Waiting list procedure improvements for master program courses in Information and Computing Sciences

Tomas van Groningen ⓘD and Sietse Overbeek ⓘD

Department of Information and Computing Sciences, Faculty of Science, Utrecht University,
Princetonplein 5, 3584 CC Utrecht, the Netherlands
Email: T.J.vanGroningen@students.uu.nl, S.J.Overbeek@uu.nl

Abstract—In higher education, at times it happens there are limited places in courses because of, for example, staffing and classroom shortages which can lead to students being wait-listed. Previous research indicates there are numerous waiting list prioritization methods in health care and public housing, whereas research in waiting list prioritization methods for course registration in higher education is very limited. Results of a literature study and interviews with domain experts have been conducted and analyzed to determine how course waiting list procedures can be improved. This has resulted in an improved waiting list procedure including prioritization methods for master program courses in Information and Computing Sciences at Utrecht University, the Netherlands.

I. INTRODUCTION

THE huge increase in jobs in the IT sector that the digital economy has offered, as well as our increasing dependence of computing skills and data, has caused a significant increase in the enrollment of students in undergraduate computer science (CS) related courses and programs across North America [1]. This is partly due to the requirement of at least a bachelor's degree for entry-level jobs within the IT sector [2]. Course enrollment increases are not only caused by the growing number of CS major students, but also due to a substantial rise of non-CS students that want to participate in CS courses [3]. The growth in the number of undergraduate computer science majors has not been matched by an increase in the number of tenure-track or teaching staff [1]. Consequently, teachers have to teach larger classes and more classes are being taught by temporary instructors such as visitors and graduate students. This is partly due to the outflow of graduated CS students into industry rather than staying in academia to teach, as they can earn up to twice as much in industry compared to what professors earn [4]. This causes a snowball effect: the shortage of CS teachers makes it more difficult for CS majors to get into and finish the classes they need to graduate. These teaching and teaching staff shortages, as well as the lack of sufficient classrooms are some of the causes of restricting certain CS courses to a limited number of students. Because the demand for courses sometimes exceeds the course capacity, waiting lists to select which students will be enrolled for the course are used. In this research a case at Utrecht University in the Netherlands will be used and the current handling process of these waiting lists contains multiple registration and prioritization challenges. This research aims to map the current process based on an already available textual description and improvements will be proposed for an optimized waiting list procedure. These improvements will be based on published literature, as well as interviews with domain experts.

This paper is organized into ten sections. In the following section, the design and structure of the research will be explained. In Section III, a motivating scenario will be described, which includes background information as well as the current situation on the procedure of handling waiting lists in the case of Utrecht University. In Section IV, the results of the literature study will be presented. Interviews were held with education coordinators of different study programs within Utrecht University and the results are described in Section V. Section VI triangulates the results from both the literature study and the interviews. Based on these results, an improved waiting list procedure will be presented in Section VII. This improved procedure will be validated with an education coordinator of Utrecht University in Section VIII, to see what final improvements can be made to the procedure. The final results after the validation are discussed in Section IV. The final section includes concluding remarks, research limitations, and avenues for future research.

II. RESEARCH DESIGN

The research that will be performed in this study is divided into three parts. Firstly, a literature study is performed to find out what is already known about waiting lists, also transcending the domain of higher education. To complement this literature with real life waiting list practices in the domain of higher education, interviews with domain experts are conducted. These experts are education coordinators of different study programs within Utrecht University, who also coordinate the handling of waiting lists for courses. The results are triangulated to find out what the most common and most useful practices are with regard to waiting list handling. Based on these results, an improved waiting list procedure will be created: a textual description complemented with a Business Process Model and Notation (BPMN) model [5]. In the last phase of the research, the proposed improvements will be

reviewed by another domain expert, to gain more insights and find out strengths and weaknesses of the proposed procedure.

A. Research questions

The aim of this study is to find out if and how waiting list procedures for master program courses in Information and Computing Sciences can be improved over current procedures, so that the chances of participating are as fair as possible for every student. The waiting list procedure for master program courses at Utrecht University are used as a case. The following research question and related sub questions have been conducted:

How can waiting list procedures for Information and Computing Science master program courses be improved to make sure that the chances of participating are as fair as possible for every student?

SRQ 1: How are waiting lists of I&CS master courses currently handled? Before the start of the research, the current situation regarding the waiting lists in I&CS master courses at Utrecht University is investigated in Section III. **SRQ 2:** How are waiting lists handled within other departments at Utrecht University? To answer this question, interviews will be conducted with university staff that handle waiting lists for courses, on which more can be read in Section II-C. **SRQ 3:** How are waiting lists handled at other educational institutes and in other fields? To answer this question, a literature study will be performed, on which more can be read in Section II-B.

