Responses to the Comments of Dr. Imreh Csanád on the PhD Dissertation, "On Modeling Building-Evacuation-Route Planning and Organization-based Multiagent Systems by Resorting to the P-graph Framework," by Juan C. Garcia-Ojeda

The author is grateful to Dr. Csanád for the time he invested in reading and reviewing the dissertation. His comments appear in section "My questions concerning the dissertation" on page 3 of his review, which have been addressed in what follows.

Comment 1: "I have no questions concerning the technical details of the work, but I have some general questions mainly concerning the building evacuation route planning part. It seems for me that in this problem usually there are some uncertainty in the input data (the possible routes, the number of people). [(a)] Are their methods handling this uncertainty and looking for robust solutions? [(b)] Do you think that the model of the robust PNS problem could be used here? I think that in both problems studied in the dissertation more objective functions could be defined. [(c)]Are there models which use multi-objective optimization to solve these applied problems? [(d)]Do you think that the transformation to the PNS framework can be also useful in case of multiple objective functions?"

Response to Comment 1, Question (a): The author believes that the work by Han *et al.* (2010) cited in the original dissertation addresses Dr. Csanád's concern. This contribution indicates that building evacuation route planning is becoming increasingly robust due to the availability of: (i) advanced forms, or methods, of computation for supporting the response to large-scale emergencies, and (ii) innovative technologies deploying sensors for gathering data in real-time to create both predicting and inferring evacuation models. In regards to the latter, one of such innovative technologies is the Internet of Things (IoT) (see e.g., Cecchinel *et al.*, 2014; Yin and Jiang, 2014). Recent experiences show that building fire-safety models based on IoT technology have at least three advantages over traditional

models (Shekhar *et al.*, 2012): (i) IoT models can make a more timely collection of information; (ii) they can analyze information dynamically; and (iii) they can provide the best rescue plan. In light of the aforementioned arguments, the author's future work will incorporate the principles underlying the IoT technology for developing robust solutions that minimize uncertainty in planning building-evacuation routes.

Literature Cited

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Response to Comment 1, Question (b): Yes, the author agrees with Dr. Csanád's on that the model based on the P-graph framework of the robust PNS problem could be deployed for building evacuation route planning. In this regard, the author hypothesizes that the combination of the P-graph framework with IoT technology could give rise to superior systems for building evacuation route planning: The IoT technology would allow the collection of input data in real time,

thereby rendering the corresponding PNS problems based on P-graphs exceedingly dynamic.

Response to Comment 1, Question (c): Yes. In fact, recent contributions in the literature have addressed both problems by adopting multi-objective optimization techniques or models (see e.g., Kou et al., 2013; Merkel et al., 2014; Yliniemi, 2014; Ikeda and Inoue, 2016; Roehr and Kirchner, 2016). Regarding the evacuation route problem, authors are mostly interested in multi-objective functions that minimize the total evacuation time, the evacuation route length, and the cumulative congestion degree (Kou et al., 2013; Merkel et al., 2014; Ikeda and Inoue, 2016). With respect to the organization-based multiagent systems, the authors are mostly interested in multi-objective functions that minimize the number of agents' coalitions (agents' grouping) as well as the number of agents' goal assignment (efficient goals' assignment).

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Response to Comment 1, Question (d): Yes. The P-graph framework offers a rigorous methodology for designing networks by using directed graphs (Vance *et al.*, 2014; 2015). Such a methodology has been employed for solving various problems in diverse domains of science and technology, which have been formulated as PNS instances (Vincze *et al.*, 2016). This argument is also validated in the author's dissertation where both problems, building evacuation route planning and organization-based multiagent systems, have been solved by resorting to the P-graph framework. Moreover, there exists evidence that both problems have been addressed by adopting multi-objective optimization techniques or models as elaborated in the preceding response. In addition, Vance *et al.* (2015) present the combination of P-graph and multi-objective optimization techniques, e.g., Pareto frontier, for solving sustainable supply chain problems where more than one objective function is defined (e.g., cost, ecological footprint, and emergy). Consequently, this evidence opens a discussion whether PNS in light of the P-graph framework can also be useful when deploying multi-objective functions related to the problems considered by the author in his dissertation, which will be investigated in the author's future efforts.

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