2. RESEARCH PROJECT (TO BE UPLOADED SEPARATELY FROM PART 1, MAX 22 PAGES)

	Description
Project Title	Humanitarian Optimization through Mat-heuristics and Metaheuristics
Project Acronym	HOMM
Project Keywords[6]	Control theory, optimisation and operational research; Application of mathematics in industry and society; Discrete mathematics and combinatorics.
Project Abstract	Post disaster relief operations and risk management studies have drawn significant attention over the past decade, aiming at increasing resilience in labour and social environments through prevention and systematic response to emergency events. Within this context, Operational Research (OR) and related fields play a key role in devising mathematical methods to assess data, guide decisions and automate processes. In disaster relief and risk management (as in other "real-world" operations), demands, availability of resources and costs may vary according to the circumstances, and the quality of the decisions made is directly impacted by changes in the current scenario. Thus, considering data uncertainty is crucial to devising more accurate and robust solutions. Different approaches can be applied to model problems under uncertain data, such as stochastic programming and Robust Optimization (RO). In the former, uncertainty is modelled through a probabilistic description and is mostly applied whenever the probability law associated with the uncertain data is known in advance. On the other hand, RO has gained particular attention over the last decades due to its power in modelling uncertainty while still applying the tooling of classical/deterministic optimization. In this project, I intend to propose mathematical programming-based heuristics (mat-heuristics) and metaheuristics to address post traumatic relief operations subject to uncertain data and modelled by means of RO. The initial focus is on the planning of rescue and recovery operations to be performed by land (i.e., using land vehicles) in emergencies caused by natural disasters and incidents in industrial sites. Consider that, within a region affected by a disaster, several locations are potentially in need of a rescue shuttle or relief resources (such as food, water, medicine or other supply). Two chained operations will be addressed in this study: (i) deciding where to place tents for temporary shelter, first aid or supply, taking into account limitations in resources for building/supplying these tents and (ii) devising rescue/supply routes --- using land vehicles --- for visiting these tents and other selected locations where there might be victims. Here, I intend to depict these real-world situations mathematically through RO versions of two classical optimization problems, namely the Facility Location problem and the Steiner team orienteering problem. The quality and efficiency of the algorithms proposed will be tested on instances built based on real data available in the Emergency Events Database (EM-DAT).

2.1 Project compliance with Normandy Smart Specialisation Strategy (S3)

[6] Please refer to the keywords list into the Guide for Applicant

For complete list of Normandy S3 objectives, domains and axis, please refer to the Guide of Applicant.

	Description
Smart Specialisation Strategy Domains	Please indicate one or several S3 domains your application complies with: - Preserving and sustainably transforming agricultural, marine, forestry and production systems; - Develop an energy mix towards zero carbon emissions; - Transforming processes for a high-performance, sustainable and digital industry; - Develop low-carbon mobility solutions that are efficient and secure; - Accelerating synergies and innovation in the service of human and animal 5P medicine; - **Make Normandy a resilient territory by mastering technological, natural, health and social risks.**
Axis	Improve risk prevention, control practices & tools in a region highly subject to natural, technological, health and social risks
Does your proposal include the transversal domain on digital?	Yes

2.2 Description of the research project

Please provide a **max 10-page description** of your research project (incl. references) for a 2-year duration, **following the below template and frame**. This must be written by the applicant using standard police (Arial/Times/Calibri etc., size 11, margins 1.5).

1. Excellence of the scientific project (*approx. 4 pages*)

1.1. General context

Post disaster relief operations and risk management studies have drawn significant attention over the past decade, aiming at increasing resilience in labor and social environments through prevention and systematic response to emergency events [6,13, 26]. Within this context, Operational Research (OR) plays a key role in devising mathematical methods to assess data, guide decisions and automate processes. In disaster relief and risk management (as in other “real-world” operations), demands, availability of resources and costs may vary according to the circumstances, and the quality of the decisions made is directly impacted by changes in the current scenario. Thus, considering data uncertainty is crucial to devising more accurate and robust solutions.

Different approaches can be applied to model problems under uncertain data, such as stochastic programming and Robust Optimization (RO). In the former, uncertainty is modelled through a probabilistic description and is mostly applied whenever the probability law associated with the uncertain data is known in advance. On the other hand, RO has gained particular attention over the last decades due to its power in modelling uncertainty while still applying the tooling of classical/deterministic optimization. In RO, the variability of the data is represented by deterministic values in the context of scenarios. Considering that each

parameter subject to uncertainty can be linked to either a discrete set (discrete scenarios model) or a continuous interval (interval data model) of possible values, a scenario corresponds to a parameter assignment, i.e., a value is fixed for each parameter subject to uncertainty. In both cases, a classical (i.e., parameters known in advance) optimization problem takes place whenever a scenario is established. The most commonly adopted RO criteria are the absolute robustness criterion and the min-max regret. The absolute robustness criterion is based on the anticipation of the worst possible conditions. Solutions for RO problems under such criterion tend to be conservative, as they optimize only a worst-case scenario. Intuitively speaking, the regret of a solution in a given scenario is the difference between the cost of such solution and the cost of an optimal one in that scenario. In this sense, the min-max regret criterion aims at minimizing (among all feasible solutions) the maximum (among all possible scenarios) regret.

In this project, I intend to propose mathematical programming-based heuristics (mat-heuristics) and metaheuristics to address post traumatic relief operations subject to uncertain data and modelled by means of RO's min-max regret criterion. The focus is on the planning of rescue and recovery operations in emergencies caused by natural disasters and incidents in industrial sites. Consider that, within a region affected by a disaster, several locations are potentially in need of a rescue shuttle or relief resources (such as food, water, medicine or other supply). Considering the scenario depicted above, two chained operations will be addressed in this study: (i) deciding where to place tents for temporary shelter, first aid or supply, taking into account limitations in resources for building/supplying these tents and (ii) devising rescue/supply routes — using land vehicles — for visiting these tents and other selected locations where there might be victims. Notice that, also in the second level of the optimization, there might be limited resources (e.g., restricted autonomy of the vehicles, amount of relief resources, etc).

