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Optimizing Decisions in Disaster Occurrence Situations

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Abstract. Under the context of maritime catastrophe, we revisit some previous work that contributed to build a design support system to better optimize the decision chain. We overview some interesting literature and focus our work in Delphi method approach, used in the collection of information about the tasks per team and to prioritize teams to enter in action. The study considered the facilities and high qualified staff (experts) of Portuguese Navy. Taking into consideration that Delphi method, where the opinion of each element of a team is considered an important information source to contribute to a decision, giving a certain specific weight per expert profile, and it is developed in successive rounds and evaluating the partial or full consensus between experts, we can refine some details, such as the way how the experts opinion contribute and how is verified the consensus. In the decision-making process, the possible refinement can contribute to optimal decisions.

INTRODUCTION

In the context of naval operations, the project THEMIS, promoted by Portuguese Navy, aimed to build a DSS to handle with disaster relief operations, where responders receive information about the incidents, the tasks to execute, the guidelines about navigation to incidents and how to perform the tasks. We can find in literature some contributions to the same problem, applying different techniques. For example, in [1, 2, 3] some applications using augmented reality were built to support different types of naval operations. In [4, 5, 6, 7] is illustrated the use of augmented reality for learning naval operations. An approach by user experience design in naval context can be found in [8]. To improve the planning and execution efforts in disaster and crisis' scenarios was built a system used to handle complex tasks like emergency response operations' coordination and execution. This system got the benefits of usability principles. Users preferences and expectations were took into account during the steps of conceptualization, design and implementation of this emergency management intelligent system, aiming to support disaster response operations. The authors of [9] suggest to allow trainees to exploit augmented reality interaction and become quickly familiar with the mobile technology adopted today in emergency response activities. In this situation, the training efficacy is improved optimizing on-site crisis preparedness activities. In [10] the authors focused in smart Innovation, systems and technologies under the topics of knowledge, intelligence, innovation and sustainability. The principal idea is embed systems with knowledge and intelligence to solve world problems in industry, environment, naval environment innovation strategies employed to make this happen effectively. The authors that contributed to [11] contemplate a wide number of topics and challenges of dealing with disaster risk reduction. Between others we evidence the topics that consider big data, cloud computing, the internet of things, natural disasters, mobile computing, emergency management, disaster information processing, disaster risk assessment and management, and disaster management simulation. In [12] is made an overview of the crisis intervention model. The task-centred model and crisis intervention share principles and methods drawn from problem-solving theory.

Summarizing, the main objective of the present work is to evidence some details about how was built and implemented a decision support system (DSS) with the ability: (a) to prioritize certain teams for specific incidents taking into account the importance of each team that acts in case of emergency; (b) to define the sequence of tasks that should perform all possible orders to be given. To project and implement such system we have considered the facilities and high qualified staff of Portuguese Navy. We have chosen a commonly used approach in forecasting studies, the Delphi method (DM), adequate to get consensus between a group of experts [13, 14, 15, 16].

The summary of this work consists in an introduction and some final remarks Sects., Sect. 2 contains some considerations about DM concept and algorithm. In Sect. 3. is explored the empirical application, namely the used data is described and some numbers are displayed. The final remarks can be found in sect. 4.

METHODOLOGY

In this section we will focused about Delphi method, a method that is exceptionally useful where the judgments of individuals, accordingly with [13], are needed to *"address a lack of agreement or incomplete state of knowledge (...) the Delphi is particularly valued for its ability to structure and organize group communication"*.

The Delphi method application can be found in numerous distinct areas: Natural sciences [13, 17, 18, 19, 20, 21]; paper pulp production [22]; automotive supply chain [23, 24]; transportation [25]; education [21, 26, 15, 27]; environmental science and policy [28, 29]; social sciences [30, 16, 31, 32]. The DM is a structured process for collecting and summarizing knowledge of a group of experts from a given area through several phases of questionnaires, with organized feedback [32]. It has the advantage of avoiding the problems associated with evaluation techniques based on traditional group opinions, such as Focus Groups, that may create problems of bias in responses due to the presence of opinion leaders [16].

