COVID-19 Africa Rapid Grant Fund

In Progress Technical Report

INTRODUCTION

With the intention to support Africa's response to COVID-19 and under the auspices of the SGCI, the NRF South Africa, IDRC, Sida, DFID, United Kingdom Research and Innovation (UKRI) through the Newton Fund, South Africa's Department of Science and Innovation (DSI), Fonds de Recherche du Québec (FRQ), SGCI participating councils, and additional partners have collaborated to implement the COVID-19 Africa Rapid Grant Fund (CARGF) to address research questions and implement science engagement activities associated with COVID-19. As a recipient of this Fund, you are required to submit an annual technical and financial report of the progress made against the proposal which was submitted in applying for a grant for this fund. ***All reports are to be submitted every year by no later than 31 August***.

Part I: General Information

Title of Project: OPTIMIZING COVID-19 PREVENTION MEASURES IN THE FACE OF SOCIO-CULTURAL BEHAVIOURS AND POPULATION MOVEMENT PATTERNS IN DEVELOPING COUNTRIES: CASE STUDY OF MOZAMBIQUE			
Principal Investigator Title, Name and Surname: Prof. Sansao Pedro			
UID Number: 130301			
Institution: Eduardo Mondlane University			
Country: Mozambique			
Call Strand: Research			
Reporting Period: final			Date: 11-09-2023
Final report?	yes		

Part II: Technical Report

The following are suggested headings for this section:

1. Project executive summary

   Life conditions in African countries are vastly different and often fragile, with conflicting limitations of both the health care system and socio-economic conditions, posing difficult challenges for decisions about enacting and lifting interventions, and negatively influencing containment as well as recording, testing and medical treatment. For example, the median age below 20, and the low rates of urbanization, could potentially lead to a lower death toll of the epidemic in African countries than elsewhere. However, having a young population implies that many infected individuals may not display symptoms and will risk infecting more people than would symptomatic individuals. Additionally, the large number of informal settlements (including residents, markets and bus stations) could accentuate this phenomenon.

   It is therefore urgent to develop a framework that could accurately predict the spread of the virus, accounting for the idiosyncrasies of the African context. A country-specific model will provide policy makers with a wide range of prediction scenarios, based on different actions they can take to address the pandemic.

   The work proposed here has the intention to contribute towards a development of tool for investigating and predicting the spatio-temporal COVID-19 pandemic activities while taking into considerations of observed trends of disease spatial spread, social behaviours, population movements patterns, migration and displacement due to war and other calamities and economic constraints by means of modelling across mathematical sciences, computing, geographic systems, social science and epidemiology. Our objective is then to use the resulting model to make predictions about the spatio-temporal spread of the disease at local and global scale and scrutinize important factors underlying such spatio-temporal patterns. Then, assess viable control strategies particularly in specific socio-cultural behaviours and economic constraints.

   Decision makers can use this modelling tool to determine the distribution of resources, the critical time for implementing interventions, and the severity and timing of the epidemic, thus reducing uncertainty in decision-making, leading to better management of disease and resources under specific national socio-economic profile.

2. Project objectives

   The work proposed here has the intention to develop tools for investigating and predicting the spatio-temporal COVID-19 pandemic activities while taking into consideration observed trends of disease spatial spread, social behaviours, population movement patterns and economic constraints. As well, to account for migration, trade and displacement due to war and other calamities compounds to factors leading to spatial spread of the disease. Our first objective is to investigate the links between variations of COVID-19 epidemiology in Mozambique and several environmental, topographic, socio-economic, socio-cultural and demographic factors as explanatory variables through the use of regressive, autoregressive and random forest spatial models. Then, utilize databases gathered on these explanatory variables to construct an interactive probabilistic network model of populations that will take spatial heterogeneity into account by allowing the local rates of spread of the disease, the rate of long-distance translocation to vary among districts/provinces depending on their human and demographics, geographic features and socio-cultural behaviours. The model would be able to predict the spatio-temporal spread of the disease within the country and scrutinize important factors underlying such spatio-temporal patterns. Our third objective is to test ideas about how social distancing, self-quarantine, and isolation measures could be optimized in high-density urban areas like informal settlements taking into account specific socio-cultural behaviours and investigating the impact of comorbidities with other infections such as tuberculosis, HIV and malaria. The fourth objective expands the previous research objective to examine questions around border closings, region-by-region opening and closing strategies, and re-seeding of infection with the aim to provide decision-makers with viable control strategies specific to socio-cultural behaviours and economic context. The project aims to tackle the following research questions:

   a) Could local propagation of COVID-19 be influenced by variation in individual's social behaviours and population movement patterns across quarantine zones, rural and urban zones? How does congested public transport influence the risks of COVID-19 infection?

