Challenges to Design a New System of School Admissions: Lessons from Recent School Choice Reforms at Boston, Chicago, & England

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Santiago, Chile

History of Student Assignment in Boston

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"The Soiling of Old Glory" by Stanley J. Forman
1977 Pulitzer Prize for Spot Photography

History of Student Assignment in Boston

- **September 1987:** The U. S. Court of Appeals rules that BPS has attained unitary status in school assignments, meaning schools are as desegregated as they can be given city demographics.
  - ✓ The BPS is free to design a new assignment plan, with no restrictions, as long as it does not take any action that might intentionally resegregate the schools.
- **December 1988:** New plan put forth where elementary and middle schools are organized into three zones: East, North, West.
  - ✓ Racial/ethnic "ideal racial percentages" (IRPs) are established in each zone reflecting the zone's student population.
    Assignment geared to be within 10% of the zone IRP whereas 35% of the seats are set aside for minorities at exam schools.
  - ✓ The mechanism, now known as the Boston mechanism, is adopted.
  - ✓ Sibling and walk zone priorities are introduced.

History of Student Assignment in Boston

- **July 1999:** Following a series of lawsuits, the School Committee votes to eliminate the use of racial/ethnic classifications in all school assignments, effective in the 2000-01 school year.
- **November 1999:** As recommended by Supt. Payzant, the School Committee adopts the New Choice Plan which reduces walk zone priority from 100% to 50%.
  - ✓ Serves as a compromise between proponents of neighborhood assignment and open access.
  - ✓ Actual language of the BPS memo:
    "Fifty percent walk zone preference means that half of the seats at a given school are subject to walk zone preference. The remaining seats are open to students outside the walk zone."

History of Student Assignment in Boston

- **July 2005:** Following a two year community engagement process triggered by the critic of the Boston mechanism in Abdulkadiroğlu and Sönmez (2003), School Committee approves adoption of the student-proposing deferred acceptance algorithm (DA) (Gale and Shapley 1962).
  - ✓ Replacing "excessively" manipulable Boston mechanism with a strategy-proof counterpart was the primary motivation of this reform.

Recent Success of the DA

- Since Boston adopted this procedure, it has spread:
  - ✓ 2007: British government bans use of versions of the Boston mechanism mandating the DA (referred as equal preference mechanism) in Nationwide admissions code.
  - ✓ 2009: Chicago abandoned the Boston mechanism midstream for its assignment to elite high schools, adopting DA.
  - ✓ 2012: Student assignment reform at Denver public schools.
  - ✓ 2012: Economics Nobel Prize awarded for "Stable allocation and the practice of market design."
  - ✓ 2013: Student assignment reform at Newark public schools.
  - ✓ 2014: Student assignment reform at Washington DC public schools.
- Implications of policy decisions on allocation of "property rights" on public school seats became more tractable and transparent by the adoption of the DA.

  This is at the heart of the most recent 2012-2013 student assignment reform at BPS.

What is an Algorithm or a Mechanism?

An algorithm is "a set of ordered steps for solving a problem, such as a mathematical formula, or the instructions in a program."

Computer Desktop Encyclopedia, © 1988-2004, Computer Language Company, Inc.

- In our case, the problem is to assign students to schools, while:
  - Respecting each student's Preferences
  - Adhering to each school's Priorities
  - Making sure that each school is filled to its proper capacity
- A mechanism uses preferences and priorities as its inputs and determines an outcome with an algorithm.

School Choice Problem

- School choice problem:
  - There are a number of students, each of whom should be assigned a seat at one of a number of schools.
  - Each school has a maximum capacity but there is no shortage of the total seats.
  - Each student has strict preferences over all schools and each school has a strict priority ordering of all students.
- Preferences: Provided by students/their families
- Priorities: Determined by policymakers, ideally with a transparent formula.

Matching and Student Assignment Mechanisms

- The outcome of a school choice problem is a matching, i.e. an assignment of school seats to students such that each student is assigned one seat and no school is assigned to more students than its capacity.
- A student assignment mechanism is a systematic procedure that selects a matching for each school choice problem.
- Choice of a student assignment mechanism is crucial and it may influence how parents submit their preferences.
- Policymaker's tasks:
  1. Choosing a well-behaved student assignment mechanism.
  2. Constructing transparent priorities that best represent the norms and objectives of the society.
     Example: Should there be neighborhood priories?
     Should priorities depend on standardized exams?

The (Old) Boston Mechanism

One of the most widely used mechanisms throughout the world relies on an algorithm used by Boston Public Schools (BPS) in the period 1988-2005:

1. For each school a priority ordering is exogenously determined.

   In case of BPS, priority of student i at a given school s depends on
   - whether student i lives in the walk-zone of school s, ,
   - whether student i has a sibling already attending school s, and
   - a lottery number to break ties.
2. Each student submits a preference ranking of the schools.
3. The final phase is the student assignment based on preferences and priorities with the following algorithm:

The (Old) Boston Matching Algorithm

Round 1: In the first round only the first choices of the students are considered. For each school s, consider the students who have listed s as first choice and assign seats of school s to them one at a time following their priority order until either there are no seats left or there is no student left who has listed it as her first choice.

Round k: Consider the remaining students. In Round k only the k^{th} choices of these students are considered. For each school with still available seats, consider the students who have listed it as their k^{th} choice and assign the remaining seats to these students one at a time following their priority order until either there are no seats left or there is no student left who has listed it as her k^{th} choice.

Very Easy to Manipulate

- Major failure: The Boston mechanism is not strategy-proof. That means, students can potentially tweak the outcome in their favor by misrepresenting their stated preferences.
- Even if a student has very high priority at school s, she loses her priority to students who have top ranked school s unless she lists it as her top choice!
- Hence the Boston mechanism gives parents strong incentives to overrank schools where they have high priority.

