Skylighting and Retail Sales

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ABSTRACT

In this paper we report on the methodology and findings of a project that found a statistically compelling connection between skylighting and increased retail sales. The use of daylighting combined with photocontrols has the potential to dramatically reduce lighting energy use in the commercial sector. This study was undertaken as part of a market transformation effort to quantify the non-energy benefits of daylight in order to encourage building owners to incorporate daylighting into their buildings.

We analyzed data on the sales performance of a chain retailer that operates a set of nearly identical stores. The analysis included 108 stores, where two thirds of the stores have skylighting and one third do not. The design and operation of all the store sites is remarkably uniform, with the exception of the presence of skylights in some. Stores in the sample were located within a limited geographic region and had similar climatic conditions. The buildings in the study fell within constrained ranges of size and age.

In this study, we used a statistical technique called backwards stepwise regression analysis which analyses the importance and impact of many variables simultaneously. The multivariate regression analysis allowed us to control for the influence of other variables, such as the size and age, which might influence sales.

Skylighting was found to have a large, positive and highly significant correlation to higher sales in this retail chain.

Limitations of the study are discussed, along with possible mechanisms for this effect, based on interviews with shoppers and various theories about how daylighting may affect humans.

Introduction

The purpose of this study was to see if we could demonstrate a clear relationship between the presence of daylight and human performance in buildings. We postulated that by focusing on buildings with skylights rather than daylighting from windows, we could isolate the effect of daylight.

In this study, we used a statistical technique called backward stepwise regression analysis which analyses the importance and impact of many variables simultaneously. The performance data used were gathered from four organizations: one retailer and three school districts. This analysis allowed us to estimate the effect of each of the known variables and to determine which variables have no significant effect. Using this method, we established a statistically compelling connection between skylighting and retail sales, and between daylighting and student performance. This paper focuses on the retail analysis.

The monthly gross sales per store were obtained from the retailer in the form of an average over an 18-month period that went from February 1 of one year to August 31 of the following year. This average sales figure was translated into a "sales index" by the retailer that we could manipulate statistically, but that did not reveal actual dollar performance, and was used as the dependent variable in the analysis. The retailer would not disclose the algorithm used to translate the gross sales into the "sales index", but we were assured that it was a relative ranking of the gross sales that was appropriate to use for our purposes of regression analysis. Stores in the sample were located within a limited geographic region and had similar climatic conditions. The buildings in the study fell within constrained ranges of size and age. The geographic region has a relatively sunny climate. All of the stores in the data set are one story.

Skylights were found to be positively and significantly correlated to higher sales. All other things being equal, an average non-skylit store in the chain would likely have 40% higher sales with the addition of skylights, with a probable range between 31% and 49%. After the number of hours open per week, the presence of skylights was the best predictor of the sales per store of all the variables that we considered. Thus, if a typical non-skylit store were averaging sales of $ 2/sf, then its sales might be expected to increase to between $ 2.61 and $ 2.98 with the addition of a skylighting system.

The skylights seem to have a major impact on the overall operation of the chain. Were the chain to add the skylighting system to the remaining 33% of its stores, yearly gross sales are predicted to increase by 11%. The difference between having none of their stores skylit and all their stores skylit is an increase of up to 40% in gross sales for the retail chain. We were not able to obtain some key data such as whether the store was adjacent to a mall or a freeway. These additional variables are described later in this paper, however if these or other variables were directly correlated with skylighting, then the omission of the variables would give their significance to the skylighting variable and bias it upward. Thus, a portion of the 40% increase in sales could potentially be due to the omission of key variables. Additional studies are currently being conducted to address these issues.

Background

Skylights provide a simple illumination function for aesthetic purposes, whereas windows may have a far more complex effect on people. Windows typically offer a view, which may provide relaxation, inspiration or distraction. They are often operable, which may add ventilation, air quality, and thermal comfort issues. Daylight illumination levels from windows are highly variable within a space, and may include components of unacceptable contrast and glare. User control of blinds or curtains also adds another variable that may be hard to account for. Windows are also connected with personal status, and may have psychological implications beyond their mere physical attributes. Skylights would not seem to be as imbued with cultural meaning and don't tend to have as much variability in their function.

