUCTION

When imagining a futuristic city, it is easy to visualize a sci-fi world of shiny skyscrapers and seamless, integrated, and advanced utility networks. Infrastructure of the future is neat and flawless – sleek design, architectural style, and contextual balance. Wired utilities are mostly underground, vehicles are automated, flying machines can deliver packages, and the environment is carefully monitored and controlled.

The proliferation of small cells is the next step toward this vision. Heterogeneous 5G networks will lay down the groundwork for enhanced services and applications that rely on high-density connectivity, multi-Gigabit Internet, and low latency. To promote this deployment and maintain a competitive technological edge on other countries, federal guidance is pushing local and state wireless permitting organizations to streamline and expedite their small cell siting processes. As cities begin to consider tradeoffs between maintaining a community aesthetic and incorporating the latest technology into public spaces, they are also influencing the variety of available wireless equipment options designed and manufactured by telecommunications companies. This paper will analyze a sample of wireless small cell infrastructure aesthetic design guidelines published by cities in the United States as required by federal guidance, categorize their common elements, and develop a framework for aesthetic design to facilitate a broader understanding of different options for cities of varying contextual preferences, conditions, and circumstances.

FCC Small Cell Order

The Federal Communications Commission (FCC) 'Small Cell Order'[1] establishes rules on many aspects of wireless siting practices, including preventing state and municipal provisions that have the effect of prohibiting the provision of wireless service, setting shot clocks to speed up the processing of cell site applications, and establishing fee limitations. It also specifies that communities continue to maintain their local authority to regulate sites on aesthetic grounds if such regulation is: "(1) reasonable, (2) no more burdensome than those applied to other types of infrastructure deployments, and (3) published in advance."[2] Publication of aesthetic standards applicable to small cell facilities "should take no longer than 180 days after publication of this decision in the *Federal Register*."[3] That date was April 15, 2019.

While most cities around the country have not yet published guidance (and were not aware of the requirement), many cities have. These small cell wireless infrastructure facilities aesthetic guidelines vary in length, complexity, level of detail, and stringency.

Methodology

This paper will analyze a sample of the most comprehensive and readily available design guidelines published on the Internet, dissect the elements of small cell design, and provide a categorization of small cell guidelines based on their contextual differences. This cross-comparative approach involves the assumption that each of the case studies have a wide variation in contextual and environmental factors, including levels of economic development, growth potential, community size, cultural heritage, policy priorities, political complexity, land and property availability, public participation, governmental hierarchies, administrative division of permitting responsibilities, the availability of human or fiscal resources, and many other local factors.

Due to these differences, it would not be possible to make deductions regarding each community's incentives in establishing different design guidelines with conclusive causality foundations. Any combination of these factors could influence the degree of public pressure, urgency, or hesitation to promote technological development and progress. The research demonstrates that the requirements of many cities can vary greatly from one another, not only in specific prescriptions, but also in the selection of aspects they choose to address. The aspects more commonly specified provide potential best practices for other cities to promote their policy priorities, whether those may be to accelerate

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[1] Accelerating Wireline Broadband Deployment by Removing Barriers to Infrastructure Investment; Accelerating Wireless Broadband Deployment By Removing Barriers to Infrastructure Investment, Third Report and Order and Declaratory Ruling, FCC 18-111, WC Docket No. 17-84, WT Docket No. 17-79, 140-18 (rel. Aug. 3, 2018) (hereafter "FCC Small Cell R&O").

[2] Small Cells – Big Win for Wireless Industry Deployment of 5G Infrastructure. (n.d.). Retrieved June 17, 2019, from The National Law Review website: https://www.natlawreview.com/article/small-cells-big-win-wireless-industry-deployment-5g-infrastructure

[3] FCC Small Cell R&O at 46

or deter deployment. This paper analyzes the following case studies to facilitate an understanding of the range of options available to communities seeking to establish or improve design guidelines:[4]

1. City and County of Denver, Colorado[5]
2. City of Greeley, Colorado[6]
3. Greenwood Village, Colorado[7]
4. City of Westminster, Colorado[8]
5. New Albany, Ohio[9]
6. City of Dublin, Ohio[10]
7. City of Columbus, Ohio
8. Washington, District of Columbia[11]
9. City of Albany, New York[12]
10. City of Madison, Wisconsin[13]
11. City of Austin, Texas[14]
12. Oregon City, Oregon[15]
13. Salt Lake City, Utah[16]
14. San Diego, California[17]
15. City of Brooklyn Park, Minnesota[18]

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[4] As a **disclaimer**, citations from these sources are hereby abbreviated as documented in the footnotes and are not intended to be conclusive. Page numbers are noted to facilitate reference but may not be the only page on which the detail appears, and are likely to change as many of these guidelines will continue to be iterated over time with new versions.

[5] City and County of Denver. "Small Cell Infrastructure Design Guidelines." Department of Public Works, Engineering Division. May, 2019. https://www.denvergov.org/content/dam/denvergov/Portals/705/documents/guidelines/PWES-016.1-Small_Cell_Infrastructure_Design_Guidelines.pdf (hereafter "Denver")

[6] City of Greeley, Colorado. "Small Cell Design Guidelines." April 11, 2019. https://greeleygov.com/docs/default-source/community-development/wireless-communications-facilities/small-cell-design-guidelines-final-draft.pdf (hereafter "Greeley")

[7] Greenwood Village, Colorado. "Small Cell Infrastructure Design Guidelines." April 2019. https://www.greenwoodvillage.com/DocumentCenter/View/18668/GV_Small-Cell-Guidelines-V32-Final (hereafter Greenwood Village")

[8] City of Westminster, Colorado. "Small Cell Infrastructure Guidelines." 2019. https://www.cityofwestminster.us/Portals/1/Documents/Government%20-%20Documents/Departments/Community%20Development/Planning/FINAL_COW%20Small%20Cell%20Infrastructure%20Guidlines.pdf?ver=2019-04-08-083523-003 (hereafter "Westminster")

[9] New Albany, Ohio. "Small Cell Design Guidelines & Requirements." November 2018. https://newalbanyohio.org/wp-content/uploads/2018/12/18.11.26-Small-Cell-DGR_Final.pdf (hereafter "New Albany")

[10] City of Dublin, Ohio. "Design Guidelines for Small Cell Facilities and Wireless Support Structures within the Right-of-Way." As Approved by Dublin City Council June 25, 2018. Ordinance 41-18 (Amended). https://dublinohiousa.gov/dev/dev/wp-content/uploads/2018/05/FINAL-DRAFT_Small-Cell-Design-Guidelines_7.2.18.pdf (hereafter "Dublin")

[11] Washington, DC. "Small Cell Design Guidelines." Third Version. March 21, 2019. https://chrs.org/wp-content/uploads/2019/02/FinalVersionSmallCellGuidelinesDDOT.pdf (hereafter "Washington, DC")

[12] City of Albany, New York. "Small Wireless Facilities – Siting, Construction, and Aesthetic Standards." Department of Planning and Development. March 27, 2019. https://www.albanyny.gov/Libraries/Planning_Development/Small_Cell_Aesthetic_Standards_DraftV3.sflb.ashx (Hereafter "Albany")

[13] City of Madison, Wisconsin. "Interim Small Cell Design Guidelines." June 25, 2019. https://www.cityofmadison.com/sites/default/files/news/attachments/small_cell_design_guidelines.pdf (hereafter "Madison")

[14] City of Austin, Texas. "Small Cell Infrastructure Design Reference Guide." Telecommunications and Regulatory Affairs (TARA). January 2019. http://www.austintexas.gov/sites/default/files/files/Telecommunications/SmallCellInfrastructureDesignRefGuidelines_jan2019.pdf (hereafter "Austin")

[15] City of Oregon City, Oregon. "Small Cell Design and Construction Standard Guidelines for Public Rights-of-Way." February 20, 2019. https://www.orcity.org/sites/default/files/fileattachments/public_works/page/12942/small_cell_public_notice_packet.pdf (hereafter "Oregon City")

[16] Salt Lake City, Utah. "Small Cell Infrastructure Design Standards." September 1, 2018. https://www.slc.gov/engineering/wp-content/uploads/sites/27/2018/08/Small-Cell-Standards-Aug-31-Revised-Version.pdf (hereafter "Salt Lake City")

[17] The City of San Diego, California. Wireless Communications Facility (WCF) Guidelines. February, 2019. https://www.sandiego.gov/sites/default/files/dsd_pc_19-020_12th_update_to_the_land_development_code_and_local_coastal_program_item_12wcf_attachment_1_wcf_guidelines.pdf (hereafter "San Diego")

[18] City of Brooklyn Park, Minnesota. "Small Cell Aesthetic Standards." April 2019. Brooklyn Park Operation & Maintenance. https://www.brooklynpark.org/assets/1/7/APPROVED_-_Brooklyn_Park_MASTER_-_Small_Cell_Aesthetic_Standards.pdf

While extrapolating the policies and preferences of these cities to others is inherently limited, these are some of the first cities to contemplate their community's aesthetic values of incorporating technology into their environment for perpetuity. Having taken the initiative to develop and publish guidelines demonstrates their uniting commitment to research, analyze, and create guidance for the long-term well-being of their community and the preservation of their heritage and cultural values.

Since these case studies are among the first efforts to conceptualize preferences for incorporating wireless technology into the built environment, this paper provides a principal analysis framework for architectural principles of small cell aesthetic design.

The resulting "Small Cells Aesthetic Requirements Framework" (SCARF) will:

- Describe the basic elements of urban architectural design as they may apply to small cell wireless technology
- Provide a cross-comparative analysis of a survey of aesthetic guideline possibilities to identify their common elements and demonstrate their variability
- Integrate the extensive varieties of options in combined design principles
- Extrapolate existing guidelines to cities which have not yet published guidelines and are seeking to understand their variety of options

II. AESTHETIC DESIGN PRINCIPLES

Purpose of Design Guidelines

A city's landscape, architecture, and the built environment unites communities and builds a common identity and culture through which generations of people can relate to those who lived there before them. The concept of identity is bifurcated into the private identity of oneself and the public identity as an affirmation to others. Architectural design reflects and codifies the practice and perception of accumulated personal identity and participation in social life as an interpretation of conventions, traditions, and experience.[19]

The perception of architecture is often creatively described as a language:

> *"You cannot construct pleasing sentences in English unless you have a thorough knowledge of the grammatical ground rules. If you abandon these basic principles of grammar, the result is discordant and inharmonious. Good architecture should be like good manners and follow a recognized code. Civilized life is made more pleasurable by a shared understanding of simple rules and conduct."* [20]

> *The language of architecture speaks to "the forces and aspirations of our times, critical respect for human achievements of the past, and the patient search for a method all lead towards discovery of the design"*[21]

> *"Interpretation is also occluded by architectural historicism. We examine a common and persistent claim made by many that theory is characterized by a successful of ages or epochs, each of which has a unitary character best described as its 'spirit'. There is a spirit of a particular age different to any other, to which architecture can and does give expression. Architecture interprets an era, and in so doing gives expression to, or embodies, cultural movements [and] distils the spirit of a time and a people in its unitary artefacts"*[22]

It seems that the unitary character of today, this spirit of our times, the zeitgeist of the modern age, is technologization. The world is using technological innovation leagues beyond previously conceived tools and methods. As the practice of agriculture allowed for gains of proximity to resources, the industrial revolution expanded gains from scale in

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[19] The two concepts of identity is "*profitably inserted into the process of architectural design … the practice and codified images of those for whom we act as trustee when we build… convention, a tradition… accumulate experience of social life in a given culture*" Meiss at 162. This experience involves "*three interwoven concepts – the pleasure of beauty, stimulation of the mind and reasoned adaptation to existing conditions*" Meiss at 202.

