A Scale-Calibrated System of Land Subdivision v1.5

Paul Knight

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"A complex system, contrary to what people believe, does not require complicated systems and regulations and intricate policies. The simpler, the better. Complications lead to multiplicative chains of unanticipated effects. Because of opacity, an intervention leads to unforeseen consequences, followed by apologies about the 'unforeseen' aspect of the consequences, then to another intervention to correct the secondary effects, leading to an explosive series of branching 'unforeseen' responses, each one worse than the preceding one." —Nassim Taleb, Antifragile

"Streets and their sidewalks, the main public places of a city, are its most vital organs. Think of a city and what comes to mind? Its streets. If a city's streets look interesting, the city looks interesting; if they look dull, the city looks dull." —Jane Jacobs, The Death and Life of Great American Cities

"The most meaningful permanences are those provided by the street and the plan." —Aldo Rossi, The Architecture of the City

"A skyscraper in a large city is a significantly more complex object than a modest family dwelling in a small town, but the underlying principles of construction and design, including questions of mechanics, energy and information distribution, the size of electrical outlets, water faucets, telephones, laptops, doors, et cetera, all remain approximately the same independent of the size of the building. These basic building blocks do not significantly change when scaling up from my house to the Empire State Building; they are shared by all of us." —Geoffrey West, Scale

"Metiendo Vivendum" (By measure we live). —Personal motto of English architect Edwin Lutyens

About the Author

Paul Knight, AICP, is an architectural and urban designer at Historical Concepts, an architecture and planning firm based in Atlanta, Georgia. Knight also serves as the executive director of the Doug Allen Institute (see information below) where he conducts research linking urban form to health, safety, and welfare. He received M.Arch and MCRP degrees from Georgia Tech in 2011.

The Douglas C. Allen Institute for the Study of Cities

The Doug Allen Institute is a non-profit 501(c)(3) organization promoting the principles of urban design and lessons of history to students and professionals. With a focus on public education, the Institute seeks to make our increasingly urbanized world a better place to live.

To learn more or to donate, please visit *www.DougAllenInstitute.org.*

Doug Allen

Douglas C. Allen, FASLA, beloved professor and visionary landscape architect, died on October 26, 2014, from brain cancer. Doug graduated in 1970 from the University of Georgia with a Bachelor of Landscape Architecture and from Harvard University in 1976 with a Master of Landscape Architecture. In 1977, he began a 37-year teaching career in the College of Architecture at Georgia Tech, except for the 1987-1988 year as visiting professor of landscape architecture at Harvard University.

Doug made seminal contributions to the field of landscape architecture, particularly to the study of cities and the urban landscape. He published, served on juries, and lectured widely at universities all over the United States. He served for several years on the editorial board of Places Journal, co-founded Georgia Tech's study abroad program in Italy, was honored by election to the Council of Fellows of the American Society of Landscape Architects (FASLA), and was awarded the ANAK Award in 2006 which is bestowed annually by a Georgia Tech secret society to a single professor for contributions to the students of the Institute.

Perhaps Doug's greatest influence was through his legendary course *The History of Urban Form* which was taught annually at Georgia Tech. As a testament to his intellect and engaging teaching style, one year his course was voted by students as the most popular elective on the entire Georgia Tech campus.

Preface

Perkins+Will, an international architecture and planning firm, received the commission to develop the Fourth Master Plan for the country of Kuwait. Not county—*country*. Let's think about that.

I recall watching the renovations of some existing water and sewer lines along a short stretch of Northside Drive here in Atlanta. It occurred in slow motion over a period of perhaps two years. Every day I would drive by, catching a glimpse of each individual frame of the real-life cartoon. There was the plan, then the concerned neighbors, then the replanning, site prep, construction with half a dozen workers watching one poor soul dig a hole, and then waiting another series of months to paint the road stripes, and finally, finally, the removal of the traffic cones and opening of the lanes. Meanwhile, elsewhere in the world, in China, India, the Middle East, dozens of cities to house millions of people had been built from scratch.

Worldwide, urbanization is happening at speeds and scales never seen until now, taking place in hastily-built megacities. The first time I saw this myself was on a trip to India a few years ago. Surrounding the highway were concentrations of new growth, forests of skyscrapers and tower cranes sprouting from the earth. I can only imagine the level of coordination for such things, picturing an army of professionals out there planning the various infrastructures, be it economic, transportation, political, legal, programmatic, environmental, sanitation, utilities, etc. But peel all of that back and consider the context of *urban form*, the underlying structure of all cities, the boundaries delineating spaces public and private, streets and blocks, mine and yours. What is happening in that domain?

Many architects and planners have created their own versions of idealized cities. Le Corbusier had his *Plan Voisin*; Frank Lloyd Wright, *Broadacre*; Daniel Burnham, *Chicago*; Hippodamus, *Miletus*; Haussmann, *Paris*; Niemeyer, *Brasilia*.

But those are mere *cities*; let's take it a couple magnitudes further to *countries*. How does one physically plan the urban form of an entire country? How does one account for all the components of the built environment within a single system, including what is known, what is unknown, and the unknown unknowns, and address the various scales of the human experience, from country-wide mega-regions harboring millions to single-person reading nooks? That's the question we want to answer, or at the very least explore.

David Green, Perkins+Will's Global Urban Design Leader, reached out to the Doug Allen Institute to do that exploration. I am excited to make the first set of these working papers available. The papers are a continuation of Doug Allen's research; they make some improvements on the American Land Ordinance of 1785, apply those lessons and principles to international lands, make a strong suggestion in regards to number theory, and extend the study into the smaller scales of design including neighborhoods, blocks, lots, buildings, and even rooms, furniture, and objects. It is by no means presented here as a refined, finished product. As a working paper, these are thoughts and ideas that are still being developed, reconsidered, critiqued, pushed, and pulled. We welcome any comments you may have.

Paul Knight, AICP
September 6, 2018

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Chapter 1: Introduction

> *The city is like some large house and the house in turn like some small city. —Leon Battista Alberti*

Cities are massive, collective designs. They are built by many hands over long periods of time, street by street, building by building. Every step of construction is managed by someone or some group of people. These managers decide where things go, what they should be, how big, how many, and how tall. Every square inch of a city is imbibed with hundreds or even thousands of decisions like these made over time. Every square inch has a history. That history is there to observe and to study if one knows where and how to look.

Leon Battista Alberti, the influential architect of the Italian Renaissance, described a city as a large house and a house as a small city. His analogy is worth some thought.

Architects design houses. Their challenge is to synthesize the basic functional requirements of building with the art of living. And they must organize a given program in a way that is both structurally feasible and aesthetically pleasing. Architects weave back and forth between design scales, from the largest site to the smallest detail. They must site the house on the lot but also consider the location of each door knob. They must work in plan, section, and elevation simultaneously, massaging the design until a coherent result is achieved. The architect also understands that the two-dimensional drawing is not the final product. They must see beyond two-dimensions and imagine a third (and fourth) to truly grasp the design they are forming. Design is not a guess; it is an intention.

A city is a house expanded and multiplied many times over. A city does not possess one designer but thousands. It does not have a single client but thousands. It does not fit on a lot but contains thousands of lots. The hallways of a city are its thoroughfares. The public rooms, its parks and civic buildings. The private rooms, its houses and dwellings. And the walls of a city, most importantly, are the things that give it structure: they are its legal boundaries.

Legal boundaries are a curious human invention. They are a reference in space specifying ownership. They simultaneously divide and join. They separate one neighbor from another, but they also bind them into a mutual understanding of "neighborliness"—*"this is mine and that is yours."*

Without walls a house falls apart. It is similar with a city. Cities, at their core, represent an equilibrium of public and private space, with boundaries acting as the binding agent between those two domains. The best cities manage to balance public and private; the worst tend to disregard public space for private interest.

Like an architect designing a house, a city planner must be able to conceptualize proper urban forms and to provide a plan that helps a city to grow into that form.

Planning a Country

Today's urban landscape is experiencing dramatic changes and rapid expansion. China and India routinely grab world headlines with their booming populations and urbanization plans. But other countries, like Kuwait, are not only planning and building cities of their own but are looking at their entire sovereign land as a unit to be subdivided in the most prosperous way possible. While this detailed consideration of an entire country expands the challenge and complexity by some orders of magnitude, the same tools and principles of design can lead us to a solution. We are simply weaving a larger tapestry. It will take more time and require more hands, but the concepts found within the design of a house can extend to that of a city and country.

While Alberti's analogy is a powerful and useful one, it is not sufficient to fully capture the complexities of urbanism. The logic of cities cannot be reduced to simple analogies or mathematical laws, regardless of how elegant their claims may be.[1] The design of cities requires an acceptance of natural complexity. This is not to suggest it is an impossible order to adequately plan for future growth. The suggestions made in this paper are not intended to be an oversimplification of reality; they are not trying to force the complexities of reality into simplified yet inadequate mathematical ratios. We are doing the exact opposite. The goal is to provide a framework that specifically does not hinge on simple or predictable outcomes, because cities are neither simple nor predictable. In a framework for urbanism, flexibility is the key quality.

The chapters that follow will address the spectrum of design scales: from the country to the city to the block to the lot. While they will be presented linearly, their mutual explorations overlap. Just as an architect weaves a house together, we are weaving a nation together. At every step, the decisions within one scale are tested and confirmed with those of another. With this methodology, the very small and the very large are intertwined: they are not many disparate designs but one holistic design.

But first, to continue with this introduction, there are a few important concepts that must be addressed. They may appear a bit random and disconnected at this point, but their importance will be made obvious (we hope) throughout the remainder of the paper.

Magnitude and Scale

The largest design scale, for our purposes, is that of a country. Abstract numbers capture the vastness of this scale: thousands or millions of square kilometers of land, millions or billions of people, and GDP in the billions or trillions. It would be foolish to believe a human to be capable of processing such raw figures. Even today's supercomputers with their machine-learning algorithms cannot begin to adequately assess this multivariate problem and provide a viable and trusted solution. But we are a wily species. Because we know our own limitations we can devise ways to work around them. If a number is too big to conceptualize, we can simply make it smaller. We can divide and conquer.

A country can be divided into regions; depending on the country and the region, this may reduce the scale by a factor of 10. But we can go further. Regions can be divided into metropolitan areas; those into cities, then neighborhoods, blocks, lots, and buildings. It is at this building scale that the transition is made from the domain of *planning* to that of *architecture*; the disciplines are one in the same, they simply reference different scales.

While figures of size and number can be used to define the different scale, they are not actionable bits of information. We are not interested in mere numbers. We are interested in their patterns, their utility, and their eventual affect on our world. It is through patterns that we can learn from history's greatest cities and apply that knowledge to the future of others. It is through utility that we can put that knowledge to work for us.

Cities change from moment to moment, their numbers constantly fluctuating. For example, Rome, Italy, reached a population of one million people by the third century AD.[2] That fell to approximately 60,000 in the middle ages,[3] only to rise again to one million by the 1960s.[4] The city itself (the idea and artifact of Rome) never wavered, but the patterns of its use ebbed and flowed through time.

Predictions and Change

It is impossible to predict the future. We'll say that again with emphasis: *it is impossible to predict the future.* To think otherwise is to succumb to the same mistakes of the past, mistakes which history makes difficult to forget. There are numerous examples of inaccurate assumptions and false foresight. Many of these examples have led to missed opportunities (e.g., the planning of some major capitals including Brasilia and New Delhi), unintended consequences (e.g., the policies that drove the development of the American suburbs), or intended consequences (e.g., the works of Robert Moses in New York). The lesson of history is to be wary of predictions. Predictions can and should be used to provide a rough guide or starting off point, but their direct application should be thoughtfully limited. A design's parti should not rest on the accuracy of a prediction alone.

This is a critical point. Especially in the design of the physical framework for a country or city, a design should not and cannot rest on a single path of realization. Instead of designing for a single possible future, we must design for all possible futures. We must establish a system that is as adaptive as possible for as many different futures as possible. It is only through flexibility that good urbanism can have a chance at materializing; as the saying goes, Rome was not built in a day. Like geology, cities require pressure and time.

While there certainly are policies that can push a country to development in a certain place or within a certain form, there must be a built-in hedge against the potential failure of complete adherence to such policies. As cities are made up of thousands or millions of people making thousands, millions, or billions of decisions over tens or hundreds or thousands of years, it is inevitable that things will change and that they will do so in complex and unpredictable ways. The second law of thermodynamics applies equally to both the universe and to cities.

Most building development that occurs today has a short-time horizon factored into their pro formas. Some timeframes are measured in mere years. On average, buildings last decades (and so do people).[5] Cities, on the other hand, can last for millennia.[6] Cities are greater than the sum of their parts; they can outlast the lifespans of their individual components. This is because a city is not a *thing* but a *structure.* This structure absorbs the contributions of individual inhabitants, whether past, present, or future. These contributions are ultimately reflected in the legal boundaries of cities. So while the grocery store or the auto dealership may one day close down, the city itself lives on, waiting to absorb our next idea.

A city is an organized territory that is only briefly populated by the people and buildings of any given moment. It's similar in biology. A boy, e.g., grows into a man, and while the body is largely the same (two legs, two arms) the mind yields over time to a different person. The man has memories of his childhood, but the accumulation of his experiences increasingly distances him from the boy of the past. The man is a new person in the same body. Likewise, the city is a constantly evolving self within the same structure.

It was stated earlier that boundaries are the structural framework of cities. Because of their physical and legal tenacity, boundaries tend to stick around for a long, long time. Once platted and surveyed, their lines over time become permanent incisions in the ground, reflected in the fences, streets, and building walls that spring directly from them. Each successive generation works within and builds upon these legal lines, altering them little if at all.

Boundaries must be designed just like anything else. In the history of cities, the placement of a boundary is the most important design move that can ever be made. The planner of a territory must look at the boundary as their primary design medium. At the national scale, the tool is called a *national ordinance*. At the city scale, it is called a *master street plan*. We will explore both of these tools in depth in the following chapters.

Dimensions and Precedent

Dimensions are the DNA of design. This applies to all scales of design, from furniture to architecture to cities. Dimensions turn abstract intentions into physical realities. Conscious design happens when dimensions yield a desired outcome. Dimensions must respond to the subtle requirements of life and unique demands of the human body; they cannot be too big or too small as there is a relatively tight range of what will work and what will not. E.g., in the thousands of years that humans have been resting on beds the dimensions of those beds have changed little, if at all. For thousands of years, then, we have required rooms of a certain size to contain beds of a certain size. Much has changed over time, but the human scale persists.

In the design of cities, a useful dimensional range is readily measurable and definable. One simply must look at precedent. Real cities, standing and operating today, provide the best evidence of what works and what doesn't work. They are a pool from which we can draw ideas, either directly or indirectly. These design lessons are available to any observant urbanist and they are innumerable.

The importance of precedent cannot be overstated in the development of any planning document. Given the lasting impact of decisions on the public framework of cities, it is incumbent upon the city planner to ensure that any document produced has first passed rigorous testing *on paper*. If an error is discovered on paper, it requires the swipe of a pencil's eraser (or perhaps the tap of a keyboards 'delete' key) to take it back and try again. On the other hand, if an error is discovered in the field (built, on the ground, with investments of time, money, energy, and materials expended) backtracking is not so easily done. One must either live with the error (and force future generations to do the same) or spend additional investments to rectify the error.

Referencing design precedent is a critical step in a successful design workflow. It can help prequalify good decisions and disqualify bad ones. If utilized correctly, the savings of money and assurances of success is unlimited.

The international cities being built today require international precedent. While subsequent chapters will include many examples of American urbanism, a substantial number of international cities will be included for comparison and will reveal many surprising consistencies of urban development around the world and throughout time.

With the aid of precedent, we don't have to start from scratch, we don't have to reinvent the wheel, we can begin with the benefit of thousands of years of country- and city-building.

Each successive scale in design is affected by those above and below it. While the influence of one scale has more weight upon those within its immediate proximity, it is not a far stretch to see how even the largest expanse of land can come to affect the smallest detail, and vice versa. If the units of measure follow the same patterns across scales, a universal design language emerges and a great level of efficiency and convenience can be attained.

