APPLYING MECHANISM DESIGN THEORY TO ALLOCATION PROBLEMS IN UNIVERSITIES

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ABSTRACT

The Assignment Problem in Economics analyses situations where a particular number of goods or services have to be assigned among a particular (though not necessarily the same) number of consumers. Examples include the assignment of jobs to workers, of rooms to housemates, of time slots to users of a common machine, all of which would be a capacity constrained problem of assignment. In such a situation, an auction mechanism, where consumers have to bid and win the auction according to defined standards to be able to consume the good or service, may be used to solve the problem. We look at some practical examples where such auctions have been used in universities and colleges for a variety of allocation problems. They include auctions and other similar mechanisms to allocate courses amongst students, as well as auctions that have been used to allocate prime parking spots in crowded campuses, and have also been used as one of the instruments to ensure efficient allocation of post graduation job interview slots at business schools. We describe each allocation situation and also analyze the characteristics of the mechanisms used in the case of course allocation.

NTRODUCTION

The 2007 Nobel Memorial Prize in Economics was awarded to Leonid Hurwicz, Eric Maskin and Roger Myerson for their pioneering contributions to Mechanism Design Theory. The term "mechanism design" understandably has engineering connotations where a machine has to be designed to conform to some set standard. However social and economic decision making can also be easily incorporated into the term "mechanism design" because in essence the phrase "a designed mechanism" can just as easily be applied to providing and sharing the cost of public goods as an example. Initially also referred to as the principal agent problem, mechanism design a "mechanism" by which a set of agents with productive capacities or consumption needs will interact with one another to allocate resources. In this case the principal or planner needs to design a mechanism of interaction among the economic agents such that an appropriate efficient allocation of resources is achieved. An example of an economic system would be the decentralized price mechanism where goods and services are allocated based on prices determined by demand and supply, with the outcome of the allocation being efficient or "Pareto Efficient" as is the standard economic term. In this economic system, a planner could design a

mechanism that would alter the decision making authority and the allocation of rewards, in which case it would resemble a socialist economic system. An auction is a designed mechanism that in many ways seeks to replicate the outcomes of a decentralized price mechanism, although the rules of the game are designed differently. Among the more popular auctions that have been used to allocate resources have been the English auction, the First Price auction, the Second Price or Vickrey auction and the Dutch auction (For an excellent description of these auctions and their uses see Cox, Roberson and Smith (1982)). Even though it is theoretically complex, mechanism design has provided a number of useful and important economic applications in recent years in the design of auctions to allocate spectrum bandwidth to mobile phone providers (see Crampton (2002)), auctions to allocate pollution permits to industries to alleviate the problems of acid rain (see Crampton and Kerr (2002)), nuagerial compensation and incentives (see Melumad, Mookherjee and Reichelstein (1995), voting systems (see Gibbard (1973)), regulation and antitrust policies (see Baron and Myerson (1982), tax systems (see Mirrlees (1986)), lotteries for allocation of students to schools (see Abdulkadiroglu and Sonmez (2003)), and labor and credit contracts (see Bolton and Dewatripont (2005).

