SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: **CA15210 (European Network for Collaboration on Kidney Exchange Programmes)**
STSM title: **PhD student long term research visit to Budapest**
STSM start and end date: **12/01/2019 to 14/04/2019**
Grantee name: **Radu-Ștefan Mincu**

PURPOSE OF THE STSM

As described in the research plan, the applicant Radu-Stefan Mincu, a PhD student at the University of Bucharest, is working on the topic of International Kidney Exchange Programmes together with his PhD advisor, Alexandru Popa (on the Romanian side of collaboration) and the colleagues from the Hungarian side Péter Biró, Márton Gyetvai and Utkarsh Verma.

The present STSM to Budapest is a continuation of previous collaboration (namely the STSMs of Radu-Stefan Mincu and Alex Popa to Budapest in April 2018 and the STSMs of Péter Biró and Márton Gyetvai to Bucharest in October 2018). This previous collaboration produced a proceedings publication at the VOCAL OR Conference, titled “IP Solutions for International Kidney Exchange Programmes”. The present STSM’s goal is to build upon the previous efforts and submit a journal version of the paper to the CEJOR journal (for the special VOCAL issue).

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

As previously mentioned, the work involves International KEPs. In the proceedings paper presented at the VOCAL OR conference, we had obtained the following results:

1. Identified details (goals, restrictions, possible benefit, general framework) of international cooperation in KEPs.
2. Designed new IP models for International KEPs according to our proposed framework of collaboration.
3. Produced long-term simulations backing up the notion that international collaboration presents an opportunity for long-term as well as short-term (stage-by-stage) improvement in the number of transplants for the participant countries.

For the journal version of the paper we focused on the following aspects:

1. Improving the IP models to better capture the international aspects of collaboration. Our models are flexible enough to model a wide range of restrictions as well as offering a concise method to control the solution components in accordance to the

type of component (cycle or non-directed-donor initiated chain) and locality of the component (national or international).
2. Conducting enhanced simulations and performing a sensitivity analysis for the parameters involved (component bound, participant KEP pool size and type of collaboration). These results are important for the planning of potential collaborations, since we can quantify the expected relative increase in the number of transplants with regard to the potential partner's parameters.
3. Streamlining our IP models to cope with larger instances or solve the previous instances faster. This was particularly useful for conducting the simulations.

To achieve these results, we presented our ideas and received feedback amongst ourselves using continuous discussions across the entire period of the STSM. A summary of the results was presented by Péter Biró at the action workshop in Porto at the end of March 2019.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

1. Firstly, we have improved our previous IP model by describing in detail how to implement the constraints considered in our framework of collaboration. We focused on cycle exchanges, but we also gave guidelines for implementing non-directed-donor chains. Additionally, we have provided a hybrid IP model for the bounded-unbounded country collaboration case that was useful in the simulations (having a reduced number of edge variables). We have amply described the particulars of these IP formulations in the third section of the paper.
2. Secondly, we have reworked our entire simulation setup and we have considered almost all combinations of relevant parameters (cycle bound, pool size and type of collaboration – none / consecutive pool / merged pool). We have given extensive data regarding our simulations describing short-term and long-term relative benefits of collaboration with regard to the considered parameters. We have shown some surprising results (equally restricted countries have the least incentive to cooperate, while cooperating with a more – or less, if not possible – restricted partner is preferred). Collaboration is preferred to non-collaboration and the merged pool programme is the most successful. Pool size positively affects collaboration. We have embedded many figures and tables in the paper that showcase these results.
3. Thirdly, we have spared no effort to improve our IP model implementations used in the simulations and we have achieved a parallelized implementation for the cycle search IP (in which most of the time is spent building the model, rather than solving it). This enabled us to perform the simulations in reasonable time and more extensively explore restriction combinations involved in cooperation. We have showcased the employed cycle formulation in the appendix of the paper.

Finally, the paper has been submitted to the VOCAL special issue of CEJOR and we are quite confident to receive a positive response.

FUTURE COLLABORATIONS (if applicable)

1. We will further elaborate of the IP models by including also different restrictions on the altruistic chains. These IP models can serve as the basis of the WG3 handbook on modelling and optimisation in international kidney exchange programmes. (This task is in accordance with the goals of WG3, which are "(ii) propose generic mathematical models for transnational markets; and (iii) propose methodologies to tackle the optimisation problem")

2. We will work on the implementation of the models and solutions in real applications. We would be happy to test our methods and analyse the benefits of cooperation for real pool data of European programmes (e.g., the Italian-Portuguese-Spanish cooperation). The Budapest research team is planning to develop a web-based application to be used in the regional collaboration, where the solution method will be based on the results of this joint work by the STSM.
3. We have been discussing to focus on a very important, but somewhat different topic regarding Kidney Exchange Programmes, namely the transplant quality. While there exist in the literature papers describing the increase in expected survival time with regard to better ABO compatibility, younger donor age and various other parameters, as well as some calculators that quantify the expected survival time for the patient undergoing a transplant, we are concerned with long term simulations that prioritize the expected survival time of the patients as an objective, rather than the number of transplants, or some other scoring criteria.
   We intend to use long term simulation techniques similar to the ones in the submitted journal paper, to describe the gains and losses in choosing quality over number of transplants in the objective function of the IP. We believe that it is important for the development of Kidney Exchange Programmes to understand the differences and aspects of changing the policy for transplantation in this way.