If You Build It, Do They Come?

The Impact of School Construction on District Enrollment in Massachusetts Public Schools, 1996 – 2006

Prepared by the

Metropolitan Area Planning Council

for the

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Credits

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Executive Summary:

Under contract to the Massachusetts School Building Authority, MAPC Data Services conducted an analysis of enrollment of public school districts before and after major school construction or renovation projects. One of the primary goals of this effort was to develop a systematic, data-driven understanding of a phenomenon that is now known only anecdotally. This research seeks to answer the following question: does enrollment increase after construction or renovation of a school facility above and beyond what would have been projected to occur in the absence of a construction event? If so, how should this finding inform enrollment projections and programming decisions by MSBA?

Based on nearly 200 school construction events, MAPC compared district enrollment patterns for the three years before a new or renovated school opens to enrollment patterns for the opening year and the three subsequent years. Districts that did not experience construction events were also analyzed in order to isolate the effect of construction. The analysis accounts for factors such as income, district MCAS scores, and building permits (all of which are also significantly correlated with enrollment patterns.) Adjustments for home sales, per-pupil expenditure, and population growth rates did not impact the results of the analysis.

MAPC found that *on average*, when a new or renovated school opens in Massachusetts, district enrollment in subsequent years is slightly higher than what would otherwise have been expected based on past enrollment trends and demographics. Increases are not observed in every district or grade, but they are widespread enough to create a small but statistically significant trend, with a predicted cumulative impact of approximately 3% by the third year after the construction year. Due to the limited number of observations, it was not possible to assess with any statistical certainty whether larger impacts are seen in schools or districts with certain characteristics.

The results of this analysis can be incorporated into MSBA's existing enrollment projection methodology. Currently, MSBA projects enrollment for future years based on average grade-to-grade ratios for the past five years. In order to reflect the impact of school construction, MAPC recommends a small, temporary adjustment (increase) in the assumed grade-to-grade ratios for the years immediately following the anticipated completion of construction, and then a return to the pre-construction grade-to-grade ratios in the period 4 years or more after construction. We recommend a standard adjustment across all school districts, but also provide bounding parameters should MSBA determine that a larger adjustment is merited due to extraordinary district attributes.

It is important to note that public school enrollment patterns fluctuate considerably from year-to-year in all districts. Schools that experience construction events are no exception; post-construction increases are the most likely outcome, but are not a foregone conclusion. No methodology can predict future class size with pinpoint accuracy, but MAPC's recommendations provide MSBA with a standardized, empirically-based strategy that neither overestimates nor underestimates the average impact of construction-induced enrollment.

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Introduction

The Massachusetts School Building Authority (the "MSBA") is an independent public authority created by Chapter 208 of the Acts of 2004 and M.G.L Chapter 70B (together the "Act"). The Act eliminated the former program for school building assistance and created a new program to provide grants to cities, towns and regional school districts for school construction and renovation projects administered by the MSBA. The MSBA is mandated with the effective planning, management and financial sustainability of investments in school building facilities. M.G.L. Chapter 70B section C specifically authorizes the Authority to "develop a formal enrollment projection model." The results of this model are a key input into school planning and programming decisions undertaken by MSBA and partner districts under a new collaborative program for school planning, design and construction.

Anecdotally, many school administrators say that construction of a new school is often accompanied by a large or unexpected increase in enrollment. Many fear a "worst case scenario" in which post-construction enrollment far exceeds projections prepared prior to construction, though few can cite specific instances where this has occurred. Stakeholders hypothesize that, attracted by the new school, many more people may move to the district or transfer their children from private schools to the public district, rendering the enrollment projections inaccurate. Such an effect might be termed "construction-induced enrollment." However, most administrators simply use the proverbial: "If you build it, they will come." This has become the conventional wisdom among many school administrators, who have asked MSBA to make substantial increases to enrollment projections (often by 10% or more) to account for such an effect.

The Metropolitan Area Planning Council's ("MAPC") research is designed to provide a more quantitative understanding of this phenomenon. In many districts, enrollment may have increased after construction, but in many other districts, it may have declined. If MSBA factors assumed "construction-induced enrollment" increase into grade-to grade ratio projections and post-construction enrollment increases do not materialize, a school district may have built, and will need to maintain, a larger school facility than needed. While a limited amount of excess capacity is not bad *per se*, the cost of school construction is considerable. In addition, districts have limited resources for the operation and maintenance of school facilities, and having to dedicate these limited resources to operating and maintaining a school facility with significant excess capacity may be viewed as wasteful and lead to discussions of school closures and consolidations. With limited financial resources at stake, school districts and the MSBA will benefit from a stronger understanding of the factors that influence enrollment.

MAPC's research described in this report seeks to determine what is *likely to happen* to enrollment after a new school is built, after accounting for the wide variety of factors that affect enrollment and the natural fluctuations that occur from year to year. At the initiation of this research, MAPC advised MSBA against the use of case studies of districts where enrollment has increased; the basis for analysis should be the full range of districts that experienced school construction, rather than most extreme or unique cases. Our analysis will complement MSBA's existing enrollment projection methodology and will provide a framework and parameters for discussing construction-induced enrollment with partner school districts.

Approach

At the outset of this analysis, MAPC identified two possible mechanisms through which construction might influence enrollment:

- Migration: More families move to the municipality because they are attracted by the new schools, or fewer families move out to other municipalities in search of better schools. In the short term such migration might be accommodated by increased sales of the existing housing stock; over the long term it may be associated with increased housing production seeking to capitalize on increased municipal attractiveness associated with the new/renovated school.

- Retention[1]: A higher proportion of school-age resident children choose to attend the district schools as compared to parochial schools, vocational/technical schools, or school choice options. This would occur through changes in the net transfer rate, with relatively more students transferring in, and relatively fewer students transferring out.

These two mechanisms are distinct from one another and are best examined separately. Migration patterns change over long time frames (decades) and are the result of many complex and interrelated factors, including land use controls, regional economics, and transportation. There are many factors that constrain the impact of school construction on migration patterns: migration is limited by housing availability; the housing market may take many years to respond to increased demand[2], and sustained demand will likely be more influenced by overall school system quality than a single new facility. MAPC determined that it was beyond the feasible scope of this study to isolate the relative influence of school construction among all the other factors that influence migration.

By comparison, increased enrollment due to higher retention rates would occur independently of demographic or housing trends, and would likely occur on a shorter time frame than migration impacts. When a new facility opens, resident children who are not enrolled in the local district may simply transfer into a district facility. It is likely that the impacts will not occur in a single year (there may be an anticipatory effect or a lag time for some students); but because the retention rate cannot be higher than 100% (not accounting for school choice students), it will not continue changing indefinitely (unlike the effect of migration). The lower the retention rate is before school construction, the larger this effect might be.

The impact of a construction-induced increase in retention would be reflected immediately in enrollment, and can be measured by the **grade-to-grade ratio**, which compares enrollment in any given year to enrollment of the previous grade in the previous year. If all students from first grade continue to second, and no new students enroll, the ratio is 1.0. If students leave and are not replaced by transfers in, the ratio is less than 1.0; and if students move or transfer into the district, the ratio is greater than 1.0.

Because grade-to-grade ratios are naturally normalized, they can be compared across districts, unlike estimates of absolute enrollment. Additionally, MSBA's enrollment projection methodology uses a 5-year average of grade-to-grade ratios as the basis for projecting future enrollment in a given grade. For these reasons, MAPC chose to use grade-to-grade ratios as the primary measure of enrollment trends for this analysis. The operative question is, do grade-to-grade ratios after construction rise more than what would otherwise be expected based on natural variability?

Data Collection

In order to investigate the influence of construction on enrollment patterns, MAPC collected 17 years of enrollment data for each district and grade in Massachusetts; and developed a database of nearly 200 construction events that took place during that time period.

MAPC collected enrollment data for all districts & grades statewide, 1992 -2006 (~41,000 "district grade years") from the National Center for Education Statistics Common Core of Data. MAPC then calculated the grade-to-grade ratio for each grade and year[3].