"Gaming" Incentives under the Boston Mechanism

Example: There are three schools a, b, c with one seat each, and three students 1, 2, 3.

	True Preferences	Priorities	
1 :	$b - a - c$	a :	$1 - 2 - 3$
2 :	$a - b - c$ or $b - a - c$	b :	$2 - 3 - 1$
3 :	$a - b - c$	c :	$3 - 1 - 2$

- Consider Family 1. Suppose they know that Family 3's preferences are $a - b - c$ but they are unsure whether Family 2's preferences are $a - b - c$ or $b - a - c$.

- If Family 2 report their preferences as $a - b - c$ then by truthful revelation Family 1 will receive a seat at school b (i.e. their top choice).
- If, on the other hand, Family 2 report their preferences as $b - a - c$ then by truthful revelation Family 1 will receive a seat at school c (i.e. their last choice).
- They can secure a seat at school a (i.e. their second choice) by "gaming" the Boston mechanism and strategically misrepresenting their preferences as $a - b - c$.
- This is a very common dilemma under the Boston mechanism!

So Easy to Manipulate, it is All Over the News!

Consider the following quotation from St.Petersburg Times:

> *Make a realistic, informed selection on the school you list as your first choice. It's the cleanest shot you will get at a school, but if you aim too high you might miss.*
>
> *Here's why: If the random computer selection rejects your first choice, your chances of getting your second choice school are greatly diminished. That's because you then fall in line behind everyone who wanted your second choice school as their first choice. You can fall even farther back in line as you get bumped down to your third, fourth and fifth choices.*

Evidence from Education Literature

Glenn (*PI* 1991) states

> *As an example of how school selections change, analysis of first-place preferences in Boston for sixth-grade enrollment in 1989 (the first year of controlled choice in Boston) and 1990 shows that the number of relatively popular schools doubled in only the second year of controlled choice. The strong lead of few schools was reduced as others "tried harder."*

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More plausible scenario: Learning

Evidence from 2004-2005 BPS School Guide

For a better chance of your "first choice" school . . . consider choosing less popular schools.

Lack of Strictly Honoring Priorities (or Fairness)

- A mechanism strictly honors priorities (or is fair) if a student never loses a seat to another student with lower priority.
- Boston mechanism does not strictly honor priorities!

  Priorities can be lost unless school ranked as top choice.
- Balinski & Sönmez (1999): If fairness is an indispensable criterion, then another mechanism, student proposing deferred acceptance (DA) is the big winner!

Interim Summary for the Boston Mechanism

- Highly vulnerable to manipulation.
- Fails to strictly honor priorities.
- Non-strategic (poor, uneducated, etc.) families are especially hurt under the Boston mechanism (Pathak & Sönmez 2008).
- Efficiency comparison with the competing mechanism DA is less clear, but only because efficiency evaluation of the Boston mechanism is non-robust and it relies on strong assumptions.

Student-Proposing Deferred Acceptance Mechanism (DA)

- The following mechanism, originally introduced by Gale & Shapley (1962), is proposed as one of the two plausible alternatives to Boston mechanism by Abdulkadiroğlu & Sönmez (2003).

  Round 1: Each student proposes to her first choice. Each school tentatively assigns its seats to its proposers one at a time following their priority order. Any remaining proposers are rejected.

  Round k: Each student who was rejected in the previous step proposes to her next choice. Each school considers the students it has been holding together with its new proposers and tentatively assigns its seats to these students one at a time following their priority order. Any remaining proposers are rejected.

The Case for DA

1. It strictly honors priorities: A student never loses a seat to a student with lower priority unless she receives a seat at a better school (Gale & Shapley 1962, Balinski & Sönmez 1999).
2. Assigns students to their best possible choices among those which strictly honors their priorities (Gale & Shapley 1962, Balinski & Sönmez 1999).
3. It is Strategy-Proof (Roth 1984).
   DA completely removes incentives to game the system: A student can only hurt herself by mis-representing her preferences!
4. Levels the playing field for families who either cannot strategize, or cannot strategize well (Pathak & Sönmez 2008).

Adoption of DA in NYC

- Shortly after Abdulkadiroğlu & Sönmez (2003) was published in June 2003, New York City and Boston both adopted the DA. However the two reforms evolved in very different ways.
- May 2003: NYCDOE Director of Strategic Planning contacted Alvin Roth for advice on the design of a new high school matching mechanism after the collapse of their mechanism.
  - Unlike most other school districts, NYCDOE did not have a direct mechanism prior to 2003.
  - Their mechanism gave students incentives to manipulate their preferences (reminiscent of those under the Boston mechanism), and it gave schools the ability to manipulate their priority ranking as well as to conceal capacity.
  - NYCDOE failed to assign roughly 30 percent of students via its mechanism in its final run, a very visible failure that required abandoning it in haste.

Adoption of DA in NYC

- October 2003: NYCDOE adopted DA for high school admissions. Strategy-profness of the DA made it particularly attractive.

  "For more than a generation, parents and students have been unhappy with the admissions process to New York City high schools. The new process is a vast improvement, as it provides greater choice, equity and efficiency. For example, for the first time, students will be able to list preferences as true preferences, limiting the need to game the system.

  This means that students will be able to rank schools without the risk that naming a competitive school as their first choice will adversely affect their ability to get into a school they rank lower."

  Peter Kerr, Director of Communications, NYCDOE

Adoption of DA in Boston

- Unlike in NYCDOE, BPS was quite satisfied with its mechanism.
- September 2003: The *Boston Globe* published an article on Abdulkadiroğlu & Sönmez (2003), describing the flaws of the Boston mechanism, and advocating the adoption of DA.
- October 2003:
  - Sönmez was invited to Boston to present the case against the Boston mechanism. Together with Abdulkadiroğlu, Pathak and Roth, he presented to BPS the case against the Boston mechanism, and proposed two strategy-proof alternatives.
  - While skeptical prior to meeting, BPS staff was convinced strategizing was likely occurring, to the detriment of students and families.
  - They invited the team to carry out an empirical study of the Boston mechanism to support the results in A&S (2003).
- July 2005: BPS gave up the Boston mechanism and adopted DA.

