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Ute Poerschke

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Data-Driven Design in High Modernism: Ludwig Hilberseimer's Solar Orientation Studies

Ute Poerschke

The Pennsylvania State University

ABSTRACT: This paper presents High Modernism as a predecessor of today's discourse on evidence-based design. The 1920s and 1930s provide rich examples of promoting the relationship between research and design, as many modern protagonists claimed their designs resulted from analyzed data and expert input rather than historical reference or creative talent. Scientists, economists, engineers, and architects alike investigated problems such as hygiene conditions in housing and cities, human needs at work and home, construction mechanization, and traffic optimization as the basis and justification of spatial designs. As an example, this paper addresses the discourse on best solar orientation of housing, with the architect and urbanist Ludwig Hilberseimer as one of several proponents of this discourse, among them Walter Gropius, Ernst May, and Le Corbusier. Regarding solar studies, Hilberseimer's projects and writings can be divided into three phases. The first phase is marked by his famous 1920s renderings of the residential city and high-rise metropolis, which conform to the orientation recommendations by urban planners Richard Baumeister and Karl Hoepfner. The second phase spans Hilberseimer's teaching at the Bauhaus from 1929 to 1933, in which he contributed to the extensive solar studies for diverse housing types undertaken at the Bauhaus building department. A third phase, in which he applied the findings to "settlement units" in linear city patterns, came to full fruition after 1938 when Hilberseimer started teaching at the Armour Institute, later renamed the Illinois Institute of Technology in Chicago. The case of solar studies in High Modernism and Hilberseimer's work in particular illuminate the challenges of relating research, performance-driven design, and actual building projects.

KEYWORDS: evidence-based design, housing, hygiene, Durchsonnung, "Licht Luft Sonne"

INTRODUCTION

The 1920s and 1930s provide rich examples of promoting the relationship between design and research, for which today we use terms such as "evidence-based" and "performance-driven" design. Many modern protagonists claimed their designs resulted from collected and analyzed data and expert input rather than historical reference or creative talent. With respect to housing, scientists, physicians, economists, and architects alike investigated problems such as hygiene conditions in housing and cities, the definition of human needs, construction mechanization, and traffic optimization as the basis and justification of spatial designs. The following paper focuses on the investigations in solar orientation of housing during that time. Architects like Walter Gropius, Le Corbusier, Otto Haesler, Hannes Meyer, and many others,¹ investigated housing schemes and urban plans with respect to solar orientation. The paper attempts to illuminate this topic by focusing on the architect and urbanist Ludwig Hilberseimer (1885-1967), whose solar studies are reflected in his projects for buildings and settlements with high and low densities. Describing the topic of solar orientation as a central driver for his architecture and urban designs will allow contemplating on the relationships of research, evidence-based design, and actual building projects.

1.0. FIRST PHASE: ENGAGING IN MODERNISM

After studying at the Technische Hochschule in Karlsruhe, Germany, from 1906 to 1910, Hilberseimer worked in several architecture offices in Bremen and Berlin. In 1919 he engaged in the socialist artist groups *Arbeitsrat für Kunst*, *November Gruppe*, and *Die Kommune*, and around this time his architectural expression changed from more historical gestures to modernism (Pommer 1988, 26-28). Many of his early modern design schemes and writings reveal an interest in achieving optimal solar orientation—as defined at that time. Hilberseimer described topography, sun orientation, and "higher viewpoints, a sense for architectonics" as the major guidelines for designing urban settlements (Hilberseimer 1927, 5).

1.1. The "Hochhausstadt" (High-Rise Metropolis)

The wide interest in housing arose from the unhealthy conditions in large cities with dense, poorly lit and ventilated blocks. For the future metropolis, Hilberseimer demanded a well-ordered city layout, healthy and comfortable apartments, without closed courtyards, but instead with open blocks for good ventilation. For best solar exposure, he recommended that street and courtyard widths measured the same as the building heights (Hilberseimer 1927, 12-13). He exemplified these demands in the famous scheme of a metropolis