MAPC collected information on the following district attributes:

- Median household income, 2000, municipality (U.S. Census)
- MCAS scores, 2000, school district (MA DOE)
- Student-teacher ratio, 3-year average 2003 – 2005, school district (MA DOE)
- Per-pupil expenditure, 11-year average 1995 – 2005, school district (MA DOE)

[1] Retention" is used here to mean the proportion of resident children who attend the public school district.
[2] Though short-term increases in supply might conceivably occur if new school construction is accompanied by overrides or debt exclusions and resulting property tax increases that stimulate some residents to sell their homes.
[3] It is worth noting that MAPC analyzed grade-level enrollment at the district level, not for individual classes or school facilities, under the assumption that the opening of a new or renovated facility would likely be accompanied by a reconfiguration of students and classes.

- Population growth rate, 1990 – 2000, municipality (U.S. Census)
- Building permits issued, 1996 – 2007, municipality (U.S. Census)
- Housing sales as % of year 2000 housing units, 11 year average 1995 – 2006, municipality (Banker & Tradesman)

These attributes were chosen because MAPC hypothesized that they could influence both enrollment changes and construction events, thereby complicating (i.e., confounding) the relationship between new construction and enrollment. MAPC assigned values for each attribute each school district and calculated a quartile rank for each attribute based on the statewide distribution of values[4].

MAPC collected and prepared data on nearly 200 construction events from 1995 – 2005. It is important to note that all new construction events were included, but renovation projects costing less than $2 million were excluded. Where there was more than one construction event of the same school type in the same district during the study period, only the earlier event was analyzed, on the assumption that any construction-induced effect would be attenuated with multiple events. New or renovated vocational-technical schools were excluded from the analysis as well. Appendix A includes a complete list of construction events that were analyzed. Table 1 shows the distribution of construction events by school type and Community Type (as defined by MAPC.)

Table 1: Construction Events Analyzed

	Elementary	Middle	High	**Total**
Inner Core	9	4	3	16
Regional Urban Centers	13	7	2	22
Maturing Suburbs	23	15	10	48
Developing Suburbs	38	23	26	87
Rural Towns	7	1	0	8
Total	**90**	**50**	**41**	**181**

Each district grade year was assigned a "time relative to construction" value for any construction project in that district for the school type that included the subject grade. For example, the fourth grade in a district two years before construction of an elementary school would be CY -2 (construction year minus two.) Only grade levels in the same school type as the construction event were considered to be "impacted grades." For example, the impacted grades for a new middle school are 6, 7, and 8.

MAPC took a two-step approach to analyzing enrollment patterns. First we evaluated all 41,000 grade years of data to determine average grade-to-grade ratios, the range of values, and the variability of the data. These observations reveal interesting enrollment patterns, but they do not demonstrate with any statistical certainty that these patterns are the result of school construction and not random variability. The second step in our analysis was to develop a multivariate regression model that seeks to estimate the effect of construction after accounting for a variety of other factors. The analytical rigor of this model provides statistically significant results that can be justifiably incorporated into MSBA's enrollment methodology.

Observed Enrollment Patterns, Statewide

MAPC analyzed the 41,000 district grade years of data in order to develop a general understanding of grade-to-grade ratios statewide to provide context for analysis of construction-induced enrollment. For each district, MAPC selected a random year from 1992 – 2005 and analyzed grade-to-grade ratios in that year and surrounding years. Figure 1 shows the distribution of grade-to-grade ratios for all 3,000 district grades in the state in the randomly selected year. This chart shows that two-thirds of district grades have a grade-to-grade ratio between 0.95 and 1.05, but there is considerable variation in grade-to-grade ratios across all districts grades.

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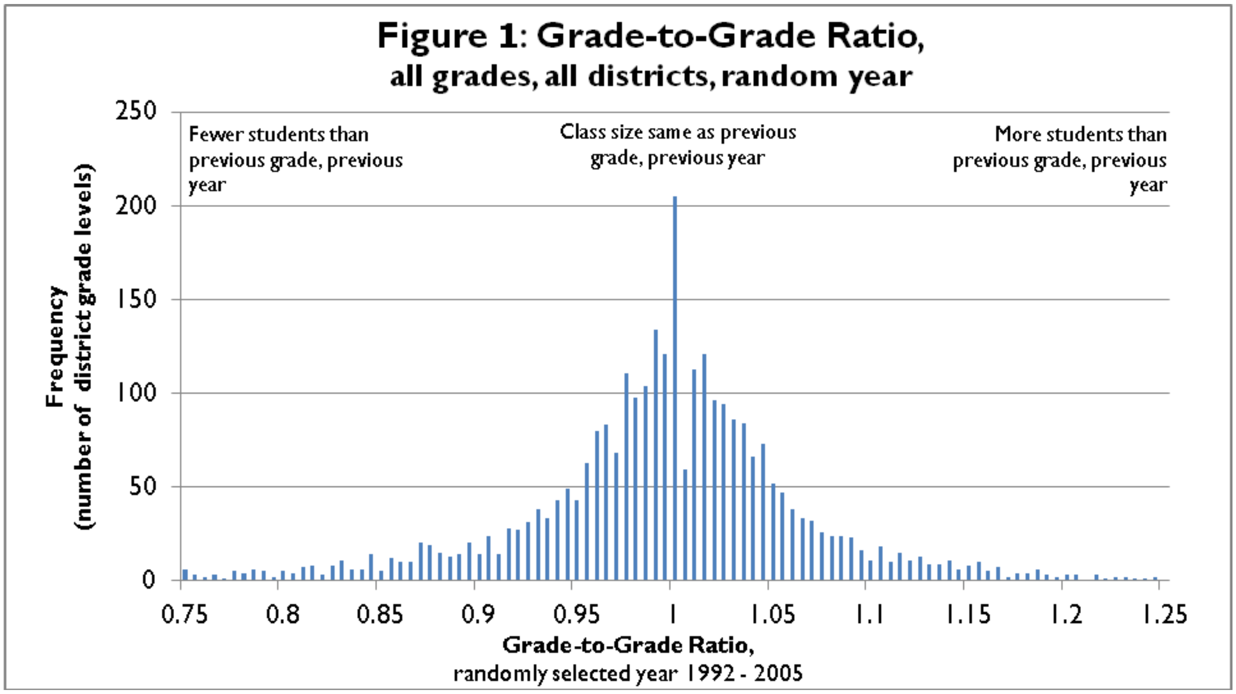
[4] For example, if a quarter of all districts statewide had population growth rates of less than 5%, a district with a growth rate of 4% would be in the bottom quartile.



Many different demographic and educational factors influence enrollment in any given year. As a result, all school districts have some natural variability in their enrollment whether or not a new school is built. Families move in and out for non-school-related reasons, other school choices open or close, etc. Figure 2 shows the response to these factors over a 14-year period in 35 randomly selected districts grades. Grade-to-grade ratios cluster around 1.0, but also fluctuate in every district grade. Some district grades experiencing wider swings than others, and some demonstrate increasing or decreasing trends over the 14-year period.