B. Literature study design

To find out how other institutes in higher education deal with waiting lists, a literature study is performed. Initially, very limited published literature was found on waiting lists and procedures in education. There is, however, information about waiting lists available university websites, in blogs and news articles. To make sure this information is included in the study, a Multivocal Literature Review (MLR) is performed [6]. A MLR is a type of Systematic Literature Review (SLR) [7] that includes both published literature and grey literature (GL). GL is mostly defined as *"literature that is not formally published in sources such as books or journal articles"*[8] and *"literature that is not controlled by commercial publishers, i.e., where publishing is not the primary activity of the producing body"* [9]. The inclusion of GL in the literature review is supposed to fill in the gaps of published literature by providing other perspectives. For this literature study, multiple search engines have been used to gather scientific as well as GL. For scientific literature, Web of Science and Google Scholar were used. For GL, Google was used. An overview of used search terms and key words per search engine is shown in Table 1.

C. Expert opinion interviews

In addition to the literature study, interviews with experts will be conducted. In contrast to mass surveys, experts are typically more informed and motivated than the average participant of a questionnaire [10]. The validity of the information

TABLE I
USED SEARCH TERMS AND KEYWORDS PER SEARCH ENGINE.

Web of Science	Google Scholar	Google
Waiting lists for courses	Waiting lists for courses	Waiting lists for courses
Waitlisted courses	Waitlisted courses	Waitlisted courses
Waiting list procedure	Waiting list procedure	Information science waitlist course
Waiting list, university	Waiting list, university	
Waiting list prioritization	Waiting list prioritization	

gathered through expert interviews is heavily dependent on the expertise of individuals being interviewed. Because this expertise is so important, the experts for this research are education coordinators of bachelor and master programs within Utrecht University. The interviewed coordinators have been selected because they coordinate programs that have a large number of incoming students every year, which makes waiting list issues likely. A summary of the results of the interviews can be found in Section V, while the entire interview text can be found in Appendix A. In the context of ethics and privacy, an Ethics and Privacy Quick Scan was conducted (see Appendix B). Based on the scan, this research has been classified as low risk with no further ethics or privacy assessment required. All participants were asked to fill out a consent form that asks their permission to participate in the research and informs them about it.

D. Validation

To validate the effectiveness of a treatment, it must be demonstrated that it would achieve the desired outcomes for stakeholders when applied to the specific problem at hand [11]. The requirements for the treatment must be clearly defined and justified, and the treatment must meet these requirements to be considered validated. When both the literature study and expert opinion interviews have been finalized, an improved waiting list procedure will be created based on several requirements, that will be drawn up based on the results from the literature study and interviews as well as aspects of the current procedure. In Section VII, this improved procedure, including requirements for the treatment, will be presented. The procedure will then be presented to the education coordinator of the master programs within the I&CS department of Utrecht University. This coordinator reviews the improved procedure and provides feedback, based on which the final waiting list procedure will be presented in Section VIII.

III. MOTIVATING SCENARIO

As mentioned earlier, the research is based on the case of the I&CS department at Utrecht University. The problem with waiting lists in this situation has to do with different enrollment periods for master courses and incoming students. In this section, the context of having a maximum number of

places for a course and different course registration periods will be explained.

A. Broader context

Waiting lists are sometimes necessary for students before they can participate in a course. This limitation can be there because of teaching staff and room capacity. Schedules for an academic year that start in September are made in January of that same year. Program directors have to provide schedulers with the number of students they expect to take part in courses for that particular year. When the enrollment for a course starts, it is possible that the demand is higher than the supply, meaning that all students that have signed up beyond the maximum capacity of the course will be placed on a waiting list. The course coordinator can ask for lecture rooms with bigger capacity, but because schedules have been made already, it is not likely that this is possible. Alternatives are teaching the course in hybrid mode or dividing the students over multiple rooms on campus, but then there is still the problem of hall availability, as well as needing more staff to guide the streaming of the lecture to multiple rooms. Another possibility is changing the design of the course to allow more students. This can range from adjusting group projects to complex implementations like using IT to automate parts of a course. One of these methods is blended learning: ways of enhancing traditional teaching with digital methods like additional online material or even building a completely new course with a blended learning concept from scratch [12]. This method could facilitate more students to take part in courses, as it allows for hybrid teaching and learning. A reason why there could be a maximum capacity of a course is because of a limited number of teachers and teaching assistants (TAs). At the I&CS department, courses in master programs generally do not have TAs, because a TA for a master course must have followed the course already and a master program is only one or two years. On top of that, many of those are also TAs for advanced-level bachelor courses. The result is that remaining TAs may have limited effect on the overall teaching staff workload reduction for master programs and may have an impact on the number of students that can be accommodated.

B. Types of courses

A master course can be of a different level for each student. There are three types of courses, the first one being a **mandatory course**: a course that the student of a certain master's program must follow. This means that when a student signs up for this course, they will *always* be enrolled. Secondly, there are **primary electives**. These are courses of which a student has to follow a certain amount. Finally, there are **secondary electives**: several courses that you can freely choose from any master program. Students on a waiting list for such a course will only be enrolled if there are seats left after having handled all other waitlisted students.

C. Course registration periods

The first course registration period for a course is the first time the enrollment for a course is opened, which means

that the maximum capacity of the course is available for registration. In an academic year, there are four teaching periods (or blocks). For the 2022/2023 academic year, the course registrations are opened for the dates that can be seen in Figure 1 in Appendix D [13].

