Estimating Office Space per Worker

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Abstract: In the world of the corporate real estate manager, space costs money and the less space we can fit our workforce into the lower are operational costs. The long-term observer of human resource and corporate real estate planners has perpetually heard discussions on how to do more with less space and bring down real estate occupancy costs. Office hoteling or sharing models, telecommuting part time, working in open standardized non-dedicated cubicles all support the aim of lowering occupancy costs. At the same time, the real estate developers, investors and analysts who forecast future office demand must estimate the space required per worker and utilize this along with employment estimates to determine future demand. If we utilized the stated goals of corporate real estate planners we might believe that total demand will be rapidly decreasing in the future. If we utilize the actual space per worker as observed in the market we might become overly ebullient and optimistic in our modeling. So, do we rely more on the rhetoric of planned shrinkages or the empirics of reality for our forecasts? That is the essence of this study - to investigate and reconcile these two diametrically opposed schools of thought and to explain why the truth lies somewhere in between. Using a simulation model we can gain insights into what drives the space consumption higher or lower. Here we account for the reality of growth and churn and downsizing all of which contribute to less effectively using office space. We also recognize that the nature of work and collaboration is now being better integrated into office designs, which will also influence the demand for various types of office space. Conclusions are that we will require more space with more collaborative formats than the optimum preference of the corporate real estate planner and less than the shadow space-laden inventory of the Great Recession.

Draft: September 12, 2012

Keywords: Office space, Space-Per-Worker, Office Demand, Space Planning, Shadow Space, Worker Churn, Space Efficiency

[1] NAIOP Foundation provided research funding for the survey work included in this draft and this support is gratefully acknowledged. The author also wishes to thank Dean David Pyke of the University of San Diego for useful contributions to the methodology used in this paper, as well as the Directors and leadership of CoreNet Global and IFMA (International Facilities Managers Association) for sharing several research reports early on in the research process. Chris Macke of the CB Investment Services Strategy group and several members of Instant Offices provided insightful comments. Dave Pogue and Lisa Colicchio of CBRE were very helpful as was Larry Bazrod, CEO of Corenet Global, and Richard Kadzis, V.P. of Corenet Global.

Estimating Office Space per Worker

I. Introduction

Office space demand estimation is an important topic representing over 12 billion square feet of space and $1.6 trillion U.S. dollars in value in the United States alone, even during the lingering recessionary market of 2009.[2] As of 2012 the office stock may be worth closer to $2 trillion.[3] Office space demand is sensitive to space requirement assumptions, utilization levels, rent levels, tenant type and culture. In many US office demand models we simply assume 200 or 250 square feet without any solid evidence for such an assumption other than conventional wisdom. If you ask a corporate real estate manager or a human resources manager they may tell you the target for their firm is 150 or even as low as 100 square feet per person in the U.S. and even less in Asian or expensive European markets. Firms that have embraced shared standardized space with little variation by rank that is not dedicated to specific employees, and work stations or laptops that hook into shared digital cloud style storage systems are, in fact, able to get by with much less space per employee. However, these low targets per worker are only possible when the firm is able to match it's leased space with a predictable number of employees spending a predictable amount of time in the office. Firms that are growing or shrinking or experiencing significant turnover struggle with matching fixed leased space with current needs.

The estimate of office-using employment growth rate is no more or less critical an assumption than the space required per worker and at the same time, the disparity of assumptions we observe in the market is baffling. More refined office demand models will use space per worker by industry sector with a forecast of the growth by each sector for each geographic market. Often the planning decisions boil down to a reasonable guess on the space requirement per worker and how important it is for everyone to have space.[4] One reason we find a huge discrepancy in the amount of space assumed to be required per person is because of terminology, as generated and used differently in the worlds of space managers and asset managers, but this only explains about 16% of the difference, as described below.

Perspectives and Terms Vary by Trade Association

In 2007 IFMA, the International Facility Management Association, in conjunction with BOMA (Building Owners Management Association International) agreed upon terms that are different from those traditionally used in commercial real estate by brokers, developers and leasing agents within NAR (National Association of Realtors), NAIOP, (Commercial Real Estate Development

[2] See "Slicing, Dicing and Scoping the Size of the Commercial Real Estate Market," Florance, Miller, Peng and Spivey, *Journal of Real Estate Portfolio Management*, Vol. 16, No. 2, 2010.
[3] Rough estimate by the author using the composite index of the Costar Commercial Repeat Sales Index, when value weighted.
[4] Some firms will allow employees to work at home or alternative work places. Others will rent temporary space for over flow demand. These issues will be addressed in more depth later in the paper.

Association) or CCIM (Chartered Commercial Investment Member). IFMA with BOMA came up with the following terms:

> "Interior Gross," which is basically the same as "Gross Area" in commercial real estate terms.
>
> "Plannable Gross": Perimeter encroachments are subtracted from gross area. For example, window seals are subtracted or posts and beams that protrude into the interior.
>
> "Plannable": Vertical penetrations like elevators and service areas are subtracted. This is fairly akin to what commercial real estate people call the RBA (Rentable Building Area) although the commercial real estate people may not subtract all space intrusions.
>
> "Assignable": This is the net usable space where all interior encroachments including demising walls and partitions are subtracted. The net useable space for commercial real estate would generally not subtract non-supporting interior dividing walls.

In a survey conducted near the end of 2009 and tabulated and published in 2010, IFMA received 424 completed responses detailing space use for different types of organizations. The sample was nationally stratified and included Canadian provinces as well as U.S. states. It was fairly proportional to population so the largest number of surveys came from California. The typical building was 31 to 50 years old but ranged from 1 to 200 years. Using the IFMA definitions of space, Plannable Gross or RBA was 93.8% of the Interior Gross. So as of 2009, landlords lost on average 6.2% of the building from rentable space, because of vertical penetrations and encroachments. When we go from RBA to "Plannable," also called "Usable Space," tenants lose 16.2% off of the RBA based on the facilities managers' calculations. When you go to "assignable" space adjusted for interior encroachments IFMA ends up at 75.6% of the RBA. This means that the tenant might consider themselves as having 250 square feet per worker (using the usable definition of IFMA) while a landlord might calculate this out at 298 square feet, as they are charging rent on the RBA space even though some of it is not usable. This helps explain how the corporate facilities managers might have smaller figures per worker than real estate people who are relying on RBA definitions.

In section II below is a discussion on US national office space per worker trends compared by various geographic metrics. In section III this same discussion is continued in light of differences by industry group. Section IV considers the impact of alternative workplace strategies and Section V reviews the prior literature upon which this research builds and section VI presents a model within which we generate estimates of the amount of space per worker that will be observed on average, in light of stated efficiency targets. In Section VII we take an operation managers perspective on optimizing space and in section VIII are the conclusions and summary of findings.

II. Space Per Worker Trends

If we only look at the square feet per worker on **new** leases where the tenant moved in within the last 90 days, we see a US national average in mid-2012 of 185 square feet.[5] Newer modern buildings also allow more efficient use of space, especially when built to suit for a particular tenant. As the lease ages, the amount of space leased and the number of workers in the space generally changes with the result that the space per worker climbs. As second generation tenants replace the first generation tenants, it is often more difficult to use the space as efficiently, and this is the case for most smaller firms who cannot, on their own, drive new supply in the market.

Some firms grow and some shrink and some are able to negotiate expansions more easily than contractions, especially in soft markets. As of 2012, on leases close to expiration the average space per worker is often double the estimate for new leases.[6] Newer firms and start-ups squeeze more people into the same space while older firms can't downsize until leases expire. This might help to explain why the average square feet per worker shown in Exhibit 1 is so much higher than the figures suggested by corporate real estate executives or facilities managers. We also must keep in mind that Exhibit 1 is based on RBA, rentable building area, and not the plannable or usable space that is used by the corporate real estate world. ***This difference in terminology alone explains as much as a 16% upward bias in the figures.*** Instead of 340 square feet, the corporate real estate person might calculate this as 283 square feet. Still, when we do not discriminate by origination date, that is, when the lease was signed, and simply look at how much space the average tenant occupies, the figures are quite large.

In soft economies we would expect a fair amount of shadow space. Shadow space is leased but not occupied. Since labor costs matter much more than occupancy costs, by a factor of approximately 10 to 15 in the typical U.S. city, most tenants are able to honor their leases until the leases expire and pay for more space than they actually need. The extra space also provides a convenient option to expand and hire more workers without the need to move. So we should expect to observe significant extra space in weaker economies, when rents seem to be bargains, and we do. When space per worker trends are climbing it usually suggests that tenants have not had the chance to downsize yet and are awaiting either the expiration of the lease or simply riding out the weak economy with extra space. The more uncertain the future need for workers the more optional space a firm needs to control in order to be able to ramp up quickly. This point will be demonstrated later in the discussion.

Exhibit 2 is a sample of averages pulled from mid-2010 from a sample of various cities. Note that while we see more space per worker in the larger cities like New York and Boston, these

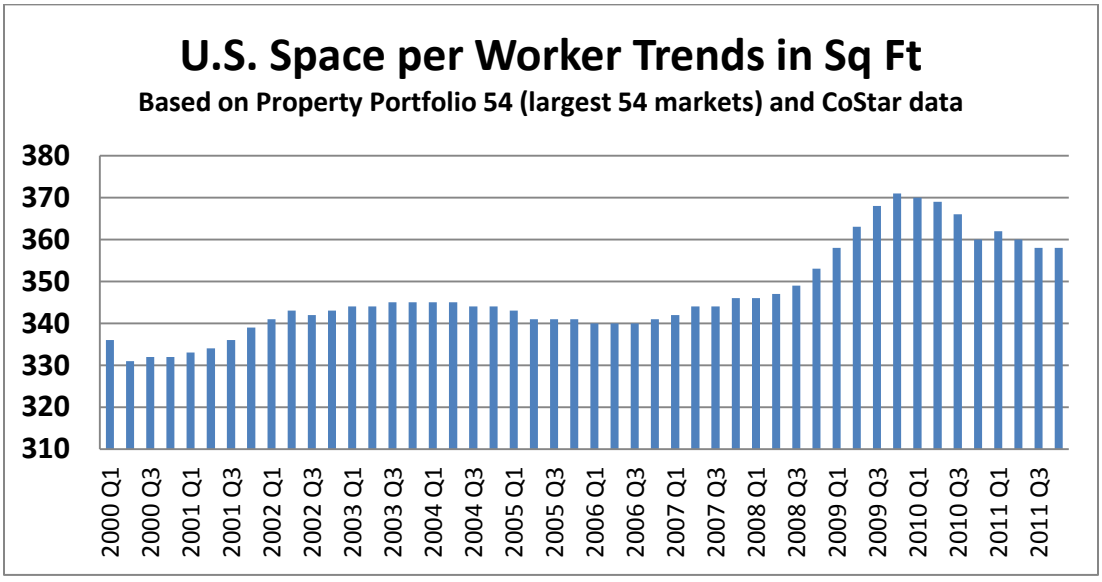
[5] Source: CoStar data in August of 2012. These numbers are reflective of the new leases in major markets and a fairly tight economic environment where firms do not want too much excess space even though they feel that current rental rates are attractive. They also suggest that firms are trying to use less space than observed on older leases which skew the averages.