As we see from the examples above, the applications of mechanism design are widespread and guite relevant to the functioning of any modern day economy, no matter what the economic system being pursued. In addition to the examples given above, for academics associated with universities and colleges, there is a growing field of practical usage of auctions right in their workplace. Educational institutions usually place limits on the number of students in a particular class. This can lead to an inefficient allocation process since there are always students that are not allocated to their first choice courses, in fact this problem can become serious for students that are at the end of their college education process and need certain classes to graduate, and may find themselves unable to get into that class. Students in many cases also need to take courses in a specific order to satisfy the prerequisites of certain upper level courses, and being unable to get into one of these courses can hinder the progress of the student towards completion of their degree within the standard timeframe. Thus university and college administrators have a special responsibility to ensure that course allocation mechanisms are designed such that students can get into their appropriate courses. The use of auctions and similar mechanisms have become quite popular as a means to ensure efficient allocation of courses, specially in large universities where the constraints of class space is a lot more serious than in small and medium size educational institutions. Auctions and similar mechanisms have also been designed in educational institutions to serve purposes other than allocation of students among class sections e.g. allocation of office and parking space to name a few. In this paper we concentrate on mechanisms that have been designed with applications in universities and colleges i.e. allocation of various products or services in academic institutions that have been implemented by specifically designed mechanisms. As the various examples will show, allocation of students to classes in an efficient manner would be an important feature of these mechanisms. However in this paper, we also provide examples of mechanisms that are used to allocate other goods and services in an academic institution e.g. parking slots and campus interview spots among others. Boyes and Happel (1989) describe a situation where an auction mechanism was designed to allocate office space in the School of Business, Sonmez and Unver (2010) and Krishna and Unver (2008) describe a course bidding system in place to allocate courses amongst students, while Budish and Cantillon (2009) describe a somewhat different mechanism to allocate courses. Apart from describing and explaining the above mechanisms, in this paper we also look at a somewhat different course allocation auction at Columbia University, an auction to allocate parking spots at Chapman University as well as the use of an auction as a partial allocation mechanism for interview spots for students at the University of Chicago. The author feels that this exposition of the use of auctions in educational institutions serves a dual purpose, namely it provides as a fairly comprehensive survey of the mechanism design applications literature in the higher education industry and can also provide college and university administrators with the tools and examples needed to implement some variation of these mechanisms in their own educational institutions.

THE ASSIGNMENT PROBLEM

The classic assignment problem as discussed in the mechanism design literature is an allocation problem whereby agents are assigned a single unit of a product or service according to a devised mechanism. Examples include assignment of rooms to housemates, schools to students and timeslots to workers etc. (see Abdukadiroglu and Sonmez (2003), Roth (2002) and Sonmez and Unver (2010)). However such assignment problems do not necessarily have to involve single unit allocations i.e. where only one unit of a good or service is allocated to one person, they could be multi-unit assignment problems. Examples include assignment of tasks within an organization, allocation of shared scientific resources amongst users, drafts for sports teams, allocation of airport takeoff and landing slots and division of heirlooms amongst heirs. As is appropriate in the mechanism design literature, allocation mechanisms are designed to implement some form of an optimal solution, which would assign the goods and services to the agents. This allocation mechanism may or may not make use of money as a means to the allocation. In this paper, we will discuss the applications of mechanism design theory to the problem of assigning multiple goods or services among a number (though not necessarily the same number) of consumers. In particular we will consider practical examples of educational institutions that have applied particular mechanisms to solve the assignment problem. As mentioned above we will look at allocations of courses to students using a "draft-like" mechanism at Harvard University, as well as allocation of courses using auctions at the University of Michigan and Columbia University. We will also discuss the use of auctions to allocate parking spots at Chapman University and to allocate office space at Arizona State University. We also look briefly at an allocation mechanism used at the University of Chicago to assign interview slots for graduating students.

ASSIGNMENT MECHANISMS FOR ALLOCATING COURSE

Specifically designed mechanisms have become quite popular at many educational institutions to allocate courses amongst its students. Typically, in any educational institution there is a class size limit, thus creating an allocation problem for administrators in the sense that some or all students may not be able to choose their most preferred courses or classes. This would be especially true in the more "popular" classes where you would expect to see a binding capacity constraint being enforced. These types of classes could be popular for a variety of reasons: because of the class itself, or because the instructor is popular, or it could be part of an educational core that is compulsory for all students, or it could be offered at a popular time relative to other similar classes or sections of the same class. In this section we will briefly describe three types of mechanisms used to allocate students to classes. The first is the Draft Mechanism that is used at the Harvard Business School. The other two are auction mechanisms that are used at the University of Michigan and Columbia University. In the analysis below the three different mechanisms are described with the help of examples and some of the differences between them are also made clear.