[20] Moughtin, Cliff. "Urban Design: Street and Square." 3rd edition. Architectural Press. 2003. ISBN 0-7506-57170. At p. 11.

[21] Von Meiss, Pierre. "Elements of Architecture: from form to place". 1990. Van Nostrand Reinhold. ISBN 0-442-31151-6. At p. 203.

[22] Snodgrass, Adrian, Coyne, Richard. "Interpretation in Architecture: Design as a way of thinking." Routledge. 2006. ISBN 0-415-38448-6. At p. 4-5.

production efficiency, the information age enables gains from cooperation by drastically lowering the transaction costs of global access and transmission of information. Throughout the guidelines, cities affirm that wireless technology "promote[s] the availability of a wide range of utility, communication, and other services to residents of the City at reasonable costs, including the rapid implementation of new technologies and innovative services"[23] and "support[s] wireless service providers in the efficient deployment of small cell technology, to the benefit of residents, businesses, and visitors."[24]

Meanwhile, cities also strive to create a balance between the need for wireless services and preserving the aesthetic quality, historic character, and pedestrian-friendly design of streetscapes, neighborhoods, and corridors associated with integrating the facilities into the surrounding environment.[25] Cities are concerned with ensuring that small cells are congruent with the existing urban design, minimally intrusive, and aesthetically acceptable in design. The purpose of the guidelines includes promoting contextual compatibility by providing safety from potential hazards and minimizing obstruction of scenic views and streetscapes, visual clutter, and line of sight for vehicles. As the definition of a streetscape can be elusive and imprecise, the following quote provides an eloquent description:

> *"Some architects define a streetscape as a series of building facades designed and orchestrated, with variations, to affect a homogenous look or setting. A streetscape may also be the texture and fabric of a street - a neighborhood - even a town or a city that may have taken decades or even centuries to 'perfect'.*
> *It can be a collection of structures of assorted styles and periods, gracefully patinaed and softened to create a unique and memorable look … it is the composition of shapes and forms - of masses and details - of shadows and highlights: sometimes balanced and harmonious and sometimes kilter and at odds with itself … Streetscapes tell stories: stories about people, about a time in history, a place or a culture."*[26]

This description illustrates the experience of an individual as he or she perceives, senses, appreciates, and identifies with the visual composition of their streets and surroundings. In addition to this enigmatic sense of self and belongingness, aesthetic guidelines also try to preserve and promote practical land uses and facilitate public health, safety, and welfare of the right-of-way.[27] The process promotes clearly-defined aesthetic standards in a nondiscriminatory fashion to all utility applicants,[28] as well as the ability to create and foster partnerships between governmental, commercial, residential, and institutional providers and users of telecommunications services.[29] They are also stated to portray a long-term large-scale plan for the urban landscape, support the growth of wireless technology, maintain quality aesthetics and neighborhood character, provide uniformity and transparency in requirements, and enable public-private partnerships.

Small Cell Architectural Design Elements

The language of architectural and city planning design includes common terms like "contextual compatibility, "aesthetically pleasing", "least obtrusive", "neighborhood character", and "cumulative impact". These terms, like many others describing art, are imprecise and difficult to apply to new and innovative structures. Art is subjective, but professional standards of urban planning and design provide a set of principles and practices in integrating aesthetically compatible and contextually appropriate functional infrastructure. These principles set a structure for how people may perceive, contemplate, feel, sense, and appreciate their experiences of public spaces.

Sources on architectural principles vary in their categorization of visual elements. One source categorizes architectural design as:[30]

1. Primary elements: point, line, plane, volume, and their transitions in-between.

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[23] New Albany at 4
[24] Madison at 3
[25] Greenwood Village at 4; New Albany at 4; Dublin at 2; Austin at 11; Albany at 1; Columbus at 46
[26] Pegler, Martin M. "Streetscapes." Retail Reporting Corporation, Inc. New York. ISBN 0-934590-78-8. at p. 7
[27] Austin at 11; New Albany at 4
[28] Columbus at 46; Madison at 3
[29] Albany at 1; New Albany at 4
[30] Ching, D.K. Francis. "Architecture: Form, Space, & Order." 2nd Edition. 1996. Van Nostrand Reinhold. ISBN 0-442-07192-8. For more details, see pages 34-35, 48, and 57.

2. Form, including: shape (circle, triangle, quadrilateral, sphere, cylinder, cone, pyramid, cube), which can be regular or irregular, and possess additive, subtractive, or dimensional transformations (altering its shape while retaining its initial identity). Each form may possess properties of size, color, texture, position, orientation, and visual inertia.
3. Form and space, including: horizontal, vertical, base, elevated, depressed, overhead, parallel, etc.
4. Organization, including: spatial, interlocking, adjacent, centralized, linear, radial, clustered, grid, etc. Forms can have centralized, linear, radial, clustered, or grid special organizations.
5. Circulation, including: approach, entrance, path-space, etc.
6. Proportion and scale, including: material, structural, manufactured, regulating, modular, visual scale, etc.
7. Ordering Principles: harmonious arrangement, axis, symmetry, hierarchy, datum, rhythm (repeated motifs), repetition, transformation (how much can be altered without loss of initial identity or concept).

In designing an aesthetic framework, an overview of architectural principles as they apply to the design of small cells facilitates the experience of small cells within the context of systematic urban design. As evident, only some of these elements are applicable to small cell design: they are typically vertical, linear, and organized in a number of potential different spatial distributions. Small cells have several components, often grouped into: the antenna, the equipment, the structure. Each of these components can include different dimensions (height, size), number of elements, forms (3D), shapes (2D), materials (and texture), color (paint), and others. In addition to the technical factors there are other factors to consider including ownership of the site, unique requirements of the district, circumstantial complexities, coexistence with other utilities, maintenance, access pathways, and limited environmental considerations. In the way aesthetic guidelines describe these elements, they include:

- A specified order of preference for types of wireless infrastructure based on existing utility aesthetics at the location
- Preference for colocation or stand-alone sites
- Size requirements for antennas, equipment enclosures, and supporting structures
- Spacing requirements between and within carrier network nodes, other utility poles, and to buildings and street furniture
- Protrusions into the sidewalk, travel-way, intersection, or another potential visual, pedestrian, or vehicular obstruction
- Consistency and uniformity between sites and with surrounding structures
- Camouflage and stealth
- Installation on traffic signals
- Deployment in residential areas
- Historic preservation
- Paint colors and textures
- Tree and vegetation maintenance

The aesthetic guidelines of San Diego helpfully identify three principles as applicable to wireless structures: balance (appearance of being evenly spaced, similar in size, and symmetrical in all directions), context (appropriate to architectural setting), and least visibility.[31] Based on these concepts, architectural design literature, and the common elements of small cell guidelines, the following principles represent an original categorization of these elements as they apply to small cells within the Small Cell Aesthetic Requirements Framework (SCARF).

SCARF consolidates and summarizes urban architectural design elements and small cell design requirements within the following four set of principles characterizing aesthetics of small cell design:

- Principle of Function – site design should fulfill its practical functional purpose
- Principle of Concealment – sites should have the lowest visibility possible
- Principle of Balance - a site should maintain order and symmetry of itself and within its surroundings

[31] San Diego at 9-10

- Principle of Contextual Compatibility – a site should be appropriate to the objective perception of its environment

All of these principles are interrelated, and each influences others to create a cohesive aesthetic. The principle of function can be at odds with concealment, or contextual compatibility. The principles of balance and contextual compatibility are complementary to the principle of concealment, as they promote the type of least intrusive visibility characterizing aesthetic appropriateness. The principle of contextual compatibility directly impacts the principle of balance in the size and spacing of infrastructure. Other considerations addressed at the end of the paper (e.g. IoT, noise, backhaul, administrative adjustments) mentioned in the guidelines may also be considered as part of the four principles, but are secondary to their fundamental aspects.

II. SMALL CELL AESTHETICS REQUIREMENTS FRAMEWORK (SCARF)

The Principle of Function

Small cells are sited for their function to increase capacity or improve mobile coverage in the area. As such, their aesthetic design should be practical for the purpose they are built and accordingly adjusted to increased or decreased number of features, functions, and services. Aesthetic value also stems from function, as the interpretation of art is tied to an appreciation of its purpose.

As the purpose relates to the design of small cell networks, it varies based on the needs of the carrier. Since small cells are used to enhance capacity or provide coverage at the edges, the network topology is dependent on many factors including radio frequency and its propagation, availability of fiber or microwave backhaul, location of electrical power runs and connections, the type of computing (edge or core) used at the site, physical space availability underground for splice points and other equipment, structural pole stability, necessity for backup power, and many other factors.

Function of Small Cell Sites

To increase number of users supported, the RF footprint of a cell site needs to be reduced. A smaller cell site reduces the RF coverage area and provides more data throughput per user. Small cells typically have a lower antenna height and operate at a lower power than traditional macrocells. These lower heights take advantage of building clutter (in urban settings) to reduce the effects of intercell interference and assuring a small RF footprint. The small cell forum defines a small cell as "a radio access point with low RF power output, footprint and range. It is operator-controlled, and can be deployed indoors or outdoors, and in licensed, shared or unlicensed spectrum."[32]

How small is a small cell? There is some confusion and lack of consensus on how big are small cells in physical size and their role in the network architecture. The equipment required to create a small cell can vary greatly in size.[33] Many people in the industry refer to the size of it as a "pizza box", which is commonly considered as a poor approximation of their actual size (in volume and dimensions). Planar antennas may have a pizza box size, but larger supporting hardware (i.e. equipment enclosure) is necessary for functionality. Other descriptions include the size of a "backpack" or "small fridge".

The term generally refers to a site that is smaller than a macro because some processing equipment located off-site and connected through backhaul. "Macro sites" are often defined as the installation of 6-12 antennas and associated equipment, while the terms "small cells" and "micro cells" generally refer to installations of 1-4 antennas with the associated equipment. Small cells provide a smaller coverage area[34] than macro cells, which can cover a half to two

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[32] "What Is a Small Cell," *Small Cell Forum* (blog), accessed July 26, 2019, https://www.smallcellforum.org/what-is-a-small-cell/.

[33] There have been a number of attempts to create a definition, but none that is universally agreed-upon. See for example, Reply Comments Of The American Public Power Association (citing "define a "small wireless facility" as having *"(1) an antenna with an enclosure exterior displacement volume of no more than six cubic feet;*" and *"(2) associated equipment with a cumulative enclosure exterior displacement volume no larger than 28 cubic feet*." See, also, the definition of "small wireless facility" in pending Missouri House Bill H.B.656, "The Uniform Wireless Communication Infrastructure Deployment Act," http://www.house.mo.gov/billtracking/bills171/hlrbillspdf/1391H.02C.pdf")

[34] "*The term 'small cell' is typically used to describe an installation that serves a small area – not to distinguish between facilities that are 'small v. those that are large*.'" Docket 17-421. Smart Communities Comments at 12-13

and a half square miles. Small cells typically use one or two frequencies which are anticipated to become in higher, millimeter-wave frequency bands as they become increasingly auctioned to commercial wireless providers.

