



Behavioral Research Applied  
Technology Laboratory

# Relational Framework for Calculating Financial Outcomes from Electrochromic Glass



November 2020

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# BACKGROUND

## Background

View is a manufacturer of innovative smart window technology that manages how light enters the workspace, keeping working environments more in line with human comfort tolerances and saving energy. View's technology allows companies to remove blinds, permitting more of the external environment to be seen from and enter a building. Exposure to nature and natural light has been shown to enhance health and productivity, and consequently View has adopted a marketing strategy strongly focused on the wellbeing benefits. View is keen to understand the economic value of the physical health and wellbeing impacts of its technology and has already conducted significant research to prove the efficacy of their product.

BRATLAB is a specialist in actuarial and wellbeing services. BRATLAB's genesis is in understanding how behaviors linked to health and happiness lead to desirable outcomes for all stakeholders - individuals, insurers, and companies. BRATLAB is uniquely experienced and qualified to help View objectively demonstrate the benefits of its products to the developers and architects that design buildings and the companies, employees and building owners that use them.

BRATLAB has been requested by View to provide an actuarial valuation of the health outcomes of its electrochromic glass technology.

# EXISTING RESEARCH

## Existing Research

View has undertaken a variety of research studies in conjunction with academic institutions to demonstrate the beneficial health and wellbeing impact that View glass technology has on office employees. The research undertaken and the main findings are summarized below:

### *Worker Reactions to Electrochromic and Low e Glass Office Windows (Hedge et al, 2018)*

This study investigates the impact of daylight and the visual effects on work productivity, work satisfaction, health and well-being of employees. Online survey was administered to 268 volunteer office workers in 5 buildings with electrochromic glasses and 45 volunteer office workers in 2 buildings with low-e glass. The survey evaluated factors including comfort, satisfaction, performance, productivity, alertness, sleep, health and well-being. Results show that respondents working in electrochromic buildings experience significantly:

- less eyestrain
- fewer headaches: there was a significant difference in the frequency of headaches. Specifically, the research noted a 49% reduction in the prevalence of people experiencing headaches and 63% reduction in the prevalence of those experiencing one or more headaches per month.
- more alertness
- greater satisfaction with lighting quality and window glass lighting quality.

### *Multi-Season Assessment of Occupant Responses to Manual Shading and Dynamic Glass in a Workplace Environment (Choi et al, 2019)*

This research summarizes a four-season study of office workers moving from a work environment in a conventional building to a work environment with dynamic glass that adjusts daylight levels in response to weather conditions. The results of the study demonstrate that dynamic glass significantly enhances employees' environmental satisfaction which in turn improves employees' environmental perceptions and psychological health. Multiple surveys conducted over the one-year period reveal that, after moving into an office with dynamic glass, 24.8% increased ability to relax, 12.7% improved concentration, 25.3% better moods, 29.4% greater alertness and a 26.0% increase in positive emotional responses.

# EXISTING RESEARCH

## *The Impact of Optimized Daylight and Views on the Sleep Duration and Cognitive Performance of Office Workers (Boubekri et al, 2020)*

This study explores the impact of optimized daylight and views on the sleep and cognitive performance of office workers. 30 knowledge workers spent one week working in each of two office environments with identical layouts, furnishings, and orientations; however, one was outfitted with electrochromic glass and the other with traditional blinds, producing lighting conditions of 40.6 and 316 equivalent melanopic lux, respectively. Participants in the optimized daylight and views condition slept 37 minutes longer as measured by wrist-worn actigraphs and scored 42% higher on cognitive simulations designed to test their higher order decision-making performance. Both sleep and cognitive function were impacted after just one day in the space, and the impacts became more significant over the course of the week. The positive effect of optimized daylight and views on cognitive function was comparable for almost all participants, while increases in sleep duration were significantly greater for those with the lowest baseline sleep duration.

## *Impact of Daylight and Views on Physical and Emotional Wellbeing of Office Workers*

This study seeks to quantify the impacts of optimized daylight and views on the physical and emotional wellbeing of occupants. Thirty knowledge workers spent one week working in each of two office environments that were identical in design and environmental conditions, with the exception of the façade: one office was outfitted with electrochromic windows, while the other had functionally standard windows partially occluded by blinds. Participants were 48% less likely to report eyestrain ( $p < 0.001$ ), experienced a significant increase in positive affect ( $p = 0.004$ ) particularly for emotions related to interestedness and attentiveness, and were 77% less likely to report feeling depressed ( $p = 0.05$ ) when working in the space with electrochromic windows.