In both levels of the optimization, priority must be given to locations that are more likely to have victims close-by. Accordingly, (uncertain) values of priority/demand can be estimated based on factors as population density or historical data related to similar occurrences (in case of floods or mudslides, for instance) in the region or even by the existence of pre-established points of gathering in case of incidents in industrial sites. Naturally, locations which are known to have victims are given top priority in the first level of the optimization (for building tents close-by) and set as mandatory in the second level (for rescuing/supply routes). The locations chosen in the first level could also be set as mandatory in the second level. To represent these real-world situations mathematically, I intend to apply RO modeling techniques to two classical optimization problems: (i) the Facility Location Problem (FLP) [22] and (ii) the Steiner Team Orienteering Problem (STOP) [3].

FLP is a classical and widely studied NP-hard optimization problem that consists of determining the best sites for factories and warehouses such that given demand points are satisfied. In general, the goal of the problem is to minimize the sum of distances from the selected sites to the demand points or the costs of opening and maintaining the facilities in the selected sites. The facilities may or may not have limited capacities for servicing, which classifies the problems into capacitated and uncapacitated variants. In particular, FLP variations have already been successfully applied to model humanitarian relief operations [23].

On the other hand, STOP belongs to a sub-class of routing problems known as orienteering problems [24]. They are defined on a graph, usually complete and undirected, where a value of priority is associated with each vertex and a traverse time is associated with each edge (or arc). They aim at finding one or more routes (in case of single or multi-vehicle variations) from an origin vertex to a destination one, while satisfying a total traverse time constraint and maximizing the cumulative priorities of the vertices visited. Any vertex/location can only be serviced once and, contrary to the classical traveling salesman problem [11], solutions for orienteering problems do not necessarily visit all the vertices of the graph, but prioritize the ones associated with higher priority values. When some of the vertices to be visited are set as mandatory, the variation of interest in this project (STOP) arises [3, 20]. In STOP, the vertex set is sub-divided into mandatory and optional, being only the later associated with priorities. The goal is to find disjoint routes (one for each vehicle) that, together, maximize the sum of priorities serviced (by visiting optional vertices), while satisfying the routes' time constraint and necessarily visiting all mandatory vertices.

Currently, STOP finds its main applications in devising the itinerary of the delivery of goods by shipping companies and in the planning of technical visits, where a priority value — which may rely on factors such as the urgency of the request and the customer's rank/category — is associated with visiting each customer/location, and deliveries/visits with top priority (e.g., those whose deadlines are expiring) are set as mandatory. Quite recently, the potential of orienteering problems for modelling post disaster relief operations was explored for the first time in an application of rescuing victims from industrial sites in Italy during emergency situations [6].

Aside from the several real-world applications linked to STOP, its theoretical complexity also makes it a particularly interesting problem. In addition to being NP-hard, solely finding a feasible solution for an STOP

instance (or proving its infeasibility) is NP-hard in the general case [4]. This fact brings and extra layer of difficulty to devise either exact or heuristics methods for the problem, since building initial primal solutions might already be time consuming.
As mentioned above, this project focuses on RO versions of FLP and STOP applied to disaster relief situations, where response speed plays a crucial role, being even more important than the optimality of the plans in some cases. This is particularly challenging when dealing with RO (min-max regret) problems, as solely evaluating the (robust) cost of a solution involves solving an instance of the corresponding classical counterpart. Considering this issue, the aim of this project is to explore efficient ways of generating high quality solutions for both problems though mat-heuristic and metaheuristic frameworks. The goal is to devise algorithms able to give quick responses considering dynamic changes in the input of the problem (e.g., modifications in priority estimations and addition of new vertices/locations to be covered). In this sense, an ideal algorithm should be able to both generate an initial feasible solution and repair/adapt a solution made infeasible due to updates in the input data.

1.2. Originality and Excellence

Three main aspects of this project make it stand out in terms of scientific contribution and innovation:

- **Pioneering in applying RO techniques to humanitarian optimization:** despite the great attention research in humanitarian relief operations has drawn in the last years, the majority of the works in the field deal with uncertainty through scenarios stochastic programming. Only quite recently the RO's potential in modeling these situations has started being explored [27]. In this sense, the (possibly positive) results obtained by this project will help support this new trend as a pro-eminent topic of study in humanitarian optimization. Additionally, applying mat-heuristics to RO problems is a research path yet to be explored in the literature;
- **Planning disaster relief operations through algorithmic solutions:** using OR approaches to guide rescue and recovery operations after natural disasters (like earthquakes, floods and mudslides) and accidents in industrial sites has gained attention in the past years. Several works, ranging from exact solutions to evolutionary-based meta- heuristics [26] have been published in the topic. A wide range of classical optimization problems have been used to model these operations, especially scheduling, routing and facility location problems [7, 9, 18]. Only quite recently an orienteering problem has been used to model these situations [6]. In that regard, this project is among the first studies that apply the modelling potential of orienteering problems in the context of disaster relief management;
- **Solving a challenging optimization problem in terms of theoretical complexity:** as previously mentioned, finding an initial solution for STOP is already NP-hard, which makes it a challenging and interesting problem to be studied, regardless of its applications to risk management and post disaster recovery.