Chicago Selective Enrollment High Schools

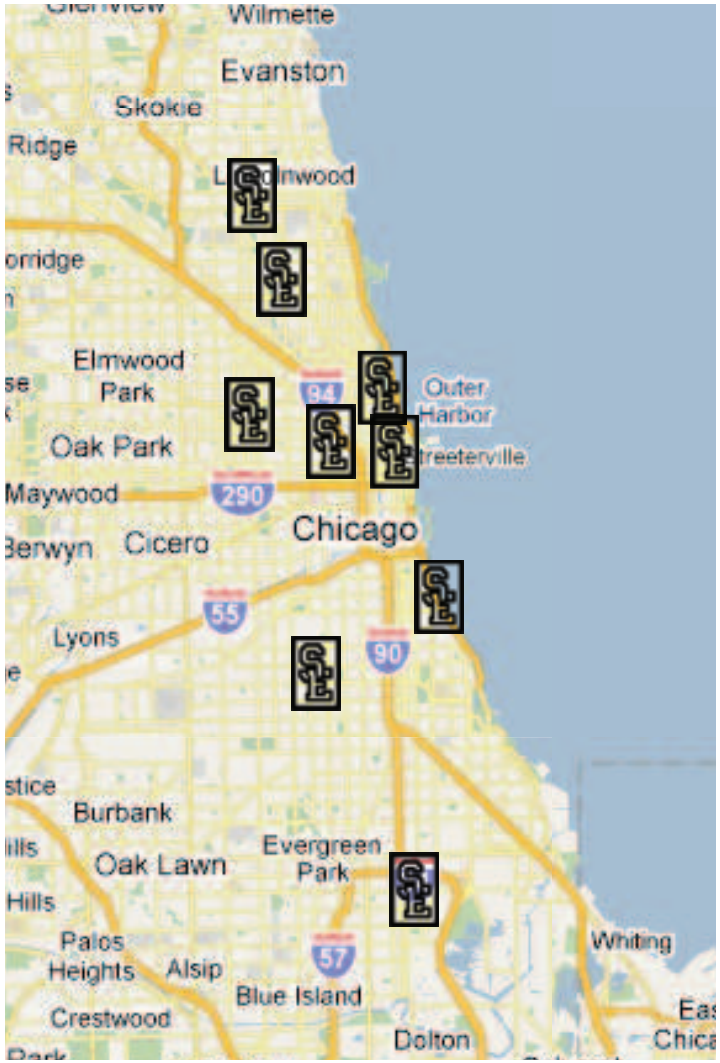
9 selective high schools

Applicants: 8^{th} graders in Chicago

Composite Test Score: Entrance exam + 7^{th} grade scores

Up to Fall 2009, system worked as follows:

- Take entrance test
- Rank up to 4 schools
- Mechanism of choice in 2009: The Boston mechanism!



2009-2010 School Choice Reform at Chicago

Chicago Sun-Times November 12, 2009

8th-graders' shot at elite high schools better

Poring over data about eighth-graders who applied to the city's elite college preps, Chicago Public Schools officials discovered an alarming pattern.

High-scoring kids were being rejected simply because of the order in which they listed their college prep preferences.

"I couldn't believe it," schools CEO Ron Huberman said. "It's terrible."

CPS officials said Wednesday they have decided to let any eighth-grader who applied to a college prep for fall 2010 admission re-rank their preferences to better conform with a new selection system.

Previously, some eighth-graders were listing the most competitive college preps as their top choice, forgoing their chances of getting into other schools that would have accepted them if they had ranked those schools higher, an official said.

Under the new policy, Huberman said, a computer will assign applicants to the highest-ranked school they quality for on their list.

"It's the fairest way to do it." Huberman told Sun-Times.

2009-2010 School Choice Reform at Chicago

- New Chicago mechanism adopted in 2010:
  - Rank up to 4 schools
  - Students ordered by composite score
  - The first student obtains her top choice, the second student obtains her top choice among remaining, and so on.
- This mechanism, known as a simple serial dictatorship, is equivalent to DA when there is a uniform priority ranking across all schools (as in Chicago).
- Unlike the school choice reforms initially in Boston and NewYork City, and later in Washington DC., Denver, New Orleans among many other school districts, the Chicago reform is conducted by policymakers without any direct involvement of economists!

Admissions Reform throughout England

- Aside from Boston (which used the Boston mechanism until 2005), variants of this mechanism have been used in numerous U.S. school districts including: Cambridge MA, Charlotte-Mecklensburg NC, Chicago, Denver CO, Miami-Dade FL, Minneapolis MN, Providence RI, Seattle, and Tampa-St. Petersburg FL.
- U.S. is not the only country where versions of the Boston mechanism are used to assign students to public schools.
- A large number of English Local Authorities had been using what they referred to as "first preference first" systems until 2007.

Admissions Reforms throughout England

- Formally, a first preference first (FPF) mechanism is a hybrid between the DA and the Boston mechanisms: Under this mechanism, a school selects to be either a first preference first school or an equal preference school, and the outcome is determined by the student-proposing deferred acceptance algorithm, where
  1) the base priorities for each student are used for each equal preference school, whereas
  2) the priorities are adjusted at first preference first schools s.t.
     - any student who ranks school s as his first choice has higher priority than any student who ranks school s as his second choice,
     - any student who ranks school s as his second choice has higher priority than any student who ranks school s as his third choice, etc.
- The Boston mechanism is a special case of this mechanism when all schools are first preference first schools and the DA is a special case when all schools are equal preference schools.

