School-Start Times Impact Analysis

An Analysis Prepared for

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ACRONYMS

AAP	American Academy of Pediatrics
CDC	Center for Disease Control
FAAP	Federal American Academy of Pediatricians
LEP	Limited English Proficiency
VBCPS	Virginia Beach City Public Schools
VDOE	Virginia Department of Education

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EXECUTIVE SUMMARY

Adolescents do not get enough sleep. As a former student of Virginia Beach's First Colonial High School, I had to wake up at 0630 every morning to get ready for school. After being up for an hour, I was usually just starting to wake up by the time I walked through the doors of FCHS to begin my first class. I was one of the lucky students, though. I lived right next to my high school, so I could wake up "late." Other students who attended First Colonial for its Legal Studies Academy had to wake up as early as 0500 to catch the 0530 bus to get to school on time. How many young professionals in Virginia Beach do you know that are required to wake up at 0500 to get to their job for a 0720 start time?

Waking up early would not be a bad thing for students if sleep studies did not show that adolescents face changing biological clocks. As children enter adolescence, which I define as the ages between fourteen to eighteen, their bodies begin to transform, forcing them to stay up and wake up later. The current Virginia Beach City Public School (VBCPS) start time schedule is incongruent with this biological need. The current schedule requires adolescents to wake up the earliest out of all Virginia Beach students, to get to school by 0720. This leads to many tired students, but, even more than that, it leads to unproductive students who struggle to concentrate. Tired students are also more likely to drive drowsy and get in car crashes. Tired students are more likely to develop depression and mental health disorders because their bodies are under stress. Tired students are more likely to show up late to school because they struggle to wake up in the morning. To alleviate these undesirable consequences of inadequate sleep, I determined four alternatives for changing school-start times based on conservations with my client, Senior Executive Director for Virginia Beach High Schools Daniel Keever, and best practices from the literature.

1. *Keep Current School-Start Times*
2. *Swap Middle and High School-Start Times*
3. *Shift School-Start Times To Start Earliest For Elementary And Latest For High School*
4. *Push Back School-Start Times by Forty Minutes*

I evaluated each alternative with respect to a) potential benefits to society including increased earnings, fewer instances of mental health disorders, and fewer teenage car crashes b) costs to society including cost of field lighting and cost of an educational campaign, and c) political feasibility in terms of two contingent valuation studies I conducted to gauge whether citizens support changing school-start times.

Based upon my analysis of the projected outcomes of these alternatives, I recommend Alternative 3: shift school-start times to start earliest for elementary and latest for high school. This alternative will require an education campaign, as a preliminary study I conducted shows that parents do not currently understand the link between school-start times and the potential benefits to safety, health, and academic performance. At the end of this report, I provide some guidelines for how VBCPS can effectively move forward with this alternative.

CONTEXT OF THE PROBLEM

PROBLEM STATEMENT

The current public school schedule for high school students in Virginia Beach conflicts with adolescent sleep patterns. The current schedule can lead to chronic sleep loss and result in adverse effects on health, academic performance, and safety. Research beginning in the 1990s consistently finds that adolescents, while still requiring between nine and nine and a half hours of sleep, face shifting sleep patterns resulting in later natural sleep and waking times. Despite this need, when parents were asked whether their children receive nine or more hours of sleep a night, they reported that only 10 percent of adolescents aged 15 to 17 received nine or more hours (*Sleep*, 2014).

Figure 1: National Sleep Study 2014
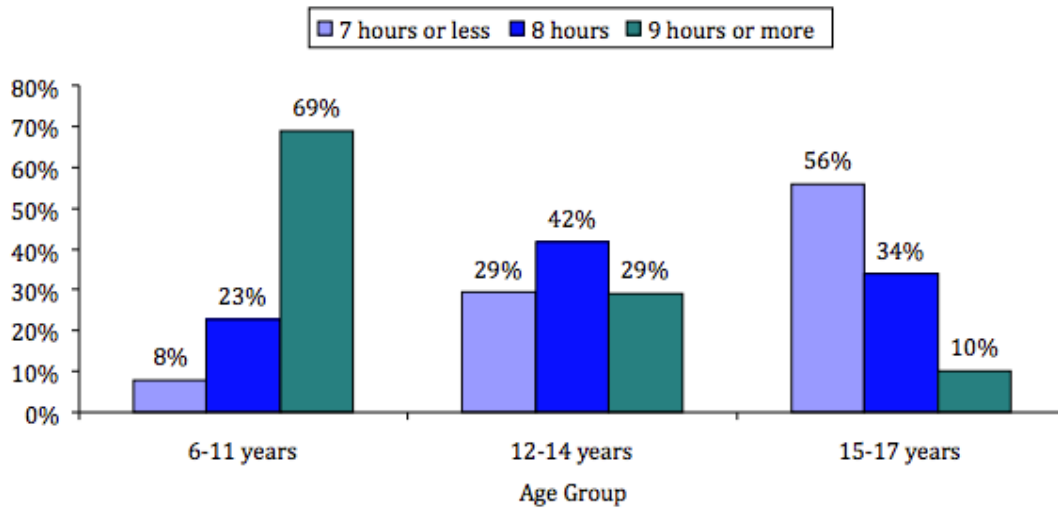
Parents also reported that 15 to 17 year old students were 26 percent more likely to fall asleep in school than children aged 6 to 11 (*Sleep*, 2014). The National Sleep Foundation's *Sleep in America* poll began in the 1990s and has consistently found similar results year after year. So why do schools start earlier for high school students when parent and student polls continue to demonstrate that high school students are more likely to exhibit sleep deprivation than their younger peers?

There are six major obstacles to delaying school start times: constituent fear of the unknown, transportation costs, scheduling issues, limited time to use public resources, less time for student extra curricular activities, and less time for family engagement. As is the case in many school systems, including Virginia Beach, school-start times have never changed, and if they have, the changes were so long ago that people do not remember. It is hard to imagine changing an institution that involves everyone in the community. Without proper communication, parents, teachers, administrators, and local community members will not understand the benefits of change. A second obstacle is that community members and taxpayers are concerned changing school-start times will add transportation costs. Third, many high school students participate in after school activities from clubs to sports to part time jobs. Moving high school-start times back

could limit the amount of time they have to participate in these activities. Fourth, delaying school-start times for high school students could negatively impact elementary or middle school students. For instance, if high school and elementary schools switch schedules, then elementary students could have to wait for the bus in the dark. Fifth, high school students with later start times would have reduced time to access public resources like the public library. Finally, teachers are worried that they will have less time to plan and less time with their families (National, *Eight Major Obstacles*). Each concern is understandable. In order to determine the validity of each claim, I performed a literature review and two Virginia Beach specific contingent valuation studies. I designed the contingent valuation studies to understand the importance of each obstacle to Virginia Beach parents and teachers, specifically.

LITERATURE REVIEW

After studying self-reported data from over 4,600 students across three states, Professor of Psychiatry and Human Behavior Mary A. Carskadon concluded, in her seminal 1990 adolescent sleep study, that adolescents do not get enough sleep. This data showed that as adolescents aged, they tended to experience a greater weekend-weeknight difference, growing from a sixty- to ninety-minute difference among 10 to 13 year olds to a three-hour difference among high school students. The growing weekend-weeknight difference attests to adolescents' changing circadian rhythms. The Carskadon study also found that adolescents who work less than twenty hours per week, attend schools with a shorter commute, and are given a strict curfew tend to receive the proper amount of sleep (Carskadon, 1990). This study provides numerous instances of self-report data documenting adolescents' changing sleep patterns, but neither study is able to show biologically that this change is due to changes in the body rather than routine. In 2006, a National Sleep Foundation poll found that eighty-seven percent of United States high school students received less than the recommended eight to ten hours of sleep (Richter, 2015).

Follow-up studies used biological sensors known as actigraph monitors to analyze sleep patterns and determined adolescents' changing circadian rhythms resulted in later sleep-wake cycles. In 1998, Carskadon conducted a second study in which she compared sleep patterns of ninth and tenth graders. Ninth graders had a 0825 start time, while tenth graders had a 0720 start time. A study of thirty-five students across both grade levels found that tenth graders woke up earlier for school but did not go to bed later, which resulted in sleep deprivation and daytime sleepiness (Carskadon, 1998). Another study in 2003, assessing 302 high school students' sleep patterns, found that those who woke up for school at 0620 slept on average seven hours and twenty minutes during the school week and thirty minutes longer on the weekend. Furthermore, they were more likely to have trouble falling asleep at an hour that would allow them to get at least eight full hours of sleep (Wolfson, 2003). This study is important for two reasons. First, it shows that even setting early bed times does not ensure that students are going to get the recommended amount of sleep. Second, it tells us that those who live farther away from their school and have to wake up earlier are at risk of receiving even less sleep. This second point could result in equity issues if it turns out that low-income students typically live farther away from school.