Traditional macro sites contain several sector antennas on top of a monopole structure connected by Radiofrequency Cabling (RF Cabling) to a Baseband Unit (BBU) and a Radio Unit (RU) located at the foot of the site enclosure area, which contains other backhaul networking equipment enclosures. More recently, the RU capability has been separated from the BBU and placed next to the antenna elements at the top of the pole with a unit called Radio Head (RRH). This relocation of the Radio Heads allows for replacing large coaxial RF cable runs with fiber optic cabling along the monopole structures. Radio Heads contain digital signal conversion capacity, filters, power amplifiers, and antenna elements. They are connected to the BBU through fronthaul fiber optic cables using a protocol called the Common Public Radio Interface (CPRI).[35]

Small cells may also be defined based on their backhaul architecture. For example, Distributed Antenna Systems (DAS) are often grouped with small cells, as they are a network of smaller antenna systems; however, their computing capabilities are offloaded to neighboring macro cells to which they are connected through fiber. This arrangement helps enable the deployment of small cells because the BBUs can subsequently be located off-site in a central location (often at a nearby macro site enclosure), together referred to as a Centralized Radio Access Network (C-RAN). More recent advancements in computational resources and software can replace many processing functions formerly contained in hardware, many of these functions are now operated in the cloud and remotely controlled.[36] The necessary components in a small cell are a radio capable of supporting the necessary bands, an antenna, and a power source, and the optional support equipment include cooling fans, backup power, converters, or other equipment. DAS also redistributes the signals to shared remote radio heads whereas small cells are the source of the signal.

The small cell definitions and descriptions continue to evolve while legacy systems continue to be in operation. This lack of agreement in small cell definitions has created problems for applying sweeping policy proposals to vague classifications.[37] As a result, the mental image many people have of small cells impacts how people view the extent of their physical intrusion, which may be entirely related to their experience with small cells and the good or bad examples they imagine.

The FCC Small Cell Order provided some clarity to this issue with the official definition of a small cell as: "mounted on structures 50 feet or less in height including their antennas [or] on structures no more than 10 percent taller than other adjacent structures, or do not extend existing structures on which they are located to a height of more than 50 feet or by more than 10 percent, whichever is greater. Each antenna is less than 3 cubic feet and all associated equipment is no more than 28 cubic feet in volume."[38] This definition benefits the regulatory environment by providing a legal classification framework in a general sense, and accordingly many cities have adopted it in their guidelines.[39] This definition typically does not include "electric meters, concealment elements, telecommunications demarcation boxes, grounding equipment, power transfer switches, cut-off switches, and vertical cable runs for the connection of power and other services",[40] it may also not include grounding enclosures.[41] The 3-cubic feet volume antenna could potentially include other elements that would have to fit into "primary equipment enclosures are no larger than seventeen cubic feet in volume."[42] Alternatively, if the antenna has attached exposed elements, it should fit "within an enclosure of not more than six (6) cubic feet in volume."[43] In contrast to small cells, some cities have also

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[35] "CommScope Definitions: What Is CPRI?," accessed July 26, 2019, https://www.commscope.com/Blog/CommScope-Definitions-What-Is-CPRI/.
[36] 3G4G Webinar. "Beginners: An Introduction to Macrocells & Small Cells." https://www.youtube.com/watch?v=CDAZL-pgXXA
[37] For AT&T, More C-RAN Is in the Clouds | FierceWireless." Accessed February 22, 2018. /wireless/for-at-t-more-c-ran-clouds.
[38] FCC Small Cell R&O.
[39] For example, "*Small Wireless Facility 50 feet or less in height including their antennas or are mounted on structures no more than 10 percent taller than other adjacent structures, or do not extend existing structures on which they are located to a height of more than 50 feet or by more than 10 percent, whichever is greater. Each antenna associated with the deployment, excluding associated antenna equipment is more than three cubic feet in volume All other wireless equipment associated with the facility is cumulatively not more than twenty-eight (28) cubic feet in volume.*" Albany at 11, Oregon City at 2
[40] Albany at 11; New Albany at 6
[41] Greeley at 2
[42] Greeley at 2,
[43] Albany at 11; New Albany at 6; Brooklyn Park at 4

attempted to define 'micro cells' under a different framework, such as: "twenty-four inches in length, fifteen inches in width, twelve inches in height and that has an exterior antenna."[44]

Regardless, these definitions of size do not define the nuances of contextual appropriateness of a site within its environment. Rethinking and redefinition of the size of these facilities should be much more dynamic and context specific, not technology specific or technically measured to the point of prescriptive absurdity. The practical implementation of these definitions is relative to the context of other facilities located in the right of way (RoW). The size and impact of a small cell may be quite large in a certain context, especially a narrow RoW.[45] Ultimately, the size of the facility is less important than its visual integration into the environment.

Types of Sites

These contextual differences result in a variety of site options depending on the availability of potential colocation structures, structural stability of available assets, or neighborhood character. Many cities vary their design guidelines for each type of small cell installation. The primary six categories of new installations are: (also see *Figure 1: Four Common Types of Sites*[46])

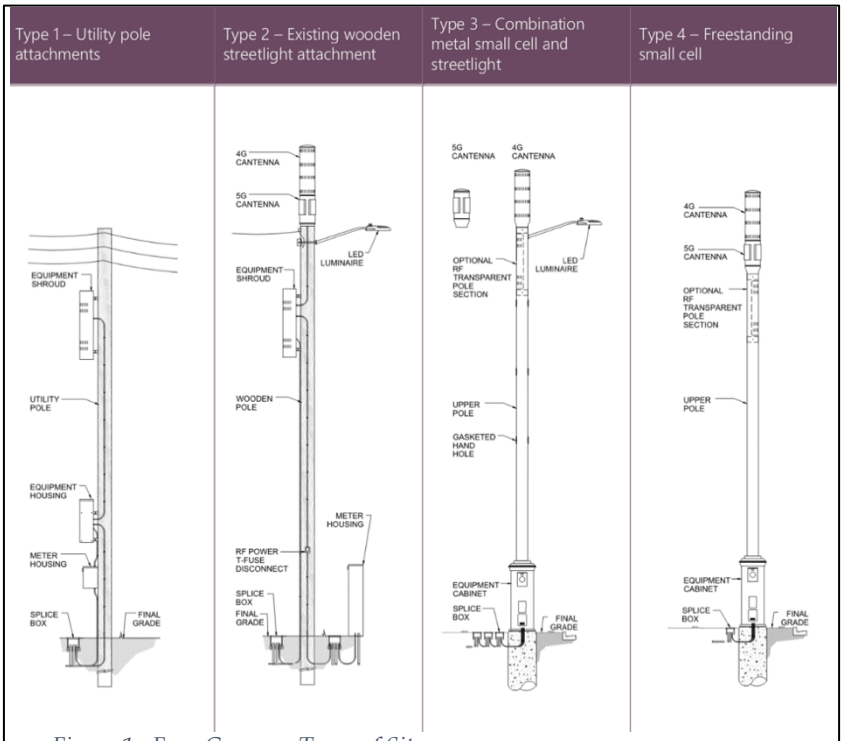

Figure 1: Four Common Types of Sites

(1) Attachment to utility poles (pole or strand mounted):[47] antennas and associated equipment can be located on a wooden utility pole if it meets structural standards. Stand mounted equipment should similarly meet size and safety requirements.[48]

(2) Attachment to wooden poles (with or without streetlight): many wooden poles may not be structurally sound to attach equipment, and they are typically required to be replaced with a steel, standalone site.

(3) Combination small cell (with or without streetlight): combination poles include all equipment necessary to create a complete standalone site. If the pole is replacing an existing streetlight, usually another streetlight should be integrated into the pole.

(4) Freestanding small cell: Freestanding small cells are typically only allowed where no other utility poles exist. These often require smooth transitions between all elements and equipment shrouds on the pole and the base.

(5) Small cell and smart city IoT (with or without streetlight): some cities require that every new site saves some structural capacity for future use, including IoT or any public services.

[44] Greeley at 2
[45] FCC Docket 17-421. Smart Communities Comments at 12-13; NATOA Comments at 11-12. San Francisco Comments at 27.
[46] Westminster at 4
[47] Denver. Zoning Guide for Telecom. https://www.denvergov.org/content/dam/denvergov/Portals/696/documents/Commercial_Zoning/Zoning_Guide_Telecomm.pdf
[48] For example: "*In the case of strand mounted equipment, 5.5 cubic feet maximum strand mount equipment shroud. Only one equipment shroud shall be installed per permit location*" Denver at 13

(6) Decorative or unique poles: Decorative or unique poles can include mast arms, decorative pole bases, luminaires, and decorations that deviate from normal guidelines. They are typically identified as non-eligible facilities for small cell installations. In some cases, decorative and unique assemblies can include a longer case-by case permit process.

The principle of function entails the site is fulfilling its purpose. The technical components and function of a cell site influence its potential deployment in the built environment and its design according to other principles. The method of its design influences the type of site that is most practical within its environment.

The Principle of Concealment

The Principle of Concealment represents the way in which sites are stealthy, minimally obtrusive, and promote the least visibility.[49] The less visible a small cell, the more it is concealed and integrated with the environment.[50] It is the minimal size and minimal height necessary or possible, and at minimum, does not to exceed prescribed maximum dimensions.[51]

To create a cohesive architectural aesthetic, (decorative) transitions between the base cover, the pole, the equipment cabinet, the upper pole, and the antenna are often required to be tapered,[52] for example: "the small cell components shall also be sized to be visually pleasing. For a combination pole to be considered visually pleasing, the transition between the equipment cabinet and upper pole should be considered"[53] (For example, see *Figure 2: Examples of Decorative Tapered Transition Shrouds*) If equipment is required to be offset from the pole, the shroud often requires wings, metal flaps, or concealment flanges, of the same design extending from the enclosure and the pole.[54] All equipment, cables, connections, and hardware should be hidden from view.[55]

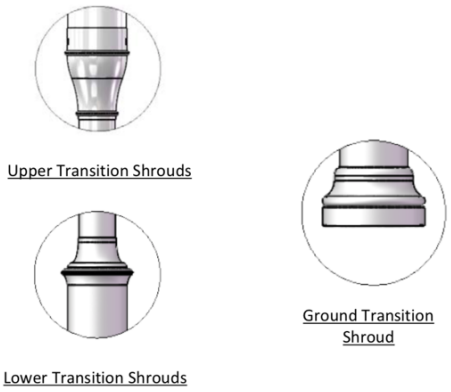

Figure 2: Examples of Decorative Tapered Transition Shrouds

The least intrusive equipment principle not only applies to cell site equipment and antenna, but also applies to electric meters (and backup batteries), smallest diameter on above-ground conduit on wood poles,[56] visibility of cabling, and smallest signage.