The Harvard Business School Draft Mechanism

The Draft Mechanism works as follows: Students are randomly assigned a draft number, and choose courses in ascending and descending orders of the assigned draft numbers in respective rounds. Prior to being assigned a draft number, students submit a rank order list of courses. At the time of a particular student's choice of a course, the mechanism allots that student their most preferred course according to their Rank Order list which they have not received and is not at capacity. Once the student's choices have been made and the round is completed, the mechanism will reverse the random number of assignments and continue allotting the students their remaining preferred course. At this time additional course scheduling constraints would be imposed where a student would not be assigned their most preferred course even if the course is below full capacity if the schedule conflicts with the students previously chosen course schedule. There is an add drop segment at the beginning of each semester that allows students to drop courses previously selected and add courses not at capacity. It does not allow trades amongst students. The example below provides a glimpse of how the draft mechanism would work.

Example 1

Suppose there are Five students: 1, 2, 3, 4, 5; and Six courses: Economics (E), Statistics (S), Management (M), Business Law (B), Accounting (A) and Finance (F). Each course has four seats in the class, and student preferences are as follows:

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1: E, S, M, B, A 2: M, F, A, B, S 3: M, E, B, S, F 4: A, E, B, F, M 5: F, A, B, S, E

Thus for Student 1, E is preferred to S is preferred to M and so on. To make things easy in this example we have limited preferences to the top 5 choices, and assume that none of the course times conflict with each other. There are four rounds, and a student will take 4 courses. Rounds 1 and 3 are in ascending order of students (i.e. Student 1 chooses first, then Student 2 etc.) while rounds 2 and 4 are in descending order. The course assignments occur in order as follows:

Round 1: 1E, 2M, 3M, 4A, 5F. Round 2: 5A, 4E, 3E, 2F, 1S. Round 3: 1M, 2A, 3B, 4B, 5B. Round 4: 5S, 4F, 3S, 2B, 1A.

Note that in Round 4 after Student 2 is assigned B, Course B is full, thus Student 1 whose assignment comes next is denied and gets their next choice A. Courses B and A are full, while the other 4 courses have 3 students each. The course loads for each of the students are: 1(E, S, M, A), 2(M, F, A, B), 3(M, E, B, S), 4(A, E, B, F) and 5(F, A, B, S).

As pointed out by Budish and Cantillon (2008), the Harvard Business School draft like mechanism has some key attractive properties. It is procedurally fair i.e. all students ex-ante are treated fairly, as opposed to a course allocation system which is determined, for example, by the number of credit hours already completed thus making it possible that a student completes his or her course allocation before another student has a chance to pick their top preference. It is also ex-post efficient. However the mechanism also provides an incentive for students to choose their preference lists strategically rather than honestly reporting their true preferences. This can have negative efficiency effects on the students as well as the process since students tend to over report (preferences) for popular courses and underreport for less popular ones, as shown in the example below.

Example 2

In this example, let there be 3 students who each will be assigned to 2 courses with 2 seats in each. Let the student preferences', using the same course prefixes as in Example 1, be given by:

Student 1: E, M, A, B Student 2: M, E, A, B Student 3: E, A, B, M

The course assignments would occur as follows:

Round 1 (ascending order of student number): 1E, 2M, 3E. Thus E is full. Round 2 (descending order of student number): 3A, 2A, 1M.

Note that in round 2 as a result of class E being full, student 2 is denied their current top preference of E, and is given A instead. Student 2 could have rearranged their preferences to read E, M, A, B and been assigned course E. Thus, student 2 would have a strategic incentive to choose the most popular course E as their top preference.

The University of Michigan Auction Mechanism

The University of Michigan (Business School) course allocation system is a subset of a broad class of auctions used among others by Columbia Business School, Haas School for Business at Berkeley, Kellog at Northwestern, Princeton and Yale School of Management. The University of Michigan mechanism provides students with a bid endowment to be used in the auction process across courses that the student desires. All bids are processed one at a time starting with the highest bid, and honored for a student if they haven't filled out their schedule and the course has available capacity. The students bid their valuations of courses. There are a fixed number of courses that students can win – it is possible that a student is successful in a larger number of courses than allowed – in that case the last course(s) won will be denied. Once all the bids are in, the bids are arranged in descending order of valuations for all courses. A bid would be deemed successful if the course still has unfilled seats, the student has unfilled slots, and the course does not conflict with the schedule of the student at that point. The lowest successful bid is the market clearing price for a course that is full, while for a course that has seats the market clearing price is zero. Bid endowments do not carry over from semester to semester.