Skylighting was a widely used method of providing light to industrial and warehouse buildings before the widespread use of fluorescent lighting. Most single-story industrial buildings built before the 1950's had rows of north-facing roof monitors which allowed ample light into the interior of these large buildings. With the advent of inexpensive

fluorescent lighting and air conditioning, daylighting techniques were abandoned in favor of electric lighting.

Recent analysis has shown that skylighting has enormous potential to provide energy savings in single-story commercial buildings. Turning off electric lights when sufficient daylight is available can save a significant amount of lighting energy costs. Because daylight introduces less heat into a building than the equivalent amount of electric light, cooling costs can also be reduced. Analysis has shown that an appropriately sized skylighting system, combined with photosensor controls to turn off unneeded electric lights, will produce net whole building energy savings in almost all parts of the country. [1] Recognizing this, some utilities provided incentive programs to encourage their customers to consider adding skylighting systems to their buildings. Nationally, 40% of all commercial buildings are single-story, and 60% of commercial square footage is directly under a roof. [2] In California, those numbers are even higher, where it is estimated that 90 percent of new construction is single-story. [3] Thus, increased use of skylighting systems could potentially save a considerable amount of energy nationally.

Retail buildings tend to be a fairly straightforward application for skylighting. The trend is towards large, single-story retail centers, with open expanses of shelving; a building type that is well adapted to a skylighting approach. Skylighting in these buildings can save significant amounts of money. For example, a skylighting system in a typical grocery store in Los Angeles has been observed to save about $ 10,000 per year.[4] A number of national retailers have adopted skylighting as a standard design feature of their stores in order to take advantage of these savings.

With the advent of more skylit stores, anecdotal stories began to surface that stores with skylighting had higher sales. One retailer reported that clothing returns decreased dramatically after installing skylights. In November of 1995, an article appeared on the front page of the Wall Street Journal business section describing Wal-Mart's experience with adding skylights to their experimental "Eco-Mart" in Lawrence, Kansas (Pierson 1995, B1). Although no numbers were offered, this article considerably raised the interest level in skylighting for retail applications. It reported that, as a last minute cost saving measure, Wal-Mart had installed skylights in only half of store.

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[1] Analysis with *SkyCalc*, a simulation program, available by downloading from www.energydesignresources.com

[2] Derived from the US Energy Information Agency publication, *Commercial Building Energy Consumption* (CBECs) 1995

[3] Personal communications from PG&E and SDG&E staff.

[4] Per monitoring by PG&E for daylighting case study series, which showed savings of 2kWh/yr per sf for a 50,000sf store paying $ 0.10/kWh.

Wal-Mart claims energy savings from drawing natural light through the skylights. But 'something else has gotten the corporation's attention,' says the [Rocky Mountain] Institute. In every Wal-Mart store, each cash register is connected in real time back to headquarters in Bentonville, Ark. According to Tom Scay, who was then the company's vice president for real estate, sales were 'significantly higher' in those departments in the daylit half of the store, and they were also higher there than in the same departments at other stores. Employees in the half without daylighting continue to try to have their departments move to the daylit side.

Such anecdotal studies have been intriguing, but have not offered a measure of how large such a positive effect might be. It has been clear for awhile that the value of such productivity impacts are potentially much greater than energy savings, not only for retailers, but for any business. A building that promises 1% higher productivity is likely to be far more interesting to an owner than a building that is guaranteed to use 10% less energy. Thus, we set out to see if a daylighting effect on performance could be demonstrated and quantified using rigorous statistical techniques.

The implications of the results of this study extend beyond the retail sector. By considering these retail findings with those from the companion study showing improved student performance in daylit classrooms, we can make a case that the beneficial effects of daylight are not likely to be confined to just schools or retail establishments, but rather that human activity in general is likely to benefit from exposure to daylighting.