Ban of FPF Mechanism in 2007

- 2003 School Admissions Code in England requires all local authorities to coordinate public school admissions.
- While a majority of local authorities adopted versions of the DA after (or in anticipation) of the 2003 code, more than 60 local authorities adopted the FPF mechanism (including several that adopted the Boston mechanism).
- The FPF mechanism was banned throughout England with the 2007 School Admissions Code along with other mechanisms that use "unfair oversubscription criteria."

Section 2.13: *In setting oversubscription criteria the admission authorities for all maintained schools must not:*

. . . give priority to children according to the order of other schools named as preferences by their parents, including 'first preference first' arrangements.

Ban of FPF mechanism in 2007

- Rationale given by Department for Education and Skills:

  'first preference first' criterion made the system unnecessarily complex to parents

- Education Secretary Alan Johnson remarked that the FPF system "forces many parents to play an 'admissions game' with their children's future."
- Great deal of public discussion throughout England.

2014 Protests in Taiwan

- Taiwan is one of many Asian countries that use a version of the Boston mechanism.
- Adoption of this mechanism for senior-high school admissions in 2014 resulted in fierce protests throughout the country, once it became clear that high score students lose seats to low score students due to their preferences.
- In one extreme case, a top A++ student is not assigned to any of her 50 choices due to aiming too high!

TAIPEI TIMES

Parents, teachers protest senior-high entrance process

By Lee I-chia / Staff reporter

Students and parents in Taipei yesterday protest against the 12-year national education system, while calling for reforms.
Photo: CNA

Demonstrators took to the streets of Taipei yesterday against a new mechanism in senior-high school admittance, which they say is unfair because it does not take into account students' grades.

The mechanism is part of the new 12-year national education system and deducts points from students each time they fail to be accepted by a school on their list, which effectively punishes children for aiming too high.

Hundreds of parents and teachers took part in the parade, organized by the Alliance on Obligatory Education.

They gathered on Ketagalan

Task #2: Design of Priorities

- Adopting a strategy-proof mechanism that strictly honors priorities assures that:
  1. Parents can be guided by public officials to simply submit their truthful preferences without ever worrying about being penalized, and
  2. priorities that are designed by the local authorities are fully reflected in the final outcomes.
- Moreover the preference data generated in the process can be safely used for various policy decisions as it represents true preferences.
- As such, adopting the DA is perhaps an easy solution for the first one of the two tasks of the policymaker, in the context of designing a school choice mechanism.
- Design of priorities, on the other hand, typically involves big debates between various interest groups since it always has important distributional implications!

2012-2013 Reform of Student Priorities in Boston

- **January 2012:** In his State of the City Address, Mayor Menino articulated support for the faction in favor of greater neighborhood assignment.

  Mayor Menino: Finishing the Job on School Assignment

  ✓ "Pick any street in our city. A dozen children probably attend a dozen different schools. Parents might not know each other; children might not play together. They can't carpool, or study for the same tests. We won't have the schools our kids deserve until we build school communities that serve them well."

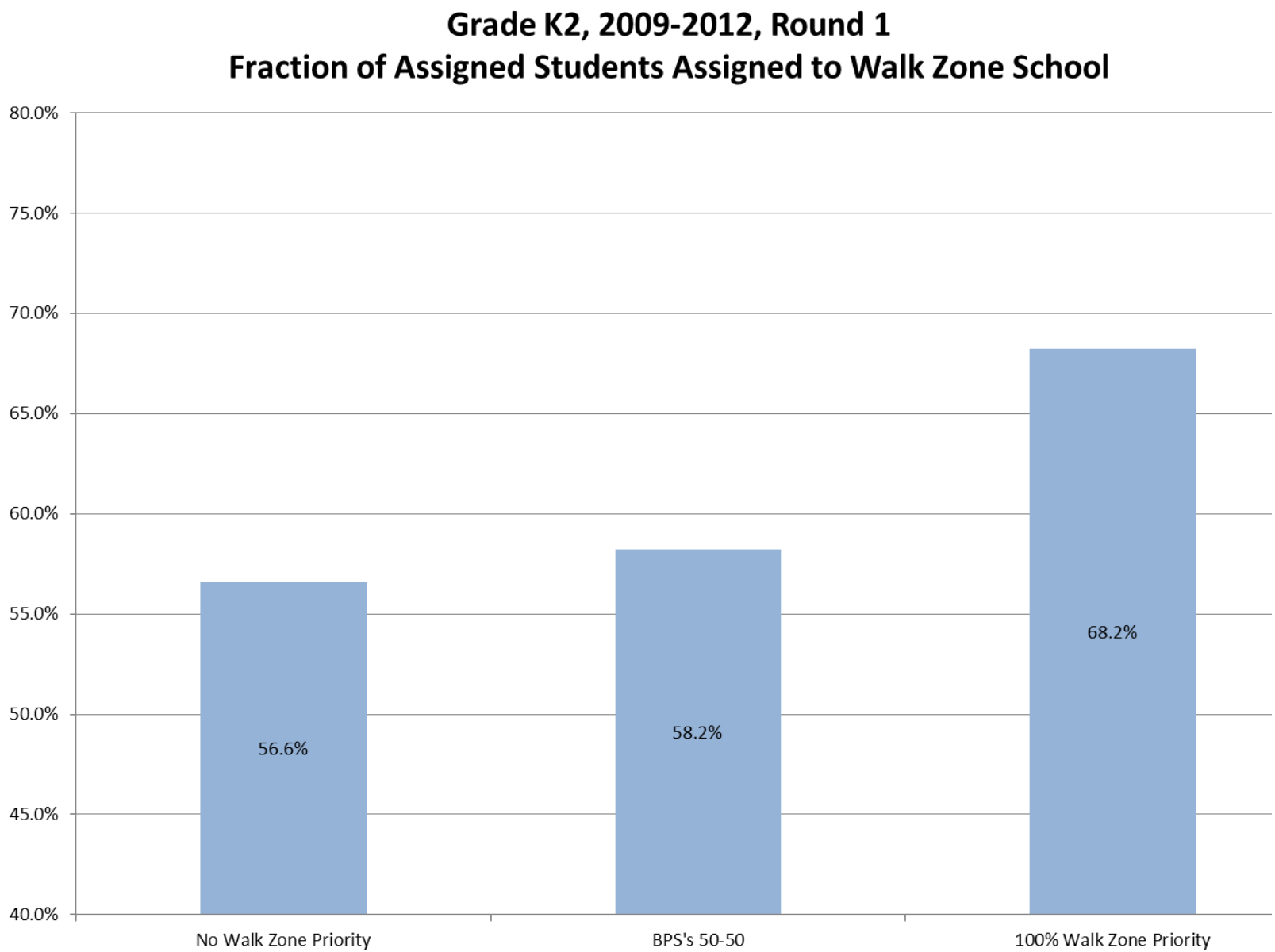
  "Boston will have a radically different school assignment process one that puts priority on assigning children to schools that are closer to their homes."