[6] For leases with original terms of five years that are within the last year of their lease, we see figures that are double the estimate for new leases. This is certainly a reflection of a soft economy and lots of shadow space.

markets also have more shadow space, as of the point of the survey, compared to smaller markets.[7] Only Honolulu in this survey is close to 200 square feet per worker as of 2010, and we know that Honolulu is an extremely supply-constrained market. We also know that in the very expensive markets of London and Hong Kong the average space per worker is on average much smaller than the figures shown here, so we should not presume that larger more expensive cities always require more space per worker.[8] Exhibit 3 provides a rough global comparison of space per worker and we note that the Japanese and Chinese occupy much smaller footprints per person on average, reflecting perhaps both costs and culture.

Certainly shadow space provides much of the explanation for the run-ups in 2008-10. If we take the lower 340 average square feet figure in the last decade as more realistic of what a firm prefers, we would estimate that, on average, firms had about 9% excess space in 2010, some much more and some much less. If you assume a lower figure, based on the more recent leases, but are still conservative at 250 square feet, you would estimate that the average firm has one-third of its space as excess shadow space as of 2010. Certainly this has and will continue to decline over time, but figures as conservative and elusive as 200 square feet per worker remain more aspirational than anything else.

Exhibit 1: U.S. Space per Worker Trends in Square Feet



[7] One other bias in the square foot per worker data is that in the larger cities where we observe retail space on the ground floors, this space is classified by CoStar as "office" and not retail space, so that there is a slight upward bias in the measurement. Certainly this is insignificant for the nation as a whole, but for large cities like New York, San Francisco and Boston it may mean as much as a 5% upward bias helping to explain why in Exhibit 2 we see larger numbers than might be expected in the larger cities.

[8] Mark Hickey and Aaron Jodka, Senior Economists from PPR (Property Portfolio Research, a division of CoStar) suggest that we observe more high-paid jobs in markets like New York and Boston compared to smaller cities and so the space allocated per person is larger while back-office people work in cheaper areas.

Exhibit 2: Square Feet per Worker By U.S. Market

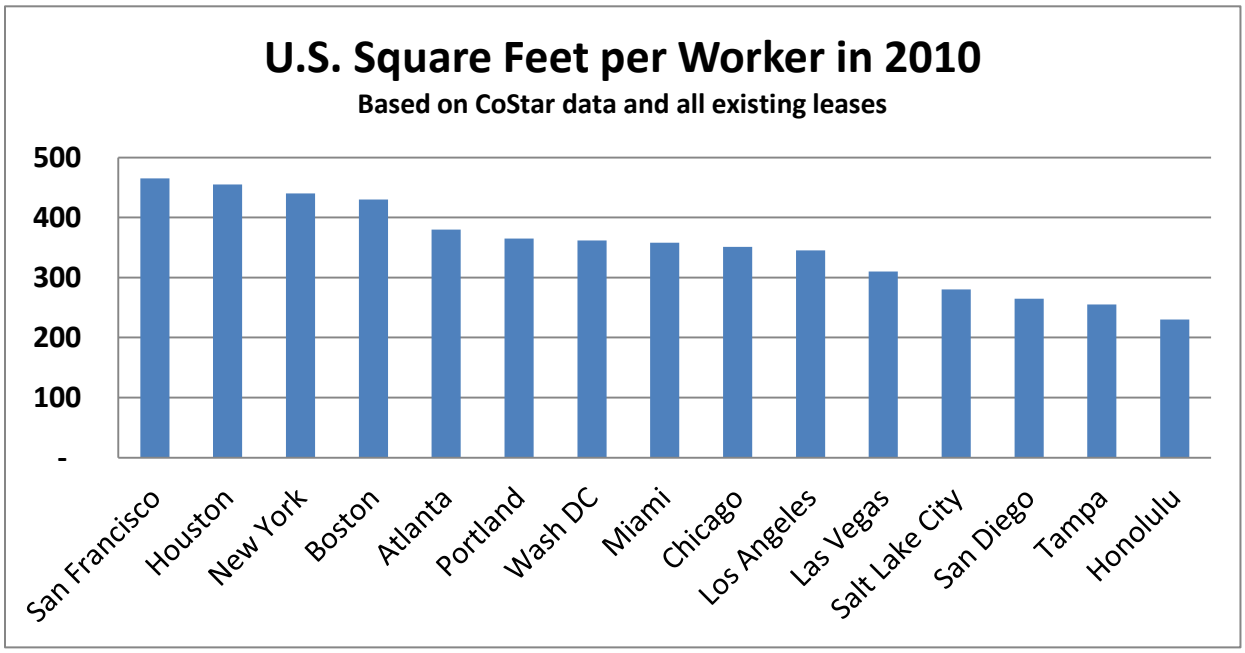
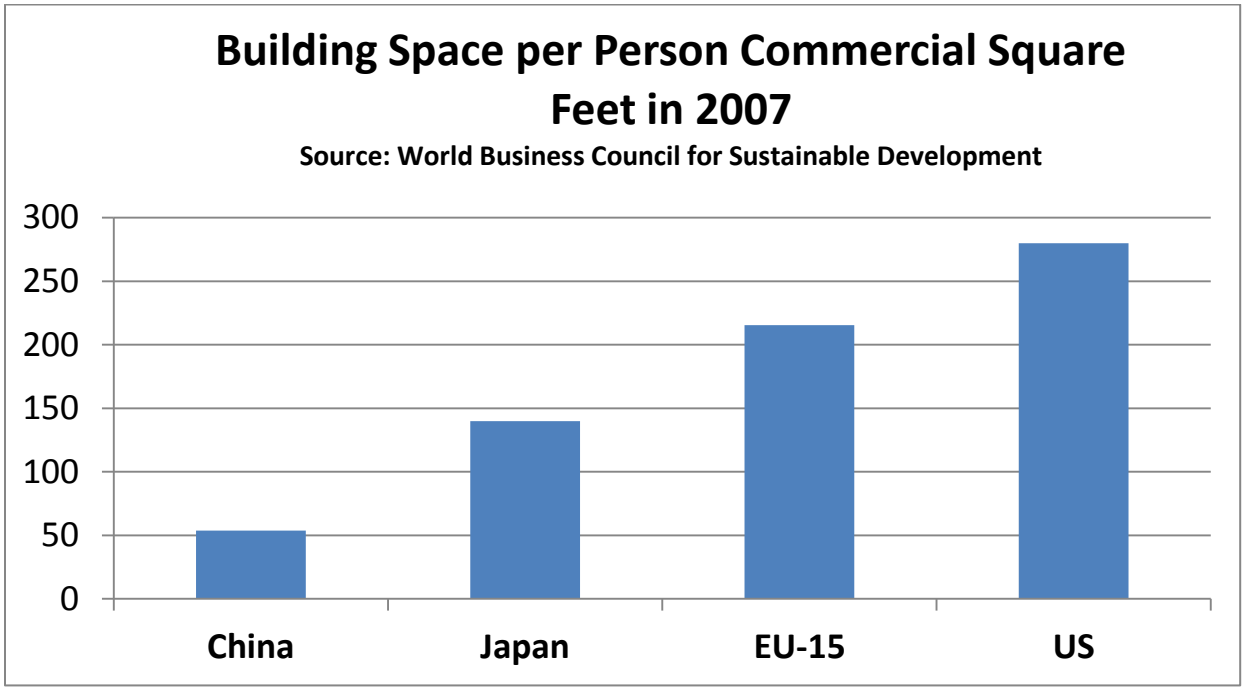


Exhibit 3: Building Space Consumption Varies Around the World



III. Space Per Worker by Industry or Function

Aside from call centers that cram a lot of workers into small cubicles where they answer telephones, we see fairly large figures for the typical space required by industry, relative to the goals stated by corporate real estate executives. At the same time call centers are now being

shifted to home-based workers, at least in the U.S., where computer networks manage phone call systems and workers answer phones when they are available, saving transport costs, overhead and allowing a more flexible work schedule so this group of intense space users may be less relevant in the future statistics. Knowing that 2011 was a year with significant shadow space, we would still expect to see some variation by industry. It is not surprising then that government space is both fairly generous to workers, but also includes some public access and service space that might help explain the well-above average space use per worker results. Law firms come in tops as high space demanders followed by accountants, architects and financial institutions, which often include generous open space at branches. The results in Exhibit 4A are not inclusive of all industries but merely serve to demonstrate that we will find systematic differences in space demands when we analyze each industry group. We compare CoStar and IFMA data in this chart, which demonstrates perhaps some systematic differences in measurement definitions as well as different samples and slightly different time periods. If a particular industry group, such as telemarketing which operates through call centers, is moving into an area and has stated that they need to hire 1,000 new workers it would have dramatically less impact on office market space demand than 1,000 architects or computer software designers. When possible, space per worker in demand estimate models should be adjusted for what is typical in the relevant industries. We see this approach used in the more sophisticated models of office demand, discusses next. In Exhibit 4B we update the data to show that over the past two years firms have been eliminating some shadow space.

