Development of View Analysis Metrics and Their Financial Impacts on Office Rents*

Abstract

A view contributes to a person's visual perception, comfort, and health in a building—reducing stress, improving concentration, increasing productivity, and bolstering creativity. Yet, what makes a view alluring is also what makes it ineffable and difficult to characterize. We introduce two new metrics to quantitatively assess view access in open floorplans, and using the metrics, we measure the economic impact of views on office rents in Manhattan, New York City. We evaluate spatial view access in 5,154 office spaces; and then, combining the view analysis results with rent transaction data, we model the financial performance of rents paid by tenants with varying views whilst controlling for other vital factors impacting office rents. We find that spaces with high access to views have a 6% net effective rent premium over spaces with low access to views. This financial impact is independent of other values drivers like daylight. In the case where there is both high daylight and view access, there is also a 6% effective rent premium. Office tenants value views and have historically paid for them. The metrics introduced in this work can be used in architectural design and planning to analyze the potential for views in new and existing buildings. The value of views is evident in human health data and, as shown in this paper, in tenant lease prices; the method proposed in this work provides a systematic means by which to further explore the value of views.

Keywords— views, viewshed analysis, hedonic pricing regression, office property values, visual comfort

*Draft manuscript. Please do not cite without the authors' permission.

1 Introduction

Views contextualize a person in space and connect them to the surrounding environment. They are the "sparkle" that contributes to occupants' comfort, perception, and feelings in a building (Clements-Croome, 2018). In workplace environments, the uplifting quality of views reduces stress, improves concentration, increases productivity, and promotes creativity (Aries, Aarts, & Van Hoof, 2015). This is of both social and economic importance, affecting both the welfare of workers and the increased labor costs due to sick days and medical leave (Gabriel, 2000). Given that adults around the world spend the majority of their time indoors (Khajehzadeh & Vale, 2017; Leech, Nelson, Burnett, Aaron, & Raizenne, 2002; Odeh & Hussein, 2016; Schweizer et al., 2007; Yang et al., 2011), the quality of indoor environments—of which views are a part—are increasingly critical to social sustainability and public health.

There have been various attempts, described below, to qualify a view, yet there is no established method for quantitatively assessing views out of a window. What makes views alluring is also what makes them difficult to characterize. Visual perception is more complicated than simply the objects in view, and therefore, evades modeling (Pepperell, 2012). Yet, there are ways to evaluate *elements* of the view. Building upon previous work characterizing views in urban design (Lynch, 1960), we argue that most views out a window share visual components—such as sky, landscape, ground, and objects of interest—in different proportions. Alongside the objects being seen, geometric spatial properties such as view angle and depth-of-field contribute to the conceptualization of a view. In combination, these elements provide a connection to the natural world; establish a sense of place in the surrounding context; and create intrigue and delight.

This paper introduces a new set of view metrics and evaluates their capacity to explain rent differences in office buildings. The method measures the composition of the occupant's view throughout an interior space from spatially-distributed viewpoints. It is designed to be applied in parallel with daylight performance simulations, thereby deepening our analytical description of the visual experience in buildings.

In addition to analyzing the components of views, this paper estimates the financial value of views in office real estate. A view is a major selling point for office real estate in arguably any market, but particularly in urban areas. Despite the industry-wide acknowledgement of their value, up to this point, there has been no study to measure the financial performance for daylight and views across a real estate market. This paper fills the gap. Using the results of the view analysis and commercial rent data, we estimate the value of views as measured by office space rent variation across the borough of Manhattan in New York City. This work builds upon previous work estimating the value of a complementary visual quality—daylight—within Manhattan office spaces (Turan, Chegut, Fink, & Reinhart, 2020). This paper addresses a key limitation in the previous study: distinguishing the value of daylight and views from one another. Considering both daylight and views together, we identify the *independent* economic impact of each visual attribute within the Manhattan office market.

The paper presents both the proposed view metrics and the economic impact of views modeled via a hedonic pricing regression. In the Methodology Section 3.1, we describe the view metrics and their analytical underpinning; this is followed by Methodology Section 3.2 in which we describe the dataset of Manhattan office spaces; and Section 3.3, in which we explain the hedonic pricing regression, estimating the financial impact of views on the overall rent price of the office properties. Similarly in the Results, we present the view metric results for all 5,154 offices in our sample in Section 4.1 and resulting view threshold levels; and then, we present the hedonic pricing results in Section 4.2. In Section 5 Discussion we touch upon the implications of this work, and in Section 6 Conclusion we summarize the work presented in the paper.

2 Literature Review

2.1 Quantitatively Evaluating Views

Views out the window have been the subject of studies across various fields for their impact on occupants in buildings (Aries, Veitch, & Newsham, 2010; C. Y. Chang & Chen, 2005; Farley & Veitch, 2001; Gladwell et al., 2012; Kim & Wineman, 2005; D. Li & Sullivan, 2016; Gilchrist, Brown, & Montarzino, 2015; Ko et al., 2020; C.-c. Chang et al., 2020; Ulrich, 1984). While there is a breadth of research evaluating the impact of views, the method of evaluation of the view itself varies greatly and is often vague. In some cases, the indicator of a view is reduced to be any visible natural element in sight (such as greenery), as observed by the surveyors or occupants; or simply the presence of a window in the room. In others, it is based on calculating the spatial elements visible from a viewpoint. For the most part, the approaches consider views from singular positions and simplify what is seen to discrete elements in the outside context. They do not account for light conditions, the framing of the view, or movement of the observer in a space. In no study, to our knowledge, is the view assessed based on spatially-distributed view access throughout the interior space, or considered alongside daylight.

In architecture studies, views are commonly assessed via geometric simulations or computer vision techniques. The former comes, in large part, from work done in the landscape and environmental planning fields. Tandy first proposed the idea of a isovist (also known as a viewshed or visibility polygon)—a 2D field of space visible at eye height—for landscape surveying (1967). This geometric approach identifies what is within line-of-sight from any particular location. Hillier employed the isovist as the basis for axial connections in his formulation of space syntax (1996). Ray-tracing based isovist analysis are used in various contemporary applications such as the Ladybug

Grasshopper plug-in (Sadeghipour Roudsari, 2016); and the work done by Doraiswamy et al. analyzing lines-of-sight for a tower in New York (2015). A separate approach, image-based view analysis, has also gained traction in the evaluation of built environments (W. Li & Samuelson, 2020). In short, view analysis methods—both geometric and image-based—continue to evolve in both practice and research (Doraiswamy et al., 2015; Studio Gang, 2016; Sasaki Associates, 2019).

While there is no firmly-established method to evaluating views, various design standards and guidelines have proposed possible methods that can be applied widely. The Leadership in Energy and Environmental Design (LEED) certification system's Quality Views credit requires views to flora, fauna, sky, movement or objects at least 25-feet (7.5-meters) away from the facade (U.S. Green Building Council, 2013). The WELL Building Standard that focuses on human health and wellness in buildings recommends that the majority of regularly occupied zones in a building are within 25-feet (7.5-meters) of a window or atrium but does not specify the type of view seen through the window (International WELL Building Institute, 2017). The European Union standard *EN-17037 Daylight in Buildings* suggests a minimum horizontal angle-of-view, depth-of-field, and layering of multiple view objects (European Committee for Standardization Technical Committee CEN/TC 169, 2018).

In architectural applications, view analysis is commonly grouped together with lighting evaluation, and specifically, daylight assessment. The properties of spatial daylight such as intensity, temporal dynamics, contrast, and spectrum can suggest whether the conditions are right for view gazing (Andersen, 2015). Yet, while there is a deeply intertwined relationship between the two phenomena, they are distinct visual qualities. It is possible to have good daylight with a bad view and bad daylight with a good view. Therefore, using daylight as a proxy for views has limited range. Nevertheless, it is imperative to consider daylight alongside views. In this work, we aim to contribute to view modeling by proposing a method that is based on geometric projections, accounts for the objects seen in the view, and complements daylight simulations for a space.

2.2 The Economic Value of Views

Views are valued in various geographic locations and cultures across the world. Specifically for residential properties, this has been studied extensively. Bourassa et al. reviewed 35 studies and found that views positively impacted property values anywhere from 1 to 147% (2004). In Hong Kong, harbor views increased values by over 2%, while mountain views and street views decreased values by 6.7% and 3.7%, respectively (Jim & Chen, 2009). A separate study of Hong Kong housing found that while overall sea and garden views had a positive impact on condominium prices, the effect depended on what storey the unit was located (Hui, Zhong, & Yu, 2012). In Yokohama, Japan, broad open views, as measured by a viewshed, had a positive impact on condominium prices (Yamagata, Murakami, Yoshida, Seya, & Kuroda, 2016). In Athens, Greece, pleasant views increased housing prices by up to 50% while unpleasant views decreased prices by up to 25% (Damigos & Anyfantis, 2011). In Geneva, Switzerland, water views increased housing rent prices up to 57% (Baranzini & Schaerer, 2011). In the United States, views have a positive impact on housing prices in a variety of contexts, from Ramsey County, Minnesota (Sander & Polasky, 2009), to Pensacola Beach, Florida (Hindsley, Hamilton, & Morgan, 2013) and Worcester, Massachusetts (Mittal & Byahut, 2019).