  ✓ Mayor Menino and Supt. Johnson then announce the formation of an External Advisory Committee (EAC) to help BPS develop a new plan in partnership with the community.

A Careful Look at the Role of Walk Zone Priority in Boston

- When BPS reduced the fraction of walk zone seats from 100% to 50% in 1999, Supt. Payzant emphasized that this reform serves as a compromise between proponents of neighborhood assignment and open access.
- Given the 2012 State of the City Address of Mayor Menino, shall we conclude that the reduction of the fraction of walk zone seats from 100 % to 50 % shifted the balance too much to the detriment of neighborhood assignment?
- Fortunately strategy-proofness of the DA allows us to consider various counterfactuals:
  - ✓ How would the outcome change if walk zone priority was maintained for all seats?
  - ✓ On the other extreme, how would the outcome change if walk zone priority was to be abandoned altogether?

A Puzzle


Grade K2, 2009-2012, Round 1
Fraction of Assigned Students Assigned to Walk Zone School
80.0%
75.0%
70.0%
65.0%
60.0%
55.0%
50.0%
45.0%
40.0%
56.6%
58.2%
68.2%
No Walk Zone Priority
BPS's 50-50
100% Walk Zone Priority

A Puzzle

- The outcome under BPS 50-50 "compromise" is surprisingly close to the outcome in the absence of any walk zone priority!

  How can that be?
- In order to solve this puzzle, we shall of course understand how BPS implements the DA when half of the seats have walk zone priority while the other half does not.
  - ✓ In particular, a seat from which half is used up when a student has high enough priority for both types of seats?

    Ex: Consider a walk zone student with a really favorable lottery number.

BPS Implementation of DA with 50/50 Slot Split

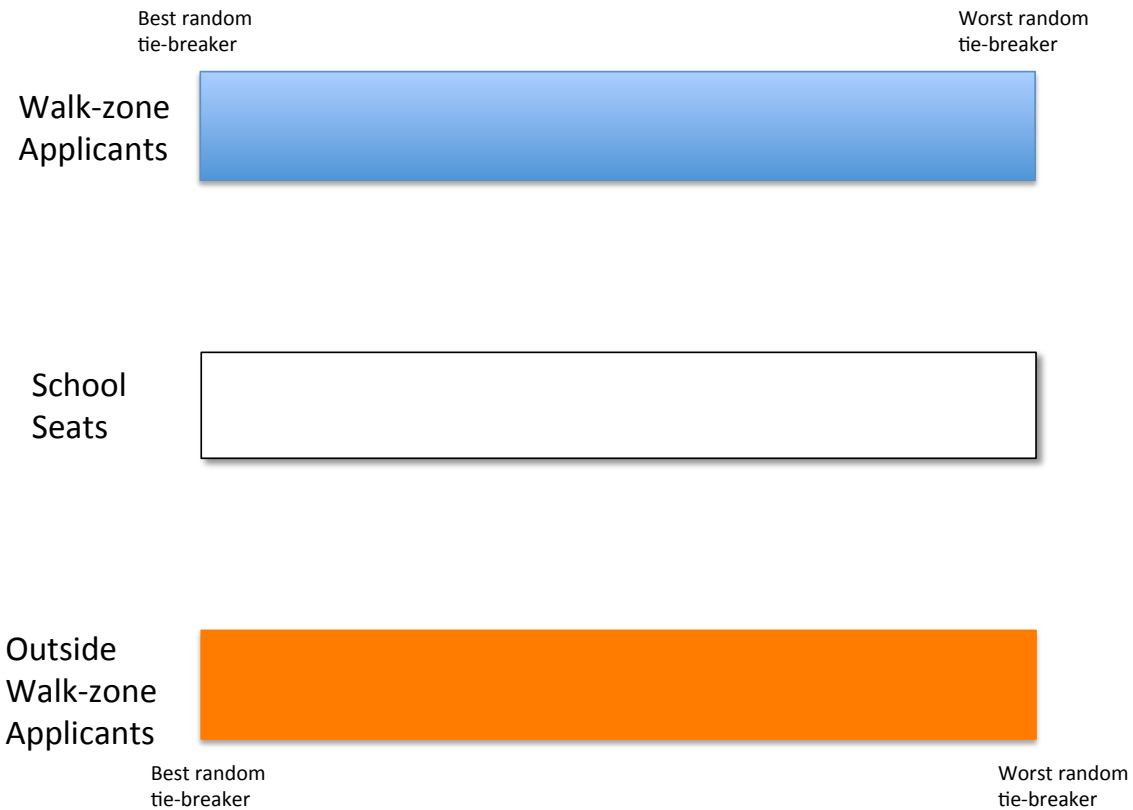
- BPS treats each school as two separate schools with half capacity each where the first half has walk zone priority and the second half does not.
- Since students provide a ranking of schools, rather then their halves, they need to decide how to "convert" student preferences over schools to student preferences over school-halves.
- At BPS this has been done by systematically ranking the walk-half before the open-half at each school but otherwise respecting the ranking between schools.

