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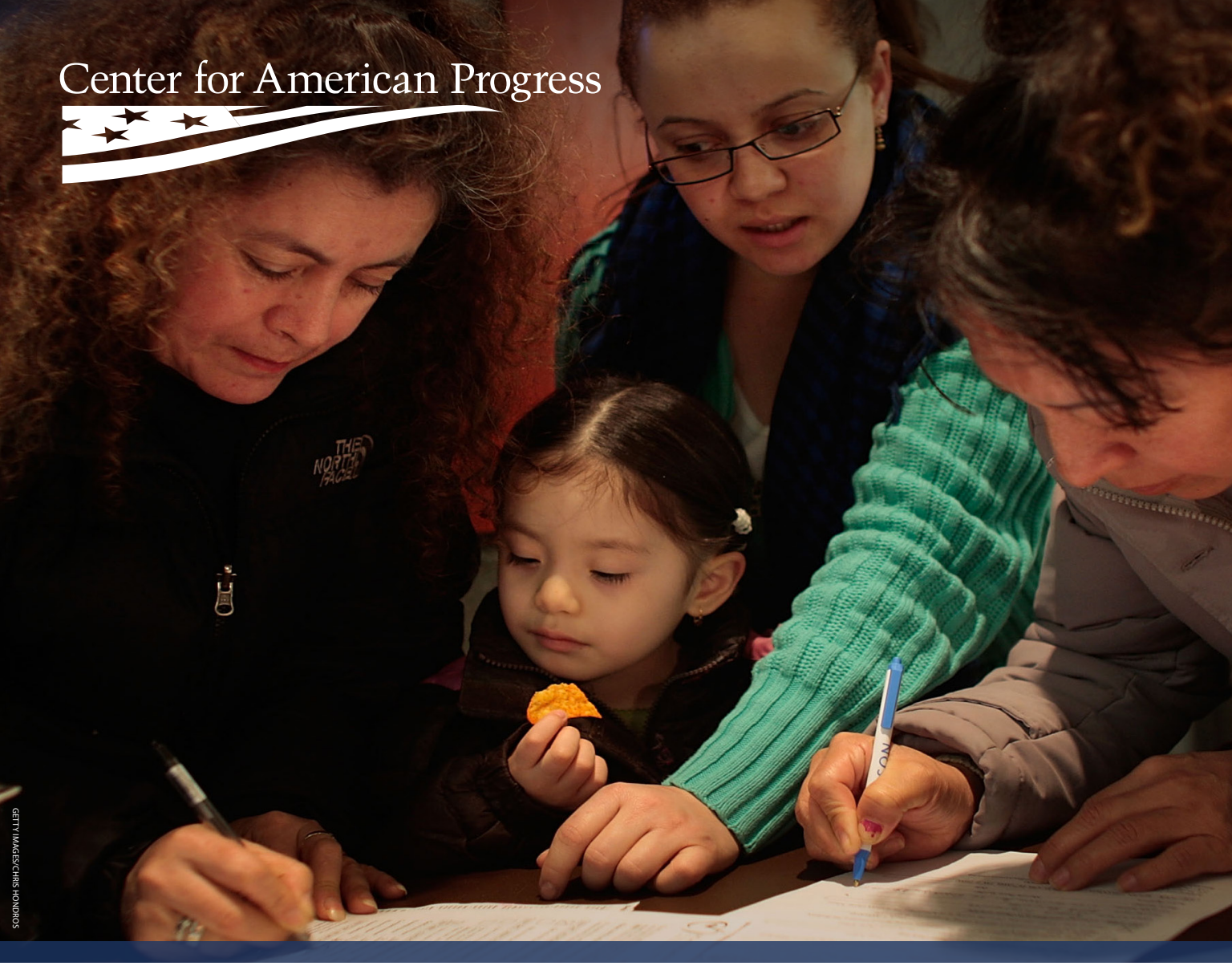

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Expanding Access to High-Quality Schools

Implementing School Choice Algorithms

By Meg Benner and Ulrich Boser November 2018

Center for American Progress

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Introduction and summary

Few clear-cut fixes exist in education. When it comes to school enrollment, however, a specific centralized process exists that is both simple for families to navigate and efficient for schools and districts.

Traditionally, school districts have assigned families to their neighborhood school by default. Yet over the past two decades, access to a variety of public school options has increased dramatically, especially in large urban areas. According to a 2017 analysis by the Brookings Institution, the proportion of large school districts that offered school choice doubled from 2000 through 2016.[1] As a result, of the more than 50.1 million students nationwide who attended public schools over the 2015-16 school year, more than 2.8 million students attended public charter schools, and more than 2.6 million students attended magnet schools. Additional students attended other types of public schools of choice, such as those with specialty or thematic programs.[2]

While the expansion of school choice has allowed parents or guardians to select schools that best meet their children's needs, some application and enrollment processes can present barriers to families with less time or familiarity with the system. In decentralized systems, for example, students must apply separately to each school. Some students may get multiple offers and hold onto seats they do not intend to accept, while others may not receive any offers at all. Families without the information or time to strategize are often left with the least in-demand schools, which often have worse academic outcomes. Meanwhile, schools and districts find it difficult to forecast enrollment as students constantly shift across their rosters and waitlists.

A centralized system can simplify enrollment for both families and schools. Students apply through a single application, ranking a list of schools that they would like to attend and receiving a single offer to one of their preferred schools. However, system design matters when it comes to centralized enrollment. Depending on how a district assigns an offer for each student, some families can unfairly manipulate the system to make it more likely that their child secures a seat at a more in-demand, usually better-performing school.