The students also have prior beliefs about the market clearing bids for each course. These prior beliefs are based on historical data about the market clearing prices that are provided by the University. As we shall see, these prior beliefs may provide an incentive to students to bid higher than their true valuations for the courses in order to win a seat at a popular course.

Example 3

Let each course have 3 seats while each student can take a maximum of 2 courses. Suppose there are 5 students bidding for 4 courses, with a maximum total bid amount of 1000 per student such that their bids are represented by the matrix below:

	Course 1	Course 2	Course 3	Course 4
Student 1	600	375	25	0
Student 2	475	300	225	0
Student 3	450	275	175	100
Student 4	200	325	350	125
Student 5	400	250	170	180

Bids are assigned highest to lowest in the following manner:

- (Student 1, Course 1): 600, Student 1 is assigned Course 1.
- (Student 2, Course 1): 475, Student 2 is assigned Course 1.
- (Student 3, Course 1): 450, Student 3 is assigned Course 1; Course 1 is full.
- (Student 5, Course 1): 400, Unsuccessful since Course 1 is full.
- (Student 1, Course 2): 375, Student 1 is assigned Course 2; Student 1's schedule is full.
- (Student 4, Course 3): 350, Student 4 is assigned Course 3.
- (Student 4, Course 2): 325, Student 4 is assigned Course 2; Student 4's schedule is full.
- (Student 2, Course 2): 300, Student 2 is assigned Course 2; Student 2's schedule is full; Course 2 is full.
- (Student 3, Course 2): 275, Unsuccessful since Course 2 is full.
- (Student 5, Course 2): 250, Unsuccessful since Course 2 is full.
- (Student 2, Course 3): 225, Irrelevant since Student 2 has a full schedule.
- (Student 4, Course 1): 200, Irrelevant since Student 4 has a full schedule.
- (Student 5, Course 4): 180, Student 5 is assigned Course 4.
- (Student 3, Course 3): 175, Student 3 is assigned Course 3, Student 3's schedule is full.
- (Student 5, Course 3): 170, Student 5 is assigned Course 3, Student 5's schedule is full, and Course 3 is full.

All 5 students' schedules are full at this moment, and all Courses except for Course 4 (with 1 student) are full. Thus the assignment ends here.

If there are ties, for example if two or more students bid the same for a course, the tie is broken by a predetermined lottery; or a student may bid the same for two or more courses in which case the tie is broken by the order of the bids. However, the one negative effect of this mechanism is that since individuals do not submit a preference listing of courses (something that the Harvard Business School Draft Mechanism did), there could be overbidding on popular courses and underbidding on less popular courses. However, submitting a preference listing as in the Harvard mechanism doesn't really solve the problem; as we explained in the previous section students could still strategically misreport their preferences.

Example 4

Continuing from Example 4, we can see that Student 5 is unsuccessful at getting either of their top two choices. Thus it is conceivable that the student will formulate a strategy of bidding higher for the most popular courses and bidding lower for the less popular courses. The bidding would thus be independent of student's actual preferences for the courses, which could lead to inefficiencies. Consider a student that has utilities (or willingness to pay) of 150 for Course 1 and 100 for each of Courses 2-6 (see Sonmez and Unver (2010) for the complete example) and has prior beliefs about the winning prices for each course. Specifically they believe that the market clearing price for Course 1 will be 0 with probability 1, the market clearing price for Courses 2-6 will be 200 with probability 0.7 and 250 with probability 0.8. The optimal bid vector has been derived (see Sonmez and Unver (2010)) as Course 1 = 1, Courses 2- 6 = 200 each. Thus assuming that the student is successful in their bidding, for any maximum number of courses allotted of 5 or less, the student will be denied a place in Course 1, their most preferred course and be allotted a weak subset of Courses 2-6. For example if a maximum of 5 Courses are permitted, the student will be allotted Courses 2-6 (assuming that their bid is higher than the lowest market clearing bid for each of the courses), if a maximum of 4 is allowed, the student will get a subset of the 5 courses and so on. The student will suffer an efficiency loss (a negative surplus calculated by the difference between the market clearing price and the maximum the student is willing to pay) for each course, as long as the market clearing price for each course is greater than or equal to 101.

