Incubation of capabilities to run centralised assignment mechanisms in Rwanda

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1 Introduction

As a result of several problems identified in the previously decentralized system in which teachers applied directly to districts, the Rwandan Ministry of Education (MINEDU) decided to instruct the Rwanda Educational Board (REB) to centralize the process. As a result, the collaboration of the International Growth Center (IGC) and Innovations for Poverty (IPA) action was formally requested by the Senior Management Team of REB. ConsiliumBots was incorporated into the project to bring the organization’s expertise in centralized assignment systems and in information interventions that assist decision-makers in education more generally.

The reach of the new centralized teacher deployment is not exactly defined in the current context, leaving some open questions and many implementation options open. Some definitions have already been made by policy-makers, at least preliminary and for the short-term, and there are some restrictions that need to be taken into account, but for the longer-term there is scope to propose different alternatives to be implemented progressively and in a data-driven logic.

The objective of this document is to present a framework to approach the centralized deployment of teachers, both considering the rules governing the system and its structure, broadly defined here as back-end components, as well as the strategies to inform and assist teachers, broadly defined here as front-end strategy. As a result of the analysis, short- and medium-term proposals are presented, to be discussed and worked with policy-makers and other actors involved in the teacher management system.

The report is organized as follows. Section 2 presents a brief summary of the context in which the policy is inserted in Rwanda. Section 3 reviews the challenges of centralizing teacher deployment and describes some of the best practices identified in the academic literature to tackle those challenges. Section 4 details the implementation questions that are still open and that need to be addressed before deciding what parts of the proposal presented in the next section are feasible to be implemented and at what speed. Section 5 presents a short- and medium-term proposal to move forward in the context of Rwanda. Section 6 explains the prototype developed by ConsiliumBots, explaining the simulations employed in the process. Finally, section 7 concludes with the next steps in the implementation process.
2 Context

2.1 Previous decentralized system

Under the previous system, teachers applied directly to the different districts for job position, and simultaneously received offers for different positions. The specific school at which a teacher was employed was determined a part of the negotiation process between prospective teachers and districts.

This decentralized process generates inefficiencies, as teachers have no obligation to reply on time to offers that they will not take, and more importantly, generates incentives to engage in unwanted practices on both sides to convince teachers to take job positions, and to obtain advantages from teachers eager to work in some districts rather than others. As a result of these problems, the decision to centralize the process was taken.

It is important to note that the education system in Rwanda has rapidly increased access to more students by implementing a double-shift policy at each school that allowed the system to basically double its capacity. The obvious side-effect of this policy however is that it increased the workload for existing teachers and schools significantly, possibly affecting learning outcomes. Moreover, the double shifting policy implies that students switch the days and hours at schools, making it difficult for families to program their routines and possibly increasing absenteeism as a result.

Increasing access to education is obviously an excellent first-step achievement, but now the challenge is to improve learning outcomes and to reduce the number of schools doing double shifts, and more generally, the workload imposed on teachers and administrative personnel at the school level. To tackle that challenge, the government is rapidly opening teaching positions throughout the country, and in that sense, the main concern is to effectively hire and retain those new teachers, during this expansion phase that will last for at least a couple of years.

With regard to challenges that are specific to the teacher deployment problem, the main one in Rwanda is related to the very high teacher attrition rates observed overall, and particularly in some districts where teacher attrition has been estimated to be over 50%. Attracting and training new teachers is challenging, which in part explains the high number of non-Rwandan teachers in the system, but retaining them seems to be one of the main concerns.
Relatively low salaries are likely a key factor behind the high attrition numbers, in combination with other difficult job conditions that possibly make it difficult to retain teachers, particularly in some schools. However, part of the problem might also be related with the way teachers are assigned to districts and schools, because if the process doesn’t optimally take teacher preferences into consideration, it is likely to then observe high teacher transfer request rates. More research into this topic is necessary, and adopting a centralized system will help to shed light on the issue.

Finally, a key concern of policy makers is to be able to bring competent teachers to all districts. The challenge here is that if some districts are not attractive for the majority of teachers, it is not feasible to convince them to take positions in these districts and/or to retain them once they have decided to do so. To tackle this issue, as discussed in section 3, complementary policies to incentives teachers might be required.