HEALTH

The National Sleep Foundation released a report in 2000, citing research from the National Institute of Health and other leading medical professionals, which explained that adolescents who do not receive eight hours of sleep a night are at risk for serious mental health problems including irritability, anxiety and depression, decreased socialization and humor, memory deficits, as well as increased use of stimulants (Smaldone, 2007). The findings from this report have been confirmed in laboratory experiments and national studies. In 2013, a review of over 1,000 contemporary laboratory and self-report sleep studies examined the effect of sleep deprivation on memory, emotional control, cell tissue repair, and metabolic regulation. The review found that when the body received insufficient sleep, each bodily function suffered but when rested, thrived. Insufficient sleep showed an especially detrimental effect on long-term memory (Bjorn, 2013).

Beyond mental health and memory, a lack of sleep also correlates with high-risk behavior (McKnight-Eily, 2011). The annual Youth Risk Behavior Survey administered to United States high school students concluded that students who reported less than eight hours of sleep were

increasingly likely to drink more than one soda per day; participate in physical fights; use cigarettes, alcohol, or marijuana; feel sad and hopeless; consider suicide; and participate in only sixty minutes of physical activity on two or fewer days a week (McKnight-Eily, 2011). A test-retest reliability study of the Youth Risk Behavior Survey found high reliability among student responses (Brener, 1999). However, the annual Youth Risk Behavior Survey is not a randomized control trial, therefore this study only provides evidence for a correlation between risky behavior and sleep, as opposed to a causal link. A 2010 study of 388 high school students in Philadelphia found that while risk-taking behavior could be the result of insufficient sleep on cognition, increased peer pressure or decreased ability to comprehend risk-taking consequences could also be causal factors (O'Brien, 2005).

ACADEMIC PERFORMANCE

A review of nine sleep deprivation and academic performance studies consistently found that sleep deprivation or fragmentation (inconsistent sleep patterns) hurts both academic performance and behavior (Curcio, 2006). Although the findings were consistent, the report called for new studies designed to control for differences between school systems.

Counties nationwide have acted on these findings by pushing back school-start times in an effort to raise achievement. Wake County, North Carolina, pushed school-start times back from 0730 to 0830 and saw an increase in standardized test scores of one to two percentile points, with the largest improvement among low performing students (Edwards, 2012). While North Carolina and four other states reported a gain in student achievement, three of the eight states included in a 2014 national study reported no significant gain in test scores (Owens, 2014). This report concludes with a reminder to school systems that school-start time interventions are not experiments and do not determine causal relationships. Before implementing a shift in school-start times, school systems must consider how counties that experienced positive benefits from a start time intervention differ. Differences, such as a different demographic population, could allow for a shift in school-start times to lead to positive student benefits.

A 2011 Brookings Report estimated that starting schools an hour later in upper middle and high school could contribute to a $10,000 to $17,500 increase in lifetime earnings per student. This increase is due in part to the positive emotional and mental effects that a later school-start time has on student achievement, especially for low performing students (Jacob, 2011). The estimate was based on a random control trial of United States Air Force freshmen assigned to start classes before 800 and after 800. Achievement for all classes was improved when freshmen, who have similar circadian rhythms to adolescents, attended class after 800. Brookings states there is no reason to believe Air Force Academy students exhibit different circadian rhythms than the rest of the population. Therefore, the results from this study are generalizable to the rest of the United States population, including Virginia Beach.

SAFETY

The National Center on Sleep and Disorders Research and National Highway Traffic Safety Administration convened an expert panel on Drowsy Driving and Automobile Crashes in 1997. Citing data from 1996, the panel reported that 56,000 crashes occurred over the course of the year where the attending police officer reported driver drowsiness. At-risk groups for sleepy driving included adolescents aged 16 to 19 who, after not getting sufficient sleep, were more likely to crash both in the morning and afternoon. The panel acknowledged that drowsy driving

has not been studied enough in a laboratory setting and that their drowsiness data was based on self-reports (Expert Panel, 1997).

Following this panel, a 2001 analysis of eighteen cross-sectional and one case-control study suggests driver sleepiness may lead to increased car crashes. The case-controlled study was the only one to find a link between drowsiness and crashes but was unable to quantify the increased risk (Connor, 2001). This study suggests that while drowsiness plays a role in car crashes, more data is needed to understand how large that role is.

Two drowsiness and car crash studies focused on high school students, expanded on this research and found that early school-start times are correlated with higher teen car crash rates. The first study found that shifting high school-start times from 0730 to 0830 decreased crash rates by 16.5 percent in Fayette County, Kentucky (Danner, 2008). A similar study in Virginia used data from the Virginia Department of Motor Vehicles to compare teen crash rates in Virginia Beach and Chesapeake, Virginia. In Chesapeake, where schools started seventy-five minutes later than Virginia Beach, teen crash rates were forty-one percent lower (Vorona, 2014). Neither study controlled for differences between cities, within populations, or over time. Thus, findings from each are largely correlational and should be interpreted cautiously.

COMPREHENSIVE STUDIES

The 2014 study mentioned earlier in reference to academic performance examined 1,000 schools across the eight states found that delaying school-start times for middle and high schools until after 0830 generated small improvements in health, safety, and academic performance. However, these positive effects were found only in five of the eight states in the study (Owens, 2014). A similar study funded by the Center for Disease Control that followed 9,000 students from eight public high schools across three states found later school-start times resulted in increased standardized test scores, fewer car crashes, less caffeine consumption, and fewer cases of depression (Wahlstrom, 2014).

A 2011 review of ten comprehensive sleep studies, including the two noted above, stressed that changing circadian rhythms lead adolescents to later sleep times, which is incongruent with early school-start times. The sleep debt incurred by this schedule hinders cognition, behavior, safety, and tardiness. Because of this, the review recommends a delay in school-start times. This review does warn that this change could have transportation and social costs, but given the links of circadian rhythms to vital statistics, with difficult to value costs to society, no benefit cost analyses has been conducted at this time (Kirby, 2011).

A longitudinal study of a New York public high school that pushed back school-start times by 45-minutes, found that improvements to academic performance and health were found in the first few years of the intervention but returned to baseline over time, while tardiness and disciplinary violations remain improved (Thacher, 2016). This study only analyzed one public high school with a student population dissimilar to Virginia Beach; therefore the results are not generalizable. While the 2011 and 2014 studies previously mentioned seemed to show a promising link between student benefits and school-start times, the New York study reminds us that school-start times will not fix all student problems and must be a part of larger school reform.

RESEARCH AND ANALYSIS

METHODOLOGY

This section will focus on how school-start times affect academic achievement. The analysis seeks to determine the best policy toward school-start times in Virginia. I will use the findings to design policy alternatives that will enable the Virginia Beach City Public School System to promote achievement within the school system.

I will not analyze in detail how school-start times affect teen crash rates and mental health. Teen crash rates were excluded solely on the grounds that preliminary analyses have already examined teen crash rates with respect to school-start times in Virginia and Virginia Beach, specifically. While these studies did not control for differences in city, time, and demographics, I was unable to obtain this information from the Department of Motor Vehicles and use the current findings cautiously throughout this report.

I excluded an analysis of mental health due to the time constraints of this analysis. I will give it attention in the subsequent benefit cost analysis. Further, after an alternative is chosen, VBCPS should consider issuing a before and after student, parent, and administrator survey to show the affects of the intervention on mental health.

Assessing Achievement

To understand the impacts of school-start times on Virginia specific achievement, I use panel data containing 1.5 million student achievement observations across four years, 2012 to 2015. I compiled the data from the Virginia Department of Education and local Virginia school systems. For the purposes of this study, the dataset is restricted to eleventh grade reading and writing student achievement, as measured by the Virginia Standards of Learning. This data will provide the most reliable comparison, as every eleventh grade student in Virginia is required to take both examinations, writing in March and reading in May. The achievement data from the Virginia Department of Education data reports on race, disability, limited English proficiency (LEP), and gender indicators by school division and school.

Prepared separately from conversations with county schools and publicly available school system online data, is a dataset including school schedules and start times for high schools across Virginia's 136 counties and cities. The school schedule indicator notes whether a school operates under 7 or 8-period classes students take every day or a 4 or 5-block schedule with daily alternating classes. The resulting analysis will assess achievement in two ways. First, I will represent the data graphically to show differences in SOL achievement by time range: 730 to 800, 800 to 830, and 830 and later. Second, I will describe the regression analysis that I ran in an attempt to understand how start times affect achievement. The regression analysis tells a deeper story than the graphs, as I was able to control for time, city-specific indicators, and demographics.