Methodology

Our interest was to study the potential effect of daylighting on the performance of people in similar buildings with and without skylights. To do this, we sought organizations with pre-existing productivity measurements that could be compared between buildings with and without skylights (or daylight). We began by casting a wide net looking for the ideal organizations that could provide us with data sets amenable to our analysis.

We were looking for organizations that operated at many nearly identical sites, where about half the sites contained skylights and the other half did not. It was important that, other than variations in daylighting, the sites be as identical as possible. They should follow similar operations, and be in similar climates. It was also necessary that there be an on-going measure of performance for each site. We conducted a nationwide search looking for organizations that met these criteria.

The Retailer

We were lucky to find a retailer who met all of these conditions, and was willing to participate in the study. This retailer provided us with basic descriptive information about its stores and a "sales index" for each location. The sales index became the measure of productivity. The retailer, which wishes to remain anonymous, operates a set of nearly identical chain stores that sell a variety of consumer merchandise.

This retailer has had a policy of building their new stores with skylights for a number of years. However, they also have a considerable number of stores built during the same

period that do not have skylights. About 2/3 of the stores in the data set have skylights and 1/3 do not. Most of these non-skylit stores were acquired during mergers with other chains. The merged sites were then remodeled to match the design image and layout of the primary chain; however, skylights were not added. About ¼ of the non-skylit stores were originally built that way by the retailer itself. Apparently some new managers acquired during the merger did not agree with the skylighting policy, and so the new store sites where they had the greatest influence were built without skylights. Thus, there was not a systematic decision made about which sites should have skylights.

The retailer believes that they are seeing significant operational savings by turning off the electric lights under the skylights. However, we did not attempt to confirm these claims in any way. Our interest was in the impacts on sales.

The design and operation of all the stores in the chain is remarkably uniform. Other than the presence of skylights, the skylit stores have two other features that differentiate them from the non-skylit stores: higher ceilings and photosensor control of the lights under the skylights. No other systematic difference between skylit and non-skylit stores was observed.

The store design of the retailer in this study would best be described as an exemplary skylighting application. The skylights diffuse any sunlight so that there is even illumination below. The design provides high illumination levels during peak daylighting conditions, often two-to-three times the electric lighting levels. The electric lighting design throughout the stores is also carefully thought out in relation to the skylighting and is consistently applied. Most of the electric lighting is fluorescent, with strategic display lighting and highlighting used in both the skylit and non-skylit stores. Quality lighting design is very clearly considered part of the merchandising strategy for the chain.

A sampling of stores, both with and without skylights, found seemingly equal attention to other design elements such as building façade, signage presence on the street, and parking lot size and accessibility. All of the stores were laid out in nearly identical fashion, so that similar items were located in similar places. Stores of the same vintage had similar signage and decoration within the stores. The individual stores are managed at the corporate level, so management and advertising is extremely similar between sites.

Data from the Retailer

The retailer provided us with sales performance data for over 100 stores that included 2/3 with skylights and 1/3 without skylights. The monthly gross sales per store were averaged over an 18-month period running from February 1 of one year to August 31 of the next. Before it was given to us, this average was mathematically transformed into a “sales index” that was appropriate for statistical analysis, but that did not reveal actual dollar performance.

Stores in the sample were selected to operate within a limited geographic region that had similar climatic conditions, and to have constrained ranges of size and age. The geographic region has a relatively sunny climate. All of the stores in the data set are one story.

The retailer was also able to provide us with additional data about each store, which included:

- Square footage of store

- Hours of operation
- Location (zip code)
- Date of original construction
- Date of most recent major renovation
- Historical "type" of store, which influenced basic construction materials and architectural design.

Additional Data

In addition, we wanted to control for potential demographic effects of each store location. The retailer did not provide us with demographic information about the store locations, so we used census data tied to the zip code location of each store. To do this, we added two fields of data derived from the U.S. 1990 Census: population and average household income per zip code.