To reduce this risk of strategic manipulation in centralized enrollment systems, Atila Abdulkadiroglu, Parag Pathak, Alvin E. Roth and Tayfun Sönmez—economists with expertise in game theory and market design—proposed a solution. They designed two fair and efficient matching algorithms—or a set of rules and calculations—to ensure that, given the preferences of all other students and schools in the system, each student receives a single offer with his or her best possible school match. Specifically, the economists designed two matching algorithms suitable for centralized assignment: deferred acceptance (DA) and top trading cycles (TTC).[3]

The economists first introduced this method in New York City in 2003, which helped streamline admissions to the city's nonselective high schools. Since 2003, additional cities—including New Orleans; Denver; Washington, D.C.; Newark and Camden, New Jersey; Boston; and Indianapolis—have adopted similar algorithms to level the school choice playing field. After New York City adopted the DA algorithm, allowing students to apply to more schools, the number of students who did not receive an offer from one of their chosen schools fell drastically—from 30,000 students in 2003 to 3,000 students in 2004.[4]

Notably, there are many contentious policy issues related to public school choice that are beyond the scope of these algorithms. For instance, communities debate which types of schools should exist and how the city and state should allocate public dollars to those schools. Families also tend to demand more seats in the most desirable schools. There should be no debate, however, that all families should have fair and equal access to the public schooling options that do exist. Carefully designed assignment systems, based on the most efficient and effective algorithms, help ensure that all families have such access.

This report provides an overview of two more fair, efficient, and transparent school matching algorithms: DA and TTC. The authors review the background of DA and TTC and how each functions, discuss how they can be implemented, and highlight how these algorithms have been used to operate enrollment systems in New Orleans, Indianapolis, and Denver. The goal is to improve the efficiency of enrollment systems, while also ensuring that every student has a fair shot at the school he or she wants to attend—something that can, in the long run, improve academic outcomes.[5]

The need for better school matching systems

When districts allow students to attend schools outside their neighborhoods, disconnected application and enrollment processes can be difficult for families to navigate. Decentralized systems benefit families who have more time or knowledge to game the system. While a centralized enrollment system may help reduce these inequities to some extent, it must also use fair and efficient matching algorithms to further level the playing field.

Methodology

The authors partnered with Parag Pathak, professor of microeconomics at the Massachusetts Institute of Technology (MIT); Eryn Heying, assistant director at MIT's School Effectiveness and Inequity Initiative (SEII); and Maggie Ji, policy and research manager at the SEII, to describe the fairer, more equitable, and more efficient school matching algorithms. Pathak, Heying, and Ji helped identify the central components of these algorithms and connected the authors to districts that have successfully implemented them.

Decentralized systems are difficult to navigate

Some cities require families and students to apply to each school separately, because there is no centralized system to coordinate application and enrollment across schools. Decentralized systems require families to devote time and resources to the selection process: They have to learn about and perhaps visit each school, keep track of various application timelines, and submit applications to each school. This can be particularly difficult for economically disadvantaged families, families who do not speak English at home, and single-parent families.

In decentralized systems, one student may receive an offer from multiple schools, while another student may not receive a single offer. The student with multiple offers may be placed on rosters at multiple schools and hold seats at schools that are in

high demand, while the student with no offers has to enroll in a less desirable school. Less desirable schools tend to have lower test scores and graduation rates.[6]

Centralized enrollment simplifies the process but does not eliminate inequities

Centralized enrollment creates a single application and assignment process for participating schools. Students submit one application ranking their desired schools. A coordinating organization—usually either a school district or an independent nonprofit—manages the application process and uses a computerized set-of-rules program, or algorithm, that aims to match students to a school on their list. Each matched student receives a single school offer.

Unified enrollment is a centralized enrollment system in which all or most schools in the city, including traditional public and charter schools, participate. Unified enrollment simplifies the application experience for families and is more efficient for school districts, because it coordinates enrollment across sectors.

Centralized enrollment is more than just ensuring that all schools in a district use a common application. A district may use a common application but still allow each school to manage its own enrollment process, meaning it is still possible for students to receive multiple offers.

In a centralized system, the entity that manages enrollment sets policies or priorities to assign students to seats when there is greater demand than supply. Importantly, the computerized program that assigns students to schools does not contain any predetermined priorities. Instead, the district or other enrollment entity sets the algorithm's priorities to align with desired policy goals.

First, the entity that manages the enrollment process places students in priority groups. Districts may choose to determine priorities such as increased school diversity, neighborhood cohesion, lower transportation costs, or expanded access to high-quality schools for economically disadvantaged students. If a district priority is to minimize transportation costs, students who live near a school might receive priority over students who live in other parts of the city. Depending on the enrollment entity's priorities, students may also receive higher priority at a particular school if they have siblings attending that school; if they are applying to continue at a combined middle and high school; or if they are eligible for free or reduced price lunch.

Students also receive a lottery number, in case they have to compete with another student in the same priority group for a school's last available seat. The lottery number functions as a virtual flip of a coin to fairly and randomly determine which student receives the last seat.

Centralized enrollment with a gameable assignment algorithm perpetuates inequities

While centralized enrollment simplifies the application process by creating a single access point for families, not all centralized enrollment systems are created equal. Though it may seem like a technical detail, the design of the algorithm that matches students to schools significantly affects students' chances of being placed at their preferred school.

Traditionally, some districts with centralized enrollment have used simple algorithms that try to assign as many students as possible to the school they rank as their top choice. These algorithms have a so-called first preference first mechanism, wherein students are given priority at each school according to how high they ranked that school among their choices.

Under these systems, informed applicants may know that many other students are likely to rank the desirable School A at the top of their list. They may then choose to rank the slightly less desirable, but nonetheless preferred, School B as their own top choice, avoiding the risk of being denied admission to School A and maximizing their chances at School B. Applicants without information about schools' relative popularity or with less understanding of various trade-offs would likely rank School A as their top choice, thereby increasing their likelihood of losing out on a seat not only in School A, but also in their second choice, School B.