## *Long Term Workplace Wellness Study*

This study investigates the change in employees' health and wellness after being relocated to offices with smart windows. 36 employees and 17 test subjects participated in the study. The result demonstrates that workers who move to offices with smart windows experience a 75% reduction in eyestrain, 63% fewer headaches and a significant increase in engagement (as measured by responses to the statements "I'm excited to go to work" with a three-fold increase, and "I'm proud of my company" with a five-fold increase) after six months in the new environment. We have conservatively moderated the increase in engagement due to the small

# EXISTING RESEARCH

sample size used in the study to 22%, being based off typical worker pride in the company (76%) and the level achievable with smart windows (93%).

In summary, in our projections we will assume that electrochromic glass has the following impact on a typical office worker that is exposed to its influence ('input'):

- 37 minutes extra sleep per night
- 75% reduction in eyestrain
- 49% reduction in the chance that they will experience one or more headache per month and a 63% reduction in the chance that they will experience more than one headache per month
- 77% less likely to feel depressed
- 22% increase in their average engagement score.

## Proportion of workforce beneficially impacted by View technology

To enjoy the benefit of the glass, workers must sit within sight of or be regularly exposed to an external window and should not be situated on the north side of the building where the impact is negligible. View's research in this area suggests that around 47% of a typical office's workers will be beneficially impacted by the electrochromic glass.

# PREVALENCE

## Prevalence of These Inputs

To understand the extent to which these outcomes have a beneficial impact on employees in the real world, we must understand the prevalence of problems leading to worse financial outcomes for firms with office workers. To illustrate, if every office worker in a business is already getting adequate quality sleep of sufficient duration, no improvement in financial performance can be achieved by View's association with a 37-minute increase in sleep duration. If everyone is sleeping less than 7 hours, all employees would stand to benefit from this intervention. The reality will be somewhere between the two and for the purposes of building an impact model we will need to know the size of the population that is currently 'at risk' and will therefore potentially benefit from exposure to View's technology.

For the model, we have determined that the following risk prevalence rates are reasonable.

### Sleep

According to the [CDC](#), on average 34.8% of the US population fails to get the recommended minimum of seven hours sleep per night. Of these about one-third, or 11.8% of the total population, fail to get at least 5 hours and are therefore at greatest risk of significant performance and productivity drops.

### Headaches

According to figures from government health studies published in *American Headache Society*, 15.3% of American adults reported migraines or headaches sufficiently severe to cause a drop in work performance and an increase in medical costs.

### Depression

According to the [CDC](#), 8.1% of American adults aged 20 and over report depression in a given 2-week period and are at risk for higher medical costs and productivity loss.

### Eyestrain

According to *The 2016 Digital Eye Strain Report* which included survey responses from over 10,000 US adults, the self-reported symptom prevalence of digital eye strain is 65%.

# PREVALENCE

## Engagement

According to *Gallup Engagement Survey*, only 34% of American workers are actively engaged at work, while 13% report being “actively disengaged” at work. These 13% are at greatest risk for increased presenteeism. The balance (53%) are regarded as being passively disengaged.

According to a report by *Chartered Management Institute*, 76% of managers say they’re proud to work for their employer. Although this is a UK study, we have assumed that it is broadly applicable to the US. We have used this as the reference point for determining the change in engagement.

## Summary

In our relational model, we will assume the following prevalence of risk for a typical View client for the inputs with a two-step risk framework:

Input prevalence	% with Risk	% without Risk
Headache	15%	85%
Eyestrain	65%	35%
Depression	8%	92%

For those inputs with a three-step framework, we will assume following typical pre-View distribution:

Risk Groups	High	Moderate	Low
Sleep	< 5.5 hours	5.5 – 7 hours	> 7 hours
	12%	23%	65%
Engagement	Actively disengaged	Disengaged	Engaged
	13%	53%	34%



# FINDINGS

## Our Research Findings

BRATLAB has examined publications in the academic press to source reliable research that links changes in the above outcomes to financial, performance and related business outcomes for companies with office-based workers. The relevant research we have discovered is as follows:

### Sleep

There is substantial research linking sleep with human performance that can be converted into financial outcomes for businesses. The articles that we are using for this project are summarized below.