FLP is a classical combinatorial problem with several practical applications, including emergency humanitarian logistical problems [8, 14], and has been studied under a range of different variations of objective function, number of the facilities to locate, uncertain data and the solution space of interest. The problem can be either deterministic (when the number of candidate facilities is finite) or continuous (if the facilities can be placed anywhere in some continuous region), and might also be classified into capacitated (if each location has a limit on satisfying demands) or not. I highlight that, despite the great amount of works dealing with FLP and its variations, a very limited number of them uses RO to model uncertainty. In fact, the use of RO in emergency humanitarian logistics in general is not widespread yet [8]. In this sense, this project is one of the pioneering works to explore this new research trend. For detailed surveys on the classical FLP and its versions under uncertain data, I cite [8, 12].
Although the literature of orienteering problems is vast, both in terms of heuristic and exact methods [16, 17, 19, 25], STOP was introduced quite recently [3], and only few works address the problem. Its single vehicle version, namely the Steiner orienteering problem, was introduced by Letchford et al. [20]. In the work, the authors propose four Integer Linear Programming (ILP) models for the problem, but no computational experiment is reported. STOP was formally introduced only few years later [3], where a state-of-the-art branch-and-cut algorithm from the literature of the Team Orienteering Problem (TOP) was adapted, and a new cutting-plane algorithm proposed. The latter work relies on a compact (with a polynomial number of variables and constraints) commodity-based formulation — also introduced in the work — reinforced by three classes of inequalities. The cutting-plane proposed not only outperforms the baseline when solving a benchmark of STOP instances, but also solves to optimality 14 more TOP instances than any previous algorithm in the literature and finds eight new optimality certificates.

Motivated by the NP-hardness of finding a feasible solution for STOP, a Large Neighborhood Search (LNS) heuristic has been recently proposed for the problem [4]. The heuristic is provided with initial solutions obtained by means of the mat-heuristic framework known as feasibility pump [15], which, in this case, uses as backbone the commodity-based formulation of [3] reinforced by two new families of valid inequalities also introduced in the work. Computational experiments show the time efficiency and effectiveness of the proposed heuristic in solving a benchmark of STOP instances. In particular, the heuristic reaches the best previously known bounds on 382 of the 387 instances and improves over the best known bounds in 21 of these cases.
More recently, motivated by applications related to emergency management in industrial plants in Italy, the multi origins capacitated team orienteering problem was introduced and solved through an ant colony optimization algorithm [6]. The problem consists of a variation of STOP in which no mandatory vertices are considered, and the vehicles do not necessarily depart from the same origin. It models the problem of evacuating the greatest possible number of people from a risky area and transferring them to a unique destination shelter using the available and limited resources.
To the best of my knowledge, this project is the first work to address an RO version of STOP.

1.3 Research Methodology

The main goal of this project is to propose innovative and efficient solutions for RO versions of FLP and STOP addressing applications in post disaster relief operations in the Normandy region. To this end, I intend to follow two research directions: (i) mathematical programming-based heuristics (mat-heuristics), and (ii) metaheuristics. Solving combinatorial optimization problems through integer programming is an NP-hard task in general. As a result, ways of addressing these problems by approximate and heuristic methods have been widely investigated in the literature [21]. An interesting research path consists in combining the mathematical formalism of mixed integer programming formulations with the flexibility and scalability of metaheuristics, thus yielding the so-called mat-heuristics. Thus, this hybridization of mathematical programming and metaheuristic is able to explore the search space in a mathematically guided way, while still avoiding the possibly big memory and time requirements that might be brought by pure mathematical programming methods.
In this first research path, there is a wide range of possibilities to be explored, especially in terms of rounding and diving mat-heuristics (for instance, Relaxation Induced Neighborhood Search (RINS) [10], feasibility pump [15] and objective feasibility pump [1]), or even simpler constructive ad-hoc heuristics. In particular, an interesting heuristic framework called Kernel search [2], which is based on the identification of promising variables (kernel) of a given model, can also be investigated for the problems at hand. For the specific case of RO problems, a promising alternative is to apply a mat-heuristic framework that I have helped devise [5], which uses dual information and is extensible to any interval data min-max regret RO problem modelled by means of 0-1 integer linear programming.
Although the potential of mat-heuristics in solving classical optimization problems can already by supported by several studies, following this research direction in this project has two main risks. First, RO problems have an extra layer of difficulty, as devising compact (with a polynomial number of constraints and variables) formulations is not a trivial task in most of the cases, especially when the classical counterpart of the problem is already NP-hard. Second, in humanitarian relief, highly efficient solutions (in terms of execution time) are crucial, which is an extra challenge for methods that, as most of the mat-heuristics, involve solving linearly relaxed models many times.
To mitigate the aforementioned risks, I intend to also conduct research in the more conservative direction of classical metaheuristics. In this case, potential alternatives for investigation are (i) local search based metaheuristics, such as simulated annealing, tabu search, iterated local search, variable neighborhood search and Greedy Randomized Adaptive Search Procedure (GRASP), or (ii) population based metaheuristics (ant colony, particle swarm optimization, genetic algorithm, etc).

1.4 Inclusion of international, interdisciplinary and/or intersectoral aspects

A key factor for the effectiveness of an optimization algorithm is the quality and accuracy of the input data provided. In this context, Machine Learning (ML) and regression techniques are powerful tools to estimate costs, expected demands and other uncertain data that can be inferred by historical data.
Accordingly, the main interdisciplinary aspect of this project takes place in the collection and treatment of data to build input for the optimization algorithms proposed. A natural result and presuppose of this project is a close collaboration between the two teams in the Host research unit which study these topics: the *Apprentissage* (APP) laboratory and the *Réseaux d'interactions et Intelligence Collective* (RI2C). They

conduct research mainly in Artificial Intelligence (including ML) and Logistics (including OR), respectively. Aside from deepening the collaboration within the Host institution, another possibility to be explored is promoting scientific interchange of knowledge with the Brazilian institution where I did my P.h.D., namely *Universidade Federal de Minas Gerais* (UFMG). UFMG has a strong board of scientists in the field of OR, stochastic programming and robust optimization, as well as in linear and non-linear integer programming. Therefore, this project has also potential to be a starting point for an important international partnership between the two institutions.