   b) Apart from local transmission, how does transnational border mobility (including migration) contribute to expansion and seeding of infection in new geographic areas?

c) What is the impact of the media in promoting COVID-19 prevention measures?

d) How do trade and investment, social networks and livelihoods (including in communities relying on income received daily to survive) impact transmission dynamics?

e) How can social distancing, self-quarantine, and isolation measures be optimized in high-density urban areas like informal settlements?

f) How can transnational border mobility openings and closing be timed to minimize cases within Mozambique?

g) How can we optimize the time to switch on and off social distancing measures? Are closures best lifted at the scale of an entire country or on a province-by-province basis? What could be the optimal combination of existing prevention measures?

h) Does coordination of testing protocols and re-opening criteria between provinces improve outcomes? How well can a spatially phased approach work at different stages of the epidemic?

i) What is the impact of COVID-19 infection in patients already infected with other pathologies?

j) Can the models to be developed be used for management of other diseases? Can they be used in similar contexts in the continent?

k) Can the results of this study improve the current national surveillance system?

3. Specify any changes to the above project objectives
   So far no change is foreseen. However, in regard to assessing the role of different control measures vaccination also has been included.
4. Progress and outputs (highlight special achievements aligned to each project objective as indicated in accepted proposal)
   Due to some delays regarding the release of funding which was made available around May 2021 added health challenges of the Project coordinator during the first months of the year the implementation of the project started around June 2021.

1) Methodology

In order to fulfill the objectives of the projects three research groups have been set, one focussing on the statistics for estimation for key epidemiological parameters, one related to geographic information science focussing on key risk factors related to spatial spread of COVID-19 in Mozambique and the last on Computational Modelling focussing on disease dynamics.

Bio-Statistics Group – this is transversal to all research questions focussing on the estimation of key epidemiological parameters and started the actual work from 01 September 2021 involving a bachelor student in Statistics by name of **Bonifácio José Carlos Nicola**. Unfortunately, this student was dropped out due to his failure to comply with the project requirements in terms of time to be dedicated to the project. Then, another student named Joaquim Cumbe pursuing bachelor's degree in Mathematics was admitted to the research group. Later on, this student left the group to pursue a different topic in Sweden through the Linnaeus Palme sponsorship. Later, we had a new student in Statistics named **Fernando Domingos Inacio,** who worked with data collected in Quelimane, the capital city of Zambezia province in the central region to investigate the impact of media in promoting preventive behaviors against COVID-19 transmission and identify factors associated with perception of the role of media in promoting risk for COVID-19 infection. Below we list estimated key epidemiological parameters:

- Incubation period
- Basic number of reproduction (R0) and serial interval:
- Effective reproduction number (Rt):
- Generation interval:

Observation: This achievement is aligned with all four objectives of the project since all models developed across the four objectives require parameter estimation.

Geographic Information Science Group – at the beginning we had three (two females and one male) bachelors students from the Geographic Information Systems course involved. However, the two females were dropped out due to their lack

of interest and time to commit to the project. Since then, we have been working with one student targeting the first two research questions and we highlight some progress:

- Using regressive and autoregressive spatial models we determined how well they can explain variations of COVID-19 in Mozambique based on several environmental, topographic, socioeconomic, behavioral, and demo- graphic factors as explanatory variables. This study was done dividing the country in terms of provinces and districts.
- Examined the performance of calibrated spatial regression models in describing the relationship between explanatory variables and COVID-19 incidence indices.

Observation: This achievement is in line with objectives one and two. Recently the student started working with the datasets at district level on various explanatory variables to construct an interactive probabilistic network model of populations that will take spatial heterogeneity into account by allowing the local and long-distance rates of spread of COVID-19 to vary among districts/provinces depending on their human and demographics, geographic features and socio-cultural behaviours.