The design and construction of buildings have always been based on the atomic units of buildings construction. By extension, this applies to cities. The standard sizes of sheets of plywood, the spacing of studs, the spans of beams, these all multiply many times over to produce individual buildings. Buildings, in turn, multiply many times over to produce blocks. Blocks lead to neighborhoods; neighborhoods to cities; cities to regions; and regions to countries. At each jump in scale, the dimensional DNA should be allowed to freely propagate. Disparate design projects (from houses to convention centers) can in fact share a universal ancestry of measurement.

When considering entire territories, small inefficiencies can add up to enormous proportions. We provide this specific but illustrative example: it is most economical if sheets of plywood evenly cover the exterior of a building's facade; otherwise the plywood must be custom cut to fit, resulting in effort, money, and material expended. This seemingly minor inconvenience gets multiplied over perhaps 30 buildings on a block amongst perhaps 30 blocks in a neighborhood and 30 neighborhoods in a city. So that original 30 minute and $100 expense overtime and across a city expands into a month of collective work and $2.7 million. And that's just cutting a piece of plywood.

A mason will look on in dismay at a dimension that does not allow an even coursing of brick. There are very few circumstances that absolutely require, say, a length of 120.27 bricks rather than an even 120 (with 0.73 bricks cut off at the end of a course, or 0.365 bricks at either end, or the mortar joints evenly adjusted ever so slightly). While the spatial needs of humans are indeed particular, they're not *that* particular. It is incumbent upon the designer to take such things into account. The associated costs and effort could be spent more wisely elsewhere.

Likewise, the city planner should be equally as dismayed when buildings do not course within a lot or lots do not course within a block. For at this larger scale of design, inefficiencies are exacerbated as they become imbedded into the very foundations (the boundaries) of the city. When the streets and blocks themselves provide inadequate sizing, ill-suited geometries, and inflexible dimensions, future generations are the ones that will toil the most.

It is relatively easy to rebuild a house; it is an entirely different undertaking to reconfigure a block or a street network. While smart urban planning cannot squelch every inefficiency, it can at least provide a better dimensional framework for the way we live our lives. This is one of the most important, far reaching, and long lasting aspects of planning.

Since human developments naturally evolve and change over time, that change must be planned for and accommodated in the layout of a territory. Flexibility in dimensions will allow for flexibility in uses. Countries and cities must have their eyes on the future, and they must lay a foundation that current and subsequent generations can comfortably build upon.

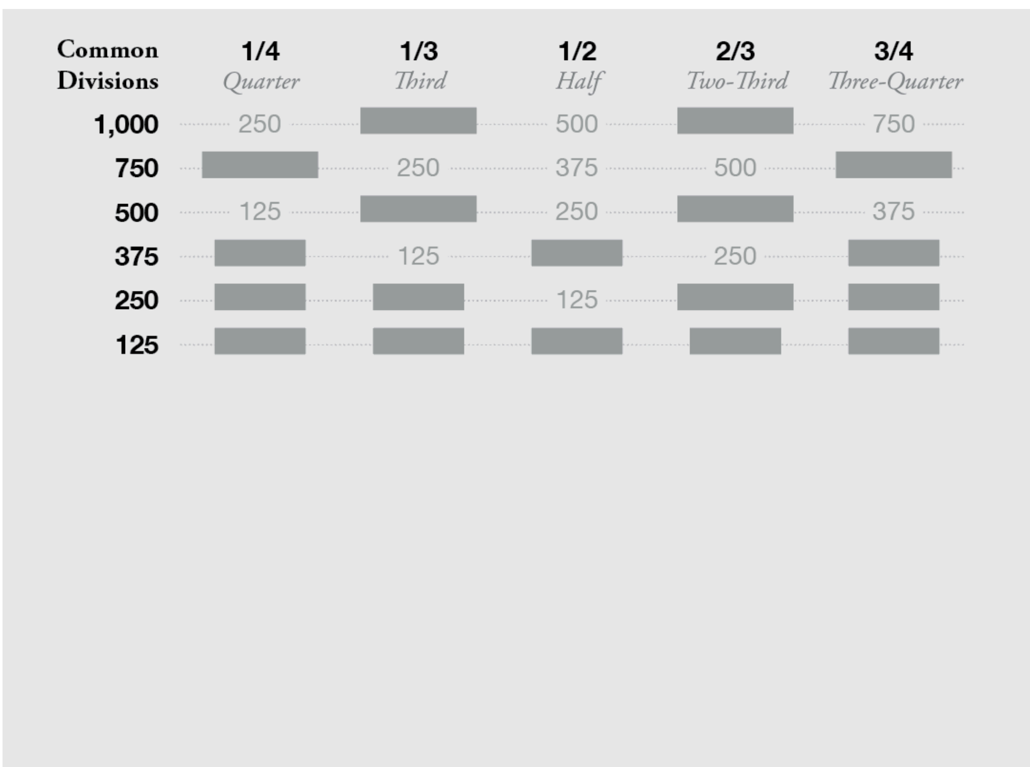
Highly Composite Numbers

Dimensions are numbers with strings attached to the real world. They are a way for us to record the sizes of things, whether as a record of something built or as a requirement of something to be built. In the applied mathematics of the built environment, dimensions are one of the primary tools. They allow us to manipulate the environment first conceptually before doing it physically; we can combine, extend, divide, or multiply lots with a simple calculation. This act of manipulation we call *design*. Easier methods of manipulation will make the design process that much more efficient. The search for a better method of manipulation (a better system of dimensions) can therefore begin as an exercise in finding the most flexible numbers.

Simply, frankly, mathematically, the number 10 is not as flexible or as fungible as the number 12. Ten has four divisors and can only be divided wholly by 1, 2, 5, and 10. Any and all other divisions will result in a remainder. Twelve, on the other hand, has six divisors and can be divided wholly by 1, 2, 3, 4, 6, and 12. Because of these additional divisors, 12 is a more workable and fungible number than 10; 12 has more utility than 10. More divisors means a number is able to adapt to more situations, making it easier to respond to a range of needs. It is similar to the malleability of gold verses the brittleness of glass; glass does one thing very well, but gold can be shaped in numerous ways as necessary.

A.C. Aitken, Professor of Mathematics at the University of Edinburgh, described twelve as “a number divisible by 2, 3, 4 and 6, while its square…144, divides by these and in addition by 8, 9, 12, 16, 18, 24, 36, 48 and 72, with all the consequences of economical and suitable use in parcelling, packaging, geometrical and physical construction, trigonometry and the rest, to which any applied mathematician and for that matter any practical man, carpenter, grocer, joiner, packer could bear witness”[7]. And he went on to describe the metric (base-10) system as "a notably inferior one; it cannot even express exactly for example the division of the unit, of currency, metrical or whatever, by so simple, ubiquitous and constantly useful a number as three”[8].

Furthermore, numbers are repeatedly subjected to multiple subdivisions. Halving, for example, is perhaps most common; in fact it is embedded in our own DNA (think about it). Twelve-hundred and its resultants can be halved four times before encountering fractions (1200 to 600 to 300 to 150 and finally to 75) while 1000 can be halved only three times (1000 to 500 to 250 to 125). But halving is not the only common method of subdivision. Thirds and fourths make frequent appearances throughout our daily lives (think about measuring cups, retail bays, divisions in a chest of drawers, money, time). With this in mind, we have analyzed numbers to see how they behave when subjected to successive iterations of subdivisions by quarters, thirds, and halves. That exercise is shown in the two diagrams below (note that the "censor bars" are covering fractional numbers; only whole numbers are counted in this exercise).



The generational subdivision of 1,000.

Common Divisions	1/4 *Quarter*	1/3 *Third*	1/2 *Half*	2/3 *Two-Third*	3/4 *Three-Quarter*
1,200	300	400	600	800	900
900	225	300	450	600	675
800	200		400		600
675		225		450	
600	150	200	300	400	450
450		150	225	300	
400	100		200		300
300	75	100	150	200	225
225		75		150	
200	50		100		150
150		50	75	100	
100	25		50		75
75		25		50	
50			25		
25					

The generational subdivision of 1,200.

Generational subdivision is being defined here as subsequent divisions of both a number and its resultant “offspring” (e.g., 600 is an offspring of 1,200, being half of 1200; 600 itself can then be subdivided further). The diagrams above reveal the superiority of 1200 over that of 1000: 1000 only has 5 generations of subdivisions, while 1200 has 14 (i.e., 1200 is almost three times more flexible than 1000). Additionally, the "offspring" of 1200 are themselves superior to the "offspring" of 1000. The numerical fungibility of "twelveness" passes from generation to generation. This is a simple observation and characteristic of mathematics and nothing more; however, it can be readily utilized in planning and architecture as we will show.

One cannot wholly divide 10 dollars or 10 meters into thirds. To do so leaves a remainder of money or land. If three people split 10 dollars, who is to end up with the leftover cent? If three property owners seek equal stakes in a 10-meter lot, where exactly should the lot lines be drawn? While pure mathematics provides a solution with repeating decimal places, the applied mathematics of the real world is at a loss. In reality, the decimal ends at some point; whether that's 10.33 or 10.3333, there will be a remainder.

To see this problem as a trivial one is to miss the point entirely. Wars have been fought and lives have been lost over the placement of boundary lines. To artificially skew one way or another can lead to unintended and undesirable consequences. A system of land subdivision must strive for absolute fairness. Numbers that are highly composite are those that contain a high number of divisors, making them perfectly suited for systems that require divisions (such as land subdivision). Highly composite numbers are more properly outfitted for the qualities desired. And they are already heavily used elsewhere.

Our construct of *time*, for example, is built on highly composite numbers. There are 60 seconds in a minute, 60 minutes in an hour, and 24 hours in a day, all superstar numbers exhibiting extreme levels of divisibility. And there's geometry, too, with a circle being divided into 360 degrees. Those degrees are divided into 60 arc minutes and those into 60 arc seconds. Both time and geometry combine together to form our modern geographical coordinate system which divides up the entire surface of the earth into highly composite units.

Highly composite numbers have already made their way into the metric system (see the table below). The built environment, as its moniker implies, requires builders in order to materialize. The builder's task is to expand the scale of a drawing to full scale and to render a drawing using real materials. It is an intense process of communication between an architect, general contractor, their subs, and their subs' subs. Given all the complexities that already exist in the act of building, it is best to maximize simplicity and efficiency in the process where possible. With that said, it is easier to cut a sheet of plywood in half when its length is evenly divisible by two (half of a standard 2,400 mm sheet yields two sheets 1,200 mm wide); the mental math is manageable and the units themselves are highlighted on a tape measurer for easy transfer. Otherwise, half of, say, a 2,437mm sheet is 1,218.5 mm, which requires both tedious counting of 1-mm markings on a tape and the use of a calculator (depending on the mental facility of the subcontractor).

Highly Composite Numbers and the Metric System[9]

METRIC	DEVICE
600mm x 600mm	Standard ceiling tile
1200mm x 2400mm	Standard sheet of plywood and drywall
60mm multiples	Plywood sheet sizing
60cm	Standard stud spacing

Whether one is dealing with ceiling tiles, beams, studs, or sheathing, highly composite numbers such as 60 become incredibly useful to work with in the field. Not only could that plywood be cut in half evenly, but it could be cut into thirds, fourths, fifths, sixths, eighths, tenths, twelfths, and so on. Ceiling tiles measuring 600 mm have a better chance at coursing out in a room of similar number than otherwise.

The task here is to incorporate this extant preference for highly composite numbers into a unified, efficient, and practical system of land subdivision. This is by no means the first time that highly composite numbers have been promoted in this way. Plato, in Book V of his *Laws* written 360 BCE, sought to apply the number 5040 to a city's citizenry and land area, stating:

> *"We will fix the number of citizens at 5040, to which the number of houses and portions of land shall correspond. Let the number be divided into two parts and then into three; for it is very convenient for the purposes of distribution, and is capable of fifty-nine divisions, ten of which proceed without interval from one to ten. Here are numbers enough for war and peace, and for all contracts and dealings. These properties of numbers are true, and should be ascertained with a view to use."*

As he wraps up his book, Plato extends this power of number and arithmetic to every facet of life:

> *"There is no difficulty in perceiving that the twelve parts admit of the greatest number of divisions of that which they include, or in seeing the other numbers which are consequent upon them, and are produced out of them up to 5040; wherefore the law ought to order phratries*[10] *and demes* [11] *and villages, and also military ranks and movements, as well as coins and measures, dry and liquid, and weights, so as to be commensurable and agreeable to one another. Nor should we*

fear the appearance of minuteness, if the law commands that all the vessels which a man possesses should have a common measure, when we consider generally that the divisions and variations of numbers have a use in respect of all the variations of which they are susceptible, both in themselves and as measures of height and depth, and in all sounds, and in motions, as well those which proceed in a straight direction, upwards or downwards, as in those which go round and round. The legislator is to consider all these things and to bid the citizens, as far as possible, not to lose sight of numerical order; for no single instrument of youthful education has such mighty power, both as regards domestic economy and politics, and in the arts, as the study of arithmetic. Above all, arithmetic stirs up him who is by nature sleepy and dull, and makes him quick to learn, retentive, shrewd, and aided by art divine he makes progress quite beyond his natural powers."

For our purposes here, we are proposing that the dimensions of all the elements of urbanism (blocks, streets, buildings, rooms, etc.) be divisible by six. This helps to ensure, to within a half unit, that designs will be efficient and sustainable through the mathematical properties of coursing, packing, and ease of use. A six-meter grid could be draped upon a landscape, much like the American Land Ordinance of 1785 (which will be discussed in the next chapter), with boundaries, buildings, streets, parking spaces, and bedrooms all snapping to their corners.[12]

Components of Land Subdivision and their Proposed Dimensions for the Metric System

METERS	DIVISIONS OF SIX	FEET[13]	DEVICE
6	1	19.7	Alley
12	2	39.4	Standard lot width
18	3	59.1	Standard right-of-way
24	4	78.7	Major right-of-way
30	5	98.4	Standard lot depth, Major right-of-way
33	5.5	108.3	Standard lot depth (to obtain a particular block size, explained later)
36	6	118.1	Standard lot depth
60	10	196.9	Min. Block Side
192	32	629.9	Max. Block Side
540	90	1,771.5	Max. Block Perimeter
600	100	0.37mi, 0.6km	Quarter Section Length
1,200	200	0.74mi, 1.2km	Section Length
7,200	1,200	4.5mi, 7.2km	Township (6x6 Sections)

Metric Area Comparisons

DEVICE	METRIC	SQUARE HEXAMETERS
Township	3,600 ha	1,000,000
Section	144 ha	40,000
Quarter Section	36 ha	10,000
12m x 36m Lot	432 sm	12
12m x 33m Lot	396 sm	11
12m x 30m Lot	360 sm	10

We will explore the benefits of this system in detail in subsequent chapters, starting with the National Land Ordinance.

End Introduction

This discussion is not meant to turn a city into a selfless machine for housing humans—far from it. The pursuit of cost savings and dimensional efficiencies runs parallel with that of environmental sustainability, economic frugalness, and higher quality of life. It is a matter of reallocating resources and reprioritizing efforts. By saving effort in one place, we can choose to spend it in another.

Using one of the most successful companies in the world today as an example, Amazon did not become the king of retail because their copy of a particular book was superior to any other. It did so because of logistics—the *Taylorization*[14] of the shopping experience. While Amazon's copy of *To Kill a Mockingbird* is exactly the same as the one in the local bookstore, the buyer didn't have to move from their reading chair to get it. Like it or not, we are living in a world of extreme efficiencies, conveniences, and razor-thin margins. The same can be said for urbanism. If good urbanism is going to compete with bad urbanism, the process must be streamlined, cheap, efficient, and easy. There is nothing wrong with those terms in and of themselves. When applied to the land subdivision process, they can just as easily result in a walkable, sustainable, and beautiful network. Many of the great gridded towns across the United States (from Pasadena, CA, to New York, NY) stand as exemplars of taylorized urbanism—even an "office boy" can lay out a good town plan.[15]

Science and art have a symbiotic relationship. Science provides the foundation for art; art encourages science to dream. In urbanism, the science of space and the art of living go hand in hand. Mathematics has allowed us to build beautiful places; we must continue to listen to the lessons it provides and adapt it to our benefit.

In closing, the scales addressed in this paper range from entire countries to individual stair steps. In regards to land subdivision (or, speaking more holistically, the subdivision of space), there are four common parameters that act across this wide spectrum:

1. Dimensions of the human scale
2. Atomic units of building construction
3. Number theory
4. Persistence of boundary lines

Keep those things in mind as you continue reading. In the next two chapters we will explore *national ordinances* and *master street plans*, respectively.