2.2 Preliminary definitions

As noted in the previous sub-section, there seem to be two layers of the teacher deployment process in Rwanda, composed by the assignment of teachers to districts and by the assignment within districts to school after that or as a part of that process. From the discussions sustained with Rwandan authorities so far, there seems to be, at least for the short-term, an agreement that the centralized system will only take care of the first part of the process, that is, the assignment of teachers to the different districts, leaving the decision to deploy those teachers to specific schools to the districts.

In line with the focus on hiring more teachers to reduce double-shifting, policymakers have defined that, at least in the short-run, the centralized deployment system will only apply to new hires. And on top of that, the decision that these teachers will take a centralized exam that will serve as an input to then assign them to districts and schools has also been made and the examination process has already been organized.

With regard to how vacancies are generated at the district level, REB already carried a process to determine the number and subject-distribution of vacancies for each district, considering the necessities of each district, the policy objectives and resource constraints.

In terms of the application process, new teachers need to apply through the public servants hiring portal, but it is unclear whether it is feasible to include a module to collect their preferences over districts in this portal, and the flexibility to build-in
additional tools to give information and assistance during the process.

2.2.1 Summary of short-term preliminary definition

- The centralized system will allocate teachers to districts.
- Only new hires will be considered.
- Teachers will take a centralized examination in their specialization subject. The exam will be taken in different locations at each district.
- Vacancies for each subject group are defined by a process already implemented by REB and therefore there is no need to collect them from districts.
- New teachers will apply through the public servants portal to be employed in the public sector. It is unclear however whether there is scope to create a complement to this portal to collect preferences, possibly managed externally, or whether it is feasible to collect preferences within the public servants portal, and in the latter case, the extend to which it is feasible to include additional information and assistance tools in that application process.

3 Framework to analyze the centralized teacher assignment challenge

The basic problem faced by policy-makers is to be able to fill as many vacancies as possible. On top of that, it is obviously preferable to fill those vacancies with more qualified teachers. Additionally, policy-makers might be interested in other objectives, such as for example fairness in the assignment across districts, both in terms of the percentage of vacancies filled, as well as the quality of teachers. Recent research has highlighted, that even when a perfect centralized assignment system might be difficult to achieve, a large fraction of the gains from centralization might be obtained implementing a reasonable policy, that will probably dramatically increase coordination and efficiency (Abdulkadiroglu et al., 2017). In that sense, Rwandan authorities are mov-

1 Abdulkadiroglu et al. (2017) estimate that implementing a standard student-proposing deferred acceptance algorithm to replace the previous de-centralized system in New York for student assignment, allowed to achieve an 80% of the maximum potential welfare. Implementing an optimal ex-post mechanism (which is not even feasible ex-ante), would have increased welfare by only about 3% additional
ing in the right direction and keeping this in mind and progressively improving the new system, rather than aiming to implement a perfect system from scratch, is the right approach.

The challenge however is that teachers possibly have correlated preferences over the different teaching positions, preferring on average some districts with more attractive teaching positions, over others. It is therefore not straightforward, and potentially not even feasible to completely meet policy objectives over the resulting assignment, and if the preferences of teachers are not adequately incorporated into the assignment process, the rate of assignment rejection might increase and/or the rate of teacher retention might decrease, ultimately affecting unpopular districts.

There are different strategies that will be discussed in this and the next sections to increase assignment rates and the quality of teachers at unpopular districts. Nonetheless, it is important to understand that these strategies have a limited impact and that ultimately the best way to increase the fairness in the allocation across districts is to make unpopular districts more appealing, either changing the structural reasons making them less appealing, or compensating with incentive schemes.

The basic components of an assignment system that takes the preferences of teachers over districts (or schools) into account are i) collecting the preference rankings of teachers over districts (or schools), ii) defining how teachers will be ranked by the different districts and iii) determining the rules/algorithm that will define where teachers are assigned. The difficulty is that the preferences from teachers need to be elicited, and that teachers will therefore only report their true preferences is they believe that doing so is in their best interest. As a results, the different components and linked.

On top of the basic components and rules of the system, which we broadly define as "back-end" components, there are different strategies that can be implemented to inform and assist teachers in the application process, which has proven to be potentially very relevant in other centralized assignment contexts. These elements will be broadly defined here as “front-end” components, not essential for an operational system, but important to achieving a successful one.