These studies show, using market-wide empirical data, that views are valued in residential properties. There is no study, to our knowledge, that has similarly evaluated the value of views in commercial office spaces. In this work, we evaluate the view and daylight premium by combining our unique view metric with office rent transaction data.

3 Methodology

3.1 View Modeling

We propose two new interconnected view metrics: *minimum view potential* (MVP) and *spatial view access* (sVA), to consider view access at the level of both the node and the floor:

- *Minimum View Potential* (MVP): The proportion of total rays cast from one origin point that intersect select outdoor view elements, expressed as a percentage (0-100%). MVP measures how much of the outside can be seen relative to the full field of view at one point.
- *Spatial View Access* (sVA): The fraction of the floor-wide analysis grid that meets a minimum MVP value, expressed as a percentage of the total area (0-100%).

Together, these metrics estimate the total potential views in the space. The method is developed specifically to be employed in parallel with daylight analysis (using standard computational daylight modeling techniques) to evaluate the rent value of daylight and views together.

The proposed ray-tracing approach is based on the idea that the quality of a view is a product of the entire composition within one's frame of view rather than a few select objects in the surrounding viewscape. We categorize objects in the urban context based on type: sky, iconic landmarks, neighboring buildings, green space, water, and ground; an approach that is similar to Lynch's taxonomy of visualized urban form (Lynch, 1960).

Spatial view access or sVA is analogous to the commonly-used spatial daylight autonomy (sDA) metric for daylight distribution, accounts for irregular distributions of views throughout a space. Just as daylighting in a space is both spatially and temporally non-uniform, dependent on proximity to a window, orientation, season, and time of day (IES Daylight Metrics Committee, 2012), we approach

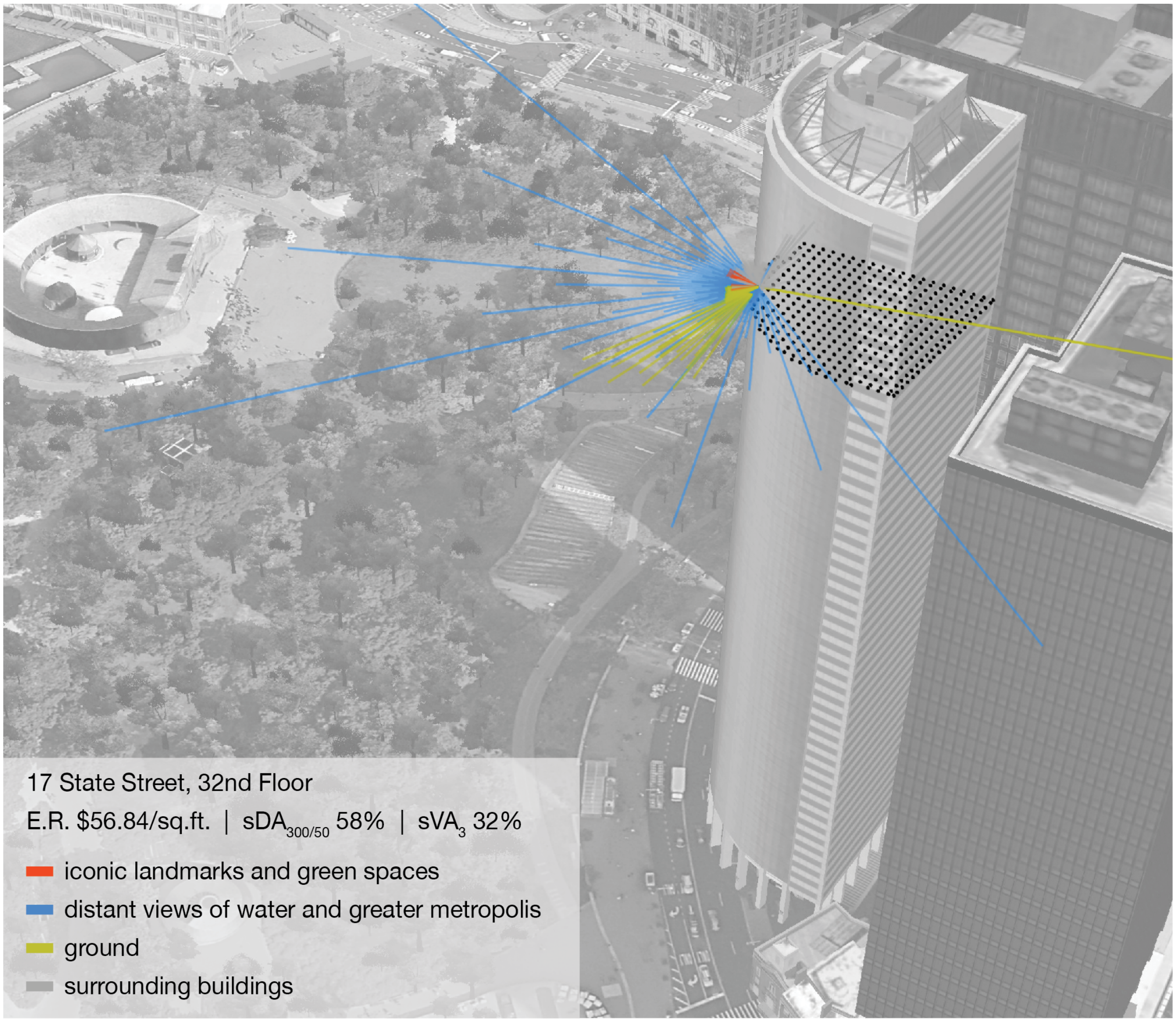

Figure 1: Illustration of rays being projected from a single viewpoint on the 32nd floor of 17 State Street. The graphic depicts the spatially-distributed grid of viewpoints as black dots. The colored lines radiating from one point on the floor depict the rays that are traced from one viewpoint. The color indicates the type of view element intersected by the ray in the surrounding context. Listed in the legend are three key metrics for the office space: effective rent (E.R) $56.84 per sq.ft. ($611.84 per sq.m.); spatial daylight autonomy ($sDA_{300/50\%}$) 58%; and spatial view access (sVA_3) 32%.

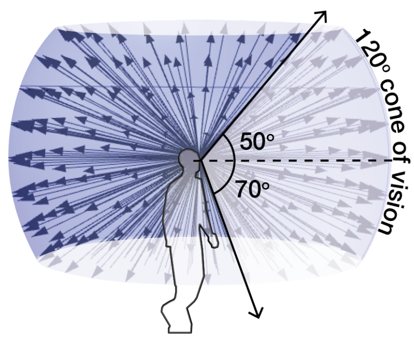

Figure 2: Rays cast from one viewpoint, at eye level in a 120-degree cone of vision.

views with a similar assumption of non-uniformity. The view in a space does not depend on the view at every point within the space. Instead, if a portion of the floorplate presents a good view, occupants will think of the whole space as having a view. This approach is particularly applicable to open floorplans.

Figure 1 depicts rays being traced from a single viewpoint on a sample office floor. The floor is subdivided into a grid of analysis viewpoints. From each viewpoint, rays are traced in a 120-degree cone of vision, as illustrated in Figure 2. Some rays intersect with the indoor space and some go through the window opening to the outside surroundings. Each object in the urban model is tagged with a type (landmark, green space, neighboring buildings, water and greater metropolis, ground, and sky). For each ray cast, the intersecting object and its distance is recorded. Rays that reach the sky are recorded in the simulation output but ultimately not considered in the view metric in order to disentangle views from daylight. This is based on the assumption that the rays reaching the sky represent direct daylight access. Appendix section A.1 provides a detailed description of the model set-up and parameters. Figure 3 depicts each type of view element as it exists in the in the 3-D urban geometric model.