Chapter 2: National Ordinance

In this chapter, we will discuss the challenges of planning at the national scale, show how previous national ordinances have assisted with that endeavor, and propose a new national ordinance based on those lessons.

What is a National Ordinance?

Our opening discussion on permanence, dimensions, and design addressed some of the themes and qualities of planning to be considered throughout this study.

In the scales of human development, the largest scale tends to have the largest impact. A nation's constitution, e.g., affects everyone, while a local ordinance is limited in scope. It is the built-in tenacity at the largest scales that make their influence worthy of the most intense study (it is much more difficult and the stakes much hire to amend a national constitution than it is a small town's municipal code). So with that, we begin at the scale of the country with a *National Ordinance*.

A National Ordinance is a guiding document for the distribution of lands across an entire country. Needless to say, it is comprehensive by necessity. It comprises methodologies, maps, principles, and policies for subdividing vast territories. While it is prescriptive in its methods, it can materialize incrementally and flexibly. It is broad brush strokes on a canvas; it allows finer details to be applied later. From a design perspective, it is a document that breaks down vast dimensions into manageable and workable units.

The *Land Ordinance of 1785* in the United States is one of history's finest examples of a national ordinance and provides us with an incredible source of design lessons. Following the US's possession of the Midwest and especially after the acquisition of the Louisiana territory from France, the US government sought a way to subdivide, sell, distribute, and occupy their new territory.[16] The challenge was simple—how does one manage and sell land that had yet to be mapped or occupied? The solution was ingenious—a surveying and organizational method that resulted in a geometric grid to guide the future growth of the nation (a grid which continues to do so to this day).

One of the primary lessons from the 1785 Ordinance rests in how it divided the scale of the country down into manageable units. By linking a system of measure with a system of survey, occupation, and development, the Ordinance provided a universal canvas for future growth. It is especially important to note that the Ordinance spoke relatively little of land uses and instead focused on land subdivision. The United States has changed dramatically over the centuries since, yet the Ordinance still provides an adequate framework. Because its divisions were based on a set of dimensions that have proven to be flexible and useful over time (within the Imperial measurement system), any development that has occurred since the first survey has been successfully and seamlessly accommodated into the framework.

A New National Ordinance

It is lessons like those from the 1785 Ordinance that can be carried forward and adapted for other countries. All country's share an unknown future. Just as the 1785 Ordinance in the US did not attempt to predict the future, nor should others.

Contrary to the unknowns of the 18th-century world, the geographical limits of the world are today known. In most cases, with the benefit of modern GPS technology and previous mapping endeavors, countries do not need to focus on discovery and can instead focus on design. A national ordinance provides the canvas for growth and sets the tone for the finer details. Its design relies on the country's unique history and unique set of contemporary circumstances.

The particulars of a metric system utilizing highly composite numbers were only briefly touch upon in the *Introduction*. Here, we will now begin to focus on them. For our new national ordinance proposed here, the major units of subdivision shall comprise the *township* and the *section*.[17]

Part of the challenge for a country's national planning efforts is knowing at what scales specific rules and design interventions should be inserted. In reality, *scale* is a continuous medium (i.e., things of all sizes are built, from the sub-millimeter to multi-kilometer). Everyday we interact with objects of all sizes: four centimeter cabinet pulls, or an elevator ride that takes us up 300 meters. But these reflect rules and designs which are often discontinuous interventions: they affect specific sizes and areas, with their influence tapering off as the scale changes (a cabinet's handle has little to do with the height of the building).

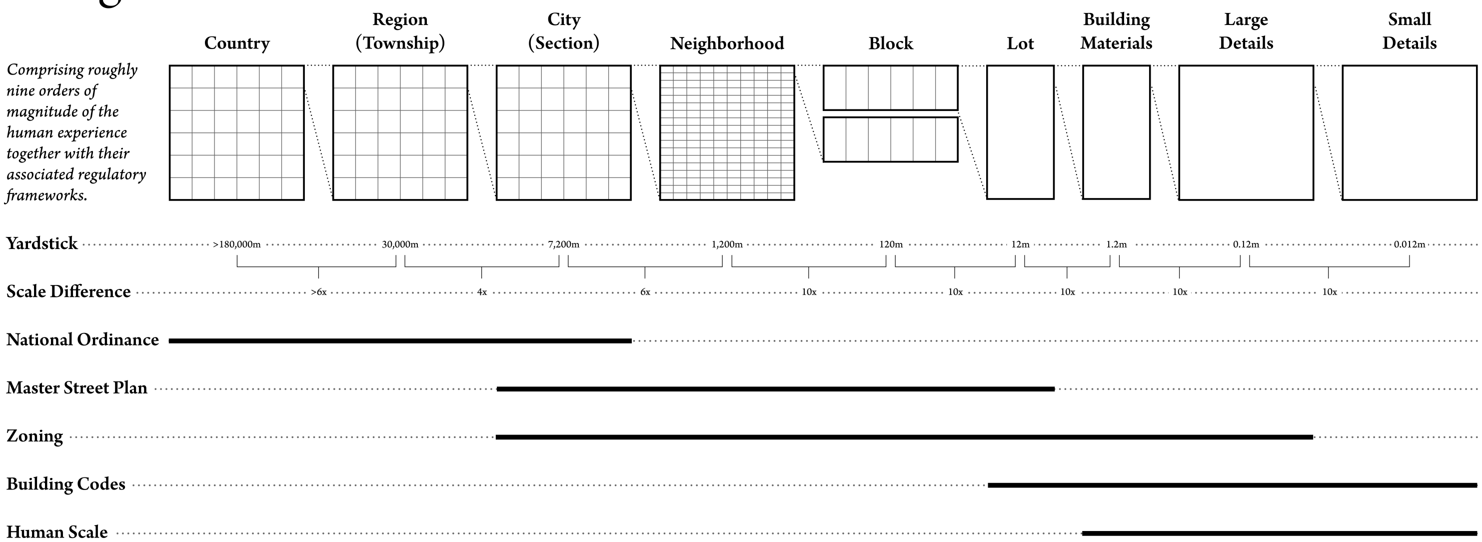
As one scale tapers off, another emerges with their associated design regulations essentially passing the baton of responsibility. These design and regulatory interventions should occur roughly at powers of 10 in scale. In other words, a regulation's domain should account for no more than about 10% (or 10 times) that of another. This allows for a degree of fine tuning across scales and results in different "yardsticks" of design (e.g., a neighborhood on the order of one kilometer versus a region on the order of 10 kilometers).

Recognizing this, we have divided a hypothetical country into the design scales listed in the table below.

The Design Scales of Urbanism

SCALE	YARDSTICK (METERS)	DEFINITION
Country	180,000+	Encompassing all sovereign lands.
Region	30,000	May be defined by political landscape, geography, existing infrastructure, metropolitan areas, among other factors.
Township (City)	7,200	A large hub of people, development, and activity.[18]
Section (Neighborhood)	1,200	A locally unique area which may be differentiated by its architecture, people, land uses, or history, among other factors.
Block	120	An area of private property surrounded on all sides by public rights-of-way. This scale may also include large buildings.
Lot	12	A private parcel of land within a block and subject to zoning regulations. This scale may also include small buildings.
Building Materials	1.2	The atomic units of construction.

Design Scales of Urbanism



Comprising roughly nine orders of magnitude of the human experience together with their associated regulatory frameworks.

The table below lists the regulatory devices that operate within the scales outlined above.

Subdivision Devices and their Associated Design Scales

REGULATORY DEVICE	SUBDIVISION DEVICE	DESIGN SCALE
National Ordinance	Township	Country, Region, City
National Ordinance	Section	City, Neighborhood
City Planning Enabling Statute	Master Street Plan	City, Neighborhood, Block, Lot

Townships

The largest unit of subdivision within our proposed national ordinance is called a *township*. A township is made up of 36 *sections* (see discussion below), with each section being 1.2 km on a side, organized into a square grid pattern of 6x6 sections, making for a township 7.2 km on a side[19].

The dimensions of townships and sections are made to be divisible by six. The 1200 m (1.2 km) unit, provides more opportunities for the devices of urbanism (lots, blocks, streets, buildings, etc) to materialize in whole meters, avoiding fractional parts, streamlining subdivision, and adapting to changing needs. Additionally, subsequent subdivisions of the 1200 m section are better facilitated than those of 1000 m, as was shown in the introduction of this paper.

The 7.2 km township is commensurate in size with major cities throughout the world (see table below). Individual townships, then, may be envisioned as potential independent towns or cities, an area of allocated land for development to grow into.

Comparison of a Township to the Sizes of Cities

CITY	SIZE (KM)	AREA (KM^2)	TOWNSHIPS
Township	**7.2 x 7.2**	**51.8**	**1.0**
Manhattan	3.5 x 20	70	1.4

Paris	11 x 10	85	1.6
Barcelona	8 x 6	48	0.9
Atlanta (Beltline)	6 x 10	48	0.9
U.S. Township	9.7 x 9.7	93.3	1.8

Each township will likely, over time, take on different characters based on its unique position, being affected by geography, population, land use, among many other factors. While the uses that will fall within each township will differ, the subdivision patterns are sized to accommodate whatever comes their way.[20]

With all of this said and proposed, the exact delineation of a township isn't as important as the individual sections that make it up. The township may be 5x5 sections, or 6x6, 10x10, or 12x12. The size may be dependent upon the exact surveying method used, or the intended jurisdiction for political or economic purposes. Here, we are defining a township in terms of the impact on the urban form of development as well as the general sizes of precedent.

Where the township may be more of an administrative unit, the section, though smaller, is seen here as the primary development unit for the region.

Sections

A township is the scale of a city; a section is the scale of a neighborhood. As referenced above, a section is 1.2 km on a side. The section is the intermediate scale in planning, falling in between that of the entire country and a single city block, roughly describing a size of a neighborhood. At this scale, land planning begins to have an immediate and daily effect on its users.

The Neighborhood Unit

The idea of the *neighborhood unit* was first proposed by Clarence Perry in 1929 in *The Regional Survey of New York and Its Environs, Vol. 7*. In that study, Perry asserted that a land plan and its associated uses should be scaled according to comfortable, pedestrian walking distances (e.g., a child's walk to school). The neighborhood unit thus combined housing, schools and other institutions, parks, and shopping all within a relatively tight urban fabric. The concept has recently been revived by the Congress for the New Urbanism.[21]

Walking rates, however, vary with the age of the pedestrian (see table below). The average young adult walks at 1.51 m/s. At this rate, a 5-minute walk would cover 450 meters. But the average older adult walks at 1.25m/s, covering 375 meters in five minutes.

Five-Minute Walking Shed for Younger and Older Pedestrians[22]

PEDESTRIAN	WALKING SPEED (M/S)	5-MINUTE DISTANCE (M)	5-MINUTE AREA (KM^2)
Young Adult	1.51	450	0.64
Older Adult	1.25	375	0.44
Average	*1.40*	*420*	*0.55*

The main idea is for a neighborhood to house the majority of one's needs within walking distance. One may only need to go to an airport once a year, but they may need to go to school or the grocery store on a daily or weekly basis. It is these daily and weekly trips that the planner should strive to accommodate within individual neighborhoods. Walkable urbanism simplifies these trips and makes them more efficient. Additionally, walkable urbanism helps to positively increase social interaction, public health, safety, and, while harder to measure, simply makes for a more pleasurable living environment[23].

The neighborhood unit and five-minute walk are fine concepts that help to break down the scale of development to more appropriately match the needs (and limitations) of people. While these lessons are important in our planning efforts, we are not using them directly here but instead have incorporated the concepts in an altered form. Consider, for example, the table below, which compares a number of neighborhoods around the world with the equivalent number of Perry's neighborhood units contained within them. In many cases, established, unique, well-defined, and functioning neighborhoods tend to be larger than a single neighborhood unit.

Sizes of Neighborhoods Around the World in Comparison to Clarence Perry's *Neighborhood Unit*

CITY	NEIGHBORHOOD	SIZE (KM)	AREA (KM^2)	NO. OF NEIGHBORHOOD UNITS
-	**Perry's Neighborhood Unit**	**0.8 x 0.8**	**0.6**	**1.0**
Atlanta	Inman Park	0.5 x 1.5	0.8	1.2
Providence	College Hill	1.0 x 1.2	1.2	1.9
New York	Forest Hills	1.0 x 1.0	1.0	1.6
New York	Greenwich Village	1.0 x 1.0	1.0	1.6
Paris	Montmartre	1.0 x 0.8	0.8	1.3
Barcelona	El Raval	0.8 x 1.5	1.2	1.9
Vienna	Inner Stadt	1.5 x 1.2	1.8	2.8
Ancient Roman Coloniae	-	0.7 x 0.7	0.5	0.8
Section	-	1.2 x 1.2	1.4	2.2
U.S. Section	-	1.6 x 1.6	2.6	4.0
U.S. Quarter Section	-	0.8 x 0.8	0.6	1.0

The street network, architectural character, and various land uses of successful neighborhoods have tended to agglomerate together in roughly similar sizes, on the order of a single square kilometer. The size of our section, proposed here to be 1.2 km, is a reflection of this observation. It is a scale at which a greater mix of uses and number of housing units may be accommodated. Additionally, it allows for an easier "one-to-one" comparison with other successful neighborhoods to draw from.

With that said, it is anticipated that each Section could evolve into a complete and independent neighborhood (or multiple neighborhoods). In the American Midwest, the 1-mile square section, e.g., are slightly too large in regards to pedestrian travel. While the US Quarter Section matches the size of a neighborhood unit at 1/2-mile on a side, the five-minute walk is only possible from the direct center of the quarter section. Additionally, the US quarter section is not the primary unit of subdivision that the writers of the 1785 Land Ordinances used. While many US Sections were subdivided into quarter sections, it was not in a consistent manner.

The comparable reduction in length as compared to the US Section promotes a finer-grained urbanism more conducive to the pedestrian. Additionally, it increases the connectivity of the overall, regional street network. The perimeter of each Section could be defined by streets or thoroughfares that, when considered together, form that regional network.

The neighborhood unit (either Perry's original or New Urbanism's modified version), when applied to large land areas, may risk putting too many "by-pass" roads in place and leaving too little room for the neighborhoods themselves. When looking at the overall street networks and neighborhood divisions of the great cities around the world (pre-1945 Atlanta, Barcelona, Paris, etc.), the "global" street network (i.e., the larger thoroughfares for moving traffic across a city) appears closer to 1.2 km intervals rather than 0.8 km intervals (though in New York’s case major thoroughfares are distributed tightly throughout the grid).[24]

All of this is not to say that the smaller scale of Perry's neighborhood unit should be avoided; far from it. Development should strive to be as mixed and as fine-grained as possible, both in subdivision and in use. But as a planning device and as a dimensional tool, we find the 1.2 km section proves sufficient for scale and proficient for dimensional fungibility.

Each section (or quarter-section, depending on housing density) should strive to contain as many land uses and services as possible, but we will not go into those here.[25] Within each section, a half-width right-of-way is included around the perimeter; as more sections agglomerate next to one another, whole-width rights-of-way will be formed along their seams. The exact dimension of the right-of-way is not precisely specified nor does it need to be provided that it falls within an appropriate range (based on precedent) and on multiples of hexameters. With all urban devices evenly divisible by hexameters a great variety of whole dimensions may be employed for all blocks, lots, and streets. This allows the widest range possible of dimensional flexibility and, by extension, sustainability, while preserving the many benefits of highly composite numbers. It preserves the integrity of the number system and helps to avoid the many pitfalls of repeating decimals and the annoyances of complex fractions.

A section does not require that all blocks and streets be identical or that all blocks course out within 1.2 km. The only requirement is that those elements are sized in units of six. Consider the section to be atomized into six-meter squares. The main purpose of the section, from an urban form perspective, is to ensure a certain level of subdivision and connectivity at the neighborhood scale.

End National Ordinance

In spite of the dimensional constraints outlined above, a great variety and character of land plans can be attained. The specific sizes of land planning devices (lots, blocks, and streets) will be heavily explored and illustrated in the next chapter on *master street plans*.