for one million people on an area of 1,400 hectare (Fig. 1), that he developed from 1924 on.² The metropolis consisted of twelve by ten blocks, 120 blocks total. Each block, providing housing for 9,000 people and 90,000 square meters of business spaces, had a dimension of 100 by 600 meters. Both the courtyard and street were sixty meters wide. Split vertically in two areas, the block consisted of five-story office and manufacturing spaces at the lower level, and fifteen stories of apartments above that.³ The actual building width of the business areas was eighteen meters, while the apartment bars were only ten meters wide. This had the effect that the apartment buildings stepped eight meters back on the street side to accommodate elevated pedestrian walkways. In addition, while the lower part had buildings on all four sides of the block, the apartments were arranged only at the long sides of a block, leading to north-south running housing bars with apartments facing either east or west. Hilberseimer justified this scheme in 1927 as follows:

"The new city layout defines its street system with respect to solar orientation; its street and block sizes demand, with respect to light and air supply, a minimum distance between the buildings that is equivalent to their height; street width equals building height. This refers to street width and block depth since the building distance within the block must correspond to the building height, too." [...] these apartments [...] can be called entirely and hygienically unobjectionable, thereby a solution for the metropolitan housing problem was found." (Hilberseimer 1927, 18-20, German)

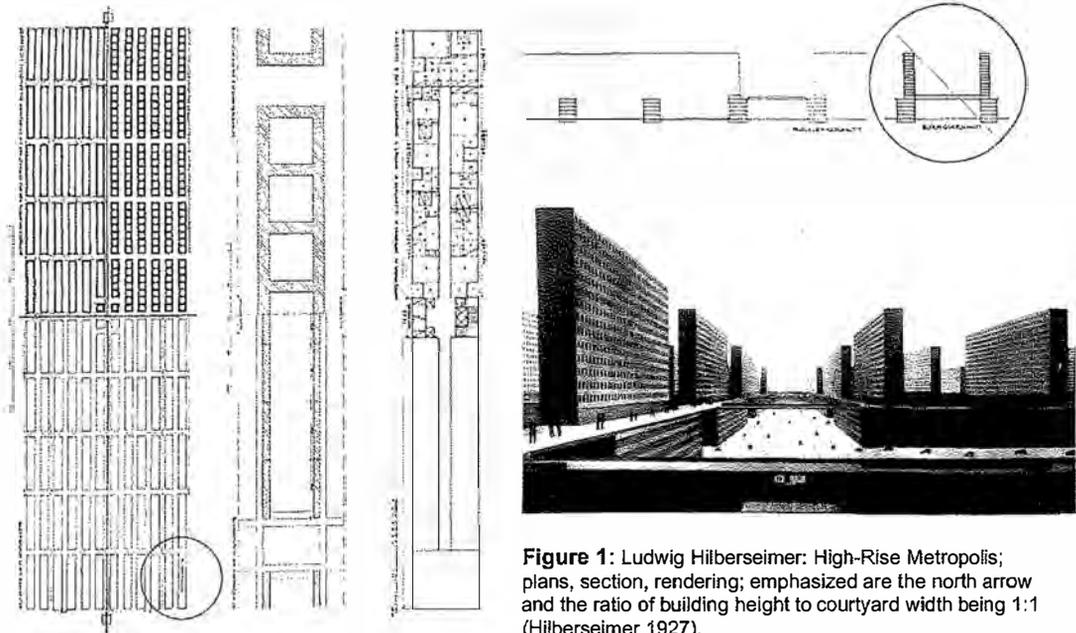


Figure 1: Ludwig Hilberseimer: High-Rise Metropolis; plans, section, rendering; emphasized are the north arrow and the ratio of building height to courtyard width being 1:1 (Hilberseimer 1927).