Exhibit 4A: Space per Worker By Industry

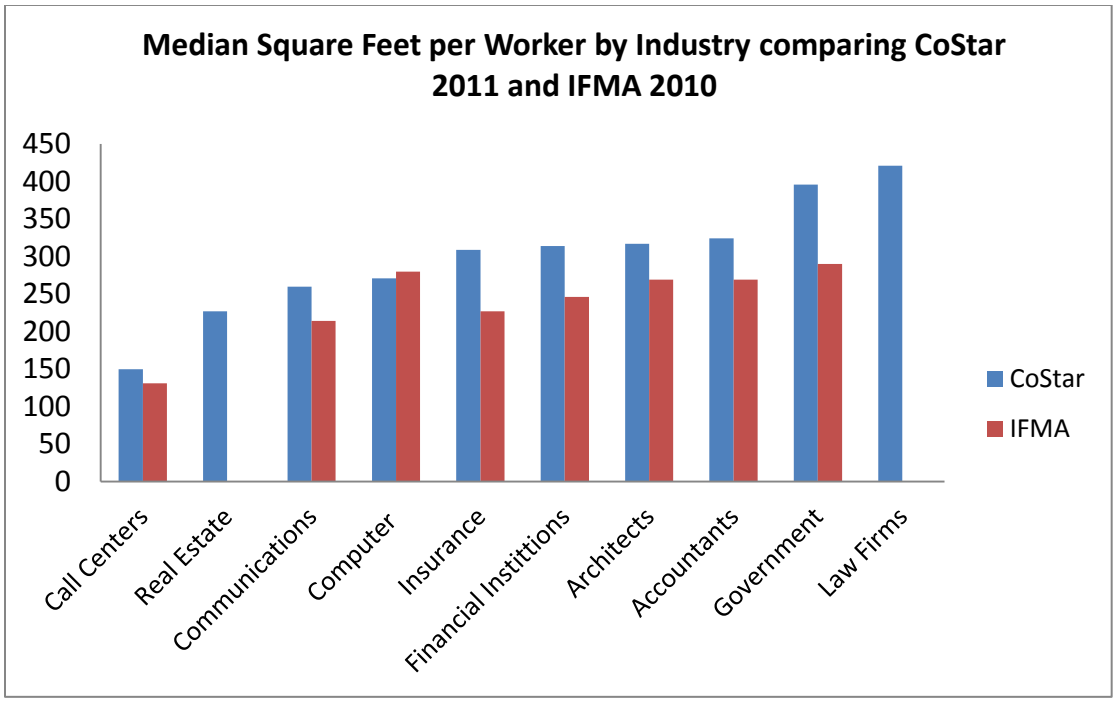
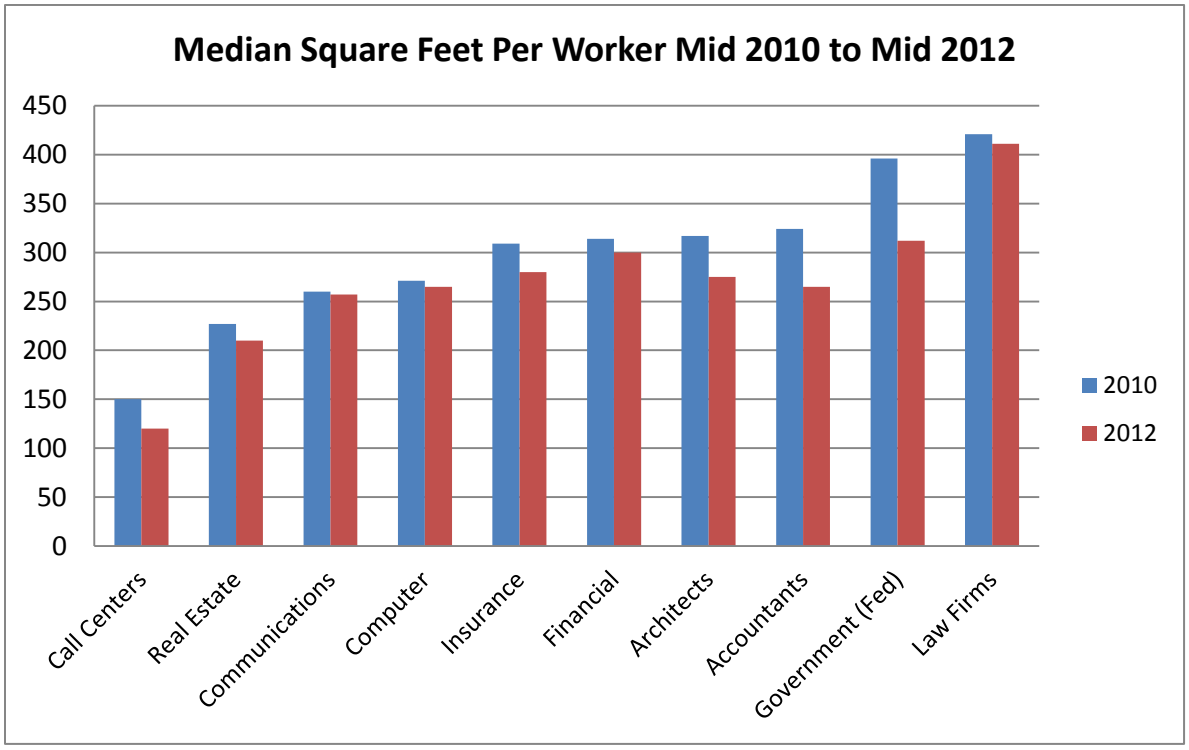


Exhibit 4B: Decline in Space Per Worker Mid 2010 to Mid 2012: CoStar Data



IV. The Impact of Alternative Workplace Strategies

Those familiar with the writers on innovation realize the importance of collaborative work environments. Those who worked with Steve Jobs, founder of Apple, have spoken about his insistence on creating an environment of chance encounters and uninhibited private exchanges, which is why he wanted people to primarily work in person.[9] Video conferencing can work as long as the images are large, high quality and include body language and many firms have started to add high quality video conference facilities in the offices of senior managers. When Pixar set up their new offices they made sure to provide lots of natural light and collaborative space.[10] Other features typical of similar firms focused on collaboration include open floor designs that let people see others working to provide a sense of excitement and a team concept, flexible space available for any kind of use, and recreation space where employees could have

[9] For example, Greg Bandeau of Pixar and Disney Animation, worked with Steve Jobs and discussed these points on September 6th, 2012 at the Global Forum on the Culture of Innovation by the Aspen Institute and the ULI in San Diego.

[10] For examples of similar workplaces around the world see http://www.hongkiat.com/blog/creative-modern-office-designs/

fun together. In a survey of office tenants by Teknion[11], a UK based firm, published in 2012, 77% of respondents said that by 2015 they will have more open collaborative workspace with fewer fixed offices, 62% said that work space would be denser and 54% said they had plans to reduce office footprints. 46% said that more work would be done at home, or outside workplaces from the coffee shop to the library, and 31% had mobile working programs. These results are consistent with the surveys of Corenet members and CBRE tenants provided in the appendix to this study in Exhibit A-1.

What every firm is seeking is greater productivity and technology now allows more flexibility in terms of where and how we work. They also want to attract and retain talent and these newer workplace designs are oriented at making workers feel they are part of a team. Cost minimization is not always a stated goal but many firms have recognized that the utilization rate of private office space is typically less than 50%. From a survey conducted by the author of both CBRE tenants and Corenet members, it appears that everyone wants to use less space.

In Exhibit A-2 we see that the smaller more private tenants use more space per worker and while both CBRE tenants and Corenet members have goals to reduce space per worker, the larger firms are more aggressive is seeking to reduce space per worker. Note also that these space per worker figures are significantly lower than the CoStar data suggests as of mid-2012. In Exhibit A-3 we see utilization rates. The CBRE tenants and the Corenet respondents suggest utilization rates of 67% and 64% respectively. Keep in mind that these are estimates and based on the author's intuition and experience, are probably higher than reality. Firms do not like admitting that they utilize the space less than they do. It is also not clear if the CBRE tenants understood the question since a few of the respondents indicated a utilization rate of 100% which means that every space is occupied all day every day during working hours. The Corenet respondents estimate is likely closer to reality.

Typical strategies to reduce space per worker are:

- ✓ Allowing the worker to work anywhere, when not in team meetings,
- ✓ Reducing the percent of dedicated private space
- ✓ Standardizing space and using more open designs
- ✓ Requiring that files are stored on a centralized server
- ✓ Using temporary office space providers when overflow demand for space exceeds capacity.

If every tenant moved to 90% office utilization rates we would see a dramatic decline in total space required, however the type of space required would often need significant retrofit. We will explore the impact of these trends later in the paper.

[11] http://www.teknion.com/

V. Prior Office Space Literature

Relying extensively on an excellent review of the literature by Rabianski and Gibler (2007) which covers the literature going back to 1965, we observe that models of office market demand analysis have become more complex and able to segment demand by industry and/or geographic area as better data has become available. Rabianski and Gibler, build upon the review work of McDonald (2002) and divide the body of literature into those models which are econometric in nature and those which are judgmental in nature. In the former case we have demand and supply models that attempt to capture the stock and flows of the office market, such as additions, deterioration or demolitions. In the latter case, we seek to understand the dynamics and how office demand is changing over time and what drives these changes, such as technology or the changing nature of where and how people work.

Early studies (Jennings 1965, Detoy and Rabin 1972, Lex 1975, Martin and English 1985) attempted to understand how much office space was needed by using ratios of non-manufacturing employment to population or office space to employment. As better industry breakdown became available, we saw more segmentation into industry grouping (Kelly 1983, Schloss 1984, Clapp 1987, Birch 1988) or by headquarters or private vs. public space or the size of the firm (Carn, Rabianski, Racster and Seldin 1988, Dowall 1988). Throughout most of the literature we see heavy reliance on FIRE employment as a proxy for office employment. FIRE is the Bureau of Labor Statistics classification for the finance, insurance and real estate industries, and this is utilized by Clapp (1989 and 1993) and many others. More ambitious modeling attempts using stock-flow models that included both demand and supply variables have been provided by Rabianski (1994 and 2004) and a continuation of work on industry segmentation as new industry classification approaches became available including both the older SIC (Standard Industrial Classification) and newer NAICS (North American Industry Classification System) first adopted in 1997. For example, Fanning (2005) uses NAICS and most studies in the future will likely rely on these more modern descriptions of industry grouping.

Most of the early models estimating future office space demand relied on crude estimates of space required per worker based on surveys from BOMA (Building Owners and Managers Association International) or gross estimates of total space divided by employment (Clapp 1993). DiPasquale and Wheaton (1996) note that space per worker should vary by occupation, that the space may vary over time as the occupation and technology changes, and that space per worker may vary by market and costs. When viewed as a factor of production we may also see that the space demand per worker varies with changes in productivity, economic cycles where we see excess or tight supplies of space, and the real or expected costs of space. DiPasqaule and Wheaton show that space demand is considerably higher per worker in relatively inexpensive markets compared with more expensive markets.[12]

[12] DiPasquale and Wheaton, *Urban Economics and Real Estate Markets*, 1996, pp. 296-297.

The typical office demand model today will be based on the growth or decline in the particular mix of various industries over the next several years in a particular metropolitan area. A few such models will differentiate the space required per worker in different industries or by the type of use (headquarters vs. branch). The sensitivity of future office demand to the estimated space required per worker cannot be overstated.

Several studies have examined the trends in the space required per worker including Grissom and Kuhle (1983), Birch (1988), Dowall (1988), Crone (1989), Powers and Hunter (1989), Ragas, Ryan and Grissom (1992), Shilton (1994), Hakfoort and Lie (1996) and Liang and Kim (1998). En masse these studies have established how the space per worker has changed over time, differs by occupation, and market conditions, type and size of organization and as technology evolves. John White's 1993 commentary on space per worker reflects acknowledgement that technology, planning and design could affect trends in the space required per worker. White writes: "In the 1960s and 1970s, the introduction of air conditioning into office buildings caused an expansion of the total space demanded per worker because air conditioning equipment took up a great deal of room….at the same time…the use of office partitions and space planning reduced the amount of space allotted per worker."

Hakfoort and Lie had several hypotheses supported in their 1996 study including the following:

1. Office space per worker differs by industry sector and occupation.
2. Office space per worker is higher in smaller and older buildings. (Less efficiency is possible in smaller and older buildings.)
3. Office space per worker tends to be smaller in more expensive (rent) cities.

Office space per worker depends on the layout of the internal space. (Better space planning reduces space per worker.) We can summarize the evolution of the models as follows:

O = total office space demand in square feet
α = space per worker in square feet
β = share of total employment that is white collar
E = total employment growth over period t
e = professional employment growth over period t
i = industry i
m = metropolitan market
h = headquarters
cbd = central business district share
s = suburban share

$O = \alpha\ \beta\ (E_m)$
$O = \alpha(e_m)$
$O = \alpha\sum (e_{mi})$
$O = e\{\sum \alpha h_{m,i,cbd} + \sum \alpha(1\text{-}h)_{m,i,cbd} + \sum \alpha h_{m,i,s} + \sum \alpha(1\text{-}h)_{m,i,s}\}$

While sequentially we have moved from models that used population or total employment estimates to models that differentiated professional employment to models that differentiated professional employment by metro, industry segment, central business district or suburban locations and headquarters or not, one critical assumption remains constant; the α, space per worker.