Chapter 3: Master Street Plans

Leaving the scale of the country and region behind, we will now address the smaller, more intimate scales of the city and neighborhood. It is here that the day-to-day operations of life emerge and finer-grained planning decisions must be made. The many components of cities (houses, people, cars, etc.) each have their unique dimensional requirements that must be understood and accommodated.

In this chapter, we will review the critical roles that streets play in both city form and function, explore an alternative to our modern-day zoning-dominated model of development, and reveal the dimensions of successful urban planning.

Streets

Permanence

What are cities made of? Think on this for a second and picture yourself walking or driving around. What do you see? Cars, dumpsters, people, trees, signs, sidewalks, ice-cream shops, shoe stores, hospitals, schools, libraries, skyscrapers, houses, apartments, etc. Cities are mankind's largest built work. Consider that each of the components just mentioned experience some level of change, at some rate, resulting in a life expectancy[26]. The average big-box retail building, for example, is built to last only 10, 15, or 20 years. Interestingly, humans, street trees, and the average building[27] share comparable life expectancies of roughly 80 years. But what is the element of the city that lasts the longest? The street.

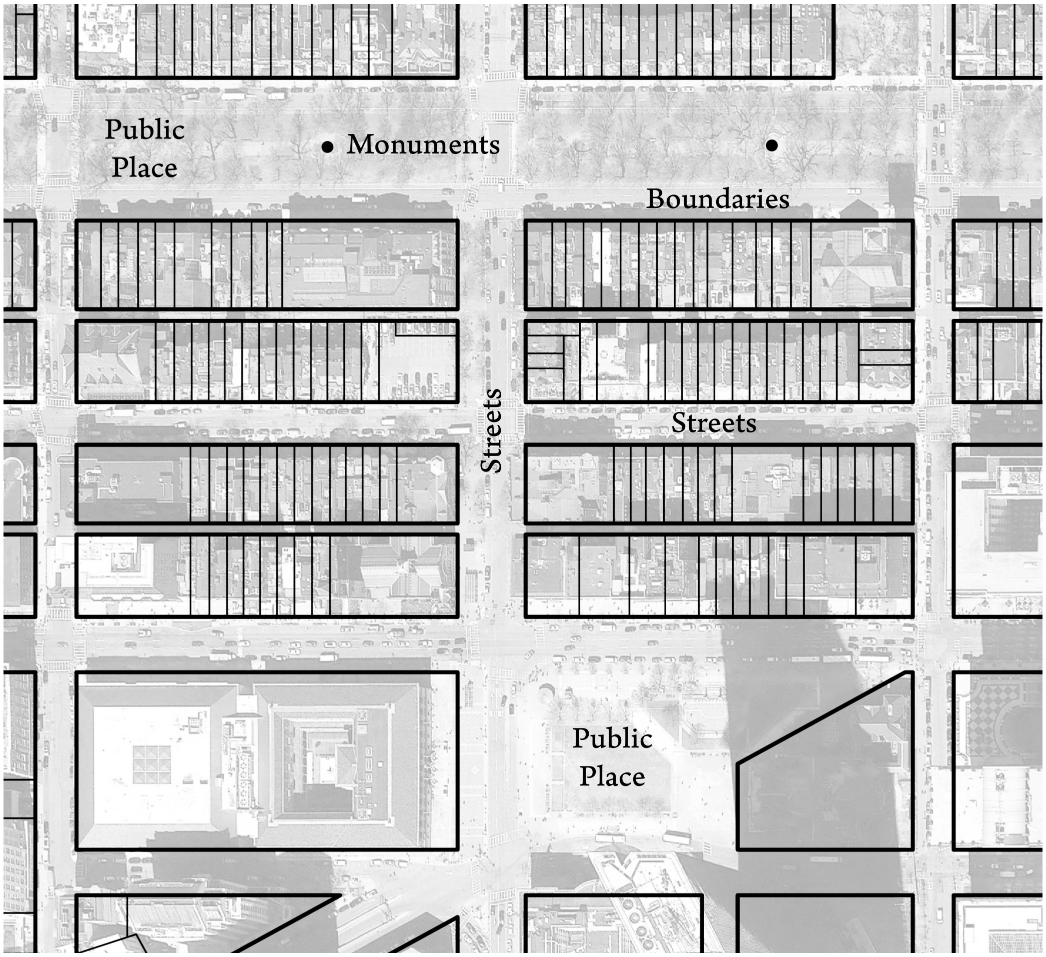
CITY COMPONENT	LIFE EXPECTANCY (YEARS)
Car	20
Dumpster	20
Building (Big-Box Retail)	20
Street Tree	80
People	80
Building (Average)	80
Building (House)	150
Street Rights-of-Way	1,000s

Streets (i.e., the boundary lines delineating the rights-of-way) can last on the order of thousands of years. An example of this is illustrated in Imola, Italy. Imola was founded by the ancient Romans about 2,000 years ago. When they subdivided their territory, they used a unit called a *heredium* which is 240 feet on a side. The word heredium shares a similar root to the English word *hereditary*. The idea was that a family would continue to pass on and inherit these heredia over time. Now imagine this taking place over a 2,000 year period, with the apex of the Roman Empire and then its subsequent decline, when everyone retreated behind the walls of their medieval cities, and then reemerged during the Renaissance, and then sparked the industrial revolution, and then had a couple of World Wars, and now everyone is walking around with iPhones. Even under the pressure of immense change experienced over that span of two thousand years, those heredia are still guiding the growth of Imola today.

Aerial photograph of Imola, Italy,[28] with its long-lasting heredia shown dashed.

The boundary lines that were established by the ancient Romans two thousand years ago have subsequently been translated into farming lots, fences, building walls, streets[29].

Streets, then, form part of the "constitutional order" of cities: together with boundary lines, public places (including parks and buildings), and monuments, they are a part of the permanent framework of urbanism. The remainder, the "representational order", makes up the stuff we see day to day: cars, people, and private buildings, etc. These elements animate the constitutional order and give it meaning, but they are fleeting relative to the permanency of the constitutional order.



An "x-ray" of Boston's urban form reveals its constitutional order.

Resilience

How do streets survive such long time scales? Where do they get their resiliency?

First, public streets are collectively owned. Each member of the public has a stake in its streets. It's relatively easy for one person to coerce a few people into doing something, but it's a lot harder for one person to coerce a few thousand or million people. A street cannot simply be moved from here to there without having to get potentially millions of people to buy into such a move. Additionally, the legal network that makes up the foundation of property ownership is a function of the location of streets. Where does a setback proceed from? The street. How does one enter their house? From the street. Streets are collectively owned and through the nature of the resultant property ownership become locked into place.

Second, streets are simply inherited assets. They are handed down from generation to generation. They are excellent receptors of investments made over time: one could start with a rutted-out dirt road, and then add some gravel, and then twenty years later add some asphalt, and twenty years later add some sidewalks, and then street lamps and street trees, and so on. As a public asset, they can be improved upon over many generations.

It is because of these two reasons that streets have survived incredible catastrophes through history. For example, the Great Fire in London in 1666 completely destroyed the city. Christopher Wren, one of the greatest architects of all time, tried to take advantage of the situation, seeing it as an opportunity to introduce new avenues (in the same fashion as Rome at the time) to London's dense, cranky street network. But because of the legal ownership patterns, the city's urban form largely reemerged from the ashes as it was before the fire. There was an urgency to rebuild, and that urgency outweighed the complexities of reconfiguring property lines.

In San Francisco in 1906, a catastrophic earthquake was followed by an even more catastrophic fire that ultimately leveled the entire city. The scenes of the destruction are striking, presenting a wasted landscape denuded of life. Similar to the case of London, Daniel Burnham (an influential American architect and planner) had spent the previous year before the earthquake reimagining the city's urban form. As a prelude to the 1909 Plan of Chicago, Burnham's plan for San Francisco had envisioned new avenues and thoroughfares, civic centers, and parks. Burnham delivered the plan to the city only a few days before the earthquake hit. And one would have thought the fire presented an incredible opportunity to implement the plan. However, similar to London, the grid of San Francisco resisted both fire and planner. San Francisco's urban form today is largely unaltered from its pre-1906 configuration.

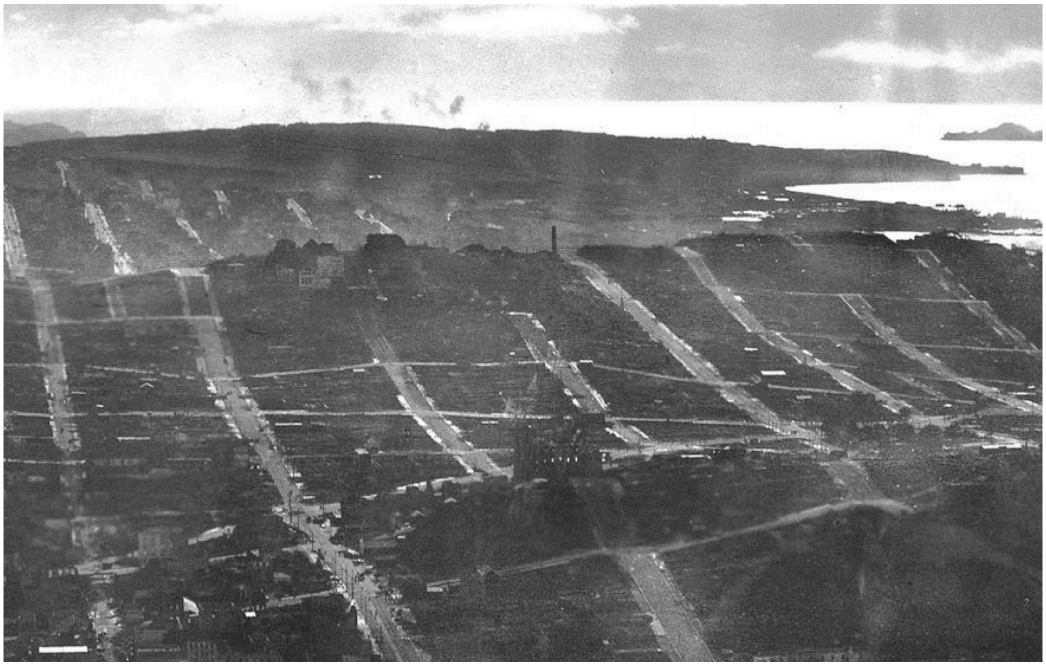


Image of San Francisco taken from a hot air balloon soon after the fire in 1906.[30] *Most of the buildings were destroyed, most of the people either perished or fled, but the streets and their associated boundary lines persisted.*

Benefits

What do streets do for a city? What do they do for us?

In today's auto-oriented landscape, the most obvious thing streets do is connect people. Whether one lives in Atlanta, Agra, Paris, or Kuwait City, streets are the medium for getting around. They are driven on, biked on, and walked on. They get people and goods from point 'A' to point 'B'.

But they require much more appreciation than this. Streets are not just for transportation. Just as importantly (if not more important), they provide access to property and they create frontage. When someone goes to Paris and marvels at the city's monuments and architecture, they are seeing Paris primarily through its streets. The face of Paris is made up of the buildings that front the street, it is how Paris presents itself to the world. The lesson here is that the more streets a city has, the more street frontage it has, which means more front doors, more front yards, and more storefronts. More streets means more opportunities to open up a city to development, to produce these vibrant neighborhoods common in the great cities of the world.

Streets also help to subdivide land into developable and accessible units. There are some dimensions of streets that do this better than others. For example, take a block that happens to be 86 meters by 158 meters on a side. In Chicago, a block of that size accommodates condo buildings, and townhouses, and some bungalows. In Amsterdam, the exact same block accommodates townhouses and a palace. In Buenos Ares, the exact same block accommodates apartments and a market. That block could also be used to accommodate a grocery store and its parking. Or a Super Walmart. How can the exact same block accommodate all these things, all these different cultures, different languages, different building types, different land uses? This kind of flexibility is an amazing characteristic of good urban form, and it is one that is measurable and useable. As was already discussed earlier in the *Introduction*, the vast majority of what is built in the world—houses, shops, skyscrapers—are all based on the same dimensional DNA.

Additionally, streets contain public utilities. As public spaces, this makes sense. David McCauley, author and illustrator, developed a wonderful book called *Underground* with beautiful drawings where he peels back the asphalt of New York streets to reveal what happens underneath. You would be amazed at what all we have shoved underneath our streets.

Finally, streets are a city's largest public space. Portland, Oregon, for example, has small blocks, 60 meters on a side. With typical street widths of 18 meters, the percentage of land in Portland that is allocated over to streets is 40%. That's almost half, by the way.

Over time and around the world, there have been numerous planners who have recognized the street's critical nature in cities. Edward Basset, one of the founding fathers of American planning and author of the 1916 Zoning Resolution in New York, said:

A civilized community needs streets for sewers, water supply, gas and electricity. This relates to the public health and comfort. It needs streets for water for fire protection and the movement of fire apparatus. This relates to public safety. It needs streets for foot and wheel traffic. This relates to all police power fundamentals.

Frederick Law Olmsted, celebrated American landscape architect:

The street plan has always been regarded as the foundation of all city planning.[31]

Otto Wagner in Vienna, one of the greatest architects in history:

Streets and squares demand the greatest care and attention in the planning of a city. They need to be discussed first.[32]

And Doug Allen, one of the greatest visionaries in planning since Kevin Lynch:

Streets are the primary structural unit of the city.[33]

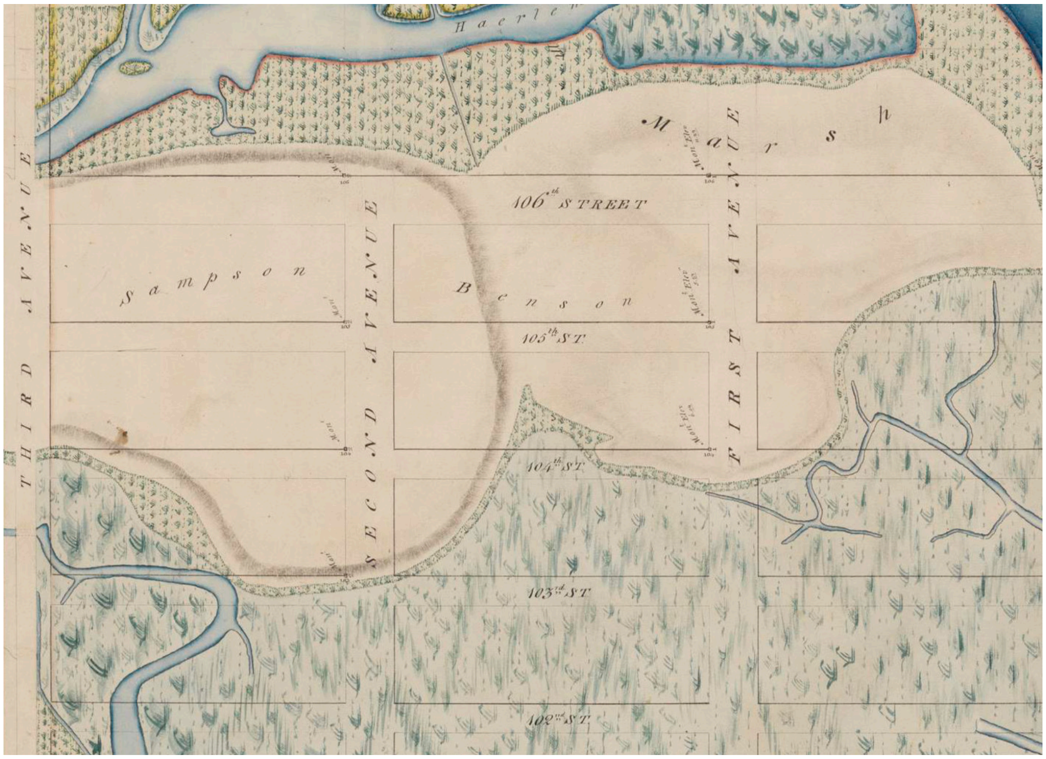
We find ourselves today, however, in a situation where city planners have either forgotten, chosen to forget, or never had a chance to learn these insights. Because of this, many of the streets built since the middle of the 20th century were put in place specifically for the movement of traffic and excluded all the other important functions and qualities of streets just mentioned. It is no wonder, then, that the places that have been built around these one-dimensional, single-use "traffic sewers" are equally as one dimensional and single use. The character of the street directly affects the character of a place. We will explore the repercussions of this and provide a fuller history in a subsequent chapter titled *The Enabling Acts*, but for now we will focus on the most important planning device ever conceived, one that has been largely lost for 100 years but holds the key, we believe, to building cities that are more walkable, sustainable, and enjoyable: *the master street plan*.