Hilberseimer achieved a high urban density comparable to Berlin's average density, but this came with a deliberate sacrifice for the apartments, which were arranged along a middle corridor, thus allowing only single-sided orientation of the apartments to either east or west. Cross ventilation and two-sided solar exposure were impossible. Later, Hilberseimer spoke extremely critically about his famous scheme, not only referring to its sterility, but particularly to its solar exposure: "The apartments did not have the right orientation. In order to reduce the city area, a higher residential density was necessary, which was achieved by arranging the apartments along a middle corridor. Consequently, the apartments could not be ventilated well. The residential density was higher than desirable." (Hilberseimer 1963, 22, German)

1.2. The "Wohnstadt" (Residential City)

In 1925, around the same time as the development of the metropolis scheme, Hilberseimer published his design of a "Wohnstadt" (Residential City), dating its development back to 1923 (Fig. 2).⁴ Similar to the metropolis scheme, although different in scale, Hilberseimer was interested in the tenement building as the most common way of living in German cities. The residential city was meant for 125,000 inhabitants. It consisted of twelve by six blocks, seventy-two blocks total or about 1,750 people per block (Hilberseimer 1927). Each block, with an elongated north-south proportion, had an approximate size of 40 by 330 meters (a description of the exact size could not be found). The shorter block sides included shops and offices, and only the long, five-story tall sides contained apartments, all of them oriented to both east and west. Similar to the metropolis scheme, these apartment bars had consistently the same spacing, no matter if there was a street or courtyard in between, to allow an even solar orientation.⁵

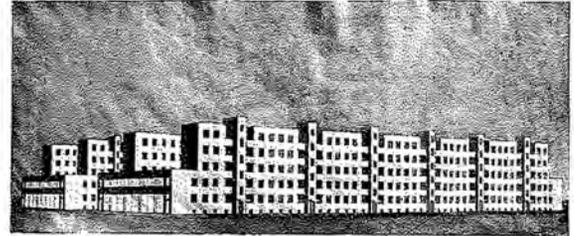
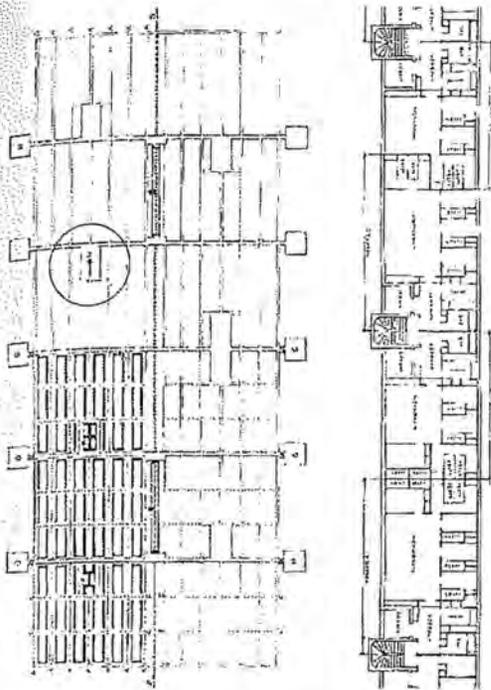


Figure 2: Ludwig Hilberseimer: Residential City; plan, floor plan, rendering; emphasized is the north arrow to show the north-south running building blocks (Hilberseimer 1926).

Sections or written statements verifying the exact ratio of building height to building distance could not be found. In the various published renderings, the distance of the housing bars seems to exceed the ratio 1:1. The floor plan reveals a narrow building width of only eight meters, with most bedrooms facing to the courtyard, and living room, loggia, and stairs facing to the street. Thus, the two apartment bars of a block were mirrored and did not follow the common orientation paradigm of the time that bedrooms should face east to the morning sun and living rooms west to the evening sun. The apartments allowed cross ventilation.

Similar to his critical evaluation of the "Hochhausstadt," Hilberseimer's later comments on the "Wohnstadt" were negative: "The orientation of the apartments is wrong. The rooms are arranged toward east and west. East orientation can be accepted, while the one toward west is to be rejected. Rejection of the orientation means at the same time rejection of the residential density. It was fundamentally wrong to assume the tenement building to be the only possible residential form." (Hilberseimer 1963, 14, German)