*Trouble Sleeping Associated with Lower Work Performance and Greater Healthcare Costs: Longitudinal Data from Kansas State Employee Wellness Program (Hui et al, 2015)*

Utilizing the Kansas State employee wellness program (EWP) dataset from 2008-2009, this study demonstrates that trouble sleeping was significantly related to negative changes in absenteeism, work performance, and healthcare costs. EWP participants (N=11,698 in 2008; 5,636 followed up in 2009) who had higher levels of sleep disturbance were associated with a linear increase of \$340 in healthcare expenditures for each of five step level increases in sleep disruption. This means that for the worst sleepers (about 3% of the population) who become good sleepers, a 17% reduction in health costs would result after one year. Those moving from moderate sleep disruption to no disruption would experience a 12% reduction.

### Conclusion

We will assume that getting good quality sleep ( $\geq 7$  hours per night) is associated with a 15% reduction in health care costs relative to those with highly disrupted sleep ( $< 5.5$  hours per night).

*Insomnia and Absenteeism at Work (Godet et al, 2006)*

The study found a linear relationship between insomnia and rates of self-reported work absenteeism. Two matched groups of occupational physicians, 369 insomniacs and 369 good sleepers, participated in the study. The insomniacs were selected according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition definition, with a 1-month reference period. Subjects were only included if they had had a history of insomnia over the previous 2 years. Participants with insomnia syndrome missed an average of 19.94 hours of paid work in the 3-month period. Participants with insomnia symptoms missed an average of 14.29 hours and participants in the good sleeper group missed an average of 5.94 hours of paid work. Participants with insomnia syndrome reported the highest link between insomnia and missed work (43.8%) compared to the insomnia symptoms group (22%) and good sleeper group (11.6%). In conclusion, good sleepers miss 74% fewer working days employees with insomnia syndrome and 47% fewer than those with insomnia symptoms.

# FINDINGS

## Conclusion

We will assume that getting good quality sleep ( $\geq 7$  hours per night) is associated with a 70% reduction in absenteeism relative to those with insomnia syndrome ( $< 5.5$  hours per night).

*The association between insomnia severity and healthcare and productivity costs in a health plan sample (Sarsour et al, 2011)*

This study examines the associations between insomnia severity and healthcare and productivity costs. 5,000 subjects with an insomnia diagnosis health claim or prescription claim in 2004/5 and 6,000 randomly selected individuals who had no insomnia related health care claims and who were representative of the health plan population were invited to participate in a telephone survey on sleep problems and associated impact. Insomnia severity was determined by participants' Insomnia Severity Index scores. The study finds that untreated insomnia is likely to be associated with increased daytime

impairment, which may translate into a more immediate loss of productivity. Loss of productivity costs in the no insomnia group were 33% lower relative to the sub-threshold insomnia group and 42% lower relative to the moderate to severe insomnia group when respectively compared to the no-insomnia group.

## Conclusion

We will assume that getting good quality sleep ( $\geq 7$  hours per night) is associated with a 40% reduction in presenteeism relative to those with moderate to severe insomnia ( $< 5.5$  hours per night), with those experiencing mild symptoms being about half as much.

## Headaches

Our research focused on identifying studies related to migraine and headache frequency, as studied in the View Research paper.

*The Burden of Migraine in the United States: Current and Emerging Perspectives on Disease Management and Economic Analysis (Hazard et al, 2009)*

The study reviews the current understanding of the burden of migraine in the U.S. A literature search using PubMed MEDLINE database and ancestral searches of relevant articles traced the history of economic articles published on migraine. The result shows that migraine sufferers are likely to experience 34% higher medical costs than control individuals. However, many of these cases were associated with the presence of psychiatric symptoms and other comorbidities and this should therefore be considered the upper bound of potential impact.

## Conclusion

We will assume that prevention of migraine and frequent headaches results in 15% lower medical costs, about 50% of the impact those with psychiatric symptoms and other comorbidities.

# FINDINGS

*Productivity losses attributable to headache, and their attempted recovery, in a heavy-manufacturing workforce in Turkey: implications for employers and politicians (Selekler et al, 2015)*

According to this research, employees with higher headache frequency report significantly higher presenteeism. Compared to employees who experience headaches more often (headaches on 2 to  $\geq 15$  days per month), employees who experience headache on  $\leq 1$  day per month have 38% fewer absenteeism days on average (0.05 days vs. 0.08 days;  $p < 0.05\%$ ). Compared to employees who experience headaches more often (2 to more than 15 times per month), employees who experience headache on 1 or less day per month have 87% less presenteeism days on average (0.18 days vs. 1.40 days;  $p < 0.05\%$ ). The less significant difference in absenteeism in comparison to presenteeism is possibly due to absenteeism being much more visible than presenteeism and is therefore less tolerated by employers. Also, as headache frequency increases, a coping mechanism might be deployed by employees to avoid missing work, even though they are largely dysfunctional when they arrive.