After the initial course registration period, there is another possibility to enroll for a course: the post (course) registration. This registration period is only opened for two days, usually two weeks before the start of the new period for which this post registration is meant. However, chances are high that the course is already full by then.

D. As-is situation

New students can start a master program in either September or February. These students are unable to sign up for courses that take place in the first period when all places are still available (initial course registration), as they do not have access to an online environment where students can sign up for courses yet. They can only sign up for courses when the deadline of the first course enrollment period has passed, which means that there is a chance that a course is already booked in full. In that case a student will be put on a waiting list. A workaround for such a student is following the course in the second year as they can sign up for the course during the first enrollment period. Giving new students priority over already enrolled students could ensure them a spot in the course they want to follow. However, if this is always done, other students will have a higher chance of not being able to follow their preferred primary elective courses. Following that, students that would like to follow a certain course as a secondary elective would be denied participation in that course, as they are then last in line in terms of priority. This is not ideal either, as there should be chances for any student to participate in a course, regardless of the course type.

The current situation regarding waiting list handling is as follows: students are placed on a waiting list if the course is full or if the course is not listed in their exam program as mandatory or primary. For the first enrollment period, only waiting lists for courses that have been booked in full are looked into. For the late enrollment period, all waiting lists are looked into. If there are waiting list candidates for whom the course is mandatory, the student will *always* be enrolled. If the course is definitely booked in full, waitlisted students that still need another course to follow in the upcoming period are offered participation in courses that have places left. The full as-is situation can be found in Appendix C.

E. Business Process Model and Notation (BPMN) model

The Business Process Model and Notation (BPMN) is a process modeling language that is used to present business processes graphically. This allows users to comprehend the activity flows, role assignments and usage of data and information [5]. In Figure 1a, the waiting list handling of the first enrollment period, as described in Section III-B, is modeled. Figure 1b shows a legend of what the different symbols and elements of the BPMN represent. Two pools, 'student' and

'Utrecht University', are used in Figure 1 and 2, with each pool representing a participant in a process [14]. These are used when the model includes multiple participants that are not physically connected to each other, which is the case here. As activities within a pool are treated as a separate and independent processes, sequence flow cannot be used to connect activities between pools. Therefore, message flow is be used for the communication between two pools. The procedure for the late enrollment period is modelled in the same way in Figure 2.
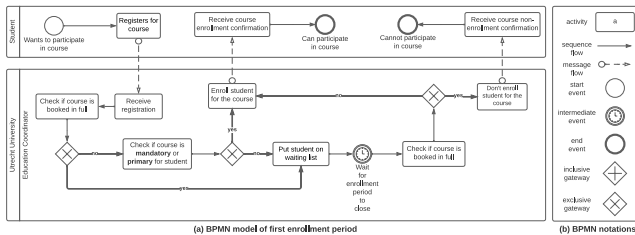

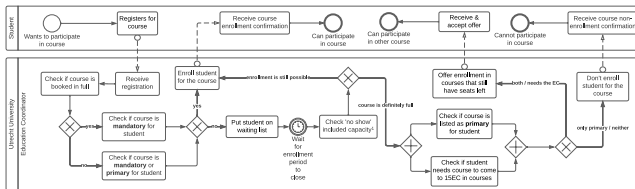Fig. 1. BPMN model of first enrollment period waiting list procedure.

Fig. 2. BPMN model of late enrollment period waiting list procedure.

IV. LITERATURE STUDY RESULTS

As explained in before, a MLR will be performed in this research. To gain insights in what has been formally published, sectors where waiting lists research has appeared a lot, like health care and public housing, will be included in this study.

A. Health care

Waiting for healthcare refers to the period of time between when a person becomes aware of a health issue and when they receive a diagnosis and treatment for it [15]. Managing and handling waiting lists is a complex problem that affects physicians, patients, healthcare systems, and governments from clinical and ethical perspectives [16]. Waiting lists have found to be the secondary most significant ethical challenge that is encountered by patients and their families in Canada [17].

The main reasons to worry about how waiting lists are handled are fairness or equity: in principle, patients who are in the greatest need for treatment should be treated first, if all else is equal. In addition, patients with the same level of urgency should have to wait the same amount of time before getting treated [18], [19]. Many waiting lists lack the implementation of this fairness, equity, and organization, as they have been constructed under time pressure with little forethought [20]. Formal policies and procedures for waiting lists should be developed and defined by health care organizations to maximize their organization and fairness. Five key concepts that should