To examine trends and potential differences between school-start times' effect on achievement, I created a kernel density graph (Graph 1). This graph shows the probability of receiving a certain score on the SOL if a student starts school between 730 and 800, 800 and 830, or 830 and beyond. Each graph is normally distributed with a mean SOL score of roughly 440 for 730 and

800, but slightly higher at 450 for 830 and beyond. While it might appear that a 730 and 800 start time range versus a 800 and 830 start time range does not really matter for student achievement, the graph below shows that students who start school between 800 and 830 will consistently score higher than students in the 730 and 800 range. This is evidenced by the tighter concentration of scores for the 800 and 830 start time range. A tighter concentration means there is less variability in scores for later start times. Starting at 830 or later is clearly the best option, though, as an 830 or later start time shows a curve shifted to the right. This indicates that 830 or later start times achieve higher SOL scores on average. This finding is consistent with the literature.

Graph 1: Kernel Density Estimate

kernel = epanechnikov, bandwidth = 15.0000
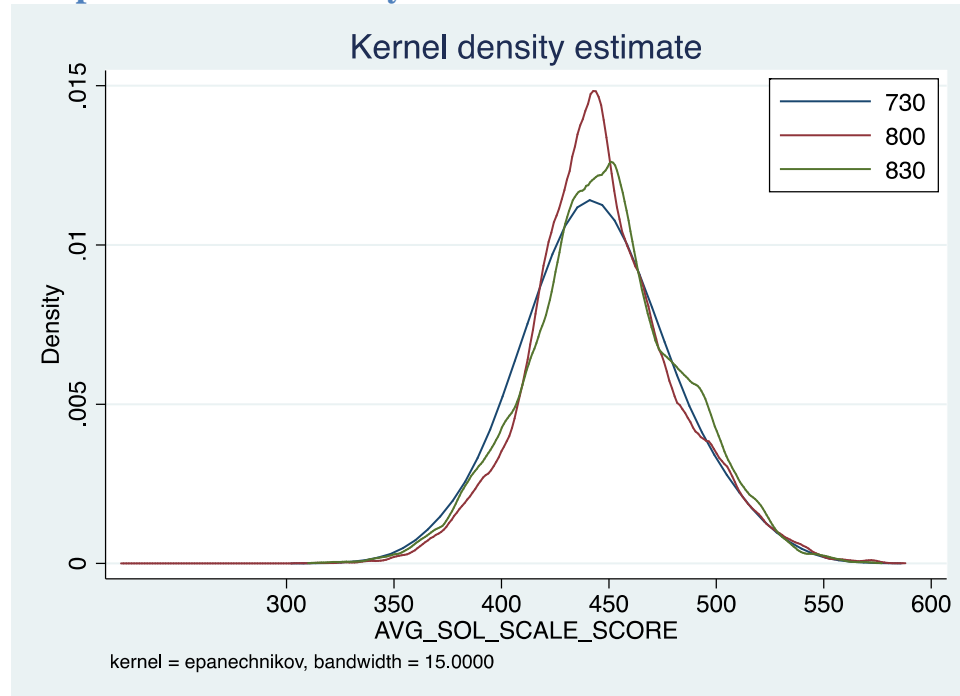
For the regression analysis I ran, I used a fixed effects model, gradually controlling for time, location, and other documented third variables. A regression model estimates the relationship between two variables; in this case SOL scores and school start times. A fixed effects model is a form of regression analysis that analyzes the impact of variables that vary over time. I use a fixed effects model for this analysis because student demographics and schools' start times change with time. Thus, my model produced the most accurate assessment of how school-start times affect SOL scores by controlling for differences among student populations and schools across the four years of my study. As expected, my model showed that later school-start times result in higher average SOL scale scores. Below is the model I used to measure the change of school-start on average SOL scale score:

$$Avg\ SOL\ scale\ score = \beta_0 + \beta_1 start + \beta_6 X + \varepsilon$$

Where *avg SOL scale score* is the average SOL scale score in reference to the English reading and writing exam, and *start* is a schools start time. X is a vector controlling the model across

time, division, and the following indicator variables: female, disability, LEP, disadvantaged, and school schedule (either block or period). Finally, ε is the error term for the equation. The regression output is described in detail in Appendix B.

The final results from the regression showed that for a one-minute delay in school-start times, average SOL scale scores increase by 0.05 points. If school-start times are pushed back by one hour, average SOL scale scores should expect to increase by three points. While on the surface this number might seem small, especially in comparison to the SOL's max score of 600, using the model outlined in the 2011 Brookings Report I found that in terms of average scale scores, an increase of 0.05 represents a positive 0.10 increase in the standard deviation of test gains. This translates to an increase of $10,000 in lifetime earnings for the average student when school-start times are pushed back by one hour (Jacob, 2011).

Summary of Findings
The Virginia Department of Education's SOL records are missing over half of the observations for disability, LEP, gender, and race variables, which I used as controls in the above analysis. The VDOE also excluded any group with fewer than ten tests, which may have skewed the final results. Second, while SOL tests are theoretically models of classroom performance, SOL tests are only used in Virginia and face sharp criticism from teachers who argue that SOL tests do not measure true classroom learning (McConnell, 2013). Finally, my calculations were not based on a randomized control trial and therefore do not show a causal relationship. While it is important to consider the limitations to my data analysis, my results are very promising. Based on the similarity between my analysis and the Brookings Report, I conclude that the correlation I found is relatively reliable and gives reason to believe that changing school-start times would result in higher academic achievement for Virginia Beach.

EVALUATIVE CRITERIA

In order to find what school-start time schedule is best for Virginia Beach City Public Schools, I determined, quantified, and monetized the most important benefits and costs to the Virginia Beach community from an analysis of leading scholarly journals and reports. Benefits include fewer teenage car crashes, fewer instances of depression, and increased potential earnings. Costs include the cost of lighting high school baseball and softball fields and cost of an educational campaign.

I did not find any studies in the literature that estimated the cost of changing school-start times to community members, so I created my own studies. This cost is important for even if the benefits to society of changing school-start times outweigh the costs, Virginia Beach parents, teachers, administrators, students, and community members might not be ready for this change or understand the relationship between school-start times and the potential benefits. To fill this void, I conducted two surveys. The first attempted to assess parents understanding of how changing school-start times would affect student health, academic performance, and crash rates. The second attempted to understand how teachers value potential inconveniences associated with changing school-start times, including less time to use public resources, less time for family and extra-curricular activities, and traffic delays.

For the purposes of this report, I do not monetize the costs of childcare and transportation and assume that both are transfers. I define a transfer as something that will pose no additional cost on society. My assumption for childcare is pulled from the literature using the logic that for every household that will lose its current childcare due to the change, another household will gain childcare due to parents and students changing work and school patterns. My assumption for transportation is based on the fact that each alternative I constructed merely swaps elementary, middle, or high school-start times, thus not exceeding the traditional number of buses needed for each level of schooling. Because my report's discussion of transportation is limited, my final recommendation on transportation will be limited, as well. VBCPS should only act on the recommendation of this report with the information gained from the transportation study currently being conducted.

With my assumptions now set in place, I will explain my process for how I calculated benefits to society, costs to society, and political feasibility. For a full explanation, including all of the assumptions and models I used for this report, see Appendix C: Benefit Cost Analysis Technical Appendix.

BENEFITS TO SOCIETY

The three major benefits of changing school-start times I found in the literature include increased earnings, improved mental health, and lives saved due to fewer teenage car crashes. I used estimates from the literature to value each benefit with respect to each alternative. While the benefit cost analysis I conducted required a monetary value for these benefits, mental health and lives saved are more than just a number on a page. When kids do not receive enough sleep, studies show that adolescents suffer and adolescents die. VBCPS should give special consideration to these potential benefits when deciding on the final school-start time schedule.

Increased academic achievement due to a one-hour change in high school-start times increases earnings by an estimated $10,000 to $17,500 over a students' lifetime (Jacob, 2011). To determine the potential benefits associated with each alternative, I scale the increase in potential earnings by the amount of time high school-start times are affected. For instance, if an alternative starts high schools later by 30 minutes, the benefit for earnings is $5,000 to $8,750 per student.