The Columbia University Auction Mechanism

The Auction mechanism at the Columbia University Graduate School of Business is quite similar to the University of Michigan mechanism, the major difference is that bidding takes place in several rounds. Bid points are given to students based on their status in the program (i.e. the number of credits they have completed); they are given initially and carry over through the course of a student's life at the University. The bids are not time dependant i.e. they can be changed for a course as long as it is before a round expires. The bidding mechanism allows overlap, which is the responsibility of the students to fix before or during add-drop, and allows a student to choose one or all sections of a course while being charged each sections clearing price. The Bids are processed at the end of each round, with the lowest successful bid for a course becoming that course's clearing price. After the first round, students can see open seats on courses prior to the beginning of the second round. Prior to round 3, students can drop unwanted courses (or sections) and get points back – there are no points refunded during add-drop. The add-drop segment requires no points (of course not all sections or courses may be available for adding. There is also a Swap option, whereby students can exchange courses with other students. If a course is full a waitlist is organized by bid amounts, the lowest bid being the clearing price in case space becomes available. All ties are broken by random lotteries.

At the beginning of their curriculum, students are given a total of 1000 points per elective requirement, and in order to provide an incentive for students to take elective courses after the first term there are extra bonuses.

There are a couple of important differences between the two bidding systems in Michigan and Columbia. Firstly at Michigan an open course is charged 0 while in Columbia it is charged the lowest bid. A more important distinction that could lead to lesser efficiency losses under the Columbia bidding system is the mechanism of multiple round bidding with students given the option until Round 3 to drop unwanted courses. This could lead to a selection more in tune with the students actual preferences compared to the Michigan system.

Example 5

Consider again, Example 3. In the case of Columbia University's bidding rules, a student is allowed to have overlaps that they may resolve before or during the add drop period. Additionally for each semester there are three full rounds that a student can bid for courses. However a student can only bid for a maximum specified number of courses, let us assume from Example 3 that the number is 2. For student 5, they can prioritize on getting their top two choices based on information gleaned from previous semester market clearing bids. Thus they have the option to bid high for Course 1 and Course 2, or they could keep their Course 1 bid the same as in Example 3, but increase the Course 2 bid to 350. Given the restriction on the number of courses they can bid on, this would be the total number of bids for Student 5 in round 1. They would be successful in getting Course 2 but unsuccessful in Course 1. The bid matrix in Round 1 would look like this:

	Course 1	Course 2	Course 3	Course 4
Student 1	600	375	-	-
Student 2	475	300	-	-
Student 3	450	275	-	-
Student 4	-	325	350	-
Student 5	400	350	-	-

Thus, Student 1 would get Course 1 and Course 2; Student 2 would get Course 1, Student 3 would get Course 1, Student 4 would get Course 2 and Course 3 and Student 5 would get Course 2. Bid points would be refunded for unsuccessful bids. The market clearing price for Course 1 would be 450, for Course 2 would be 325 and for Course 3 would be 350. After the first round and before the start of the next round, all students would get a chance to review their courses, and could drop them at the start of the next round if they are not satisfied with the price that they paid. Thus Student 5 could reconsider paying 325 for Course 2, and Student 3 would probably definitely reconsider paying 350 for being the only bidder for Course 3. Unless some students withdraw their bids for Course 1 and Course 2, both of these are full. Thus Course 3 and Course 4 would be the only ones offered in Round 2, and assuming Student 4 withdraws their bid for Course 3, Students 2, 3, 4 and 5 would each bid for the one remaining course on their schedule. Each would be permitted one bid, or they could wait till the add drop period when they could get into a course free of points, since there are bound to be empty seats in at least one of these two courses. We would still have the problem of overbidding for popular courses and underbidding for not so popular ones, but the students in this bidding scheme have an opportunity to reconsider their bids and opt out of a class if they feel they have paid too high a price in points. Thus they have a chance to limit their loss of surplus. Additionally since there are multiple rounds, it is likely that the clearing prices for the same course section could be different in different rounds. This adds a further strategic element to the bidding process of students.