Mathematical & Computational Modelling Group – we started with two students, one doing bachelor degree in Mathematics and the other doing Master degree in Mathematics. The bachelor student named **Ronaldo Texeira** has been working on a mathematical epidemiological model with the aim to investigate the effect of immigration, vaccination, asymptomatic infection, immunity and environmental transmission on the dynamics of COVID-19. He defended his monograph in October 2022 and then continued with us to perform optimal control analysis. His work attempts to answer research questions e) and g). For the master student named **Alfredo Zacarias Muxlhanga**, his work focussed on developing a computational model focussing on incorporating individual's mobility patterns for investigating research questions related to social distancing, implementation of COVID-19 control restrictions such as lockdowns. The other two master students joined the project later in 2022, where one (named **Paulo Joaquim**) aims to expand the work of the first master student with focus to social distancing and coordination of lockdowns protocols. While the other (**Amosse Andre Chicomo**) expands the work of the bachelor student in regard to optimal vaccination strategies and optimal control in general. Main achievements so far:

- An agent-based model developed and calibrated with mobility data from Maputo, COVID-19 cases;
- COVID-19 lockdowns restrictions have been examined;
- An agent-based model developed and being calibrated with socio-cultural and local mobility data collected in Quelimane and Nampula;
- An agent-based model developed and being calibrated with socio-cultural and local mobility data collected in Quelimane and Nampula;
- Meta-population model developed and being calibrated with inter-district and inter-provincial mobility data collected across the country;

Observation: This achievement is in line with objectives three and four. Activities are still ongoing as we still have two MSc students attached to the project.

2) Project Activities

A. Inception and Research Workshop

During the week 28th February to 05th March 2022 we organized the first workshop in a rural place in Gaza province (Zona Brasa Workshop details). The purpose of the workshop was to officially launch the project and to achieve consensus of what the project is hoping to achieve – a collective understanding as well as to create a platform for a fruitful collaboration among various existing research sub-groups. It was also an opportunity to review the priority activities of the first year of the project action plan for each sub-group as well as to introduce requirements according to procedures and

policies for the project management and ensuring adequate monitoring and technical and financial reporting.

Figure 1 Zona Brasa

In total we had four project team members and four students organized as follows:

- Sansao Pedro - Project coordinator
- Mathematical & Computational Modelling Group – Sansao Pedro, Victor Santos & Ronaldo Teixeira (BSc student) and Alfredo Muxlhanga (MSc student);
- Geographic Information Science Group – Mario Chelengo, Manuel Bila (BSc student);
- Bio-Statistics Group – Osvaldo Loquiha, Joaquim Cumbe (BSc student);

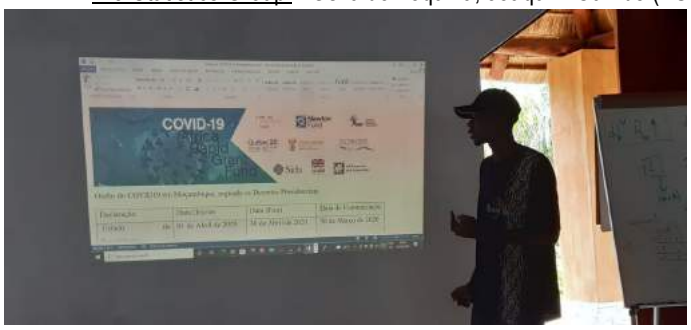

Figure 2 Zona Brasa

The workshop objectives, main activities and all management aspects of the project were presented to all participants on the first day by the project coordinator then followed by a moment for questions and answers. Then, followed by the presentation sessions dedicated to the presentation of the progress of each research sub-group since the beginning of the project in May 2021 as well as the plan of activities to be carried during the workshop. In the following days the sessions were dedicated to presentation and discussion of the current progress of each sub-group (see appendix II), during which all participants were called to engage. It was really very productive on all levels. Those in need of statistical expertise had it at hand, those in need of geospatial expertise either mathematical or computational they had it at hand and we were able to make progress. At the end of the workshop, discussions with attendance focused on the following main points:

- Strategy to adopt to deal with the current global health situation for successful project implementation, knowing that activities planned for this first year will focus on field work for data collection;
- Issues of lack of time of project team members and other concerns surrounding the commitment of students involved in internships;

- Preparation and planning for data collection activities across the country (south, center and north regions);
- Strategy to adopt for ensuring successful project implementation after the workshop – regular meetings to take place on Thursdays.
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B. Progress Meetings

Since the start of the project the coordinator has been conducting regular meetings on Thursdays with all research groups in order to monitor the progress of project activities. During the meeting all students attached to the project were invited to present their progress and received feedback from their peers and research team.