1.3. Justification of East-West Orientation

Hilberseimer's layouts for the high-rise metropolis and residential city were based on reviews of publications on city densities and solar calculations. A vast majority of authors around 1900 concluded that building blocks with a north-south running axis were the preferable scheme in dense cities.⁶ One example is Reinhard Baumeister (1833-1917), professor of urbanism in Karlsruhe while Hilberseimer was a student.⁷ Already in 1876, Baumeister complained about the unhealthy conditions of dense urban city blocks: "For the human being to prosper, sun light and pure air are necessary. [...] light is removed by excessively dense positioning of buildings, limited courtyards, and small windows; air is spoiled by dense crowding in few small rooms."⁸ In addition, Baumeister criticized that most building codes, while only vaguely asking for the development of healthy living conditions, lacked clear regulations about distances, heights, and arrangements of buildings. He therefore recommended that "the most favorable and at the same time simplest ratio $h=b$ should be adopted," while "h" is the building height and "b" the distance between buildings (Baumeister 1876, 317, German). In other words, he recommended a 45° angle between the bottom of a building and the eaves of an opposite building to determine building height and distance. Baumeister further complained that building regulations existed mainly for the street side of buildings. Since courtyards commonly had much worse conditions—such as an approximate $h=3b$ rule in Hamburg or $h=5b$ in Paris—he asked for the same rule of a 45° angle for rear buildings and courtyards (Baumeister 1876, 323-325, and 1905, 277). However, with respect to scientific evidence, he added in 1905: "The ratio between height and distance of $h=b$ cannot be theoretically justified, but only based on a feeling that tries to negotiate between considerations for health and for ground use." He again summarized that "the hygienic ideal is $h=b$, that is a 45° incidence angle of light." (Baumeister 1905, 275, German) This rule applied to all orientations; no difference was made if buildings had a north-south or east-west axis.

A more scientific approach was undertaken by Karl Hoepfner, professor of urbanism at the Technische Hochschule in Karlsruhe, in his book *Grundbegriffe des Städtebaus* (Basic Concepts of Urbanism) of 1921. Hoepfner became highly influential to Hilberseimer, particularly by coining the term "Durchsonnung" (sun shining through) that can be found in Hilberseimer a decade later.⁹ In his book, Hoepfner extensively wrote about the necessary sun exposure of rooms, façades, and the ground surface around buildings. In the first step of the argumentation, Hoepfner acknowledged the superiority of south orientation, stating that in "fall and spring, and particularly in winter, that is in the most important times [...] the sun can shine at midday for a long time fully and deeply into the south rooms. [...] but you cannot grant this advantage to a few inhabitants if in return the others, three to four times more of them, have to accept very health-damaging dwelling conditions" (Hoepfner 1921, 193-195, German). He added that north façades were inherently unhealthy, often dealing with mold, and therefore should be avoided, and also warned that the south façade could be overheated in summer (Hoepfner 1921, 173). In a second step, he then listed the advantages of apartments facing east and west, with his main argument being that east and west façades would be at least equal. Blocks should be designed in a way "that potentially all rooms receive in an equal amount a portion of the overall achievable amount of 'shining through'" (Hoepfner 1921, 173). In numerous diagrams, Hoepfner compared differently oriented blocks with respect to solar exposure and shading (Fig.3) and showed that, while for free-standing buildings the south orientation is superior, this orientation leads to excessive shading when used in dense urban areas: "The insolation of south rooms in free-standing buildings is good already in fall and spring, and exceptional in the winter months [...]. However, dense urban areas have the disadvantage that the sunrays particularly in the winter months, in which they are the most valuable, are hold off by the buildings opposite the street." (Hoepfner 1921, 150) In other words, he claimed that best orientation differs for low-rise settlements with individually optimized buildings and dense urban areas where entire blocks and streets had to be optimized: When dealing with urban density, best orientation turns to east and west. Hilberseimer followed this recommendation, but, as will be shown below, came back to Hoepfner's analysis a few years later to arrive at opposite conclusions.

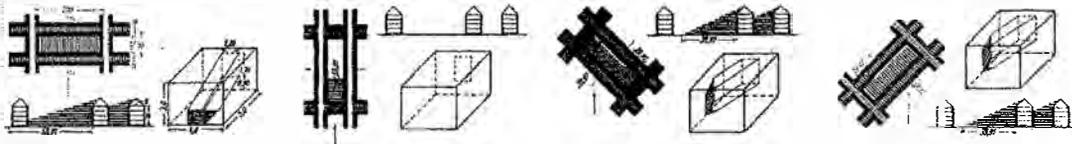


Figure 3: Karl Hoepfner: Study of sun exposure for differently oriented blocks for the winter solstice at 12 noon; altitude 17° 36'. Left to right: east-west block, north-south block, and diagonal blocks (Hoepfner 1921).