be considered during the assessment of patients on waiting lists are considered to be severity, urgency, relative priority, need, and expected benefit [19]. Severity refers to three aspects: the level of suffering, limitations in performing daily activities and the risk of passing away early. Urgency indicates the need for immediate clinical intervention or surgery. Urgency and priority seem strongly related: when a patient's situation is very urgent, he or she should be prioritized over a patient whose situation is not as urgent. The term need is often a point of discussion, as sometimes it is seen as equal to severity while others define it more like urgency. According to guidelines from the Victorian Government Department of Human Services in Australia, patients should be placed in different urgency categories based on their clinical need [21]. The patients that are in the most urgent need for surgery are placed in a higher category than others, giving them higher priority. Expected benefit refers to the degree of benefit a patient would experience from surgery, and the probability of that benefit occurring. These two factors can differ from patient to patient, e.g., the benefit of surgery can be large for a certain patient while the likelihood of occurrence is low, and vice versa. There are two types of benefits: the elongation of a patient's lifespan and improvements in a patient's life quality, where the latter is often seen as most important. To make waiting lists fair for every patient, several prioritization methods have been created. A commonly used prioritization method is ranking patients that need elective surgery by the urgency of the needed treatment based on clinical and social criteria [22]. Patients are put in a group that represents their medical situation, which is assigned to a maximum time for the surgery those patients should have to wait [23]. These medical conditions vary from emergency (needs immediate revascularization) to marked delay (3 to 6 months waiting time). Another method to rank patients on a waiting list is a scoring system that assigns a 'priority score' to each patient [24]. Patients will be ordered on a waiting list based on their priority score, which is based on a patient's urgency of need. This priority score will be added up to an accumulating waiting list score each week, which allow waitlisted patients to climb up.

Within the literature, many articles explicitly define certain priority criteria. These criteria are based on the severity of the disease and consequently the urgency of treatment, while social factors are often considered as well [25]. Priority criteria are criteria on which a patient is ranked before being put on a waiting list. This ranking will then define their level of urgency and thus their place on the waiting list. They have two essential functions: they are used to prioritize and schedule surgeries for patients on the waiting list, as well as to create profiles of the patients on the waiting list based on their specific needs and characteristics. A priority criteria form for hip and knee replacement can be seen in Appendix D, Table I [26]. The higher level a patient scores for each criterion, the higher their score will be for the level and thus for their overall score. The panel members that tested this method concurred that the criteria accurately reflected the way

surgeons perceive priority and urgency of patients that are in need for hip or knee replacement. Similar criteria and urgency levels have been developed for general surgery in Western Canada [25]. After a series of testing, a set of final priority criteria was drawn up (see: Table II in Appendix D). These criteria were deemed logically valid and easy to use. The use of clinical priority criteria is supported by doctors from western Canadian provinces, and they think they are aligned with worldwide expert opinions on the urgency of surgery. In Australia, at least up until 2010, patients that were in need for surgery were placed in one of three clinical urgency categories which have been established nationally [21]. These priority criteria categories can be found in Table III in Appendix D. This system makes for a simple form of prioritization, but lacks specific guidelines for surgeons to make decisions on a patient's clinical need for treatment as it does not consider many other (social) factors when deciding on the urgency. In Italian National Health Service, recommended maximum waiting times for patients based on the urgency level of their needed treatment have been formalized [22]. Five urgency-related groups have been created, all with a maximum number of days a patient should have to wait before receiving surgery (see: Table IV in Appendix D).

B. Public housing

Most states in Australia use a waiting list with several categories of housing need to prioritize applicants on waiting lists [27]. To even be eligible to sign up for public housing, an applicant must fulfill certain criteria, like living in the state or area of applying, owning an Australian passport and having a significantly low income. When a participant fulfills all of these criteria, they will be put on a waiting list based on the category they are put in. Each state operates their own form of ranking applications, which can be seen in Table V in Appendix D [28]. These criteria consider both medical and social factors. More general priority criteria for Australian public housing have been drawn up as well. Some common reasons for someone to be prioritized over others are domestic violence, disability, and homelessness [29]. Another method to rank patients on a waiting list is the priority points system. With this system, applicants receive points based on their level of need for housing. Both the level of need and the number of points can be reconsidered as long as an applicant is on the waiting list [29]. Points are often awarded for current housing conditions, disability, family size, and medical need.

C. Educational institutions

The Universites of North Georgia and University of Denver state that their waiting lists for (most) courses are handled with a first come, first served function [30], [31]. The only criteria that students must meet to get on a waiting list, in most cases, are not having schedule conflicts, fulfilling course entry requirements and not already taking the maximum number of hours. The University of Auckland may select the order of students on waiting lists for courses on academic merits, for example a GPA requirement [32], while the Washington

College of Law waiting lists take priority to make the waitlist process as fair as possible [33]. Due to high demand for courses, the Information Science (IS) department from Cornell University has set up priority criteria for course enrollment: IS majors come first, followed by IS major applicants, then IS minors, fourth come seniors in others fields and finally all other students, where seniors are prioritized over freshmen [34]. Boston University also gives preference to seniors over undergraduate students, but only after giving priority to all College of Arts & Sciences and Graduate School of Arts & Sciences students [35].

V. EXPERT OPINIONS

For the expert opinions, multiple semi-structured interviews were performed with education coordinators of different departments and study programs within Utrecht University. The interviews were conducted with the education coordinators of the Biology and Pharmacy bachelor programs and the education coordinators of the Graduate School of Life Sciences.