C. Data Collection

Within the project we conducted four field works, one focussing in the south region of the country, the second in the central region, the third in the north region and the last across the entire country for collecting inter-district and inter-provincial mobility data. For the first three field works we had to hire and train field assistants to assist in conducting the surveys. For the last one we did it ourselves, the project coordinator, **Mario Chelengo** and **Alfredo Muxlhanga**. Field assistants were hired through a public advertisement call, targeting university students with ability to engage with local community officers, to conduct data collection through surveys as well as reporting data in accordance with activity protocols after the training. In detail, the following skills were required for field assistants: participate in the training, know how to select samples, conduct interviews at home (with the interviewee) as well as via cell phone (daily calls), explain the objectives of the Survey/Research, and its procedures for participants who are being interviewed, clearly interpret interview questions to help participants understand and provide correct answers, record answers according to the interviewee's clarifications, as well as filling in the information collected daily in the system via a smart cell phone. In addition to the skills, other requirements included: being a higher education student, having a personal smartphone, speaking Portuguese fluently, speaking the local language fluently, having a teamwork spirit, knowing the geographical area of work, experience in using android cell phones in data collection, ability to work hard for long hours and with minimal supervision, have physical aptitude to carry out field work, strictly meet targets, good communication skills, have a spirit of individual and collective responsibility and have good civic and moral behavior. These requirements were applied in all regions selected for the surveys.

The training consisted of two moments. The first consisted of the perception of each question in the questionnaire as well as the general aspects of ethics in each community. The second consisted of spatial aspects, such as the geographical location of sample points. In both, data filling in the virtual system was taught. The training took place for 5 days where the first for questionnaire explaining, the second for GIS tools and the last 3 for questionnaire test.

The first data collection activity took place in the south region of the country across 17 neighborhoods of urban districts among the 63 that make up the City of Maputo (Maputo City Survey details). The fieldwork took place between 27th March and 04th April 2022 that consisted of diary questionnaires for seven consecutive days from Saturday to Sunday aiming to collect data that could be used to estimate the individual's mobility patterns. Below (Questionnaire) is the sample of the diary used which starts with personal information such as age, gender, how long the contact with the person was over the entire day, places where contact(s) occurred, whether there was skin-to-skin contact.

From this data the master student was able to estimate the contact matrix and mobility matrix to be fed in on his agent-based model.

Figure 3 Sample points

Figure 4 Field assistant badges

The second data collection took place recently in the central region of the country 16 neighborhoods of both urban and rural districts among the 50 that make up the city of Quelimane in Zambezia province (Quelimane Survey details). The fieldwork took place between 12th July and 01th August 2022 that It consisted of 4 forms, two of which are similar to those used in Maputo City, but with some adjustments because in addition to the contacts we have a age-structured component, that is, we seek to know the ages of the people with whom the participants have contacts. The other two were added for the study of socio-cultural behaviours and the impact of the dissemination of information about COVID-19 by the media (Questionnaire).

Figure 5 Field assistants

After the City of Quelimane, we returned to the south area where we extended the data collection work to the entire Maputo Metropolitan Area (in addition to the City of Maputo, it includes the Municipality of Matola and the districts of Marracuene and Boane) and this time we climbed 25 neighborhoods between October 20th and November 8th, 2022 (Maputo Metropolitan Area details).

At the end of 2022, we visited the northern region of the country, where we collected data in 16 neighborhoods among the 25 that make up the City of Nampula between November 29th and December 19th, 2022, using the same questionnaires used in Quelimane (Nampula Survey details).

More recently, in 2023, it was carried out across the country asking about the mobility of people using interprovincial and interdistrict transport (Interprovincial and Interdistrital transport survey details). This research took place between the 27th of June and the 25th of July 2023 in all semi-collective passenger terminals located in the districts of the South, Center and North of Mozambique, covering the provinces of Maputo, Gaza, Inhambane, Sofala, Manica , Tete, Zambézia, Nampula, Cabo Delgado and Niassa. In this sense, two groups of data are considered, the first, with regard to joint monthly and annual records recorded by the Associations of Rail Passenger Transporters, which are not always available, and the second group of data, with regard to accumulated mobility daily at interdistrict and interprovincial level that it was possible to obtain for all provinces once the data collection model was developed by the project team (see appendix containing the model structure used).