Master Street Plans

What is a Master Street Plan?

A master street plan is a plat that depicts both current and, most importantly, *all future streets within an entire jurisdiction*. That is to be taken literally: within a jurisdiction, within an entire town or city, every single street that is ever going to be built is planned for at once. Think of it as a pre-approved subdivision plat; it is a drawing of a city's desired urban form.

This may sound far fetched, but history provides us with numerous examples of its successful use. One of the most famous and well-documented[34] examples of a master street plan is the 1811 map of Manhattan. At that time, a group of Commissioners, seeing substantial growth looming in New York's future, sought to provide a physical framework for that growth, one that addressed not necessarily the "what" but the "where" of city planning. They didn't know what was coming, but they created a logical pattern of subdivision to give all the unknowns a place to go. Over the following decade after the street plan was adopted, the streets indicated on Manhattan's 1811 map were surveyed in the field. Large stone monuments were used to mark the corners of future blocks with the future right-of-ways offset from them. By physically surveying the streets, the plan was taken from paper into reality and could thus be protected from physical infringement (whether unintentional trespass or otherwise). A master street plan is no good unless it is on a plat that defines precisely where the boundary lines are going to be.



Plat of 1811 Manhattan plan by the surveyor John Randell, Jr.

In the Commissioners' report that accompanied the plan, they projected it would be at least "a thousand years" before the plan was physically realized in its entirety.[35] The actual streets of Manhattan, however, were largely built out over a single century. But consider the amount of change that Manhattan experienced over that time: exponential population growth, political regimes, building technologies, etc. As development occurred, as developers saw individual needs for housing and schools and shops, the streets were simply constructed per the plan, piece by piece. Remarkably, even with Manhattan's rapid and history-making changes, this adherence to the street plan lasted well into the 20th century culminating in its eventual and substantial completion.

A master street plan is a simple line drawing, showing the boundary lines that indicate private property and public property. As we have seen, all of urban design can be reduced to a delineation between public and private property. A master street plan reflects this clearly and succinctly.

A street indicated on a master street plan appears simply as two parallel lines which are separated by some scaled distance. A series of 18-meter wide rights-of-way may appear identical on a master street plan, but in reality they may take on dramatically different characters: one my be a rutted-out dirt road, while another my be paved with sidewalks and lined with skyscrapers. The boundary lines are indistinguishable in plan view; they are essentially the same street. But streets grow up differently under different circumstances even if they share the same dimensional DNA. Given enough people, enough building, enough time, and the right dimensions, a rutted-out dirt road can grow into an urban thoroughfare.

We provide two analogies here that may help to further emphasize the utility of a master street plan:

A master street plan is like a jigsaw puzzle: When you buy a puzzle it comes in a box, and on the cover of that box is a picture. That picture is your goal. It guides your placement of the pieces. So regardless of how long it takes you, regardless of how many people are involved, eventually you will reach your goal. And a master street plan operates in the exact same way. Regardless of whether it takes ten years, or a hundred years, or a thousand years, whether it takes ten developers or a thousand developers, as long as there is an established reference, the city will reach its desired urban form. Thus, a city without a master street plan is like a puzzle without a picture: there are no references for where the pieces should go. But unlike puzzle pieces, once the components of cities are placed they are incredibly hard to pick up and move if necessary, making master street plans all the more useful.

A master street plan is like a blueprint for a city: In architecture, the construction drawings of a house reveal the locations of where each wall should be built. A builder adheres to the plan, constructing the walls where indicated. The result, after a while, is a house that reflects the original intention, the original plan.

It is a similar exercise for a city: a master street plan shows where each street should be built. Developers adhere to the plan, constructing new streets where indicated. The result, after years or decades, is a city that reflects the original intention, the original plan.

The building of a house is not left to mere chance, and neither should be a city. The application of a master street plan is the most direct way to achieve a desired urban form and thus ensure that a certain level of walkability, adaptability, efficiency, and economy are built in.

While a house is built at once, that does not mean it cannot change: rooms can be painted various colors, pictures can be hung from the walls, inhabitants can move in and move out, even additions and renovations are an option. It is similar with a city. Even though a physical street plan becomes locked into place, all the life that happens within that framework of streets is allowed to change and adapt as it naturally needs to. Streets are there only to provide structure, not content.

Planning in the Right Order: Subdivision and Zoning

City planning is a complex process, especially in our modern times. However, it can largely be reduced into two primary domains: zoning (the regulation of private property) and subdivision (the order of public property). These two domains compete for attention, but over the last century zoning has come to dominate the process.[36] We will show here how putting zoning first is detrimental to the more permanent and important patterns of subdivision.

Any many jurisdictions around the world today, zoning is the first step in the land development process: residential here, commercial there, and office over there. This is promoted as the most important determinant in advancing health, safety, and welfare and in protecting the public interest because of the power it has in separating *incompatible uses.* The concept of keeping incompatible uses started off in a logical manner—*do not build houses next to a coal-burning factory*—but over time the definition has become broadly applied to almost anything (e.g., keeping multi-family units away from single-family units). [37]

Only after the land uses have determined is subdivision taken into account, and this is only done on a parcel by parcel basis. What happens in this way, however, is that the subdivision patterns produce a street network that has no additional connectivity because the patterns are bounded by each individual parcel under consideration (i.e., there is no plan present that says *leave a street stub out here on your property for a future connection across another property*). Zoning, by definition, is a private matter.[38] To limit the planning of streets (which is by definition a public matter) to the confines of private parcels is one of the greatest errors—if not the greatest error—of our modern planning process. As new development occurs, it latches on to the existing street network.

When zoning occurs first and subdivision is determined on a parcel-by-parcel basis, the inevitable result is an unwalkable, unsustainable urban form, one that minimizes connectivity, minimizes street frontage, minimizes opportunities for vitality, minimizes the ease for redevelopment, and minimizes public space. The poster child of this urban form is the cul-de-sac. Cul-de-sacs are great at accommodating quiet, single-family detached houses, but that's it. By design, they are largely incompatible with other uses. This has been the dominant urban form in post-WWII America. Unfortunately, it coincided with a boom in population, production, and development, ultimately surrounding our cities with first, second, and third ring suburbs. When more development and people occupy a network of this type, that means the density of cars goes up, which worsens traffic problems. The only solution in this context then is to expand the capacity of each individual road by adding lanes, which spurs more development and more cars.[39]

But there is an alternative to this approach: putting streets first and land uses second. A master street plan is the first thing to consider in a streets-first process. In this way, as development occurs it is known that the resultant street network has built-in connectivity, built-in walkability, and built-in adaptability, so that in the future when things change (recall from the Introduction that things will change as much as you may not want them to) that change is readily absorbed and accommodated in a proven pattern of urban form. Zoning can adjust as it needs to on top of the street plan. People can move in or move out, buildings can shift around, and the street plan can be the constant background for that development. And it all works because the streets, blocks, and lots are a function of a time-tested dimensional DNA.

The Benefits of a Master Street Plan

There are many benefits to incorporating a master street plan into the planning process, including:

1. **Frees up municipal resources**: As a pre-approved subdivision plat, a master street plan streamlines the review process. This allows planning authorities to focus on other critical issues, like affordability and housing. Without a master street plan, every development must be reviewed as new, unnecessarily waisting time and soaking up resources. However, if the jurisdiction's subdivision plan is completed all at once, then as long as a developer conforms to the plan the review time is minimal. If the developer wishes to deviate from the plan, they can do so, but they have to submit a variance.
2. **Saves developers and home buyers time and money**: As a pre-approved subdivision plat, developers can get their projects completed more quickly and at reduced cost, with the efficiencies and savings trickling down to the home buyers.
3. **Prescriptive, not postscriptive**: Rather than relying on after-the-fact tactics, once the harm has already been done, or ineffectual connectivity metrics, or parcel-by-parcel subdivision reviews, a master street plan ensures that a desired urban form will materialize.
4. **Guides incremental development**: While a master street plan is established up front, its execution occurs over decades and centuries. As the city grows, a master street plan is there to guide that growth.

Designing a Master Street Plan

It has been shown that streets provide important functions beyond those of mere transportational purposes and that they are the longest-lasting elements of a city's infrastructure. Now the question is how does one actually design a master street plan? The best way to determine that is to look at precedent: to look at the best examples of town planning the world has to offer. There are many sources one can to turn to to assemble this list of precedent, but for this paper we are focusing on those neighborhoods selected by the American Planning Association as the most walkable, sustainable, and enjoyable.[40]

The following is a partial list of precedent used for analysis in this paper which includes many of the neighborhoods designated by the APA as "great places" as well as other cities from around the world to broaden the scope of research: Amsterdam, Aosta, Ashland, Austin, Baltimore, Banff, Bangkok, Barcelona, Beaufort, Beckley City, Boise, Boston, Brunswick, Buenos Aires, Cacalchen, Cairo, Cape Town, Charleston, Cincinnati, Durango, Evanston, Forest Hills, Franklin, Frederick, Grand Rapids, Hattiesburg, Innsbruck, Istanbul, Key West, Kuwait City, Lafayette, Madison, Marfa, Mason City, Miletus, Mones Cazon, Montgomery, Nantucket, New Delhi, New Orleans, New York, Oak Park, Owatonna, Paragonah, Paris, Providence, Riverside, Savannah, Siloam Springs, Spokane, St. Augustine, Staunton, Vienna, and Walla Walla.

Analyzing precedent

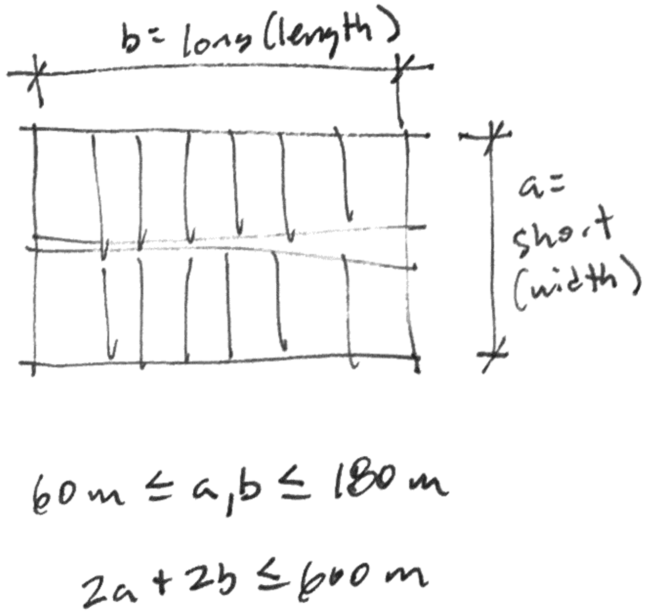
These precedents have all the characteristics of great places: they possess some combination of walkability, sustainability, enjoyability, beauty, and vibrancy. By carefully analyzing their urban forms—their streets, lots, and blocks—we can learn what urban forms yield the best urbanism. By measuring block sizes and their geometries, right-of-way widths and their networks, we can determine the ideal structure of the best cities in the world. While the precedents mentioned here represent the spectrum of urbanism—from small towns to large cities, from East to West—they possess uncanny similarities in their mutual urban forms. Our research, which we share below, reveals a universal law of urbanism, a common dimensional DNA, that results in their successes. That universal law is presented below in four major rules: block size, block geometry, right-of-way width, and alleys. These rules can be applied to small developments, entire neighborhoods, or whole cities.

The method of data collection was a simple, mechanical process: using tax maps, GIS, and aerial photographs, urban forms were measured and recorded into a spreadsheet. The data recorded include the short and long block side lengths, block perimeter, block area, block geometry, right-of-way width, and alley width. The four rules presented below are the result of elementary statistical analyses of this data collection.

The Dimensions of Good Urban Form

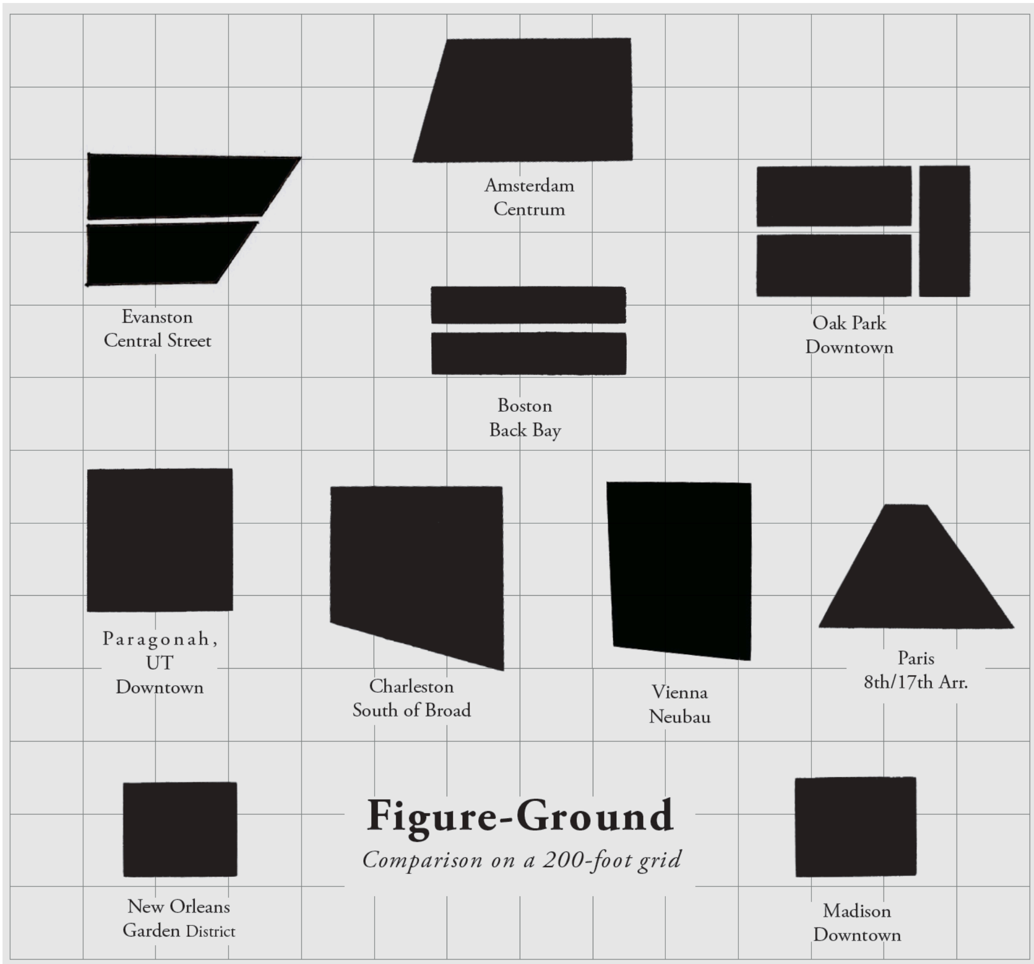
Rule #1: Block Size

> *Blocks should have sides greater than 10 hexameters (60 meters) and less than 30 hexameters (180 meters), with the perimeter less than 100 hexameters (600 meters).*



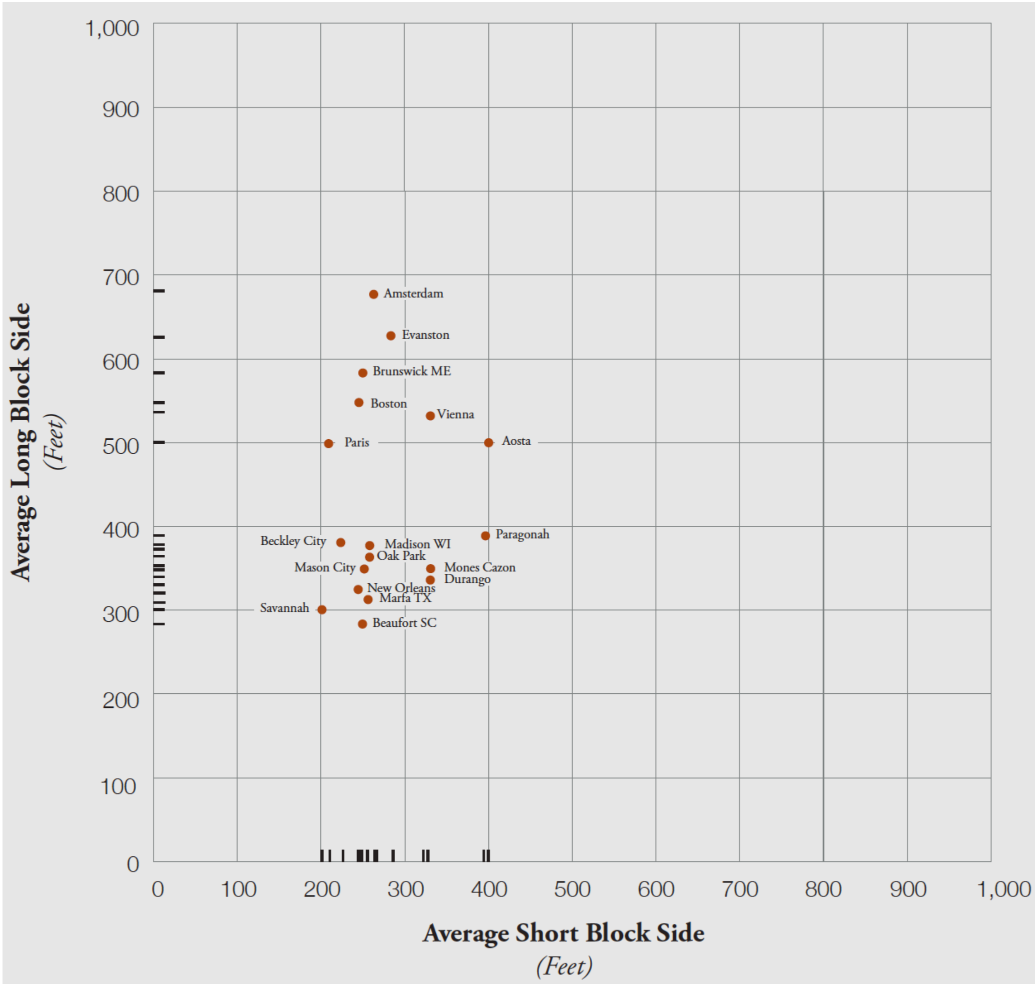
Perhaps 80% of good urban form is embedded in this one rule; no other metric is as powerful as this one. Many of the desired aspects of urbanism, including walkability, adequate street frontage, and adaptable land subdivision, are a distinct function of block size. If one were to implement only one rule, this would be it.