All of the interviewed experts pointed out that they use a different approach to the 'regular' waiting list procedure. Rather than filling up the course capacity before placing students on a waiting list, the course capacity is set to zero in the course registration system, which means that every student that signs up for a course is placed on a waiting list automatically. After the end of the initial course registration period, the waiting list is closed and a spreadsheet with data about students is generated. When the course capacity allows all students that registered for the course to participate, all students are placed for the course. When the number of registrations exceeds the course capacity, the education coordinator or teacher has to decide which students will be enrolled for the course. Criteria have been set up to make this process as fair as possible. A frequently occurring problem all of the interviewees mentioned is that students often register themselves for multiple courses in the same timeslot, hoping they will be registered for at least one of those courses. By doing that, they essentially take an additional spot on the waiting list for a course. The Biology bachelor program came up with an additional method to overcome this problem. A student can sign up for only one course per timeslot but can name a second and third choice course including motivation. When they cannot be placed for their first choice course, the education coordinator will check if the student can be registered for a course of their second or third choice, which is almost always possible. In the rare case that the student cannot be registered for either of the three preferred choices, the student will have to choose another course during the post registration period. All interviewed education coordinators also mentioned that they do not offer elective courses in the first teaching period in the first period of the first year of the program. Only compulsory courses are offered in this period, for which (new) students are signed up by the university.

For both the Biology and Pharmacy bachelor programs, a list of priority criteria is used to decide which students will be enrolled for a course when it happens to be overbooked [36].

The criteria for Pharmacy bachelor courses can be found in Table VI in Appendix D. Priority criteria 7 and 8 are only used in case of great urgency. When a course within the Biology bachelor program happens to be overbooked, all registered students will be filtered through several criteria to narrow the registrations down to the maximum capacity the course allows. The so-called hard criteria are handled first as seen in Table VII in Appendix D, and if after that the number of students still exceeds the course capacity, the remaining criteria from Table VIII will be looked into [37]. Students that fulfill the most remaining criteria will in this case be placed for the course. This means that there is a possibility for a student that they will not be enrolled for the course, regardless of fulfilling the hard criteria, because of the maximum course capacity.

VI. Triangulation of results

A very common factor across all of the published literature is the importance of the urgency, severity or need when prioritizing someone, rather than waiting time. Generally, the time spent, position on a waiting list and even order of registration for a waiting list are not often used. Prioritizing people based on several factors that have nothing to do with time is considered to be a fair method to deal with the allocation of people to waiting lists. Many universities in the US of which data was available handle their waiting lists for courses on a first come, first served basis. This is a rather simple method compared to the methods found in the other literature and the extensive procedures and filtering criteria to filter out students from a waiting list. This importance of the urgency, severity or need when prioritizing someone for medical elective surgery or for public housing is captured in priority criteria. These are criteria, often ranked from most important to least important, on which someone is prioritized according to what they score for each criterion. For good procedures, these criteria should be clearly defined, ranked and sometimes even categorized. When this is done, procedures are transparent which allows precise insights for everyone on the waiting list on which place they have been put and on the basis of what criteria this place has been decided. In some waiting list prioritization methods, the importance of time is considered. In some cases, patients that have been ranked at the hand of several priority criteria will be placed in one of multiple categories, which are connected to a recommended maximum waiting time before surgery for a patient. In a few cases, time spent on a waiting list is considered as important, and was taken into account while creating certain priority formulae. This means that someone who has spent a long time waiting already will get a slightly higher priority score than someone who has not been waiting for surgery or treatment as long. Priority criteria in the literature on waiting lists in the medical domain go further than just deciding who should be prioritized according to the severity and urgency for needed surgery. The criteria often also consider the impact the disease or untreated condition has on the patient's social factors such as their ability to perform their daily activities, work and live independently. The same goes for the literature on public

housing waiting list prioritization. Here, social factors like a person's medical condition and their age are considered when deciding someone's place on a waiting list. This inclusion of social factors are not part of the priority criteria for courses as mentioned by the interviewees.

VII. Optimized waiting list procedure

To construct an improved waiting list procedure for the I&CS department, a list of requirements for this improved procedure will be set up. A requirement is defined as a goal for the treatment that is going to be designed [11].

A. Defining requirements

A requirement is a desired characteristic or objective for a treatment that is being developed [11]. The treatment that is being designed here is the optimized waiting list procedure for master program courses in I&CS in the case of Utrecht University. Based on the problems that are faced currently, and all of the information that was gathered from the literature study and expert opinion interviews, the following two requirements have been drawn up to realize this optimized procedure: 1) The new procedure should provide fairer chances for all new and active students to participate in a course; 2) a list of ranked prioritization criteria should be created, to make the prioritization of students on waiting lists fair and transparent.