Space planners and in particular the corporate real estate managers from CoreNet Global and the facilities managers from IFMA (International Facilities Managers Association) continually strive for greater space use efficiency including office hoteling or sharing plans and more standardized and substitutable space. The goals of several reports from these two key trade associations are often 165 to 185 square feet per worker, and if you presume an increased trend toward telecommuting and office sharing, the existing office stock seems grossly superfluous. For example, in a 2010 report by Cushman & Wakefield aimed at corporate real estate executives, the firm suggests that space per worker can be reduced by 25%, not by reducing the actual office space per worker but by increasing the headcount per unit of space with more sharing of space.[13] Based on this presumption, Cushman & Wakefield illustrates the benefits of moving from 200 square feet to 150 square feet per headcount. Naturally, such strategies - if widely implemented - would quickly reduce the total demand for office space.[14]

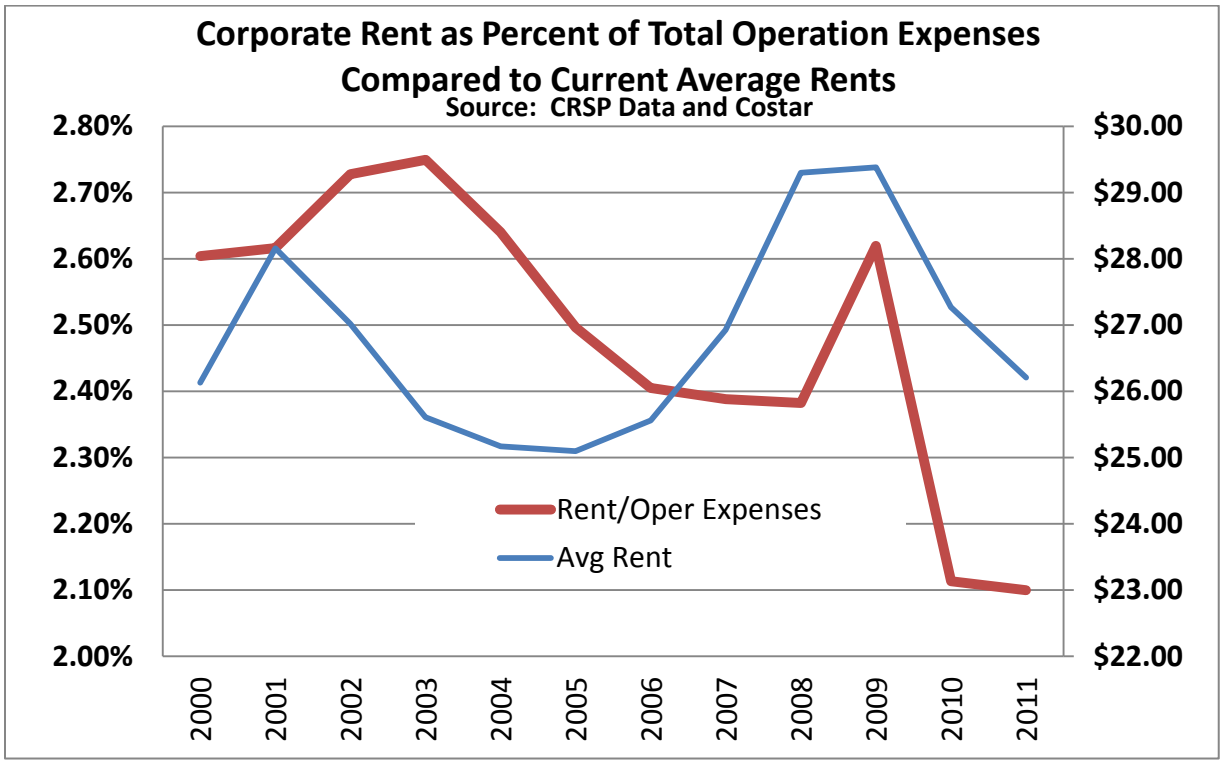
As we read the goals of space planners and then compare the realities of space per worker trends and the space per worker on new leases we find they are totally incongruous. Bible and Whaley (1983) hinted at one reason for such differences in that occupied net space and actual leased space may differ and today we must presume a great deal of space is leased that is not actually required. As leases expire we should expect that new leases for many downsized firms will be in smaller spaces and lower space per worker figures. However, these economic cycles are not new, so unless the real costs of space have significantly declined, we should expect that space utilization and efficiency will trend down. We also note that if you start with assignable space per worker (their actual cubicle or office space) we see that from 1994 - 2010 the allocated space per person has declined slightly, from 115 to 95 for senior professionals and 90 to 75 for professional technical staff, excluding the conference space, team space and common areas that may have increased slightly over this same time period.[15]

To examine if the real costs of occupancy have trended down and if this could explain greater demand for total space or less pressures for the efficient use of space, we pulled a sample of CRSP (Center for Research in Security Prices) data from public companies and produced the following two Exhibits 5 and 6. What we observe in Exhibit 5 is that rent relative to operational

[13] Cushman & Wakefield "Occupancy Optimization Considerations for Professional Service Firms" by Matt Jackson and Nnenna Alintah, 2010, **Business Consulting Report**.
[14] One assumption, verified in many studies suggesting office hoteling, is that many professionals are often out of the office in meetings, on sales calls, or engaged in business travel.
[15] See IFMA 2010 Space Benchmarking Report.

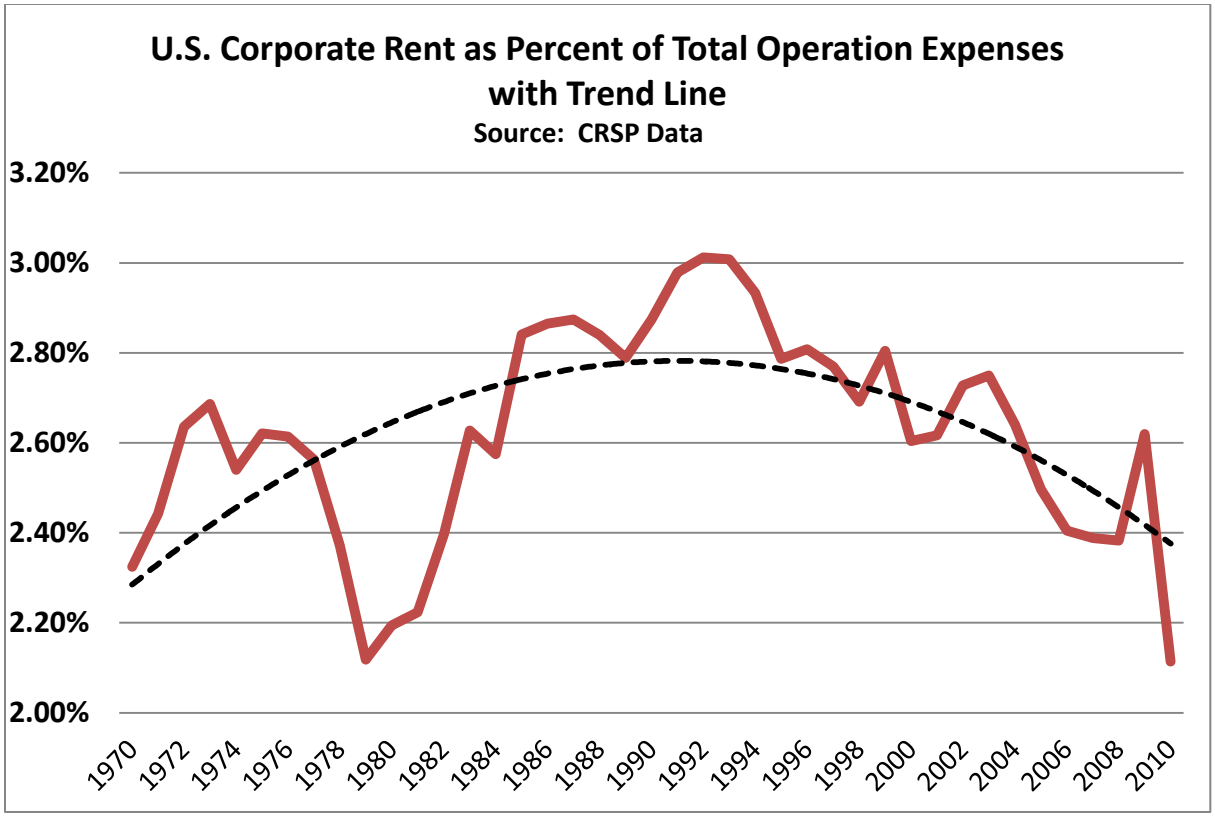
expenses are proportional to and lag average rents, so that as rents go up or down, so do the rent to operational costs for the firm.

Exhibit 5: Corporate Rent Relative to Total Operational Expenses of All Public Companies and Average Rent



What we observe in Exhibit 6 is that from 1970 - 2009, occupancy costs relative to total operational costs (including labor and all costs) increased in the 1980s and then have generally declined. From a peak of some 3% of all operational costs in 1993, we see that rent declined to around 2% of total operational expense in 2009, a relative decline of 50%, suggesting the real costs of occupancy have declined significantly from 1990 - 2010.

Exhibit 6: Public Corporation Rent as a Percent of Operational Expenses



Importance of the Space per Worker Estimate: Many analysts need to translate the changes in employment to expected changes in demand for space. Aside from adjustments for particular industries, if the average presumed is based on something slightly less than the current U.S. space per worker as the long-run equilibrium estimate, we might use 350 Square feet per worker. If we relied upon the targets of the managers from IFMA or CoreNet Global we might use something closer to 185 or 200 square feet, and the difference in total space demanded is enormous, with one estimate at nearly double the other. The truth probably lies in between and in the next section we will explore how we might reconcile the goals for space per worker with the actual observed market evidence. We will not try and differentiate demand for space as a function of quality (Class A, B or C or with the CoStar 5 Star System) but leave that to future research.[16]

[16] We do know that historically as the office market weakens and real rents decline tenants often upgrade to better space.

VI. Office Space Per Worker, OSPW, Simulation Model Description

The following variables describe key elements in the decision as to how much space to lease. We recognize that extraordinary space demand can be fulfilled with temporary office space providers and we will deal with that issue in more detail below.

x_i = office space type, 1, 2, 3, 4, etc. where each type represents a non-interchangeable type of space with any other. Space types typically are of different sizes with larger sizes allocated to more senior staff and management.

s = shared office space percentage for each office space type x_i from 0 to 1.0 for 100%.

n = lease term in months or the specific month.

gw = goal space per worker in terms of average square feet based on total firm space divided by the average number of workers allocated office space. The total space of the firm is based on rented building area, RBA, including all space required for the firm such as common areas and conference rooms and hallways and storage areas.

ge = goal space per employee based on the total number of employees of the firm assigned to a particular regional or office. This is merely a derivation of gw dependent on t, described below.

t = percentage of total worker time expected to be spent intentionally working at home or airports or coffee shops or other locations.

p = percentage of the time that workers spend with clients or outside the office, in work related functions, while they are based in the traditional office space. This time may overlap with t above, unless defined as while based in the regular office space.

gr = growth rate in the firm in terms of employees per year stated on a percentage basis in negative or positive terms.

c = churn rate based on the percent of employees that turnover each year from 0 to 1.0 for 100%.

cm = average time in months required to fill a vacated position.