Systems driven by a first preference first mechanism incentivize applicants with more information to manipulate the system. As a result, applicants with more information are more likely to get a seat in one of their desired schools. Applicants without this knowledge may rank long-shot, in-demand schools first, causing them to get locked out of placement in not only their first-choice school, but also in other schools that they ranked second or lower.

In fact, some districts explicitly recommend that parents choose schools that are not highly competitive. Before New York City implemented its new system in 2003, its

high school directory instructed applicants to "determine what your competition is for a seat in this program."[7] In Boston, the 2004 school brochure recommended that "for a better chance of your 'first choice' school … consider choosing less popular schools."[8]

It is challenging for applicants to accurately assess the odds of being accepted to a certain school and strategize their school rankings accordingly. However, it can be especially difficult for economically disadvantaged or disconnected families who may lack the time and information to play the game. Furthermore, experience and social networks increase understanding of the application process, putting newcomers at a disadvantage.

In addition to being unfair, these systems are inefficient, leaving many students without a match to any of their chosen schools. Unassigned students are either placed at a school they did not choose or asked to participate in additional rounds of matching, in which they can only select from a smaller pool of less in-demand schools that have seats remaining. These less desirable schools tend to have worse educational outcomes, such as lower test scores and graduation rates.[9]

Fair and efficient matching algorithms level the playing field

Atila Abdulkadiroglu, Parag Pathak, Alvin Roth, and Tayfun Sönmez, economists specializing in game theory and market design, crafted school choice matching algorithms that are resilient to gaming and produce better matches for all students. Two algorithms—DA and TTC—do not penalize students for ranking high-demand schools at the top of their lists, and districts can customize the DA or TTC algorithms to reflect their policy goals. Policymakers should consider the trade-offs of each to determine which algorithm best suits their context.

> DA and TTC are strategy-proof algorithms that consider student preferences alongside district and school priorities to create a single best offer for each participating student.

As previously noted, districts can customize both DA and TTC. Overall, the two algorithms are more similar than different. However, districts and policymakers should consider the trade-offs of each to determine which is best for them.

TABLE 1

Comparison of the benefits of deferred acceptance (DA) and top trading cycles (TTC)

Benefit	DA	TTC
Students are not rewarded for strategically ranking schools instead of revealing their true preferences	Always	Always
Students and schools do not prefer each other over their assigned matches	Always	Almost always
Students do not want to swap their school assignments with other students	Almost always	Always

Source: For a complete list of sources, see endnotes in Meg Benner and Ulrich Boser, "Expanding Access to High-Quality Schools: Implementing School Choice Algorithms" (Washington: Center for American Progress, 2018), available at https://www.americanprogress.org/?p=460771.

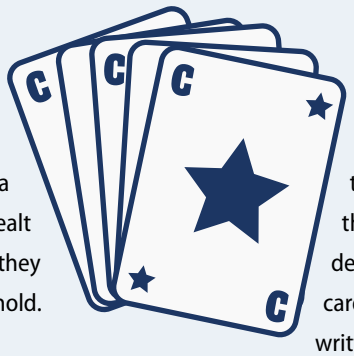
The deferred acceptance algorithm

DA algorithms create stable matches between schools and students and allow both to set preferences for their desired match. The underlying research to develop DA formed the basis of the 2012 Nobel Memorial Prize in Economic Sciences[10] and is also the same process used to match medical students to residency programs in the United States.[11]

DA is unique in the way it matches students to schools. It loops through a series of tentative matches between schools and students; no decision is final, and each acceptance is deferred until the entire process ends. Each student applies to his or her first-choice school, which either tentatively accepts or rejects the student based on its priorities. Each student who is not yet matched to a school applies to their next choice. Each school tentatively accepts or declines the student and can release a student who was tentatively accepted in a previous round if a new applicant with higher priority emerges in a later round. The process continues until all students are matched or until students exhaust all their preferences. If students do not receive any of their preferences, the entity that is managing the enrollment process will assign them to a school.

Deferred acceptance: A game of cards

One way to think about the DA algorithm is in terms of a card game in which schools are players and applicants are cards. Players have in mind the suits they prefer and try to build their preferred hands as cards are distributed to them—that is, each school uses its enrollment priorities to determine which students it will tentatively accept. Meanwhile, written on each card is an ordered list of players that dictates the order in which cards are distributed to the players—that is, each student submits a ranked list of schools. At the start of the game, each card is dealt to the first player written on it. The players keep all the cards they are dealt, unless they end up with more cards than they can hold.



In this case, players would only keep the cards with their preferred suit and give back the extra cards to the dealer. In the event that a player has to decide between multiple cards of the same suit, she or he makes the decision based on a dice toss—the equivalent of lottery numbers in a DA system. The dealer then distributes each of the remaining cards to the second player written on them. Again, the players either: keep the cards if their hand is not yet full; keep the cards and trade back less preferred cards if their hand is full; or decline the card because their hand is already full with cards that they prefer. The process repeats until the dealer either has no cards left or until each card has already been sent to all the players written on it. In the school enrollment context, the entity that is managing the enrollment process will assign a student to a school if the student does not receive any of his or her preferences.

Because assignments are not finalized until the end of the DA process, each applicant has a fair chance of being considered by a school on her or his list, regardless of how high she or he ranked the school compared with other applicants. Applicants gain nothing from misrepresenting their true preferences or ranking fewer schools. Because DA cannot be gamed, it levels the playing field for families regardless of the time and resources they possess.

In contrast to conventional algorithms, DA ensures that matches strictly adhere to enrollment priorities and student preferences. A student will never lose his or her spot at a preferred program to a student with a lower priority. Therefore, no student and school pair should prefer each other over their assigned matches. However, after DA has finished running, there may be pairs of students who would rather have the other's assigned school—but these instances are exceedingly rare. It is not possible to have a system that strictly adheres to enrollment priorities and student preferences and also never results in an instance where a pair of students may want to trade their assignments, in violation of a school's priority.