2.0. BAUHAUS INVESTIGATIONS: "MISCHBEBAUUNG"

In 1929, Hilberseimer was appointed as Bauhaus teacher, working first under director Hannes Meyer until 1930, then under Ludwig Mies van der Rohe until the closing of the Bauhaus in 1933. During the entire period, Hilberseimer's research and design work shifted away from studying dense blocks in residential cities or metropolises toward the design of mixed-used areas with high- and low-rise housing. Slowly, his understanding of best orientation for housing changed. Hilberseimer first experimented with schemes in which single- and multi-family buildings had diverse orientations to east, west, and south (avoiding north). At the end, he claimed that for all residential buildings south orientation should be achieved—thus abandoning the widely accepted argument that south orientation was ideal for single-family housing, but not practical for multi-family apartment blocks because of a lack of density. While in his earlier schemes he subordinated an ideal solar orientation under the requirements for density, now it was density that had to subordinate under the requirements for best orientation. Hilberseimer increasingly became a critic of high density, stating as early as 1930 that "a perfect solution is only possible by giving up today's population density of the metropolises and by extensive decentralization of the city area" (Hilberseimer 1930a, 520).

2.1. Mixed-Rise Multi-Family Blocks and Single-Family Units

In a 1929 article for the Bauhaus journal, Hilberseimer presented a scheme of five-story north-south running buildings for families alternating with ten-story buildings with apartments for singles and childless couples. Rooms were oriented to east, west, and some to south (Fig. 4). He stated that "the blocks were laid out in a way that they have the relative largest sun illumination when living rooms are allocated in both directions" (Hilberseimer 1929a, 4). A similar 1929 article presented different settlement layouts that show his interest in mixed heights, mixed building types, and apartments facing east, west, and/or south (Hilberseimer 1929b).

In the early 1930s, Hilberseimer became interested in the single-story, L-shaped single-family house, which, in his view, combined "the advantages of the townhouse with the ones of the free-standing house" (Hilberseimer 1931, 1, German). While the free-standing single-family house provided the highest flexibility of arrangement and expression, maximum solar exposure, and complete isolation from neighbors, and the

townhouse allowed cheaper building with the disadvantages of limited east and west orientation and less isolation from neighbors, the L-shaped house benefitted from a direct garden access of all rooms while allowing a good isolation from neighbors and a perfect solar exposure with the main spaces oriented toward east, west, and south. Hilberseimer's investigation of the L-shaped single-family house became increasingly sophisticated and the type advanced to one of his preferred building types over the years, allowing "free arrangement and more intensive insolation of the rooms" (Hilberseimer 1931, 1, German) (Fig. 5).

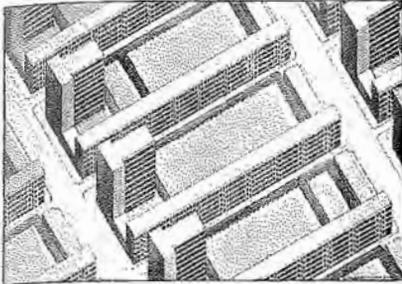


Figure 4: Ludwig Hilberseimer: Ten-story buildings alternating with five-story buildings (Hilberseimer 1929a).



Figure 5: Ludwig Hilberseimer: Proposals for L-shaped single-family houses (Hilberseimer 1931a and 1932, Wagner 1932).

2.2. Comparing Urban Density

Along with these investigations, Hilberseimer began comparing high-rise and low-rise housing units with regard to best orientation and population density. Through diagramming he showed that there was no great difference in density between both housing types if each targeted an equal standard for best solar exposure rather than reducing the standard for multi-family housing (Hilberseimer 1931a, 1931c). In addition, Hilberseimer compared the density of low-rise and high-rise types with the existing density of Berlin and other cities. He calculated, for example, that the high-rise type would allow 384 people per hectare and the low-rise one 324 people per hectare, while comparatively Berlin had a range of 300 to 383 people per hectare—all quite similar. However, at that point, he questioned "if the population density of today's metropolises should be the standard of the population density of a city at all" (Hilberseimer 1931c, 778) and promoted, for the sake of better solar exposure, to decrease the density of urban areas to below 300 people per hectare (Hilberseimer 1931b, 251). His guiding principle was that each room of an apartment should receive at least two hours of direct sun insolation every day—a number that he later increased to four hours. And he concluded that the development of mixed settlements ("Mischbebauung") would best acknowledge different user types without sacrificing density. Also in 1931, Hilberseimer arrived at a scheme in which he oriented both high-rise and low-rise buildings toward south allowing direct sunlight into rooms while avoiding shading of other plots (Fig. 6).