  Interestingly, this decision was viewed as a detail and left to BPS software support.
- Let us walk through the implications of this "coding decision" for a simple example with:
  - ✓ One school with twice as many applicants as the # of seats, and
  - ✓ the same # of walk zone applicants as outside applicants.

An Example (From 03/07/2013 Testimony before the Boston School Committee)

For simplicity, this example assumes same number of walk-zone applicants and outside walk-zone applicants.

Scenario 1: All Slots are open (0% Walk-Zone Priority)



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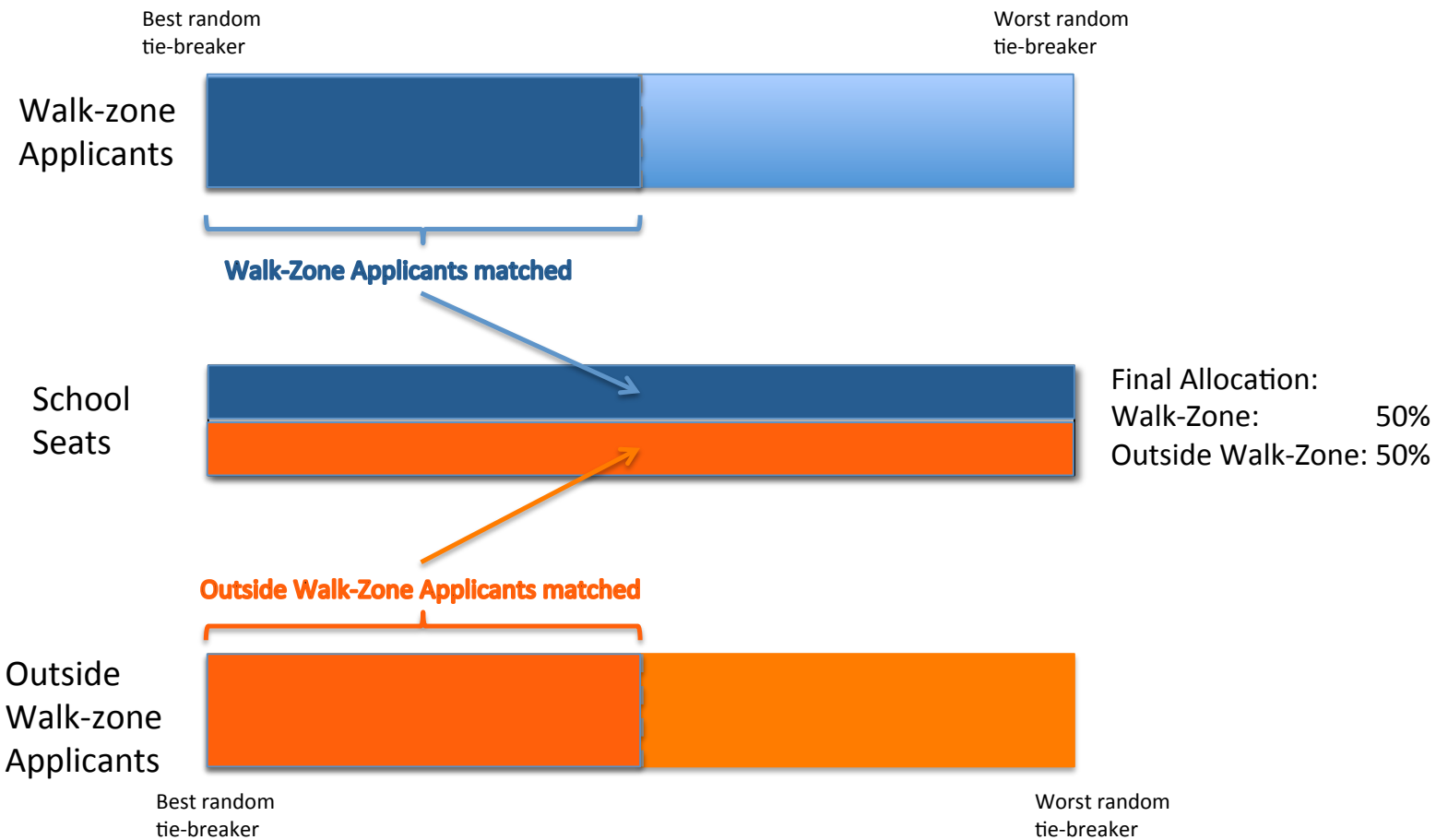