It was built a survey about the existing emergency teams as well as all possible tasks (orders) in case of emergency. Meetings with navy officers with large experience in emergency cases, some documents/memos were collected and analyzed, some exercises were performed and all details registered. Direct observation of a simulation (DISTEX - an exercise of a catastrophe in which humanitarian aid) was required. Subsequently, the data collected was organized and validated by a Lieutenant Captain and Rear Admiral, with large experience in catastrophe situations.

EMPIRICAL APPLICATION

The potential group of experts were inquired about some individual characteristics of their profile: age, gender, professional rank, training class, type of experience in response to disasters (real versus train exercise), total ship boarding time (less than 1 year, 1-3 years, 3-5 years, more than 5 years). The experts were all males, at least with 5 years on board, aged between 35 and 54 years, Captain-lieutenant, Captain-of-sea-and-war and Captain-of-frigate (the most common), 25% have real past experience of disaster response, 75% are training experienced. The first round of DM required the identification the level of priority that each team should carry out each task. A Likert scale of importance from 1 (Not Important) to 6 (Extremely Important) for all possible tasks to be carried out during a humanitarian disaster operation for each existing team that can provide its service. The level of priority that each team should carry out each task: questionnaire with a Likert scale of importance from 1 (Not Important) to 6 (Extremely Important) for all possible tasks to be carried out was also required. A total of 572 questions considering 52 tasks and 11 teams were filled. To identify the tasks that reached consensus, the inter quartile range (IQR) was chosen as measure of consensus: when IQR less than 1 means that more than 50% of the responses are within 1 point of the Likert scale. For each task, it was considered a weighted mean based on the experience of each expert. At the end of first round, between 572 questions there was no consensus on 290 questions (50.7%); 282 questions had IQR higher than 1; 8 questions did not meet the requirements. At round 2, were considered 290 questions, 265 (91.4%) reached a consensus. At third round were considered 25 questions. A simultaneous interview with two respondents (two experts in last round were Commanders with the Captain-of-the-Frigate position used to coordinate and develop training and training actions, such as the DISTEX exercise, a simulation of a natural catastrophe) was scheduled with the objective of defining the final result of the tasks. The validation of all the answers obtained in previous rounds in order to identify possible errors was also performed. In Fig. 1 is summarized the Delphi method approach. An extension of this work can be found in [33] where some interesting details are explored and displayed. In [34, 35] are proposed some refinements, namely the weights of experts response are computed by similarity of the individuals using multidimensional scaling.

FINAL REMARKS

In the present manuscript we performed an overview about the construction of a DSS to use in an environment of a maritime disaster. We have updated the state of art and illustrated how we could organize the teams and how to get

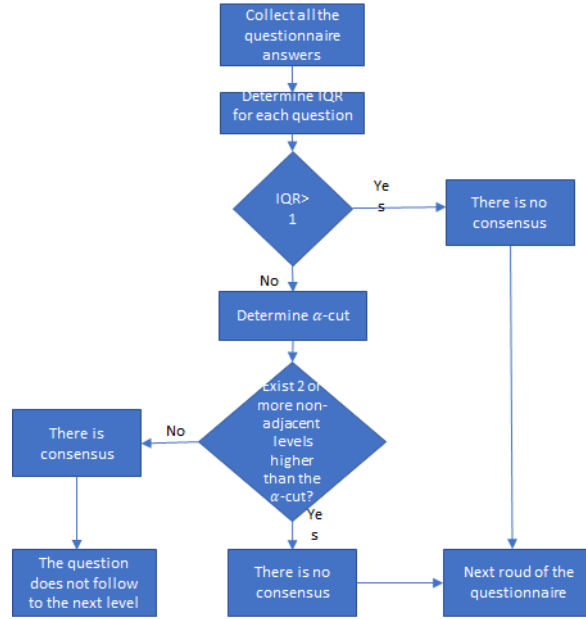


FIGURE 1. Delphi method approach.

the prioritaire order of teams and actions. As future work, we intend to refine the DSS, studying the effect of other dispersion measures than the inter quartile range to classify the consensus/no consensus. These idea is seen as an extension of the work [33, 34, 35] that we expect successfully contribute to optimize the chain decision.