D. Workshops and Conferences

Apart from our weekly meetings we organized a training workshop in Mathematical Biology targeting final year students in mathematical sciences and related fields (DMI Workshop details). The workshop took place at the Department of Mathematics and Informatics between 19 and 21 September 2022 delivered in three major lectures and hands-on activities:

- Introduction to disease modelling (SIR models, basic reproduction number, qualitative analysis, simulation and parameter estimation) - case study of COVID-19 in Mozambique. This lecturer was given by the project coordinator and the practical session by Ronaldo Teixeira (BSc student);
- Introduction to agent-based models - case study of COVID-19 in Mozambique. This lecturer was delivered by the projector coordinator together with Alfredo Muxlhanga (the MSc student);

- Risk maps analysis for COVID-19 in Mozambique. This lecturer was delivered by a project researcher, Mario Chelengo together with Manuel Bila (BSc student)

Being the Chairman of the Local Organizing Committee of the annual conference of the Southern Africa

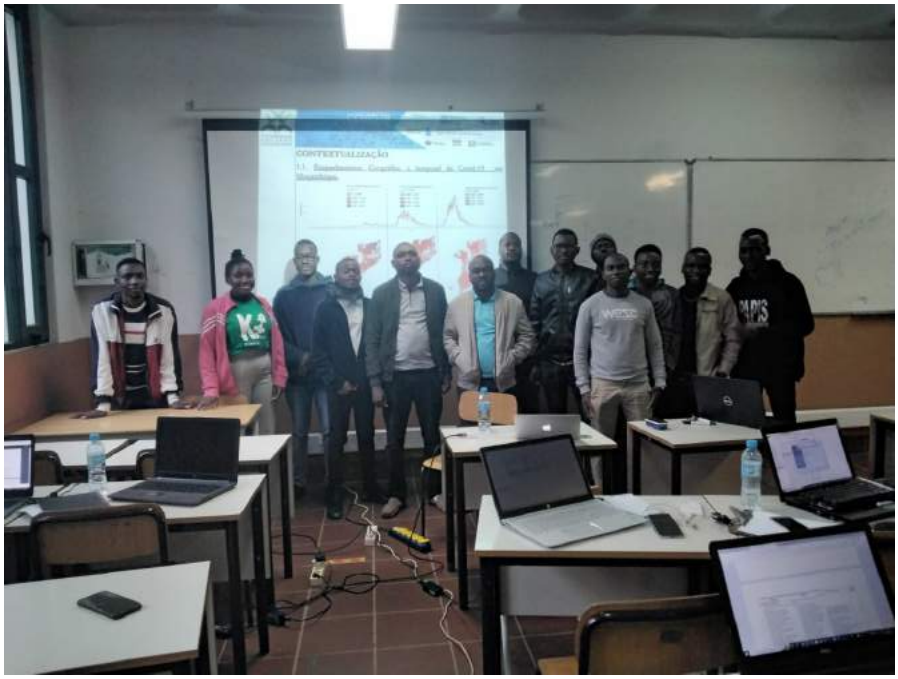

Figure 5 DMI workshop

Mathematical Sciences Association (SAMSA 2022) that took place at UEM in November 22-25, 2022, I co-organized together with SAMSA, Auburn University and the Mozambique National Health Institute (INS) a one day symposium named One Health that took in November 21 (SAMSA Conference details). The symposium theme was **Mathematics Connecting to One Health** and the symposium gathered among others, Allied Health organizations, agencies, government, industry, nonprofits, and academia organizations based in Mozambique.

Figure 6 SAMSA conference

Apart from the SAMSA 2022 annual conference, our research team also participated in the UEM Faculty of Science Scientific Week that took place in September 19-23, 2022 where our intern student Ronaldo Teixeira won the Best Presentation Prize. Recently, in July 16-21 the project coordinator participated in the annual meeting of the Society for Mathematical Biology that took place at The Ohio State University in Ohio Columbus, USA.

3) Achievements

- **Objective I:** In summary for this objective we have achieved 100% of the planned work.
- **Objective II:** In summary for this objective we have achieved about 70% of the planned work. Recently we started working with the datasets at district level on various explanatory variables to construct an interactive probabilistic network model of populations that will take spatial heterogeneity into account by allowing the local and long-distance rates of spread of COVID-19 to vary among districts/provinces depending on their human and demographics, geographic features and socio-cultural behaviours.
- **Objective III:** For this objective we have achieved about 85% of the planned work and activities are ongoing to cover the remaining part.
- **Objective IV:** For this objective we have achieved about 70% of the planned work and activities are ongoing to cover the remaining part.

5. Indicate how the project has mainstreamed gender in its implementation
   At the beginning we had two female students but they dropped out to pursue other research topics for their monographs.