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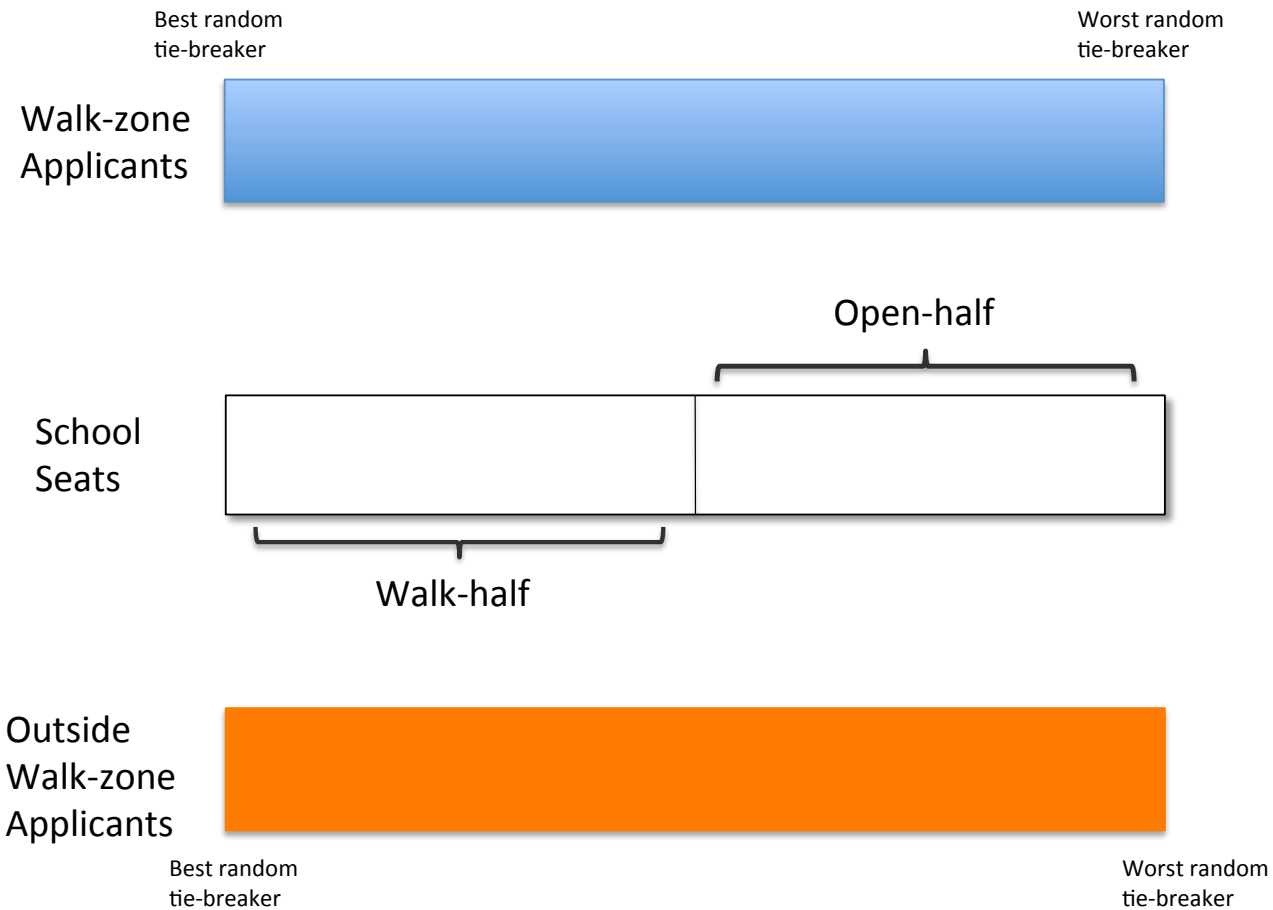
Scenario 2: 50-50 slot split (50% Walk-Zone Priority – 50% Open Priority), Walk-half first – Open-half next, Same tie-breaker for both halves (Current BPS)



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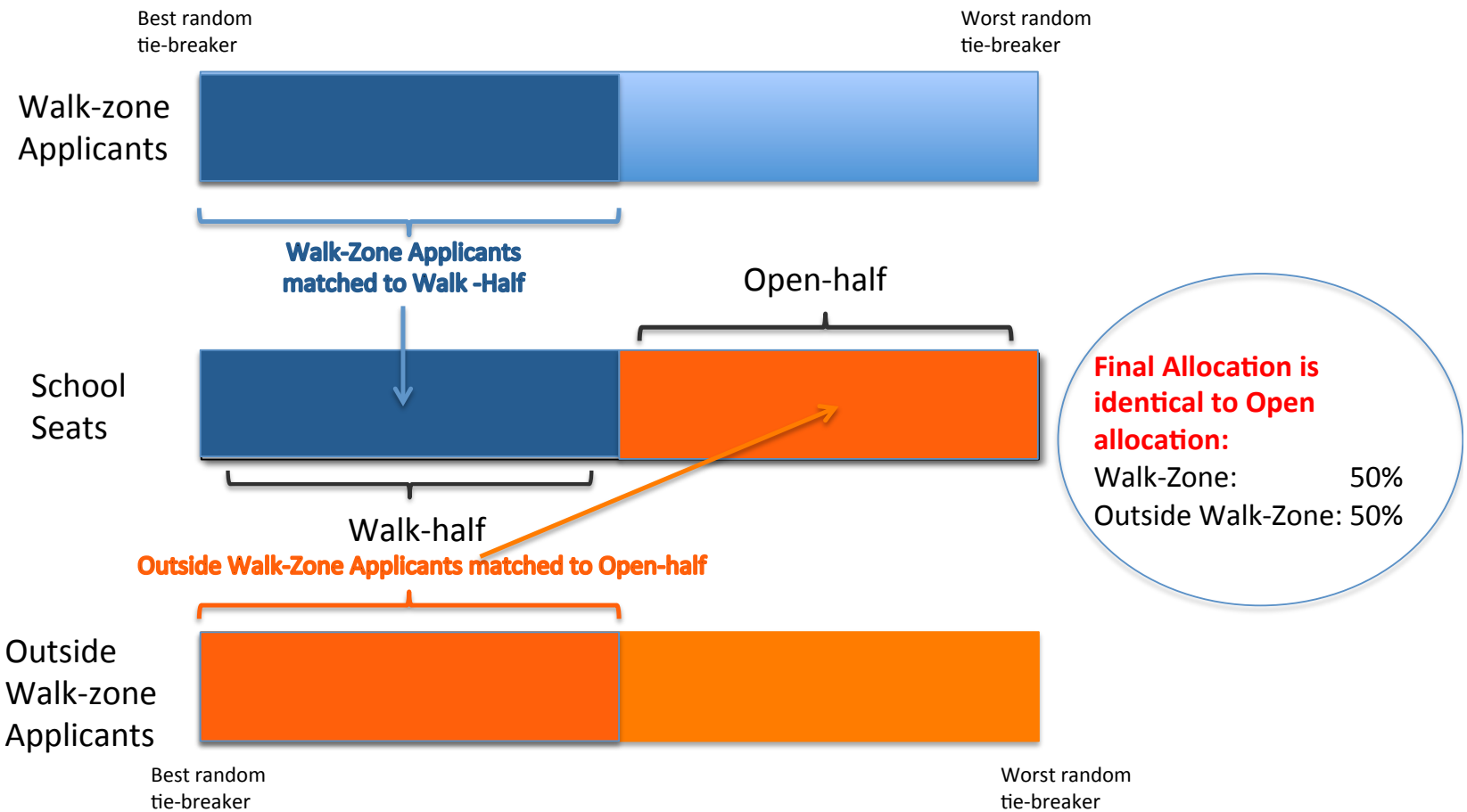


Why does the BPS treatment of the two halves eliminate the potential "second-bite" role of the open–half?