A study of the United States Panel Study of Income Dynamics estimated that the average economic cost of psychological problems during childhood at $10,400 (2007) per year or $12,189 (2016) per year (Smith, 2010). The estimate includes the cost of hospitalization, decreased productivity, and medication. Not included in this estimate, is the cost of suffering to the student and family. Depression affects between 6 percent and 20 percent of adolescents, meaning as many as 4,000 students in Virginia Beach could be suffering due to depression (Smith, 2010). Using both estimates, I calculate a range for the total mental health benefit pushing back high school-start times might have for each option. While this estimate does not include suffering, VBCPS must consider the relief a change may bring to students in pain.

Currently there are no rigorous studies showing the actual difference in school-start times and crash rates. The best data currently available comes from Vorona (2014), an observational study that estimates a reduction in teen car crash rates of between 0.013 and 0.0254 for high schools starting 75 minutes later in the day. To estimate potential benefits, I multiply this number by the total number of current teenage car crashes in Virginia, the percent of drowsy driving crashes that result in fatalities and rear impacts, and the American Automobile Association's estimate for the cost of crashes to society. The cost of a crash to society is based on estimates from insurance policies, but does not include the family or friend's burden when a child or friend dies. VBCPS must give this value special consideration, as even a policy that saves one child's life can benefit so many.

The most important assumption I used when calculating the above benefits was in terms of my lower bound and upper bound estimates. For my lower bound estimates for each benefit category, I assumed that benefits would only appear in the first four years after changing school-start times and then return to normal levels (Thacher, 2016). For the upper bound, I assumed the intervention would accrue benefits for each year the school system remained on this new schedule. I included a discussion of the other major assumptions I used to calculate each benefit below. My full rationale is in Appendix C. Due to time constraints and lack of literature on the subject, I was unable to monetize the increase in well-being to teachers and administrators as a result of school-start time changes.

COSTS TO SOCIETY
The two major costs of changing school-start times include the cost of lighting fields and the cost of an education campaign. The costs of changing work schedules, daily routines, transportation, childcare, and commuting are not included in the benefit cost analysis, as past literature shows these costs are transfers (Kirby, 2011). I used estimates from the literature to monetize each cost with respect to all alternatives. I include a discussion of the major assumptions I used to calculate both costs below. My full rationale is in Appendix C.

If high school-start times are pushed back, high schools will have to light currently unlit athletic fields that are used during the winter when the sun sets before 1700. Collectively nineteen

baseball and softball fields are affected and require lighting across nine of Virginia Beach City Public Schools' twelve high schools (Appendix A). To determine the cost of lighting fields, I used the market price for field lighting. I received a quote from Musco Lighting, VBCPS' field-lighting vendor, estimating the cost of installation, equipment, and operating costs. The lighting equipment Musco Lighting recommends uses shieling techniques to direct light and limit the spread to unintended users. This technology should limit neighbors concerns that new field lighting will result in unnecessary light pollution. Each alternative that suggests changing high school-start times will result in the same field lighting cost.

Deciding on a new school-start time and transitioning into the new school-start time schedule will require the city of Virginia Beach to devote staff to a new School-Start Time Task Force and an on-going education campaign. VBCPS is going to put a School-Start Time Task Force in place for one year to determine which school-start time schedule to choose. Since VBCPS will create this task force regardless of the option chosen, I treat this cost as a sunk cost and do not include it in the final cost estimate. The education campaign, on the other hand, is an optional campaign I suggest VBCPS consider. The campaign, if VBCPS chooses to implement it, would continue for the life of the project. To estimate the cost of the education campaign I assumed that after the task force disbands, one VBCPS employee would continue to develop educational pamphlets for teachers, parents, and students reminding them of the importance of healthy sleep patterns. Each alternative will bear the cost of the education campaign, because no matter what Virginia Beach should educate the public on healthy sleep. For further assumptions related to the cost of working group members and town hall operation see Appendix C.

FEASIBILITY

The decision to shift school-start times will affect a number of groups in Virginia Beach. The most important groups are VBCPS parents and students. If VBCPS decides to shift school-start times, it will affect parents' work schedules. A parent with elementary school students will have to either work with their employer to shift their schedule or find daycare for their child. Closely related to this issue, elementary aged students could have to wait in the dark for a bus, while also having to adjust to a new schedule. While I assumed changes in work schedules, childcare, and inconveniences would be transfers for the purposes of the benefit cost analysis, my assumption does not preclude affected individuals from opposing a switch. Furthermore, just as parents and students will have to adjust to a new schedule, so will administrators, teachers, and coaches who form the structure of the public school system.

I used a contingent valuation survey to determine what inconveniences of shifting school-start time, including decreased time for family, after school activities, and use of public resources, would be greatest for teachers. My survey is based on a limited twenty-teacher sample. The results showed that 60 percent of teachers were concerned that a new schedule would result in less time with family, while only 50 percent were concerned that a new schedule would adversely affect after school activities, use of public resources, and traffic delays. These results show that teachers are split as to whether a shift would pose any additional inconveniences or not. This study should be interpreted cautiously as the survey was hypothetical and teachers likely did not think that VBCPS would execute this plan. This means they were likely to under report their true feelings about inconveniences associated with this plan. If currently half of teachers oppose this plan, it is likely that even more will oppose the plan when VBCPS introduces it.

The second contingent valuation study I conducted determined whether parents believed shifting high school-start times would result in benefits to health, academic performance, and teenage car crash rates. When asked how effective they thought shifting times would be at improving the above benefits, the average response was "moderately effective" and the next most frequent response was "somewhat ineffective." If this is any indicator of how parents currently perceive the relationship between school-start times and its possible benefits, Virginia Beach City Public Schools will have to concentrate its efforts first on educating the public of what Virginia Beach as a whole stands to gain from a change in school-start times. The cost of the education campaign is included above. It is impossible to know, though, whether the campaign will be effective or not.

Also important in this process are the individuals living in neighborhoods near public schools. A switch in school-start times will result in changing bus routes, which could disrupt daily routines and commuting. And, if high school-start times are pushed back later, sports fields will require lighting. Putting up lighting could diminish housing values and affect resident's view sheds. The costs to both groups are difficult to calculate but important for VBCPS to consider, especially since residents could form opposition coalitions.

In an effort to gauge teachers, administrators, parents, and students' opinions, Virginia Beach City Public School System is conducting a stakeholder survey. The survey results will begin to determine the feasibility of each alternative when taken in conjunction with the benefit cost analyses. I say begin, because VBCPS should also work to inform residents of shifting start-times and its potential benefits. VBCPS should then collect the views of residents in neighborhoods bordering public schools. Gathering their views will help VBCPS begin to understand resident concerns in terms of daily inconveniences. Without the views of residents, VBCPS will have an incomplete view of how many people would oppose the switch after being given all of the information on the benefits.

Due to the large uncertainties associated with shifting school-start times and community concerns, I conducted a break-even analysis. My break-even analysis would tell us how much it would have to cost a single resident of Virginia Beach in inconveniences, in order to not go forward with an option. My analysis assumes that changing school-start times would affect each of Virginia Beach's 44,000 residents. So, if an alternative expected a net benefit of $44,000, the total inconveniences to residents, in terms of traffic delays, less time to use public utilities, etc., would have to be $1 for Virginia Beach not to pursue an alternative. Providing this number should help VBCPS when interpreting the total cost of a school-start time shift to community members.

ALTERNATIVES

I determined four alternatives for changing school-start times for the Virginia Beach City Public School System based on conservations with my client, Daniel Keever, and best practices from the literature.

1. *Keep Current School-Start Times*

2. *Swap Middle and High School-Start Times*

3. *Shift School-Start Times To Start Earliest For Elementary And Latest For High School*

4. *Push Back School-Start Times by Forty Minutes*

Below I describe and assess each alternative with respect to potential benefits to society, costs to society, and political feasibility. Benefits and political feasibility are estimates based on the best available literature, therefore when interpreting the results VBCPS must remain cautious. My estimates are conservative as the studies I base my estimates on are not randomized control trials. The total benefits could be lower or higher than I anticipated. I end each section with a break-even analysis, to show what the minimum cost to a resident would have to be for Virginia Beach not to go forward with an alternative. The outcomes matrix on page 20 reflects my best interpretation of the implications of each alternative according to the evaluative criteria discussed above. For more information on the estimates and models I used in my benefit cost analysis, see Appendix C.

ALTERNATIVE 1: KEEP CURRENT SCHOOL-START TIMES

VBCPS should keep the current school-start schedule as shown below.