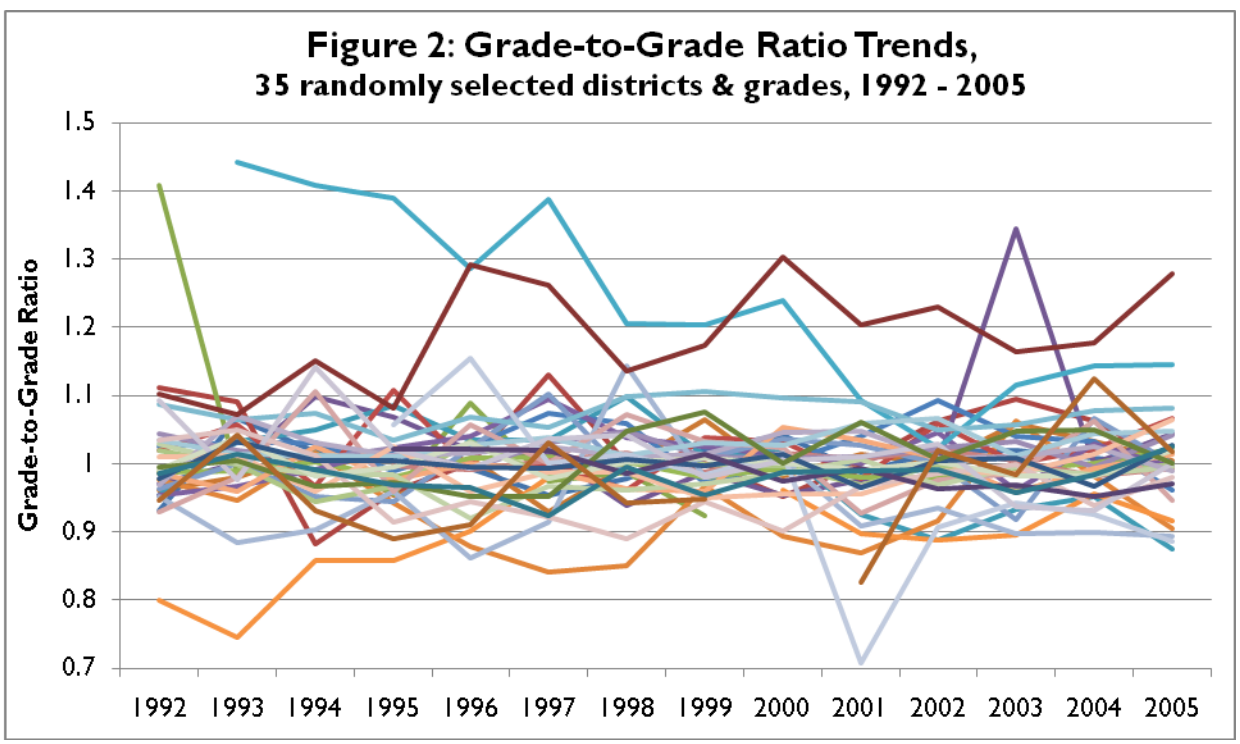
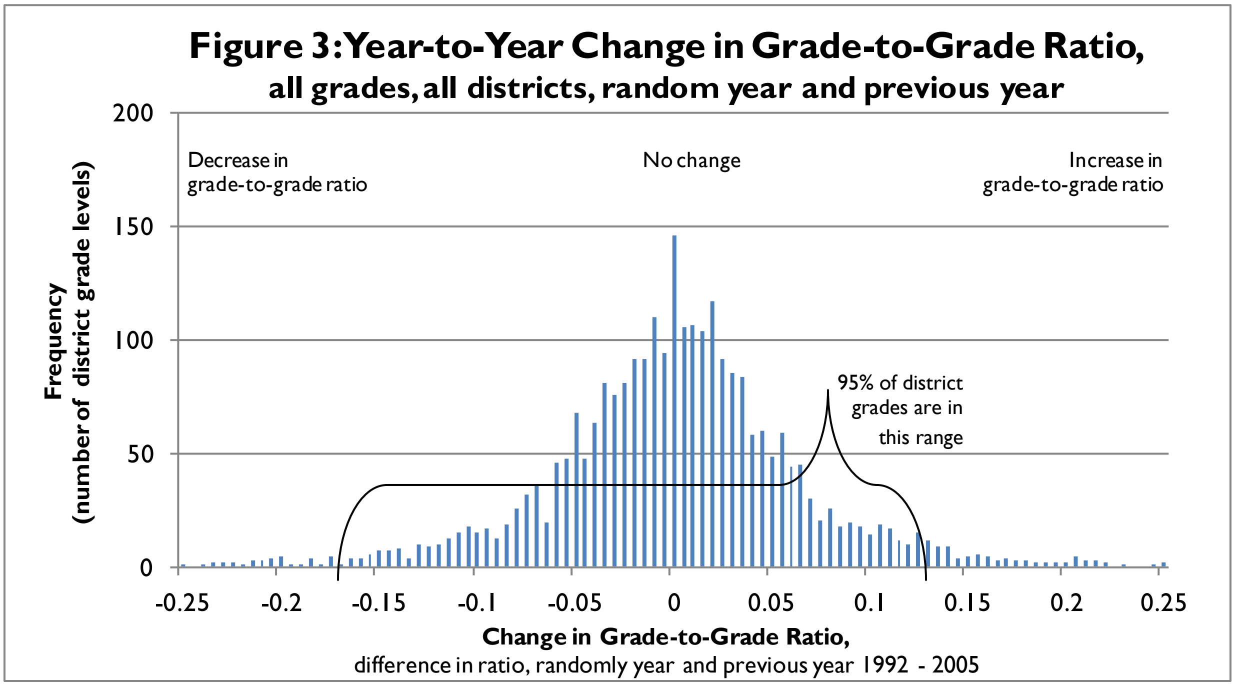
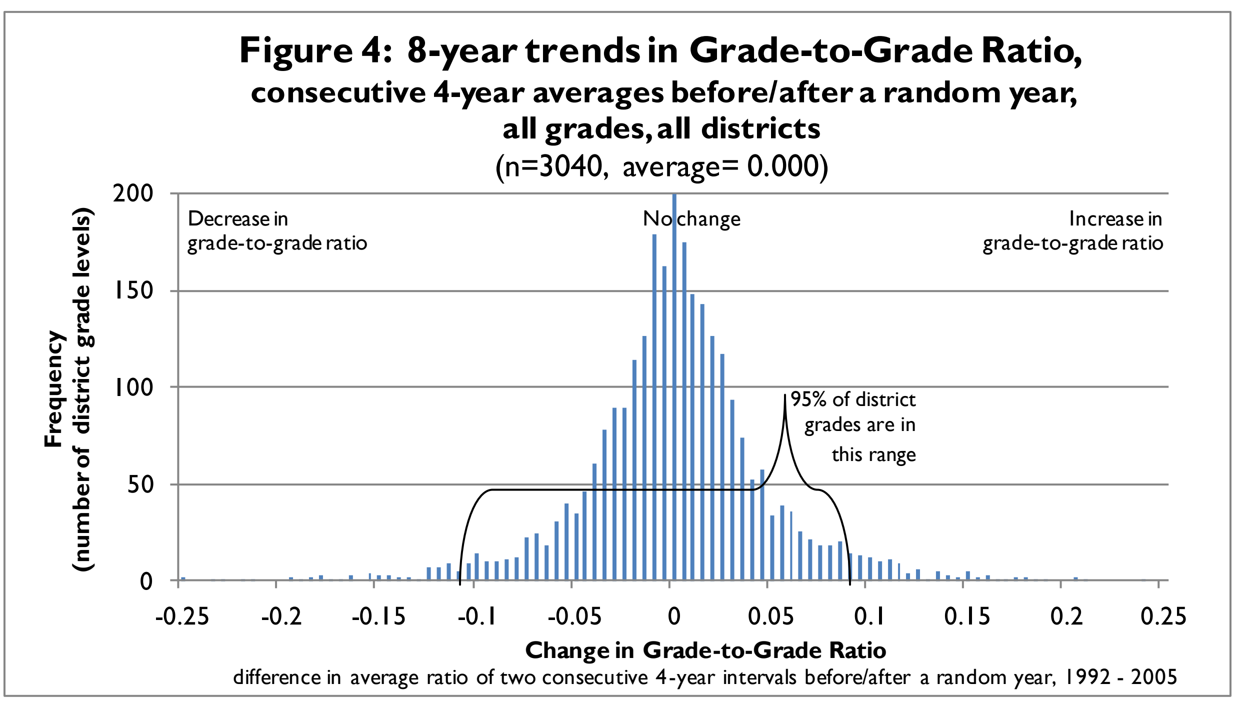


Figure 3 depicts this variability for all 3,000 district grades by comparing the grade-to-grade ratio in the randomly selected year to the ratio in the previous year.



Constancy is rare; the ratio remained the same in only 5% of the observed grades. Two thirds of district grades' grade-to-grade ratios vary by less than 0.05 from year to year; in a third of district grades, grade-to-grade ratios increase or decrease by more than 0.05 from one random year to the next. For example, if there were 100 district grades of 100 students in a given year, 65 of those district grades would have between 95 and 105 students the following year, and 35 district grades would have fewer than 95 or more than 105 students. It is important to note that the increases in some grades are balanced by decreases in other grades, so the average change from year to year is effectively zero.

While there may be considerable fluctuation from year to year, fewer districts show increasing or decreasing trends over longer time periods time. Decreases in one year are compensated by increases in subsequent years. As a result, the long-term variability is less than the year-to-year variability. Figure 4 shows the difference in average grade-to-grade ratio for two consecutive four-year intervals (before and after the randomly-selected year), for all district grades in the state.