U = utilization rate defined as the percent of total time desks are occupied using a one shift day of 8 to 10 hours. There is no weighting by square feet, so each desk is counted as one. This calculation is an output that is based on the simulation results. Where U exceeds 1.0 there would a need to double up, use conference rooms for temp space, secure or rent temporary space outside the regular office. This variable is an output that is put into an optimization framework using a stock out model approach, as described in the next section.

The goal space, gw, is based upon the following process: If the firm is growing, then it is solved at the end of the lease term and back calculated to find the amount of space occupied in each

period back to the start of the lease. We assume here that this is only one type of space, although this will be relaxed below. The process is merely a geometric progression, where:

gw = ge/t(p) and then we solve for each period of the lease back to zero based upon the following pattern derived from the compounded growth rate:

(1) $OSPW = ge/t(p)/(1+gr)^n$

The importance of solving for the space required in any period is that while the goal space may be 100 square feet per worker, a firm signing a 5 year lease will need to over consume space in the beginning in order to accommodate employee growth. Alternatively, the firm could price out the required extra space and this would feed into the maximum reservation price for a lease option clause permitting expansion when required. Longer term leases that may take advantage of cyclical "bargains" require extra consumption up front. While firms rarely sign long term leases while in downsizing mode, downsizing simply happens unexpectedly, and this also results in extra space consumption. Such uncertainty is modeled through the range of growth rate assumptions, from negative to positive, using the 90% confidence range of typical growth rates for a sample of CBRE tenant firms and Corenet Global members.

Note that office space per employee is merely a function of what percent of the workforce is assigned traditional office space.

Now let's factor in time out of the office, which is only relevant if $s > 0$, and we need to do this for each office type x_i so that we repeat and sum the model based on allocating all space to one of the potential office space types.

(2) $OSPWx_i = s(ge/t(p)/(1-gr^{)n})$ so this sharing of space has the effect of reducing the total space required as a function of the degree of sharing and p, the time spent working outside the office, while assigned to space inside.

Next let's factor in the churn rate, c, and time to fill the vacated slots, cm.

(3) $OSPWxi = s(ge/t(p)/(1-gr)^n)/(cm/12c)$ so this has the effect of adding some friction to the efficient use of space by acknowledging that some of the time space will be empty waiting for new hires.

Next, let's factor in various types of space in the simulation by using a ratio of space for each office type, thus for type x_1 we may have 1.5 times the average space per worker and for x_4 we may have .5 times the average space per worker. The average weighted space will be the same as for the goals, but we must recognize that churn in space x_1 in this case will create a larger impact on the overall unplanned space per worker compared to the x_4 worker type space. We do not show this in equations since it is merely a repeat of (3) above for each x space type where the result is summed. Note that the more office type spaces that cannot be substituted, the more friction in the system.

For the assumptions behind the model, we used a survey conducted through the assistance of Corenet Global, representing larger than average tenants, and CBRE, representing more typical smaller scale tenants. The intention was to generate a representative range of results over the spectrum of office users, but not to do a definitive study over all function and industries and geographies. Such research will require a much larger sample over many geographic regions. The results of this survey are provided in the appendix.

VII. Office Space per Worker Demand Generated from an Operations Management Perspective[17]

Imagine inventory as space available to house workers and imagine that we are unsure about how many workers we will need to house over the next several years. The longer the term of our analysis the more difficult the problem becomes, and in turn optimal space decisions are harder for longer-term leases or when owned space is involved.[18] Still this operations management is a useful framework for modeling space demand, consistent with an optimization based on marginal utility analysis in economics.

From an inventory management perspective, we have two kinds of costs: overage costs, $C_{o,}$ when we have too much inventory (space) and underage costs, C_u, when we have insufficient inventory. We need to select the right level of inventory or office space per worker, OSPW, that balances these two costs. If these two costs were equal then we would end up seeking the amount of OSPW that has a 50% probability, P, of being too much or too little space. In this case, we seek to find OSPW that satisfies the following condition:

$$P(OSPW) = C_u/(C_u+C_o) \text{ such that } P(OSPW)<X = .5 \text{ where X is the actual space required.}$$

The ratio which provides an optimum could be based on the marginal costs of adding temporary space, where available, such as that provided by instant office space providers. Using a sample of temporary office providers[19] and annualizing the cost, which obviously will vary by market, we end up with typical rents at least four times that of traditional space. This is akin to comparing a hotel room rent with an apartment and so such differentials are not unexpected. This

[17] See Silver, E.A., D.F. Pyke and R. Peterson "Chapter 10: Style Goods and Perishable Items" in *Inventory Management and Production Planning & Scheduling*, John Wiley & Sons, Third Edition, 1998. Note that if we took a space planners' perspective, we might start with a cubicle or office and make assumptions about how many times and what size of conference space and team space that employee type might need to generate a total space demand model. In either case we should end up with an average target of space per worker, when the worker is actually present.

[18] One can imagine shorter-term leases with lots of options to renew and lots of expansion rights as a solution to such problems, but these lease clauses are not free and need to be priced. These issues will be addressed later.

[19] Such as HQ, Instant, Regus and others provide monthly rentals of fully furnished spaces while firms like Liquid Space, see www,liquidspace.com provide small conference rooms by the hour. The costs for a typical Instant workstation may run $800 to $900 per month for 120 square feet plus access to conference space and common areas, converting to about double the rate for long term leased traditional space in bulk. For the instant space provided by firms like LiquidSpace we see rates in the $60 to $90 US dollar per hour range for a conference room in a major city that would hold 4 to 6 people.

is similar to using the differential between the costs of having too much space to the cost of having sufficient space. The cost of having too much space is less than the cost of not having enough, so if the cost of too much space is one-fifth that of too little space, we end up with the same exact ratio, as when the costs of marginal space is five times as expensive, seeking the following solution:

$P_x<OSPW = 4/(4+1) = 4/5 = 80\%$

implying that we wish to have 80% confidence that we will have sufficient space. P_x is the probability the demand for space is less than x, the actual needed. If the cost of temporary space is higher, say nine times that of regular space, then we will want to be 90% confident we have sufficient space at any point in time.[20]

The approach used in operations management is no different from that used in microeconomics where we set the marginal benefits equal to the marginal costs as the minimal sufficient condition for an investment decision, such that the last unit of space added, $OSPW^*$, is that which sets the expected cost of too much space, C_o, equal to the expected cost of too little space, C_u, recognizing that these costs may not be equal per unit of space.

The concept of optimizing office inventory or seeking to avoid stock outs of sufficient space is identical and parallel to the utilization, U, goal of firms, where they seek a minimum or average utilization rate. Utilization rates are based upon the occupancy rate for all available desks over the course of working days, measured periodically. Traditional firms have rather modest utilization rates, typically 50% to 60%, according to Corenet Global research.[21] But those firms which allow sharing of desk spaces, known as non-dedicated office space, and some telecommuting may experience utilization rates of 80% or higher.[22]

The Effect of Friction: When internal spaces are not substitutable.

The above model becomes more complicated when the internal spaces (inventory) are not substitutable. We might think of office cubicles as fairly homogeneous and substitutable and in those firms with fairly generic and flexible space, there is less friction in adjusting to the needs of workers with different levels of specialization and authority. In firms with more structured authority or specialization and less flexible space, there will be higher transactions costs to adjust space resulting in space inventory supply friction. In this case, the optimal space model becomes a summation of several sub-space optimization models, each with its own inventory of space and its own demand.

[20] General estimates for temporary office space suggest the cost is about 8 to 10 times the typical cost for longer term leased space, based on anecdotal evidence collected by the author at the CORENET Global conference in 2012.
[21] See research reports at www.corenetglobal.org The survey in the appendix conducted here suggests slightly higher rates but it is not clear that all respondents understood the term correctly.
[22] Firms like Accenture and Procter & Gamble intentionally run at 80% and even 90% or higher utilization rates.

Firms like Procter & Gamble have moved to more standardized space, which allows for greater ease of space optimization strategies. Other firms with formal hierarchies of managers, each with different space requirements, will end up with much more required space per person simply because of the lack of substitutability. Think of a firm with one CEO, one COO, 10 senior VPs and 30 VPs, 50 sales staff and then 300 other staff workers of various kinds, each with their own space requirements. A senior VP leaves the firm and rather than move a regular VP into the office, it sits empty rather than risk the charge of favoritism being applied to the facilities manager that allocates space. These frictions increase the need to secure more space per worker for the entire firm as the probability increases that space will remain unoccupied for uncertain periods. So we can conclude that the less substitutable the space, the higher will be the summed average space per worker in a firm, all other things equal.

One can also envision the effects of turnover on optimal space decisions. The lower the level of turnover – often a sign of a well-managed and well-motivated workforce – the easier it is to plan for space needs. Some firms have turnover rates above 30% and rather than constantly moving workers to empty offices, many desks or cubicles are likely to remain unoccupied pending the time required to recruit, train and re-staff. So, the higher the turnover rates of any given firm the higher the variance of total space demand and the increased likeliness of needing more space per worker.