Figure 6: Ludwig Hilberseimer: Scheme for a "Mischbebauung" with L-shaped single-family houses and high-rise buildings, all oriented toward south (Hilberseimer 1931c).

2.3. Justification of South Orientation

Hilberseimer's extensive sun studies culminated in two articles, published in 1935 and 1936 in the journal *Moderne Bauformen*, which can be seen as a summary of his Bauhaus investigations on solar orientation of dwellings. The first article focused on the housing unit, the second on the urban layout. In the first one, "Raumdurchsonnung," he showed in diagrams that in north-south running buildings, although the sun shines on east and west façades for quite a long time, little sun radiation actually comes *into* the room. Stating that insolation was not a matter of surface, but one of space—which he called "Durchsonnung" (shining through)—he concluded that buildings with south, south-east, and south-west orientation of all main rooms were the most preferable. He recommended that building codes should require minimum standards of

“Durchsonnung” of apartments, particularly for the winter conditions. This would result automatically in requirements for minimum distances between buildings and restrictions of allowable building heights (Hilberseimer 1935, 36). In the 1936 article, “Raumdurchsonnung und Siedlungsdichtigkeit,” Hilberseimer came up with a table that presented the necessary distances between buildings for a four-hour insolation of rooms at the winter solstice (Fig. 7). South-facing buildings in Berlin (51.5° north latitude), according to this table, would need a distance of 4.73 times the building height for sun exposure between 10am and 2pm. With the same four-hour insolation, the distance would increase to 6.78 times the building height if the settlement was built in Moscow (55° north latitude) and decrease to 3.63 times the building height in Paris (48° north latitude) (Hilberseimer 1936, 69). In conclusion, for Hilberseimer, it was ultimately the sun angle which determined the density of a settlement. However, he also showed that a layout of three-story buildings with south orientation and four-hour insolation would achieve a density of 322 people per hectare, which he considered too high a density anyway.

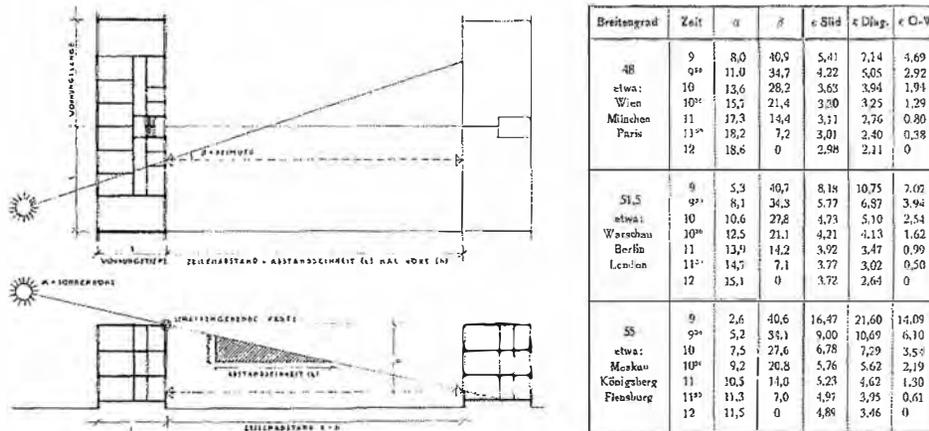


Figure 7: Diagram showing the spacing of buildings needed for sun exposure. The table columns include latitude, time, altitude, azimuth, and distance of buildings for south, diagonal and east-west orientation (Hilberseimer 1936).