Cities vary on their requirements for an electric meter, often dependent on local electric company rules. Meters or backup batteries may be considered equipment that add unnecessary bulk and volume to a site. Cities may require that they are not installed on the pole: "Any necessary meter or other accessory cabinet shall be installed on the outside edges of the street, behind the sidewalk, bicycle or multi-use trail, and said cabinet shall meet all location and landscaping requirements".[57] For example, Albany "strongly encourages site operators to use flat-rate electric service when it would eliminate the need for a meter. When a meter is necessary, it should be the "smallest and least intrusive electric meter available [and] painted to match the pole."[58] In contrast, a meter may be preferred, but flat rate may be

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[49] "*Concealment will include approved camouflage or shrouding techniques*" Albany at 6, Columbus at 51;
"*All Network Node equipment internal to the Pole, conceal it behind an exterior shroud, or place it underground*" Austin at 18;
"*Conceal mechanical equipment and devices associated with wireless facilities in underground vaults or unobtrusive structures*" San Diego at 5;
[50] San Diego at 12
[51] For example, equipment should be the "*smallest size practicable to house the necessary small cell facilities and equipment*." Dublin at 16; "*minimizes its aesthetic impact*" Salt Lake City at 8; "*the smallest, least visually intrusive antennas, components, and other necessary equipment*" San Diego at 8; "*smallest and least intrusive means available to provide small wireless services to the community*" Brooklyn Park at 4
[52] For example, "*Antennas should be the same diameter of the pole at the point of attachment, and should appear as a seamless vertical extension of the pole*" Columbus at 52; Madison at 22; Dublin at 17; Austin at 27; Greenwood Village at 26; Salt Lake City at 8;
[53] Denver at 20
[54] Columbus at 53; Dublin at 16
[55] "*No equipment should be visible outside the pole*" San Diego at 42; "*All hardware connections shall be hidden from view*" Austin at 23; Greenwood Village at 25; Dublin at 15
[56] For example, "*smallest diameter… with a maximum of ... 4 inches*" Columbus at 53
[57] Greeley at 9; Also, "*The meter shall be contained in a ground mounted utility box, unless permitted to be inside an equipment cabinet*" Salt Lake City at 8; "*Back up batteries must be in a ground mounted utility box, or underground where possible*" Salt Lake City at 12
[58] Albany at 8

negotiated if a (slim profile) glass bubble meter is impractical.[59] If feasible, there should be one meter for all carriers in a multi-carrier site.[60] The cities that require a meter[61] require keeping the power supply separate from streetlights or other city infrastructure.[62] In addition, cities often require that power and fiber conduit or another internal divider is separate from the power source providing service (streetlight or otherwise) to the original purpose of the structure.[63] This separation of service facilitates site workers to have the ability to disconnect the radios and power when working on the pole either above or below the meter, if present (rather than to the side), or in pull/splice boxes.[64]

All cabling is required to be completely concealed and well-sealed on freestanding small cells.[65] All cables cannot be spooled, coiled, looped, or stored on the pole without an enclosure.[66] On existing utility poles, the cabling and conduit are required to be as flush to the pole and to the ground as possible.[67] Often, the connections are required to transition directly into the pole without any external junction box or enclosure.[68]

Excessive signs and logos are typically prohibited unless required by law or city preference.[69] As they may be considered advertising, corporate labels, graphics, or visibly depressed manufacturers logos on equipment are typically not allowed and should be painted over or filled in.[70]

When RF warning and identification labels are required, concealing them includes having the smallest, lowest visibility signs.[71] RF labels may be required to be as close possible to the antenna and face away from the street,[72] or be clearly visible from the ground to roadside below.[73] In residential areas, it may preferable that they are facing the street.[74]

The size of signs, planters, photocells, smart nodes, flags, banners, and other protrusions may have other unique requirements. Some cities require small cells to include these additions if they are deemed to be useful and appealing.[75] On existing poles that already include these protrusions, small cell installation should not be obscuring or interfering.[76] Signs can also provide a nice source of coverage to shield the cabinet on a pole from view.[77]

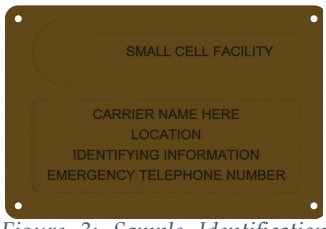

Figure 3: Sample Identification Sign

Owner identification plates are typically specified as a four-by-six inch maximum size and include contact information for the site, such as the carrier's name, location, and

[59] Columbus at 52
[60] Columbus at 52
[61] Salt Lake City at 12
[62] Oregon City at 12
[63] New Albany at 11; Greenwood Village at 26
[64] Columbus at 52; Salt Lake City at 11; Westminster at 17; San Diego at 42
[65] "*All cabling shall be hidden within conduit, shrouds, or by other concealment techniques*" Columbus at 51;
"*Concealed from view and be underground between the pole and the ground mounted cabinet*" New Albany at 12, Greenwood Village at 7, Albany at 7, Austin at 27;
"*With no doghouse and no looping cables*" San Diego at 34;
"*Overhead wires connecting the antennas to the equipment are not permitted*" San Diego at 36;
"*Providers shall not attach or mount any Small Cell Wireless telecommunication equipment onto aerial cable spans*" Oregon City at 11;
"*Exposed wires, cables, connections and external conduit are prohibited*" Dublin at 18;
"*Any cable access point on the pole shall be sealed with a manufactured product ... duct seal or putty is not an approved product*" Greeley at 8
[66] Dublin at 18; Columbus at 51; Albany at 7; San Diego at 41
[67] "*As flush to the pole as possible, using stainless steel banding straps. Through-bolting or use of lag bolts is prohibited*" New Albany at 12, Salt Lake City, Albany at 6, Columbus at 53, Dublin at 16
[68] Albany at 7; Columbus at 51
[69] Columbus at 51; Oregon City at 12
[70] Salt Lake City at 8; Denver at 8; Columbus at 51
[71] New Albany at 9; Columbus at 52
[72] New Albany at 9
[73] Denver at 8
[74] Columbus at 52
[75] For example: "*City reserves the right to attach any sign (such as a no parking sign) on the monopole*" Salt Lake City at 22; Albany at 9
[76] Albany at 9; Salt Lake City at 19; Salt Lake City at 8
[77] Salt Lake City at 18

emergency number.[78] (For an example, see *Figure 3: Sample Identification Sign*[79]) These labels may be specified to be written in letters no longer than one inch,[80] and the background of the sticker should match the color of the equipment with black lettering.[81]

The principle of concealment may present the most difficult design issues for small cells. The function of the small cell requires a number of elements which can be difficult to blend. It typically results in a cost tradeoff where the cost of concealment may outweigh the value of the investment or require cost savings in other respects. As this principle increasingly dominates concerns over small cell design and integration, better market solutions may be produced to lower the aggregate cost of concealment for many deployments.

The Principle of Balance

The Principle of Balance is closely related to the appearance of order, uniformity, alignment, consistency, regularity, repetition, and symmetry in the design and placement of small cells. According to one author: "Regularity is necessary to man. The more complex the environment, the more we need to simplify and summarize to understand and get our bearings"; the eye groups things of the same type, resemblance and proximity dominates differences even when elements are not exactly the same – a coherent group of sufficiently close elements.[82]

A balanced site is less visually intrusive, more aesthetically cohesive, and considered to contribute to the principle of concealment. For a cohesive aesthetic, the poles should match the style of all other surrounding poles and streetlights, and any pole extensions should match the look of the pole.[83] San Diego's aesthetic guidelines have specific well-crafted language regarding symmetry and balance: "All visible elements should have symmetry in all visible dimensions. Antennas and concealment elements should not dominate the element they are placed on", including being approximately equal in dimensions and evenly spaced out in a way that appears symmetrical.[84] For example, in Columbus: "the equipment shroud, electric meter, and disconnect should be placed on the same side of the pole and stacked as closely as possible along a common centerline."[85] In addition: "No interruption of architectural lines or horizontal or vertical reveals is permitted."[86] For example, pole mounted equipment, including shrouds, should be long and narrow, with a width roughly equal to that of the pole.[87] These principles apply to both equipment and concealment elements. It may be that symmetry may not be desired or perceived as balanced, depending on the context. The support structures themselves should replicate the design and proportions of the surrounding structures they are imitating.[88]

Balance also applies to alignment of new poles with centerlines approximately in the middle of other structures, such as existing streetlights, third party poles, and street trees.[89] They should be located within the amenity zone whenever possible.[90] Maintaining a visual and physical organization of structures within the right-of-way, as measured from the center of the base of the pole, reflects the cumulative impact of all the structures as perceived in whole. When streetlight and street tree alignment are offset within the amenity or curbside zones, prioritize alignment of the small

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[78] Greenwood Village at 26; Denver at 8;
"*Opposite the direction of vehicular traffic of the adjacent roadway*" Dublin at 16, Columbus at 52;
"*5 feet above finished grade*." Westminster at 11, Madison at 19
[79] Greenwood Village at 51
[80] Denver at 8
[81] Columbus at 52
[82] Von Meiss, Pierre. "Elements of Architecture: from form to place." 1990. Van Nostrand Reinhold. ISBN 0-442-31151-6. At pages 31-32.
[83] "*The same small cell pole aesthetic is to be used in the same immediate area to maintain a cohesive appearance*" Greenwood Village at 17;
"*Each Pole component shall be architecturally compatible to create a cohesive aesthetic*" Austin at 19, Westminster at 20, Greenwood Village at 28;
"*The small cell facility shall be architecturally compatible with the design of the kiosk and create a cohesive aesthetic*" Salt Lake City at 32;
"*Equipment shrouds should be the same width and color and stacked to present a unified design aesthetic*" Columbus at 53
[84] San Diego at 10
[85] Columbus at 53
[86] San Diego at 25
[87] Columbus at 53
[88] San Diego at 36
[89] New Albany at 13; Albany at 8
[90] e.g. "*tree lawn*" Westminster at 26; Austin at 29; Columbus at 50; Salt Lake City at 25; Westminster at 32; Greenwood Village at 40; New Albany at 11

cell facility with streetlights.[91] The discussion on spacing of small cells within their environment later in the paper contributes to the Principle of Balance.

The principle of balance plays an important role in the amount of attention a site draws. If it is well integrated with its surroundings and looks consistent within itself, many people may not notice it, lowring its visual impact, and contributing to the principle of concealment.

The Principle of Contextual Compatibility

Since small cells sited by different companies can result in clusters of small cells that are visually unappealing and detract from the aesthetic of the community,[92] cities promote consistency and uniformity of a site with its surroundings. For a site to be respectful to its context, the design should mimic existing neighborhood character, including the architectural styles, standards, and dimensions of the surroundings,[93] including consideration of other poles in the vicinity, overall site appearance, and cumulative impact.[94] For a small cell to be considered contextually appropriate, it should be minimally obtrusive by matching the existing features of its surroundings, including the colors, textures, design, material, and styles of buildings, street furniture, and streetscapes.[95] Commonly, all small cell equipment including antennas, brackets, cabling, shrouds, disconnect switches, and any other associated equipment must be painted and textured the same color as the pole and surrounding streetlights in the vicinity.[96] For example, see *Figure 4: Unacceptable Design*[97] and *Figure 5: Same Design as Figure 4, but with Differing Rationale*[98] on how the same design can be interpreted differently depending on neighborhood context.

Cities vary in their preference for equipment shrouds based on the type of uniformity they wish to promote within their built environment. Most cities specify the sizes they prefer for wireless equipment (ground, base, or pole-mounted), antennas, and support structure. *Figure 6: Size-Regulated Components of Cell Sites* illustrates types of components regulated by cities and **Appendix A** *Table 1: Size Requirements for Small Cells* describes varying details in specifications.