The image below compares the median-sized blocks of various neighborhoods. At first glance, some of the blocks are a little more angular than others, some have alleys while some don't, but overall they are remarkably similar. They are all relatively the same size, relatively the same shape. Notably, in some cases they are indistinguishable: for example, the Garden District of New Orleans and downtown Madison, Wisconsin, utilize essentially the same block. And Charleston and Vienna are barely distinguishable from one another. A worldwide pattern is already evident here.



A visual comparison of median-sized blocks in various neighborhoods on a 200-foot grid.

Now let's compare these blocks in another way. We can reduce median block sizes to a point on a number field (refer to the image below), with the average short block side for each neighborhood falling along the x-axis and the average long block side falling along the y-axis. If block size was random or did not factor in determining great cities, we would expect to see these points dispersed haphazardly across the number field, but interestingly they huddle together in one relatively tight area. This is not an outcome of the universe telling us how big a block should be; instead, it is a product of millions of decisions made by people and planners over the centuries, fine-tuning the dimensions of urban form. The consensus is astonishing.



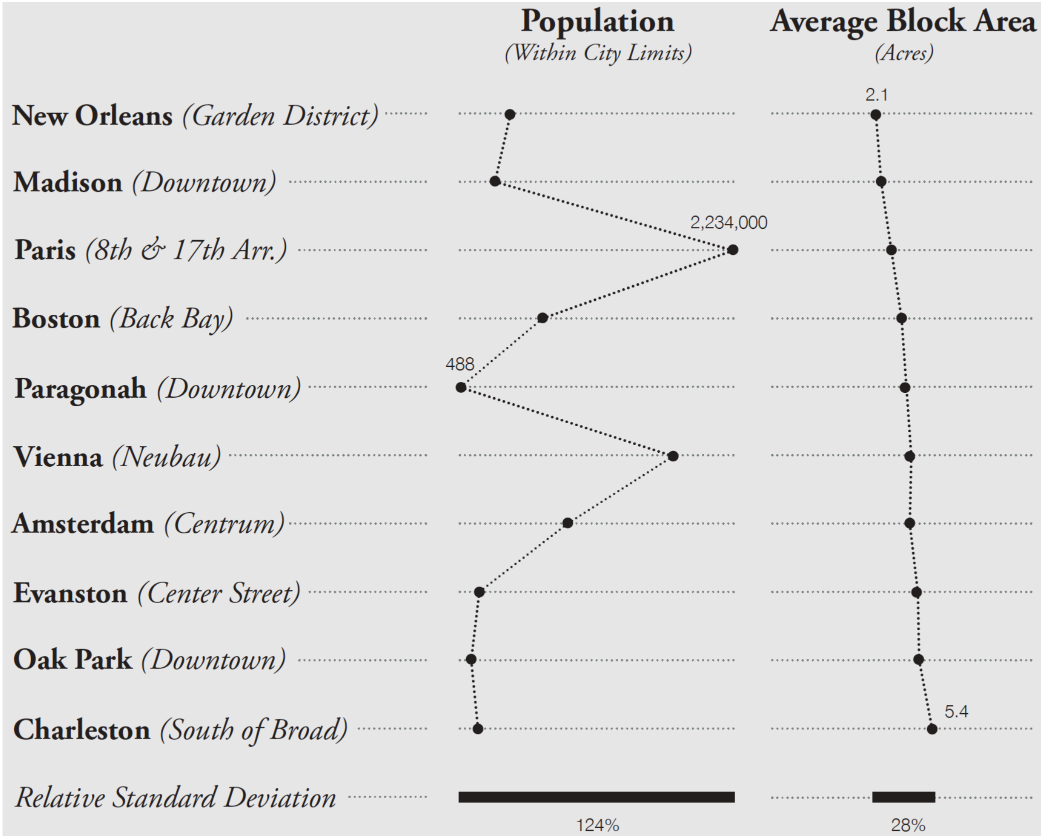
Jane Jacobs, the venerable New York journalist and observant urbanist, stated in her famous book *The Death and Life of Great American Cities*:

> *"Frequent streets and short blocks are valuable because of the fabric of intricate cross-use that they permit among the user of a city neighborhood. Frequent streets are not an end in themselves. They are a means toward an end... Frequent streets are effective in helping to generate diversity only because of the way they perform. The means by which they work (attracting mixtures of users along them) and the results they can help accomplish (the growth of diversity) are inextricably related. The relationship is reciprocal."*

Our analysis above reveals the numbers behind Jacobs's observations. Our study of great places shows that on average their blocks fall somewhere between 60 meters and 180 meters. As one additional constraint, their perimeters are bounded by about 600 meters (e.g., a square block 180 meters on each side has a perimeter of 720 meters which falls outside the range). What is incredible about this is that our study incorporates places not only all over the world but places that were built at various times, tens, hundreds, or even thousands of years ago. Yet the data show us that the range we are talking about isn't 60-6,000 meters, or 60-600 meters, but a tight 60-180 meters.

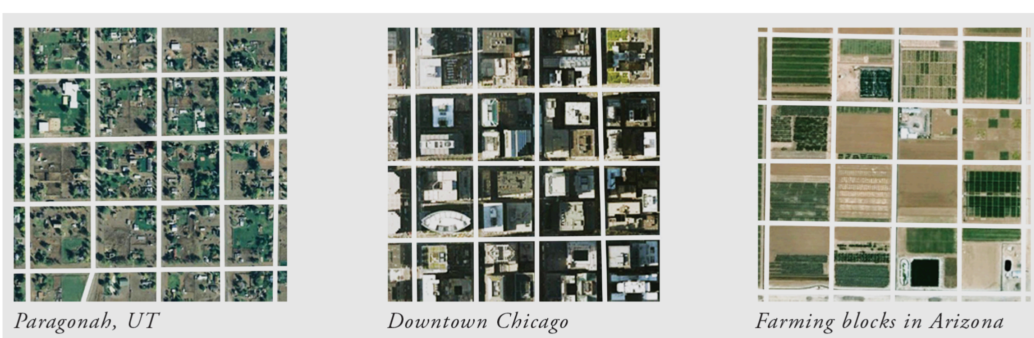
If we break it down between each side of a block the variances get even tighter. The figure above also tells us something about block orientation. The average short side range is only 200 feet to 400 feet; the average long side range is 300 feet to 700 feet. The reason or this is that typically the short side is a function of a lot's depth. Because blocks are typically composed of two lot tiers and because lot depths typically fall in the 100 ft to 200 ft range, this narrows the overall range of block width. Block length, however, is a function of lot width and can change simply by appending more lots side by side. In this case, the block length can easily expand without sacrificing lot efficiency. This is why block length falls within a higher range.

It is a common misconception to assume that small blocks imply high population density and big blocks imply low population density.[41] As it turns out, block size has little relationship if any to population. In the analysis shown below, the populations span a wide spectrum, ranging from 488 people in Paragonah, Utah, to 2.2 million people in Paris, France. However, amongst all the cities shown, their block sizes are in an incredibly tight range, with a relative standard deviation[42] of only 28%. Essentially, what is being reflected here is a universal urban form: all these cities represent the spectrum of everything ever built on the planet, and yet they're all operating within the same relative block size.



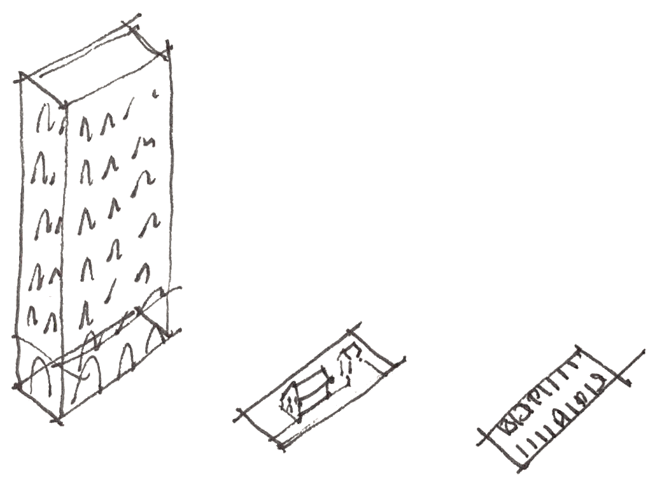
Comparing block size to city population.

Finally, we can see how differently a 120-meter square block can be used (refer to the image below). While all the blocks represented are the same size and shape, they have each come to accommodate an incredible range of land uses. One is a farming block in Arizona, the other a small town in Utah, and the other the thriving downtown of Chicago. Same block, different use.



The same 120-meter block utilized differently in three different cities.

This discussion of block size also leads to one on lot size. The dimensional adaptability of blocks continues down to the dimensional adaptability of lots. For example, a standard 18-meter by 36-meter lot is a surprisingly versatile unit of land. That lot could accommodate everything from a house to a parking lot to a skyscraper. While the heights and land use intensities vary, the critical point is that all these uses essentially occupy the same foot print. In plan view, a house with a yard can take up just as much space as a 40-story skyscraper.



A lot width of 12 meters (2 hexameters) is an ideal dimension because 1) it can accommodate these varied uses and 2) because of its mathematical fungibility.[43] Furthermore, lots work best when the narrow side faces the right-of-way. Some reasons for this include:

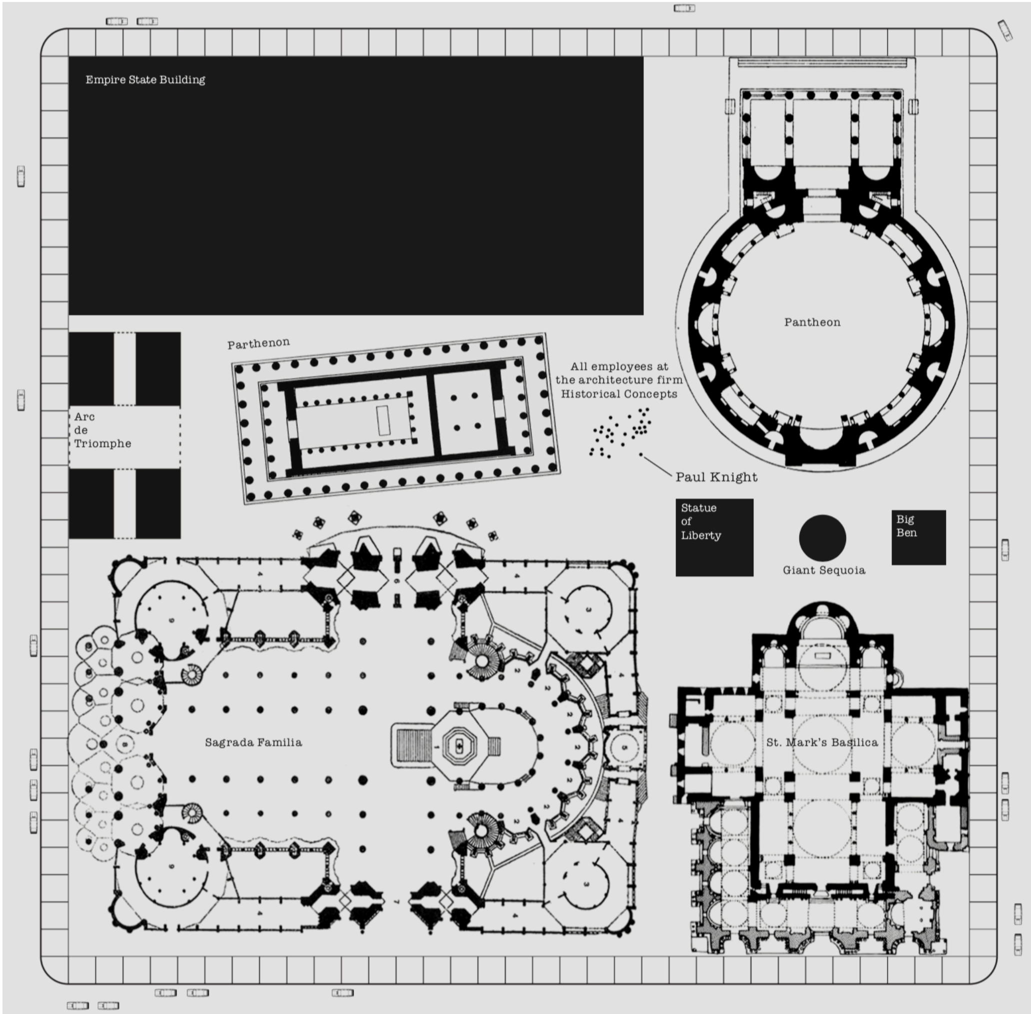
1. It is more economical for a lot owner to own a smaller portion of street a right-of-way than otherwise.
2. Smaller frontage units allow more lot owners to face the street per unit length which translates into more opportunities for a vibrant mix and proximity of land uses.

3. Smaller frontages also allow for more access points (shop fronts, front doors, etc) which further contributes to vitality.
4. Building layouts tend to favor elongated rectangles over squares for various reasons including the limits of natural light and the proportions of individual rooms (not every room in a house or office needs to be a square).

Let's now leave the discussion of small blocks and consider what happens when blocks are too big. In Salt Lake City, Utah, the blocks are 201 meters (660 ft) on a side with a perimeter of 804 meters (2,640 ft). This clearly does not pass our *Rule #1*. This block depth implies a lot depth of 100 meters. As we have just seen with the discussion about lot size, there are very few things that we build in this world that require a 100-meter lot depth. Because of that, in Salt Lake City what has happened over time is that property owners along the edge have sold the back half of their lots. This has resulted in an inner block of development inside an outer block. But this interior development does not benefit from the exposure that a street provides; consequently, they do not contribute to the vitality of Salt Lake City's streets.

A block in Salt Lake City, Utah.[44] Dotted line indicates area of internal development.

The diagram below further illustrates the absurdity of Salt Lake City's block size.