3.0. CHICAGO YEARS: “SETTLEMENT UNITS” AND THE “RIBBON SYSTEM”

After immigrating to the USA in 1938, where he taught at the Armour Institute of Technology (renamed the Illinois Institute of Technology in 1940), Chicago, Hilberseimer’s interest in best solar orientation of housing and its consequences regarding urban density remained central. George E. Danforth described an annual school party dedicated to Hilberseimer—known as “Hilb’s Day”—that was celebrated close to the winter solstice, “a day central to his insistence on correct orientation—so that major rooms would receive at least four hours of sunlight” (Danforth 1988, 14). The requirements regarding solar orientation formulated in his 1935 and 1936 articles remained the basis of his teaching and later his leadership in the Chicago City Planning Office. The concept of the mixed settlement (“Mischbebauung”) and the merging of urban and rural forms of living, already apparent in the schemes of the early 1930s, became driving forces in his further development of settlement structures. In the following decades, no new insights regarding solar orientation appeared. Hilberseimer, while sticking to his findings from 1935 and 1936,¹⁰ focused on the development of “settlement units” that organized single-family L-houses and multi-family high-rise buildings with proper solar orientation along “fishbone-like street systems” that were connected to larger transportation arteries with commercial and industrial areas. These settlement units could be combined to “settlement aggregates” of various sizes to become a pattern spanning large regions (Hilberseimer 1944). Hilberseimer described this “ribbon system” as follows: “In spite of the fact that one of its aims is its decentralization, its metropolitan character will be maintained, only under much more satisfactory conditions. [...] The city as a whole would emerge more or less with the landscape, in fact would become part of it.” (Hilberseimer 1967, 34) Hilberseimer now claimed that 200 people per hectare or eighty people per acre would be the desired density, which was the average of Paris with 140, Greater Berlin with 120, London with sixty, and Chicago with fifty people per acre (Hilberseimer 1944, 93, and 1963, 49).

In 1955 the opportunity arose to build such a settlement unit: the Lafayette Park Detroit (in collaboration with Ludwig Mies van der Rohe and Alfred Caldwell). In early sketches, Hilberseimer drew his preferred building types—the L-shaped single-story house and the high-rise apartment building, both facing mainly toward south-east. In the completed project of 1963, however, both of them had disappeared, and one-story row houses, two-story townhouses and multi-story apartment buildings with single-sided apartments were realized, all of them facing in all directions, even to north-east and north-west (Fig. 8). Hilberseimer was not able to follow through with his preferred housing types for best solar orientation.



Figure 8: Lafayette Park Detroit: Sketch by Ludwig Hilberseimer from 1956 and final site plan; rearranged to show true north (Waldheim 2004).

RESEARCH, DESIGN, AND ACTUAL BUILDING PROJECTS

Hilberseimer's solar studies and adaptations to housing units and urban designs provide rich documents to reflect on the relationship of research and design in High Modernism and today. Modernist architects asked for a scientific foundation of building not only for social, technical, or economic progress, but also or even mainly for artistic reasons; grounding design on scientific findings was meant to create a cleansing effect for the—seemingly—superfluously and meaninglessly ornamented architecture of the nineteenth century. The underlying hope was that data-driven design could become an expression of the modern time. Hilberseimer, as one of many protagonists, embraced this goal by demanding, already early in his career, that “extreme objectivity, mathematical clarity, geometrical rigor, and exactest constructiveness are not only technical, but eminently artistic problems. They are the very essence of our epoch.” (Hilberseimer 1922, 832, German)