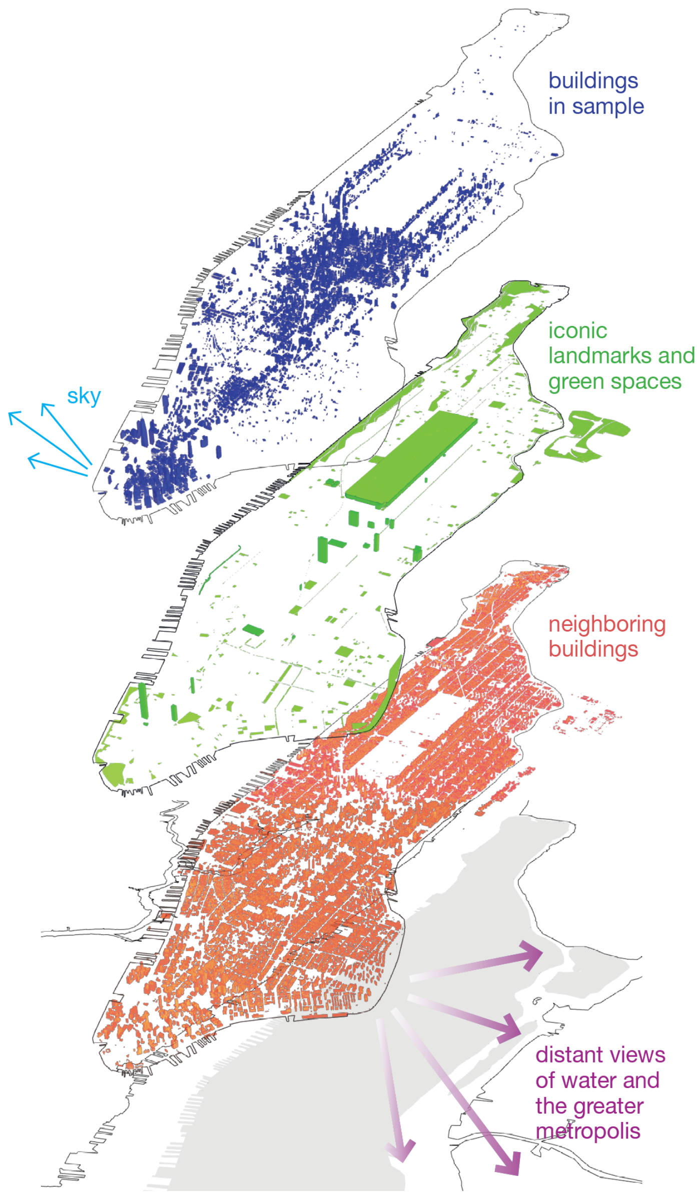

Figure 3: View elements by layer in the 3D model: buildings in the sample, iconic landmarks and green spaces, neighboring buildings, distant views of water and the greater metropolitan area, and sky.

3.1.1 View Analysis Example

To demonstrate the view simulations at the floor level, we present the results for floors within an example office building: 17 State Street. The building is located at the southern tip of Manhattan, looking over the water to the south and west. The 43-floor office tower, constructed in 1988, was designed by Emery Roth & Sons and developed by the William Kaufman Organization. The building massing, characterized by the sweeping arc in the southwest orientation, maximizes views over the Hudson River. Figure 1 illustrates how rays are cast from a single viewpoint node in the 6-foot-by-6-foot (1.8-meter-by-1.8-meter) floor-wide analysis grid. For each ray, the simulation outputs the object intersected in the surrounding environment, the distance of the intersection from the origin, and the position of the intersection. The majority of rays extend to the water, as depicted in blue. The ray direction and length changes based on the location of the node on the floor.

For the single viewpoint depicted in Figure 1, an MVP value is calculated. This procedure is then carried out for every point within the analysis grid on the floor to derive the floor-wide sVA_3.

Figure 4 illustrates the calculation of the MVP at a single viewpoint and the floor-wide sVA_3 calculation. The MVP is calculated as follows: 6,111 rays are cast from the point; of those points, 959 rays reach the outside. Thus the proportion of total rays that reach the outside (the MVP) is 16%. The sVA is the portion of the floor-wide points that have a minimum view access, as determined by a minimum MVP threshold. We determine this to be 3% MVP. Section 4.1 will describe how we determined the 3% MVP threshold based on the view analysis results for the Manhattan-wide sample. If the MVP is less than 3%, then the point is considered to be more inward-facing than outward-facing.

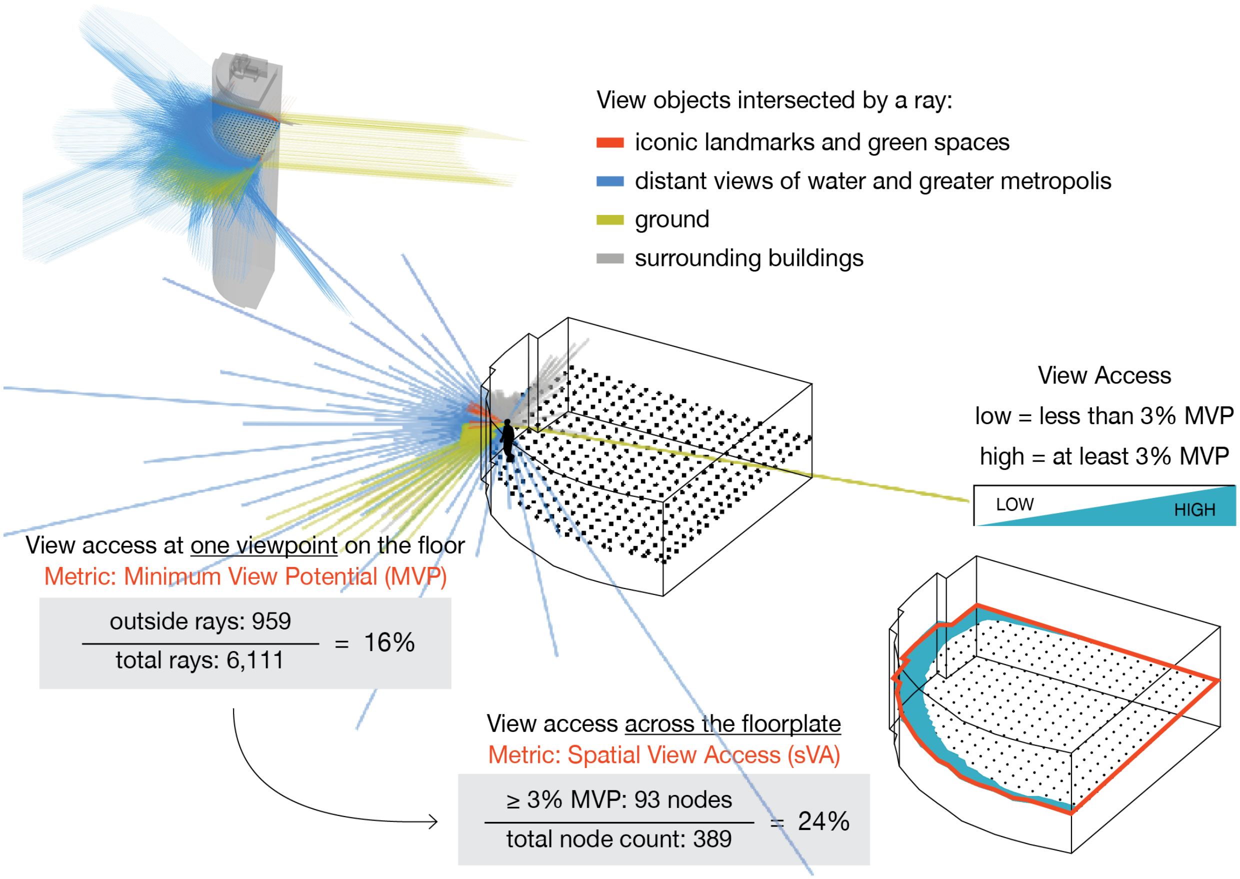

Figure 4: View analysis results for the 32nd floor of 17 State Street. The floorplate axonometric illustration at the top left shows the rays cast from one viewpoint node on the floor; the middle illustration depicts the rays cast from each viewpoint in the analysis grid; and the bottom right illustration shows the zone of high view access along the curved perimeter of the building. The Minimum View Potential (MVP) is calculated for each viewpoint as the rays reaching the outside over total rays; and the Spatial View Access (sVA_3) is calculated for the entire floor as the proportion of viewpoint nodes that have at least 3% MVP.

3.2 Data

In total, we analyze 6,267 offices with lease contracts signed between 2010 and 2016. The spaces are located on 5,154 floors throughout Manhattan. We compile property and building data for the sample from multiple sources: a city-wide 3D geometric model from New York City's Department of Information Technology and Telecommunications; property information from the city's Department of Planning; rental contract data from CompStak; sustainable building certifications from Green Building Information Gateway; telecommunications data from Geotel; green space and hydrography data from the NYC OpenData online portal (run by the NYC Department of Information Technology and Telecommunications); and landmark sites from the publication *Curbed New York* (CompStak Inc., 2018; NYC Department of Information Technology & Telecommunications, 2016b; NYC Department of City Planning Information Technology Division, 2018; U.S. Green Building Council, 2018; GeoTel, 2018; NYC Department of Information Technology & Telecommunications, 2016a; Curbed, 2019).

As previously described, we evaluate views *alongside* daylight performance in the offices. Thus, there are two variables of interest in the financial regression analysis: spatial view access (sVA_3) and spatial daylight autonomy (sDA). The view access dataset is generated as per the methodology described in the previous section. The daylight performance values come from a previous study on the same sample of office spaces (Turan et al., 2020).

3.2.1 Data Summary Statistics

Table 1 presents the descriptive statistics (mean and standard deviation) for the office sample as a whole, as well as in four sub-samples: observations with *no daylight or views*, *high daylight only*, *high views only*, and *high daylight and views*. High daylight is defined to be minimum 55%

$sDA_{300/50\%}$; high view access is defined to be minimum 10% sVA_3. 64% of the contracts in the sample have neither high daylight nor views; 19% have high daylight only; 8% have high views only; and 8% have both high daylight and views. In total, 1,008 observation, or 16% of the full sample, meets the 10% sVA_3 view threshold. The dependent variable is the logarithm of the net effective rent in U.S. Dollars. The average net effective rent across all observations is $49.94 with a standard deviation of $20.55 per square foot ($537.55 with a standard deviation of $221.20 per square meter).