	Student Hours
Elementary Schools A	
Morning Session	810-1120
Afternoon Session	1130-1440
Elementary Schools B	
Morning Session	840-1150
Afternoon Session	1200-1510
Middle Schools	0920-1550
High Schools	0720-1410

I included this option primarily as a comparison for the other alternatives and to illustrate how keeping school start times, which will produce no benefits to society, will cost the city. If VBCPS pursued this option, I would still recommend implementing an ongoing educational campaign because it is VBCPS' responsibility to teach its students healthy sleeping habits. The educational campaign would cost $83,609.

The current political feasibility for this option is high as there is no strong political pressure from the community to change the school schedule, but as evidence of the harm of school-start times continues to grow, the political climate could change thereby necessitating reform. The organization SLEEP in Fairfax organized and lobbied for later high school-start times in Arlington, Virginia. In 2001, Arlington, Virginia shifted their school-start times. SLEEP attributes this change in part to their lobbying efforts. SLEEP organized parents, teachers, and community members in Arlington to inform the public of the benefits of adjusted school-start times. A similar coalition of concerned community members could come together in Virginia Beach to raise similar awareness and force change.

ALTERNATIVE 2: SWAP MIDDLE AND HIGH SCHOOL-START TIME SCHEDULE

VBCPS should swap middle and high school-start times. This shift will not affect Elementary Schools A and B. The new schedule is listed below:

	Student Hours
Elementary Schools A	
Morning Session	810-1120
Afternoon Session	1130-1440
Elementary Schools B	
Morning Session	840-1150
Afternoon Session	1200-1510
Middle Schools	0720-1410
High Schools	0920-1550

I modeled this alternative after Arlington, Virginia's new school-start time schedule using the following rationale (Changing, 2005). Adolescents from eighth to twelfth grade are at the greatest risk of not getting enough sleep. Swapping middle and high school times will allow for the majority of these students to get more sleep without adversely affecting elementary aged students. There is concern that middle school students, many of whom just came from elementary school, should not be waiting for the bus at 0720 in the morning. If Virginia Beach City Public Schools pursued this alternative, they could pair this alternative with Alternative 4: pushing all school-start time schedules by thirty minutes.

Cost to Society

Moving high schools later will require lighting on nineteen total baseball and softball fields, which will cost the city between $3,073,998 to $3,370,968 including installation, equipment, and operating costs over the next 25 years. The cost of implementing the educational campaign would cost VBCPS $83,609. The education cost is continuous. Educating parents and teachers on healthy sleeping habits should become a regular part of VBCPS programming in order to ensure students are constantly reminded of the benefits of adequate sleep. The total cost of this option ranges between $3,157,607 and $3,454,577.

If this option were not paired with Alternative 4: push back school-start times by forty minutes, middle school students would be starting earlier than 0800. This could hurt the academic performance of eighth grade students, as their biological rhythms are beginning to change. Currently no good evidence exists for how much an earlier start time will affect eighth grader well-being, so I controlled for this uncertainty in my estimate for increased academic performance below. VBCPS could take precautionary steps to avoid potentially harming eighth grader achievement by pairing this alternative with Alternative 4, but Alternative 4 could hurt high school after-school employment. These are important trade-offs to consider when deciding on the best alternative for VBCPS students.

Benefit to Society

Later school-start times for high school students will likely result in improved academic performance for high school students, improved mental health, and fewer teen crashes. While I expect academic performance and mental health to increase for high school students, starting

middle school students earlier could hurt eighth grade students. Because of this ambiguity, I adjusted for uncertainty and lowered the expected benefit values for potential earnings due to increased academic performance and fewer instances of mental health disorders. Ultimately I determined the benefits to potential earnings to range between $2,633,052 and $14,649,241. For mental health, I calculated a range from $16,454,493 to $167,148,194. To determine a more accurate monetary benefit to society, Virginia Beach City Public Schools should either wait to implement this option until more concrete research is conducted on school start times and middle school achievement, or monitor these benefits themselves through surveys if this alternative is chosen.

Finally, because middle school students cannot drive, a change in start times will only affect the portion of driving high school students, therefore the benefit of decreased car crashes to society should be between $7,202,383 to $47,649,957. I estimate the total benefits to range between $26,289,928 and $229,447,392. This total may be much higher, though, as my estimates do not take into consideration pain and suffering.

Mental health disorders and lives saved are two benefits that have enormous ramifications for our community. VBCPS is committed to keeping its students safe, and while the benefits I estimated are quite large, this alternative may leave some middle school adolescents at greater risk for mental heath disorders as their bodies begin to change. VBCPS must keep in mind the potential suffering of these students when considering this alternative.

Feasibility
The benefits of this alternative outweigh costs between $23,132,321 and $225,992,815. While these benefits are impressive, administrators, teachers, parents, and students are currently resistant to change and are likely to oppose this switch as it could limit the time available for high school after-school activities. This concern is likely to disappear after the first year the new schedule is put into place, as the literature shows that communities grow accustomed to the new schedule and realize the benefits of more rested and productive students.

While concerns over high school students may disappear over time, middle school safety could be jeopardized for as long as the school schedule remains changed. Many middle students just out of elementary school would have to wait outside in the dark for half of the school year for the bus. Eighth grade students may also face negative academic and mental health outcomes due to the change in start times. With limited evidence as to how middle school students would be affected, stakeholders are likely to oppose this alternative.

To determine the degree of potential stakeholder dissatisfaction with this option, Virginia Beach City Public Schools could issue a public survey or even devote a series of four to five public town hall meetings to discussing concerns associated with this alternative. If VBCPS estimated the cost to citizens at more than $526 per person, then VBCPS should not pursue this option.

ALTERNATIVE 3: SHIFT SCHOOL-START TIMES TO START EARLIEST FOR ELEMENTARY AND LATEST FOR HIGH SCHOOL

VBCPS should shift school-start times so elementary schools starts the earliest between 0720 and 0740, middle schools starts at 0840, and high school-starts the latest at 0920. The new schedule is listed below.

	Student Hours
Elementary Schools A	
Morning Session	0720 - 1030
Afternoon Session	1040 – 1350
Elementary Schools B	
Morning Session	0740 – 1100
Afternoon Session	1200-1510
Middle Schools	0840 – 1150
High Schools	0920 - 1550

By creating a schedule that gives students an extra hour of sleep per day during the school week as they move from elementary to high school, Virginia Beach City Public Schools will provide a schedule that aligns more appropriately with adolescents' changing sleep patterns. I modeled this alternative after the recommendation from the previously mentioned 2011 Brookings Report. A major concern with this alternative as currently constructed is that elementary students would have to wait outside in the dark for the school bus. If VBCPS paired this alternative together with Alternative 4: pushing school-start time schedules back by forty minutes for all students or if VBCPS could reconfigure the busing schedule to accommodate a 0750 and 0810 start time for elementary students, VBCPS could improve or even eliminate concerns for elementary student safety.

Cost to Society
Moving high schools later will require lighting on nineteen total baseball and softball fields, which will cost the city between $3,073,998 to $3,370,968 including installation, equipment, and operating costs over the next 25 years. The cost of an educational campaign would remain the same for this option at approximately $83,609. I estimate the total costs to society to range between $3,157,607 and $3,454,577.

If this option were not paired with Alternative 4 or did not push back elementary school-start times to at least 750, this alternative would not be possible. A 0720 start time for elementary school students endangers elementary school children, as they would be waiting outside in the dark for a bus. The cost of safety is not monetized in this report but should be weighed very heavily by VBCPS when considering which school-start time schedule to choose.

Benefit to Society
This schedule should improve academic performance, health, and teen crash rates for high school students. I calculated each benefit and determined that this schedule should increase earnings between $3,510,735 to $19,532,321. I calculated the benefits for fewer mental health disorders to be between $24,681,740 and $195,006,227. Finally, because middle and elementary school students cannot drive, the benefit of decreased car crashes to society from fewer teenage crashes

should remain the same ranging between $7,202,383 to $47,649,957. I estimate total benefits to society to range between $35,394,858 and $262,188,505.

Once again, these benefits do not take into consideration the reduced suffering and pain from students whose mental health disorders are improved or the lives that are saved due to fewer drowsy driving crashes. Even saving one life can have a huge impact on the families and friends that would have been affected. The benefits to society are likely much higher than the number I was able to calculate and VBCPS should consider this when choosing the new schedule.

Feasibility
The benefits for this option outweigh the costs between $32,237,251 and $258,733,928. Stakeholders including administrators, teachers, parents, and students resistant to change, are likely to oppose this switch, though. Not only does this alternative advocate for a full overhaul of the current schedule, even more elementary students would have to wait outside in the dark for the school bus. If Virginia Beach City Public Schools could find the busing capacity, they could rearrange or introduce new busses to handle the elementary school load and shift start times later to 0750 and 0810. This would reduce concerns about elementary students waiting outside for the bus and ensure that school-start times remain aligned with recommendations from sleep cycle experts. I would not advise pairing this alternative with Alternative 4, though, s pushing all start times back by forty minutes could adversely affect high school students ability to work part time after school jobs.