There are two reasons:

1. PROCESSING ORDER BIAS: The earlier the walk-zone slots are processed, the fewer the number of Walk-zone applicants are to compete for open slots.

Walk-zone applicants competing for open slots

Outside walk-zone applicants competing for open slots

When the walk-half is processed before the open-half, twice as many outside applicants as walk-zone applicants compete for the open slots.

Had all applicants been given an even shot for open slots, a third of open slots would be assigned to walk-zone applicants and two-thirds to outside-walk zone applicants.

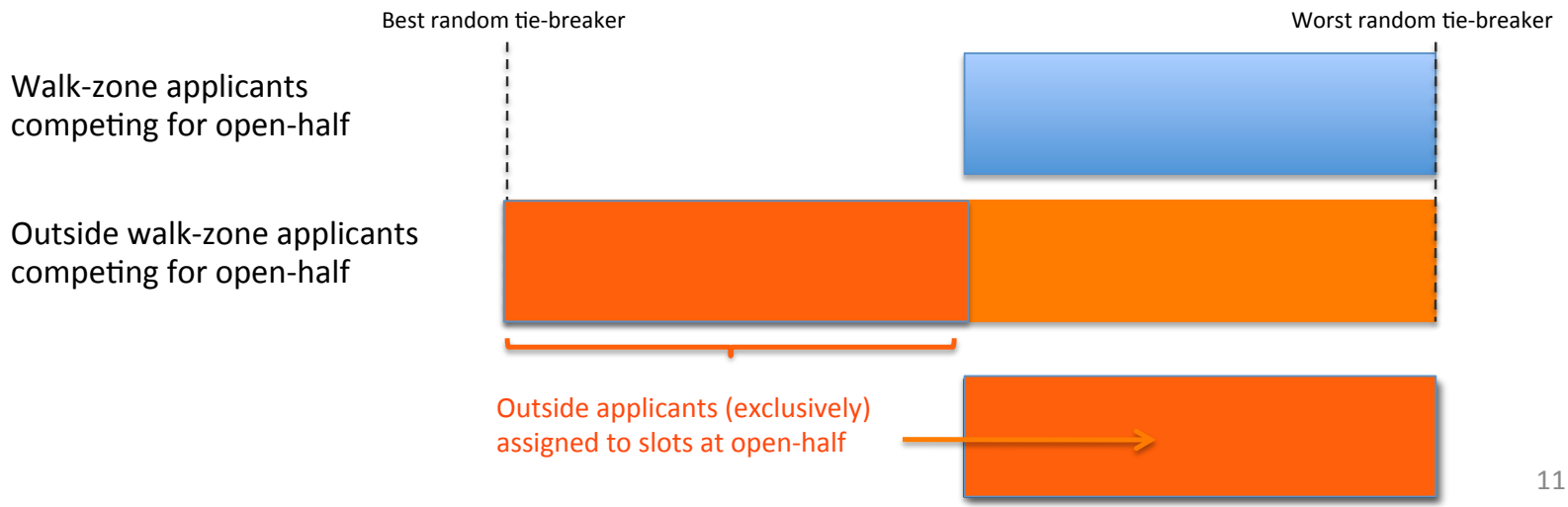
Elimination of the potential "second-bite" role of the Open–half

This is, however, not what happens under current BPS policy and the EAC recommendation. Despite the intended "second-bite" at a school, none of the open slots are assigned to walk zone students!

The more troublesome problem is the following:

2. RANDOMIZATION BIAS: There is an important unintended implication of using the same random tie-breaker for both halves. Since BPS first processes slots in the walk-half, those who remain all have unfavorable lottery numbers.

In this example, walk-zone students have no shot for the open half!

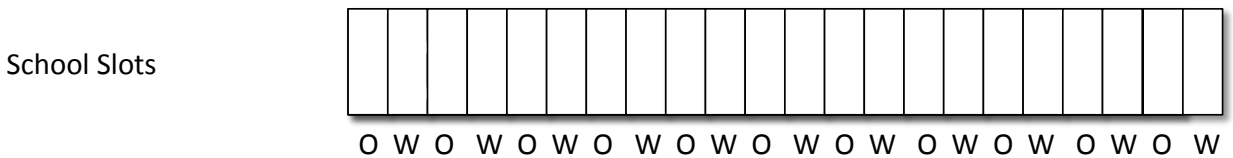


Policy Recommendation for BPS

Is there a fully transparent procedure which eliminates both types of biases in allocation of open slots?

Yes. The following unbiased treatment removes both sources of bias.

1. Rather than processing all slots in the walk-half before all slots in the open half, rotate between the two types of slots.



2. To avoid the major disadvantage to walk-zone applicants at open slots, use a second lottery number for these slots. This will give walk-zone applicants a fair shot for open slots.

While removing both biases is ideal, correction of the second one is key to have a transparent system.

Otherwise, the 50-50 slot split appears cosmetic and may unintentionally mislead the community.

Conclusion

- Design of various institutions is one of the most important roles of the government.
- Good use of economic principles and game theory in these designs can result in significant gains for the society!

That is our agenda in the emerging field of Market Design.