Simulation Analysis of Optimal Space per Worker

We can simulate many of the effects discussed above and will do so below. The key variables for the simplest model, where all workers are treated the same (no difference in space per worker) are as follows, with the low, base and high figures provided:

	Low	Base	High
Initial number of workers		119	
Average space per worker as targeted by space planners	65	150	200
Annual turnover rate in employees	5%	20%	33%[23]
Time in months required to fill a position	1	3	5
Growth rate in the firm with respect to number of total employees	0	5%	18%
Length of initial lease	3	5	10

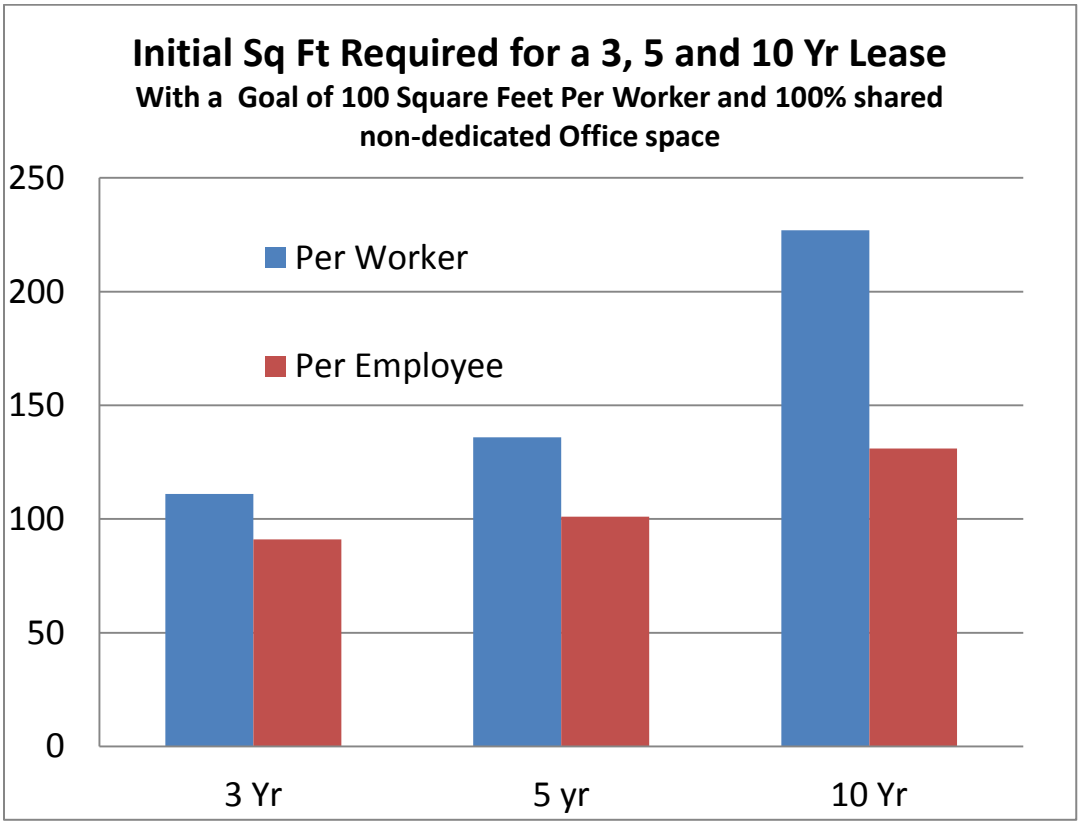
[23] This assumption is higher than revealed in the survey but the author is aware of a few firms with turnover near this higher range.

Triangular distributions were utilized in a Monte Carlo style simulation with the following results. First, we will compare lease terms, then volatility and substitutability.

Comparing Three-, Five-, and 10-Year Leases

The longer the term of the lease, the more space that must be leased now relative to the average number of employees using that space over the term of the lease. In Exhibit 5 we use 100% non-dedicated office space and assume that 50% of the employees are randomly out of the office at any one time on average. The other assumptions are as listed above with an average employee growth rate of 5%. The goal of the tenant is to get down to 100 square feet per worker, noting that many of the employees are out of the office at any one time. The results are fairly obvious that the faster the firm is growing the more space you need to lease up front, in order to accommodate the extra employees. However, we also note that uncertainty over growth rates and the ability to renew existing space and option addition space with expansion clauses suggest great benefits to shorter leases, such as 5 years, even for growing firms. That explains why expansion clauses are so common among many office leases and why 5 year leases are far more common than 10 year leases.

Exhibit 5: The Impact of Lease Term on Space Required at the Time of the Initial Lease



The growth rate of the firm is particularly important and we will show that below for a 5 year lease. We now use 150 square feet per worker as the target goal for the tenant, but just as easily could have used 100. OSPW stands for office space per worker and we show the entire range of results. On average we will need 204 square feet when the configuration target is 150 and we are using a five year lease and the firm has a range other assumptions, such as growth rates, as described above. At the 90% confidence level, suggesting we wish to be 90% sure that we have sufficient space, we will need to secure approximately 215 square feet. Thus, we initially need 43% extra space beyond the target. In the third year our results suggest average space per worker of 168 and 200 at the 90% confidence level.

Exhibit 6A: Space Required Per Worker as a Function of Growth Rates (First Year Results)

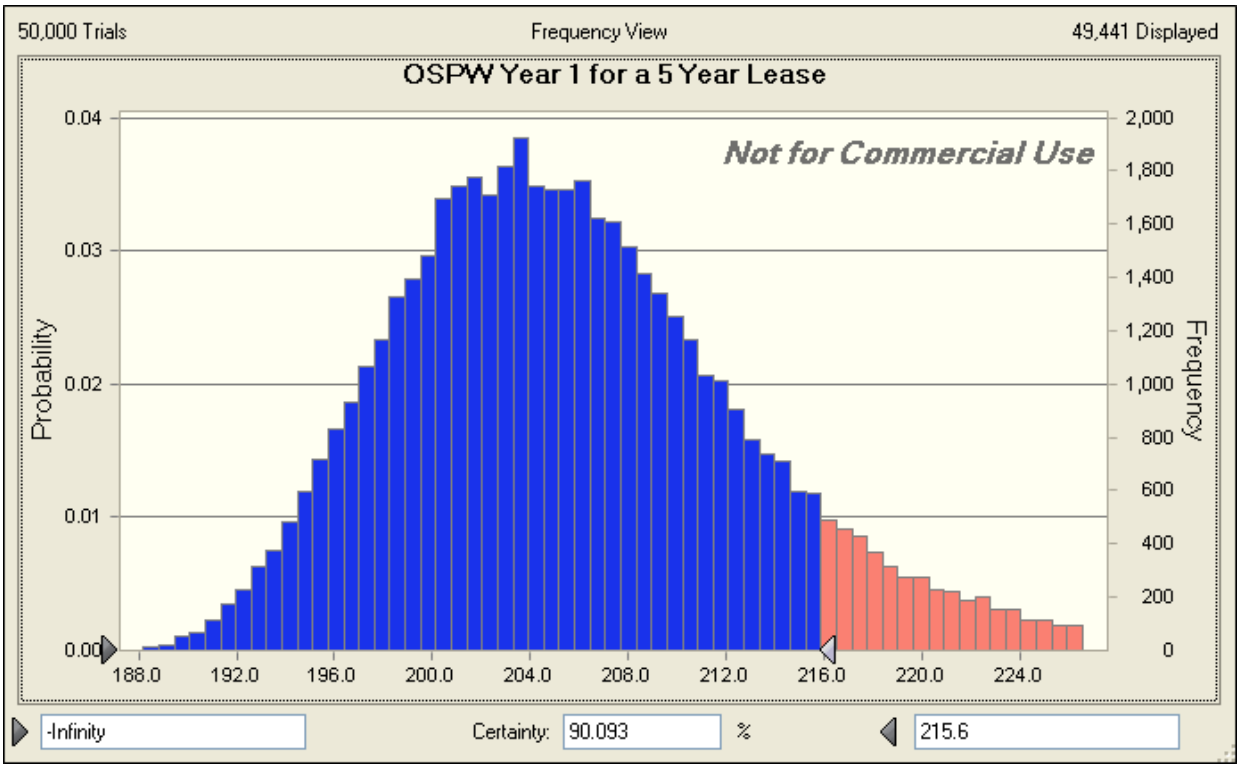
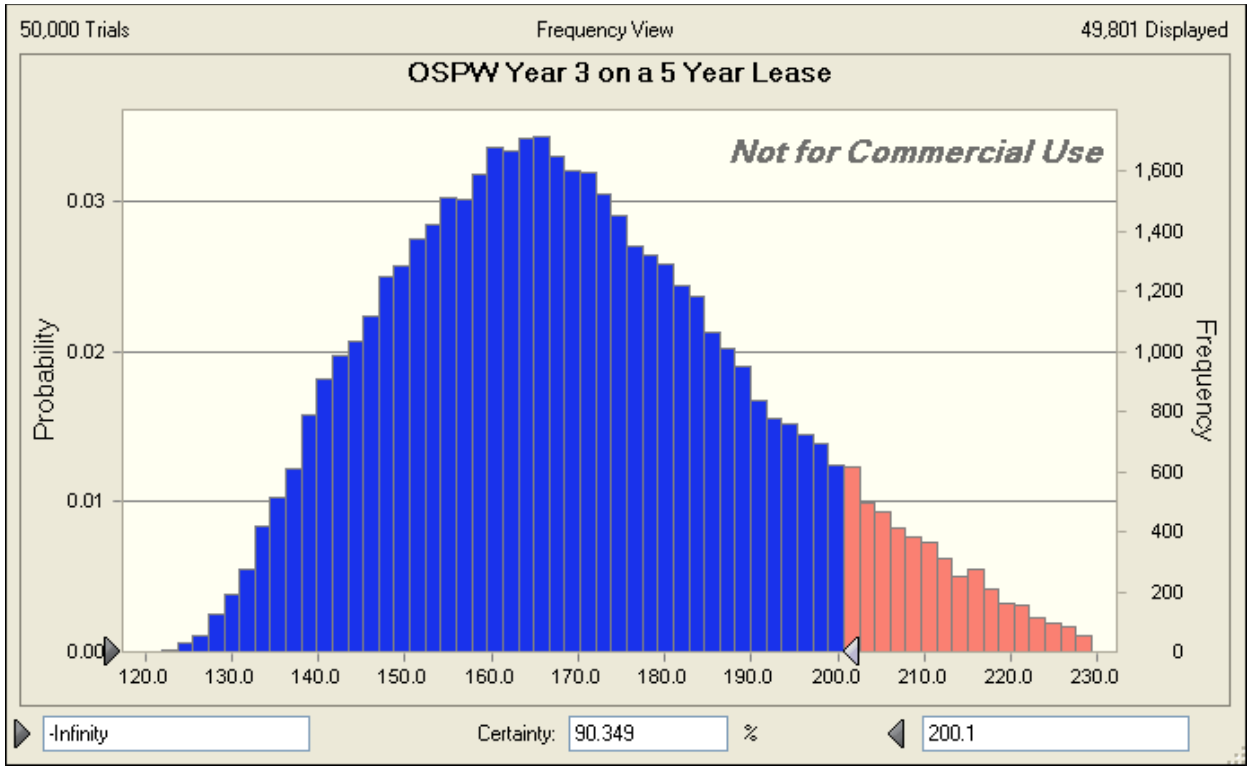


Exhibit 6B: Space Required Per Worker as a Function of Growth Rates (Third Year Results)