B. Defining priority criteria

The literature and interview results show that there are certain eligibility criteria to even get on a waiting list for public housing or for waitlisted courses respectively. Of course, if entry requirements are set for a course, students cannot participate in the course if they do not meet these requirements. Therefore, this should be considered during the course enrollment periods, like the Biology and Pharmacy bachelor programs do: if a student does not meet the entry requirements of the course, the student will not be eligible and thus not be registered for the course. Rather than using this as a priority criterion, it will be an eligibility criterion, like found in the literature. Before a student is put on a waiting list for a course to have a chance of participating in the course, he or she must fulfill the entry requirement(s), if any apply (E1 in Table II). A rule that was already in use is that students for which the course is mandatory should always be enrolled for the course. It is related to the priority criteria from Cornell University, where IS majors are prioritized over others. Therefore, this rule will be maintained for the improved procedure in the form of a priority criterion (P1). Some of the I&CS master programs offer certain study paths that a student can follow. A student that wants to follow a course for the path should get priority over students for which the course is not included in their path. This is defined as priority criterion 2 (P2) in Table II. The next priority criterion concerns primary elective courses. These are courses that are less important compared to mandatory courses (P1) and courses that are part of a path (P2), and thus, are given a lower ranking (P3) in Table II. Another important factor regarding prioritization is the need

for at least two courses per period. Every student should be able to obtain 15 EC (7.5 EC per course) per period. If a student is still on a waiting list for a course after the late course enrollment period and needs to follow that course to come to 15 EC in courses for the upcoming period, the student will be prioritized. This will only apply for the waiting list handling of the late course enrollment period, as after that period, students will not get another chance to sign themselves up for a course. This rule is maintained from the existing waiting list handling procedure and formulated as a priority criterion (P4). The final factor that will be used is considering students that signed up for a course in a previous year but were not enrolled. Both the Biology and Pharmacy bachelor programs have formalized this into a priority criterion, which is what will be done for the optimized I&CS procedure as well. It is listed as priority criterion 5 (P5) in Table II. Finally, if there are a few spots left for a course where there are too many waitlisted students, a draw will take place to decide which remaining students will be enrolled for the course.

TABLE II
ELIGIBILITY AND PRIORITY CRITERIA FOR OPTIMIZED WAITING LIST
PROCEDURE.

Rank	Criterion
E1	Student must fulfill entry requirements of the course
P1	The course is labeled as mandatory for student: the student must be enrolled for the course
P2	The course is part of the track or path that the student is following[1]
P3	The course is labeled as primary elective for student
P4	Student needs course to come to 15 EC in courses for upcoming period[2]
P5	Student signed up for course before but was not enrolled

[1] Only applies for courses in master programs that offer tracks or paths.

[2] Only applies for waiting list handling of late course enrollment period.

C. To-be situation

The proposed waiting list procedure for I&CS master program courses is divided into two segments: an improved procedure for both the first/initial and the late/post course enrollment period. The improved procedures are based on the current procedure, but also assess the problem described in Section VII-A and include the priority criteria that have been defined in Section VII-C. For the (first/initial) course enrollment period for period 1 (P1) of a new academic year, all active students can sign up for courses before the summer break. For the 2022/2023 academic year, this enrollment period was opened from May 30, 2022, to June 24, 2022 (see Table III). For the improved procedure, all students that sign up for courses within this period will be put on waiting lists for the courses. This is possible by putting the course capacity for all courses at zero, so that all students are placed on the waiting list automatically. As seen in Table III, there is a period of more than three months between the final application deadline for new students, June 1, and the start of the teaching period, on September 12. The university will review any application

that is completed before the deadline and strives to inform the applicant within 20 working days [38]. This means that there is enough time left between the review of all applicants and the start of the first period of the new academic year starting in September. Thus, these students can still be added to the waiting lists for the courses they would like to follow.

TABLE III
DEADLINES & DATES REGARDING NEW STUDENTS STARTING IN
SEPTEMBER & FEBRUARY [13], [39].

Event	September 2022	February 2023
Application deadline (non-EU)	01/04/2022	01/09/2022
Application deadline (EU)	01/06/2022	15/10/2022
Start course enrollment period	30/05/2022	31/10/2022
Deadline course enrollment	24/06/2022	25/11/2022
Post course enrollment period	22/08/2022-23/08/2022	23/01/2023-24/01/2023
Start of teaching period	12/09/2022	06/02/2022

The procedure will work identical for the enrollment for courses that start in period 3 (P3) in February. For this period, there are new students as well as already enrolled students that have to sign up for courses. The final application deadline for new students starting in February 2023 is October 15, 2022. The start of the teaching period is February 6, 2023, almost 4 months later than the final application deadline (see Table 12 for dates). Again, the applications are aimed to be reviewed within 20 working days, leaving enough time between the review of all applicants and the start of the teaching period. This allows all new students to put themselves on waiting lists for courses. When the number of registrations for a course does not exceed the course capacity all registered students will be enrolled. Otherwise, certain students will be selected to be enrolled for the course based on the priority criteria defined in Section VII-C. For teaching periods 2 and 4 (P2 & P4), there is no inflow of new students. All students sign up for courses during the course enrollment periods as seen in Table 12 and are automatically put on a waiting list. After the enrollment period has closed, the selection process will be performed based on the priority criteria defined in Section VII-C. When the course capacity is exceeded, students will be filtered through the priority criteria. The procedure can be seen in the 'selection process' sub process in Figure 4 in Section VII-D. The handling of the waiting lists of the first enrollment period has to be done before the post course enrollment period opens. Students that were not enrolled for a course during the waiting list selection process of the first enrollment period will be informed before the post course enrollment period opens. That means that they have time to look for another course to follow, for which they can register themselves during the late enrollment period. For the post enrollment period, only courses that have not been booked in full during the first enrollment period will be shown to students. Students that have not been enrolled for one or more course(s) can then only choose from these courses. The waiting list handling procedure will work similarly to the process of the first course