Figure 4: Unacceptable Design

Figure 5: Same Design as Figure 4, but with Differing Rationale

[91] Denver at 11;
"*At a distance which is the same as the prevailing separation distance among existing structures and poles in the surrounding vicinity*" Brooklyn Park at 7
[92] "Montana City Moves to Block 'Unsightly' 5G Installations," n.d.
[93] Greenwood Village at 13; San Diego at 5
[94] New Albany at 13; Salt Lake City 12
[95] New Albany at 13;
"*All WCFs shall be designed to be visually unobtrusive. All WCFs must utilize building materials, colors, textures, screening and landscaping that effectively blend the facilities within the surrounding natural setting and built environment to the greatest extent possible. The WCF shall have limited exposed cabling and mounting hardware. The applicant shall comply with any reasonable conditions imposed by the city to accommodate the particular design, appearance or intended purpose of the WCFs to avoid the intangible public harm of unsightly or out-of-character deployments. Placement of any required warning signs or signs related to equipment information shall be directed away from adjacent residential structures and out of direct sight lines whenever possible. Concealment or camouflage options should be presented with the application to minimize the impact of the WCF on the historic property or district.*" Greeley at 9
[96] San Diego at 40; Columbus at 51; Westminster at 11; Dublin at 15
[97] Austin at 24
[98] Greenwood Village at 23

Some cities may prefer only pole-mounted enclosures - no ground-mounted pedestals or cabinets separate from the pole,[99] whereas other cities discourage pole-mounted equipment.[100] They may require the shape of the pole, including the antenna and base equipment to be round,[101] or that all ground-mounted or pole-mounted components should be contained and concealed within a single shroud (including the electric meter and disconnect switch) in least obtrusive locations.[102] Often, any equipment boxes should be hidden behind plants and fences to blend in with the landscape of the surroundings, which are required to be maintained.[103]

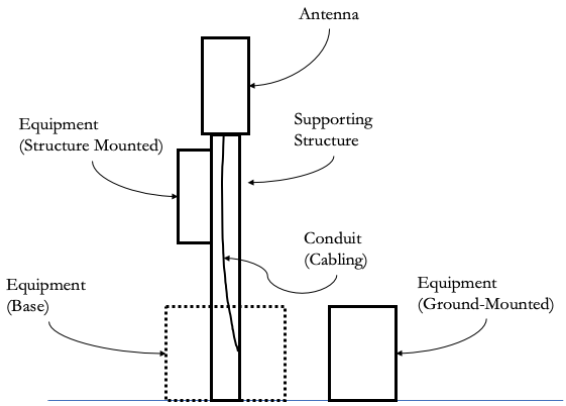

Figure 6: Size-Regulated Components of Cell Sites

Considering the lack of any vertical infrastructure in undergrounded districts, cities are hesitant to allow new small cell structures. When necessary, cities require that they are not wood poles, the service lines are undergrounded, and all cables are within the cylinder of the pole.[104] Some cities do not allow pole mounted equipment in those districts.[105] In addition, some may require undergrounded equipment vaults where technologically feasible or in certain districts.[106] Denver states that if the city decides to underground utility lines or redesign the streetscape in the future, small cell equipment should be removed and reinstalled in accordance to the new guidelines at no cost to the city or the power company.[107]

As applicable to consistency of site sizes and other undergrounded utilities, the principle of contextual compatibility may be relative depending on its district. In some cases, cities specific the order of preference based on each district, especially historical and residential, with specific requirements regarding colocation.

Order of Preference

Many cities have categorized their districts and issued different preferences depending on the availability of utility poles, historic character, viewscapes, and other factors at each district. Cities prioritize colocation of equipment, sometimes only on wireless facilities and other times on other types of infrastructure. Most cities also prioritize siting in industrial and commercial areas over residential areas.[108] More preferred locations include non-historic buildings, third party poles on streets, and unnamed alleys. The least preferred locations are typically historic districts, road medians, bridges or elevated roadways, and mixed-use zoning districts.

Several cities have created detailed maps showing both preferred locations with the probability of expedited permitting and disfavored locations that would involve a more comprehensive administrative process on a case-by-case basis. In Austin, for example, preapproved locations are considered 'regular' (usually consisting of sites that receive power from existing AE streetlight infrastructure), and involve an easier process involving fewer departments

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[99] "*No ground-mounted shrouds, including those that would house backup power supply or other supporting equipment, shall be allowed within the public right of way.*" Westminster at 9; Also, Greenwood Village at 5;
"*Antennas – must be top-mounted, within a radome*" Brooklyn Park at 4

[100] "*All pole mounted equipment must be installed as flush to the pole as possible … as close together as possible and on the same side of the pole. Pole mounted equipment is strongly discouraged*" New Albany at 12

[101] Greenwood Village at 18; Dublin at 15

[102] New Albany at 12 (ground-mounted); Albany at 5 (pole-mounted)

[103] "*Cabinets should be placed as far as from the public street as possible and ideally behind existing horse fence*" New Albany at 12-13; Columbus at 53; Greeley at 9

[104] Albany at 6; Dublin at 18

[105] Albany at 6

[106] "*Where existing equipment and utilities are located underground, the City may at its discretion, require the installation of pad-mounted or vault-mounted equipment. Undergrounding of utilities is generally encouraged throughout the City.*" Columbus at 51; Also, undergrounded vaults are requested in some districts, but required in Village zones in New Albany at 12 and Albany at 8

[107] Denver at 8

[108] For example, Madison at 8

than an 'irregular location', which involves other departments depending on the type and circumstances of the proposed site.[109] DC similarly shows acceptable locations where sites are allowed, and placement in alternative locations requires a further approval process.[110]

Historic Areas

Many cities discourage or prohibit placing sites within 300 feet or along the frontage of a historic site as listed in the National Register of Historic Places, as well as their view on surrounding street vistas.[111]

Washington, DC, as a representative historic city has a particular concern about the visual clutter of small cell infrastructure on the city's vast number of historic buildings "the federal and cultural resources of the National Mall and its environs are inherently unique in the District".[112] As a result, Washington DC created an incremental, phased approach to first allow a conservative number of poles with pre-approved locations marked on a published map.[113] They discourage placement of small cells near entry ways and encourage undergrounding cabinets.[114]

Residential Areas

As with historic areas, residential areas are typically discouraged from siting small cells. For example, in Salt Lake City:

> "A wireless provider may not install a new utility pole in a public way adjacent to a residential zone, if the curb to curb measurement of the street is 60 feet wide or less as depicted on the official plat records or other measurement provided with the application, unless the City has given prior written consent based on evidence provided that demonstrates:
>
> - There is insufficient wireless service to meet the demand in the immediate vicinity.
> - There are no other feasible options to provide adequate service along the residential street.
> - Preferred to be between curb and sidewalk in park strip.
> - If no park strip is available, consider a corner installation before an installation on lawn."[115]

In Greenwood Village, poles in residential zones are required to be decorative and "serve two or more functions such as providing light and wayfinding"; However, since the city also desires to avoid light pollution, the lighting may be required to be decorative and nonfunctional, based on the preference of the community.[116]

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[109] Austin at 13
[110] DC at 6-8
[111] Madison, in particular, has specific language for protecting historical vistas, including: "*Small Cell infrastructure located in unnamed alleys within a historic district shall setback a minimum of twenty feet (20') from the inside edge of adjoining sidewalk*"(Madison at 15);
"*Primary, Radiating, Orthogonal, Major Cross-Axes, Tangential, Frontal, and Axial Street vistas that contribute to the Capitol Corridor & Downtown Urban Design Guidelines Plan National Register of Historic Places nomination*" Madison at 27;
"*Avoiding impact on the most important view sheds and vistas within the Capitol Corridor & Downtown Districts [and] minimizing the impact on the character of designated districts, including Urban Design Districts, historic districts, landmarks, and protected open spaces*" Madison at 6;
In addition to federally protected properties, these restrictions can also apply to local landmarks, requiring a special administrative approval. Salt Lake City at 12; See also: Austin at 29; Salt Lake City at 25; Westminster at 32; Greenwood Village at 40
[112] "*A strong tradition of public space planning in the late 19th and early 20th centuries built upon Washington, DC's historic plans through intentionally designed public infrastructure and streetscapes, such as curb and gutters, tree planting, streetlights, and traffic control devices*" Washington at 3
[113] Washington, DC at 5
[114] "*These entrances are delineated by one or more of the following features, such as: doors, pilaster, entablatures, balustrades, sidelights, columns, fanlights, stairs or ramps, podiums, plinths, flagpoles, sculptural or decorative elements, and designed landscape plantings flanking the entry.*" Washington, DC; Denver at 9
[115] Salt Lake City at 26
[116] Greenwood Village at 30-32

Colocation Preferences

To minimize the number of new poles and reduce visual clutter and impacts, many cities encourage the colocation of multiple carriers if the site remains within a reasonable size or if more than one site would be required within a busy intersection.[117] For example: "the City of Albany desires and encourages collocations between multiple wireless service providers on the same support structure whenever feasible. If the applicant chooses to not collocate when options appear available, demonstrative proof must be provided as to why collocation is not feasible", especially within 250 feet of another site.[118]

While colocation is typically encouraged on poles with an existing small cell facility, colocation of wireless sites on other types of poles is relative. Some cities disfavor colocation either in areas where there are plenty of siting opportunities and if the size would be significantly larger. Poles with electrical facilities, traffic signaling, or that only serve to provide a guy wire for other poles (assuming they are sufficiently structurally-sound) are less preferred.[119]

Many existing streetlights are not sufficiently structurally sound to include cell site equipment. These are usually required to be replaced, especially to avoid two sites next to each other, disrupting the principle of balance (for example, see *Figure 7: Sites Next to Each Other*.[120]) On existing streetlights, Adding lights to poles may be discouraged or required depending on whether their installation is seemed necessary in context with other luminaries in the street.[121] Lights present on hardware typically are required to be shielded from public view.[122]

Figure 7: Sites Next to Each Other

Traffic Poles

Many cities do not permit installation of small cells on city-owned traffic poles or where it may "will interfere with, or detract from, traffic control devices"[123] or "with the integrity of the facility in any way that may compromise the safety of the public."[124]

In cities which encourage the use of traffic signals, it is contingent on comprehensive requirements. The site must be demonstrated to not interfere with traffic signals, the pole may need to be removed and replaced, all equipment must be mounted within the vertical shaft, no equipment on mast arms, all existing openings are preserved, and all electric and fiber equipment is completely within the pole structure with no external equipment.[125] For example, see *Figure 8: Traffic Signals Before and After Small Cells*[126] and *Figure 9: Acceptable Small Cell Design on a Traffic Pole*[127] for cases when Greenwood Village considers small cell enhancements to its current traffic signal design.