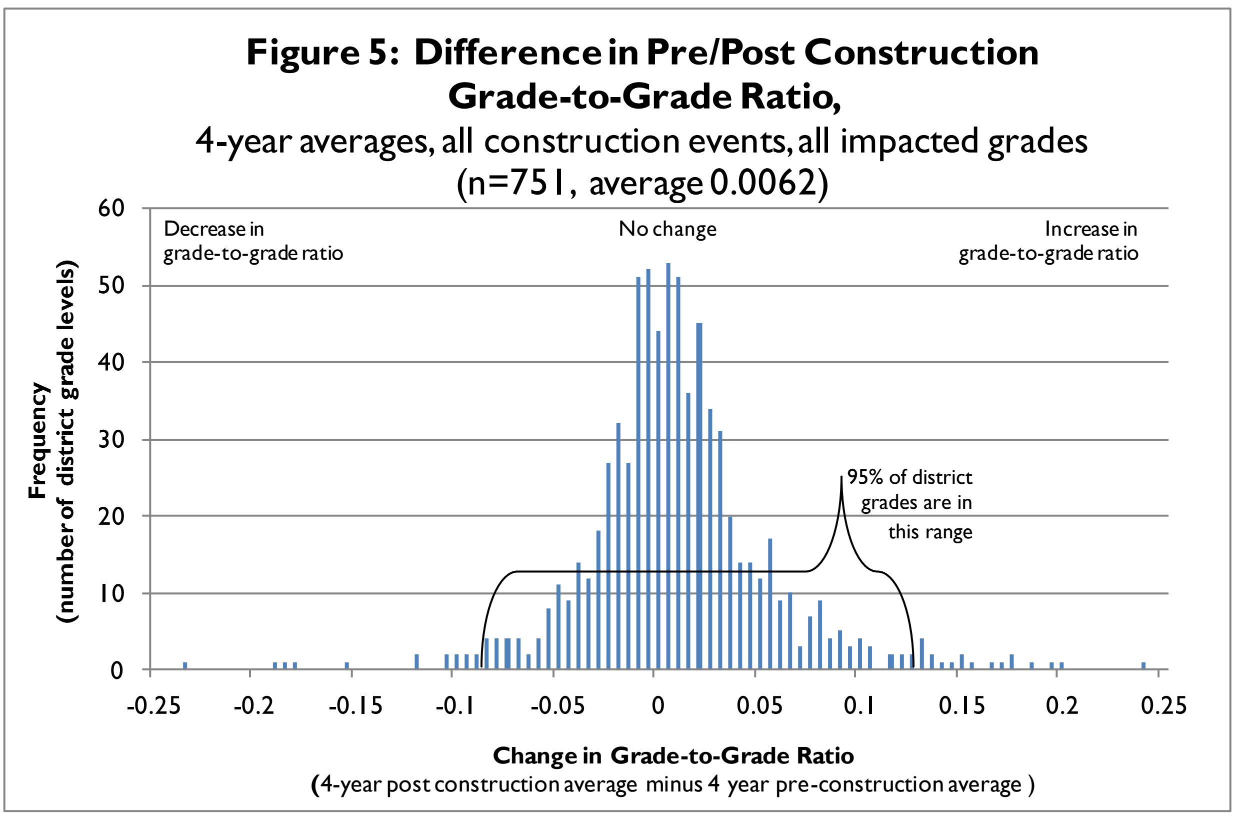


This chart shows a tighter distribution than the year-to-year change depicted in Figure 3. For example, of 100 district grades with an average of 100 students over a random four-year period, 82 would have an average of 95 – 105 students for the following 4-year period; only 18 district grades would have fewer than 95 students or more than 100 students. It is important to note that overall, there is little net change: while 51% of districts have a increase in the ratio (versus 49% with a decrease), the average change across all district grades is effectively zero (0.000). In other words, the average class size would remain 100, in this example.

The variability depicted in Figures 3 and 4 is important, since MSBA's enrollment projection methodology uses a 5-year average of grade-to-grade ratios to project future enrollment. This methodology is based on the sound assertion that the best predictor of a district's future enrollment is its own present and recent past. Even in the absence of construction, projections based on recent grade-to-grade ratios may overestimate enrollment in some future years in some districts, and underestimate enrollment for other years and districts. However, these over- and under-estimates balance each other out so that *on average*, projected enrollment is comparable to actual enrollment (there is no systematic under- or over-projection. Now we turn to enrollment data from schools that experienced construction events to see if grade-to-grade ratios appear different.

Observed Enrollment Patterns, Construction Districts

As described below in the section on methodology, MAPC collected and prepared data on nearly 200 construction events from 1995 – 2005. Figure 5 shows the difference in average grade-to-grade ratio for the four-year intervals before and after construction. This chart is comparable to Figure 4, except that it shows data only for those district grades impacted by construction.

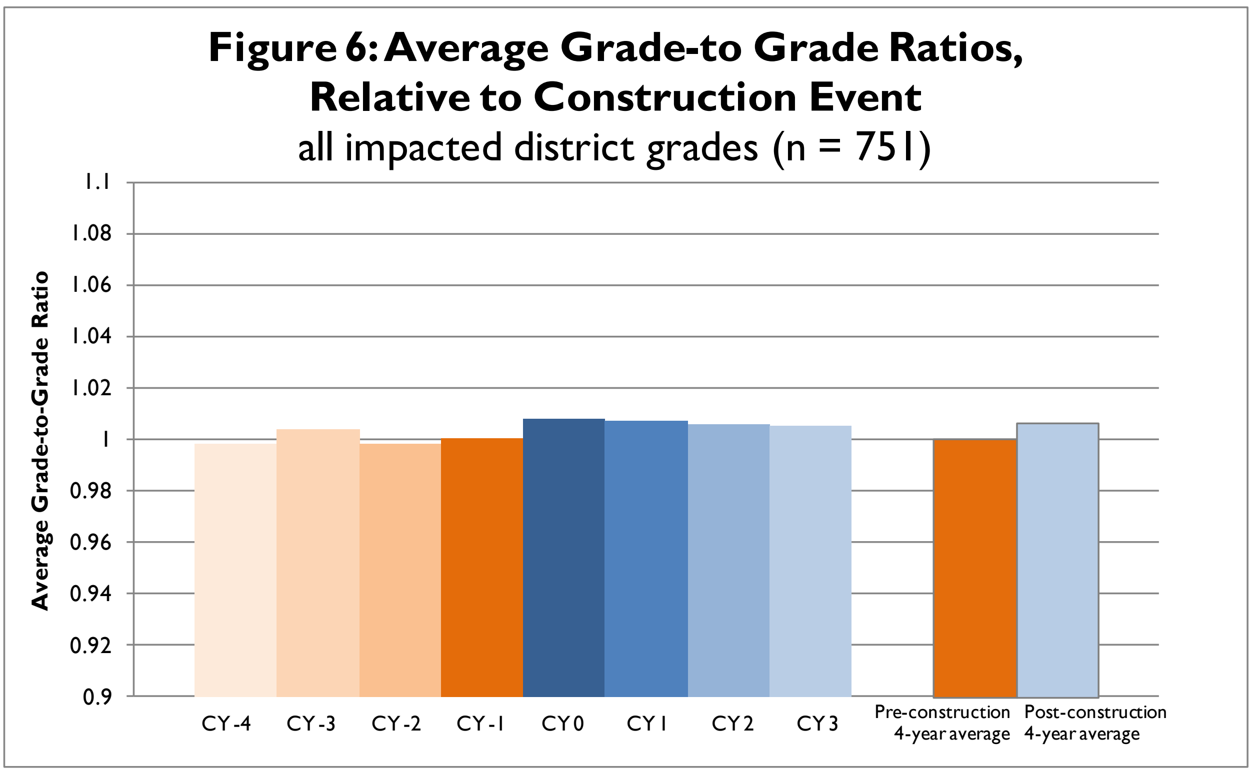


Like Figure 4, values are distributed normally; however, these values suggest a shift toward higher grade-to-grade ratios: 60% of district grades have a value greater than zero, and the average value is 0.0062 (versus 51% and -0.0006 for randomly-selected district grade years shown in Figure 4.) In other words, 100 district grades with an average of 100 students in all grades in the four years before construction would have an average of 100.6 students in each impacted grade after construction. It is important to note that for 40% of the district grades, the value is less than 0.0, indicating that the post-construction average is less than the pre-construction average. Table 2 presents the distribution of observations.