New York City's nonselective high schools have been using DA since 2003 to match about 70,000 students to approximately 400 schools each year.[12] Other cities—including New Orleans; Denver; Washington, D.C.; Camden; Boston; and Indianapolis—have also adopted DA.[13]

The top trading cycle algorithm

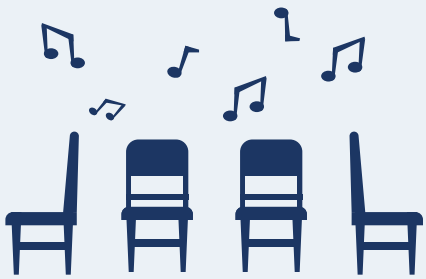
Like DA, TTC cannot be manipulated by applicants who strategically rank schools. However, unlike DA, TTC seeks to swap assignments between students to ensure that they receive their more preferred choice, even if their preference does not match the enrollment priorities of each school. In other words, TTC does not strictly adhere to enrollment priorities but rather favors the goal of trying to maximize student choices.

Under TTC, each applicant starts by applying to his or her first-choice school, and each school accepts only the students with the highest enrollment priority. The remaining applicants continue to apply to their most-preferred school that has open seats, while schools continue accepting students with the highest priorities out of those still applying. Notably, however, groups of students can trade priorities among themselves, enabling each student to get into his or her most-preferred school among those with available seats.

For example, suppose Amy's most-preferred choice is Washington High, while Tim's is Central High. Washington High gives highest priority to Tim and not Amy, while Central High gives highest priority to Amy and not Tim. The algorithm would switch Amy's and Tim's priority designations so that they would each get placed at their most-preferred school. These transfers can be between more than two players, in which case it becomes a trading cycle rather than a one-to-one switch. Like DA, the TTC process repeats until each student is assigned or until each student has had a chance to apply to all of the schools on his or her list.

Top trading cycle: A game of musical chairs

TTC is analogous to a modified game of musical chairs in which the chairs represent seats at schools and the players represent student applicants. The game starts with each applicant sitting in a seat at the school where they hold the highest enrollment priority. However, this is not necessarily the seat that they want the most. Applicants who are exactly one swap away from their most-preferred seat are allowed to trade, while students more than one swap away must go through multiple rounds. The swap could be a simple trade with one other applicant or a simultaneous series of linked trades with many other applicants. When applicants get their most-preferred seat, they drop out of the game and take their chair with them. The remaining applicants repeat this process until everyone drops out, either because the player gets a preferred seat or does not want any of the remaining seats. The entity that is managing the enrollment process will assign students to a school if they did not receive any of their preferences.



As with DA, TTC gives no advantage to students who misrepresent their true preferences or rank fewer schools than they would attend in order to get into one of their top choices. Because the algorithm only swaps to move students to a more-preferred school, students benefit from the algorithm only if their application states the true order of their preferences.

In contrast to DA, TTC provides the best possible matches across all students. After the TTC algorithm finishes running, no two students should want to switch their assignments with each other. Because swaps involve trading priorities between students, TTC may not be suitable if districts want to strictly adhere to their own enrollment priorities. However, the progression of trading cycles does take into account enrollment priorities to the maximum extent possible, while also ensuring the best possible matches for students.

Currently, no public K-12 districts use TTC. New Orleans' Recovery School District used TTC to match students in 2011 but switched to a DA system soon after to incorporate public and private schools that wanted to preserve their enrollment priorities.[14] Policymakers in some cities also report that TTC is more difficult to explain to parents and students than DA, but it may be appropriate if a city or district wants to prioritize the best possible matches for students. This may be particularly relevant when schools' priorities are geographic considerations and not based on criteria such as entrance examinations or interviews.

Implementing fair and efficient school matching systems

Both DA and TTC require schools to participate in centralized assignment, where all students apply using one application and are assigned to one school. Implementing centralized assignment requires a standardized, transparent set of assignment rules across participating schools. Unified enrollment requires an additional step: All public schools in a city or region, including traditional public schools, magnet schools, and public charter schools, must participate and buy into the centralized enrollment system.

To unify enrollment, the district must work with other sectors or entities that run schools, such as local charter management organizations, local charter authorizing boards, or regional magnet programs. Some districts, such as Denver Public Schools, directly manage the common enrollment process across sectors,[15] while others develop an independent entity to manage the matching process. For instance, Enroll Indy—an independent nonprofit organization in Indianapolis—manages unified enrollment for Indianapolis Public Schools (IPS) and most of the city's public charter schools.[16] Washington, D.C. uses a slightly different model to manage its unified enrollment system: My School DC is housed within the Office of the State Superintendent of Education (OSSE) and is independently supervised by the Common Lottery Board. The Common Lottery Board comprises representatives from both D.C. Public Schools and public charter schools.[17]

Participating schools and the managing entity must consider a few components that are critical to the effective implementation of both DA and TTC enrollment systems:

- **How many schools can a student rank?** The managing entity may wish to designate a maximum number of schools that a student applicant can rank. However, for DA and TTC to be fully resilient to manipulation, applicants must be allowed to list as many options as they would like. Students who can rank an unlimited number of schools on their application are less likely to prefer more options than they can rank, which would require them to strategize about which options to include.[18]

Some districts may be concerned that letting students rank an unlimited number of schools could encourage students to apply to schools in which they do not seriously intend to enroll. In reality, the rate at which students enroll in their assigned school has been shown not to vary, regardless of how many options they are allowed to rank.[19]

- **What are the enrollment priorities?** Districts must decide on the policy objectives governing enrollment priorities in the matching process. These objectives often require community buy-in. Many centralized enrollment systems include enrollment priorities for siblings, students who live near a school, or students who previously attended a feeder school—schools that send the majority of their graduates to a particular school that may have a similar theme or instructional program. Systems may also give priority to students who qualify for free or reduced price lunch.