Finally, there are policies that are not part of the back- nor front-end components, but rather complementary to the system and potentially informed as part of the front-end strategy. These policies, mainly related to incentives and other teaching management policies also play a relevant role in a successful assignment system, given that
they shape the preferences of teachers over districts and schools. Each of these parts of the system is now separately discussed.

3.1 Back-end components

The main back-end component of the system is the algorithm or assignment rules, that determine how teachers are assigned and the incentives faced by teachers when reporting their preference ranking. However, having an application system where teachers can efficiently and transparently report their preference ranking is also an important component. For the latter, the main point is that it is convenient to implement an online system to be complemented with policies to facilitate access to the system when and if required, to guarantee transparency and efficiency, and to be able to use technological tools on the front-side end of the platform.

3.1.1 Algorithm

Basic framework

One very important aspect of the choice of mechanism is to determine what the optimal strategy is for participants. Many mechanisms have the property that they generate incentives to be strategic and misreport their preferences. In non-strategic mechanisms, applicants and schools are better off reporting their preference order truthfully, while in strategic mechanisms, it might be better to strategically report preferences untruthfully to increase the likelihood of being assigned to a more preferred outcome.

Theoretically, for a given set of preferences, there might be conditions under which it is potentially better to implement a strategic mechanism. However, in practice, decision-makers have trouble understanding how to form optimal strategies or are misinformed about the probabilities assigned to their choices, which oftentimes generates consequential mistakes in the applications (Kapor et al. 2019). For that reason, and to facilitate the information provision, non-strategic mechanisms are usually recommended, at least in a first stage.

There are two famous algorithms that are useful to convey the point about strategic behaviour, the Boston algorithm and the Deferred-Acceptance (DA) algorithm, famously introduced by Gale and Shapley (1969). To explain them, let’s assume for simplicity that all teachers are ranked by districts only according to their score, that teach-
ers have only one specialization subject, and that each district has only one vacancy.

The **Boston algorithm** operates with the following set of rules:

1. Break ties (teachers with same exam score) randomly

2. **Step 1**
   
   (A): Each teacher proposes to its preferred district.
   
   (B): Each district is assigned to the teacher with the highest score among those that proposed.

3. **Step K**
   
   (A): Teachers not assigned in step K-1 propose to their next most preferred district (if there are no more districts left in the preference ranking, then the teacher does not propose in this or the next rounds).
   
   (B): Each empty district is assigned to the teacher with the highest scores among those proposing in this round.

4. END: When all districts are assigned or there are no more proposals left.

In this mechanism, if preferences are correlated, it might be strategic for a given teacher to report a less popular district higher in the preference-ranking to increase the likelihood of being assigned to that option. As a simple example suppose we have three teachers, one with score 100, another one with score 99 and a third one with score 50, and two vacancies at schools A and B respectively. Assume all teachers prefer school A and then B. If the teacher with score 99 reports A highest in the ranking and the teacher with score 50 reports B, the former one is left un-assigned and would have been better-off reporting B first.

As a contrast, the **DA algorithm** operates under the logic of temporary assignments, hence the name deferred acceptance, because the assignment is only made definitive in the last step of the algorithm.

The **DA algorithm** follows the following procedure:

1. Break ties (teachers with same exam score) randomly

2. **Step 1**
(A): Each teacher proposes to its preferred district.

(B): Each district is temporarily assigned to the teacher with the highest score among those that proposed.

3. **Step K**

(A): Teachers not assigned in step K-1 propose to their most preferred district, among those left in their preference ranking - the ones they have not proposed to - (if there are no more districts left in the preference ranking, that teacher does not propose in this or the next rounds).

(B): Each district is temporarily assigned to the teacher with the highest scores among those proposing in this round and the teacher temporarily assigned in step K-1.

4. END: When there are no proposals left.

Using the same example as before, the teacher with score 99 is better-off reporting truthfully, independently of what the other teachers propose, and is always assigned to school B.

In the context of this example, the result of the DA algorithm is equivalent to that of the **priority mechanism**,\(^2\) in which teachers directly choose their assignment among available options, starting with the teacher with the highest score. While this procedure is simpler to implement and understand, its drawback is that it only works when all districts have the same ranking for teachers, and when teachers only have one specialization subject to be ranked for. Moreover, this mechanism does not adequately accommodate specific challenges of the teacher deployment problem, such as the existence of couples of teachers applying together.