Table 2: Difference in Pre-/Post-Construction Grade-to-Grade Ratio, 4-year averages, all grades

Pre-/Post-Construction Change	Number of District Grades Observed	
Increase >0.10	28	41% of districts increased by 0.01 or more
Increase 0.05 - 0.10	71	
Increase 0.01 - 0.05	206	
Increase <0.01	104	33% of districts changed less than 0.01
No Change	44	
Decrease <0.01	103	
Decrease 0.01 - 0.05	150	26% of districts decreased by 0.01 or more
Decrease 0.05 - 010	36	
Decrease >0.10	9	
TOTAL	**751**	

Figure 5 shows a different approach to visualizing enrollment data for district grades that experienced a construction event. This chart shows average grade-to-grade ratios for all impacted district grades year-by-year relative to the construction event. It shows that during the four years prior to construction (CY-4 to CY-1), average grade-to-grade ratios hover around 1.0; in the year a new or renovated school opens (CY0), average ratios jump to 1.008 and remain above 1.005 through the third year after the construction year (CY0). The 4-year averages for the pre- and post-construction years are also shown on the right side of the chart. The pre-construction average is 1.0002, while the post construction average is 1.0065. The difference between these two values is the difference in 4-year average pre/post construction grade-to-grade ratio, depicted in Figure 6.



These enrollment patterns suggest that, after construction, the average grade-to-grade ratio for impacted grades increases; and more district grades experience an increase than a decrease in grade-to-grade ratio. However, these observations do not prove that an increase in grade-to-grade ratio is not necessarily "caused" by school construction—it may be part of the natural variability seen in all districts, and demonstrated in Figures 2 through 4. MAPC determined multivariate statistical analysis was the best mechanism to determine whether the observed increase in grade-to-grade ratio could be statistically correlated with construction events.

Multivariate Model

In order to analyze and quantify the potential impact of school construction on enrollment, MAPC created a multivariate regression model that seeks to estimate the effect of construction after accounting for a variety of other factors. This model seeks to quantify general patterns of enrollment and the natural variability that occurs from year to year. Grade-to-grade ratio is the dependent variable in the model; grade-to-grade ratios across all districts are compared to each other while simultaneously accounting for factors that may influence grade-to-grade ratios, including construction events. This allows us to assess whether post-construction ratios are larger than would be expected based on natural variability. **The observations above are based on what happened in the past; the model results describe what is statistically probable in the future, and are thus appropriate to be incorporated into the enrollment projections.**

MAPC developed a model that incorporates 41,000 grade years of data, as well as municipal or district attributes for each grade and information about the construction events. MAPC ran a series of univariate regression models to determine which district-level characteristics (such as average income or MCAS scores) are significantly correlated with grade-to-grade ratio, then created a multivariate model that includes the significant covariates and the variable reflecting the time relative to construction for districts that had a construction event. Detailed methodology for this model is in Appendix B.

The model can account for differences in enrollment patterns that are correlated with other community or district characteristics such as income, MCAS scores, growth rates, and others. With this broader community context, the model can estimate the relative impact of construction under different conditions. **Given the variability across districts and the relatively small number of districts with specific characteristics, the model cannot be determinative about what will happen in a specific district after construction; it can simply identify what is most likely to happen in order to avoid systematic bias in the enrollment projections.**

Model Results

MAPC's analysis found that in the two years before a new or renovated school opened, grade-to-grade ratios in a district are statistically indistinguishable from ratios for the same school type in other districts with similar income, MCAS scores, and new building permits. The year a new or renovated school opens ("the construction year"), the impacted grades in that school district experience *on average,* a small but statistically significant increase in grade-to-grade ratio (approximately 1%). The effect continues in subsequent years and declines slightly, to approximately 0.7% in the third year after the construction year. These increases were significant after accounting for other factors that may have influenced enrollment, such as income, MCAS score, and building permits.

Across all schools statewide, grade-to-grade ratios are positively and significantly correlated with MCAS scores, income, housing permits, population growth rate (1990 – 2000), and Community Type, when analyzed individually in a univariate model. When incorporated into a multivariate model that includes all five of these attributes, the effects of MCAS, income, and housing permits are attenuated but still significant. Population change, which is strongly correlative with housing permits, is not significant in the multivariate model. Student teacher ratios, per-pupil expenditure, and housing sales are not statistically correlated with grade-to-grade ratios when analyzed in a univariate model and were therefore not included in the multivariate analysis. Community Type was excluded from the multivariate model for two reasons. Because Community Type is collinear with income and housing permits, including it in the model would attenuate the effect of those parameters. Also, community type is a semi-qualitative category, and MAPC felt the model would be more useful to MSBA if based solely on quantitative variables. Table 3 shows the results of the final multivariate model.

Table 3: Results: Final Multivariate Model—Construction-Induced Enrollment
(Statistically significant parameters are shaded)

Parameter	Estimate	Significance (P value)	95 % Confidence Interval	
			Lower	Upper
Income	0.002	**0.042**	0.000	0.003
MCAS	0.007	**<.0001**	0.005	0.008
Housing permits	0.002	**0.000**	0.001	0.004
Population Change	-0.001	0.237	-0.002	0.001
CY-3	0.005	**0.029**	0.001	0.010
CY-2	0.000	0.994	-0.005	0.005
CY-1	0.002	0.463	-0.003	0.008
CY0 (year new school opens)	0.011	**0.000**	0.005	0.016
CY1	0.009	**0.001**	0.004	0.015
CY2	0.006	**0.034**	0.001	0.012
CY3	0.007	**0.022**	0.001	0.013

The "Estimate" column shows the modeled impact of each attribute on grade-to-grade ratio. The significance column shows the P value, which is a measure of statistical significance. The smaller the P value, the less likely it is that the observed variation is due to random chance. The "Lower" and "Upper" values are the upper and lower bounds of the 95% confidence interval.

The first three parameters apply to all district grades statewide. The positive estimates indicate that, regardless of construction events, districts with higher income, MCAS scores, and building permit issuances have higher grade-to-grade ratios[5]. The high P value for population change indicates that the 1990 – 2000 growth rate is not statistically correlated with grade-to-grade ratios.

The parameters beginning with "CY" indicate time relative to construction. CY-3 is the third year before the construction year. CY0 is the construction year (the year the school opens.) CY3 is the third year after the construction year. The very small coefficients and lack of statistical significance for CY-2 and CY-1 indicate that, in the two years before a new school opens, grade-to-grade ratios in a district are statistically indistinguishable from other districts with comparable income, MCAS scores, and housing permits. In the year that a new or renovated school opens, the model estimates that grade-to-grade ratios for impacted grades are 0.011 higher than comparable districts and grades. While the very low P value indicates that this difference between impacted grades and other grades is not due to random chance, the model cannot predict the coefficient with absolute certainty. The confidence interval for CY0 indicates that we can be 95% certain that the true coefficient is between 0.005 and 0.016.

The positive and statistically significant estimates continue for subsequent years, with a slight decline from CY0 to CY3, indicating that the effect on grade-to-grade ratios continues over those years. It is also important to note that the effect is cumulative; increased enrollment in one year will be carried over to future years, and will be the subject of future years' grade-to-grade ratios. Adding up the effects for the construction year and the three following years results in a cumulative impact of approximately 3.3%. In other words, enrollment in the third year after the construction year is likely to be 3.3% higher than would otherwise be expected.

The model also found an unexplained but statistically significant coefficient for CY-3, of approximately 0.5. While a coefficient for CY-4 was not calculated, empirical observation such as Figure 6 suggest that this coefficient for CY-3

[5] Income, MCAS, and Housing Permits are included in the model as discrete variables with a value of 1 through 4, representing the district's assignment to statewide quartiles. The positive values on these estimates indicate that grade-to-grade ratio is positively correlated with these three parameters. For example, districts in the second income quartile have grade-to-grade ratios that are, statistically speaking, 0.002 higher than the ratios for districts in the first income quartile.

represents an increase over the baseline grade-to-grade ratio. MAPC does not have a hypothesis for why this "bump" occurs in CY-3.