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[117] "*The collocation of wireless facilities on existing support structures (that are engineered to accommodate such facilities) is strongly encouraged*" Dublin at 13; Albany at 1; Columbus at 51; New Albany at 9; Westminster at 24
[118] Albany at 5; New Albany at 10
[119] Columbus at 50
[120] Greenwood Village at 12; "*Most of the existing street light poles are not capable of accepting new equipment. Therefore, the provider is required to remove and replace those poles with a combination street light/antenna pole*." Brooklyn Park at 4
[121] Columbus at 51; Austin at 34; Madison at 13; Westminster at 16
[122] Albany at 6; Dublin at 18; Columbus at 51
[123] Denver at 7
[124] Albany at 9
[125] Greenwood Village at 15; Austin at 34; Greeley
[126] Greenwood Village at 16
[127] Greenwood Village at 16

Some cities prefer small cells are installed on existing utility poles or streetlights[128] whereas others prefer the existing structure replaced with a combination small cell and streetlight. Some examples include:

- Westminster: replace the existing streetlight with a new combination metal small cell and streetlight, followed by installing a new freestanding small cell, a small cell on an adjacent structure of a building, and lastly, on a utility pole.[129]
- Salt Lake City: first, prefer equipment on-strand attached to a utility pole, then on utility pole, then plain wood or metal street lights, freestanding monopoles, attachment to traffic signals, and lastly, attachment to area street lights.[130]

Figure 8: Traffic Signals Before and After Small Cells

Figure 9: Acceptable Small Cell Design on a Traffic Pole

Some cities prefer installations on their streetlight poles while others do not. Some cities prefer sites on city owned streetlights (existing or replacement),[131] whereas others will rarely permit such installations.[132]

Some cities define its preferred roads on which to place small cells, for example:

- In Oregon City, preferred sites are expressways, major arterial roads, minor arterial roads, collector roads, and local roads, respectively. In addition, Oregon City prefers placing it on first a support structure, then a third-party utility pole, then a third-party streetlight.
- Greeley prefers sites first in unnamed alleys, then streetlights with cobra heads or on 3rd party poles, followed by standalone poles on streets or named alleys, and traffic signal poles.
- In Washington DC, disfavored locations include "medians and traffic islands, bridges, tunnels, overpasses and elevated roadways."[133]

[128] "*The intent is to locate on existing infrastructure already occupying the right of way. In selecting a lower-preference location, applicants should demonstrate why more-preferred locations were not feasible*" San Diego at 39
[129] Westminster at 5
[130] Salt Lake City at 10
[131] San Diego at 4
[132] Albany at 9
[133] Washington at 5

Spacing

Spacing requirements contribute to the principle of contextual appropriateness by defining the site's placement within the broader city's design plan. Predictably, some network providers which build in strategic locations early can take advantage of more favorable conditions, leaving subsequent applicants with less desirable locations. The concern of many cities is the potential for dense deployments for every carrier (see *Figure 10: Simulated Overcrowding Scenario of Carriers Deploying Proprietary Sites*[134]). Such density affects the neighborhood aesthetic, character, and harmony, and result in cities issuing spacing requirements between and within carrier network nodes. As a result, many cities require a typical distance of 250 feet between other small cells regardless of carrier.[135] This distance is typically radial (spans around corners, into neighboring streets). In contrast, Dublin has a 300-foot linear distance from other small cells,[136] and Albany specifies that the distance is 150 feet if a site could be collocated.[137] For the same carrier, there is a requirement for a 750 feet radial separation distance (for example, see *Figure 11: Separation Requirements for Nodes* and *Figure 12: Spacing of Installations Per Block*[138]).[139] There may also be specified separation distances between small cells and other streetlights, utility poles, or traffic signal poles, that vary widely from 5 feet[140] to 75-150 feet.[141] In contrast, Greenwood Village requires a 600 foot radial separation distance from any other pole, telecom or otherwise,[142] while New Albany similarly requires 250 feet.[143]

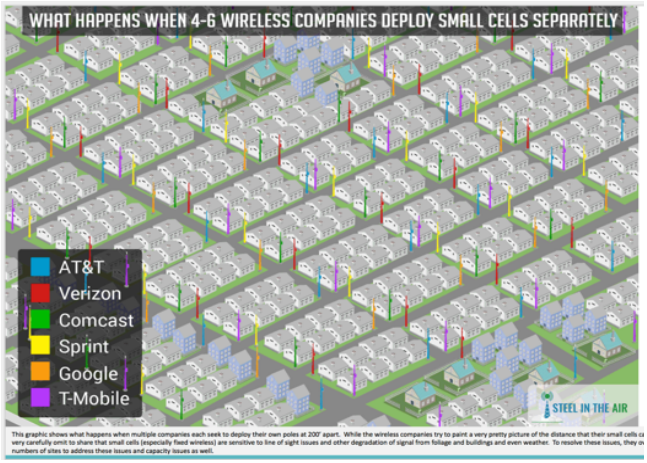

Figure 10: Simulated Overcrowding Scenario of Carriers Deploying Proprietary Sites

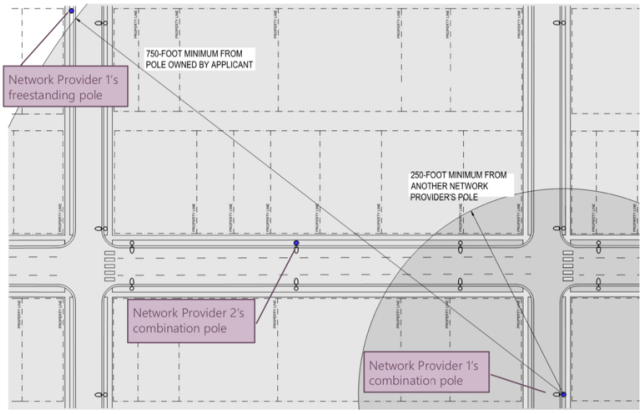

Figure 11: Separation Requirements for Nodes

There are many other specific spacing requirements from trees, buildings, residences, permanent objects, fire hydrants, bike lanes, and others (for example, see *Figure 13: Pole Distance from Property Line*[144] and *Figure 14: Placement of a Small Cell between Commercial Buildings ensures Minimal Impact*). Distances from residence driveways is typically 5 feet,[145] while Madison requires 6 feet, and Greeley and Washington DC require 15 feet.[146]

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[134] Schmidt, Ken, "Densification of Small Cells - YouTube," SteelintheAir, accessed July 26, 2019, https://www.youtube.com/watch?v=YZLct9Ug5J8.
[135] Albany at 8; Salt Lake City at 27; Westminster at 32; Austin at 29; Columbus at 50
[136] Dublin at 12
[137] Albany at 54
[138] Madison Guidelines at 12
[139] Westminster at 26
[140] Austin at 30
[141] Albany at 4
[142] Greenwood Village at 30
[143] New Albany at 11
[144] Madison Guidelines at 8
[145] Columbus at 50; Denver; Westminster; Greenwood Village at 42
[146] Madison; Greeley at 6; Washington, DC at 14

As previously mentioned, the principle of balance states the placement of new sites should be in alignment, approximately in the middle of existing trees, streetlights, and utility poles. More specifically, that separation distance is typically a minimum of 15 feet, away from trees to avoid disrupting their root zone.[147] It may also be specified as "having a six (6) inch or greater diameter at breast height"[148] or "one foot for each inch of the tree's diameter measured at 4' 6" from grade, or a minimum of fifteen feet (15'), whichever is greater.[149] No new small cells should necessitate any removing or pruning of trees.[150]

Table 6-2: Permissible Spacing and Frequency of Installations

Blockface Length Intervals[1]	Outside Areas of Special Interest		Inside Areas of Special Interest		Limit per Carrier per Block[4]
	Number of Small Cell Facilities Permitted per Blockface[2]	Minimum Distance between Facilities on same Blockface[3]	Number of Small Cell Facilities Permitted per Blockface	Minimum Distance between Facilities on same Blockface	
0'-150'	1	N/A	1	N/A	1
151'-300'	1	N/A	1	N/A	1
301'-450'	2	60'	1	N/A	1
451'-600'	2	60'	2	90'	1
601'-750'	3	60'	2	105'	2
Over 750'	3	60'	2	120'	2

Figure 12: Spacing of Installations Per Block

For more detailed information on spacing, see **Appendix B** *Table 2: Distances of Small Cells Away from Other Infrastructure*), summarized by the *Figure 15: Spacing Requirements 1 (see Appendix B)* and *Figure 16: Spacing Requirements 2 (see Appendix B):*

Figure 13: Pole Distance from Property Line

Small cells are typically required to be at least two feet away from any travel way, pedestrian or vehicular.[151] or more generally in a way that does not obstruct, impede, hinder, or create safety hazards, on the travel way or the use of the Right-of-Way.[152] They should face away from the direction of vehicular traffic, historic properties, nearby residential windows, and storefront windows in commercial areas.[153] They should be outside of intersections sight triangles, and between property lines or parcels "to avoid interference with building face, views, business signage, pedestrian flow, etc.[154] as well as at building corners (for example, see *Figure 17: Corner Spacing Requirements*[155]) instead of in the front of the building façade and sight lines.[156]

Figure 14: Placement of a Small Cell between Commercial Buildings ensures Minimal Impact

[147] Greenwood Village 40; Westminster at 26; Salt Lake City 25; Columbus at 50; Austin at 29; Washington, DC
[148] Dublin at 13-14
[149] Denver at 12
[150] Albany at 5; Denver at 12; DC NP; Madison at 13
[151] Austin at 25; Westminster at 26; Dublin at 13; Columbus at 50; New Albany at 5; Dublin at 13; Albany at 5; Oregon City at 11
[152] Salt Lake City at 25; Westminster at 32; Greenwood Village at 40
[153] Columbus at 51-53; Dublin at 16; San Diego at 40
[154] Salt Lake City at 25; Columbus at 50; New Albany at 11
[155] Austin at 31-32
[156] Westminster at 32; Denver at 37; Greenwood Village at 40; Salt Lake City at 25

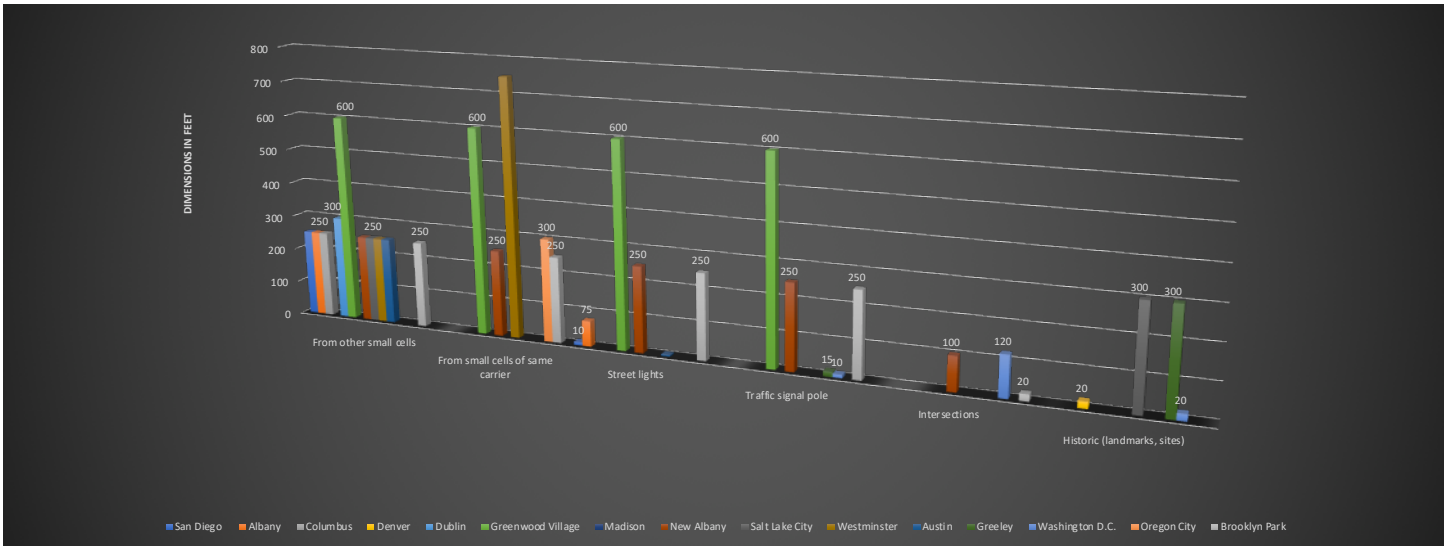

Figure 15: Spacing Requirements 1 (see Appendix B)