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REFERENCES

- [1] M.J. Marques, F. Elvas, I.L. Nunes, et al., Augmented Reality in the Context of Naval Operations, In: T. Ahram, W. Karwowski, R. Taiar (Eds.), *IHSED 2018, AISC 876*, 307-313 (Springer, Cham, 2019).
- [2] I.L. Nunes, R. Lucas, M. Simões-Marques, N. Correia, Augmented reality in support of disaster response, In: I.L. Nunes (Eds.) *Proc. Advances in Human Factors and System Interactions, AHFE 2017, AISC 592*, 155-167 (Springer, Cham, 2018).
- [3] I.L. Nunes, R. Lucas, M. Simões-Marques, N. Correia, An augmented reality application to support deployed emergency teams, In: S. Bagnara, R. Tartaglia, S. Albolino, T. Alexander, Y. Fujita (Eds.). *Proc. 20th Congress of the Inter. Ergonomics Association, IEA 2018, AISC 822*, 195-204 (Springer, Cham, 2019).
- [4] A. Correia and V. Conceição, Survey on Augmented Reality Technologies for Naval Training, 2019 14th Iberian Conf. Information Systems and Technologies (CISTI), 1-6 (IEEE, Coimbra, 2019).
- [5] A. Correia, A. Gonçalves, M. Zacarias, Using Augmented Reality for Learning Naval Operations. In: Á. Rocha, R. Pereira(eds), *Developments and Advances in Defense and Security. Smart Innovation, Systems and Technologies, SIST 152*, 475–485 (Springer, Singapore, 2020).
- [6] A. Correia, P. B. Água and T. Luzes, Virtual Reality for rescue operations training, 2021 16th Iberian Conf. Information Systems and Technologies, CISTI2021, 1-6 (IEEE, Chaves, 2021).
- [7] F. Elvas, *Realidade Aumentada Aplicada a Panoramas Táticos*, (Naval Academy-Univer. Military Institute, Almada, 2018).