MAPC also sought to determine whether the effect of construction was larger in certain school types, community types, or districts with certain attributes. In order to explore this question, we selected only those districts in a particular quartile or school type and ran the multivariate analysis on those districts alone. We performed this "stratified analysis" on each parameter that was statistically significant in the initial multivariate model, including those parameters that were not included in the final multivariate model (specifically, Community Type.) This exercise allowed us to investigate how the various predictor variables behaved in different contexts, testing, for example, whether the construction year parameter coefficients were larger or smaller in districts with specific characteristics. However, the results for these stratified analyses were not statistically significant for most parameters that were significant in the full model, most likely because each stratified analysis contained only a small number of observations. Specifically, none of the stratified analyses demonstrated any consistent pattern for estimate and significance of the CY-3 to CY3 parameters.

Conclusions and Recommendations

MAPC's statistical analysis of nearly 200 school construction events predicts that that, on average, grades experiencing a construction event are likely to experience a small increase in grade-to-grade ratio after a new or renovated school opens. The increase is not observed in every district and grade, but it happens often enough to create a measurable systematic impact on enrollment, not currently accounted for in the projections methodology. Adjustments to the methodology, described below, can help to account for this effect. No methodology can predict all the observed variation in grade-to-grade ratio, but our recommended adjustments will ensure that the projections do not systematically underestimate post construction enrollment.

MAPC recommends that MSBA make the following modifications to the enrollment methodology; all of these recommendations are based on the assumption that MSBA is using a 5-year average of grade-to-grade ratios to project future enrollment (baseline ratio):

- When projecting enrollment for CY0, add 0.011 to the baseline ratio for each grade impacted by the school construction
- When projecting enrollment for CY1, add 0.009 to the baseline ratio for each grade impacted by the school construction
- When projecting enrollment for CY2, add 0.006 to the baseline ratio for each grade impacted by the school construction
- When projecting enrollment for CY3, add 0.007 to the baseline ratio for each grade impacted by the school construction
- When projecting enrollment for CY4, return to the baseline ratio for each grade impacted by the school construction

By incorporating these adjustments into the methodology, MSBA's enrollment projections will reflect the enrollment patterns *most likely* to occur after construction. It is possible that some school administrators may argue that a higher adjustment is necessary due to unique local conditions, and MSBA may have reasons to believe that an additional increase is merited. In these cases, MAPC recommends that the adjustment be capped at the upper bound of the 95% confidence interval. Adjustments to the baseline ratio would be as follows:

- CY0 adjustment: up to 0.016
- CY1 adjustment: up to 0.015
- CY2 adjustment: up to 0.012
- CY3 adjustment: up to 0.013
- Return to the baseline ratio for CY4

MAPC believes that these recommended adjustments to MSBA's existing enrollment methodology will adequately account for the observed effects of construction-induced enrollment, while also limiting the production of excess school capacity created as a contingency for such effect.

Appendix A:
List of Construction Events Analyzed

District	School	School Type	Project Type	Project Cost	Year Opened
Acton-Boxborough	Acton-Boxborough Reg HS	HS	Addition/Reno	$ 55,381,040	2004
Acushnet	Acushnet ES	Elementary	Renovation	$ 15,992,495	2002
Acushnet	Albert F Ford MS	Middle	Addition/Reno	$ 13,700,660	2005
Amherst	Crocker Farm ES	Elementary	Addition/Reno	$ 9,204,131	2002
Amherst-Pelham	Amherst Reg MS	Middle	Renovation	$ 6,011,335	2000
Andover	High Plain ES	Elementary	New	$ 34,586,432	2002
Arlington	Peirce ES	Elementary	New	$ 14,542,122	2003
Ashburnham-Westminster	Oakmont Reg HS	HS	Addition/Reno	$ 36,249,446	2001
Athol-Royalston	Athol-Royalston MS	Middle	New	$ 23,535,060	1999
Barnstable	Barnstable MS	Middle	New	$ 26,586,699	2000
Bedford	Lt Eleazer Davis Primary	Elementary	New	$ 18,795,726	1999
Bedford	John Glenn MS	Middle	Renovation	$ 22,187,148	2003
Belchertown	Belchertown HS	HS	New	$ 49,159,868	2002
Bellingham	Bellingham HS	HS	New	$ 46,468,635	2001
Bellingham	Bellingham Memorial MS	Middle	Addition/Reno	$ 18,918,580	2002
Berkley	Berkley MS	Middle	New	$ 22,753,175	2002
Berkshire Hills	Muddy Brook Reg ES	Elementary	New	$ 20,814,349	2005
Berkshire Hills	Monument Valley Reg MS	Middle	New	$ 23,205,172	2005
Beverly	North Beverly ES	Elementary	New	$ 15,396,141	2002
Blackstone-Millville	Frederick W. Hartnett MS	Middle	New	$ 24,616,028	2003
Boston	Orchard Gardens K-8	Elementary	New	$ 34,663,189	2002
Boston	Mildred Avenue MS	Middle	New	$ 55,264,391	2002
Bourne	Bourne MS	Middle	New	$ 32,397,411	2000
Boxford	Harry Lee Cole Primary	Elementary	Addition/Reno	$ 3,856,868	1997
Bridgewater-Raynham	Raynham MS	Elementary	New	$ 38,016,923	2001
Brockton	Dr W Arnone Comm ES	Elementary	New	$ 29,298,728	2002
Brookline	Edith C Baker K-8	Elementary	Addition/Reno	$ 16,258,261	2000
Canton	Dean S Luce ES	Elementary	Addition/Reno	$ 15,452,912	2004
Central Berkshire	Becket Washington ES	Elementary	Addition/Reno	$ 6,844,068	2003
Chatham	Chatham ES	Elementary	Addition/Reno	$ 13,079,194	1997
Chatham	Chatham HS	HS	Addition/Reno	$ 21,484,709	1998
Chelsea	Chelsea HS	HS	Renovation	$ 19,238,492	1996
Clinton	Clinton ES	Elementary	New	$ 21,955,197	2003
Concord	Alcott ES	Elementary	New	$ 14,251,744	2004
Dennis-Yarmouth	Dennis-Yarmouth Reg HS	HS	Renovation	$ 33,563,562	2005
Dighton-Rehoboth	Dighton-Rehoboth Reg HS	HS	Addition/Reno	$ 27,927,214	2004
Douglas	Douglas ES	Elementary	Addition/Reno	$ 8,829,179	2002
Douglas	Douglas HS	HS	New	$ 34,298,069	2003
Dover-Sherborn	Dover-Sherborn Reg HS	HS	New	$ 42,090,925	2004
Duxbury	Chandler ES	Elementary	Addition/Reno	$ 15,041,067	2003
East Longmeadow	Birchland Park MS	Middle	New	$ 29,584,870	2000
Edgartown	Edgartown ES	Elementary	New	$ 17,532,598	2003
Erving	Erving ES	Elementary	Addition/Reno	$ 9,618,885	2003
Fall River	William S Greene ES	Elementary	New	$ 31,961,445	2002
Framingham	Cameron MS	Middle	Renovation	$ 29,696,486	2000
Franklin	Helen Keller ES	Elementary	New	$ 27,257,061	2002
Franklin	Remington MS*	Middle	New	$ 28,970,164	1996
Freetown	Freetown ES	Elementary	Addition/Reno	$ 14,889,939	2000
Freetown-Lakeville	Freetown-Lakeville MS	Middle	Renovation	$ 39,485,138	2000
Gateway	Russell ES	Elementary	Addition/Reno	$ 3,594,695	2002