3.3 View Valuation in Commercial Offices

We employ a hedonic pricing model (Rosen, 1974) to estimate the value of views. Hedonic pricing theory measures the value of differentiated products, considering the utility derived for the tenant by building, contractual, temporal, and neighborhood characteristics (Chegut, Eichholtz, & Kok, 2014; Chegut, Eichholtz, & Rodrigues, 2015; Fuerst & Wetering, 2015; Eichholtz, Kok, & Quigley, 2010; Feige, Mcallister, & Wallbaum, 2013). Equation 1 presents the functional form of the vectorized hedonic model specification

$$logY_i = \alpha + \phi D_i + \beta B_i + \gamma L_i + \delta N_i + \omega T_i + \epsilon_i, \tag{1}$$

where the dependent variable Y is the realized logarithm of net effective rent per square foot for rental contract observation i. D represents two variables of interest, spatial daylight autonomy (sDA) and and spatial view access (sVA). The view metric, sVA, is included as a dummy variable indicating if a rental contract observation i has high view access—defined to be at least 10% spatial view access with 3% minimum view potential (10% sVA_3). Section 4.1 describes the rationale behind the 10% threshold for sVA_3. The daylight metric is included as categorical variable indicating the

Table 1: Summary statistics for variables included in the daylight and view hedonic model. Mean and standard deviation presented for all observations, as well as for the sub-samples representing office spaces that meet the minimum daylight and view performance thresholds separately and together. For categorical variables, the mean indicates the percentage of observations that fall within each category.

		All Observations		No Daylight or Views		High Daylight Only		High Views Only		Daylight and Views	
Dependent Variables		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Net Effective Rent ($ per sq.ft.)		49.944	(20.551)	46.138	(16.207)	54.540	(23.463)	56.948	(29.278)	62.288	(24.391)
Log Net Effective Rent		3.839	(0.376)	3.773	(0.346)	3.921	(0.386)	3.948	(0.412)	4.058	(0.392)
Variables of Interest											
Spatial View Access (sVA_3) of at least 10% (1 = yes)		0.161	(0.367)	-	-	-	-	1.000	(0.000)	1.000	(0.000)
Spatial Daylight Autonomy ($sDA_{300/50\%}$)	Low (0-55%)	0.724	(0.447)	-	-	-	-	-	-	-	-
	High (55-75%)	0.161	(0.367)	-	-	0.619	(0.486)	-	-	0.498	(0.500)
	Very High (75-100%)	0.115	(0.319)	-	-	0.381	(0.486)	-	-	0.502	(0.500)
Building Characteristics for Each Contract											
Building Class	A	0.545	(0.498)	0.460	(0.498)	0.572	(0.495)	0.892	(0.311)	0.818	(0.387)
	B	0.383	(0.486)	0.451	(0.498)	0.366	(0.482)	0.080	(0.272)	0.178	(0.383)
	C	0.072	(0.258)	0.089	(0.285)	0.062	(0.240)	0.028	(0.165)	0.004	(0.063)
Building Age at Lease Signing (years)		67.766	(29.284)	73.225	(28.705)	67.305	(26.797)	41.669	(22.278)	51.098	(25.176)
Renovated building (1 = yes)		0.500	(0.500)	0.500	(0.500)	0.521	(0.500)	0.496	(0.500)	0.459	(0.499)
LEED Certified (1 = yes)		0.121	(0.326)	0.120	(0.324)	0.080	(0.272)	0.215	(0.411)	0.141	(0.349)
Fiber Lit Building (1 = yes)		0.950	(0.219)	0.937	(0.243)	0.954	(0.210)	0.992	(0.089)	0.998	(0.044)
Lease Contract Terms											
Transaction Floor Number	0-15	0.620	(0.485)	0.826	(0.379)	0.327	(0.469)	0.227	(0.419)	0.075	(0.263)
	16-30	0.276	(0.447)	0.155	(0.362)	0.553	(0.497)	0.367	(0.483)	0.484	(0.500)
	31-45	0.091	(0.287)	0.019	(0.136)	0.095	(0.294)	0.337	(0.473)	0.410	(0.492)
	46 and over	0.013	(0.113)	0.000	(0.000)	0.025	(0.158)	0.068	(0.252)	0.031	(0.174)

Table 1 – *Continued from previous page*

		All Observations		No Daylight or Views		Daylight Only		Views Only		Daylight and Views	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
——											
Lease Duration (years)	5 or less	0.393	(0.488)	0.402	(0.490)	0.428	(0.495)	0.263	(0.441)	0.365	(0.482)
	6-10	0.423	(0.494)	0.395	(0.489)	0.499	(0.500)	0.361	(0.481)	0.527	(0.500)
	11-15	0.135	(0.342)	0.152	(0.359)	0.061	(0.239)	0.221	(0.415)	0.096	(0.295)
	16-20	0.036	(0.186)	0.037	(0.188)	0.011	(0.103)	0.118	(0.323)	0.012	(0.108)
	21-25	0.007	(0.084)	0.007	(0.084)	0.000	(0.000)	0.032	(0.177)	0.000	(0.000)
	26 or more	0.005	(0.070)	0.007	(0.081)	0.002	(0.041)	0.004	(0.063)	0.000	(0.000)
——											
Free Rent Period (months)	No free rent	0.184	(0.387)	0.196	(0.397)	0.181	(0.385)	0.118	(0.323)	0.157	(0.364)
	6 months or less free	0.546	(0.498)	0.521	(0.500)	0.656	(0.475)	0.442	(0.497)	0.584	(0.493)
	7-12 months free	0.228	(0.419)	0.240	(0.427)	0.153	(0.360)	0.299	(0.458)	0.243	(0.429)
	13-18 months free	0.035	(0.184)	0.040	(0.196)	0.009	(0.095)	0.084	(0.278)	0.012	(0.108)
	19-24 months free	0.005	(0.068)	0.002	(0.042)	0.002	(0.041)	0.038	(0.192)	0.002	(0.044)
	Over 24 months free	0.003	(0.054)	0.002	(0.044)	0.000	(0.000)	0.018	(0.133)	0.002	(0.044)
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Landlord Concession (Work Type)	As-Is	0.016	(0.127)	0.018	(0.131)	0.012	(0.110)	0.016	(0.126)	0.018	(0.132)
	Built to Suit	0.001	(0.025)	0.000	(0.022)	0.001	(0.029)	0.002	(0.045)	0.000	(0.000)
	New Building Install.	0.044	(0.206)	0.041	(0.199)	0.056	(0.230)	0.030	(0.171)	0.055	(0.228)
	Not Specified	0.140	(0.347)	0.141	(0.348)	0.170	(0.376)	0.048	(0.214)	0.145	(0.353)
	Other	0.001	(0.025)	0.000	(0.022)	0.002	(0.041)	0.000	(0.000)	0.000	(0.000)
	Paint & Carpet	0.002	(0.042)	0.001	(0.035)	0.002	(0.050)	0.004	(0.063)	0.002	(0.044)
	Pre-Built	0.023	(0.149)	0.019	(0.138)	0.034	(0.180)	0.008	(0.089)	0.039	(0.194)
	Tenant Improvements	0.770	(0.421)	0.777	(0.417)	0.719	(0.450)	0.886	(0.319)	0.729	(0.445)
	Turnkey	0.003	(0.058)	0.002	(0.042)	0.004	(0.064)	0.006	(0.077)	0.012	(0.108)
——											
Transaction Size (sq.ft.)		34,335	(83,088)	39,474	(92,568)	11,904	(23,163)	68,119	(1.10e+05)	14,190	(30,255)
Sublease (1 = yes)		0.118	(0.323)	0.124	(0.330)	0.089	(0.284)	0.157	(0.364)	0.100	(0.300)
Partial Floor Flag (1 = yes)		0.523	(0.500)	0.526	(0.499)	0.548	(0.498)	0.508	(0.500)	0.455	(0.498)
Multiple Floors in Lease (1 = yes)		0.237	(0.426)	0.263	(0.440)	0.150	(0.357)	0.317	(0.466)	0.167	(0.373)
Tenant Broker (1 = yes)		0.628	(0.483)	0.628	(0.483)	0.576	(0.494)	0.761	(0.427)	0.618	(0.486)

Table 1 – *Continued from previous page*

	All Observations		No Daylight or Views		Daylight Only		Views Only		Daylight and Views	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Landlord Broker (1 = yes)	0.682	(0.466)	0.676	(0.468)	0.666	(0.472)	0.771	(0.421)	0.684	(0.465)
Number of Observations	6,267		4,041		1,218		498		510	

daylight autonomy level ($sDA_{300/50\%}$ 0–55%, 55–75%, 75–100%) for rental contract observation i. B is a vector of exogenous hedonic building characteristics (such as age, class, LEED certification, etc.) of the building in which the rental contract observation i is located. L is a vector of the lease contract terms (such as lease duration, transaction floor number, landlord concessions, etc.) for rental contract observation i. N is a vector of exogenous location fixed effects by Manhattan neighborhood, represented by 24 submarkets (such as Chelsea, Financial District, Grand Central, and Times Square), as defined by Compstak (2018). T is a vector of time fixed effects by quarter and year that the lease is executed, between 2010 and 2016. ϕ, β, γ, δ, and ω are the estimated parameter vectors, representing the functional relationship between each independent variable and the dependent variable. ϵ is the error term, a vector of independent, identically distributed regression disturbances.