enrollment period. The only difference is that priority criterion P4 will also be used during this process, which does not apply for the first course enrollment period waiting list handling. To make sure students understand how the procedure works and how the waiting lists are handled, the procedure should be written down clearly. As the procedures for the first and late enrollment period are now almost identical, the redesigned BPMN model found in Figures 5 and 6 below applies for both the course enrollment periods. The process maintains many elements from the models that were created based on the as-is situation in Section III-D. One new element that has been added is the sub-process 'Selection process', denoted as an activity with a small square at the bottom with a plus sign. It explains the selection of students on the waiting list by using the defined priority criteria. This collapsed sub process can be found in Figure 4.
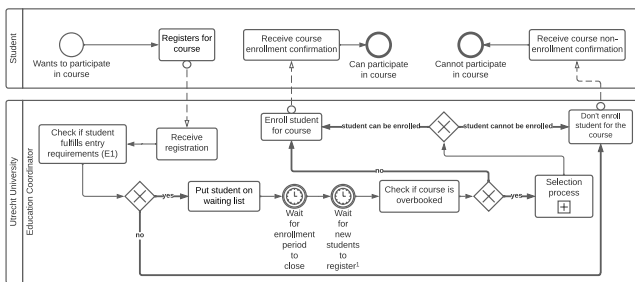

Fig. 3. BPMN model of proposed improved procedure.

The sub-process 'Selection process' in Figure 6 below shows the handling of a waiting list when all students are placed on the waiting list and the course is overbooked. The list of students will then be filtered through the priority criteria that have been defined in Section VII-C until the number of students is sufficiently reduced so that the course capacity is not exceeded. The full process is described in Figure 6. As steps 2-5 are recurrent, there are no separate activities for these steps and a loop has been created to represent these cyclic steps. The procedure continues in Figure 5 at the outflowing sequence flow from activity 'Selection process'.
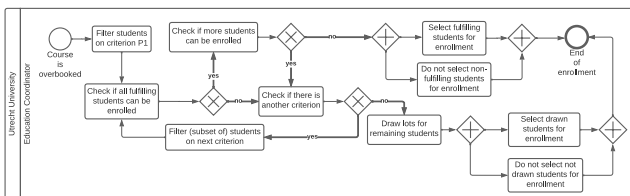

Fig. 4. BPMN model of 'Selection process'.

VIII. VALIDATION

To validate the optimized waiting list procedure that has been created in Section VII above, another expert opinion will be used. The optimized procedure will be proposed to the education coordinator of the I&CS master program courses, as that person possesses all of the necessary knowledge about the current process and the problems that are faced. This knowledge is needed for the validation to work, as only an expert on the domain can imagine realistic problem contexts

and make assumptions on how the proposed procedure could work in practice [11]. If the proposed waiting list procedure does not satisfy the expert, the artifact will be revisited and adjusted or even redesigned according to expert feedback.

A. I&CS education coordinator interview results

The following questions, with the answers that were given written out directly below each question, were asked based on the proposed procedure. **What aspects of the proposed improved procedure are improvements over the current procedure?** The improved procedure does indeed solve the problem of late incoming new students and will provide these students with a fairer chance to participate in elective courses in the periods in which they start (periods 1 and 3) compared to the current procedure. **What drawbacks are there to the proposed improved procedure?** The handling of waiting lists that contain all students for a course will require significantly more time, a higher budget and staffing. It will take more time and staffing to sort out waiting lists by hand, as for the improved procedure, all courses use waiting lists. The proposed improved procedure is also not in line with current back-office procedures. Active students will feel less motivated to sign up for courses timely, as they will not be registered straight away if they do. It could also lead to them signing up for multiple courses, as with a waiting list, they cannot immediately see if they will be signed up for a course. **What aspects of the proposed improved procedure could be done differently or revised?** All of the mentioned drawbacks can be improved upon, e.g., the extra time, effort and resources the improved procedure requires. **Could the proposed improved procedure be used in the future; is it realistic and feasible?** Yes, but it will require alignment with the back-office as it will cost time and money to follow an enrollment procedure that is different from the usual procedure.