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2. Impact of the project *(approx. 3 pages)*

2.1 Impact

This project meets directly the Smart Specialisation Strategy (S3) goal of making Normandy a resilient territory by mastering technological, natural, health and social risks, as the optimization problems addressed in this study model, as generically as possible, situations of response/rescue after natural/industrial disasters. In fact, I intend to use data from real incidents to build test instances and assess the performance of the proposed methods in the experiments to be conducted. The idea is to use information compiled by the Centre for Research on the Epidemiology of Disasters (CRED), which was made available in their Emergency Events Database (EM-DAT, https://www.emdat.be/). Upon access to data related to incidents within Normandy, they should also be included in the experiments.
In particular, the project contributes to two of the S3 areas/ambitions for 2027:

- **New technologies for risk anticipation and prevention:** develop applications of these technologies for anticipation and prevention of risks in order to make Normandy a resilient territory for 2027;
- **Practice for risk management:** make Normandy a resilient territory towards human or natural changes and risks.

This project will also sum up efforts with the current initiatives in the Host institution on planning robust strategies for dealing with emergency incidents in Normandy. There are two projects currently active in this topic, but focusing on applications using Unmanned Aerial Vehicle (UAV). In my project, the mathematical modelling and algorithmic approaches have as premise operations by land vehicles, thus matching the ongoing projects in a complementary way.
In terms of scientific contribution, this project has two main impacts:

- **Assess the potential of mat and metaheuristics in disaster relief optimization under uncertainty:** although there are already several works proposing algorithmic solutions for planning operations in emergency events, dealing with the uncertainty involved in the input data is mainly neglected or modelled through scenario stochastic programming. Then, the first goal of this project is to further explore RO as an alternative to model these situations, which require fast and dynamic responses under uncertain conditions. In particular, I intend to experimentally evaluate if model-based mat-heuristic and metaheuristic frameworks can be sufficiently efficient in these cases;
- **Solving a challenging theoretical problem through innovative methods:** as mentioned in Section 1.2, STOP is a particularly complex combinatorial problem, as finding an initial feasible

solution for it is already NP-hard. Then, devising innovative and efficient methods for this problem is also a relevant contribution from the theoretical point of view.

2.2 Career Development

I discovered my passion for research and optimization in the beginning of my second year of undergraduate in Computer Science at *Universidade Federal do Ceará* (UFC), Brazil, where I joined the research group of Parallelism, Graphs and Optimization. Since this first contact, I started to picture myself as a full-time researcher in the long-term. Nevertheless, due to the non-favorable research conditions in Brazil in the last years, I started to search for job positions outside Academia. Accordingly, during my last year of P.h.D., I also worked as an independent optimization consultant/developer and, in the last three years, I have been working as an optimization software engineer and data scientist: I have started at a Belgian company whose main product is a proprietary software for supply chain solutions and, later, contributed to optimizing logistic and production operations in a latin american *e-commerce* shipment company and in an European steel producer.

My last professional experiences gave me the chance of dealing with “real-world” applications in OR while working in multicultural teams. Nevertheless, at this point, I see this Fellowship as a great opportunity to further enrich my knowledge and get back to something that I have been passionate about since my early days in college: doing research.

The first aspect of this Fellowship that attracts me is the possibility of working with autonomy, by selecting a research topic that is in accordance with both my personal interests and Normandy Smart Specialisation Strategy's goals. Also in this sense, I see it as a great opportunity to broaden my knowledge and fill some gaps in my academic development. Although I have already had contact with mat and metaheuristics, my main works involve exact approaches (especially cutting-planes and Benders' decomposition). Then, this project is an opportunity to dive into the vast collection of non-exact techniques available in the literature.

The Host institution I have chosen to conduct my project particularly attracts me due to its board of researchers in the field of humanitarian optimization. Aside from my adviser Andréa Cynthia Santos, a few researchers from laboratories at *Le Havre Normandy Universite* have expertise in this field: Christophe Duhamel, Eric Sanlaville, Adan Yassine, Anne Pantet and Christophe Bisiaux. Some of them already have and/or had ongoing or previous collaborations with my advisor. Moreover, I am aware of the existence of organizations in the region dedicated to planning risk management initiatives in industrial activities: ORMES (https://www.ormes.fr) and Synerzip-lh (https://www.synerzip-lh.fr). They can be important sources of input data for devising scenarios in computational experiments.

At last, the experience of living abroad, getting in contact with a different culture and expanding my professional and social networks surely make the opportunity even more attractive. In summary, I believe this Fellowship meets my short and long-term goals of getting back to research, making my know-how portfolio more robust and becoming a full-time researcher in a well-regarded academic institution.

2.3 Transfer of knowledge and training

This project will be hosted by *Le Havre Normandy University* (ULHN), more precisely by the *Laboratoire d’Informatique, du Traitement de l’Information et des Systèmes* (LITIS). There, I intend to work in the *Réseaux d’interactions et Intelligence Collective* (RI2C) team, which has an history on solving several applications covering different phases of disaster handling, such as assessment, readiness, relief and recovery. This team also deals with dynamic systems, optimization and logistics in general. The LITIS-RI2C has a strategical position in the Normandy territory on these applications, with several past and recent projects on the topic. To name a few: (i) ASTREOS (*Maîtrise des flux dans les systèmes socio-techniques),* from 2018 to 2020; (ii) FEDER AMED (Multidisciplinary analysis of Domino effects), from 2017 to 2020; and, more recently, (iii) ANR LIAD (Optimizing and valorizing sites’ dismantling in the aftermath of industrial disasters in urban areas – A reverse logistics application) and (iv) FEDER-FSE LIS (Logistics operations after industrial disasters).

Aside from the intellectual resources available in the LITIS team, the research unit chosen also has the structural means to support my research. In practical terms, the LITIS-RI2C has a powerful grid machine for the computational experiments needed, physical space for my office, and can also provide me a personal computer. Moreover, the team can help me broaden my professional network through the several associations it collaborates with (like SINERZIP-LH, ORMES and ROADEF). As a result, I believe that the Host institution (and the specific research unit) chosen is the perfect place to re-engage myself with research, having all the means (both structural/technological and scientific/intellectual) to help me achieve the personal and professional goals involved in this project.