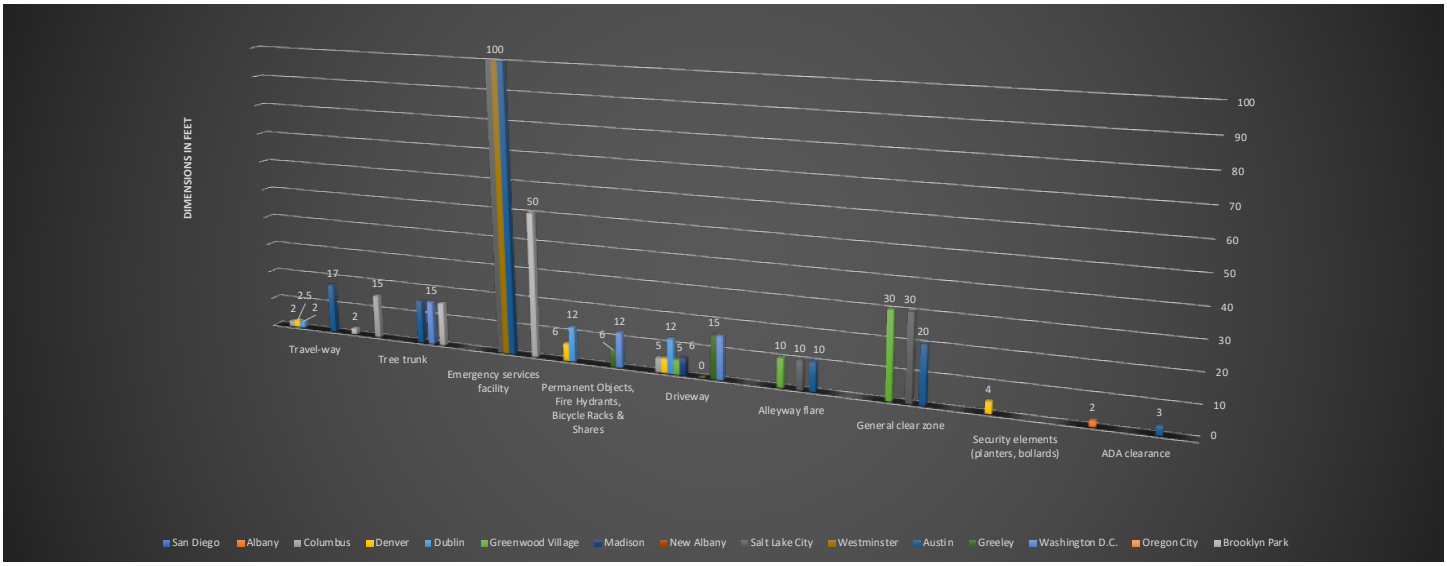

Figure 16: Spacing Requirements 2 (see Appendix B)

Other

The following provisions may be included in the four principles of the SCARF, but they are secondary in their fundamental purpose and are thus acknowledged in a separate section.

Priority Rights / IoT

Installation of wireless networks will enable municipal service infrastructure, and as such, many cities with an eye toward the future, require wireless carriers to install extra capacity in the small cell poles installed on the RoW, including structural capacity, conduit space, sweeps, and hand holes. For example, a minimum of 15% of the pole design structural capacity 'shall be reserved' for future City installations.[157] For "future public safety or transportation uses"[158] the city may reserve space [for] pole include blank connections for City use such as cameras, food truck connections, Wi-Fi, wayfinding signage, or banners.[159] These spaces may include 2" PVC conduit sweeps,[160] spare sweeps capped for future service,[161] and hand holes.[162] Applications can be denied if the space is not reserved. Also, if, and when, carriers no longer use the small cell, "the city may retain ownership of a replacement wireless support structure."[163]

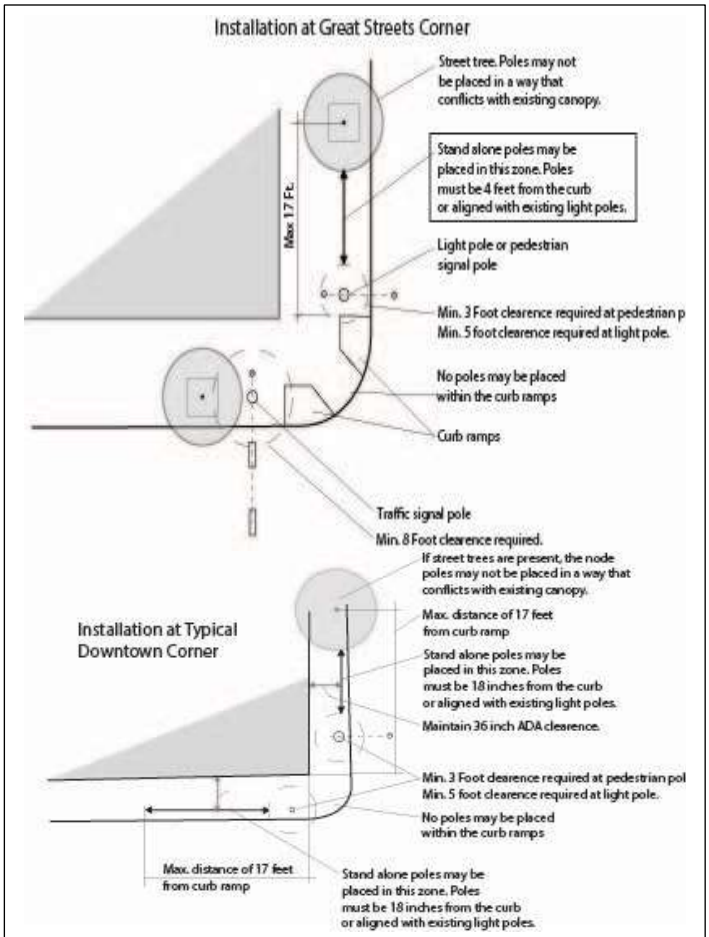

Figure 17: Corner Spacing Requirements

Proprietary Poles

Aesthetic guidelines apply to all poles in the city regardless of ownership, but if small cells are attached to city-owned streetlights, a separate agreement is required between the city and carrier which may have further conditions.[164]

Wood poles

With an eye on the future, some cities prefer no small cells mounted on wood poles. Several cities reserve "the right to require a metal pole rather than a wood pole based on the built, natural environmental character", and are not permitted in some areas, such as areas with undergrounded utilities or those with no existing wood poles.[165]

Noise

Passive cooling fans and other ventilation systems are preferred because they do not produce ambient noise.[166] Where necessary, the equipment should be placed in locations where noise can be suppressed.[167] Noise is often generally

[157] Columbus at 54; Greenwood Village at 24; Salt Lake City at 22; Westminster at 25
[158] Albany at 9
[159] Columbus at 54
[160] "Eight (8)" Westminster at 25 and Greenwood Village at 24
[161] Westminster at 25; "*up to four (4)*" Greenwood Village at 24
[162] "A hand hole" Greenwood Village at 26;
"*Six (6) hand holes shall be provided along the upper pole, if requested by the City, each set to be spaced 5'-0" apart, to maintain City fiber and electrical service for streetlights and future IOT attachments. Grommets Weatherproof grommets shall be integrated into the pole design to allow cable to exit the pole, future IOT attachments, without water seeping into the pole*" Westminster at 24
[163] Dublin at 12
[164] Madison at 25; New Albany at 11
[165] New Albany at 13; Albany at 9; Columbus at 50; Salt Lake City at 12
[166] Westminster at 24
[167] Westminster at 13; Albany at 7

limited to 30dBa at one meter (3.28 feet)[168] and other times at 50 dB, 40 dB, 45 dB within 3 feet of a park, or 55 dB within 10 feet of a property line.[169]

Backhaul

Cities prefer undergrounded fiber backhaul over wireless (microwave) backhaul.[170] Some cities prohibit wireless backhaul within the RoW.[171]

Trash Prevention

To prevent accumulation of trash, litter, debris, and other objects, most cities require that cabinets do not have any flat, horizontal surfaces that create a ledge. Most cities consider it a ledge if it is larger than 1.5 inches.[172]

Administrative Adjustments

The extent of administrative discretion to deviate from published guidelines can vary depending on circumstances on a case by case basis.[173] Cities will consider if a location is necessary for a carrier's network even if there are no alternative locations that meet stated guidelines.[174] Some cities reserve the right to propose an alternate location for a new wireless structure within a certain area, it may be defined as 100 feet[175] or 150 feet "of the proposed location or within a distance that is equivalent to the width of the right-of-way… whichever is greater."[176] "unless the applicant can demonstrate with clear and convincing evidence that it is not technically feasible".[177] Similarly, cities may allow deviations from guidelines such as installations outside of the pole's communications space, side-mounted antennas when top-mounted is not possible, if it would be more appropriate for the neighborhood character and appearance.[178] If prescribed dimensions are not technically feasible, some cities may allow a size adjustment (e.g. 10%, 6" in width, 12" in height for cabinets, pole diameter, or location) or property line extension (e.g. 10'), providing other requirements are met.[179]

V. CONCLUSION

This research involves the collection and analysis of currently published and released small cell aesthetic guidelines from a variety of cities across the United States. Since releasing aesthetic guidelines for small cells is a relatively recent occurrence, this research provides a leading cross-comparative analysis of their potential standards, incorporation into established architectural principles, and categorization into an aesthetics framework.

The commonalities and differences between these guidelines will affect the deployment of small cells within various communities. The research demonstrates the wide variability of small cell aesthetic guidelines from different cities around the country. This disparity reflects cities' interpretation of future-looking wireless development based on different local conditions and environments. However, it also demonstrates the difficulty in interpreting these guidelines by carriers seeking to deploy infrastructure in different jurisdictions of varying aesthetic requirements.

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[168] Greenwood Village; Westminster at 24; Madison at 24
[169] "*5dBA above ambient sound, not to exceed 30 dBA as measured at a property line*" Salt Lake City at 10;
"*For any property where no adjacent parcel is zoned residential, the sound level at the property line shall not be greater than fifty dB; For all other cases, the sound level shall not be greater than forty dB when measured at the nearest residential parcel's property line*" Oregon City at 12;
"*If active cooling is required, the following guidelines apply for sound limits. a. Goal of less than 30 decibels within 3 feet of any property line. b. Maximum of 45 decibels within 3 feet of any residential property line or park c. Maximum of 55 decibels within 10 feet of all other property lines*" Columbus at 53
[170] Columbus at 53
[171] "*Microwave, macro towers, and other wireless backhaul facilities are not permitted within the right-of-way*" Dublin at 18
[172] San Diego at 40; Salt Lake City at 12; Westminster at 20; Greenwood Village at 18; Austin at 23; Madison at 23; Columbus at 54
[173] Westminster at 27
[174] For new poles or, for example, a decorative city streetlights may approved on case by case basis if proven necessary. Albany at 4
[175] Dublin at 13
[176] Albany at 5
[177] New Albany at 9
[178] Columbus at 52
[179] Albany at 10

This disparity can become a deterrent in the strict adherence to city guidelines and a barrier to entry for providers needing to understand and interpret a wide variety of guidance. Potential criticism of these guidelines can include lack of objectivity, overly-prescriptive rigidity, pressure to mimic other deployments, and reliance on administrative discretion. Since art is relative rather than rules-based, personal aesthetic preferences can compromise the objective basis for judging applications, especially between different review bodies. In compensating for this possibility, guidelines can also lose a degree of flexibility necessary for innovation and lead to monotonous imitation and repetitive designs. In supporting community priorities, whether growth or preservation, maintaining previous projects, or continuing a specific development strategy, it can be difficult to assess public interest as it changes over time. These problems can lead to an overreliance on appeals and case-by-case decision making, increasing costs, delays, resources consumption, and strained professional relationships.