**Desirable properties of an algorithm**

As discussed above, being non-strategic is a desirable property in an algorithm, as it makes it easy for participants to report their preferences optimally for them (just being truthful). If “maximizing utility” is a concern, one would ideally want to know the intensity with which the different alternatives in a ranking are preferred. And for that reason, as a second best, there is also a case to implement strategic mechanisms.

\(^2\)Also known as the serial-dictatorship mechanism
In practice however, as Kaport et al., 2019 highlight, theoretical gains from strategic mechanisms might be eliminated by the fact that applicants have a hard time getting their strategies right, and mistakes might end-up being very costly to their assignment.

Other desirable properties in an algorithm are:

- **Stability**: No teacher/vacancy pair would be better-off rejecting their current assignment and matching instead between each other.

- (Pareto) **Optimality**: The assignment cannot be change to make someone better-off without making someone else worse-off. Otherwise, there might be an obvious improvement to be made.

A well known result for the matching literature is that it an algorithm that is both strategy proof for all participants and stable does not exist. Nonetheless, it is possible to obtain a stable matching that is optimal and where reporting preferences truthfully is the dominant strategy, for one side of the matching.

Specifically, the teacher-proposing DA algorithm, is a non-strategic stable algorithm that is optimal for teachers. Therefore, considering that districts might not even be allowed to submit rankings over teachers in this context, using the DA algorithm as a building block it probably the best alternative to allocate teachers.

In concrete, for the specific case of Rwanda, we recommend implementing an algorithm based on the teacher-proposing DA mechanism because it is simple, and then introducing gradually specific rules to address specific issues that concern policy makers. In particular, if in the future transferring teachers are included in the system, the way priority is given based on experience and performance should be studied carefully in the ongoing exchanges with policy makers in Rwanda to determine the best way to incorporate some, if any, dynamic considerations.

**Challenges in the teacher deployment context**

The reason why simply using the basic DA algorithm framework to allocate teachers is not ideal, is that there are some specific features of the job market for teachers that make it desirable to introduce adjustments. A preliminary complication, not considered above, is that a teacher might be trained to lecture in different subjects, and districts of schools might not be indifferent about hiring the teacher for one or another
of those subjects. This is however easily accommodated withing the DA algorithm procedure, and for that reason it will not be discussed further.

The two main challenges of teacher deployment highlighted in the theoretical and empirical matching literature are i) the problem of complementarities in the preferences of teachers, and specifically the existence of couples of teacher applying for job positions together, and ii) if transferring teachers are included - which is desirable to do in the future to have a unified system-.

The problem of matching with couples has been extensively studied in the context of American Physicians, and the existence of a stable matching in this context is not guaranteed. However, in contexts where the number of applicants and vacancies are large enough and where couple applications are not too many, stable matchings are more likely to exist (Kojima et.al., 2013; Ashlagi et.al., 2014).

Roth and Peranson, 1999 studied the problem for the American Physicians matching and developed an algorithm to include couples, iterating between the equilibrium allocation without taking couples into account, and the iterative inclusion of couple applications, using the deferred-acceptance logic. Ashlagi et.al., 2014, use a slightly modified version of that algorithm, named Sorted Deferred Acceptance (SoDA), and argue how it improves over Roth and Peranson’s algorithm.

For the context of Rwanda, we propose to include couple applications, when not for 2019, for 2020, applying the results of the existing applied and theoretical literature, and carefully studying the observed behavior of teachers and the properties of the allocation obtained using SoDA or a similar procedure.

With regard to including transferring teachers, there are two issues to be taken into account. First, transferring teachers need to be compared with new teachers, and that implies defining if all vacancies will be available to both types of teachers and how teachers are going to be prioritized or compared for vacancies available to both transferring and new teachers. This is somewhat more a policy implementation rather than algorithm design question. Nevertheless, it is importante to have in mind that this decision will have importante effects over the incentives and the behaviour of applicants, and that therefore careful design and study is required. This is in any case a problem to be addressed in the longer-term, and therefore not a pressing concern, given that for now the decision is to restrict the system to new hires.