4 Results

We present the results of, first, the view analysis; and second, the financial valuation study, which relies upon the view metrics measured in the first section.

4.1 View Threshold Levels

We analyze view access in 5,154 office floors throughout Manhattan. Using the distribution of the sample-wide results, we determine the minimum MVP threshold, i.e. the minimum proportion of total rays cast from one origin point that intersect select outdoor view elements needed to count toward the floor-wide sVA_3 value. The MVP threshold is akin to the spatial daylight autonomy's minimum daylight threshold (e.g. 300 lux for at least 50% of the occupied hours) (IES Daylight Metrics Committee, 2012).

Table 2: View access analysis summary statistics. The number of analysis nodes reflects the size of the floor (as the nodes are distributed in a 6-foot-by-6-foot grid across the floor). The ray counts summarize the rays cast across the whole floor. The spatial view access (sVA_3) is the proportion of the floor area that meets the minimum 3% outdoor ray threshold. 5,154 unique office spaces were modeled; because there are multiple transactions for some floors (either over time and/or partial floor transactions), there are 6,267 observations in the full sample.

	All Observations				Floors with High View Access (Min. 10% sVA)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Number of nodes on floor	512	(427)	13	4,690	560	(368)	47	3,778
Total rays cast throughout floor	3.13e+06	(2.61e+06)	79443	2.87e+07	3.42e+06	(2.25e+06)	2.87e+05	2.31e+07
Number of rays that reach outside	3.18e+05	(2.06e+05)	19,723	4.13e+06	3.27e+05	(1.64e+05)	59,093	1.51e+06
Proportion of rays that reach outside	0.123	(0.056)	0.017	0.735	0.109	(0.035)	0.047	0.550
Spatial View Access, sVA_3	0.048	(0.111)	0.000	1.000	0.258	(0.149)	0.100	1.000
For all rays that reach outside, proportion reaching each view element								
Neighboring buildings	0.878	(0.153)	0.028	1.000	0.664	(0.161)	0.135	0.972
Ground	0.022	(0.043)	0.000	0.625	0.018	(0.027)	0.000	0.280
Iconic landmarks	0.011	(0.041)	0.000	0.604	0.042	(0.085)	0.000	0.604
Green spaces	0.002	(0.010)	0.000	0.199	0.005	(0.019)	0.000	0.199
Water	0.010	(0.032)	0.000	0.277	0.047	(0.065)	0.000	0.277
Sky	0.077	(0.118)	0.000	0.972	0.225	(0.111)	0.000	0.502
Observations	6,267				1,008			

Table 2 presents a summary of the view analysis results for two samples: (1) all observations and (2) a sub-sample of floors with high view access, defined as minimum 10% sVA_3. Across all observations, the average proportion of rays that reach the outside from a viewpoint is 12%. However, based on the location of an individual viewpoint is in a floor plate, there is significant variation in the the portion of rays that reach the outside – for most viewpoints that are away from the perimeter of a building the proportion is less than 1%.

Of the rays that reach the outside, the majority—on average 88% for all observations and 66% for the high view access group—intersect with adjacent neighboring buildings. Rays that reach the sky are the second largest group, on average 8% for all observations and 23% for the high view access group. Rays that intersect with ground, iconic landmarks, green spaces, and water constitute between 1 to 2% across all observations and 2 to 5% in the high access group. The sharp decrease in the proportion of rays hitting these object types is not surprising because there are fewer of these elements in the urban context model. As they are less common, these are also generally the coveted elements in a viewscape. See Table 2 in the Appendix for a detailed description of the types of outside view elements that are intersected by the rays.

Based on the simulation output, our goal is to establish an MVP threshold that distinguishes the viewpoints with high view potential from spaces with low view potential. To do this, we test three MVP threshold values: 1%, 3%, and 5%. Figure 5 depicts the histogram distribution of sVA values using each MVP threshold, separated by color. The aim of testing these threshold values is to define a metric that rewards the area of a floor high view access, without being too restrictive or rewarding the whole floorplate; and secondly to define a metric that distinguishes the top 10 to 20% of the Manhattan-wide sample with the highest spatial view access relative to the rest of the office spaces. We examine the 75th and 90th percentile of sVA values for each MVP threshold across the sample. For MVP thresholds 1%, 3%, and 5%, the 90th percentile for sVA is 83%, 17% and 6%

respectively. This mean, for example, that if the MVP threshold is 1%, then the sVA for spaces in the 90th percentile is 83%.

Looking at the distributions, we determine which combination of MVP and sVA provide best distinguish the top 10 to 20% of the office spaces from the rest of the sample. Ultimately, we define 3% MVP and 10% sVA_3 to define high view access. Conceptually, this means that for a space to have *high view access*, at least 10% of the floor-wide analysis nodes have a 3% MVP (i.e. 3% of the rays see an outdoor view element). These thresholds created a distribution of the results such that 17% of the observations have high view access. Across the full sample, the mean sVA_3 is 4.8%, while for the high view access sub-sample, mean sVA_3 is 25.8%.

Figure 6 illustrates the view analysis results on six sample floor plans. The figure depicts the high-view-access-zone on each floor plate, and lists the effective rent price, sDA, and sVA_3 values for comparison. As visually-illustrated in the figure, the high view access area always follows the perimeter of the floorplate, however it can be concentrated in particular orientations depending on the where view sight lines exist.

4.2 View Value Results

The hedonic model dissects the effective rent price of lease contracts into individual building and neighborhood characteristics, estimating the added value of each characteristic. The dependent variable, net effective rent, is the value that the tenant is willing to exchange for a bundle of qualities in the leased space that include building characteristics, lease contract conditions, relative spatial market supply and demand, and macro-economic conditions. We estimate Equation 1 using ordinary least squares with robust standard errors. We find that this form of the ordinary least squares model provides the best linear unbiased estimator of coefficients with heteroskedasticity-consistent robust standard errors (White, 1980). We consider two variables of interest: daylight ($sDA_{300/50\%}$) and

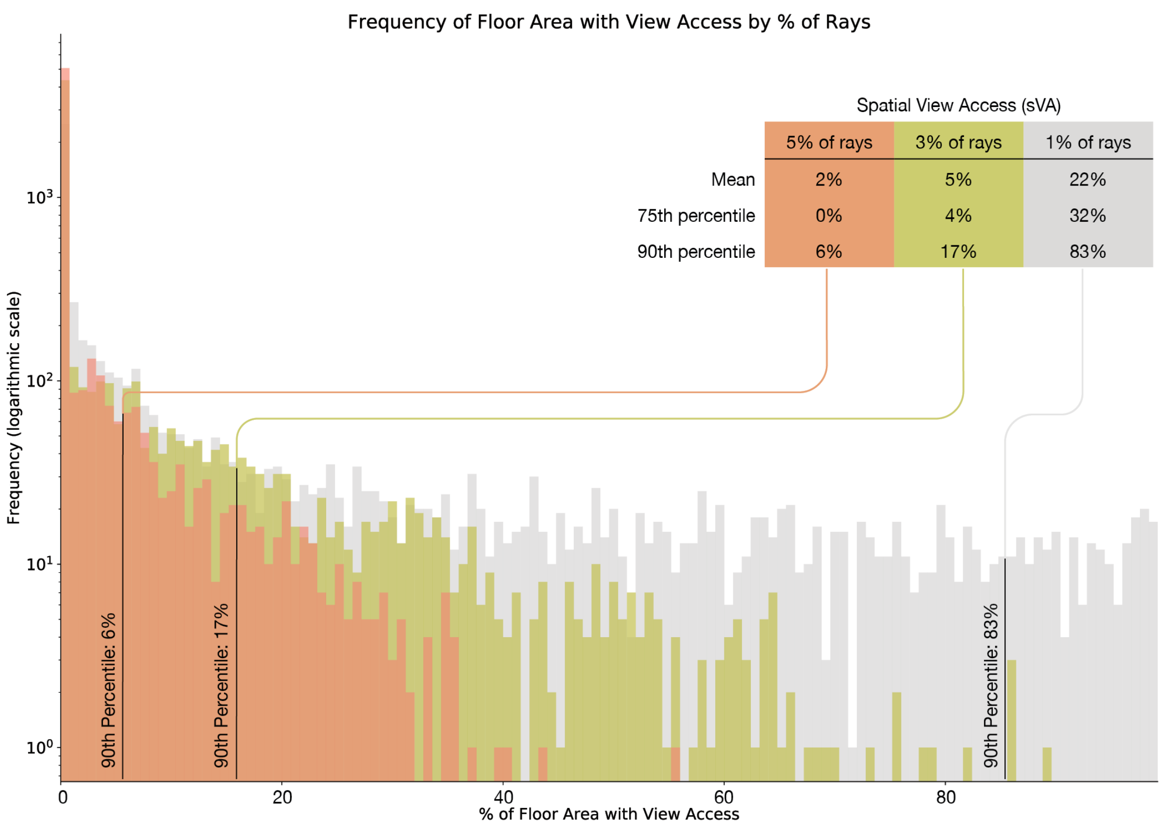

Figure 5: Distribution of floor-wide view access (sVA) results with three minimum view performance (MVP) thresholds: 1%, 3%, 5% of the total rays cast from a point. The y-axis of the plot is on a logarithmic scale to account for the high concentration of observations with very low sVA. The table in the top right of the plot presents the mean, 75th percentile, and 90th percentile for each threshold considered. The color of the distribution plot corresponds to the color of each threshold in the table (5% - orange, 3% - green, 1% - grey).