An interesting future endeavor would be to look at actual data from course allocation auctions conducted by an academic institution and compare the winning bids over time to give us an idea about average bids and also success of the auctions. While it would be interesting to look at the costs and benefits of these auctions, in a practical sense it would be extremely difficult to get these types of data. The costs are just eh administrative costs of getting the students used to a different course allocation system from the standard course registration systems they have always used. This may involve some amount of training for the students but would otherwise involve little cost (in fact a glance at the Columbia University website reveals a variety of information available to students with the intention of not only providing training for them but also provide them with earlier winning bids for courses so they can formulate an optimal bid strategy (see https://boss.gsb.columbia.edu/registrar-student/Home.tap). The only other cost would be to have appropriate servers to handle the bids and process them – again with colleges and universities relying on online courses and materials for delivery of a significant part of their education these server capacities are pretty readily available. It is also true that a number of academic institutions especially the ones with large enrollments that usually have a problem with inefficient allocation of courses among its students have been the ones at the forefront of experimenting with these new mechanisms to allocate courses. In the follow up paper we describe how the Columbia University bidding system evolved over time and the changes that they have made, in addition to statistically analyzing the bidding. In an article in the Chicago Tribune (see Harris(2011)), the bidding mechanisms at Northwestern and Kellog are explained in detail as well as an explanation of an interesting resale feature of the bidding mechanism used at UPenn Wharton. The presence of this type of write up in a non academic setting signifies the permeation of these auction mechanisms into the consciousness of the general business media, rather than just being relevant in academic journals.

OTHER EXAMPLES OF AUCTIONS IN ACADEMIC SETTINGS

Auctions for Interview Slots

In this section, we briefly look at the allocation mechanisms for interview slots at Business Schools. This has been done in one of two ways: the traditional way of doing it is to leave the interview invitations completely to the employers. However there have been some Universities, for example Michigan, Chicago and UCLA where a proportion of the interview slots (a specific number) are closed and candidates are invited by companies, the remaining slots are open and graduating students can bid for those slots. However, unlike course bidding, there are no capacity constraints for students who can be scheduled for as many interviews as their bids allow. At the University of Chicago the bidding mechanism that is used is as follows: the companies have both an invite and a bid component i.e. they can choose a fixed number of interviewees themselves (based on their own preferences) while a fixed number is allocated to the highest bidders among interviewees. Both these numbers vary based on the number of interviews a company plans to hold.

For a schedule consisting of 13 half-hour interviews, companies get to choose interviewees for 9 slots while 4 slots are filled by the top 4 bidders for interviews with that company. Similarly if a company chooses to have 45 minute interviews, they get to invite 6 interviewees while 3 interviewees come from the bids. Other interview formats are 60 minutes (with 5 invites and 2 bids) as well as back to back pairs of interviews with similar bid and invite ratios. Typically the students have 1000 points that they can bid for interviews with companies. Since this is a one-shot game, the leftover points cannot be carried over to another. Thus students that have NOT been selected for interviews by a company (based on the company's preferences) get to bid for interview slots with that company. The number of bidders having the highest bids (not including ties) equal to the number of bid slots available wins the auction and get to interview with the company. Once the auction is completed the school uses a complicated algorithm to allocate the schedules.