This demographic information is only a proxy for the influence of store location. We would have preferred a population density measure instead of raw population per zip code, but that information was not easily available. We do not know how representative the zip code location is of the population actually served by the store. The store could be located on the edge of a zip code boundary and more predominately serve other neighboring zip codes. We don't know how large each store's territory is. In some cases sales may be reduced by other members of the chain that are close by, reducing the effective population served by each store. We also don't know how many competing companies are within the territories for each store. Presumably some locations have more competition than others do.

A more sophisticated analysis would have also included a measure of the number of competitors within a given range, more information about the demographic characteristics of the population served by the store, and perhaps also information about a store's relation to various traffic corridors such as freeways. Internal analysis might also have included information about the experience of individual store managers, or other measures of how well the sales staff might be expected to perform. However, this information was not available to us, and therefore we cannot account for the influence of these variables. Unfortunately, the omission of any one of these variables has the potential to bias the coefficient estimate of skylighting.

On-Site Observations

We visited one dozen of the stores to confirm the information in the data set, and perform some on-site observations. On-site observations involved walking around the public areas of the store, observing and interviewing customers and staff. The focus of these site visits was to see if there was any other obvious influence on sales that we should explore further, or if there was any obvious correlation between skylighting and some other aspect of store configuration or operation that we should try to account for. We also used the site visits as an opportunity to probe how the skylights might potentially have an effect on sales.

Interviews

Informal interviews with shoppers repeatedly confirmed that the vast majority of shoppers were not aware of the skylights. The questioner, looking just like any other shopper, would approach a shopper and ask: "May I ask you a question?" The response was universally affirmative. We then asked, "What do you think of the skylights in this store?" The typical response was to look up, look puzzled, and then say, "That's funny. I never noticed them before." Out of 42 interviews in 10 skylit stores, only three shoppers could be found who were already aware of the skylights. Two of those volunteered that they had only noticed the skylights because their small child had pointed them out on an earlier trip, while looking up at a balloon or other bright object.

The questioner then asked: "Does this store feel any different to you than other stores like this?" By far the most common response (80%) was, "This store feels cleaner." The second most common response (65%) was, "It feels more spacious, more open." About one third of the respondents also mentioned that it was brighter. Three middle-aged respondents volunteered that they specifically came to this store instead of another closer to their home because they liked how it felt—cleaner, more open. Three elderly respondents commented on how important the brightness and the light quality were for them (although none had been aware of the skylights). Two middle-aged respondents talked about how important "natural" light was. Two older men commented that the energy savings must be considerable. Not one respondent objected to the skylights or had any negative comments about them.

Five store managers were interviewed about the skylights. All were positive about them, and reported they thought their customers liked them. Two mentioned the importance of energy savings. One commented on the "inviting feeling" the skylights created. Five store clerks were also interviewed: three were generally indifferent to the skylights; two were very positive, one saying, "I love them!"

Findings

Using statistical analysis, it was determined that there were five main variables that had a significant effect on the gross sales per store. These variables are: the presence of skylighting, the number of hours the store is open per week, the population and income of the store's zip code, and the number of years since the store has last been remodeled. Next, the magnitude of the effect of these variables was determined.

The results of these statistical tests are graphed in Figure 3 below. This graph clearly shows the magnitude of the skylighting impact compared to the other significant variables. We discuss each variable in turn.