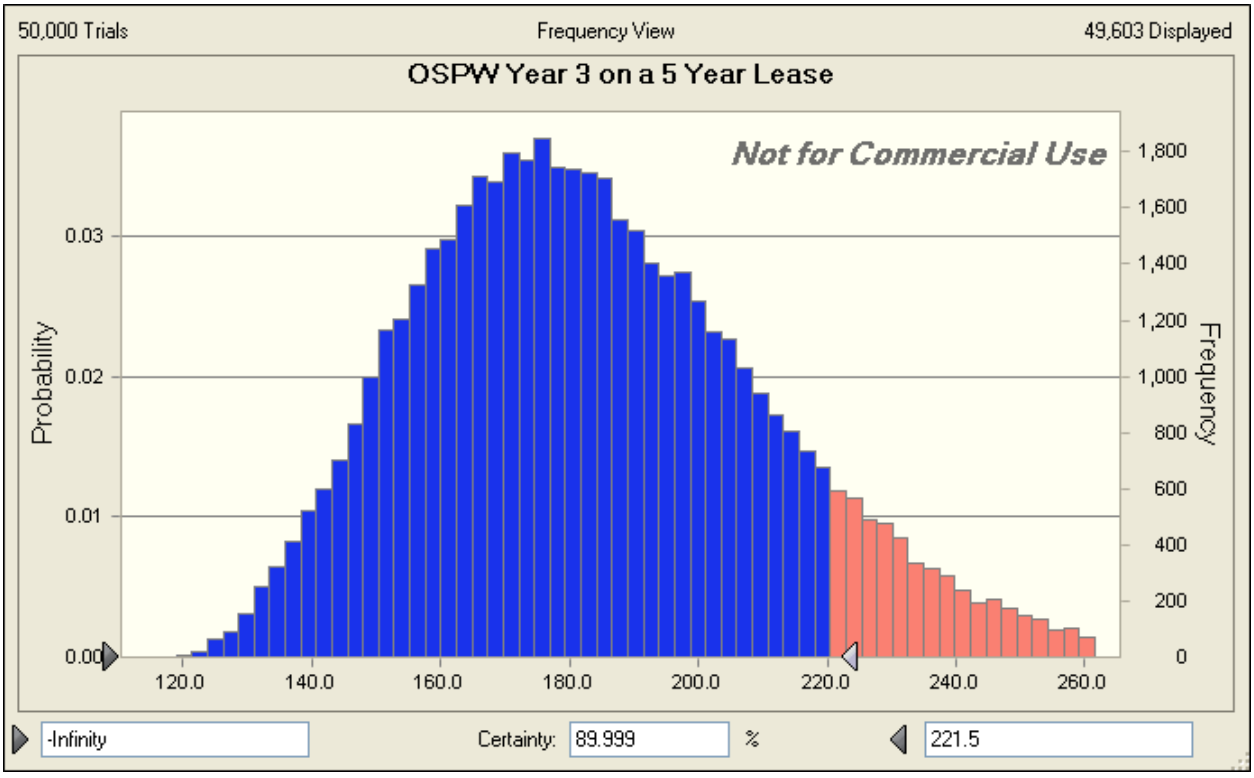
Churn rates and employee turnover are investigated next. We go back to our base case but increase the churn rate of the employee turnover. While there is some impact, it is modest as long as the time to fill positions is modest with low volatility. So, churn alone does not have much impact. On the other hand when the time required to fill a position increases, we see corresponding and somewhat linear increases in the amount of space required, so that if the average churn is 10% and we go from 1 month to fill a position on average to 3 months, we will increase the vacant space and resulting space per worker by approximately 2%.

Unique office spaces and what we call here space friction has far more impact than churn rates. When a firm has 100% standardized non-dedicated space, in theory anyone can use any office, but when we increase the number of unique offices and make these non-substitutable the demand for office space accelerates especially when all space is dedicated to specific individuals. Below we introduce four types of space that are not substitutable and allow frictions in all three spaces with the same general assumptions as in the base case, except that staff space is not substitutable with middle management and neither are substitutable with senior management, we get a result that is much larger than in the case of homogeneous space, all of which may be substituted. We use the following unique space assumptions:

Space Type	Percent of Total	Ave. Sq. Ft Each (including common areas)
1	80%	117
2	10%	150
3	7.5%	300
4	2.5%	450

The results are shown in Exhibit 7 below with 100% sharing among the space type 1 but no sharing within space types 2, 3 and 4. The average space allocation is 142 for each worker, but with turnover and growth and space frictions, we observe significantly higher figures. In year one the space required per worker is 220 on average and 251 at the 90% confidence level. We show year three below, which suggests 181 square feet on average and 221 at the 90% confidence level.

Exhibit 7: Space Required Per Worker With Dedicated Space for Senior Management and Non-Dedicated Space for Staff with an Overall Goal of 142 Square Feet Per Worker.



Simulation Model Findings

1) While firms may target 200, 150 or figures as modest as 100 square feet per worker, only a firm with an extremely stable worker base, little turnover, modest growth and fairly standardized non-dedicated space could possibly get close to achieving these targets on average over the course of an entire lease. The longer the lease the harder it is to hit targets.
2) The higher the confidence limit required that all workers will have sufficient office space, the larger the space per worker required. As we relax assumptions about worker stability and firm growth, we find that much more space is required relative to initial worker counts at the start of a lease than expected at lease expiration.
3) The faster the growth rate of the firm in terms of required workers, the more space required at the start of a lease. Shrinking firms will far exceed space per worker targets which explains much of the shadow space observed in the market during and shortly after recessions.
4) The greater the churn rate of workers, the more space required per worker, but only modestly. Time required to fill a position has more impact.
5) The greater the number of non-standardized spaces that are not substitutable between ranks within the firm the lower will be utilization rates and the greater will be the space per worker. In firms with totally dedicated space and several layers of unique spaces, the average consumption of space per worker will be as much as twice or more that of a firm which shares standardized non-dedicated space. The implication is that branch operations with more standardized space will be able to use space more efficiently than headquarters and those with more managerial delineation within office space allocations.

Implications

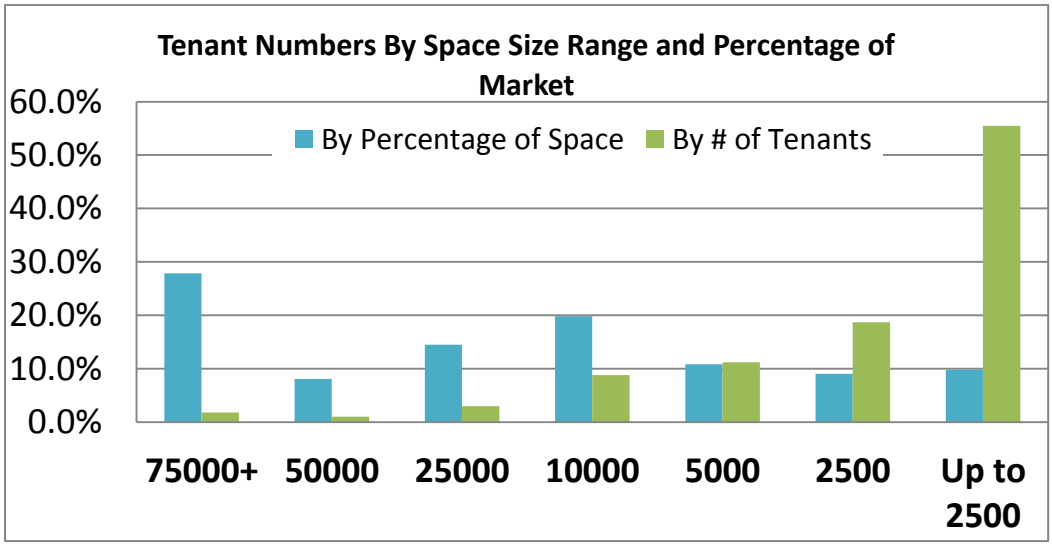
Based on input from Corenet Global members and CBRE tenants, the larger tenants are the ones working harder to use space more efficiently, especially those with footprints over 75,000 square feet. This group tends to encourage digital storage on centralized cloud based servers and use non-dedicated standardized space for all but the most senior of managers. This group represents 1.8% of all tenants in the US by count and 27.9% of all office space. Those using more than 50,000 square feet represent 36% of the total office stock. In Exhibit 8 below we show the proportion of space occupied by tenant size. If we assume that using some of the space sharing strategies described above, that 36% of the firms can reduce their primary leased office footprint by 50%, moving from 250 to 125 square feet, this would be the equivalent of 540 million square feet out of some 12 billion office square feet as of 2009.[24] Historically this is equivalent to 3.6 years of average US deliveries of net new space to the market which has averaged close to 150

[24] Using CoStar estimates on the size of the market based on "Slicing, Dicing, and Scoping the Size of the US Commercial Real Estate Market" by Florance, Miller, Spivey and Peng, Journal of Real Estate Portfolio Management, Vol. 16, No. 2, 2010.

million square feet per year since 1983. At the same time we recognize that little space has been added from 2009 through 2012 and the office stock has actually shrunk due to increasing obsolescence. Absorption has been positive for the two years prior to third quarter 2012.[25]

Decreases in total office consumption based mostly on higher utilization rates, take time, and it is likely that these moves towards more efficient use of space will require many years of transition. At the same time that we are seeing some downsizing, we are witnessing a new kind of space being required, one that lets in more natural light with better natural ventilation, with better temperature control and providing for more collaborative and more productive workspace.[26] With this perspective in mind, much of the existing office space is obsolete and requires retrofitting. As such, there will be substantial opportunity for both redevelopment of old space and new development of better space in the growing markets. The innovations of cloud based computing, shared storage, video conferencing and high speed internet has freed up locational constraints allowing many professionals to work anywhere they wish, mostly coming to the office for collaborative work and meetings and some firms are taking advantage of this flexibility.[27] If all the 12 Billion plus square feet of existing US stock were instantly updated to accommodate the new style of work and the higher quality features of more sustainable real estate, we would not need any more space for a few years. But such a transition to better space takes decades as we only build about 2.1% of the stock on average in net new space each year and significantly remodel something close to the same amount.

Exhibit 8: Proportion of Space Occupied in Each Space Size Range By # of Tenants
Source of data: CoStar 2012



[25] Source: CoStar reports.
[26] See the work of Miller and Pogue (2009) or Miller, Pogue, Tu and Saville (2010) To achieve LEED certification, leadership in energy and environmental design, as developed by the US Green Building Council, requires that 75% of the occupants have access to natural light. See www.usgbc.org. LEED certified office space now accounts for about 15% of the total space of all US office space.
[27] For example, Procter & Gamble and Accenture.

VIII. Conclusions

Since the turn of the millennium, we have seen office space per worker in the U.S. average more than 300 square feet, while at the same time many space planners were aiming at much lower targets. Office space per worker peaked near 370 square feet at the end of 2009, a year or so after the trough of the recession. In the years that followed, leases finally expired and firms were able to downsize space that was no longer needed. Clearly, significant shadow space remains as of 2012, and some will be eliminated as the lease cycle facilitates the ability to wring out more excess. Yet net absorption has outpaced this downsizing in most markets and many firms have continued to hold onto excess space, in part because the real costs have come down over the last two decades. We must also keep in mind that IFMA and Corenet Global use definitions that result in space estimates per worker that are some 16% smaller than those used by NAIOP and BOMA resulting in significantly different reports on space actually occupied.[28]

The largest firms have embarked on path towards more efficient use of space seeking much higher utilization rates. This is possible only with extensive use of standardized non-dedicated space and a policy which allows great flexibility in terms of where employees work. Slightly more than a third of the market is represented by larger firms that are attempting to downsize footprints over the next several years. Still the culture of private space remains and the transition to smaller footprints will not occur at speeds greater than the normal net increases in office demand. And the need for collaboration and innovation works against this trend of working at home or even in private offices, suggesting the need for more common area. Some firms have also added significant play space in attempts to keep workers happy and retain talent. It is too soon to know if this is a general trend or more aligned with software, design, entertainment and web based services.[29]

Few firms will ever be able to hit their target allocations of space per worker. The reasons are quite straight forward. Firms must anticipate growth and turnover, time to fill positions, and the types of spaces that are required. Seldom can any firm forecast growth rates or unexpected shrinkages of workers so accurately that this alone results in some over consumption of space relative to average needs. Shorter term leases with expansion options may alleviate some of this over capacity but during tighter rental markets such expansion space, in nearby locations, will not always be available. The research here suggests that excess capacity of as much as 40% is necessary in the beginning of a five year lease for a firm that expects to grow rapidly. Temporary office space, using conference rooms, or letting employees work at home, may alleviate some pressure when a firm reaches capacity, but temp space alternatives are fairly expensive compared to long term leased space and not yet that available in smaller markets.