- **Who will audit the system?** An outside individual or entity should audit the system to ensure that rules are coded correctly and outcomes are consistent with enrollment priorities. A number of districts with centralized enrollment systems publish audit reports for the sake of transparency, accountability, and learning.[20]

- **How will policies be communicated to students and families?** The managing entity should provide informational tools for families to understand the goals and operation of the enrollment system and its benefits; learn about the available school options; and receive instructions for applying to schools and checking results. Most entities that manage the enrollment process offer these resources online. Some hire community liaisons to partner with community-based organizations to share the information in community centers or even from door to door.

- **What technology systems need to be put in place?** Computerized systems can help ease the burden of collecting application forms, linking applications to existing registration data, and running the assignment algorithm.

Cost

The cost of switching to DA or TTC varies significantly across districts. If a city or district already has a centralized enrollment system, switching the algorithm may only require coding changes and communication to stakeholders. If a city or district does not have a centralized enrollment system, switching to DA or TTC requires integrating existing applications and matching processes into one system.

In Chicago, for example, students were still submitting paper applications only a few years before the city switched to using the DA algorithm. Before implementing the algorithm, the district needed to transition to computerized collection of student applications and tracking of open school seats.[21]

The considerations listed above are critical to any centralized matching process, and the associated costs are not specific to only DA or TTC.

Improving the student experience with more efficient matching systems

This section describes three districts that are currently using DA within a unified enrollment system: New Orleans, one of the oldest adopters of the algorithm; Indianapolis, which launched its OneMatch system in 2017; and Denver, which adopted unified enrollment using DA in 2012. Each matching process looks different to reflect the districts' unique political and education contexts, but the use of the algorithm ensures fair access to public schools of choice and efficient matching.

To collect information for these case studies, the authors interviewed individuals who developed or managed enrollment systems in New Orleans, Indianapolis, and Denver.

EnrollNOLA, New Orleans: Encouraging school participation, educating the community

New Orleans is unique in that the vast majority of its public schools—all but two—are charter schools. Following Hurricane Katrina in 2005, the Recovery School District (RSD)—a statewide school district that assumes oversight of underperforming schools across the state—took control of most public schools in New Orleans and converted them to charter schools.[22] Citywide enrollment was decentralized for most public schools, which required families to travel around the city and individually apply to each school they considered.

EnrollNOLA—managed by the RSD at the time—launched the OneApp unified enrollment system in 2012 to simplify the application process for families and increase school match efficiency. Today, EnrollNOLA is housed under the Orleans Parish School Board (OPSB), the school district in New Orleans that now operates more as a charter authorizer than a traditional school district. EnrollNOLA manages the admissions and transfers for all but three of the city's public schools, as well as private schools that participate in the Louisiana Scholarship Program—a voucher program that provides families with a fixed amount of public funding to put toward private school tuition. As part of this work, EnrollNOLA implements OneApp—the annual lottery and admissions process for all participating schools.[23]

Building community understanding of the system

Ray Cwiertniewicz, the former executive director of student enrollment at OPSB who was responsible for supervising OneApp, notes that one of EnrollNOLA's biggest ongoing challenges is helping families understand how the enrollment process works—specifically, what OneApp can and cannot do.

According to Cwiertniewicz, "[T]he algorithm itself is remarkable and, through the rules, optimizes a family's ability to get their highest ranked choice. It is as fair a way [of assigning students] as you can create. But the complexities of the algorithm that make it efficient also make it harder to explain." He explained that it is common for families who do not get their top choices to believe the algorithm "is unfair."[24]

EnrollNOLA seeks to communicate the algorithm in a way that is accessible to everyone. The organization makes itself available to families to explain how the lottery works and provides detailed explanations about why students were or were not assigned to a certain school when families inquire. In addition, EnrollNOLA posted a short, animated video to their website to describe how the process works.[25]

Parent and guardian engagement is vital to running an effective unified enrollment system. As the entity that runs the matching process, EnrollNOLA is a necessary touch point for all families, and many families come to the organization with concerns beyond enrollment. Cwiertniewicz said, "It is hard for some families to separate enrollment processes with the fact that there are not enough seats to meet demand for many schools."[26] When concerns go beyond enrollment, the organization connects concerned families to other agencies.

EnrollNOLA works closely with the other departments at the RSD and OPSB to connect families to the right individual with whom they can share their concerns. EnrollNOLA also uses the information it collects from enrollment management when determining charter renewals or growth within a charter network. These data are also shared with outside researchers who use the data to shed light on school performance.

Impact of OneApp

The match rate in New Orleans has increased over time. In the 2012-13 school year, the rate at which students received an offer from any one of the schools they ranked was 78 percent. During the 2017-18 school year, 81.3 percent of families who listed at least three choices were matched. The match rate is higher for families who rank more schools. For the 2017-18 school year, families who listed seven to eight choices had a match rate of 100 percent.[27]

The match rate is only one measure of how well the algorithm is performing. Most importantly, Cwiertniewicz notes that OneApp's algorithm ensures that every student has a fair shot at each open seat, but the algorithm itself cannot create more seats at the most in-demand schools.[28]

The OneApp system has also dramatically increased the data available to the RSD and OPSB. Students cannot receive multiple offers, enabling policymakers to make more accurate enrollment projections. In addition, OneApp collects a wealth of data, including on school demand and school transfers, that helps the RSD and OPSB support schools and plan for school expansion, closure, or development.

Ray Cwiertniewicz, the former executive director of student enrollment at Orleans Parish School Board, provides some advice:[29]

> *Keep family experience at the top of your mind. Try applying for seats in an area with centralized systems and in areas without to understand how difficult it is to access decentralized choice systems.*
>
> *Implementing this system gets easier with time. The hardest part of creating the system is disrupting the status quo with a unified enrollment system. Within a few years, schools realize that they can be successful with a centralized system and it greatly increases efficiency.*

Enroll Indy, Indianapolis: Building political will and awareness

During the 2017-18 school year, the city of Indianapolis launched a landmark unified enrollment system. The nonprofit organization Enroll Indy created a single application point, OneMatch, for all public schools in the Indianapolis Public Schools district and more than 90 percent of the charter schools authorized by the city of Indianapolis and the Indiana Charter School Board (ICSB).