Auctioning Faculty Offices at Arizona State University

In this application the major difference from the previous cases discussed is the use of money used as an allocation medium. However the basic mechanism still remains an auction. The background story in this application (Boyes and Happel, 1989) is that due to a rebuilding of

the College of Business at ASU in 1983, a reallocation of faculty offices was necessitated. Offices were distinguishable based on whether they had a window or not - having a window would imply a superior office space. Different Options were exercised at the different departments within the College of Business. The Management Department (as well as the Marketing and Accounting Departments) opted for the Seniority option whereby the more senior faculty got the offices with windows. Predictably junior colleagues complained that the senior faculty was precisely the ones that were less productive because they were tenured so in fact the administration was punishing productivity. The Finance Department Chair decided to have a sign up sheet posted without prior warning with the order of allocation determined by the order of names on the sign up sheet. Again, faculty who remain devoted to research inside their offices were at a disadvantage, while faculty that wandered the hallways often would have an advantage, arguable again rewarding the relatively non productive faculty. The Economics Department Chair, realizing the inefficiencies in the mechanism used by the other departments to allocate offices, came up with the idea of using an auction mechanism. Since the idea was to avoid rent seeking and transaction costs, rather than gathering revenue, the department settled on a first price sealed bid auction (which has been shown to be revenue deficient to both the English auction and a second price sealed bid auction (see Coppinger, Smith and Titus (1980) and Cox, Roberson and Smith (1982) for analytical explanations of this) though it is easier to implement than either of them). The revenue collected from the auction was divided up among student scholarship funds, and faculty travel funds. Subsequent vacancies were filled up by similar auctions.

Auctioning Parking Spots at Chapman University

Chapman University in Southern California chose a novel way to approach the perennial problem of parking especially at urban campuses namely there are too few prime parking spots and too many cars jostling for these spaces. That inevitably means that commuters spend a lot of time driving around the prime parking spaces in the hope that someone will leave and they will get the spot. This is obviously inefficient as it leads to losses of time and fuel, not to mention causing more environmental pollution than necessary.

The allocation of parking spaces around the academic institutions in the country are normally done in one of two ways – use of a differentiating mechanism - chronological i.e. the earliest applicants get the best spots, or seniority i.e. in the case of students seniors get the first pick followed by juniors followed by sophomores etc. Another interesting idea is the use of differentiated pricing for different parking lots i.e. the most convenient and hence popular parking lot is the most expensive and so on. This can be either decided by a central University agency like Public Safety or can be decided by an auction which is what Chapman University has chosen to do.

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The Auction works as follows: the parking spots are auctioned as a premium over base rate. There are some parking lots that cost just the base rate (usually the farthest or the least convenient ones) so students that do not want to pay extra for a premium spot can avail of these. The auction is designed as a decreasing price auction; it starts at the highest possible premium. Students and Faculty/Staff bid the maximum premium they are willing to pay, after a specific time (30 minutes) premiums decrease by a specific amount (\$2). The market clears when you have the same number of parking spots and the same number of bidders at a price (or higher), which is the market clearing price. Thus bidders have the option to wait for a lower price as time goes by, but also have a higher risk of losing out on prime parking lots. On the other hand, since they do not get penalized for being the first ones to bid when the premiums are the highest on account of the market clearing price being the lowest price at which the number of spots and bidders are equal, bidders may choose to bid at high premiums, not willing to take the risk of losing out on prime spots. However, if a sufficient number of bidders bid at a high premium, there is a chance that a parking lot could be filled and the bidders pay a price higher than their optimal price. Any ties at any point are settled chronologically.

Example 6

Let the number of parking spots to be auctioned = 5. Number of people interested in bidding = 10.

Suppose the bidding for a premium starts at \$100. There is 1 bidder at that price. After 30 minutes the premium drops to \$98 with just the 1 bidder. After 30 more minutes the premium drops to \$96 with still just the 1 bidder. After three subsequent 30 minute intervals, the premium drops to \$90 and we have 3 bidders. The bidding has to continue because until now we have 5 parking spots and only 3 bidders. After a few more rounds at \$80 we have 4 bidders and at \$72 we have 5 bidders. The auction closes with the premium price being \$72 and the five bidders being the winners each paying the price of \$72.