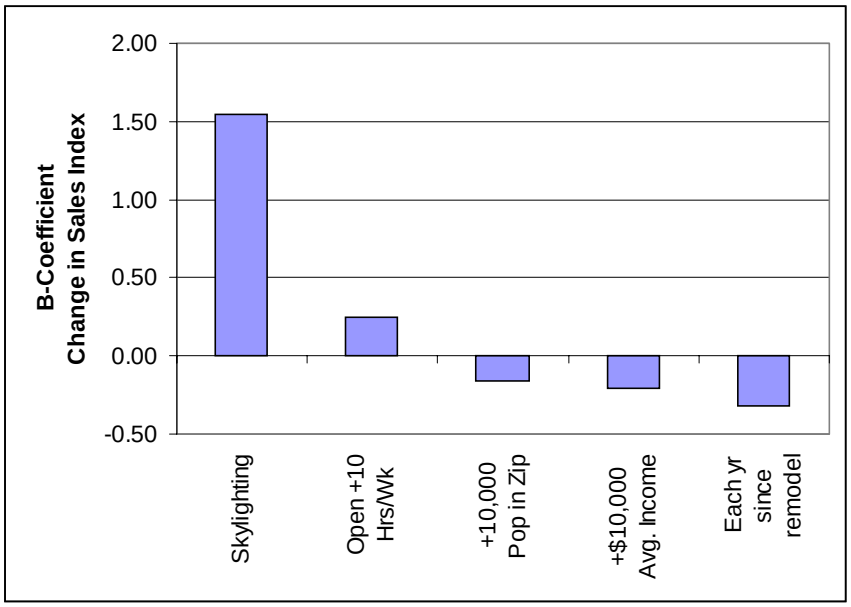

Figure 1. Change in Sales Index per Variable

Skylighting. A store with skylights is observed to have a sales index higher than an equivalent store without skylights. This is clearly the largest effect of any of the variables considered, (at B=+ 1.55). It is possible that there may be other reasons that the skylit stores are performing so well as a group. In our site visits, we made every effort to try to identify other characteristics of the skylit stores that might contribute to higher sales, but we did not find any obvious candidates. However, that possibility should always be kept in mind when examining these results.

Hours per week. Opening more hours per week is seen to have a weak positive effect on store sales. Ten additional hours of operation per week shows a sales index increase of 0.2. The small effect here may be a function of the compressed range of hours possible for the stores in this chain, or the likely possibility that the optimum hours of operation for each store location has already been determined and implemented.

Population and income. The negative effects shown here might seem to be counter intuitive. One might expect that having more people in the zip code where the store is located, and especially having a higher average income, would instead produce a positive effect on sales. However, the negative effect may occur since more densely populated and higher income areas may attract more competition, both from within the chain and from outside competitors. Indeed, on our site visits we noted that the stores in the chain did seem to be more closely spaced together in higher income areas. This was not confirmed in any formal fashion.

Years since remodel. The number of years since the last full remodel of the store is a highly significant variable. Each year since the last remodel shows a negative effect. A store, which was last remodeled five years ago, has lost about as many sale index points as a skylit store gains. Thus, according to this equation, if the chain remodeled all of its stores at least every five years, the effect would be of the same magnitude as adding skylights to all of the stores.

Error! Reference source not found. below presents the prediction equation that resulted from the backward stepwise regression.

Sales Index = 2.47 + 1.55 (Skylights) + 0.02 (Hours open per week)
– 0.16 (Population-per 10,000) – 0.20 (Average income-$10,000s)
– 0.32 (Years since last retrofi) + 6.91 (Outlier 97) + 4.98 (Outlier 57)
+ 4.23 (Outlier 94) + 5.82 (Outlier 15)

Figure 2 below presents the results of the regression equation in tabular form.

SIGNIFICANT VARIABLES	B	Std. Error	t	Sig.
(Model Constant)	2.47	1.52	1.63	0.106
Skylights	**1.55**	**0.36**	**4.35**	**0.000**
Hours open per week	0.02	0.01	2.65	0.009
Population (per 10,000)	-0.16	0.08	-1.99	0.049
Average income ($10,000s)	-0.20	0.10	-2.03	0.045
Years since last retrofit	-0.32	0.06	-5.12	0.000
Outlier 97	6.91	1.41	4.90	0.000
Outlier 57	4.98	1.44	3.47	0.001
Outlier 94	4.23	1.43	2.97	0.004
Outlier 15	5.82	1.57	3.70	0.000
Model R^2		**0.58**		
NON SIGNIFICANT VARIABLES:		Store types		
		Gross square feet		
		Years since original opening		

Figure 2. Retailer Regression Findings

The table shows that the skylighting variable has the strongest positive effect on sales of all variables considered. The outlier variables were added for sites with studentized residuals over $|3|$. The outliers remained significant throughout the analyses, thus were included in the final model. The outliers were inspected for any commonality, however none were found. The outliers were both skylit and non-skylit stores with the average incomes, populations, etc. not far from the average of all sites.