Second, for transferring teachers it is necessary to define whether they will be allowed to securely hold their current job position, while applying to a new one. If so
decided, a modified version of the DA algorithm where incumbent teachers are ranked at the top in the school/district where they are currently working allows to include that feature easily into the algorithm. The problem, as studied by Combe et al., 2017 is that altering the real ranking of districts (or schools) might lead to a sub-optimal and non stable allocation, and to make progress over the shortcoming of the modified DA algorithm, they propose a new algorithm labeled Block Exchange algorithm.

As explained above, for the short-run it is not a priority to include concerns about transferring teachers, but for the longer-run it will be important to hopefully include them into the centralized allocation system, and to do so, it is obviously desirable to take the theoretical and empirical limitations of the modified DA algorithm into account.

3.1.2 Platform

To be able to run the algorithm and determine the allocation, vacancies at the district (or school) level need to be identified, and preference rankings from teacher (and potentially districts or schools) need to be obtained. In the case of Rwanda, at least for 2019, the process and vacancies have already been established, but the way in which preferences will be obtained - if at all - is not yet certain.

To collect preferences in an efficient and organized way, an online platform into which teachers sign in using a unique identifier and select their preference ranking of districts (or schools) is ideal to secure a transparent and cost-efficient process. Moreover, an online platform gives the opportunity to inform teachers using videos and other informative materials, potentially complemented with other front-end elements to be discussed in the next subsection.

In some places, governments build and have control of the application platform, while in others (school districts in the US for example), the process is externalized. The main trade-off in this decision is between on the one hand having total control of the application platform and data collection process, and on the other, having a specialized firm run a process that only occurs one time each year and that has some technical components that are not easy for governments to address effectively.

In the context of teacher deployment, the number of applicants is not as large as in the context of the student assignment, which implies that the burden on the platform is lower, particularly during the first hours of the application process, when conges-
tions levels are usually high. Nevertheless, building a user-friendly interface, with Application Programming Interfaces (APIs) embedded to give personalized feedback to applicants, and effectively including information content is not straightforward. This will be highlighted in the next subsection.

3.2 Front-end components

There are at least four front-end components, detailed below, that potentially make a difference in the quality of the applications, either improving the available information to decision-makers, or providing personalized assistance during the application process. To motivate, the following figure shows the result of a simple risk-warning implemented in Chile in the context of student assignment, to those families with a calculated non-assignment risk over 30%. As observed in the Y-axis, the number of additional schools included in the application, after the initial application, is doubled for the treated group, showing that applicants react to feedback.

Figure 1: Risk Warning Implemented in Chile in the 2018 Student Assignment Process

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3 Applicants can modify their application throughout the application period.
The front-end components summarized here are the following:

1. **Validating administrative**:

   In assignment systems where priorities are used, one simple but important front-end feature is to include a module where the personal information and priority information of an applicant is validated. This allows applicants to identify and correct administrative data error early in the process and make sure that their priorities are correctly processed.

   In the context of teacher assignment in Rwanda, there is less scope for this functionality. Nonetheless, it would be useful to validate the address of teachers to assist them in the search process, and possibly their scores if they are manually typed.

2. **Vacancy Information Exploration Tool**:

   To form their preference rankings, teachers need to first gather information about the different job positions offered at the different districts. The way this is traditionally done in generating a search webpage, where teachers can find specific districts or schools and get information about them. The problem with this alternative is that oftentimes teachers have incomplete information and biases when they start their search process, and therefore it is convenient to take a proactive approach when presenting the available options, using an exploration instead of search logic.

   Regardless of the type of information provision chosen, the information displayed to teachers would depend on available information about the characteristics of districts and their vacancies, as well as potentially about the schools where the different vacancies are located within districts.

   To convey the likelihood of assignment at the different districts, showing data on the volume of applicants at every district and the rate of accepted positions might also be useful. The only caveat is that one needs to be careful not to disincentivize applications to districts with high congestion levels. In a DA algorithm, teachers should not be discouraged to include positions that are hard to obtain in their preference ranking, but rather to include all districts in which they would accept a job offer in their application, and rank them truthfully.

3. **Application Simulator**
Understanding how the system works, and specifically how the algorithm operates, is not simple. A simple way to explain the process to teachers is using a communications strategy, where informational videos can be used to explain the system as effectively as possible. The problem however, is that it is difficult to cover all possible scenarios and doubts in the communications material.