Now, let me outline my professional and personal skills that match the Host institution interests. From my

previous and current experiences as a researcher and a developer, I could build a solid basis in Computer Science and OR, with strong foundations in linear and integer programming, mathematical modelling, robust optimization, graph theory and network optimization. Furthermore, at this point of my career, I feel capable enough of conducting research with autonomy as well as in close collaboration with other researchers.
My main previous experiences as a researcher were focused on transportation problems, both in classical/deterministic vehicle routing and in versions taking into account uncertainty (in particular, robust optimization). Moreover, my professional experiences in private companies addressed logistics and supply chain problems, with focus on inventory optimization. Since the chosen Host institution has several ongoing projects in the field of logistics, I believe my knowledge and experience in transportation and inventory optimization fit the institution's needs.
Moreover, my academic background in more theoretical research, combined with my last experiences with more applied “real-world” research and development, have helped me broaden my analytical skills. With this mixture of academic and industrial experiences, I have learned to depict and solve mathematical problems in a less conservative, yet pragmatic, manner.
This ability can be useful when building connections between academic and social/industrial environments, either when assessing possible application's needs or communicating the research findings to a broader audience in a less technical language.

2.4 Communication, Dissemination and exploitation of results

As a first way of sharing the research findings, I intend to present preliminary and final results throughout the course of the Fellowship in seminars within the Host Research unit. I believe that sharing the results in early stages of the research is particularly important to obtain feedback and insights from a qualified audience, thus identifying flaws and possible improvements as soon as possible.
Once the research reaches more mature levels and the first consistent contributions are achieved, I plan to expose the results in international conferences, according to the impact of the findings. International conferences are usually a good occasion to share scientific contributions with a broader, yet selected, audience. Particularly in OR, they are also a starting point for submissions of full papers to peer-reviewed journals in subsequent special issues. At last, according to the relevance of the project's outcomes, I intend to submit the compilation of the findings to well-regarded journals in OR. Ideally, *International Journal of Disaster Risk Reduction*, *Computers & Operations Research*, *European Journal of Operational Research* and *Transportation Science* are examples of journals in which I aim to publish the findings.
In terms of international conferences, I believe the scopes of *International Symposium on Combinatorial Optimization (ISCO)* and *International Workshop on Model-Based Metaheuristics* might fit the research directions I intend to follow in this project.

3. Implementation of the project *(approx. 3 pages)*

3.1 Work programme, resources

The main macro activities planned for the 24-month horizon of this Fellowship are described as follows.

1. **Literature review:**
   - **1.1.** studies addressing the classical counterparts of the RO problems of interest in this study, trying to identify solution approaches that can be extended to RO. Since the RO solutions also rely on efficiently solving the classical counterparts, it is also crucial to select the state-of-the-art classical approaches in these cases;
   - **1.2.** literature on disaster relief problems, focusing on solutions modelling uncertainty via RO;
   - **1.3.** most recent trends on mat-heuristics and metaheuristics in general, trying to identify which ones can be adapted to RO cases;
2. **Writing and dissemination of results:** the process of writing scientific material should be performed throughout the Fellowship horizon, in an incremental way, by the time each planned activity is concluded. This continuous process includes (i) preparing and performing public presentations of the results achieved by the research and (ii) the compilation of the results to be submitted to peer-reviewed conferences/journals;
3. **Building test instances**: effort should be dedicated to analysing the data available in the Emergency Events Database (EM-DAT, https://www.emdat.be/) and other sources in order to build test instances to be used in the computational experiments;
4. **Devising and developing solution approaches:** this is a crucial step in the project, consisting of

defining the most promising techniques in the literature that fit the specific needs of the optimization problems addressed. They should be carefully selected (based on the state-of-the-art literature) and adapted to the problems of interest in this study. Also in this phase, the actual development/coding of the algorithms takes place. The idea is to apply, whenever possible, the same general meta and mat-heuristic frameworks to both problems addressed. Accordingly, this phase should be done for the two research directions chosen in an independent way:
   4.1. Mat-heuristic(s);
   4.2. Metaheuristics(s);

5. **Computational experiments:** an extensive set of experiments should be performed to fine-tune and assess the performance of the algorithms proposed at solving the test instances. These experiments should be done separately for the two research directions chosen:
   5.1. Mat-heuristic(s);
   5.2. Metaheuristics(s);
6. **Statistical study of the results:** heuristic solution often rely on non-deterministic algorithmic choices based on probability. For these cases, it is relevant to perform statistical tests (e.g., Wilcoxon, Iman-Davenport and Nemenyi tests) to ensure that the results obtained are statistically significant (i.e., not attributed to chance):
   6.1. Mat-heuristic(s);
   6.2. Metaheuristics(s);

The expected time schedule for the aforementioned activities within the 24-month horizon of the Fellowship is detailed in Figure 1.

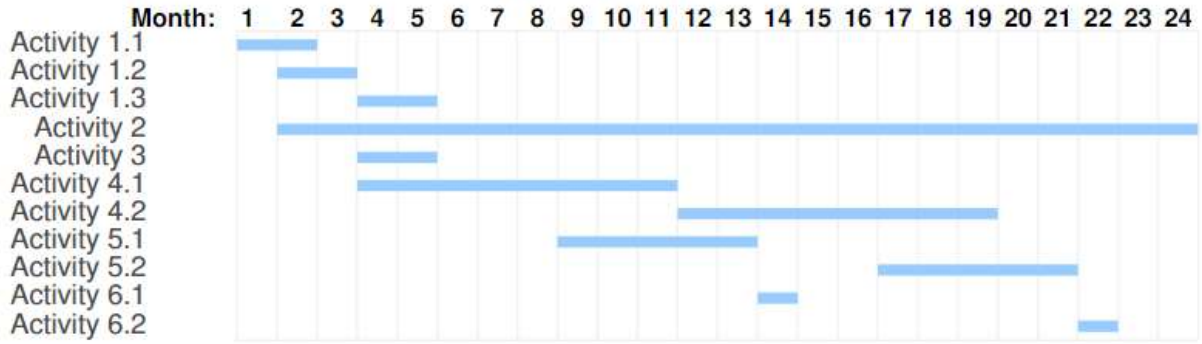

Figure 1. Expected time schedule for the activities planned.