Discussion and Conclusion

It is useful to try to translate the results of the model into terms that can be applied to other situations. In this analysis, we were not able to describe the absolute dollar value of the skylighting variable, therefore we will try to describe the relative effect of the presence of skylighting on sales in other ways.

Interpreting the Retailer Results

These results show that adding skylighting to the average non-skylit store within the chain would be likely to improve its performance by 40%, with a probable range somewhere

between 31% and 49%. Thus, if this non-skylit store were averaging sales of $ 2/SF, then its sales might be expected to increase to between $ 2.61 and $ 2.98 with the addition of a skylighting system.

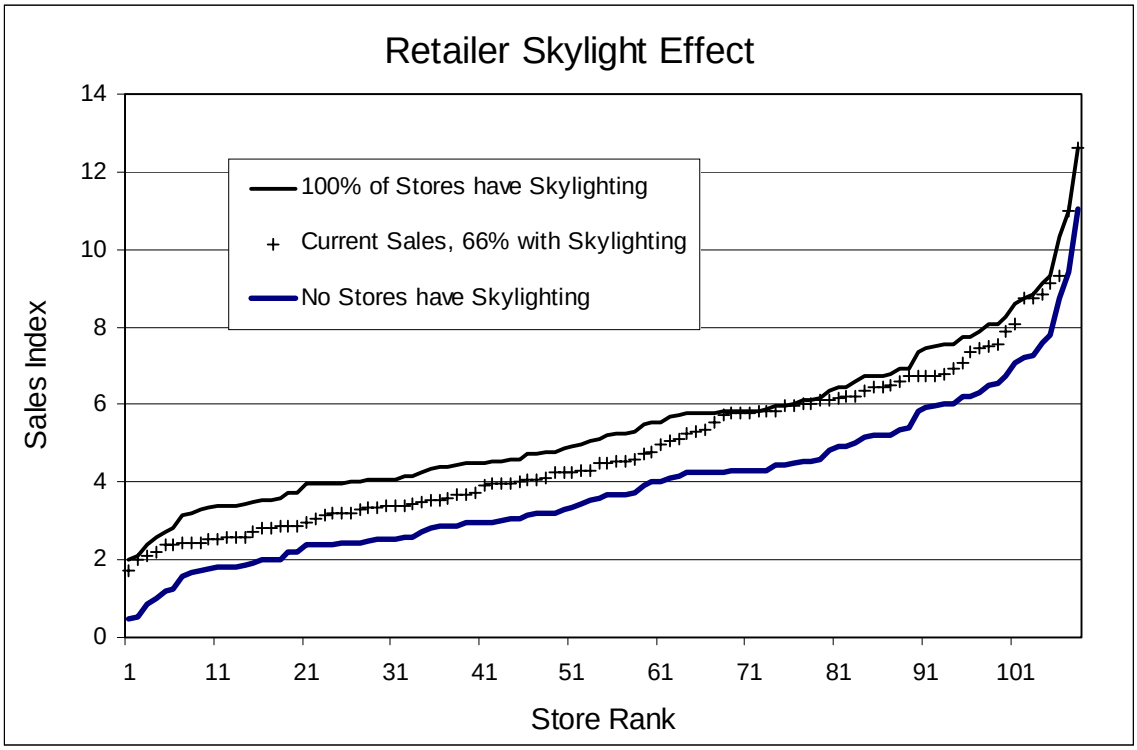

Figure 9. Chain-wide Sales Index with and without Skylighting

An alternative way to think about the impact of the skylighting is to ask how skylighting affects the overall gross sales for the chain as a whole. Currently 66% of the chain's stores have skylighting. If the chain added skylights to the rest of its locations, what effect would that have on gross sales? Figure 9 shows both the effect of adding skylighting to all stores in the chain, and the effect of removing the skylighting from all stores. The difference is dramatic. If this particular chain were to add skylighting to the remaining 34% of its stores, chain-wide sales could increase by up to11%. The difference between no skylighting in any of the stores, and skylighting in all of the stores, is a likely 40% increase in chain-wide gross sales.