A single Salt Lake City block can harbor many famous buildings and monuments of the world.[45]

Recall that a block is defined as an area of private property surrounded on all sides by public rights-of-way. Let's apply that definition to the blocks of Alpharetta in suburban Atlanta, Georgia. The urban form of Alpharetta possesses innumerable cul-de-sacs, and by definition cul-de-sacs do not connect through, they stop and avoid connection. This results in block sizes of enormous scale which looks all the more ridiculous even when compared to the over-sized blocks of Salt Lake City (see image below). Given the weight that block sizes have in urbanism and based on these observations alone, it is safe to say that Alpharetta will never possess the qualities of a walkable, vibrant, mixed use community; it simply does not have the urban form to support it.

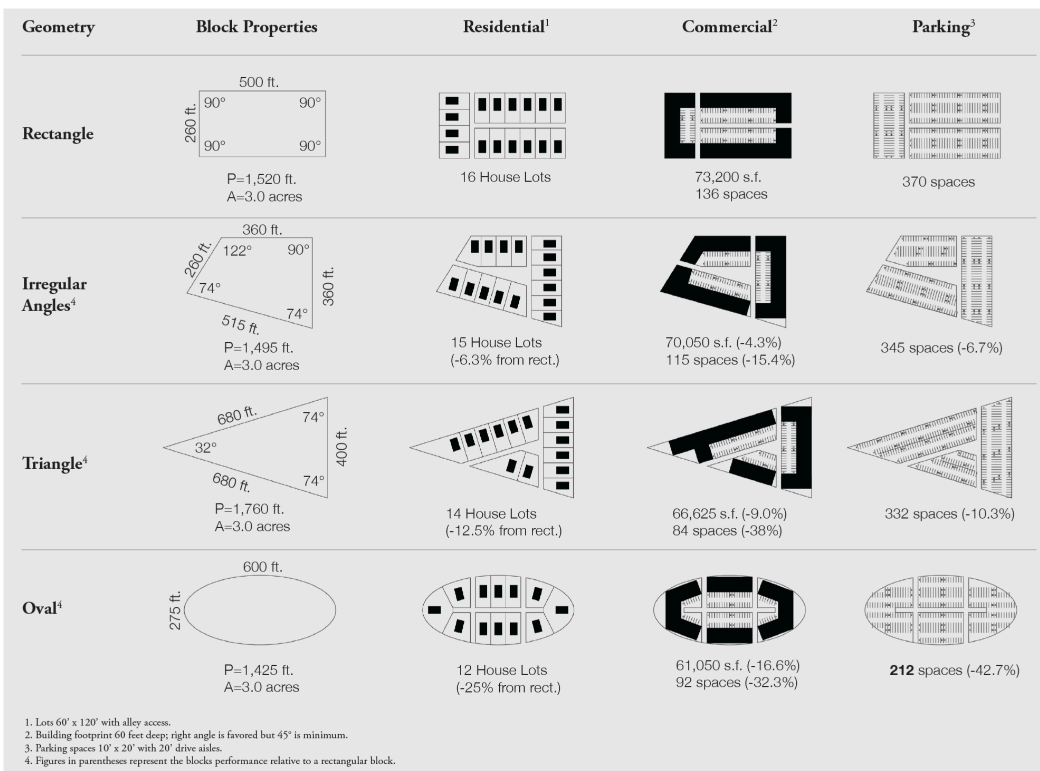
Comparing an over-sized block of Salt Lake City to the enormity of a block in Alpharetta, Georgia.[46]

Rule #2: Block Geometry

> *Blocks should be composed of straight line segments with preference given to rectangles; a long side to short side ratio of 1.5:1 or greater is also preferred.*

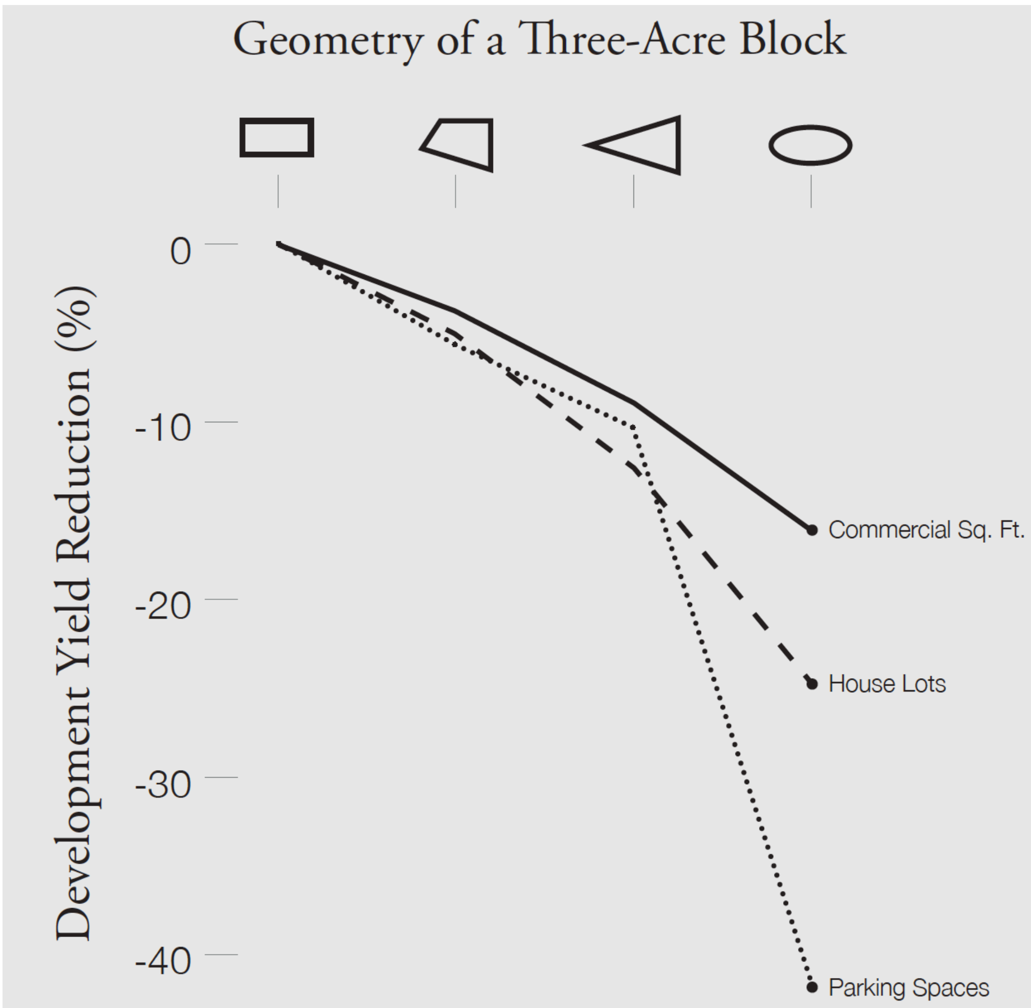
In our study, we found the majority of blocks were straight-sided and rectangular. Why? Consider first that rectangles are everywhere. They're in our buildings, bedrooms, TVs, doorways, drawers, chairs, books, papers, iPhones, parking spaces, shipping boxes, agricultural fields, computers, briefcases, CCDs, and rugs. Rectangles are fairly useful forms for us. The commissioners of Manhattan in 1811 recognized as much saying that "straight-sided and right-angled houses are the most cheap to build and the most convenient to live in."[47] That statement is as true and relevant today as it was then or as it was 2,000 years ago.

Secondly, we can consider the relative yields of different block geometries (rectangles, irregular angles, triangles, and ovals). We isolated the variable of geometry by holding the area of the blocks constant. We tested the resultant blocks against three different land uses: residential, commercial and parking. We attempted to keep the physical parameters of each land use the same across all he blocks. The results are shown in the table below.



Comparison of the efficiencies of blocks of similar size but varying geometries.

In terms of houses, the rectangular block can accommodate 16 standard house lots, the irregular block can accommodate 15, the triangular can accommodate 14, and the oval can only accommodate 12. The decline in efficiency is easily seen and it continues across all land uses (see the graph below). The further one gets away from the rectangle, the less efficient the block becomes. The reason for this is purely geometrical: there is a "flat packing" efficiency created given all the rectangles we have in our lives. These objects (buildings, beds, books, etc) perfectly pack into corners, leaving no waste of land area. Only few buildings in this world are truly curved: most are actually *faceted*, meaning they are made up of rectangular building materials (bricks, beams, plywood) that are turned at each juncture along a curve at some desired tolerance.

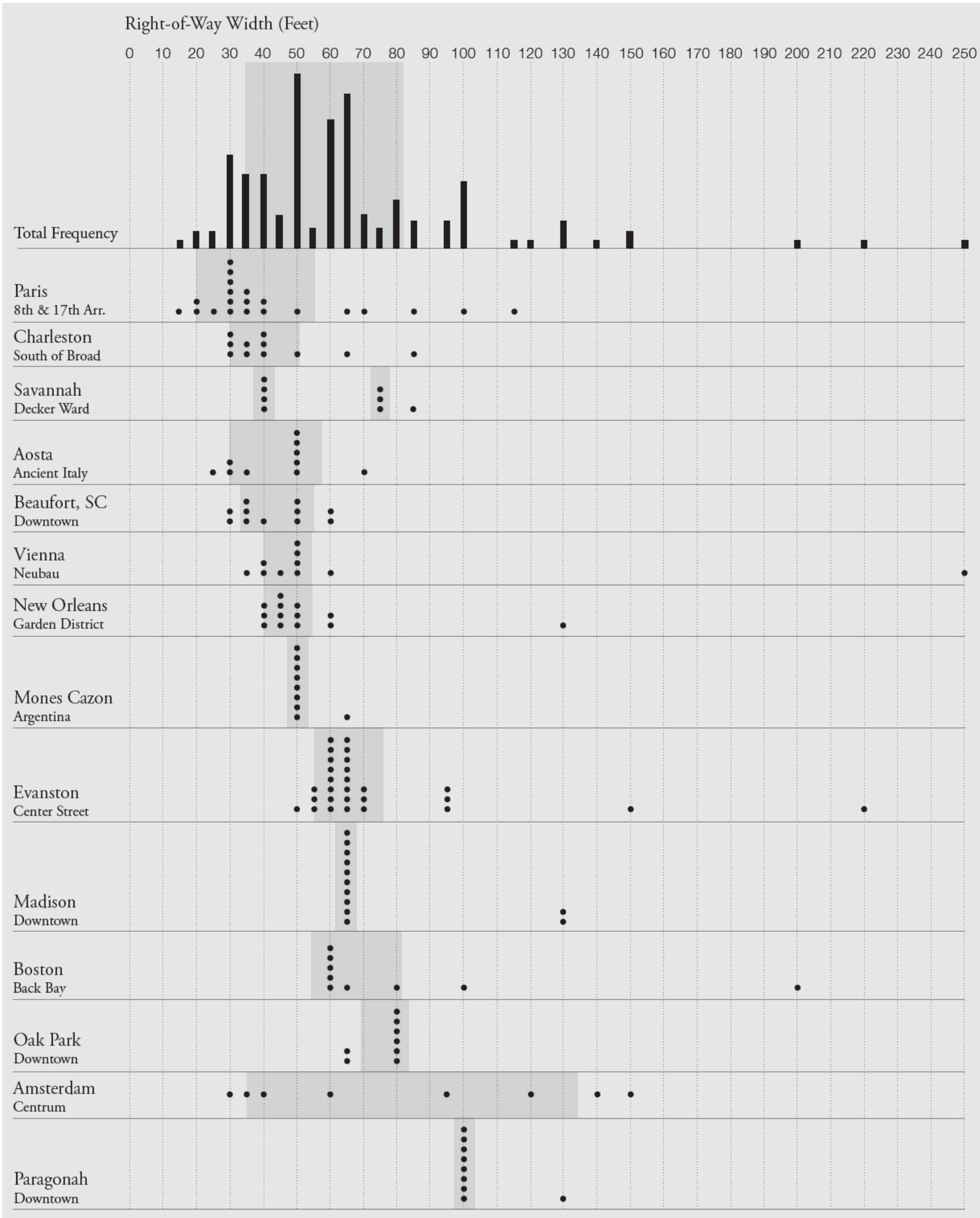


A visual display of the loss in efficiency as blocks become less and less rectangular in form.

Rule #3: Rights-of-way

Most rights-of-way should have a width between 2 hexameters (12 meters) and 4 hexameters (24 meters); a limited number of rights-of-way may be larger or smaller.

The table below[48] shows the distribution of rights-of-way of varying widths across our sample of precedents. The dots represent individual rights of way, the bars represent the total numbers, and the gray shaded areas represent the standard deviation about the mean. By comparing the total frequency of rights-of-way across these varied great places, it is evident that the majority fall between 12 meters (about 40 feet) and 24 meters (about 80 feet), with many residing around 18 meters (about 60 feet).



Counting the widths of rights-of-way in various cities to determine overall width frequencies.

An 18-meter right-of-way is incredibly versatile. It can be a deserted country road, a suburban street, or a major urban thoroughfare.

A dirt road in Iowa, 18 meters wide.[49]

A suburban street in Providence, Rhode Island, 18 meters wide.[50]

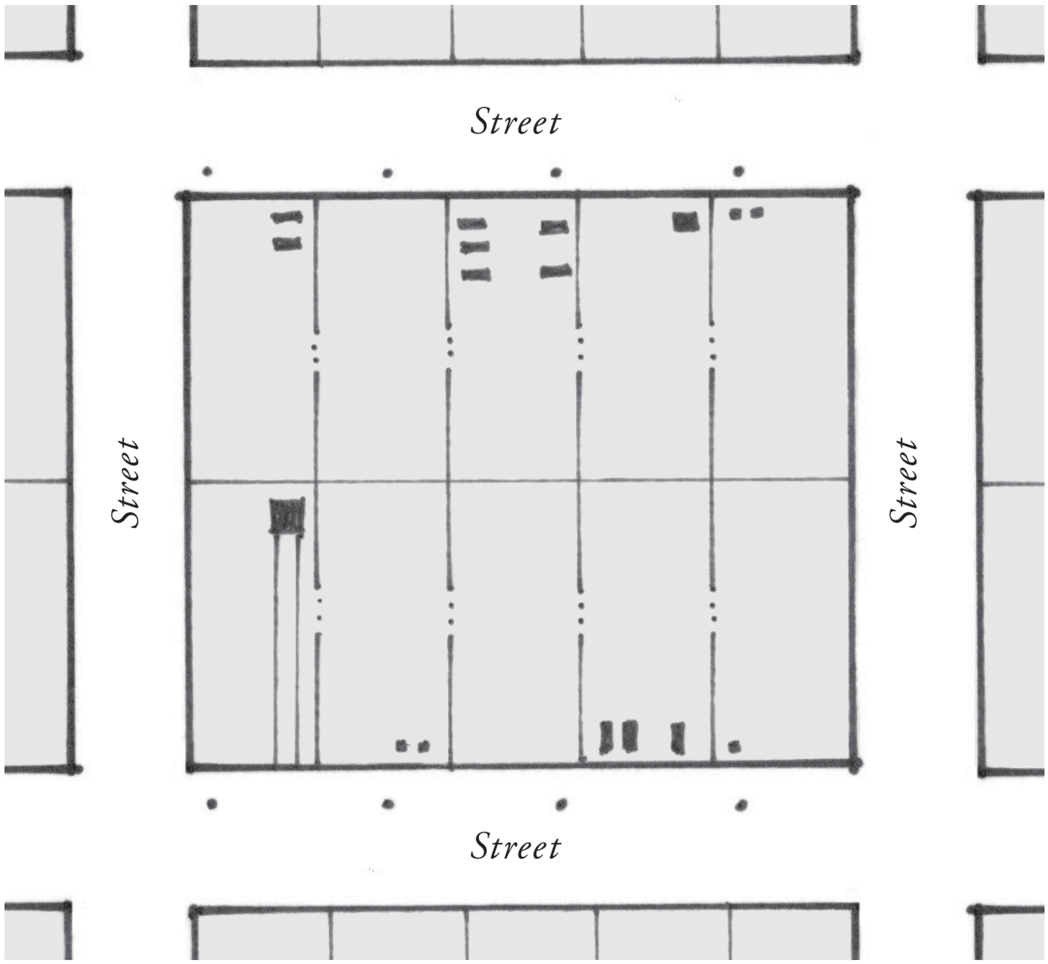
An urban street in New York, New York, 18 meters wide.[51]

Rule #4: Alleys

> *Alleys should be between 1/2- to 1-hexameter (3-6 meters) in width and be present in most, if not all, blocks.*

Alleys are the unsung heroes of good urbanism. They increase connectivity, access, efficiency, sanitation, light, and air. Take, for example, Commonwealth Avenue in Boston, Massachusetts, one of the most beautiful streets in the world. It is essentially a 100-foot linear park flanked on either side by streets, sidewalks, setbacks, and townhouses. Such a beautiful, manicured scene is only possible because of the alleys dividing the blocks. Alleys are the ideal locations for housing the necessary unpleasantries of modern urban life including power lines, parking spaces, dumpsters, water meters, and fire escapes.