Two types of deliverables are expected as outcome of this project:

- **Software application:** core algorithms devised and experimentally tested in the research. Ideally, at least two algorithms (a metaheuristic and a mat-heuristic) for each research problem to be followed in the project:
  - Mat-heuristic-based algorithms: coded in C++, possibly using ILOG CPLEX (https://www.ibm.com/analytics/cplex-optimizer) or Gurobi (https://www.gurobi.com) as mathematical solvers;
  - Metaheuristic algorithms: coded in C++.

User-friendly interface for input and output of data to/from the application should also be provided (possibly in Python);

- **Research paper(s):** according to the impact of results of the experiments conducted on the algorithms developed, compile the findings in the format of short and full paper(s), to be submitted for publication in appropriate peer-reviewed international conferences and journals.

In practical terms, three main indicators can help assess the success level of the project:

- How many of the activities planned in the programme were finished within the pre-established horizon. In particular, were the planned deliverables actually delivered by the end of the project?
- Do the proposed algorithms outperform the sate-of-the-art literature in terms of time execution speed? Are the favourable results reproducible when considering instances built from real historical data related to natural/industrial disasters?

- Were the resulting research papers submitted/published in journals/conferences of high impact factor?

Regarding resources, there is limited need, as the project relies mainly on computational experiments. As mentioned in Section 2.3, the Host research unit already has the resources needed for my work, which are (i) a powerful grid machine for the computational experiments needed, (ii) physical space for my office, and (iii) a personal computer for coding the proposed algorithms, compiling results and writing the scientific papers.

3.2 Name of the Host Institution and the Host Research unit

The institution and research unit chosen to host this project are *Le Havre Normandy Universite* (ULHN) and *Laboratoire d'Informatique, du Traitement de l'Information et des Systèmes* (LITIS), respectively. In particular, the project fits the scope of *the Réseaux d'interactions et Intelligence Collective* (RI2C) laboratory within LITIS. The ULHN-LITIS-RI2C conducts research on complex systems, focusing on the interactions and collective intelligence of systems. Its researchers study dynamic systems, optimization and logistics, with application in transport, disasters management, among other topics.

2.3 CV – Track Record

The CV-Track record should be limited to a **max 5 pages in total** (incl. list of publications) and should include the standard academic and research record.

Apart from the standard academic and research fields, **please complete the information below by following this template** (in reverse chronological order) and delete the items when non-applicable:

1. *Personal administrative data* (name, first name, date of birth, nationality, reference ID…)
   Name: Assunção de Almeida
   First name: Lucas
   Date of birth: April 18th, 1988
   Nationality: Brazilian
   Passport number: FT521571

2. *Education*
   - Ph.D. Production Engineering | Sept. 2015 – Aug. 2019
     Institution: Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
     Major: Operational Research
     Advisor: Geraldo Robson Mateus
     Project title: Optimization algorithms for the Steiner team orienteering problem
   - M.Sc. Computer Science | Mar. 2013 – Mar. 2015
     Institution: Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
     Major: Operational Research
     Advisor: Thiago F. Noronha | Co-advisor: Andréa Cynthia Santos
     Project title: Optimization algorithms for the restricted robust shortest path problem
   - B.Sc. Computer Science | Jul. 2007 – Dec. 2011
     Institution: Universidade Federal do Ceará, Fortaleza, Brazil
     Global weighted average grade: 9.215/10.0

3. *Current and previous positions (please highlight international and cross-domain experience)*

• **Senior Optimization Data Scientist** | **Arcelormittal**, Espírito Santo, Brazil | Sept. 2022 – present
Description: part of the Advanced Analytics team, responsible for mapping opportunities of process improvement within the steel production plants and devising solutions combining Machine Learning and Optimization.
Technologies: Python, C++, Gurobi, git
• **Senior Optimization Analyst** | **Mercado Livre**, São Paulo, Brazil | Jun. 2021 – Aug. 2022
Description: part of the Shipment Optimization Team (SOT), responsible for planning through optimization algorithms the logistic operations (scheduling, inventory placement, bin packing, first-mile and last-mile transportation, etc) underlying Mercado Livre's e-commerce platform. In particular, I was an analyst in the project of Inventory Placement and my work consists of proposing and developing algorithms for distributing the inbounds through the available facilities/warehouses, while taking into account transportation costs, demand forecasting and capacity restrictions.
Technologies: Golang, C++, CPLEX, git
• **Software Engineer (Optimization) | OMP, Antwerp, Belgium** | Jun. 2020 - May 2021
Description: worked in the support and extension of heuristic solvers developed within the proprietary software for supply chain solutions. I have mainly worked on heuristics to guide and optimize inventory replenishment and reduce overload on machines used for production, while taking into account complex supply chain restrictions, such as allocation/pegging constraints.
Technologies: C++, git, SVN
• **Senior Optimization Consultant** | **OMP**, São Paulo, Brazil | Sept. 2019 - Jun. 2020
Description: responsible for configuring, fine tuning and coding within the OMP's supply chain tool, which integrates all levels of the supply chain — from operational to tactical/strategic decisions. The software has optimization solvers as its core and my main role was to apply Mixed Integer Programming (MIP) fundamentals to model customer-specific constraints used in simulations of cost-profit scenarios.