Indianapolis has various types of public schools, including magnet, choice, innovation, and neighborhood schools. For the past several years, IPS had a common application system for its magnet and choice schools, but the system lacked transparency. Families did not understand the process the district used to assign students. Some students received multiple offers to different schools, while other students received none. Districts finalized placements behind closed doors, making it difficult for families to assess if assignments were fair. Until 2017, each Indianapolis charter school ran independent applications and lottery processes on different deadlines.

Identifying the problems with the prior enrollment system

In 2013, Caitlin Hannon—the founder and executive director of Enroll Indy—began advocating for a more efficient way to match students with schools. At the time, Teach Plus published a report highlighting that one of most common reasons for involuntary teacher transfers in IPS was difficulty in predicting enrollment.[30]

Following the report's publication, Teach Plus hired the Institute for Innovation in Public School Choice (IIPSC), led by Neil Dorosin, to examine the current enrollment system in Indianapolis across all public schools. Dorosin interviewed and conducted focus groups with stakeholders including parents, school leaders, and administrators. Parents and guardians found the current enrollment system difficult to navigate, inefficient, and unfair to some families.[31] Some parents reported that they did not know that their children could enroll outside of their neighborhood school, while other families dedicated weeks to researching and applying to schools. Of the students who applied to schools outside their neighborhoods, some were admitted to more than one school and appeared on multiple school rosters until the first day, making it difficult for schools to project enrollment and the number of staff members needed for classrooms. Students who received multiple offers could hold spots in schools that other students wanted, making it difficult for families to plan for the next academic year. Moreover, IPS and individual charter schools could not demonstrate that their admission decisions were fair.[32]

Creating a fair, efficient, and transparent process

With a clear, documented problem, Hannon built political will for a solution and sought to implement a unified enrollment system.[33]

In 2015, Hannon received a seed grant from the Michael and Susan Dell Foundation and the Walton Family Foundation through The Mind Trust and developed a steering committee with stakeholders from IPS and charter schools in Indianapolis. The group met every two weeks for six months to discuss how Indianapolis could adopt changes to the enrollment system to make it fairer, more efficient, and more transparent. The working group was a key mechanism in giving key players a say in the development of the new system. They discussed questions both big and small: Who would run the process? How many schools could families rank on the application? Hannon also convened parents to provide input on questions related to their experience. Recommendations from the steering committee and parent group were taken to an executive committee that included the superintendent of IPS, the head of charter schools for the city of Indianapolis, and the chair of the ICSB.

Given the political dynamics within the city, the group decided to create an independent organization, Enroll Indy, to operate the unified enrollment system. Enroll Indy has been philanthropically funded since its inception in 2015. During fiscal year 2019, the three public entities that oversee Enroll Indy—the city of Indianapolis, IPS, and the ICSB—will contribute public dollars to the organization.

Each student can rank up to 10 schools in their OneMatch application. There were three application deadlines in the system's first year, but Enroll Indy shifted to two deadlines in its second year. Students are most likely to get one of their top picks if they apply by the first deadline. Some students may receive no matches if they apply to a limited number of high-demand schools. In the first year, the match rate across all three rounds was 84.5 percent.[34]

Enroll Indy worked closely with Atila Abdulkadiroglu of Duke University, IIPSC, and the MIT School Effectiveness and Inequality Initiative to determine the best algorithm to use in the matching process. Abdulkadiroglu, an expert in school choice systems, helped Enroll Indy create a system that reflected city priorities. The system gives geographic priorities for IPS and some charter schools.[35]

To develop and launch OneMatch, Hannon built a team of five additional staff members with a mix of project management, data analysis and oversight, and community engagement skills. The organization also employs five part-time enrollment guides who inform and liaise with the community. Enroll Indy relies on technical staff members to manage the outside vendors that build a family-friendly platform that allows schools, district administrators, and staff to pull meaningful data to inform their operations.[36]

Increasing community awareness

Enroll Indy worked with 61 community partners, including libraries, community centers, and churches; campaigned on social media; and canvassed neighborhoods to encourage participation in the unified enrollment system and help families learn about school options. Between November 2017 and June 2018—the enrollment period for the 2018-19 school year—Enroll Indy reached more than 25,000 households through canvassing or phone banking.[37]

Impact of OneMatch

Unified enrollment simplified and streamlined the application process for families in Indianapolis, and participation in the unified enrollment process increased the number of applications to IPS choice schools. Applications increased from 2,800

students for the 2017-18 school year to 3,800 students for the 2018-19 school year. Enroll Indy is unable to report the change in participation rates for charter schools, because charter schools did not use a common enrollment system until this year. Furthermore, Enroll Indy saw more applications in the areas in which it canvassed to increase awareness of OneMatch to community members. Based on census tract data, Enroll Indy increased participation among low-income families and narrowed the income gap among families who applied before the first and final deadlines.

As of July 2018, Enroll Indy had received 9,668 applications for the 2018-19 school year, and 84.5 percent of those applicants were matched with one of their ranked schools.