## Conclusion

We will assume that prevention of frequent headaches ( $>1$  per month) results in 85% lower incidence of presenteeism and a 35% reduction in absenteeism.

## Depression

Most of research we found is linked to major depressive disorder which would be an extreme example of the conditions measured in the View study population ('feeling depressed'). Therefore, the impact below should be considered the upper bound of potential impact.

*The direct healthcare costs associated with psychological distress and major depression: A population-based cohort study in Ontario, Canada (Chiu et al, 2017)*

This study estimates direct healthcare costs incurred by a population-based sample of people with psychological distress or depression. The study sample consisted of 9,965 individuals, of whom 651 had psychological distress and 409 had Major Depressive Disorder (MDD). Mean age was 44.3 in the comparison group, 40.8 in the psychological distress group and 39.3 in the MDD group. Substantial healthcare costs are found to be associated with psychological distress and depression. Health care costs consisted of costs for hospitalizations, ED visits, and outpatient visits. The result reveals that population with major depression symptoms have significantly higher costs in all cost categories. After adjusting for baseline variables, participants in the major depressive disorder group have 14% higher total healthcare costs (\$3,323 vs. \$2,831,  $p < 0.05$ ).

## Conclusion

We will assume that those who move from 'feeling depressed' to no longer feeling depressed experience 10% lower health care costs.

# FINDINGS

## *Impact of Depression on Work Productivity and Its Improvement after Outpatient Treatment with Antidepressants (Woo et al, 2011)*

This study estimates the lost productive time from absenteeism and presenteeism and its resulting cost among workers with major depressive disorder compared with a comparison group. A total of 106 employees aged 20 to 60 years were screened from four outpatient psychiatric clinics located in highly industrialized districts in Seoul, Korea and participated in the study. Results show that workers with major depressive disorder have significantly higher lost productive time compared to control group, and therefore have higher absenteeism and presenteeism costs. Absent days from work are significantly higher in the major depressive disorder group compared to control group (24.75 hour vs. 4.27 hours;  $p=0.015$ ). In terms of costs, annual cost of absenteeism was calculated as \$4,405 per person in the major depressive disorder group, and \$725 per person in the comparison group, resulting in an 83.5% reduction. Self-reported presenteeism is also significantly higher among major depressive disorder group (5.16 vs. 7.62;  $P < 0.001$ ). In terms of costs, annual cost of presenteeism was estimated to be \$13,396 per employee in the major depressive disorder group, and \$6,967 per employee in the comparison group, a 48.0% reduction.

### **Conclusion**

We will assume that those who move from ‘feeling depressed’ to no longer feeling depressed experience 50% of the impact of those with Major Depressive Disorder, and will therefore allow for a 40% reduction in absence and a 25% reduction in presenteeism in the model.

## **Digital Eyestrain**

The research we found regarding digital eye strain, also known as computer vision syndrome, is on dry eye disease which is a major symptom of digital eye strain in the workplace.

### *Impact of Dry Eye Disease on Work Productivity, and Patients' Satisfaction with Over-the-Counter Dry Eye Treatments*

This study assesses the effect of dry eye disease on work productivity and performance of non-work-related activities. 158 symptomatic dry eye patients naïve to prescription medication participate in the study. Dry eye severity (worse eye) was graded by the clinical investigator on a 4-point scale ranging from level 1 (mild to moderate conjunctival signs and symptoms) to level 4 (conjunctival scarring/severe corneal staining and severe symptoms) in accordance with International Task Force (ITF) classification guidelines. Productivity related measures (absenteeism and presenteeism) were measured using Work Productivity and Activity Impairment (WPAI), adapted for dry eye. Over the past 7 days, work time missed due to dry eye (absenteeism) averaged 0.4% and impairment of work performance due to dry eye (presenteeism) averaged 28.7%.

# FINDINGS

## Conclusion

We will assume that those who move from experiencing eye strain to being symptom free experience no change in absence rates and a 25% reduction in presenteeism.

## Engagement

### *State of the American Workplace Report 2013*

This report by Gallup highlights the engagement aspect of Gallup's ongoing report of American workplace from 2010 to 2012. The report includes an overview of the trend in U.S. employee engagement and the impact of engagement on organizational and individual performance. To compose this report, a meta-analysis using 263 research studies across 192 organizations in 49 industries and 34 countries was conducted. Results show that engagement has a significant impact on many productivity factors. A 37% decrease in median absenteeism is found between companies in the top-quartile and bottom-quartile.

## Conclusion

We will assume that those who move from actively disengaged to engaged experience a 35% reduction in absenteeism.