6. Outputs and Dissemination
   - One report detailing the estimates of key COVID-19 epidemiological parameters;
   - One bachelor monograph defended, discussing the Effect of Immigration, Vaccination, Asymptomatic Infection, Immunity and Environmental Transmission in the transmission dynamics of COVID-19 in Mozambique;
   - One manuscript presents COVID-19 spatial incidence rates across the three major epidemic waves and their relationship with environmental, topographic, socioeconomic, behavioral, and demo- graphic factors as explanatory variables.
   - One master dissertation defended, discussion about how individuals mobility patterns impacts the transmission dynamics of COVID-19 in Mozambique using an agent-based model;

- One bachelor monograph defended, discusses the role of the media in promoting preventive behaviors against COVID-19 and identifies factors associated with perception of the media's role in the spread of COVID-19 infection..
- One manuscript presents COVID-19 pandemic planning implications of population mobility patterns in Mozambique;

More information about outputs and dissemination can be found here Outputs and Dissemination details.
In collaboration with Local Organizing Committee of the Southern Africa Mathematical Sciences Association Annual Conference SAMSA 2022 (https://samsa2022.uem.mz/) we are organizing a one day symposium named One Health to take place on the 21st November, where we aim to present and discuss the results of the project.

7. Indicate how the project has contributed to Covid-19 response (project's impact, and significant changes witnessed as a result of project implementation)
    - One of the project team member has been actively involved in the COVID-19 Scientific Technical Committee;
    - Our work on the estimation of COVID-19 key epidemiological parameters has been useful on guiding National Health Institute decision making through the COVID-19 Scientific Technical Committee;

8. Indicate how the project has leveraged opportunities, networks, other projects and partnerships in its implementation
    - Through the project we have been able to put together 3 units of the department to collaborate, that is, Mathematics, Statistics and Geographic Information Science. This is now an established research group and ideas are in place to transform this research group in a research center of multidisciplinary studies applied in solving health problems;
    - Through the project we have been able to offer internships for students. This is fundamental to be able to advance research by buying time from students;
    - Through the project we have been able to establish an international collaborative research team;
    - Through the project we have been able to extend our local network with allied health organization through the One Health symposium;
    - Through the project a MoU is underway between the Faculty of Science and National Health Institute;

9. Reflect on project implementation risks and mitigation
    - The biggest challenge is manpower in terms of time needed during the implementation of the project. For instance two master students involved in the project are very slow as they fail to commit their time for research.
    - We rely on students in order to advance with the project, however, this can be time consuming as much time is needed for their training before they can actually give a contribution to the project.
    - Another challenge has to do with student dropouts..

10. The NRF would appreciate brief comments on your view of how the oversight, management and administration of this project funding has functioned
    We had delays for the release of the first bunch of funds which I think is typical for this kind of funding where various countries and individual projects are involved.

11. Financial reporting summary

Item Description	**Cost (in USD)**			**Total**
	1st Year	2nd Year	3nd Year	

Research operating costs	2,093	23,502	4,784	30,378
Research equipment and infrastructure (should not be more than 15% of total budget)	1,388	1,533	0.00	2,921
Consumables	0.00	0.00	0.00	0.00
Mobility Costs (Airfare, accommodation and subsistence)	0.00	23,376	6,942	30,318
Conference/Workshop	0.00	5,957	6,313	12,270
Publication related costs	0.00	0.00	0.00	0.00
Indirect Costs			1,106	1,106
TOTAL	3,481	54,369	19,145	76,995

12. List of Annexures

Note: Items 1 to 12 should be limited to a maximum of 15 pages. Additional annexures can be provided to augment the technical report.

FINANCIAL REPORTING GUIDELINES

The financial reporting template is attached in Appendix 1. Please ensure that your financial reporting template corresponds with the correct strand i.e. 1) *research; 2) science engagement - call to science and health journalists and communicators; and 2) science engagement - call to science advisers.*

SUBMISSION OF REPORTS

The guidelines for submitting reports on the NRF online submission system.

REPORTING SCHEDULE (Technical & Financial Reports)

Call Strand	**Report 1 - Due Date**	**Report 2 (Final)**
Research	31 August 2021	31 August 2022

Science engagement - call to science and health journalists	31 August 2021	31 August 2022
Science engagement - call to science advisers	31 August 2021	31 August 2022

APPENDICES

I. Appendix 1: Financial reporting

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