To determine the degree of potential stakeholder dissatisfaction with this option, Virginia Beach City Public Schools could issue a public survey or even devote a series of four to five public town hall meetings to discussing concerns associated with this alternative. If VBCPS estimated the cost to citizens at more than $733 per person, then VBCPS should not pursue this option.

ALTERNATIVE 4: PUSH BACK SCHOOL-START TIMES BY FORTY MINUTES

VBCPS should shift school-start times for all grade levels back forty minutes. The new schedule is listed below.

	Student Hours

Elementary Schools A
    Morning Session
    Afternoon Session
	
	 0850 – 1200
	 1210 – 1320

Elementary Schools B
    Morning Session
    Afternoon Session
	
	 0920 – 1230
	 1240-1550

Middle Schools	1000 - 1630
High Schools	0800 - 1450

By creating a schedule that gives students an extra forty minutes of sleep, we are moving closer to the American Academy of Pediatricians' recommended 0830 high school-start time. Because we are still not achieving the ideal 0830 start time, this option will improve academic performance, health, and teen crash rates but by less than previous options. For middle school students, a 1000 start time could push school activities to the morning rather than after school, which could create access issues for those students who cannot get to school without the school bus system.

Cost to Society

Moving high schools later will require lighting on nineteen baseball and softball fields, which will cost the city between $3,073,998 to $3,370,968 including installation, equipment, and operating costs over the next 25 years. As for every option, there is the cost of the education campaign of $83,609. The total cost of this final alternative is the same as the previous options at $3,157,607 and $3,454,577.

There are no unintended costs to safety as a result of this option, but it does not achieve the maximum benefit for improved mental health, academic performance, and teenage driving safety. Moreover, this option could result in an equity issue if middle schools begin to hold extra curricular activities in the morning and do not provide busing for all students.

Benefit to Society

This option should improve academic performance, health, and teen crash rates for high school students, but by less than previous options. To account for this difference in time, I weighted each benefit for an additional forty minutes of sleep for high school students rather than an hour. This lowered each estimate to between $1,404,294 and $7,812,929 for potential earnings, $14,809,044 and $117,003,736 for mental health savings, and $2,880,953 and $19,059,983 for teenage car crashes. The total benefit to society for this alternative ranges between $19,094,291 and $143,876,648.

The benefits for this alternative are about fifty percent less than the benefits calculated for Alternatives 2 or 3. This difference shows how much of a difference sleep has on student health,

safety, and job potential. This option does provide incalculable benefits in terms of reduced suffering and lives saved, but by less than the previous two options. At the same time though, this option provides no additional safety concerns to elementary or middle school students. This trade-off is the most important trade-off of the entire paper and VBCPS must give it serious thought when deciding on the right alternative.

Feasibility
The benefits of this alternative outweigh the costs on the order of $15,936,684 to $140,422,071. While this option begins to address sleep experts' concerns about high school-start times, this option does not achieve the optimal schedule for high school students to start school at 0830. If stakeholders find out about this fact and concern grows for adolescent sleep patterns, community members could push for later start times. If VBCPS were to institute this plan and then face backlash later from stakeholders, this would cause a drawn-out school schedule change. There is currently no precedence for a demand to lengthen school-start times more, so this concern is largely unlikely to occur.

This option affects all school systems and stakeholders including administrators, teachers, parents, and students, could oppose this switch due to the change it might cause in work schedules and traffic patterns across the city. While the benefits are lower for this alternative compared to Alternative 2 or 3, this would likely face the least amount of political pushback among teachers and administrators since the change is uniform for all educational professionals.

To determine the degree of potential stakeholder dissatisfaction with this option, Virginia Beach City Public Schools could issue a public survey or even devote a series of four to five public town hall meetings to discussing concerns associated with this alternative. If VBCPS estimated the cost to citizens at more than $362 per person, then VBCPS should not pursue this option.

EVALUATION OF POLICY OPTIONS

OUTCOMES MATRIX

Below is an outcomes matrix I created to easily compare the costs and benefits of each alternative. Alternative 3: shift school-start times to start earliest for elementary and latest for high school is the clear winner with the greatest net benefits to society by over $9,000,000. My calculation for Alternative 3 neglects the cost of safety to elementary students, as well as the benefits of reduced suffering and mental health. These are important trade-offs, especially as VBCPS considers the next best alternative. Alternative 2: swapping middle and high school start times is very similar to Alternative 3 but results in reduced benefits to academic performance and mental health for middle school students.

As the story of political feasibility begins to show, there are important trade-offs when considering the motivation for this report and how well each alternative meets the six evaluative criteria. I believe the greatest trade-off is between political feasibility and overall benefits to society. Pushing back start times by 40 minutes has the lowest potential benefits to students but also poses the smallest risk to safety. This is primarily due to the fact that high school students are still not going to school at the time sleep professionals deem optimal, 0830. The analysis I presented earlier of 11th grader English SOL scores in combination with studies from leading experts in the field of adolescent sleep patterns tells a clear story. An 0830 start time is better than an 0800 start time for student health and achievement. Unfortunately, parents and stakeholders do not fully understand the link between this intervention and possible benefits. Alternative 3 on the other hand, requires elementary students to wait in the dark for the bus, but provides the greatest benefits to middle and high school health, safety, and academic potentials. Below I discuss the political feasibility of shifting school-start times, but my discussion is limited due to the difficult of monetizing and quantifying this value.

I made an attempt to determine political feasibility through a Virginia Beach parent contingent valuation study. In my study, over 70 percent of parents stated they were likely to spend $0 to push back school-start times. Parents also did not find the evidence convincing that outlined how shifting school-start times would result in benefits to students and society. My study had a total of twenty responses. With incomplete data, I suggest VBCPS move forward with their stakeholder survey to determine whether my findings are accurate. If they are, VBCPS must consider ways to educate the public about the importance of changing school-start times; otherwise, any alternative, other than Alternative 1: keep current school-start times, will face difficulty. Furthermore, VBCPS should tailor their report to determine what time parents would feel the safest letting their children wait outside for the school bus. If 0720 is too early, then VBCPS would have to adjust Alternative 3. Thus, VBCPS must trade-off stakeholder well-being for increased potential benefits. VBCPS has the ability to lower the cost to stakeholders but such a change requires time and resources. There are no other major trade-offs beyond political feasibility, costs to stakeholders, and potential benefits. These trade-offs are the most important for VBCPS to consider as they can easily help or hurt a plan come to fruition.

Table 1: Outcomes Matrix

	Field Lighting	Education Campaign	Student Achievement (Potential Earnings)	Mental Health	Teenage Crash Rate	TOTAL	BREAK-EVEN
Alternative 1: Keep School-Start Times	$0	Estimated $83,609	$0	$0	$0	-$83,609	NOT APPLICABLE
Alternative 2: Swap Middle and High School-Start Times	$3,073,998 to $3,370,968	Estimated $83,609	$2,633,052 to $14,649,241	$16,454,493 to $167,148,194	$7,202,383 to $47,649,957	$23,132,321 to $225,992,815	$526
Alternative 3: Shift all School-Start Times	**$3,073,998 to $3,370,968**	**Estimated $83,609**	**$3,510,735 to $19,532,321**	**$24,681,740 to $195,006,227**	**$7,202,383 to $47,649,957**	**$32,237,251 to $258,733,928**	**$733**
Alternative 4: Push Back School-Start Times 0:40 Minutes	3,073,998 to $3,370,968	Estimated $83,609	$1,404,294 to $7,812,929	$14,809,044 to $117,003,736	$2,880,953 to $19,059,983	$15,936,684 to $140,422,071	$362

RECOMMENDATION

The alternatives I discussed in detail in this report are not mutually exclusive. However, based on a thorough evaluation of each alternative according to the criteria and the relative trade-offs, I recommend that **Virginia Beach City Public Schools realign school-start times to start earliest for elementary schools and latest for high schools** as it provides the greatest potential benefits to society.

Currently Alternative 3 is not politically feasible in Virginia Beach because preliminary studies show that parents do not understand the effects of early school-start times on mental health, academic performance, and teenage car crash rates. With proper implementation focusing on stakeholder education and outreach, VBCPS could convince the Virginia Beach community of this program's merit thereby ensuring an effective adoption of the alternative.