- [8] M.J.S. Marques, A. Correia, M.F. Teodoro, Isabel L. Nunes , Empirical studies in user experience of an emergency management system, In: I.L. Nunes (Eds.). Proc. Conf. Human Factors and System Interactions, AHFE 2017, AISC , 7-108 (Springer, Cham, 2018).
- [9] M. Sebillio, G. Vitiello, L. Paolino, et al. Training emergency responders through augmented reality mobile interfaces. *Multimed Tools Appl*, **75**, 9609–9622 (2016).
- [10] IOT with Smart Systems, In: J. Choudrie, P. Mahalle, T.Perumal, A. Joshi (eds), IOT with Smart Systems, Proc. ICTIS 2022, Smart Innovation, Systems and Technologies, SIST **312** (Springer, Singapore, 2023).
- [11] Information Technology in Disaster Risk Reduction, First IFIP TC 5 DCITDRR International Conference, ITDRR 2016, Sofia, Bulgaria, November 16–18, 2016, Y. Murayama, D. Velev, P. Zlateva, J.J. Gonzalez (Edts), (Springer, Cham, 2017).
- [12] B.M. Ramos, R.L. Stetson, Problem-Solving Theory: The Task-Centred Model, In: D. Hölscher, R. Hugman, D. McAuliffe (eds.). *Social Work Theory and Ethics. Social Work.* (Springer, Singapore, 2022).
- [13] C. Powell, The Delphi technique: Myths and realities. *Meth Issues Nursing Research*, **41(4)**, 376–382 (2003).
- [14] L. Reuven, H. Dongchui, Choosing a technological forecasting method, *Ind. Manag.*, **37(1)**, 14–22 (1995).
- [15] G. Rowe, G. Wright, The Delphi technique as a forecasting tool: issues and analysis. *Int. j. forecasting*, **14(4)**, 353–375 (1999).
- [16] J.G. Wissema, Trends in technology forecasting. *Research and Development Manag.* **12(1)**, 27-36 (1982).
- [17] P. Nasa, R. Jain, D. Juneja, Delphi methodology in healthcare research: How to decide its appropriateness, *World J Methodol.* , 2021 Jul 20; **11(4)**, 116–129 (2021).
- [18] S. Keeney, H.A. McKenna, F. Hasson, *The delphi technique in nursing and health research* (Wiley, 2011).
- [19] A. Quartiroli, R.D. Wagstaff, Practitioners in search of an identity: A Delphi study of sport psychology professional identity, *Psychology of Sport and Exercise*, **71** (2024).
- [20] M. Spitschan, L. Kervezee, R. Lok and et al, ENLIGHT: A consensus checklist for reporting laboratory-based studies on the non-visual effects of light in humans, *eBioMedicine*, **98** (2023).
- [21] E. De Vet, J. Brug, De Nooijer, J., et al., Determinants of forward stage transitions: a Delphi study. *Health Education Research* **20(2)**, 195–205 (2005).
- [22] M.Fraga, A economia circular na indústria portuguesa de pasta, papel e cartão, Master dissertation, (FCT-Univ. Nova de Lisboa, Almada, 2017).
- [23] S.G. Azevedo, H. Carvalho, V.C. Machado, Agile Index: Automotive Supply Chain. *World Academy of Science, Eng. and Technology*, **79**, 784–790 (2011).
- [24] S.G. Azevedo, K. Govindan, H. Carvalho, V.C. Machado, Ecosilient Index to assess the greenness and resilience of the up stream automotive supply chain, *J. Cleaner Production*, **56**, 131-146. (2013).
- [25] Y. Duvarci, O. Selvi, O. Gunaydin, G. GÜR, Impacts of Transportation Projects on Urban Trends in İzmir. *Teknik Dergi*, **19(1)**, 4293–4318 (2008).
- [26] J. Osborne, S. Collins, M. Ratcliffe, R. Millar, R. Duschl, What “ideas-about-science” should be taught in school science? a delphi study of the expert community. *J. Res. Sci. Teach.*, **40(7)**, 692–720 (2003).
- [27] G. Skulmoski, F. Hartman, J. Krahn, The Delphi method for graduate research. *J. information tech. educ.*, **6**, 1–24 (2007).
- [28] D.A. Potts, J.S. Ferranti, J.D. Vande Hey, Investigating the barriers and pathways to implementing satellite data into air quality monitoring, regulation and policy design in the United Kingdom, *Environmental Science and Policy*, **151** (2024).
- [29] H. Brunt, J. Barnes, J. Longhurst, et al., Enhancing local air quality management to maximise public health integration, collaboration and impact in wales, uk: a delphi study, *Environ. Sci. Policy*, **80**, 105–116 (2018).
- [30] J. Landeta, Current validity of the Delphi method in social sciences, *Technological Forecasting and Social Change*, **73(5)**, 467–482 (2006).
- [31] H.M. Gunaydin, *Impact of Information Technologies on Project Management Functions*, Ph.D. dissertation, (Chicago Univ., Chicago, 1999).
- [32] M. Adler, E. Ziglio, *Gazing into the Oracle: The Delphi method and its application to social policy and public health*, (Kingsley Publishers, London, 1996)
- [33] M. Simões-Marques and et al., Applying a Variation of Delphi Method for Knowledge Elicitation in the Context of an Intelligent System Design, In: I.L. Nunes (Eds.). Proc. Human Factors and System Interactions, AHFE 2019, AISC **959**, 386–398 (Springer, Cham, 2020).
- [34] M.F. Teodoro, M.J.S. Marques, I. Nunes, G.Calhamonas, M.A.P. Andrade. Using MDS to Compute the Contribution of the Experts in a Delphi Forecast Associated to a Naval Operation’s DSS. In: O. Gervasi et al., *Computational Science and Its Applications, ICCSA 2020, LNCS 12251* (Springer, Cham, 2020).
- [35] M.F. Teodoro, M.J.S. Marques, I. Nunes, G. Calhamonas, M.A.P. Andrade, New Refinement of an Intelligent System Design for Naval Operations. In: J. Machado, F. Soares, J. Trojanowska, S. Yildirim, (Eds.), *Innovations in Mechatronics Eng., LNME* , 164–177 (Springer, Cham, 2022).