It should be remembered that there were many other variables not considered in our analysis, such as the number of competitors within a store's territory. Also, in spite of the apparent uniformity of the stores, there may be operational differences between skylit and non-skylit stores that were not visible to the observer. For example, the air temperatures might be slightly different, or they may tend to use different music play lists that somehow affect sales. If such additional variables could be properly identified and found significant in the analysis, then magnitude of the skylighting effect would probably be reduced somewhat.

There is also no way to know how these results would translate to another retail chain. A different chain would have a different distribution of sales per store, which would change the percentage effect. It is, of course, also unknown how skylighting of a different

design would affect a store with different operations. The results of the regression equation are specific only for this data set. However, while magnitudes may vary in other analyses, we can say that in this case there clearly seems to be a strong positive effect to skylighting, and it is quite significant.

Mechanisms

With this analysis, we have shown a clear relationship between skylighting and increased sales, and quantified the effect for this particular chain. The next question that arises is why does this happen? What is causing the increased sales?

Unfortunately, this kind of analysis cannot prove that skylighting causes increased sales. It can only demonstrate that there is a strong correlation between the presence of skylighting and increased sales. The reason for the effect is left to speculation at this point. Below we discuss a number of possible mechanisms for such an effect.

Customer loyalty. In our interviews, it was clear that customers were not consciously aware of the skylights. But a number of them did express loyalty to a skylit store, because it seemed cleaner, or had better lighting. A few mentioned that they did routinely travel a little farther to shop at a skylit store over another option closer to their home. This informal survey suggests that there may be a customer loyalty effect to skylights. This would translate into a competitive advantage in attracting and keeping more customers.

More relaxed customers. It may be that once a customer is in the store the skylights somehow relax them, in a manner similar to piped-in music, which has been found so effective at relaxing customers and encouraging them to spend more time in a store shopping. We do know from interviews that customers seem to have positive feelings about the skylit stores and identify those stores with an airy, clean feeling.

Better visibility. The high illumination levels along with improved lighting quality from the daylight may make it easier or more comfortable for customers to select products. Especially for elderly customers with declining eyesight, labels are likely to be more legible during the peak daylight hours. It may be easier to find products and/or discriminate between alternatives with daylight illumination.

More attractive products. The skylights may make products seem more attractive, inducing customers to buy more expensive products, or simply more products, than they otherwise would. It is possible that the visual quality provided by daylighting, with high color rendition and three-dimensional modeling, may make products look more appealing.

Employee morale. It could be that employees have higher morale, and as a result provide better service. We did not have any way to measure employee productivity. Ultimately, in a retail environment, employee productivity would be measured by sales per employee hour. Logically, if there are higher sales per store, and no increase in the staffing level, there will also be higher sales per employee hour.

Any one of these mechanisms, or all of them, may be responsible for the increased sales. In order to apply these findings to other retailers, and other organizations, it would be useful to understand which qualities of skylighting are the most influential. However, understanding the actual mechanisms may ultimately not be as important as determining the design characteristics of a high performing skylighting system. At this point in time, that information may best be obtained from a knowledgeable designer with substantial daylighting experience, rather than from a scientific study.

Applying the Results outside of the Retail Sector

Another important question to consider is whether these results translate outside of the retail sector. If skylighting is associated with higher sales, does that mean it might increase productivity in a manufacturing building, or improve morale in an office building, or reduce absenteeism at a postal facility? If so, by how much? The answer is, of course, that we don't know.

However, in a companion study, we have shown that daylighting is associated with higher test scores in elementary school students. Considered as a whole, the two studies suggest that there is a general principle at work whereby daylight affects human beings in a positive way. Furthermore, these studies indicate that when this effect can be quantified, the impact can be quite significant.

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