After the application and matching process, Enroll Indy administered a parent survey. More than 75 percent of respondents said that the process was easy to complete and that it was easy to find information and navigate OneMatch.[38]

Caitlin Hannon, executive director of Enroll Indy, offers some advice:[39]

> *Don't let the perfect be the enemy of the good. Every district or related entity will start this process from a different place. You can refine the algorithm and process as you go, and it is most important to get something off the ground.*
>
> *Develop a clear problem statement to build political support for a change.*

Denver Public Schools: Increasing socio-economic diversity

Denver Public Schools (DPS) in Colorado has effectively used enrollment priorities, such as the goal of increasing socio-economic diversity, when implementing DA. In 2012, DPS adopted a unified enrollment system that uses DA. The enrollment system, SchoolChoice, is managed by DPS and assigns students to most public schools in the city, including magnet, charter, innovation, and other public schools of choice. DPS has successfully managed the enrollment process with charter schools, in part because DPS is currently the sole charter school authorizer and therefore is already involved with charter school operations and management.[40]

Many of the priorities in Denver's system are similar to those of other districts. For instance, students have a better chance of getting into a school if they have a sibling attending, making it easier for parents to drop off and pick up their children. Students are also more likely to get into a school within walking distance, a priority meant to foster community cohesion.

In 2017, DPS started a pilot program intended to increase schools' socio-economic diversity. Specifically, the program assigned priority to students who receive free or reduced price lunch for some of the district's most affluent public schools. DPS surveyed the socio-economic balance of public schools in the district and considered the demographics of surrounding schools. The socio-economic compositions of 30 of the 40 most affluent public schools, out of a total of 200 public schools, were significantly less diverse than the overall city.[41]

DPS used application and enrollment data from previous years and ran different models to determine how to assign priority to students to ensure that schools were more reflective of the city's population. Schools were given the option to opt into the pilot, which helped ensure that the shift in enrollment was gradual and that participating schools would be able to prepare and ensure a better experience for all students.

The pilot policy change was successful. From the 2016-17 through the 2018-19 school years, 287 students in the primary entry grades—kindergarten, sixth grade, and ninth grade—were admitted to schools where they would not previously have been enrolled as a result of the free and reduced price lunch pilot, and an additional 260 students in those grades enrolled in those pilot schools under this priority.[42]

However, effective socio-economic integration of schools requires more than an additional priority in a unified enrollment system. Offering districtwide school choice and redrawing attendance boundaries are important, but school segregation is also a product of generations of inequitable housing and school funding policies.[43]

Conclusion

The ultimate goal of school systems is to improve the quality of all public school options and advance student outcomes. A rise in public schools of choice, including charter, innovation, and magnet schools, has allowed parents and guardians to select among more public options to find a school that is likely to best meet their children's needs. Unfortunately, most existing public school choice enrollment systems are unfair and difficult for families to navigate. Families with more time and knowledge of these processes have an advantage and can manipulate the system.

Parag Pathak and his colleagues developed algorithms to ensure that any district can efficiently and fairly administer a common enrollment system. Deferred acceptance and top trading cycles are strategy-proof and encourage students and their families to accurately report their school preferences. Various districts across the country have implemented these algorithms with positive results. These districts match more students with one of the schools they rank than districts with conventional enrollment algorithms.

As school systems with multiple public school options for students continue to work to improve the quality of all schools, they should also make sure that every student has a fair shot at the school he or she wants to attend. To that end, implementing unified enrollment systems using DA or TTC is an important step that every public school system should take.

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Appendix:

More resources on school choice algorithms

This appendix includes additional research and technical resources on centralized enrollment systems, including deferred acceptance and top trading cycles algorithms.

Technical resources on school choice design

- Atila Abdulkadiroglu, Parag A. Pathak, and Alvin Roth, "Strategy-proofness versus Efficiency in Matching with Indifferences: Redesigning the NYC High School Match," *American Economic Review* 99 (5) (2009): 1954–1978, available at https://economics.mit.edu/files/3962.

  Description: The authors evaluate different ways to assign tiebreakers to students who share the same level of priority at a given school in a two-sided market, such as New York City, where both students and schools carry distinct preferences. They highlight the trade-off between a system that is strategy-proof and one that yields the most efficient matches.

- Parag A. Pathak, "What Really Matters in Designing School Choice Mechanisms." In Bo Honoré and others, eds., *Advances in Economics and Econometrics: Eleventh World Congress, Volume 1* (Cambridge, United Kingdom: Cambridge University Press, 2017).

  Description: This paper highlights the most important and common issues involved in the practical design of school choice systems: vulnerability to manipulation; transparency of the assignment process; coordination of offers across multiple schools; aftermarkets for unmatched or unsatisfied students; and influences on student preferences, such as household decision-making and school quality.

- Center for Reinventing Public Education, "Stakeholder Engagement for Common Enrollment Systems" (2014), available at https://www.crpe.org/sites/default/files/crpe-brief-stakeholder-engagement-common-enrollment-systems-rev2016.pdf.[44]

  Description: Common enrollment systems are necessary to implement a DA or TTC model. This white paper offers guidance to policymakers as they engage with stakeholders to shift toward common enrollment.

- Atila Abdukladiroglu and Tayfun Sönmez, "School Choice: A Mechanism Design Approach," *American Economic Review* 93 (3) (2003): 729–747, available at https://www.aeaweb.org/articles?id=10.1257/000282803322157061.

  Description: This paper launched the agenda of using ideas from matching theory for school assignment. It first proposed that Gale-Shapley and TTC can be used for school choice and provides a concise description of both of these mechanisms and their properties.

Annotated academic literature on school choice design

- Atila Abdulkadiroglu and others, "The Boston Public School Match," *American Economic Review* 95 (2) (2005): 368–371, available at https://economics.mit.edu/files/3021.

  Description: Drawing on prior work by Abdulkadiroglu and Sönmez, the authors detail how Boston's previous assignment system, which relied on sibling and walk zone priorities, disincentivized students from ranking their true preferences. They propose the DA and TTC mechanisms as alternative system designs to remove this disincentive. The former would guarantee that no student would lose a seat to a student with lower priority and be assigned to a less preferred school, while the latter would guarantee final assignments in which no two students would both be better off by switching their seats.

- Atila Abdulkadiroglu, Parag A. Pathak, and Alvin E. Roth, "The New York City High School Match," *American Economic Review* 95 (2) (2005): 364–367, available at https://seii.mit.edu/wp-content/uploads/2011/12/Paper-New-York-City-High-School-Math.pdf.