To mitigate these issues, a consolidation and unification of guidelines will be necessary to promote small cell technology development and deployment. The more common guidelines pointed out in this paper include compliance with existing state, federal, and local laws, spacing requirements, and preference for order in the amenity zones. The guidelines which are more varied include an order preference for types of sites depending on local conditions and many differences in the size and placement requirements for antennas and equipment. Some cities define a set of preapproved locations for a more streamlined permitting process. Aesthetically, all cables and conduit are typically required to be hidden from view and integrated into a tapered shroud, with some cities requiring equipment to be housed at the base, pole, or ground enclosure. Undergrounded equipment enclosures are typically preferred where feasible, and base enclosures are sometimes required to be rounded for consistency with other infrastructure.

In creating aesthetic design guidelines, cities should be strive for a balance between precision and flexibility, vision and abstraction. Design thinking is a strategy that allows for transparency and simplicity in the process but maintains room to innovate and experiment. Incorporating design thinking of site deployment and development as a process rather than a product allows for improvements and iteration over time. If possible, cities should create an experimentation space where carriers can build trial mock-ups of potential innovative designs and long-term planning. Also, if public review processes for aesthetic guidelines are feasible, community feedback can facilitate a better representative understanding of local cultural preferences. Guidelines should be clear on objectives and purpose as they are an aspirational goal for growth that is demonstrative of underlying planning principles. Cities should develop checklists to demonstrate demonstrable findings in assessing applications. Lastly, it should be remembered that policies and rules are useful in general application, but can be impractical or inapplicable in a small percentage of cases. Flexibility and common sense are irreplaceable when it comes to processing site applications. Sometimes, a difficult deployment can yield the most useful lessons for site design and innovation.

This research provides a cross-comparative analysis of a survey of aesthetic guideline possibilities and options to identify the common elements in guidance plans, integrate the extensive varieties of options in combined design principles, and create an broader understanding of options for cities seeking to improve or publish small cell aesthetic guidelines. The next steps for this research include expanding recommendations for procedural best practices beyond aesthetic guidelines to streamline small cell permitting processes across different cities and communities.

APPENDIX A

Table 1: Size Requirements for Small Cells

	Equipment			Antenna	Supporting Structure	Other
	Pole-Mounted	Base	Ground	Dimensions		
San Diego	7 ft^3, 24"W x 12"D Behind road signage [4]	One cabinet 7 ft^3, 24"W x 12"D [39] No empty space. Bottom 66" of pole may be up to 18" [42]		Limit one shroud >= 24" all dimensions [37], [4] Shroud: H < 1/3 X pole height, D < 38" [23]	D < 14" (same as antenna shrouds) [42] H = applicable height limit in the area, or be no taller than 40' [42], industrial areas < 50', on existing structure < additional 5' [51]	
Albany	Protrusion < 12" or 18" with stand-off brackets H < 40", W < 2 X pole diameter; all on same side of pole [8]		1.5 X width of existing light or 24" diameter [6]	protrusions should not exceed the circumference of the structure by more than two feet [7]	H on existing poles may not exceed such poles by greater than 10' [6]. For an existing wireless support structure, the antenna and any associated shroud or concealment material are permitted to be collocated at the top of the existing wireless support structure and shall not increase the height of the existing wireless support structure by more than 5' [6] For free-standing, street facing, < 15' and equipment cabinet > 10' above ground. [6]	
Columbus	All equipment > 15' above the ground	H < 5' [54] D <16"-20" [54]		Vol < 6 ft^3, D < 14", H < 5' [52]; On top, not offset; side-mounted parallel to roadway [52]		Stand-off mounts < 6" (must incl wings) All equipment < 53 ft^3 [53]
Denver	38" H X 16" W X 12" D [10]		Not permitted [10]	D < 14", H < 5' If protrusion = 5.5 ft^3 shroud, (25 in x 25 x 25 – or cylinder (up to) 47 inches with 8 inch radius – 16 inch diameter). Shroud W, D, H < 16" No antenna(e) shall be attached on an arm adjacent to the pole [8]	H on existing Poles: not extend the existing pole to a height of more than 36" or by more than 10 %, whichever is greater.	
Dublin	All equipment W < diameter of pole (generally) < max 1.5 x diameter of top of pole [15-16]	D < 24", H < 5' [16]		within shroud <6 ft^3 [15]	Face protrusion < 18" [16] D < 12" @ base, < 8" at the top [14] Tapered Poles: 0.5 - 0.75 of max width of cabinet, with O.D. < 10" [14] H = not increase the overall height of the existing wireless support structure by more than 5' [11], the maximum permitted height for private wireless support structures, antennas and associated small cell facilities shall not exceed forty (40) feet in height above established grade as measured at the base of the wireless support structure, except as provided below. shall not exceed 35' when: - within 300' of the proposed site for a new wireless support structure in the same or connecting rights-of way, and there are no existing wireless support structures or utility poles greater than 30' above ground level; - The maximum permitted height for building construction in the underlying zoning district is 35' in height above ground level or less.	All 28 ft^3 [15]
Greenwood Village	Round, D < 20", H < 5' (shroud max) [25], [38]			D < 16", other antenna types D < 20" H < 7.5' [26]	Upper pole diameter: scaled to 0.5 (0.4 [38]) to 0.75 times the size of the equipment cabinet with 10" minimum, 12.75" maximum outer diameter. [26, 36] (8" - 10" O.D. [28] Maximum heights are limited to 30' in residential areas, and 40' in commercial area when combined with a streetlight. Any freestanding facility is limited to a 30' [13]	All equipment < 7.5' [26]
Madison	In special interest areas, all equipment > 17'			Vol < 3 ft^3 [20] 4G-LTE: Maximum 14" outer diameter, maximum height shall be 5' from top of cantenna to pole attachment point. (note:	H = no more than 10% higher of any pole on the same block as the proposed structure up to a maximum height of 50 feet. not exceed 50 feet above ground and is to remain within 10 ft. of the	

	above ground (except meter) [15]			7" radius, 3 ft^3, means up to 33.7 inches, smallest radius you can have with 5 feet is 5.2" radius – 10.4 inch diameter) [20] 5G only: D < 16" O.D. < 19", H < 5' [20] (3 cubic feet, 8″ inch diameter, 25 ¾ inches long. 5.2(44)/ 10.4 diameter) [20] Dual technology (Typically 4G & 5G): 16" O.D. with 19" (maximum) protrusions for 5G antennas. Maximum height shall be 6'-8" from top of cantenna to pole attachment point [20]	tallest existing support structure, tower, or utility pole that is in place on the same block [12] must be a minimum of 12' above any pedestrian or bicycle thoroughfare and a minimum of 16' above any traffic lane.	
New Albany	Cabinet < 24" from pole [12]			Panel-style: H < 30', W < 12" Cantenna: H < 30', D < 16" [11]		Cables: Stand-off mounts: < 4" [12]
Salt Lake City	Mounted > 8' Street facing: higher than 16' [8]	Must be round, 16" < D < 20" [19]		Located on top, D < 14" [8]	H = < 7' additional on existing pole [11] 2/3 the height of a typical small cell pole. Antenna equipment can range from five to seven feet in height, and can be attached to the top or middle of the pole. Electrical cabinets and other support equipment can range from four to five feet in height and around three feet in width [2] Any pole with a collocated small cell shall not exceed 50 feet including the equipment. [9]	13" W X 24" H X 18" D, by Quazite [38]
Westminster	Shroud: 49 H X 19" W X 13" D [11]			G-LTE: Maximum 14" outer diameter, maximum height shall be 5'-0" from top of cantenna to pole attachment point. If the antenna is mounted to the side of the pole it shall be located inside a maximum shroud of 49"H x 19"W x 13"D. 5G only: Maximum 16" O.D. with 19" (maximum) protrusions for 5G antennas. Maximum height shall be 5'-0" from top of cantenna to pole attachment point. If the antenna is mounted to the side of the pole it shall be located inside a maximum shroud of 49"H x 19"W x 13"D. Dual technology: 16" outer diameter with 19" (maximum) protrusions for 5G antennas. Maximum height shall be 6'-8" from top of cantenna to pole attachment point. If the antenna is mounted to the side of the pole it shall be located inside a maximum shroud of 49"H x 19"W x 13"D. [11]		Strand-mounted equip: shroud < 55 ft^3 [13]
Austin					Scaled to 0.5 to 0.75 the size of the equipment cabinet, with a 10-inch minimum outer diameter [23] [27]	
Greeley					Pole H < 10' higher than original pole, always < 50' Streetlights 44' or 10% whichever is greater	

APPENDIX B

Table 2: Distances of Small Cells Away from Other Infrastructure

	San Diego	Albany	Columbus	Denver	Dublin	Greenwood Village	Madison	New Albany	Salt Lake City	Westminster	Austin	Greeley	Washington D.C.	Oregon City
From other small cells	250' [42]	250' [8] 150' (if can be colocated) [54]	250' [50]		300' (lin) [12]	(Any pole) 600'(rad) [30]		(Any pole) 250' [11]	250' [27]	250' [32]	250' [29]			
From small cells of same carrier						(Any pole) 600'(rad) [30]		(Any pole) 250' [11]		750' [26], [32]				300' (lin)
Travel-way			2' [50]	(Curb) 2.5' [11]	(Edgeline) 2' [17]						(Curb) 18" [29] (Curb ramp) 17' [30]			
Street lights	10' [42]	(Lights < 150' spacing) 75' [4]				(Any pole) 600'(rad) [30]		(Any pole) 250' [11]			5' [30]			
Traffic signal pole						(Any pole) 600'(rad) [12]		(Any pole) 250' [11]				15 [6]	10' [14]	
Intersections								(residential, yards, ped zones) 100' [11]				30' x 30 ' [6]	< 120' road, 30' x 30' else 50' x 50' [14]	
Building face				10' [7]								10' [6]	10' [14]	
Tree trunk			15' [50]								15' [29]		15'	
Historic (landmarks, sites)				(sidewalk edge) 20' [9]					300' [12]			300'	(sidewalk edge) 20'	
Emergency services facility									100' [25]	100' [32]	100' [29]			
Permanent Objects, Fire Hydrants, Bicycle Racks & Shares				Fire Hydrants: 6' [11]	Permanent Object: 12' [17]							Fire Hydrants: 6' [6] Racks and shares: 6' [6]	Permanent Object: 12' [14] Fire Hydrants: 6' [41 Racks: 3' [14]; Shares: 4' [14]	
Driveway			5' [50]	5'	12' [17]	5' [42]	6'			5'		15' [6]	15' [14]	
Alleyway flare						10' [30]			10' [25]		10' [29]			
General clear zone	Discouraged on streets with curb-to-curb <40' [42]					(For <18" base cabinets) 20', else 30' [30]			(For <18" base cabinets) 20', else 30' [25]		(For <18" base cabinets) 20', else 30' [25]			