The evidence I used to come to my final recommendation is incomplete. VBCPS must consider evidence from this report in conjunction with formal stakeholder feedback as well as the current school-start times transportation study before formally choosing an alternative. Both studies could uncover unanticipated expenses rendering my recommendation too costly for implementation.

NEXT STEPS

To ensure Alternative 3 is effectively implemented, VBCPS should first conduct a formal stakeholder survey to better understand the concerns of the Virginia Beach community in relation to this program. The stakeholder survey should reach out to parents, teachers, administrators, students, and community members. Each group will be affected by this change, so it is important for VBCPS to give everyone the opportunity to state their opinion. The VBCPS stakeholder survey should both inform community members of the potential benefits associated with a new start time schedule as well as elicit feedback as to what community members continue to be concerned about after the survey's educational portion. VBCPS should use this information to develop an effective outreach and education campaign.

After the results are in from the survey, VBCPS should consider these findings along with this report and the transportation study to begin a public implementation process modeled after Arlington, Virginia's. Arlington, Virginia changed their school-start time schedule in 2001. During their implementation period, they took special care to talk to stakeholders and use what they learned to set reasonable assumptions. For instance, their primary goal was student safety and their secondary goal was a good education. To ensure safety, they made a goal that no school should start before 0750 (Changing, 2005). Virginia Beach should follow this model. They should use the findings from these three reports and set a few goals they would like to meet. Setting goals with stakeholders will show VBCPS' commitment to the students and other stakeholders.

While VBCPS conducts the preliminary analysis of these three studies, my client Daniel Keever should begin creating a school-start times working group made up of a total of twenty members. The working group's central focus should be educating and engaging the public over the course of the 2016-2017 school year. Mr. Keever should work actively to get a representative body of volunteer stakeholders. Volunteers should represent each of the major groups of stakeholders as well as various views on the issue of school-start times. By ensuring diversity within the working group, the committee should be able to expect certain criticisms related to the switch and develop a plan using that information to educate the public. Diversity within the group should also help with engagement, as people are generally more likely to attend an event if they know who is going or if they feel needed.

The working group should aim to have at least one educational event a month and should constantly work on engaging the public in an online town hall forum. An educational event can range from reaching out to schools to attend faculty meetings to going out into the community and canvass. Working group members leading these events should focus on the benefits of changing school-start times. They should talk about the research that is out there and other school systems that have done it. They should frame the change as a good thing that should benefit everyone, even though it might add some inconvenience into everyone's lives while adjusting to the new schedule. After this is framed, working group members should field concerns, making sure they are truly appreciating the feedback they get while remaining positive.

The online town hall forum will allow any stakeholder to share their views about the school start-times process. The working group needs to ensure access, though. I recommend introducing the online town hall to the public through the school systems and social media. VBCPS and the working group could develop a take-home flyer that provides information to parents, teachers, administrators, and students about the new schedule and the online platform available to receive questions or concerns. To engage the community, working group members should tweet and post on Facebook a quick blurb about the program and how all citizens should get involved with the town hall. In any process like this it is important not to dwell on the negative. The working group should focus on framing the intervention in a positive light and encouraging all community members to get involved, not just those that oppose.

By ensuring all voices are heard within the Virginia Beach community, VBCPS can begin incorporating stakeholder goals, adjusting them if necessary, and developing the right plan for Virginia Beach that simultaneously serves the needs of the students and the general public. My recommendation is based on the current literature not public sentiment. While I believe realigning school-start times has the best chance of reaping the most benefits, it might not be possible with the current VBCPS budget and stakeholder climate. This process will allow VBCPS to first understand their limitations and then frame the process to the public with the help of a representative working group to lead VBCPS to the best alternative with the community and students' best interest in mind.

This alternative is not the catch-all solution to the problem of inadequate sleep. Virginia Beach City Public Schools must consider ways to constantly educate students on the importance of good sleep habits. It is very likely that if any alternative is chosen, some, if not all, students will revert back to their normal sleep habits. To prevent this, VBCPS should undertake to educate

parents, teachers, and students on healthy sleep habits. It would be helpful for VBCPS to monitor students' mental health (before *and* after implementing any schedule changes) through student and parent surveys to ensure the alternative does not harm students. VBCPS should consider a similar monitoring system for any other measures they are concerned about, including after-school work opportunities.

APPENDIX A: Athletic Field Lighting

ATHLETIC FIELD LIGHTING				
SCHOOL	FOOTBALL	BASEBALL	SOFTBALL	SOCCER
Bayside	X			X
Cox	X			X
First Colonial	X			X
Green Run	X			X
Kellam	X	X	X	X
Kempsville	X			X
Landstown	X	X	X	X
Ocean Lakes	X			X
Princess Anne	X		X	X
Salem	X			X
Tallwood	X			X

*X denotes whether the relevant high school currently have field lighting for that sport.
*These are the only sports played during daylight savings when the sun sets earlier.

Appendix B: Regression Output

Correlation between school-start time and average SOL scale score (English reading and writing 2012-2015). Data provided from VDOE.

REGRESSION OUTCOMES						
	1	2	3	4	5	6
Start time	.0330	.0356	.0430	.0492	.0510	.0571
Female		11.63	6.43	6.19	6.93	6.90
Disabled			-50.6	-51.3	-50.1	-50.3
LEP				-38.2	-30.1	-30.4
Disadvantaged					-26.2	-26.2
Schedule2						-4.65
Constant	420	414	419	417	425	421
R^2	0.0026	0.0323	0.3494	0.4042	0.4852	0.4873
N	1466853	881505	483507	246837	139626	139626
Note: All coefficients were significant to $p<0.001$						

FIXED EFFECTS REGRESSION OUTCOMES			
	1	2	3
Start time	0.0579***	0.0397***	-0.027
Female	6.88***	7.41***	7.179109***
Disabled	-50.9***	-48.8***	-51.84129***
LEP	-30.1***	-36.2***	-41.95182***
Disadvantaged	-25.9***	-21.8***	-19.14719***
Schedule2	-4.77***	-3.69***	5.09*
Constant	445***	472***	510***
R^2	0.653	0.713	0.778
N	139626	81447	81447
CONTROLS			
Time Fixed Effect	X	X	X
Race Fixed Effect		X	X
Division Fixed Effect			X
Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$			

*Division is not significant, which is expected because divisions are not directly comparable to one another.

Appendix C: Benefit Cost Analysis Technical Appendix

GENERAL ASSUMPTIONS

1. I chose a 25 year time horizon because the quote I received from Musco Lighting was an estimate of the costs over the next 25-years. Additionally, 25-years is a standard time frame in benefit cost analyses.
2. I chose a 7 percent discount rate. This is standard practice (United, 2003).
3. All benefits and costs accrue at the end of the year. This is standard practice.

POTENTIAL BENEFITS

1. The number of high school students in Virginia Beach were calculated based on the current number of high school students attending school in the city, 21,322 (National, *District*). When calculating each of the benefit categories below, I assumed zero growth within the student population, as the Weldon Cooper Center does not project student population growth over the next 25 years (Lombard, 2014).
2. The following are the steps I took to calculate the benefit of fewer teenage car crashes
   a. Dr. Robert Vorona collected data from Virginia Beach and Chesapeake DMV's to compare car crash rates between children aged 16 to 19 who attend high school 75 to 80 minutes later. This is not a randomized study and it does not control for time or city fixed effects, so the results from this study are just correlational (Vorona, 2014). There are no rigorous studies showing the actual difference in crash rates between schools, therefore the rates from this study are most likely higher than the true effect. I use the evidence from this study as a conservative estimate of the number of students that are likely to benefit from this intervention.
   b. The Vorona study stated that a 75 minute later start time should expect to see a decrease in total car crash rates between 0.013 and 0.0245. They totaled 850 teenage drowsy driving car crashes in Virginia Beach (Vorona, 2014). To determine the number of students benefiting from a later start time, I assumed a linear relationship and divided 0.013 and 0.0245 by 75 minutes to get the reduced probability of a crash for every minute of a later start time. This gave me a lower and upper bound estimate of the probability of a crash.
      i. To determine the total benefit of fewer teenage car crash rates with respect to each alternative, all you have to do is multiply the probability of a crash for every minute of a later start time by the minute delay in high school start times the alternative is causing. For instance, Alternative 4: delays school start times by 40 minutes, so multiply part b by 40.
      ii. For alternative 2 and 4, which both push back high school start times by 120 minutes, I limit the delay in school start time to 100. I do this for two reasons. First, 120 is 40 minutes outside the range of the study, which could introduce uncertainty. Second, the literature shows that the optimal school start time is between 0830 and 0900, so I assume that once this ideal is hit, the reduced probability of crashes will not benefit from a later school start time.