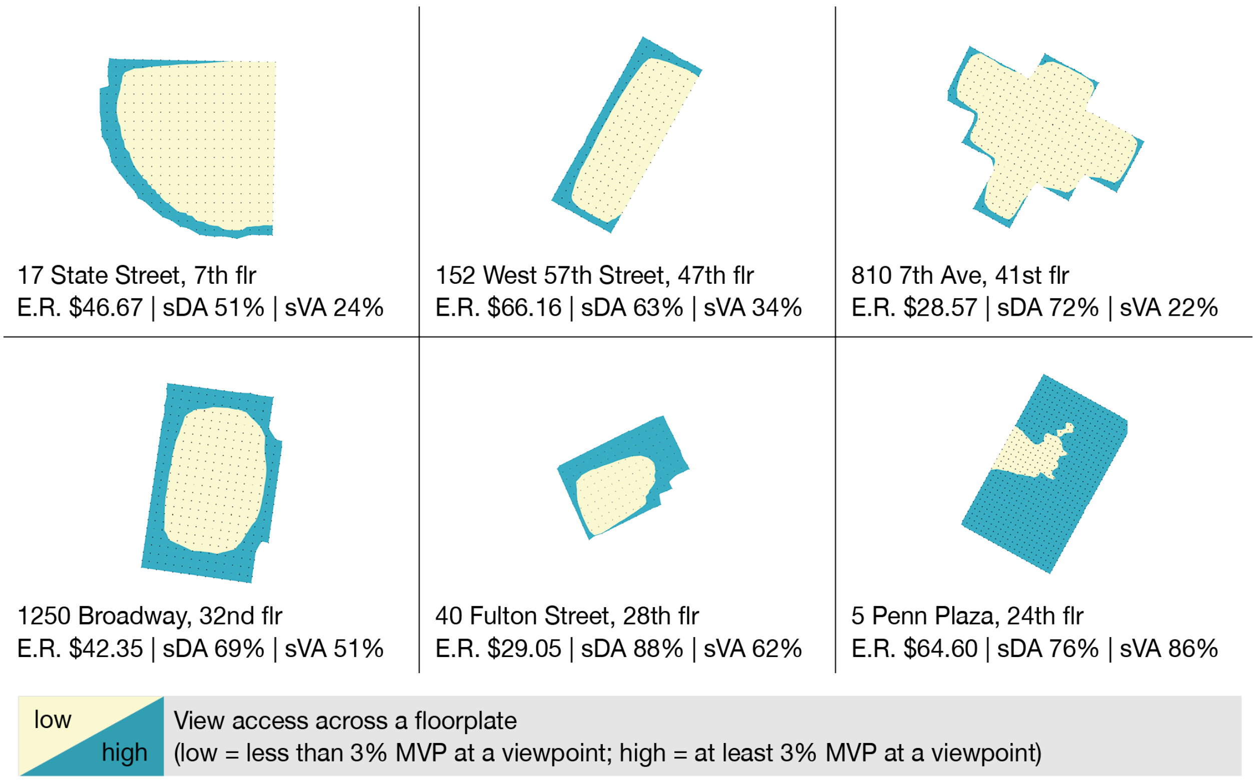

Figure 6: Spatial view access (sVA) results visualized on six office floors in the sample. The high view access area is highlighted on each floorplate, showing the nodes for which the MVP is over 3%. For each floor, the following metrics are also listed: the effective rent (E.R.) per square foot; the spatial daylight autonomy ($sDA_{300/50}$); and spatial view access (sVA_3).

views (sVA_3). For daylight, the low daylight (0-55% $sDA_{300/50\%}$) level serves as the base category, and the model measures the value of high daylight (55-75% $sDA_{300/50\%}$) and very high daylight (75-100% $sDA_{300/50\%}$) relative to the base. For view access, we specify a dummy variable to identify lease contract observations for floors with at least 10% sVA_3.

Table 3 presents the regression results. Column (1) presents the results of the model that includes only the daylight variable of interest: spatial daylight autonomy. Column (2) presents the results of the model with both variables of interest: spatial daylight autonomy and spatial view access. Column (3) incorporates the interaction effects between daylight and views to complete the fully-specified model results. Column (4) presents results for a trimmed distribution, eliminating the lease contract observations with the top 1% of net effective rent values. All models control for location fixed effects, time fixed effects, building characteristics, lease contract terms, and the interaction between daylight and floor number.

The main results of the regression, presented in column (3), show that the model explains up to 59.7% of the variation in net effective rent. This is in line with earlier previous studies that use the same data (Liu, Rosenthal, & Strange, 2016; Chegut & Langen, 2019). In the full specification the results for daylight (sDA) are nearly identical as those in the daylight-only model: spaces with high daylight (55-75% $sDA_{300/50\%}$) have a 5.3% premium over spaces with low daylight, while spaces with very high daylight command a 6.4% premium over spaces with low daylight. The view access (sVA_3) results show that, alongside the daylight impacts on net effective rent, spaces with high view access (10-100% sVA_3) have a 6.3% premium over spaces with low view access (0-10% sVA_3). To illustrate these values, consider a standard office space with low daylight and low view access that transacts for $50.00 per square foot ($538.20 per square meter). The same space with *high daylight and low views* would transact for 5.3% more or $52.60 per square foot ($566.19 per square meter), ceteris paribus. Alternatively, the same space with *high view access and low daylight* would transact for 6.4% more or $53.20 per square foot ($572.64 per square meter), ceteris paribus. The condition in which the space has both high daylight and high view access will be explored separately in Section 4.2.1.

The building characteristics and lease contract terms stay relatively unchanged between the daylight-only model in column (1) and the daylight and view access model in column (3). In most cases, the coefficients shift by 0.001-0.002, less than the standard error for the term. All of the building characteristics maintain a coefficient within this margin. The lease term characteristics that change are the following: The impact of 21-25 year lease terms (relative to 6-10 year lease terms) decreases from 20.4% to 19.2%. The discount for 19-24 months of free rent (relative to 0-6 months) shifts from -13.0% to -14.7%; and for over 24 months free, the discount shifts from -6.5% to -7.2%. The landlord concessions with the greatest impact increase slightly, namely the impact of a pre-built unit increases from 9.9% to 10.2% and a turnkey unit decreases from 14.1% to 13.7%. There is a decrease in the value of high floor numbers for all categories, especially for the highest floor numbers (floor 46 and over), for which the premium decreases from 32.1% to 27.0%.

Like the building and lease term characteristics, the time and location fixed effects are relatively stable with the addition of views to the model. The macroeconomic conditions, represented by the transaction period (year-quarter from 2010 to 2016), show a steady positive increase in the price starting in late 2011 (relative to 2010, quarter 1). The location fixed effects, represented by the Manhattan submarkets (i.e. neighborhoods), have sizable impact on the net effective rent, ranging from -41.3% to 40.0% depending on the submarket (relative to Grand Central).

In short, the 6% impact of view access on the net effective rent is comparable in magnitude to other building attributes and lease characteristics that a tenant considers when choosing an office space. For example, a renovated building has a premium of 4.0%, relative to a non-renovated building. Amongst landlord concessions, a new building installation has a 6.5% added value and a turnkey property has a 13.7% added value, relative to tenant improvements.

4.2.1 Interaction of Daylight and Views

Views and daylight are closely related. If a space has high view access, it may also have high daylight access, and vise versa. In a dense urban environment like Manhattan, particularly in tall buildings, spaces on higher floors are more exposed to daylight and views because of the height above the ground. At the higher elevations, there are less surrounding buildings to shade the facade and block the views to the distance. At low and mid-level floors, the access to daylight and views is less directly correlated. Depending on building form, orientation, and context, the lower floors can receive daylight but there be little access to views. Inversely, a building may be located next to a park or other open expanse, which provides views but due to shade from surrounding buildings is still shielded from sunlight. In our sample, 64% of the offices have *neither* a high view or daylight access; 19% have high daylight access only; 8% have high view access only; and 8% have *both* high view and daylight access. These categories, summarized in Table 1, are based on the thresholds established to distinguish spaces with high view access and high daylight access.

