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An orienteering-based approach to manage emergency situation

Ilaria Baffo [a], Pasquale Carotenuto [b,*], Stefania Rondine [b]

[a]*DEIM – Industrial Engineering School, University of Tuscia, Largo dell'Università snc, 01100 Viterbo, Italy*
[b]*Consiglio Nazionale delle Ricerche - Istituto per le Applicazioni del Calcolo "M. Picone", via dei Taurini 19, Roma - 00185, Italy*

Abstract

The emergencies management in industrial plants is an issue widely discussed in the literature and in the European legislative framework. Despite the large interest shown by the different actors involved in emergencies management, neither scientific nor in industrial field, have developed intelligent tools to support the decisions in these particular contexts. This work, realized inside an Italian financed project (DIEM-SSP), faces the problem to evacuate the greater number of persons from a risky area and transfer them in a unique destination outside from this area using the available and limited resources. Supposing that these persons have problem of mobility, the problem to solve becomes this: collect the highest number of persons from several origins and bring them into a unique destination, using a limited number of capacitated vehicles respecting a time limit. This problem has been modelled as a Multi origins Capacitated Team Orienteering Problem (Mo-CTOP) and solved implementing Ants Colony Optimization algorithm (ACOa). Results and tests are given in order to validate the proposed model and to offer a solution for a real case treaty into the abovementioned project.

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Keywords: Routing; Orienteering; Metaheuristic; Ant Colony Optimization; Emergency

1. Introduction and literature review

The paper focuses on the complex issues arising from emergencies management in industrial plants. The problem is faced from disaster manager's point of view. Often in the tackled scenario – industrial disasters - the human behaviors play an important role and they are hard to manage and simulate. For this reason, the coordinator's role is crucial for a successful resolution of the emergency. The scientific literature offers several techniques and approaches for helping the coordinator but often these are hard to implement or little useful in real context. To remedy this lack, the authors offer, in this work, a Decision Support System (DSS) for the problem of people's

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evacuation. In Italy, the civil protection is the government entity in charge of managing this kind of emergencies, both for industrial and natural disasters. Usually the coordinator's role of several rescue teams is hired by this entity. The lack of intelligent tools and adequate communication protocols, often represents the greatest barrier toward an efficient resolution of the emergency. Given the impossibility to include all the variables of the rescue process, this paper focuses on a particular problem: evacuate the highest number of persons with little mobility from a hazardous area in the shortest period of time. In particular, the problem includes the question relative to collect persons with problem of mobility in several emergency vehicles coming from different origins and headed to single destination (first aid area).

Operation Research (OR), from long time, faces problems relative to emergency states and healthcare. The literature is rich of contributions on problems like Assignment of rescue teams by Zheng et al. (2015), and by Wex et al. (2014), Scheduling of nurses' shifts proposed by Dowsland (1998), operations of people's evacuation faced by Sbayti and Mahmassani (2006). The authors propose in this work a re-solution approach for the route planning applying a variant of the Orienteering Problem (OP) or the Team Orienteering Problem (TOP) capacitated, as previously made by others researchers like Rath and Gutjahr (2014). Usually, the OP like defined by Chao et al. (1996) and Vansteenwegen et al. (2011) is modelled as follows: several locations with an associated score have to be visited only once in order to obtain a total trip score, generally the problem is formulated with one origin and one destination. The objective is to obtain a total trip score as high as possible without violating a time restriction. On the other hand, the Team Orienteering Problem (TOP) proposed by Chao at al. (1996) and Archetti et al. (2007) is an OP where the goal is to determine the path for each team member, each limited by a maximum time and oriented to maximize the total score collected by the team. Also for the TOP, the formulation of the problem foresees unique origin and unique destination for all teams. To apply the orienteering approach in this context, means to assign a score for each collected person and do so within a certain period of time. In the team orienteering problem, each available vehicle is assigned to an itinerary of visits so as to maximize the total profit. But, differently to actual literature, the proposed model foresees the possibility to have more origins and one destination. Therefore, the proposed optimization model represents a decision support tool for the civil protection in case of disaster, useful to plan the evacuation routes based on the position of people, availability of vehicles, time of evacuation, m points of origins and one final destination (shelter). The real utility and application of these models is possible thanks to the development of ad-hoc heuristics as for example a Tabu search developed in Tang and Miller-Hooks (2005). The authors have projected to face the orienteering problem, implementing two meta-heuristics based on evolutionary algorithms, which are the Genetic Algorithm (GA) and the ACOa. In this work the implementation and the results of the last one are presented. ACOa was proposed by Marco the Dorigo in 1992 in his PhD thesis and better detailed in Dorigo and Blum (2005). ACOa is inspired in the pheromone trail left by the ants in the foraging. The ants use pheromones as a communication medium, the algorithm is based on this indirect communication. The pheromone trails in ACOa are used as information which ants probabilistically adopt to construct solutions of the problem. This algorithm aims to search an optimal path in a graph, based on the behaviour of ants seeking a path between their colony and a source of food. The original idea has been then diversified to solve a wider class of numerical problems including the one here discussed.

Others applications of ACOa are successfully presented in literature for solving orienteering problems, the most of these are works of Montemanni and Gambardella, Montemanni and Gambardella (2009). There are also contributions of ACOa applications in the field of emergencies and disaster relief operations. In Yi and Kumar (2007), for example, is faced the problem of dispatching commodities to distribution centers in the affected areas and evacuating into two phases decision making: the vehicle route construction and the multi-commodity dispatching. In this paper an ACOa is implemented, tested and compared in order to understand the limitations and opportunities offered by this approach to solve the faced problem into real situations, with capacitated constraints of vehicles and different origins of departure of them.

The validation of the designed algorithms is conducted preliminary thank to tests made on known instances. For small instances of the problem is also possible to compare the solutions obtained by this heuristic algorithm with results obtained thanks to Cplex Optimizator, implemented in IBM Ilog Opl or Solver Studio for Excel.

The scenario for the real application comes from a test case selected into a national research project financed by founds "PRIN" of MIUR and called DIEM-SSP, Disasters and Emergencies Management for Safety and Security in industrial Plants. This issue is dealt with in a long time, in Europe for example, the use of the number 112 was