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[28] IFMA is the Institute of Facilities Managers Association and NAIOP is the International Association of Industrial and Office Properties. BOMA is the International Building Owners Managers Association.

[29] For example, IDEO, Microsoft, Google, Facebook and Pixar all provide significant recreation facilities within their main offices. See http://www.hongkiat.com/blog/creative-modern-office-designs/ or http://www.fastcodesign.com/1664735/what-schools-can-learn-from-google-ideo-and-pixar

Firms retaining a multi-level hierarchy of management, with office space configuration as a signal of rank, will find it harder to use space efficiently just as second generation tenants do not fit as efficiently into any given space as first generation tenants.

Other trends that might help explain the seeming excess of space compared to space planning targets include the trend toward multi-office branches and the existence of global firms that require occasional office space for visiting colleagues and clients. Many a senior management person retains an empty office in one city while using a visiting office space in another city.

The demise of the office market has certainly been exaggerated, and we will likely see a continuation of space demand far in excess of the targets espoused by space planners. Moving forward in time we will see some firms achieve square feet per worker of less than 100 square feet, but given the cultural impediments and the challenges of predicting growth rates, we are more likely to see figures at double these targets for quite a while. It is unlikely in the real world of worker turnover, with both growing and shrinking firms, that typical firms will ever reduce actual space per worker to the stated goals. New trends in collaborative workspaces aimed at enhancing innovation and productivity may actually force a more rapid pace of renovation and new buildings to replace the significantly obsolete office configurations of 2012.

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Appendix: Survey Results

Exhibit A-1: Corenet Global and CBRE Survey Median 2012 Results

Attribute	**Corenet**	**CBRE Tenants**
First Generation Space	50%	26%
Second Generation Space Refurbished	50%	74%
Non-dedicated Shared Space as % of All	15%	5%
Allow Telecommuting By Workers (yes)	71%	55%
Use Temporary Office Space Providers (yes)	21%	3%
Time required to fill a position (Ave Months)	3.8	1.8
Typical lease in years	5.0	5.0
Lease expansion options (yes)	57%	58%
Different types of office space configurations	2.9	3.3
Private space as percent of all space	20%	36%
Years in Business	30.6	22.0
Average Number of employees	29,623	204
Publicly Owned	75%	36%
Non-Profit Firm	7%	0

We might generalize that the much larger Corenet Global type tenants are more likely to be using first generation space, allow telecommuting by employees, use temporary office space for over flow demand and utilize space at higher rates with less private space. Both large and small firms had several types and sizes of space. Five year leases, often with renewals and expansion clauses were common. One might have expected the larger firms to use longer leases but apparently the need for longer leases is accomplished through options for renewal.

Exhibit A-2: RBA Space Per Worker and Target Space Per Worker in Square Feet

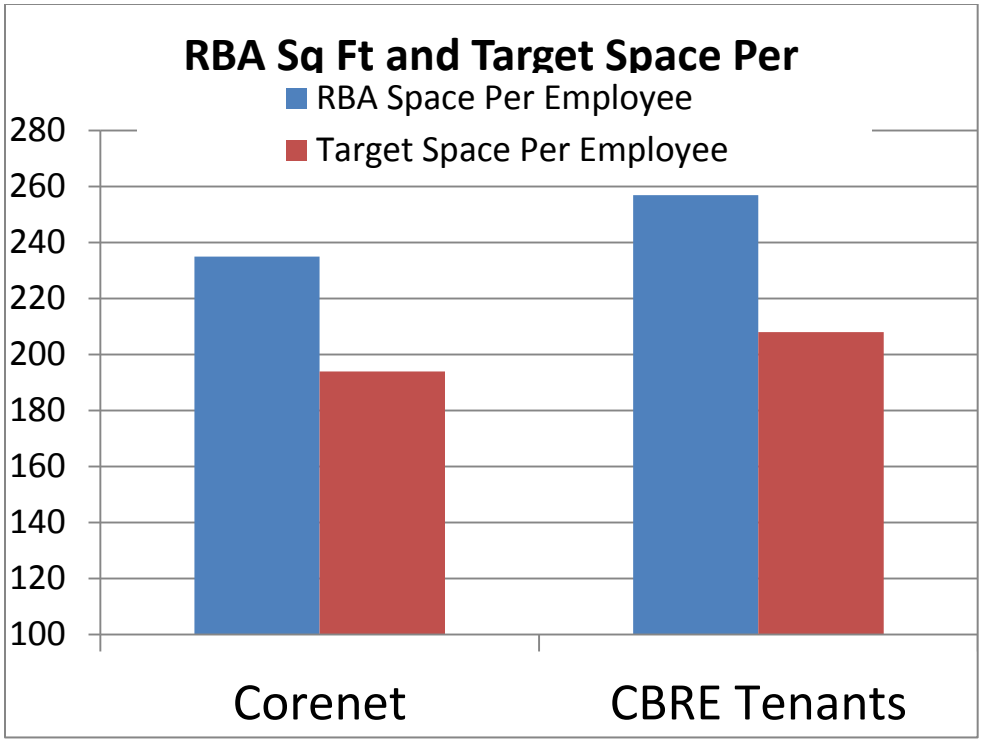


Exhibit A-3: Utilization Rates

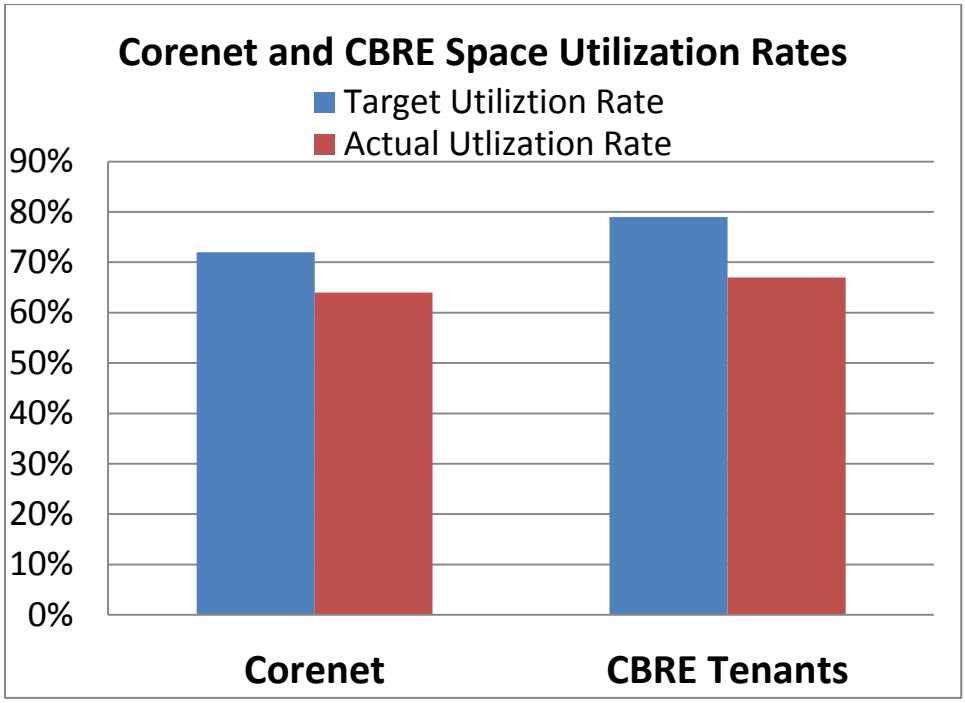
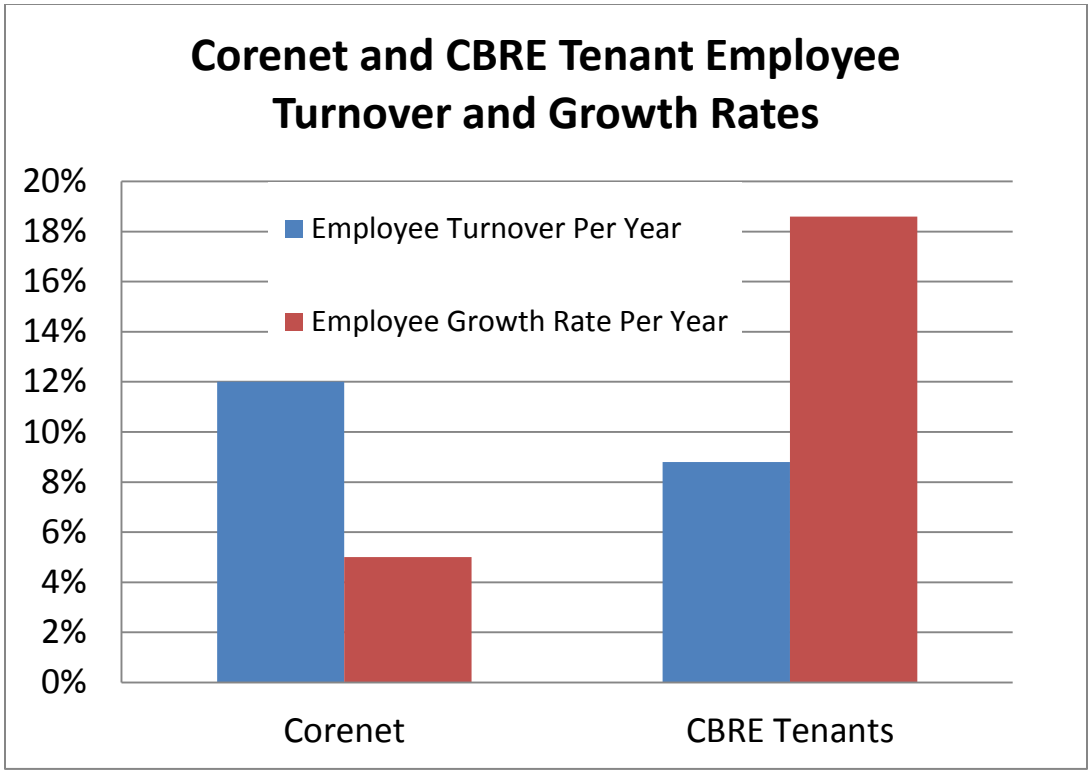


Exhibit A-4: Employee Growth Rates and Turnover Rates



In Exhibit A-4 above we see the much faster growth rate expectations of the smaller firms and the slightly lower turnover rates. These are consistent with prior expectations and verify a range of turnover assumptions in the models tested. The time required to fill a position is also much longer for the larger public firms, again consistent with priors and assumption ranges used in the simulation models.

Exhibit A-5: Industry Composition of Respondents