As described in Section 3.1, we design the view metric sVA_3 to exclude sky views in order to disassociate the metric from daylight access metric $sDA_{300/50\%}$. Thus, in the regression, we specify the daylight ($sDA_{300/50\%}$) and views (sVA_3) as independent. Yet, it is impossible to disassociate them completely. To test collinearity between the variables, we interact $sDA_{300/50\%}$ and sVA_3, as presented in column (3). The interaction term is the multiplication of the sVA_3 dummy variable with a single $sDA_{300/50\%}$ variable that includes both high and very high daylight (55-75% and 75-100% $sDA_{300/50\%}$) observations. The interaction term represents the conditional impact of having both high daylight *and* high view access. The results show that the interaction term has a -5.1% impact on the net effective rent with a standard error of 2.3%. This means that, for a space with *high daylight*

Table 3: Hedonic pricing regression: daylight and view results. The dependent variable is the logarithm of net effective rent per square foot ($/sq.ft.). Column (1) presents the regression results of the model that includes only the daylight variable of interest sDA. Column (2) presents the results of the model containing both the daylight and views variables of interest, $sDA_{300/50\%}$ and sVA_3. Column (3) incorporates the interaction effects between daylight and views, and presents the fully-specified model results. Column (4) presents results for a trimmed distribution, eliminating the lease contract observations with the top 1% of net effective rent values.

Variables	(1) Daylight Only	(2) Daylight + Views	(3) +Interactions	(4) Trimmed
Daylight: Spatial Daylight Autonomy (Base Level: $sDA_{300/50\%}$ 0-55%)				
High Daylight	**0.052*****	**0.051*****	**0.053*****	**0.044*****
(sDA 55-75%)	[0.014]	[0.014]	[0.014]	[0.014]
Very High Daylight	**0.063****	**0.060****	**0.064****	**0.063****
(sDA 75-100%)	[0.027]	[0.027]	[0.027]	[0.027]
Views: Spatial View Access, (Base Level: sVA_3 0-10%)				
High View Access	-	**0.037*****	**0.063*****	**0.044*****
(sVA_3 10-100%: 1 = yes)	-	[0.012]	[0.017]	[0.016]
Building Class (Base Level: Class A)				
Class B Building	-0.114***	-0.113***	-0.113***	-0.116***
	[0.010]	[0.010]	[0.010]	[0.010]
Class C Building	-0.200***	-0.199***	-0.200***	-0.203***
	[0.017]	[0.017]	[0.017]	[0.016]
Building Age at Lease Signing (years)	-0.010***	-0.010***	-0.010***	-0.010***
	[0.001]	[0.001]	[0.001]	[0.001]
Building Age, Squared	0.000***	0.000***	0.000***	0.000***
	[0.000]	[0.000]	[0.000]	[0.000]
Renovated Building (1 = yes)	0.040***	0.041***	0.040***	0.050***
	[0.007]	[0.007]	[0.007]	[0.006]
LEED Certified (1 = yes)	0.004	0.002	0.002	0.007
	[0.010]	[0.010]	[0.010]	[0.010]
Fiber-Lit Building (1 = yes)	0.022	0.021	0.021	0.019
	[0.016]	[0.016]	[0.016]	[0.016]
Lease Term Duration (Base Level: 6-10 years)				
Lease term 5 years or less	-0.047***	-0.047***	-0.047***	-0.041***
	[0.008]	[0.008]	[0.008]	[0.008]
Lease term 11-15 years	0.061***	0.060***	0.059***	0.056***
	[0.010]	[0.010]	[0.010]	[0.010]
Lease term 16-20 years	0.097***	0.097***	0.096***	0.085***
	[0.018]	[0.018]	[0.018]	[0.017]
Lease term 21-25 years	0.204***	0.197***	0.192***	0.194***
	[0.043]	[0.043]	[0.043]	[0.043]
Lease term 26 years or more	0.057	0.056	0.056	0.051

Table 3 – *Continued from previous page*

	(1)	(2)	(3)	(4)
	[0.051]	[0.051]	[0.051]	[0.049]
Free Rent Period (Base Level: 0-6 months)				
No free rent	0.023**	0.024**	0.024**	0.022**
	[0.009]	[0.009]	[0.009]	[0.009]
7-12 months free	-0.033***	-0.034***	-0.033***	-0.024***
	[0.009]	[0.009]	[0.009]	[0.009]
13-18 months free	-0.054**	-0.056***	-0.056***	-0.048**
	[0.021]	[0.021]	[0.021]	[0.021]
19-24 months free	-0.130**	-0.141***	-0.147***	-0.113**
	[0.055]	[0.054]	[0.054]	[0.056]
Over 24 months free	-0.065**	-0.070***	-0.072***	-0.061**
	[0.027]	[0.027]	[0.026]	[0.027]
Transaction Size (sq.ft.)	0.000***	0.000***	0.000***	0.000***
	[0.000]	[0.000]	[0.000]	[0.000]
Sublease (1 = yes)	-0.171***	-0.171***	-0.171***	-0.160***
	[0.011]	[0.011]	[0.011]	[0.011]
Partial Floor Flag (1 = yes)	0.038***	0.039***	0.038***	0.030***
	[0.008]	[0.008]	[0.008]	[0.008]
Multiple Floors in Lease (1 = yes)	0.007	0.009	0.009	0.007
	[0.010]	[0.010]	[0.010]	[0.010]
Tenant Broker (1 = yes)	0.010	0.010	0.010	0.014*
	[0.008]	[0.008]	[0.008]	[0.008]
Landlord Broker (1 = yes)	0.035***	0.036***	0.036***	0.030***
	[0.009]	[0.009]	[0.009]	[0.009]
Landlord Concessions / Work Done (Base Level: Tenant Improvements)				
As-Is	0.041	0.040	0.041	0.033
	[0.029]	[0.029]	[0.029]	[0.029]
Built to Suit	-0.044	-0.041	-0.046	-0.017
	[0.069]	[0.066]	[0.067]	[0.059]
New Building Installation (NBI)	0.065***	0.065***	0.065***	0.066***
	[0.012]	[0.012]	[0.012]	[0.011]
Not Specified	0.032***	0.032***	0.032***	0.040***
	[0.009]	[0.009]	[0.009]	[0.009]
Other	0.012	0.017	0.018	0.019
	[0.056]	[0.056]	[0.055]	[0.056]
Paint & Carpet	0.058	0.054	0.052	0.068
	[0.059]	[0.060]	[0.060]	[0.056]
Pre-Built	0.099***	0.101***	0.102***	0.106***
	[0.021]	[0.021]	[0.021]	[0.020]
Turnkey	0.141***	0.135***	0.137***	0.134***
	[0.040]	[0.040]	[0.041]	[0.039]

Table 3 – *Continued from previous page*

	(1)	(2)	(3)	(4)
Transaction Floor Number (Base Level: Floors 0-15)				
Transaction Floor Number 16-30	0.121***	0.116***	0.112***	0.104***
	[0.010]	[0.010]	[0.011]	[0.010]
Transaction Floor Number 31-45	0.225***	0.203***	0.187***	0.176***
	[0.021]	[0.022]	[0.023]	[0.023]
Transaction Floor Number 46+	0.321***	0.292***	0.270***	0.162***
	[0.069]	[0.069]	[0.069]	[0.059]
Interaction Effect: sDA Level x Transaction Floor Number				
High sDA x Trans. Floor 16-30	-0.030	-0.030	-0.022	-0.025
	[0.020]	[0.020]	[0.020]	[0.019]
High sDA x Trans. Floor 31-45	-0.027	-0.026	0.006	-0.014
	[0.033]	[0.033]	[0.037]	[0.036]
High sDA x Trans. Floor 46+	0.073	0.081	0.118	0.219**
	[0.093]	[0.092]	[0.093]	[0.087]
Very High sDA x Trans. Floor 16-30	-0.042	-0.043	-0.034	-0.023
	[0.031]	[0.031]	[0.032]	[0.031]
Very High sDA x Trans. Floor 31-45	-0.070*	-0.066*	-0.038	-0.031
	[0.038]	[0.038]	[0.040]	[0.040]
Very High sDA x Trans. Floor 46+	-0.233**	-0.210*	-0.186*	-0.099
	[0.113]	[0.115]	[0.113]	[0.105]
Interaction Effect: Daylight (55% sDA minimum) x View Access (10% sVA minimum				
Daylight x View Interaction	-	-	-0.051**	-0.022
	-	-	[0.023]	[0.022]
Location Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects	–	Yes	Yes	Yes
Constant	3.928***	3.925***	3.923***	3.935***
	[0.034]	[0.034]	[0.034]	[0.034]
Observations	6,267	6,267	6,267	6,205
R-squared	0.602	0.603	0.603	0.594
F Adj R2	0.596	0.597	0.597	0.588

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1

and high view access, the impact of both variables on net effective rent is the addition of +5.3% for high daylight, +6.3% for high views, and -5.1% for the interaction between daylight and views, resulting in a combined impact of +6.5%. Conceptually, the -5.1% coefficient for the interaction term indicates that there is value to having both high daylight and high views, however it is not necessarily much greater than having each quality on its own.