District	School	School Type	Project Type	Project Cost	Year Opened
Gateway	Gateway Reg MS	Middle	Addition/Reno	$ 26,311,233	2003
Gill-Montague	Turners Fall HS	HS	Renovation	$ 32,980,379	2004
Grafton	Grafton ES	Elementary	New	$ 16,014,109	2002
Greenfield	Greenfield MS	Middle	Renovation	$ 30,615,713	2001
Groton-Dunstable	Groton Dunstable Reg HS	HS	New	$ 53,053,888	2003
Hampden-Wilbraham	Mile Tree ES	Elementary	Addition/Reno	$ 8,347,107	1999
Harwich	Harwich ES	Elementary	Addition/Reno	$ 20,452,244	2003
Hatfield	Hatfield ES	Elementary	New	$ 9,259,607	2003
Haverhill	Pentucket Lake ES	Elementary	New	$ 21,119,382	1998
Haverhill	Dr Paul Nettle MS	Middle	New	$ 26,500,159	2000
Hawlemont	Hawlemont Reg ES	Elementary	Addition/Reno	$ 6,822,330	2003
Holliston	Placentino ES	Elementary	Renovation	$ 49,912,785	1998
Hopedale	Memorial ES	Elementary	Renovation	$ 11,491,861	1995
Hopkinton	Hopkinton HS	HS	New	$ 54,589,986	2001
Hudson	C A Farley ES	Elementary	Addition/Reno	$ 15,014,508	1999
Hull	Hull HS	HS	Addition/Reno	$ 19,784,000	2005
Hull	Memorial MS	Middle	Renovation	$ 13,129,395	2002
King Philip	King Philip MS	Middle	Addition/Reno	$ 27,620,582	2001
Kingston	Kingston IS	Elementary	New	$ 24,661,945	2000
Lanesborough	Lanesborough ES	Elementary	New	$ 14,214,622	2001
Lawrence	Emily G Wetherbee K-8	Elementary	New	$ 42,262,605	2003
Lee	Lee ES	Elementary	New	$ 19,991,143	2002
Leominster	Sky View MS	Middle	New	$ 24,400,215	2003
Lexington	Harrington ES	Elementary	New	$ 16,348,909	2004
Lincoln-Sudbury	Lincoln-Sudbury Reg HS	HS	New	$ 74,728,720	2005
Littleton	Shaker Lane ES	Elementary	Addition/Reno	$ 7,757,014	1999
Littleton	Littleton HS	HS	New	$ 36,202,986	2002
Longmeadow	Wolf Swamp Road ES	Elementary	Addition/Reno	$ 10,981,974	2002
Lowell	Stoklosa MS	Middle	New	$ 31,585,570	2005
Ludlow	Ludlow SHS	HS	Addition/Reno	$ 34,335,626	2000
Lunenburg	Lunenburg Primary	Elementary	New	$ 15,163,120	2005
Lynnfield	Huckleberry Hill ES	Elementary	Renovation	$ 11,724,765	2004
Lynnfield	Lynnfield HS	HS	Renovation	$ 19,003,203	2003
Lynnfield	Lynnfield MS	Middle	New	$ 22,913,507	2003
Marblehead	Marblehead HS	HS	New	$ 46,112,730	2002
Marblehead	Marblehead Veterans MS	Middle	Addition/Reno	$ 23,495,676	2004
Marshfield	Martinson ES	Elementary	Addition/Reno	$ 13,155,043	1999
Marshfield	Furnace Brook MS	Middle	Addition/Reno	$ 26,509,583	1999
Marthas Vineyard	Marthas Vineyard Reg HS	HS	New	$ 33,344,029	2001
Mattapoisett	Center ES	Elementary	Addition/Reno	$ 14,404,560	2004
Medfield	Memorial School	Elementary	Addition/Reno	$ 14,855,933	2003
Medfield	Medfield SHS	HS	Addition/Reno	$ 51,202,892	2005
Medfield	Thomas Blake MS	Middle	Addition/Reno	$ 5,858,874	2005
Medford	Brooks ES	Elementary	New	$ 20,168,303	2003
Medway	Medway HS	HS	New	$ 41,552,945	2005
Melrose	Roosevelt ES	Elementary	New	$ 12,557,084	2002
Mendon-Upton	Henry P Clough ES	Elementary	New	$ 16,393,207	2003
Methuen	Marsh Grammar K-8	Elementary	Addition/Reno	$ 36,684,337	1997
Millis	Millis HS	HS	Addition/Reno	$ 13,304,732	1998
Monson	Monson HS	HS	New	$ 30,216,981	2000
Nashoba	Mary Rowlandson ES	Elementary	Addition/Reno	$ 19,827,941	2002
Natick	Bennett-Hemenway ES	Elementary	New	$ 21,341,650	1999

District	School	School Type	Project Type	Project Cost	Year Opened
Natick	Wilson MS	Middle	New	$ 26,511,381	2003
Needham	Broadmeadow ES	Elementary	Addition/Reno	$ 22,663,709	2002
New Bedford	Roosevelt MS	Middle	New	$ 54,634,361	2001
Newton	Williams ES	Elementary	Addition/Reno	$ 5,372,234	2001
Newton	Newton South HS	HS	Addition/Reno	$ 70,604,166	2004
North Adams	Drury HS	HS	Renovation	$ 24,404,305	2001
North Andover	Thomson ES	Elementary	New	$ 13,438,375	1999
North Andover	North Andover HS	HS	New	$ 58,239,808	2004
North Middlesex	Nissitissit MS	Middle	New	$ 24,119,647	2002
Northampton	Northampton HS	HS	Renovation	$ 41,560,928	1999
Northboro-Southboro	Algonquin Reg HS	HS	Addition/Reno	$ 63,316,646	2005
Northborough	Marion E Zeh ES	Elementary	Addition/Reno	$ 12,153,807	1998
Norton	Norton MS	Middle	New	$ 33,293,207	1998
Norwell	Norwell HS	HS	Addition/Reno	$ 19,399,163	2003
Norwell	Norwell MS	Middle	New	$ 22,881,749	2002
Oxford	Alfred M Chaffee ES	Elementary	Addition/Reno	$ 10,854,822	2003
Oxford	Oxford HS	HS	New	$ 28,061,794	2002
Peabody	Thomas Carroll ES	Elementary	Renovation	$ 16,885,401	2003
Pembroke	Pembroke Community MS	Middle	Renovation	$ 17,938,948	2003
Petersham	Petersham Center ES	Elementary	Renovation	$ 5,198,790	2003
Pioneer Valley	Warwick Comm ES	Elementary	New	$ 5,457,440	1999
Pittsfield	Allendale ES	Elementary	Addition/Reno	$ 8,777,559	1999
Plainville	Anna Ware Jackson ES	Elementary	Addition/Reno	$ 16,729,727	2002
Plymouth	Plymouth South MS	Middle	New	$ 35,221,253	1999
Provincetown	Veterans Memorial ES	Elementary	Renovation	$ 2,347,702	2002
Quincy	Point Webster MS	Middle	Addition/Reno	$ 12,043,195	1998
Randolph	Randolph Community MS	Middle	Addition/Reno	$ 25,049,838	1999
Reading	Wood End ES	Elementary	New	$ 12,564,357	2004
Richmond	Richmond Consolidated K-8	Elementary	Addition/Reno	$ 10,685,555	2001
Salem	Bates ES	Elementary	Addition/Reno	$ 18,965,594	1999
Saugus	Veterans Memorial ES	Elementary	New	$ 18,209,468	1999
Seekonk	George R Martin ES	Elementary	Addition/Reno	$ 13,371,135	2001
Seekonk	Seekonk HS	HS	Addition/Reno	$ 23,927,033	2002
Seekonk	Dr. Kevin M. Hurley MS	Middle	Addition/Reno	$ 14,395,905	1997
Sherborn	Pine Hill ES	Elementary	Addition/Reno	$ 9,217,157	1998
Shirley	Shirley MS	Middle	New	$ 17,184,078	2003
Shrewsbury	Shrewsbury Sr HS	HS	Addition/Reno	$ 91,097,352	2002
Shrewsbury	Oak MS	Middle	Addition/Reno	$ 20,314,119	2004
Silver Lake	Silver Lake Regional MS	Middle	New	$ 31,209,547	2004
South Hadley	South Hadley HS	HS	Renovation	$ 24,789,481	2001
South Hadley	Michael E. Smith MS	Middle	Renovation	$ 19,320,237	2000
Southborough	Mary E Finn School	Elementary	Addition/Reno	$ 17,511,529	2002
Southborough	P Brent Trottier MS	Middle	Addition	$ 11,413,400	1999
Spencer-E Brookfield	East Brookfield ES	Elementary	New	$ 11,457,811	2002
Springfield	Frederick Harris ES	Elementary	Addition/Reno	$ 23,631,693	2001
Springfield	Van Sickle MS	Middle	Addition/Reno	$ 71,203,613	2001
Stoneham	South ES	Elementary	New	$ 15,631,437	2000
Sudbury	Josiah Haynes ES	Elementary	Addition/Reno	$ 13,502,498	1998
Sudbury	Ephraim Curtis MS	Middle	New	$ 34,261,026	2000
Tantasqua	Tantasqua Reg SHS*	HS	New	$ 79,196,884	2002
Tewksbury	John F. Ryan MS	Elementary	New	$ 24,046,476	1999