Therefore, an application simulator tool, that uses data on past applications to convey the potential results of any given application, is an ideal way to help teachers understanding how to use the system correctly, and the value of including all districts where they are willing to work in their preference ranking, to minimize the risk of non-assignment. In practice, a simulator tool could be very similar to the prototype developed by ConsiliumBots and explained in section 6.

4. Warnings

In a best case scenarios, teachers are perfectly informed about their alternatives and the expected congestion, as well as about how to apply correctly. In practice however, applicants oftentimes make mistakes, even when a good communications and front-end strategy has been implemented. To tackle this issue, there are two types of live feedback messages that can be given during the application.¹

The first type of messages are specifically about the likelihood of assignment in the different alternatives included in the application, and critically, the risk of non-assignment, which we label risk warnings. To compute that estimated risk, one possibility is to use data of previous processes. But when that data is not available, and to complement it with the data of new applicants, one can also use the data of applicants that have already submitted an application during the process to extrapolete congestion. The latter is in fact precisely what was done in the case of Chile, as illustrated in figure 1.

The second type of feedback message consists of providing information or nudges about other alternatives that the applicant might want to include in the application, based on the administrative data (address, score, and potentially other characteristics), and the districts included in the application, which we label options feedback. Nudges might be used to foster applications into rural or more vulnerable areas, that might be less appealing to teachers based on their characteristics, but are precisely the areas that are more in need of motivated teachers, and where they can therefore make the bigger difference if we tap on their intrinsic motivation.

¹Or offline using for example text messages
3.3 Complementary policies

Even with the perfect back- and front-end strategies, there are limits to what can be achieved in terms of policy objectives like fairness in the assignment, as for example measured by the percentage of vacancies filled at each district and the heterogeneity of teacher scores across districts.

To make further progress, ultimately the best solution is to make unpopular districts more appealing to teachers, thus making it more likely that those districts are included in more preference rankings, and reducing the correlation in teacher preferences. To do so, changing the underlying characteristics that explain why some districts are less popular might prove extremely difficult, and therefore, the alternative of implementing incentives schemes that compensate for those characteristics might be considered.

One could categorize incentives in two groups. On the one hand, those that are implemented outside from the assignment system, and on the other, those implemented within.

In the first group, the main potential policies are implementing salary incentives for teachers that take jobs in unpopular districts, and/or career promotion incentives, that award teachers that take those jobs with better career prospects (ultimately also affecting their compensation, but affecting other dimensions as well).

In the second group, the main idea is that one can reward teachers that take positions in unpopular districts with a better position to choose their next job in the future, specifically implementing priorities for transferring teachers from unpopular districts after completing a giving number of years at those districts, or improving their ranking making it more likely that they are matched in a more preferred district or school in the future.

Conceptually, one could even determine optimal monetary incentives within the assignment mechanism, and use a VCG-type mechanism. Even abstracting from the many concerns that such a mechanism would raise in practice and just focusing on the theoretical implications, the fact that teachers are surely not risk neutral over changes in their total compensation implies that this approach wouldn’t be able to deliver “the optimal” allocation.

Bottom line, is that to implement a successful assignment mechanism, the approach needs to be incremental. We start with hopefully good ideas and then make them pro-
gressively better studying the results of the system and of the different policy alternatives highlighted throughout this section.

4 Policy implementation questions

Policy-makers need to be at the center of the design of any successful centralized assignment system, because they are going to be the ones managing the system, but more importantly, because policy-makers have the required in depth knowledge of the political system, policy objectives, and policy priorities.

The first question therefore is related to what those policy concerns and priorities are, starting with the main objectives that are expected to be achieved with a centralized system. In the case of Rwanda, transparency and efficiency seem to be a central concern, but other possible objectives are related to fairness, teacher retention, teacher performance and quality, etc.

With regard to more specific implementation questions, we drafted a short list of some of the aspects that need to be resolved in the short- and medium-run.

Some general questions:

1. Is the plan to implement a system that only assigns teachers to districts, or potentially one that directly assigns them to vacancies at the school level?

2. If a staggered assignment system is implemented, would it be feasible to implement a centralized assignment system within districts? Would districts need to opt-in, or could this be part of the centralization policy?

3. Is there a plan regarding transferring teachers, specifically to include them or not within the centralized assignment system. If not, how is this process going to operate?