The 2.3% standard error for the interaction coefficient indicates that, while statistically significant, the effect of the interaction is relatively dispersed. Nevertheless, the result for the interaction effect is somewhat surprising, given that both daylight and views are highly valued in real estate. We expect that having both qualities in a space would yield to a higher premium than either characteristic on its own. These results prompt avenues of further investigation into the relationship between daylight and views, to better understand how building occupants and tenants differentiate between the two visual qualities.

5 Discussion

It is widely accepted that views positively contribute to the occupants' experience in an office space. Their impacts reflect in both the health benefits and the allure they hold in the real estate market. This paper aims to analytically evaluate how views are understood and valued, both spatially and financially. The proposed view metrics, minimum view potential (MVP) and spatial view access (sVA), provide analytical measures of the view in a space before it is built. The metrics utilize existing design analysis tools (namely, computational daylighting simulation methods) and therefore, are suitable for integration into the architectural design and planning processes. While these metrics do not, nor can they ever, capture the full quality of a view, they are practical indicators of the potential for views. Similarly, the financial results presented in this paper, provide a picture of how tenants value views, using market-wide empirical data. While providing analytical insight into the viewing experience, the work has limitations. We discuss these shortcomings in this section, starting first with the view analysis framework and metrics, followed by the hedonic model.

In the proposed view analysis method, we evaluate views assuming that occupants move throughout a floorplate, and account for dynamic visuals as they change position. Views in all orientations are counted. We cast rays in a 120-degree cone of vision, 180-degrees around the viewpoint, as depicted in Figure 2. The reasons for this are two-fold: one, we assume that occupants will turn their heads and face different directions over time; and two, we assume a open floor plan office, thus the furniture can be oriented in different directions. Further work to refine the internal floor layout and the facade assumptions will help to refine the view analysis. Additionally, in future steps of this work, the analysis method could be modified to target particular views, such as preferred orientations—for example, views that shift over the day based on the position of the sun to best illuminate a landmark or to see the sunset. Finally, the view analysis framework presented in this paper considers only those views that one sees outside a window. In future work, it would be valuable to expand the method to account for internal views. Internal visual connections are an important aspect of how one perceives a space, arguably even more than outdoor views because the objects in sight are in close proximity to the occupant. By evaluating both indoor and outdoor views at once, we can more comprehensively assess the visual experience of occupants. Previous work mapping the internal visual connectivity throughout a floorplate exists and can be incorporated into the method proposed in this paper (Turan & Reinhart, 2019).

The view analysis approach and metrics have yet to be validated. The approach presented in this paper is the first step of a more robust view evaluation method for use within architectural practice, and we see it as a method that will evolve. Nevertheless, the approach does show statistical significance in the economic hedonic analysis. This is not a confirmation of the method's validity, yet the results suggest that the method is differentiating views to some degree.

We carry out a hedonic pricing regression to identify the impact that each property has on the net effective rent for office leases. We are particularly interested in disentangling the relationship between views and daylight. Broadly, the two qualities are closely related as they are both part of one visual experience. We find that while they are correlated, each has its own economically and statistically significant value. The addition of the view variable does not change the value premium of daylight, as established by (Turan et al., 2020). When both high daylight and high view access exist in a space, their combined value is 6.5%—just over the impact of either characteristic on its own. This finding encourages further investigations into how both daylight and views are characterized in space, and how occupants value each quality.

The small margin between the results of daylight and views evaluated together and separately illustrates how the two factors are both entwined and independent. They are both experienced by individuals in a building at a human level, together and separately. In real estate, the experiential quality of daylight and views can be lost in the tally of building specifications. Building upon this work, and thus moving beyond simplification of these qualities, we intend to introduce a nuanced understanding of visual attribute performance into financial analysis. Measuring the economic value of daylight and views distributed throughout a space provides a new way through which to frame the building's relationship to both its occupants and its surrounding world.

6 Conclusion

The value of views in buildings, from an experiential and human health standpoint, is well-known. In the financial models that inform investment decisions, however, this visual design attribute is often considered qualitatively and vaguely. In this paper, we first present two metrics for analyzing spatially-distributed views, and based on the view performance on each floor in a Manhattan-wide sample, we estimate the economic value of view in commercial office properties.

The metrics proposed in this paper are *Minimum View Potential* (MVP) and *Spatial View Access* (sVA). The MVP describes how much of an outdoor view can be seen from one point in the analysis area, and is measured as a percentage of total rays cast from that point that intersect view elements in the urban context. The sVA is a measurement of the sufficiency of MVP viewing potential in an indoor space; it is defined as the percentage of the analysis area that has a minimum viewing potential. The sVA takes into account the spread of view accessibility across a entire floorplate, unlike other view metrics which consider the view at discrete points within space. The methodology used to model views relies upon well-established daylight simulation techniques, and therefore can be easily integrated into an existing computational design workflow. We apply the framework to a sample of 5,154 office spaces throughout Manhattan in New York City.

While economic preferences do not directly reflect individuals' perception of a view, in real estate, it is commonly accepted that tenants pay for better views. Using the results of the spatial view analysis, we employ a hedonic model to measure the economic value of views alongside other factors that impact office property rent prices. Our results document that spaces with high access (10-100% sVA_3) to views have a 6% premium over spaces with low access to views. Because daylight and views are closely entwined, their combined impact on rent price is considered with the inclusion of an interaction term that accounts for their collinearity. Accounting for their interaction, we find that the value of spaces with *both* high view access and daylight, similarly, is 6%. This result indicates that there is value to having both high daylight and high views, however it is not necessarily greater than having each quality on its own.

Recognizing that daylight and views have statistically and economically significant values proportionate to other building and lease characteristics can drive decision-making of various stakeholders in the design and planning of commercial buildings. It is well known that daylight and views positively impact the health and well-being of occupants of a building; this work provides means—both through the proposed metrics and the measured view value— to quantitatively analyze views in the design and development process.

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A Appendix

A.1 View Analysis Modeling Set-Up

The proposed framework utilizes the Rhinoceros 3D modelling environment and its visual scripting plug-in Grasshopper, with the lighting simulation tool Radiance and DIVA-for-Rhino (Robert McNeel & Associates, 2016b, 2016a; Solemma, 2018; Ward, 2016). To tag each type of view element, we label all 3D objects by layer. A 6-foot-by-6-foot (1.8-meter-by-1.8-meter) analysis grid is created on each office floorplate using DIVA-for-Rhino. We assume a 30% window-to-wall ratio and 11.4 foot (3.5 meters) floor-to-ceiling height for all spaces. The models do not include internal partitions, furniture, core spaces, or window treatments such as blinds. This is a limitation of the input data and modeling approach. However, most rented office spaces are fit-out by the tenant once they move in, and often the internal layout is modified during the fit-out. Assuming that the tenant will change the space once they occupy the floor, the model estimates the total possible daylight that the space receives considering the external context and floor plate shape. In other words, the simulations estimate the total *potential* views in the space.

To carry out the raytracing, we use the Radiance program *rtrace*. A Python script initiates the Radiance simulation and post-processes the output to return the view results. An array of 6,111 rays are cast from the position of a observer's eye within a 120-degree cone of vision at an eye height of 5-feet (1.5-meters). We assume that one's perception of a view within a space is often not based on the field-of-vision from one specific position and direction in space. Rather, we consider that occupants' might consider the view at multiple positions in a space and the changing views that they experience as they move through a space. Therefore, all orientations are weighted equally.

A.2 View Metric Assumptions and Parameters

MVP is designed to identify the areas in a floorplate with a potential view. It is developed on the assumption that some positions within a floorplate have a preferable view. The outdoor view elements are considered in the view analysis based on the following criteria:

1. Iconic landmarks, green spaces, and water/distant view rays are included without any exclusion.

2. Neighboring buildings and ground rays that are at least 18-feet (6-meters) away from the origin of the ray. Neighboring buildings and ground rays that terminate closer than 18-feet from the observer are excluded from the MVP calculation. We assume that neighboring building or ground rays that are closer than 18-feet do not add to the quality of a view.[1] The minimum distance is based on the EU standard *EN-17037 Daylight in Buildings*, which suggests that

[1]In the simulation, the majority of neighboring building and ground rays intersect a view element beyond 18-feet. In the Manhattan-wide view simulations (to be discussed in Section 4.1), only 20% of neighboring building rays and less than 1% of ground rays terminate less than 18-feet from the origin point.

views are at least 18-feet away from a building (European Committee for Standardization Technical Committee CEN/TC 169, 2018).

3. Sky rays are excluded completely from the MVP calculation. These are the rays that extend uninterrupted through the urban context to reach the sky. To some extent, they are a proxy for direct solar access. Therefore, to differentiate the view metric from daylight in the hedonic pricing model, we do not count sky rays in the MVP.[2]

[2]If applying the view analysis framework outside the context of this thesis sky rays may be included in the MVP calculation to account for open sky views, which can be essential to a good view. We exclude it in this case because of the close correlation between the sky view and daylight access.