District	School	School Type	Project Type	Project Cost	Year Opened
Tewksbury	John W. Wynn MS	Middle	Renovation	$ 19,525,147	2003
Topsfield	Proctor ES	Elementary	Addition/Reno	$ 7,911,318	2000
Triton	Triton Reg HS	HS	Addition/Reno	$ 45,444,476	2000
Tyngsborough	Tyngsborough ES	Elementary	New	$ 24,788,328	2002
Wachusett	Houghton ES	Elementary	Renovation	$ 30,811,584	1998
Wakefield	Dolbeare ES	Elementary	Addition/Reno	$ 14,845,376	1998
Walpole	Boyden ES	Elementary	Addition/Reno	$ 6,658,355	2002
Waltham	William F. Stanley ES	Elementary	New	$ 20,960,410	2003
Waltham	John W. McDevitt MS	Middle	Renovation	$ 23,981,860	2003
Wareham	Wareham MS	Middle	Addition/Reno	$ 23,803,091	2005
Watertown	Watertown HS	HS	Addition/Reno	$ 11,543,534	2004
Webster	Anthony J Sitkowski IS	Elementary	New	$ 23,359,008	2005
Wellesley	Sprague ES	Elementary	Renovation	$ 21,790,977	2002
Westborough	Westborough HS	HS	Addition/Reno	$ 65,438,659	2002
Westfield	North MS	Middle	New	$ 34,707,369	1999
Westford	Rita E. Miller ES	Elementary	New	$ 19,262,938	2002
Westford	Stony Brook MS	Middle	New	$ 29,326,367	2002
Weston	Country ES	Elementary	New	$ 20,631,617	2003
Weston	Weston HS	HS	Addition/Reno	$ 26,620,640	1998
Weston	Weston MS	Middle	Addition/Reno	$ 22,620,840	1999
Westwood	Martha Jones ES	Elementary	Addition/Reno	$ 9,398,331	2005
Westwood	Westwood HS	HS	Addition/Reno	$ 64,270,872	2004
Whitman-Hanson	Indian Head IS	Elementary	Addition/Reno	$ 10,791,695	1999
Whitman-Hanson	Whitman Hanson Reg HS	HS	New	$ 52,438,885	2005
Whitman-Hanson	Hanson MS	Middle	New	$ 22,318,358	1998
Williamstown	Williamstown ES	Elementary	New	$ 16,828,222	2002
Winchester	Ambrose ES	Elementary	New	$ 13,625,942	2005
Woburn	Shamrock ES	Elementary	New	$ 13,501,544	2002

Appendix B:
MSBA/MAPC Construction-Induced Enrollment Study - Methodology

Enrollment data and Municipal Assignment (Fall 2008)

- The list of school district with associated town name is obtained from MassGIS School District layer. MassGIS has three school district layers: Elementary School, Middle School, and High School. By overlay (intersect) each school layer with MA town layer, we identified the town name for each district for three school types. Then we combined the three school district layers, the result table is: All_School_District.xlsx. Most school districts only have one town associated with them, while some regional districts have multiple towns.
- Using the "Muni lookup table", each district is assigned to one of MAPC's Statewide Community Types (8 types). Regional districts that contain more than one community are assigned based on the largest municipality (largest population in 2000) in the district. K:\DataCenter\Projects\MSBA\CCD DATA\District_Town_Community type.xlsx
- The cohort survival rates for all grade transitions for all school districts in the state, for the years 1993 – 2006, are from MA DOE enrollment data (accessed via the National Center for education Statistics Common Core of Data). Cohort survival rate is calculated by dividing the enrollment for a given grade by the enrollment for the previous grade in the previous year. K:\DataCenter\Projects\MSBA\CCD DATA\CCD_DISTRIC_93_06_ALL GRADES.xlsx
- The cohort survival rates table is then linked with the district/town/community type table, producing the cohort survival rates for school districts, town and community type. K:\DataCenter\Projects\MSBA\CCD DATA\Cohort Suvival Rate_district_town.xlsx This table excluded school districts from CCD data, such as charter school and "Non- op" schools, which are not the school districts our studies focus on.

Construction Events and Covariates, Data Preparation (Spring 2009)

- Downloaded and formatted audit list containing construction event information
  - Linked to May 2008 update for most complete construction information possible
- Downloaded and formatted school needs summary containing last renovation dates
- Manually linked audit list and school needs summary based on district and school type
- Created unique ID for each construction event by concatenating 'districtID_year_school type'
- Created same 'districtID_year_school type' unique ID for each entry in existing CSR database (August 2008)
- Linked construction events to CSR by unique ID
  - This gave us one CSR entry per grade per year per district, with construction event information appended if an event occurred in that district, year, and school type. [School types: elementary: K – 5; middle: 6-8; high:9-12].
- Input datasheet into SAS to create variables indicating time relative to construction event for each year of enrollment data.
  - Variables included "construction year," "one year post construction," "two years post construction," and so on. Years prior to construction were also indicated. These dichotomous indicator variables took a value of 1 if the condition was true (e.g., "one year prior to construction" took a value of 1 in 1998 if construction occurred in 1999) and 0 otherwise.
  - If more than one construction event occurred for the same school type in the same district, the earlier construction event was chosen and the later event dropped. About 2% of records were affected by this decision.
- Collected covariate information at the district and municipal level
  - District level: MCAS scores in 4^{th}, 8^{th}, and 10^{th} grades; per pupil expenditure; student teacher ratio
  - Municipal level: Housing permits; housing sales; population change from 1999 – 2000; population 2000

- Linked municipal and district-level covariates using existing school district-municipality crosswalk table (created August 2008 for phase 1 of the MSBA Construction Induced Enrollment Study). This assigned municipal-level covariates to the correct school districts
- Districts were assigned a rank of 1 through 4 for each indicator, based on quartiles for each indicator.
- Covariate table was checked for quality assurance (QA) against original input tables by an analyst uninvolved in the project (a sample of ~20 randomly selected entries were reviewed)
- The QAed covariate table was imported into SAS and linked to the CSR information based on district ID. This final table contained CSR, construction event, and covariate data.
- The final table was checked for quality assurance against either original input tables or tables that had previously been QAed (roughly 40 randomly selected rows were reviewed for correct time relative to construction events, CSR, community type, and covariate information).
- The resulting final input table contained a unique identification code indicating grade and district. This unique code was used to follow the enrollment patterns of any given grade in any given district over time. We fit several linear mixed models to assess the impacts of construction events on CSR.

Statistical Analysis (Spring/Summer 2009)

- Used SAS version 9.2 for all analyses
- Linear mixed models assumed that CSRs of individual "district grades" were correlated from year to year (e.g., the CSR of the first grade in Abington in 1998 was correlated with, or very similar to, the CSR of the first grade in Abington in 1997). We told the model to assume that these relationships were strongest from year to year, and decreased in strength over time (e.g., 1997 and 1998 were likely to be the most similar, where as 1997 and 1999 would be less similar to each other. In other words, 1999 was more likely to be influenced by 1998 than it was to be influenced by 1997). In SAS, thisis called a first order autoregressive covariance structure. Assuming these relationships added power to the model and allowed us to better understand changes to CSRs over time.
- We first ran the model to assess the fit of our assumed covariance structure and to see how time was related to changing CSRs (i.e., whether there was a linear or quadratic relationship with time). We decided that the first order autoregressive covariance structure and quadratic effect of time fit best; we used restricted maximum likelihood (REML) estimation methods for subsequent analyses.
- First we fit a model predicting CSR based on year, school type, community type, and time relative to construction events.
- Then we fit a series of models adding each covariate to this base model one by one to see if any were significant and should therefore be included in our final model describing the impacts of construction event on CSR.
- Next, we ran a multivariate model, including the base model variables plus all covariates that were significant in the previous phase. Covariates that were not significant in the multivariate model were removed and the model re-fit until we arrived at the most parsimonious description of CSR possible, based on our available data.
- Next, we fit the parsimonious multivariate model restricting our analyses to one school type at a time.
- Finally we re-fit the full multivariate model, removing the community type variable to explore whether any of the original variables would change in significance (i.e., if they were co-linear with community type).