4. Is it feasible to implement incentives, either within or outside of the assignment system? If yes, what would those incentives look like to try to communicate them to new teachers if possible.

More specific question about the assignment rules:
1. Is there a decision regarding the allowed length of the preference ranking? We would suggest to avoid placing limits, because they will lead to less assignments and possibly strategic behaviour.

2. Are couple applications going to be allowed?

3. How are teaching subjects for teachers and vacancies going to be defined and matched?

4. Will teachers only be ranked according to their scores, using the same ranking at all schools? If transferring teachers are included, will some vacancies be open to both new and transferring teachers? And in that case, how would both types of teachers be compared?

5. Might/will districts be allowed to choose how they rank teachers?

6. Might/will districts be allowed to choose quotas over some characteristics of the teachers (e.g. gender)?

5  Short- and medium-term proposals

In the short-run the priority should be to get the policy going, implementing at least some of the basic back-end features discussed in section 3, starting with a simple DA based algorithm. On the medium-run and long-run however, it is possible to make more back- and front-end considerations into account, progressively making the system better.

5.1 Long run: Aiming towards an optimal assignment system

Starting with the proposal for the long-run, to have somewhat of a best-case scenario in mind, we suggest following the next set of recommendations:

1. Implement an algorithm based on the DA algorithm with teachers proposing.
   - Use an online platform to collect teacher rankings and potentially complement with offline system to improve access.
• Include the couple-application option using one of the frontier adaptations to include couples (e.g. Sorted DA).
• Potentially allow for existing teachers to apply to transfers, with their current position secured. (Improve assignment using the method recommended by Combe et al., 2017, based on Erdil and Ergin, 2008 improvement cycles).
• Implement incentives to attract (good) teachers to unpopular districts/schools and adjust them based on the evidence.

2. Implement a secondary round of assignment to give a chance to unassigned teachers to fill vacancies.

• Teachers accept/reject their assignment and decide whether to enter the waiting list.
• The process is then repeated for empty vacancies.

3. Implement an information provision and assistance strategy: Front-End Strategy + Communications Strategy.

5.2 Short run: Focus on central components and incremental approach

For the short-run, we need to take time and policy restrictions into account. To do so, we propose to do a version of what is described next:

1. Create a webpage where teachers are able to inform themselves about vacancies and the assignment system.

• Possibly complement the platform with information provision at teaching schools and outreach if contact information is available.

2. Collect the preferences the same day or the day before the exam, using a trained group of individuals and a tailored-made application platform based on the prototype developed by ConsiliumBots for this project.

• Example: we can have instructions to apply using the phone or a computer connected to internet and the possibility to apply through a tablet provided at the school.
• Leave the application platform open to allow teachers to modify their ranking.
• Use personalized feedback and nudges to try to incentivize teachers to apply to unpopular districts and to reduce un-assigned teachers.

3. When exams are scored and announced, run the algorithm with current application and give personalized feedback to try to reduce un-filled vacancies.

• Leave the process open for some days after announcing scores to give teachers time to include more preferences.

4. If possible, implement a secondary process for un-filled vacancies and rejected assignments with a waiting list.

6 Prototype and Simulations

We developed a simple prototype of an application framework, to illustrate how an online application platform might work, and to illustrate the risk-feedback component discussed above. To be able to compute risk, we made a number of assumption to simulate teachers with different scores, specialization subjects, and preference rankings, using some of the available data to make the exercise somewhat realistic.

We first explain the different scenarios simulated, to then explain the logic of the prototype for interested users. It is relevant to note that the prototype is build under the assumption that teachers apply directly to schools, but this is just an illustration, and all relevant points are exactly the same if we were to do the exercise applying to the direct level.

6.1 Simulated centralized assignment exercises

Vacancies

We simulated vacancies using a very simple process with the available data. First, we allocated 1000 vacancies to different schools, prioritizing schools with a high student-teacher ratio. We then distributed these vacancies between subjects, using only three subjects for simplicity (Mat, Eng, Kin), and using the share of teachers in each subject to allocate the share of vacancies. To allocate a specific subject to a given vacancy, we used the share of teachers in each subject at each school to create a “relative necessity” index.
**Teachers**

We next simulated teacher preferences using a simple school attractiveness proxy, based on the weighted average standardized learning score of a school. We computed the number of (weighted) SD above or below that average score for each school, and adjusted that score one SD down for schools with a bad infrastructure.\(^5\)

We then assigned specialization subjects to teachers using the share of teachers in different subjects and randomly assigned scores between 0-100. The preference ranking of each teacher was computed using the mean utility for each school described above and a random variable to reduce the correlation in preferences.