Technologies: C++ like proprietary programming language, SVN
• **Researcher** | **Universidade Federal de Minas Gerais** | Sept. 2015 - Aug. 2019
Description: design and development of exact and heuristic algorithms for a class of classical routing problems with profit collection, namely orienteering problems. The main contributions of the research are:
* a new cutting-plane algorithm (along with three classes of valid inequalities/logic cuts) able to solve to optimality 15 more instances than any other previous exact algorithm and find eight new optimality certificates;
* proposal of mat-heuristics based on Feasibility Pump and a Large Neighbourhood Search (LNS) heuristic with a long-term memory component based on Path Relinking
Technologies: C++, CPLEX
• **Freelance** Optimization Consultant | **Concert Technologies**, Belo Horizonte, Brazil | Aug. 2016 - Apr. 2017
Description: devised and developed the optimization algorithm called within a tool responsible for planning the pruning of trees interfering with electrical grids in urban areas. The application takes into account resource constraints (such as costs, work horizon, etc) and works on real world city-based networks with up to 6000 electrical posts
Technologies: C++, CPLEX
• **Researcher** | **Universidade Federal de Minas Gerais** | Mar. 2013 - Mar. 2015
Description: design and development of optimization algorithms for robust optimization versions of classical NP-hard combinatorial problems. Two main contributions can be highlighted:
* a linear programming based heuristic framework for a class of min-max regret robust optimization problems. The heuristic improves the bounds obtained by a classical 2-approximation algorithm. While solving two problems in the class, the average bound improvements were up to 20.88% and 29.31%
* the first formal proof of the finite convergence of a widely used logic-based Benders' framework from the literature of robust optimization
Technologies: C++, CPLEX
• **Systems Analyst** | **Database and Systems Laboratory**, Fortaleza, Brazil | Mar. 2012 – Oct. 2012
Description: part of the team responsible for the development of the multi-platform hardware diagnostic tool for laptops and desktop computers manufactured by LENOVO:
* Collaborated on the development of the command line interface of the application, dealing with argument parsing, log generation, concurrency and pipeline buffer synchronization
* Devised and implemented test cases for unit testing the application
Technologies: C++, Google Test C++

4. *Teaching, supervising and mentoring activities*

- Teaching Assistant | Feb. 2017 – Jun. 2017
  Description: assistance in mentoring students enrolled in the course of Convex and Linear Programming, at the department of Production Engineering, Universidade Federal de Minas Gerais, Brazil.
- Teaching Assistant | Feb. 2014 – Jun. 2014
  Description: assistance in mentoring students enrolled in the course of Heuristics and Metaheuristics, at the department of Computer Science, Universidade Federal de Minas Gerais, Brazil.

5. *Scientific evaluation/ reviewing activities*
   - Peer review for international journals:
     - Computers & Operations Research
     - International Journal of Production Research
     - Expert Systems with Applications
   - Peer review for international conference:
     - 4th International Symposium on Combinatorial Optimization, ISCO 2016

6. *Funding received so far*
   • Scholarship | Ph.D. level | Sept. 2015 – Aug. 2019
   Funding agency: Brazilian National Council for Scientific and Technological Development (CNPq)

• Scholarship | M.Sc. level | Mar. 2013 – Mar. 2015
Funding agency: Coordination for the Improvement of Higher Education Personnel, Brazil (CAPES)
• Scholarship | Scientific Initiation level | Apr. 2010 – Dec. 2011
Funding agency: Brazilian National Council for Scientific and Technological Development (CNPq)

7. *10 major publications in peer-reviewed scientific journals, peer-reviewed conference proceedings and/or monographs of their respective research fields, indicating also the number of citations (excluding self-citations) they have attracted*

• Publications in peer-reviewed journals (in reverse chronological order)
– Assunção, Lucas; Santos, Andréa Cynthia; Noronha, Thiago F.; Andrade, Rafael. Improving logic-based Benders' algorithms for solving min-max regret problems. Operations Research and Decisions, v. 128, n. 2, Sept. 2021. Citations (excluding self-citations): 0
– Assunção, Lucas; Mateus, Geraldo Robson. Coupling Feasibility Pump and Large Neighborhood Search to solve the Steiner team orienteering problem. Computers & Operations Research, v. 128, April 2021. Citations (excluding self-citations): 2
– Assunção, Lucas; Mateus, Geraldo Robson. A cutting-plane algorithm for the Steiner team orienteering problem. Computers & Industrial Engineering, v. 135, p. 922-939, 2019. Citations (excluding self-citations): 3
– Assunção, Lucas; Noronha, Thiago F.; Santos, Andréa Cynthia; Andrade, Rafael. A linear programming based heuristic framework for min-max regret combinatorial optimization problems with interval costs. Computers & Operations Research, v. 81, p. 51-66, 2017. Citations (excluding self-citations): 8
– Assunção, Lucas; Santos, Andréa Cynthia; Noronha, Thiago F.; Andrade, Rafael. On the Finite Optimal Convergence of Logic-Based Benders' Decomposition in Solving 0–1 Min-Max Regret Optimization Problems with Interval Costs. In: Cerulli R., Fujishige S., Mahjoub A. (eds) 4th International Symposium on Combinatorial Optimization (ISCO), Vietri sul Mare, Italy, 2016. Lecture Notes in Computer Science, vol 9849. Springer, Cham, 2016. Citations (excluding self-citations): 1
• Proceeding/presentations in international conferences (in reverse chronological order)
– Assunção, Lucas; Santos, Andréa Cynthia; Noronha, Thiago F.; Andrade, Rafael. On the Finite Optimal Convergence of Logic-Based Benders' Decomposition in Solving 0–1 Min-Max Regret Optimization Problems with Interval Costs. 4th International Symposium on Combinatorial Optimization (ISCO), Vietri sul Mare, Italy, 2016
– Assunção, Lucas; Noronha, Thiago F.; Santos, Andréa Cynthia; Andrade, Rafael. A linear programming based heuristic for robust optimization problems: a case study on solving the restricted robust shortest path problem. 5th International Workshop on Model-Based Metaheuristics, 2014, Hamburg, Germany
• Proceedings/presentations in Brazilian conferences
– Assunção, Lucas; Noronha, Thiago F.; Santos, Andréa Cynthia; Andrade, Rafael. Uma Heurística baseada em Programação Linear para o Problema do Caminho Mínimo Robusto Restrito. XLVI Simpósio Brasileiro de Pesquisa Operacional (SBPO), 2014, Salvador, Brazil