c. For each alternative, I then multiplied the probability of a crash by the number of minutes later high schools start by the number of total crashes. I assumed 850 crashes to stay constant because I had no reliable data sources to assume that crashes would increase over time.

d. Using information from AAA Drowsy Driving guide, I determined the percent of drowsy car crashes that result in fatalities and injuries. 1.5 percent of drowsy crashes result in death, where as 71 percent result in injuries (AAA, 2005). For this report, I assumed an injury resulted from a rear impact in order to develop a conservative estimate for the cost of a car crash. I then multiplied these probabilities with the number from c to get four values – the lower and upper bound estimates for fatalities and the lower and upper bound estimates for rear impacts.

e. To determine the cost of fatalities, I then determined the numbers in d by the value of statistical life, $9.4 million (Thomson, 2015).

f. Based off of insurance claims, the Insurance Institute for Highway Safety calculated the cost of a rear impact in property damage at $3000 (2016) (Insurance, 2008). I multiplied this by the probabilities of rear impacts calculated in d to determine the cost of a rear impact in property damage.

g. The average auto liability claim for bodily injury was $15,443 (2013), so $15,908 (2016) as calculated by Verisk Analytics (Rocky, 2015). Thus, $15,908 is the cost savings due to decreased hospitalization. I multiplied this value by the probability of a rear impact found in d to get a lower and upper bound estimate for the cost of hospitalization.

h. After all of these numbers were calculated, I discounted each using a 7 percent discount rate for the 25-year life span of the program.

i. Evidence shows that teen car crash rate benefits might taper off after four years, so I took my lower bound estimate found in h and limited that calculation to the first four years (Thacher, 2016). I then add all of the values together across the time horizon and determine my final estimates.

j. The degree of confidence for this estimate is low due to the rigor of the studies associated with the calculation.

3. Mental Health

k. A study of the National Survey of Children's Health determined that inadequate sleep is associated with mental health disorders (Smaldone, 2007).

l. A study of the US Panel Study of Income Dynamics determined the economic cost of psychological problems during childhood and calculated it at $10,400 (2007) per year or $12,189 (2016) (Smith, 2010). This cost includes the cost of hospitalization, medication, and decreased productivity.

m. The above study also states that depression effects between 6 percent and 20 percent of adolescents (Smith, 2010). Six percent of adolescents seek help, while 20 percent are expected to have some form of depression or mental health disorder.

n. I assume a one-hour delay in school-start times will decrease the total instances of depression between 3 and 7 percent. This estimate is conservative and is based on the idea that we expect to see a decrease in mental health disorders, but by an unknown amount. There is currently no good evidence on how much mental

health disorders actually decrease, but for the purposes of this analysis I assume a range of 2 to 6 for Alternative 2, 3 to 7 percent decrease for Alternative 3, and a 1.8 to 4.2 percent decrease for Alternative 4. To determine the value for Alternative 4, I took 60 percent of the expected decrease of Alternative 3.

    i. While both Alternative 2 and Alternative 3 effect high school-start times equally, I expect some eighth middle school students will suffer due to the change in schedules in Alternative 2. Because of this, I lower the estimate for Alternative 2. These estimates are based on quantitative research as opposed to qualitative research, so I keep these estimates very conservative.

o. To determine the actual estimates, I multiply the entire student population by the values found in d, I then multiply these values by the cost of a mental health disorder found in a. This provides me with a lower bound and upper bound estimate.

p. I take the values in e and discount them with a 7 percent discount rate.

q. Once the values are discounted I limit the benefits to the program for my lower bound estimate to just the first four years. I then add all of the values together across the time horizon and determine my final estimates.

r. The degree of confidence for this estimate is low-medium. While the studies are not rigorous due to reliance on self-report data, the surveys are representative of high school students generally. The assumption for the decrease in mental health disorders for high school and increase in mental health disorders for middle school students lowers the overall degree of confidence estimate to a low-medium because these are largely hypothetical.

4. Potential Earnings

s. Brookings published a report showing that a one hour start time delay can increase student potential earnings increase by $17,500 (2007) or $20,511 (2016) This number came from a randomized control trial from freshmen students at the US Air Force Academy (Brookings, 2011).

t. For my analysis, I broke down the $20,511 increase to one-minute increments by assuming a linear relationship. There is currently no evidence to support my assumption of a linear relationship, but this is the best information currently available.

    i. For Alternative 2, which pushes back high school-start times by 120 minutes, I limit the delay in school start time to 75 minutes. I do this for three reasons. First, 120 minutes is 60 minutes outside of the range used in the Brookings Report, which is likely to introduce uncertainty. Second, because the literature shows that the optimal school start time is between 0830 and 0900, I assume that once this ideal is hit, potential earnings will no longer benefit from a later school start time. Finally, I push the benefit back because this report states that eighth grade middle school students earlier school start time will likely negatively effect their potential earnings. As a result of this warning from the Brookings Report, I limit the total benefits to only 75 percent of what we would expect to see in the case of Alternative 4 below.

      ii.   For Alternative 3, I multiply the value in t by 40 minutes for the 40 minute delay to determine the proper benefit.

      iii.   For Alternative 4, which pushes back high school-start times by 120 minutes, I limit the delay in school start time to 100 minutes. I do this for two reasons. First, 120 minutes is 60 minutes outside of the range used in the Brookings Report, which is likely to introduce uncertainty. Second, because the literature shows that the optimal school start time is between 0830 and 0900, I assume that once this ideal is hit, potential earnings will no longer benefit from a later school start time.

u. I broke the $20,511 figure down to a yearly figure by dividing $20,511 by 45, assuming that everyone works from 20 to 65.

v. With this figure I started calculating the benefits after six years of implementing an alternative, assuming that all high school graduates would start working after two years of college. I multiplied the yearly increase in earnings by the total number of graduates.

w. I discounted the values in d. with a 7 percent discount rate.

x. Once the values are discounted I limit the benefits to the program for my lower bound estimate to just the first four years. I then add all of the values together across the 25-year time horizon and determine my final estimates.

y. The degree of confidence for these assumptions are medium- high because the evidence is based on a random control trial, but my assumption to split up lifetime earnings linearly and assume high school graduates will benefit two years after graduation is not based in rigorous analysis.

COSTS

1. Baseball and Softball Field Lighting

    a. A report on the effects of changing school start times cited field lighting as a necessary cost associated with pushing school start times later (Shapiro, 2015).

    b. Musco Lighting provided me with a quote for the cost of installation and equipment. The quote provided a range representing two different lighting schemes.

    c. I based the operating costs, including energy consumption and the cost of group relamps, on the costs of an average baseball and softball field as calculated by Musco Lighting (Musco, 2015). I used the same company for this estimate because Musco Lighting typically services fields throughout the entire lifespan of a product and they are VBCPS' lighting specialists.

    d. I only calculated operating costs every ten years because Musco Lighting states that typically lights burn out around the same time and group relamps are cheaper than individual relamps. Additionally, the first ten-year period poses no additional cost to VBCPS because Musco Lighting provides the first relamp for free.

    e. As in the previous calculations, I discounted the costs using a 7 percent confidence interval.

    f. I have a high degree of confidence in these estimate because they are all based on quotes and averages from VBCPS' actual field lighting provider.

2. Task Force and Education Campaign Costs

g. I based my assumptions for the number of working group members and the work required to form a task force and education campaign on conversations with Daniel Keever, my client, and documentation from a similar implementation project completed with the Arlington School System.

h. I decided that the task force would require 10 volunteers, 10 VBCPS staff members, and 1 VBCPS staff website personnel. I decided that VBCPS would only need one VBCPS staff member devoted to the education campaign.

i. I assumed the task force would only operate for one year, starting next year, while the education campaign would continue for the entire lifespan of the project.

j. To determine the cost of the task force and education campaign, I multiplied the number of volunteers by the average volunteer opportunity cost (Grantspace, 2016). I multiplied the number of staff by the median hourly wage for a white-collar worker in Virginia (Point, 2016).

k. I then discounted those values using a 7 percent discount rate.

l. I have a high degree of confidence in these assumptions as the numbers of volunteers and workers were based on conversations with my client and a review of a similar implementation process done in Arlington, Virginia. Additionally, the wages are standard practice and come from Virginia's median white-collar wage rate and volunteer wage rate.

m. In my comprehensive spreadsheet, I included the cost calculation for the task force purely for VBCPS to see the full accounting costs associated with this project.

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