  Description: The authors describe their work to help New York City redesign its public high school matching procedure. The previous decentralized system, which allowed five choices and multiple offers per student, suffered from congestion that resulted in 30,000 students being administratively placed in programs that they had not chosen. It was also prone to manipulation, as students were encouraged to consider their competition before revealing their true preferences. Some schools also concealed capacity to reserve seats for more preferred students.

  In 2004, the New York City Department of Education implemented a student-proposing DA algorithm, which allowed 12 choices per student and minimized incentives for students to game the system. This algorithm was appropriate for a two-sided market such as New York City, where students have distinct preferences

for different schools and schools have distinct preferences for different students. As a result of the implementation, the number of students left unassigned dropped from 30,000 in the 2002-03 academic year to 3,000 in the 2003-04 academic year.

- Parag A. Pathak and Tayfun Sönmez, "Leveling the Playing Field: Sincere and Sophisticated Players in the Boston Mechanism," *American Economic Review* 98 (4) (2008): 1636–1652, available at https://economics.mit.edu/files/3025.

  Description: The authors document different types of student applicants in the Boston allocation mechanism. Some applicants are "sincere," meaning they report their true preferences. Others are "sophisticated," meaning they report preferences to achieve the best possible placement given other applicants' preferences. The authors demonstrate that sincere students tend to lose their priorities to sophisticated students. Sophisticated students may receive a better placement under the Boston system than they would under DA, which does not incentivize gaming the system. In light of these findings, the authors argue that strategy-proof mechanisms such as DA would help ensure fairness across applicants with differing levels of sophistication.

- Parag A. Pathak and Jay Sethuraman, "Lotteries in Student Assignment: An Equivalence Result," *Theoretical Economics* 6 (1) (2011): 1–17, available at https://econtheory.org/ojs/index.php/te/article/viewFile/20110001/4777/165.

  Description: This theoretical paper proves that, in one-sided markets,[45] there is no difference between a TTC match that uses a centralized lottery and a process that allows schools to conduct their own lotteries.[46]

- Parag A. Pathak and Tayfun Sönmez, "School Admissions Reform in Chicago and England: Comparing Mechanism by Their Vulnerability to Manipulation," *American Economic Review* 103 (1) (2013): 80–106.

  Description: The authors argue that invulnerability to manipulation is an increasingly important objective for policymakers in school assignment systems, illustrated by policy changes in Chicago and England. However, some newly adopted assignment systems do not completely eliminate vulnerability. The authors propose a formal approach to compare vulnerability to manipulation across different systems. They find that the so-called first preference first mechanism, wherein students are given priority at each school according to how high they ranked that school among their choices, is most prone to manipulation.

- Christopher Avery and Parag A. Pathak, "The Distributional Consequences of Public School Choice." Working Paper 21525 (National Bureau of Economic Research, 2015), available at https://www.nber.org/papers/w21525.pdf.

  Description: The authors develop a model for simulating the potential of school choice programs to improve access to high-quality schools relative to residential programs. Results suggest that school choice programs are more effective at

narrowing the range of differences in quality across schools in a city. However, the lowest-income families may not necessarily have greater access to school quality. The narrowed range in school quality is reflected in housing prices, thus families at the extreme ends of the income spectrum seek more suitable options in another city.

- Umut Dur and others, "Reserve Design: Unintended Consequences and the Demise of Boston's Walk Zone," *Journal of Political Economy* (forthcoming).

  Description: The authors show that, in a DA mechanism, reserved seats can be ineffective in boosting the priority of certain students if the order of precedence is incorrectly specified.[47] Both increasing the number of reserved seats relative to open seats and raising the precedence of open seats relative to reserved seats leads to increased likelihood of admission among applicants eligible for the reserved seats.

- Atila Abdulkadiroglu and others, "Minimizing Justified Envy in School Choice: The Design of New Orleans' OneApp." Working Paper 23265, (National Bureau of Economic Research, March 2017), available at https://www.nber.org/papers/w23265.

  Description: The authors demonstrate that TTC mechanisms are suitable for assignment systems that seek efficiency as a primary goal; in other words, the final assignments are such that there is no way for two students to both benefit from swapping their assignments. Compared with all other similarly efficient mechanisms, TTC results in the fewest number of students who lose a seat at a school they prefer to another student with lower priority—so-called justified envy. In comparison, the more common DA algorithm eliminates justified envy but is less efficient than TTC.

- Atila Abdulkadiroglu, Nikhil Agarwal, and Parag A. Pathak, "The Welfare Effects of Coordinated Assignment: Evidence from the New York City High School Match," *American Economic Review* 107 (12) (2017): 3635–3689, available at https://economics.mit.edu/files/14608.

  Description: The authors compare New York City's uncoordinated assignment system with centralized assignment using a DA mechanism by examining both systems' effects on families. Students across all demographic groups, boroughs, and baseline achievement levels receive, on average, a more preferred assignment from the coordinated mechanism. Students who were most likely to be left unassigned under the old system benefited the most. In addition, the geographical distance between a student's school and home increased by 8 1/2 miles on average, suggesting that students choose to travel beyond their neighborhoods to access preferred schools. Students who were mostly likely to be administratively assigned in the uncoordinated system also saw increases in test scores and graduation rates in the centralized system.

- Christopher Avery and Parag A. Pathak, "Missing 'One-Offs' in High School Choice in New York City." In Scott Duke Kominers and Alex Teytelboym, eds., *More Equal by Design: Economic Design Responses to Inequality* (Oxford, United Kingdom: Oxford University Press, forthcoming).

  Description: The authors find that high-achieving students from low-performing middle schools are less likely to apply and enroll in high-performing high schools in New York City. In addition, these students experience worse educational outcomes than similarly high-achieving students from high-performing middle schools.

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