Without alleys, all these objects would need to occupy the front of the lots, interfering with the very face of the city and causing not only aesthetic harm but functional drawbacks.



With no alleys present, many undesirable objects must occupy the front of lots.

With alleys present, many undesirable objects can occupy the back of lots.

Alleys also provide additional access. Without alleys, all access (including curb cuts) must occur at the front of the lot. With alleys, access can occur in the back of the lot, freeing the front of the lot for broader porches or wider storefronts. Additionally, these consolidated access points for vehicular traffic make for a more walkable urbanism as there are fewer curb cuts (i.e., conflict points) with pedestrians.

Manhattan provides a good lesson of what happens when alleys are not incorporated into the urban form of a city. As the image below shows, trash pick up is forced to occur on the sidewalk which is not an ideal experience anyone: worker, resident, or tourist.

Because of the lack of alleys in Manhattan, trash collection must occur on the main sidewalks and streets.[52]

Note by the author, November 12, 2018: Consider whether alleys should be a "rule" or a "suggestion". The data do not back this up necessarily as alleys are not ubiquitous across the study areas. As there are further discussions that need to be added to this paper (street network, parks, etc), this discussion on alleys could be moved there, leaving three rules and, say, seven "considerations."

End Master Street Plans

The rules presented here are based on a simple and direct analysis of precedent. Dimensions do not lie. By measuring cities, past and present, their design lessons can be learned and utilized for new developments. For countries and cities to compete in the global marketplace, to meet the demands of its citizens, to live up to its aspirations, and to provide all the necessary components of life, they must build the most beautiful, efficient, and enjoyable public house (city) for its people possible. They must become an exporter of good urban principles. This begins at the level of the street plan. Just as every house needs a plan, every city needs a master street plan.

The legal aspects and enabling statutes necessary to implement master street plans will be addressed in the next chapter.[53] An example subdivision code and example application of the entire system of subdivision so far presented—from the National Ordinance down to individual master street plans—will be covered in the subsequent chapter where we will see how the utilization of the hexameter unit maximizes the efficient and sustainable use of the land while providing for a proven dimensional framework of good urban form.

Enabling Statutes and Conclusion

Introduction

City planning, as mentioned earlier, is divided into two domains: that which is public and that which is private. This paper has addressed the distribution and design of the public domain and the elements thereof including its boundaries, streets, public places (like parks and civic buildings), and public monuments. The private domain comprises everything else: people, buildings, signage, land uses, etc. The public domain is more or less permanent; the private domain is more or less changeable.

The history of city planning in the United States provides an invaluable lesson in this regard. In the early 20th century, city planning was just being organized as a profession. The organizers developed model planning laws that correctly divided cities into their public and private components. But over time the profession has departed substantially from this as it now focuses heavily on a set of documents that, in their origin, were limited only to the regulation of private property (just half of the planning problem). To this we are referring to Zoning: that leviathan released onto the modern planning world which has devoured more good intentions and proper planning principles than all ill-informed architects and planners combined, leaving in its wake unsustainable, unadaptable, unwalkable, placeless sprawl.

Lessons from America's Enabling Statutes

Cities of the post-industrial 1800s around the world were suffering from similar health crises: people were living next to where they worked, and because they worked in unsanitary, unhealthy, unsafe environments they were literally dying from the proximity. To make matters worse, many lived in overcrowded tenement houses without adequate light, air, or sanitation. At that time, people, for the most part, lived in cities by necessity, not by choice. Many cities were dangerous, filthy, and unpleasant places to call home. As the world urbanized, the crisis worsened.

To address these real concerns and stave off future ones, many cities in America began drafting and adopting their own zoning regulations. The concept of zoning—the regulation of private property including land uses and building volume—was first utilized on a city-wide scale in New York when its *Zoning Resolution* was passed in 1916. The *Resolution* sought to separate incompatible uses from one another (like coal-burning factories from houses) and to regulate height and bulk of buildings for the purposes of preserving light and air for the city's streets and parks.

In an effort to achieve consistency and efficiency, an Advisory Committee on City Planning and Zoning was formed under President Herbert Hoover to create model laws that could be adopted across the country. These laws would do two things: 1) provide a national framework of planning and design principles, and 2) provide a vetted legal basis for utilizing these principles and effectuating physical plans. The committee correctly saw the city planning problem as one divided between public and private property and so created two Enabling Statutes to address each of these domains: the Standard City Planning Enabling Act (SCPEA) to address all public property and the Standard State Zoning Enabling Act (SSZEA) to regulate all private property.

The intention behind these two documents was for the SSZEA to be subservient to the SCPEA, as the SCPEA was viewed as the parent document being broader in scope.

To that end, the definition of "comprehensive plan" is originally defined in the SCPEA in this way:

> *"It shall be the function and the duty of the commission to make and adopt a master plan [a comprehensive plan]. Such plan...shall show the commission's recommendations for the development of said territory, including, among other things, the general location, character, and extent of streets, viaducts, subways, bridges, waterways, water fronts, boulevards, parkways, playgrounds, squares, parks, aviation fields, and other public ways, grounds and open spaces, the general location of public buildings and other public property, and the general location and extent of public utilities and terminals, whether publicly or privately owned or operated, for water, light, sanitation, transportation, communication, power, and other purposes; also the removal, relocation, widening, narrowing, vacating, abandonment, change of use or extension of any of the foregoing ways, grounds, open spaces, buildings, property, utilities, or terminals; as well as a zoning plan."*[54]

While the list is indeed comprehensive, it can be broken down into a few broad categories including "public ways", "public buildings", "public property", "public utilities", and "zoning". *Zoning* is originally defined in the first sentence on the first page of the *Zoning Primer* written in 1926 as such:

> *[Zoning is] "the application of common sense and fairness to the public regulations governing the use of private real estate."*

"*Private real estate.*" Going back to the definition of comprehensive plan, the division of the city planning problem is clearly delineated here between public and private. Each of the Enabling Acts has an associated critical map with physical implications: The Zoning Act utilizes a zoning map; the City Planning Act utilizes a master street plan (see discussion of master street plans in the previous chapter).

These Acts, known together as the Enabling Acts, formed an excellent foundation for American planning. Unfortunately, their the plan was not fully followed through and the documents' powers, once mutual or weighted toward the public domain, has shifted dramatically to focus almost solely on zoning.

How and why did this happen? Seeing zoning as the most pressing issue at the time, the SSZEA was published in 1926 and then only later, in 1928, was the SCPEA released. But in their haste the drafters of these foundational documents put the cart before the horse: as zoning's promise and influence took over the planner's mindset and toolbox, it garnered more attention, leaving the critical pieces found in the SCPEA ultimately disregarded. There was little regard as to where or how land uses would connect up, or how the respective urban forms of new towns or cities would be utilized once those land uses changed over time.

In the 1947 decision of Bishop vs. Board of Zoning Appeals of the City, the court went so far as to redefine "comprehensive plan" (thus circumventing the SCPEA all together) as:

> *"A general plan to control and direct the use and development of property in a municipality... by dividing it into districts according to the present and potential use of the properties."*

"*Use*." Land use. Zoning. According to this definition, one no longer needed to provide a master street plan (that framework, structure, or skeleton of urban form that organizes a town or city for centuries and millennia) within a comprehensive plan; instead, one only needed a zoning map. Today, the zoning map is the foundation of almost all comprehensive plans.

The problem is that land uses are fleeting. They come and go. They are a variable. It is no wonder then why so many comprehensive plans today so quickly go outdated—it is the variable of land uses that forces them to keep up. Great American cities like Philadelphia, New York, Washington, and Chicago did not begin life with a zoning map—they materialized through the rigorous and patient execution of a master street plan. The planners and designers for those cities created a framework of streets that would prove to adapt to a multitude of unforeseen futures, including a multitude of unforeseen land uses (the Commissioners of New York in 1811 could not possibly have foreseen the coming of the skyscraper; General James Oglethorpe, when laying out the town of Savannah in 1732, could not possibly have predicted the sizes of dumpsters and waste-management trucks that work so well within the alleys he ultimately drew).

It is imperative for the success of cities that a master street plan precede a zoning plan. To put it as simply as possible: a planning process that puts zoning first and land subdivision second will result in unsustainable, unadaptable, and unwalkable urban forms. It is the critical point of this paper that land subdivision be considered *before* land use. It is the public framework of streets and blocks that must be designed in meticulous and rigorous detail. Many of those details have been addressed in previous sections of this paper.

Any city-wide, town-wide, or neighborhood-wide plan (by any name, be it comprehensive plan, master plan, or the like) that does not have a land subdivision pattern as its foundation, regardless of scale, location, time, or money, will ultimately fail to live up to the expectations of the designers or the challenges that history will inevitably throw at it. One cannot create a solid foundation for a city based on the variable of land uses; one can only do this using the permanence of the public framework by directly placing and shaping its boundaries, streets, public places, and monuments.

History is clear: land subdivision must take precedent over land use. Then, and only then, will a neighborhood, town, city, region, or country be allowed to grow and evolve into something great, unique, sustainable, and adaptable, just as the development of all the great examples of urban form throughout history have done. Cities are not about projects, they are fabric. It is the primary mission of the planner to establish and promote that fabric; the lessons and principles outlined in this paper (which are all based on extensive analyses of urban forms that vary by scale, time, and location) acts as a guide in that regard.

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1. We must be vigilant. H.L. Mencken, one of America's great writers of the 20th century, warns us that "for every complex problem there is an answer that is clear, simple, and wrong".
2. Doug Allen, "History of Urban Form" introductory lecture, delivered at Georgia Tech, 2013.
3. ibid.
4. ibid.
5. For more discussion on this, refer to the chapter on Master Street Plans.
6. Some examples: Athens, Greece; Damascus, Syria; Cairo, Egypt.
7. For the complete paper see http://www.dozenalsociety.org.uk/pdfs/aitken.pdf
8. ibid.
9. This paper uses the SI metric system simply because that is the system as adopted by Kuwait which served as the general context of this research. However, we are strongly in favor of the Imperial System and will work to develop a modified paper to utilize those unique (and superior) properties. Or, better still, we hope to develop a version following the TGM system which fully utilizes the base-12 number system; for more information on that, visit: http://www.dozenal.org/drupal/content/tgm-coherent-dozenal-metrology.html
10. A tribal subdivision (per Merriam-Webstier.com).
11. A unit of local government in ancient Attic (per Merriam-Webstier.com).
12. A version of this has already been adopted for mapping and location purposes. *What3Words* has draped a three-meter grid across the entire globe to simplify coordinates. See https://what3words.com. Thanks to the power of number, their system and and the one presented in this paper is readymade for syncing.
13. Shown here for reference for the Imperialists among you.
14. https://www.britannica.com/biography/Frederick-W-Taylor
15. As John Reps paradoxically laments in his book *The Making of Urban America*. See Chapter 11: Checkerboard Plans and Gridiron Cities. Reps focused more on the perceived flaws of the grid (its supposed mundaneness) rather than its actual properties and many benefits (navigability, efficiency, walkability, adaptability, among others).
16. For an excellent survey of these events, see Andro Linklater's book *Measuring America*.
17. These terms are being borrowed from the 1785 Land Ordinance of the United States. We welcome alternatives.
18. There are as many definitions of the word *city* as there are cities in this world. For the purposes of this paper, we will use the definition developed by Doug Allen in his "History of Urban Form" course at Georgia Tech: "A city is a political association

manifest as a collective work of architecture built over time. A city contains two orders: a political order and an economic order. The political order is a framework of common elements owned collectively. The economic order consists of individually owned parcels and their occupants within that collective framework."

19. Given the subtle curvature of the earth, the townships, when surveyed, will have to be adjusted in certain intervals to maintain order. That discussion is beyond the scope of this paper.
20. This is a critical point and will be addressed more fully in the next chapter on *master street plans*.
21. See https://www.cnu.org/publicsquare/2017/10/31/25-great-ideas-new-urbanism
22. Walking speeds are taken from Richard L. Knoblauch, Martin T. Pietrucha, and Marsha Nitzburg, reporting their research in "Field Studies of Pedestrian Walking Speed and Start-Up Time." The paper appeared in the Transportation Research Board's Transportation Research Record No. 1538, Pedestrian and Bicycle Research, published in 1996 at http://www.usroads.com/.
23. For more on the benefits of walkability, see "Walkable City: How Downtown Can Save America, One Step at a Time" by Jeff Speck
24. To emphasize this again, these are not hard and fast rules because cities are not hard and fast machines looking for the next computer input. These are general guidelines stemming from observations that reveal a relatively tight dimensional range of what works and what doesn't work, but there are always exceptions.
25. Note that we are not attempting to study or specify the magical numbers or ratios of these land uses. That is beyond the scope of this paper, which is focusing strictly on the urban form of places. A neighborhood may need one school, or it may need five; it may need 100 detached homes or 10,000 apartments. It simply depends on the thousands of other variables that define cities and how they are to be occupied and used. Our job here is to stretch and mount the canvas; we leave the picture painting to you.
26. This concept of life expectancy is addressed by Brenda Scheer in "The Anatomy of Sprawl", *Places* Volume 14, Issue 2.
27. There is a lot of spread in this number. The average residential building lasts about 150 years, but the average big-box or low-quality apartment complex lasts about 20 years. The overall average for all buildings is roughly 80 years.
28. Google Earth image, 2018.
29. "Street" is being referred to here not just as the asphalt, or the thing one drives on. Rather, the legal definition of "street" is a public right-of-way with its boundary lines that distinguish between public property and private property. The whole cross section of the right-of-way is the street: from property line to property line

30. From the collection of the US Library of Congress.
31. Address before the Second National Conference on City Planning, 1910.
32. From Wagner's book *Modern Architecture*, 1902.
33. From Doug Allen's "The History of Urban Form," Lecture 01, delivered 2013.
34. In 2012, the Museum of the City of New York held an exhibit titled "The Greatest Grid" which explored the history of the city's grid plan. A book of the same name contains numerous, well-written, insightful essays on the significance of the plan and is well worthy of study.
35. Remarks of the Commissioners for Laying out Streets and Roads in the City of New York, Under the Act of April 3, 1807
36. Knack, Ruth and Israel Stollman. “The Real Story Behind the Standard Planning and Zoning Acts of the 1920s,” *Land Use Law* (February 1996).
37. For more on this history, refer to works by Ruth Knack, Michael Wolf, Jane Jacobs, and Andres Duany in the bibliography.
38. See the first sentence of the first page in *A Zoning Primer* written in 1926 as a guide to the Standard State Zoning Enabling Act written in 1922.
39. This concept is known as *induced demand*. See works by Andres Duany and Jeff Speck in the bibliography.
40. Refer to https://www.planning.org/greatplaces/ for more information on the criteria of selection
41. This likely stems from the fact that many cities built at the turn of the century incorporated small blocks, and over time development has naturally been concentrated there of decades or centuries.
42. Recall from your statistic class that relative standard deviation is a standard deviation normalized about the mean. In other words, it is a measure of variance that allows you to compare completely different things: in this case, population and block size.
43. Refer back to the discussion of number theory in the introduction.
44. Aerial photograph by Google Earth. Diagram by the author.
45. Diagram by the author.
46. Diagram by the author.
47. Remarks of the Commissioners for Laying out Streets and Roads in the City of New York, Under the Act of April 3, 1807
48. Note that this particular analysis was done using imperial units. This will be adapted to metric in future updates to this paper.
49. Photograph by the author.
50. Photograph by the author.
51. Photograph by the author.

52. Photograph by the author.
53. The chapters on Enabling Statutes and Model Subdivision Regulations are forthcoming.
54. A Standard City Planning Enabling Act, p. 13.