2.4 Ethics self-assessment

Please complete the table below and comment if necessary. For full guidelines on each area, please refer to the H2020 ethics self-assessment guide "How to Complete your Ethics Self-Assessment" available at:

http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/ethics/h2020_hi_ethics-self-assess_en.pdf

☒ *"I confirm that I have taken into account all ethics issues described below and that, if any ethics issues apply (any Yes identified in the below table), I will complete an ethics self-assessment document following the H2020 ethics self-assessment guide and attach the required documents to my application."*

		Yes	No
1. Human embryos/foetuses			
Does your research involve Human Embryonic Stem Cells (hESCs)[7]?		☐	☒
If yes :	Will they be directly derived from embryos within this project?	☐	☐
	Are they previously established cell lines?	☐	☐
Does your research involve the use of human embryos?		☐	☐
If yes :	If yes will the research lead to their destruction?	☐	☐
	Does your research involve the use of human foetal tissues/cells?	☐	☐
2. Humans			
Does your research involve human participants?		☐	☒
If yes :	Are they volunteers for social or human sciences research?	☐	☐
	Are they persons unable to give informed consent?	☐	☐
	Are they vulnerable individuals or groups?	☐	☐
	Are they children/minors?	☐	☐
	Are they patients?	☐	☐
	Are they healthy volunteers for medical studies?	☐	☐
Does your research involve physical interventions on the study participants?		☐	☒
If yes :	Does it involve invasive techniques?	☐	☐
	Does it involve collection of biological samples?	☐	☐
If your research involves processing of genetic information, see also section 4.			
3. Human cells/tissues			
Does your research involve human cells or tissues (other than from Human Embryos/Foetuses, i.e. section 1)?		☐	☒
If yes :	Are they available commercially?	☐	☐
	Are they obtained within this project?	☐	☐
	Are they obtained within another project, research unit or institution?	☐	☐

[7] https://ec.europa.eu/research/participants/data/ref/h2020/legal_basis/fp/h2020-eu-decl-fp_en.pdf

	Are they deposited in a biobank?	☐	☐
4. Personal data			
Does your research involve personal data collection and/or processing?		☐	☒
If yes :	Does it involve the collection and/or processing of sensitive personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	☐	☐
	Does it involve processing of genetic information?	☐	☐
	Does it involve profiling, systematic monitoring of individuals or processing of large scale of special categories of data, intrusive methods of data processinges it involve tracking or observation of participants?	☐	☐
Does your research involve further processing of previously collected personal data (secondary use)?		☐	☒
Does your research involve publicly available data?		☒	☐
Is it planned to export personal data from the EU to non-EU countries? (specify the type of personal data and countries involved)		☐	☒
Is it planned to import personal data from the EU to non-EU countries? (specify the type of personal data and countries involved)		☐	☒
5. Animals			
Does your research involve animals?		☐	☒
If yes :	Are they vertebrates?	☐	☐
	Are they non-human primates?	☐	☐
	Are they genetically modified?	☐	☐
	Are the cloned farm animals?	☐	☐
	Are they endangered species?	☐	☐
6. Third countries			
In case of non-European countries are involved, do the research related activities undertaken in these countries raise potential ethics issues? If yes, please specify the countries involved (max 1000 characters): Please notice that "*in case activities undertaken in non-EU countries raise ethics issues, the applicants must ensure that the research conducted outside the EU is legal in France".*		☐	☒
Is it planned to use local resources (e.g. animal; and/or human tissues samples, genetic material, live animals, human remains, materials for historical value, endangered fauna or flora samples, etc.)?		☐	☒
Do you plan to import any material from non-EU countries into the EU? *For data imports, please fill in also section 4.* *For imports concerning human cells or tissues, fill in also section3.* If yes, please specify the material and countries involved (max 1000 characters):		☐	☒
Do you plan to export any material from non-EU countries into the EU? *For data exports, please fill in also section 4.* *For exports concerning human cells or tissues, fill in also section3.* If yes, please specify the material and countries involved (max 1000 characters):		☐	☒
In case research involves low and/or lower-middle income countries, are any benefit-sharing actions planned?		☐	☒

7. Environment, and health and safety		
Does your research involve the use of elements that may cause harm to the environment, to animals or plants? *For research involving animal experiments, please fill in also section 5.*	☐	☒
Does your research deal with endangered fauna and/or flora and/or protected areas?	☐	☒
Does your research involve the use of elements that may cause harm to humans, including research staff?	☐	☒
8. Dual use		
Does your research involve dual-use items in the sense of Regulation 428/2009[8], or other items for which an authorisation is required?	☐	☒
9. Exclusive focus on civil applications		
Could your research raise concerns regarding the exclusive focus on civil applications?	☐	☒
10. Misuse		
Does your research have the potential for misuse (malevolent/criminal/terrorist abuse,..) of research results?	☐	☒
11. Other ethics issues		
Are there any other ethics issues that should be taken into consideration? If so, please specify (max 1000 characters):	☐	☒

If you have entered any issues in the ethics issue table, **you must perform an ethics self-assessment in accordance with the guidelines "How to Complete your Ethics Self-Assessment" and complete the table below.**

Ethical dimension of the objectives, methodology and likely impact
Explain in detail the identified issues in relation to: – objectives of the activities (e.g. study of vulnerable populations, etc.) – methodology (e.g. clinical trials, involvement of children, protection of personal data, etc.) – the potential impact of the activities (e.g. environmental damage, stigmatisation of particular social groups, political or financial adverse consequences, misuse, etc.) N/A.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32009R0428

Compliance with ethical principles and relevant legislations
Describe how the issue(s) identified in the ethics issues table above will be addressed in order to adhere to the ethical principles and what will be done to ensure that the activities are compliant with the E U / national legal and ethical requirements of the country or countries where the tasks are to be carried out. Please join any necessary supporting documents via the "other documents" annex. N/A.