**Simulated scenarios**

Finally, we considered 4 different simulation scenarios combining:

- The ratio of teachers (applicants) to vacancies 1.5 and 2. "Apps. L or H".
- The minimum length of a preference ranking between 2 and 4 schools (max length was set at 10): “Length 2 or 4”.

**Results**

Given that the specific numbers in the simulations are meaningless, we present results graphically, to compare the results across the different regions of Rwanda, comparing the different simulated scenarios. We have basically two relevant dimensions. The first one is the share of vacancies filled within a geographic unit of analysis, which we did for provinces, districts and sectors. And the second one, is to compare the average score of teachers assigned within a geographic unit of analysis, with the score of the population, for which we use the number of SD of the region mean above (or below) the population mean.

\(^5\)We had no theory-driven way to do this, and generating heterogeneity was preferable, thus the relatively large correction.
The main point of figure 2 is that more vacancies are filled if more applicants are attracted, but also if the preference rankings of applicants are longer, which might be at least partially achieved using a communications and/or front-end strategy.

The next figure basically present the same point, but for districts and sectors respectively.
Figure 3: Share of Vacancies Filled Across Districts

(a) Apps L Length 2

(b) Apps L Length 4

(c) Apps H Length 2

(d) Apps H Length 4
With scores results are less clear. Bringing more applicants increases the number of filled vacancies, and also increases the score of assigned teachers, but results are small. Increasing the length of preference rankings on the other hand, might increase or even slightly decrease scores, because teachers benefited by increasing the length of their application not the teachers with the highest scores.

This result is shown in figure 5, where the “best results” are obtained increasing the
number of applicants without increasing the length of the preference ranking.\textsuperscript{6}

**Figure 5:** Number of SD of Average Score of Sector over Population Average

As a contrast, a simulated exercise of changing the assignment algorithm from a BA assignment to a DA assignment for the deployment of teachers in Ecuador, showed that possibly the main gains are obtained by matching teachers with higher scores, rather than by increasing the number of vacancies filled, highlighting the fact that a DA mechanism has the desirable property that it makes it more likely to match teachers with high scores, independently of the order of their preference ranking.

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6.2 Prototype

The prototype developed by ConsiliumBots builds on the scenarios described above, simulating the assignment in each one of them 1,000 times, and using the assigned score distribution for each vacancy, to compute the probability of assignment for a fictional teacher with any given score, applying to vacancies in any specific subject.

In the prototype, available in this link - https://rwanda-demo.firebaseapp.com/ -, the first section requires to select the scenario under which the exercise is performed, and then enter the score of the applicant, along with other personal information, that is not serving any purpose in the exercise. Then, a teacher with a given score, and in one of the four given scenarios, selects schools filtering within provinces, districts and sectors, as well as the subject of the different vacancies (which is not really relevant for the purpose of the simulator).

After adding some schools to the application, the next window provides feedback about the likelihood of assignment at the different schools, as well as the likelihood of non-assignment. The applicant can then choose to move the schools in the preference ranking and/or add more schools, and the probabilities of assignment (and non-assignment) are updated accordingly.

The prototype is still of rough version of how a functional application platform might operate, but it allows us to convey the idea that it is important to carefully design the interface to report preferences, because this is an ideal instance to inform and assist applicants, ultimately improving the results of the system.

7 Next steps

As highlighted in sections 4 and 5, the first step is to decide whether the basic back-end building blocks explained in this proposal will be implemented this year. If so, the definitions regarding the assignment rules and how the preference collection are going to operate need to be decided as soon as possible, to start informing new teachers about the system and the process.

The second step in this process, would be to gather available information about vacancies and districts, and to organize in a simple platform, to allow new teachers to inform themselves about available alternatives.
Beyond this year, the key message is that an incremental and evidence-based approach is necessary to progressively achieve a well-functioning application system. In ConsiliumBots we are available to offer advice and assistance, and moreover look forward to having the opportunity to contribute in the process.
References


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