### *The Association of Employee Engagement at Work with Health Risks and Presenteeism (Burton et al, 2017)*

This study investigates the relationship between employee engagement and work performance factors among employees in a global financial services corporation. As a result, the highest engaged employees had significantly less presenteeism (7.7%) than the mid engagement (9.2% presenteeism) and worst engagement (14.0% presenteeism) groups.

## Conclusion

We will assume that those who move from actively disengaged to engaged experience a 45% reduction in presenteeism.

# FINDINGS

## Summary

Based on these research findings, we have established the following parameters for change when input risk moves from poor to good.

Input prevalence	Medical Costs	Absence	Presenteeism
Headache	-15%	-35%	-85%
Eyestrain	--	0%	-25%
Sleep	-15%	-70%	-40%
Depression	-10%	-40%	-25%
Engagement	--	-35%	-45%

Note that these are the impacts of moving from high risk to low risk. For engagement and sleep where there is a three-step risk profile, we will assume that 50% of the beneficial impact will be achieved as a consequence of moving from one level to the next (from High to Moderate risk, or from Moderate to Low).

# FINANCIAL IMPACT

## Deriving a Financial Impact

We will derive a financial impact by determining the annual financial benefit to the corporate customer occupying the office space, and project those benefits out over ten years, discounting the future gains to a net present value to compare to the cost of the View installation. To convert the beneficial outcomes to a statement of financial impact for the company, we need to make additional assumptions. These are summarized to the right.

### Assumptions

- Absence rates from all causes except approved vacation time are 3% of total working days
- The average cost of presenteeism in a business pre-View is 180% of the corresponding absence cost
- Average wage inflation will be 2% per annum over the next ten years
- Health plan premium inflation will be 6% per annum over the next ten years
- 90% of employees are members of the health plan with premium funded by the employer
- The client company's discount rate for evaluating future benefit of capital investments is 8% per annum i.e. the company would expect at least an 8% return on capital invested in infrastructure or the business
- Per Frontczak et al., 2011, we will assume that 47% of the total employee population will be beneficially impacted by View windows

## Adding Client Specific Data

For the purposes of illustrating the impact and building an initial calculation, we have worked with an illustrative client with details set out below:

- 800 total employees in a 150,000 sq. ft. building
- Average annual payroll cost \$80,000 per employee
- Average annual health plan premiums \$7,000 per employee

## Illustrative Results

Based on these example demographics, the estimated annual saving is \$421,640 or \$527 per employee broken down as follows:

Initial Annual Savings by Source	Total	Per employee
Medical costs	\$51,400	\$64.25
Absence	\$76,936	\$96.17
Presenteeism	\$293,312	\$366.64
<b>Total</b>	<b>\$421,640</b>	<b>\$527.05</b>

When we project this annual gain out over a ten-year period and discount the results to the present day, the estimated net present value (NPV) from the introduction of View technology is \$3,247,280 or \$4,059 per employee. This result may be compared to the cost of the View installation.

NPV of Savings by Source	Total	Per employee
Medical costs	\$455,320	\$569.15
Absence	\$580,144	\$725.18
Presenteeism	\$2,211,816	\$2,764.77
<b>Total</b>	<b>\$3,247,280</b>	<b>\$4,059.10</b>



# CONCLUSION

## Conclusion

Although we have not evaluated the savings against the costs of a View installation, our calculations suggest that there are significant potential cost savings and performance improvements available to those that install EC glass. These savings are built on the most robust research available, but there is significant uncertainty about the true values of impact in the office setting, and every situation will have its own considerations. These numbers can be used as a rough guide only to any party looking to establish return on investment for installation of View EC Glass.



**Colin Bullen FIA**  
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November 2020

## About BRATLAB

Short for "Behavioral Research Applied Technology Laboratory," BRATLAB sets out to answer a set of crucial questions related to habit creation and work context: Which habits really matter, and to what degree? How do we support people to practice these habits by changing the contexts of influence around them, so that they experience change as easy and natural, leaving them feeling highly engaged? What is the predicted actuarial value of the changes made by employers to the environmental contexts in which employees work? BRATLAB does this by systematically reviewing all published articles explaining the relationship between behavior and context change and outcomes of interest, as well as studying all the real world and laboratory-based circumstances in which sustained behavior change happens.

BRATLAB bridges the gap between academic research and best practices across industries to solve the unique business problems of health and behavior change in companies. We work directly with employers to build productivity enhancing strategies and with solution providers to help them both optimize and evaluate the impact their solutions can have on their corporate clients.