As the aim for this research was to make chances of participating in courses fairer for every student, the procedure with placing all students on a waiting list for a course will be maintained. Of course, handling all waiting lists for all courses there are by hand requires a lot of time from support staff, as also mentioned during the expert interviews in Section V. A solution to this problem could be automating this process. As the set of priority criteria is defined clearly, the enrollment of students could be automated. An example of how such a filtering system could work is shown in Figure 5, that is revised based on the feedback from the expert. The sorting out of the waiting lists is now done by the 'Student Filtering Program'. This lane has been added in Figure 5, and 'Education Coordinator' has been changed to 'Student Filtering Program' in Figure 6. The 'Student Affairs' lane has been added as well, as they officially enroll students for courses, not the education coordinators.
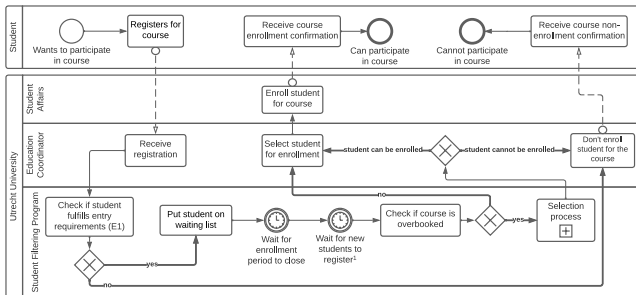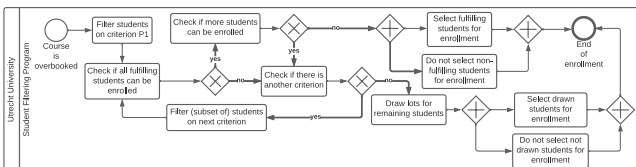
Fig. 5. Redesigned BPMN model.

Fig. 6. Redesigned sub-process 'Selection process'.

IX. DISCUSSION

The handling of waiting lists is a complex process. The main theme across literature and the conducted interviews is the importance of urgency and need when allocating applicants for waiting lists. In contrast, available grey literature showed a predominance of rather simpler first come, first served methods. As these methods would not contribute to solving problems faced in the situation at Utrecht University, this method was not considered for the proposed improved procedure.

The studied literature provided waiting list management and handling in other domains, while the interviews added an educational perspective. The combination of the most important findings from those two methods has provided a new perspective on waiting list handling, namely in the domain of education. The proposed improved procedure was presented to the education coordinator of the I&CS department at Utrecht University as part of the validation of the new process. According to the feedback, the new procedure does indeed tackle the problem that was aimed to solve, but also has drawbacks. The biggest drawback is that the procedure would require significantly more time and resources to operate. This problem can be solved by automating the process, as proposed in Section VIII-B. Other issues, like more uncertainty for students if and when they will be placed for a course were not solved for now, but could be investigated further. Even though many studies have been conducted in the field of waiting list procedures, prioritization and management, no formal literature was found on the handling of waiting lists for courses in (higher) education. This means that the proposed improved waiting list procedure is not based on research in the exact same application domain. The mentioned interviews were conducted with domain experts from one university in one country. Moreover, interviews were only performed with education coordinators within the Science Faculty. Due to time limitations and because programs from other faculties that were approached said they do not use waiting lists for courses, no others were interviewed. This may have an impact on the generalizability of the results.

X. CONCLUSIONS & FUTURE RESEARCH

The problems that were aimed to tackle in this research were related to waiting list problems for master program courses within the I&CS department at Utrecht University. The main research question was the following: "How can waiting list procedures for master program courses in I&CS be improved to make sure that the chances of participating are as fair as possible for every student?". The methods mentioned in Section VIII-B after refining the proposed procedure from Section VII based on received feedback provide an answer. Based on literature and interview results, waiting list procedures can be improved by integrating three aspects into the process. The first one is changing the use of waiting lists. Instead of using a waiting list only as soon as the course is booked in full, all students will be put on a waiting list upon registration for a course automatically. This allows for more students to get onto the waiting list for a longer period of time, so incoming students can register themselves for courses as well. The handling of the waiting list can then be postponed until all students have signed up for a course. The second aspect is formalizing the handling of the waiting list by defining priority criteria. In the current procedure, there are some rules about who to prioritize over others, but there is no (ranked) list of the exact criteria on which waiting lists are handled. Explicit information about waiting list handling is also currently not provided to students. The defined priority criteria for the improved procedure allow for a fair process of selecting which students will be enrolled for a course. When a student is not selected for a course, the student can easily be notified by mail that explains why. For transparency reasons, these criteria should also be published on the department's web page. The final optimization that has been made over the current procedure is the automation of the process. Based on that filtering process, an information system or education coordinator decides which students will be enrolled.

Future research could gain more insights on the handling of waiting lists for courses in higher education. Research on a larger scale could be conducted to investigate how other colleges and universities handle waiting lists for courses. This will lead to an even better understanding of how these processes work in a wider variety of educational institutes in multiple countries. Based on a larger data set that contains several perspectives on waiting list handling for courses, an even more optimal procedure could be realized. The importance of including factors such as student age, bad habits, or disabilities could be investigated in future work. Finally, as a result of the procedure that was created after the validation session a proposal for automation is made which is part of future research.

APPENDICES

- For Appendix A, see: https://osf.io/h3g5x
- For Appendix B, see: https://osf.io/pe43y
- For Appendix C, see: https://osf.io/eprbw
- For Appendix D, see: https://osf.io/agn3h

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