This is an example of a modified Dutch Auction using a multi unit uniform price auction format. In a traditional Dutch auction, a single unit or a single product cluster is auctioned, and the price decreases until there is one person willing to pay the named price. Thus the bidders are aware that the bids that they make will be the prices that they pay for the product or service, thus creating an incentive for the bidders to strategically lower the bids. Bidders, by bidding lower than their valuation, balance the risk of losing out on a product and the reward of paying a lower price. However, in the modified Dutch Auction, since there are many identical parking spots that are auctioned and an individual has unit-demand for the spots, the final selling price is equal to the last price bid. Thus, for all but one individual, the bid is unrelated to the price paid. For the last individual that submits a bid and hence pays a price equal to the bid, they could behave strategically and bid lower to lower the price that they (and everyone else) pay; however by lowering their bid they could also lose out on the spot. However this incentive for strategically lowering the bid by the last bidder can be removed by recording each individual's maximum price, and setting the final price to be equal to highest bid lower than the market clearing bid. Thus every bidder has an incentive to bid non-strategically i.e. every bidder would bid their true valuations.

Example 7

Suppose there are 4 parking spots being auctioned and 7 individuals with valuations of (in dollars) 100, 90, 80, 70, 60, 50 and 40. If everyone bids honestly, then under the modified auction stated above, the first 4 bidders are awarded the four parking spots for a price of \$60. Individually none of the first four bidders have an incentive to manipulate their bids – the only way any of them could change the outcome would be to bid lower than \$60 in which case they would not win the parking spot - a definite loss of surplus compared to (for example) having a valuation of \$100 and paying \$60 for the parking spot – a surplus of \$40.

In the case that we use the original auction mechanism, the first four bidders would win the parking spots and pay \$70. Thus the fourth individual would have an incentive of lowering their bid (and thus lowering the payment) and still being the fourth individual. In fact, all of the top four bidders would have that incentive. However this is somewhat unrealistic if the auctioneer (the University) provides little or no information about how close the bids are to clearing the market. It would imply having a lot of knowledge about expected valuations of individuals and some history of the bidding values. But given that the Dutch Auction format was chosen for its simplicity and speed, it is unlikely that individuals especially faculty staff and students at a University would expend that much energy just to save a few dollars – the cost benefit does not add up.

Also, as we can see, the original format is actually better as far as revenue is concerned for the University. Thus even though the revised format has the beauty of eliciting truthful preferences from individuals, it is actually less appealing from a revenue standpoint.

CONCLUSIONS

In this short paper, we have provided an exposition of the various mechanisms used by academic institutions to allocate services like courses, parking spots, and office space and interview slots. We described the workings of each mechanism as well as looked at the positive and negative features of each of them and illustrated them with the use of examples. While other real world application of designed mechanisms like auctions designed to allocate pollution permits or distribute bandwidth to mobile phone providers have as their principle motivation generation of revenue, in these examples from Academia, the principle motivation is to allocate the product or service efficiently. Thus in our analysis we have concentrated on describing the

benefits as well as the inefficiencies that we think occur in these mechanism. This paper concentrates mainly on course allocation mechanisms and we note that academic institutions especially the larger ones have become more and more comfortable implementing some form of course allocation system that is different from the standard registration format used in most academic institutions. We also note that the major cost of these mechanisms is really the process of getting students acquainted with the specific auction or course allocation mechanism and to make sure that the students are properly trained to use these mechanisms efficiently. The academic institution does not collect any revenue in the course allocation mechanisms but does reap the benefits of having the courses allocated more efficiently. Interesting future research would come in the form of analyzing actual data related to some of these auction mechanisms. Fortunately, Columbia University as well as the University of Michigan provides publicly available data on their course allocation auctions. Thus, in a follow up research paper to this one, we will try and use the publicly available data to statistically analyze some of the issue that we have described and illustrated in this paper using examples. This will provide a deeper understanding of the benefits and costs of some of these auction mechanisms that have been described here.

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