Although there is no such urgent call for renewing architecture today, implementing research in design might still have a similar reasoning of using research for form finding. Architects are highly interested in parametric design or tools to compute big-data to arrive at new forms. Research to accommodate individual needs (above all ADA) or to reduce energy wasting has increased enormously and its impact is evident when looking at the built environment. However, if there is “scientifically optimized design,” would not all buildings look the same? And if so, how then is our individuality expressed? Already modernist architects expressed an unease with respect to such questions. Hugo Häring, for example, raised concerns when he stated for Hilberseimer's and Le Corbusier's metropolis visions that their plans did “not allow any space for liveliness” and were “only optimization of objective concepts, debasing the human being to a thing. [...] Truly social can only be what furthers the individual. The opinion that social life leads to uniformity, standardization and typification is wrong, the opposite is right. [...] Even the existence of the sun only compels the concession of orientation. The city lives in the pure air of spiritual order.” (Häring 1926, 172-175) While for Hilberseimer solar orientation became one of his central topics of investigation that allowed unquestionable results and design proposals grounded on substantiated knowledge, he knew well how to respond to arguments such as Häring's. He repeatedly stated that this knowledge led solely to abstract types that required adaptation to real, concrete situations. He distinguished research (also design as research) as the abstraction of a given problem from actual building projects at specific sites. He called the former “demonstration attempts”: “Their task is, purely abstractly, to develop fundamental principles of urbanism out of current needs: to achieve general rules that allow the solution of particular concrete tasks. Only abstraction from the specific case allows showing how the disparate elements which make a metropolis can be brought together in a relationship-rich order.” (Hilberseimer 1927, 13) With respect to his urban schemes, he repeated that “these proposals should be neither city designs nor standardization efforts of a city. Both is impossible since there is no city as such” (Hilberseimer 1927, 20). Similarly, he stated in 1944 that the “proposed combinations of settlement units to form cities [...] are abstractions. Absolute cities do not exist. Cities are individuals. [...] these elements which we have described, and their manifold possibilities of combination, must remain in the realm of theory. We need such theory as a starting point for the discovery of our methods of work. But when we undertake the actual work of planning, our methods must always be modified by reality.” (Hilberseimer 1944, 128). One could argue whether Hilberseimer was even interested in concrete building projects. His abstract renderings of purified timeless ideas, created throughout his career, are his most powerful and captivating works, addressing intellect and emotions alike. Richard Pommer came to this conclusion, stating: “What mattered to him was not the realities of urban planning, but the perfect form alone, the representation of absolute types, whether a pure bedroom town or a self-sufficient urban center.” (Pommer 1988, 40).

In Hilberseimer's case, the most straightforward lesson with respect to utilizing research for architectural form finding comes from his own rejection of his supposedly optimized early 1920s city plans after continued investigations during his time at the Bauhaus. Changing his position was entirely based on giving a different aspect of the problem more importance than it had before. In his metropolis and residential city projects, he emphasized the need for urban density, thus resulting in a preference of north-south streets and building façades that were lit longer in the winter time. In his later settlement units, he stressed four-hour insolation within the main rooms, thus resulting in preferring east-west streets and lower urban density. In other words, scientific knowledge in architecture is useful to understand particular aspects of a project, but this knowledge must still be weighed with respect to its importance in this project. This remains true with our computational tools today, which can calculate "optimized forms" out of an increasing number of variables or aspects. When it comes to real-world projects, the number of such variables will always remain indefinite and there is no way of quantifying all of them for computational simulation and scientifically weighing their importance. Beyond the increasing research in the architectural fields and the further optimization of identified problems, there are still innumerable aspects that require the architects' expertise in creating meaningful wholes. Storytelling as a strategy to unify an indefinite number of challenges and aspects would become obsolete only if we were able to reduce building to a set of identifiable, weighable variables.

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ENDNOTES

- ¹ See Perlin 2013, Denzer 2014, Poerschke 2015 and 2016.
- ² Pommer mentions that "[o]ne of the drawings is dated "Dez. 1924" (1988, 51, note 91). The project is published in Häring 1926, 172-175, and Hilberseimer 1927, 17-20. Cf. Hilberseimer 1930b, 610.
- ³ The scheme is described in Hilberseimer 1927, 18-19.
- ⁴ Cp. Pommer 1988, 30 and 50, note 84. The *Wohnstadt* was also published in Hilberseimer 1926 and 1927.
- ⁵ Cp. Hilberseimer 1963, 14.
- ⁶ Other are, for example: Atkinson 1905, De Fries 1919, Rey/Pidoux/Barde 1928, Schmitt 1930.
- ⁷ Cp. Pommer 1988, 23.
- ⁸ Baumeister 1876, 16, German. Baumeister addressed light and air but not a need of direct sun.
- ⁹ For the term "Durchsonnung," see Hoepfner 1921, 142. Hilberseimer referred to Hoepfner in 1935.
- ¹⁰ For example, Hilberseimer 1944.