



Central European journal of operations research (CJOR) “operations research applied to health services (ORAHS) in Europe: general trends and ORAHS 2020 conference in Vienna, Austria”

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Accepted: 13 November 2021 / Published online: 10 December 2021
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Abstract

This article provides a short summary of the research topics and latest research results of the European Working Group “Operations Research Applied to Health Services” (ORAHS) organized as an e-conference in July 2020 at the University of Vienna, Austria (<https://orahs2020.univie.ac.at/>). Furthermore, challenges for OR in health care including application areas, decision support systems, general trends, and modelling techniques are briefly illustrated from an European and international perspective by providing selected essential literature reviews.

Keywords Strategic health care management · Health economics · Health care workforce scheduling · Health care operations management · Disease policy modelling · Emergency medical services

Mathematics Subject Classification 90-02

1 Introduction

Health care around the world is facing unprecedented challenges due to global development. There are ongoing technological advances in health care but they are not affordable for everyone (Amiri et al. 2021). Migration and displacement pose one of the most significant humanitarian challenges (Bozorgmehr et al. 2020). The changing population structure in many developed countries requires new approaches and solutions for health care (Rouzet et al. 2019). The slowdown in economic development in

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some countries around the world is also putting public health budgets under pressure (Karanikolos et al. 2016). Climate change and political instability are increasingly affecting the health sector (Watts et al. 2020). As epidemics such as the current corona virus disease (COVID)-19 as well as various natural and man-made disasters pose particular threats, the health care sector must prepare for them urgently (e.g., Sharma et al. 2021; Makwana 2020). Health care policy makers are therefore forced to provide high quality services with tight budgets and a limited workforce by taking ethical issues into account. For this, policy makers need decision support by qualitative and quantitative Operations Research (OR) approaches as well as decision support systems (DSS) in order to prepare for these challenging situations by providing solutions for simple to even extreme scenarios.

To cope with health care challenges, the **EURO Working Group on Operational Research Applied to Health Services (ORAHS)** was formed in 1975 as part of a program for developing special interest groups within the European branch, EURO, of the International Federation of Operational Research Societies, IFORS (<http://orahs.di.unito.it/about.html>). The group has currently more than 330 members from more than 30 countries, mainly from Europe but also from overseas (e.g., USA, Canada, and Australia). The group meets for a week each summer in a different, mainly European, host country to discuss 140 talks and tens of posters on average. The objectives of the group are to impart ideas, knowledge and experience on the application of OR approaches and methods to problems in the health services area, mutual support of members, co-operation on joint projects and stimulation of approaches and attitudes in the field of applied Operational Research.

The ORAHS group has been very active which is also represented by several special issues in international scientific journals related to the yearly meetings (e.g., Rauner and Vissers 2003, Davies and Bensley 2005, Brailsford and Harper 2007, Dexter 2009, Xie et al. 2010, Aringhieri et al. 2013, 2016a, 2016b; Hans and Vliegen 2014, Çayırılı 2015, Mallor et al. 2018) as well as special issues and review papers on general trends in applications of OR in the health care sector (e.g., Rauner et al. 2005, Harper and Baker 2005, Brailsford and Harper 2008, Brailsford et al. 2009, Rais and Viana 2010, Brailsford and Vissers 2011, Brailsford et al. 2012, Weber et al. 2014, Morton et al. 2016, Royston 2016, Morton et al. 2021). Furthermore, several books edited by group members appeared over the last 20 years (e.g., Brandeau et al. 2004, Vissers and Beech 2005, Ozcan 2005, Zaric 2013, Brailsford et al. 2014, Carter et al. 2018, Kahraman and Topcu 2018, Masmoudi et al. 2021). Furthermore, the group members are actively involved in editorial boards of national and international OR societies. Finally, journals were established by efforts of our members such as *Operation Research for Health Care* (Elsevier), *Health Systems* (Taylor & Francis), and *Health Care Management Science* (Springer).

In 2020, the 46th meeting was virtually organized as a zoom conference at the University of Vienna, Austria (<https://orahs2020.univie.ac.at/>) due to the COVID(corona virus disease)-19 pandemic. More than 150 participates contributed with more than 100 scientific papers including two outstanding keynotes, a round table on prevention, a COVID-19 policy modelling session, and two sessions of the working group on health care and disaster management of the Austrian OR Society (ÖGOR), <https://oegor-hcdm.univie.ac.at/>.

This issue of the Central European Journal of Operations Research reflects some selected contributions on key health care policy problems that cover a variety of application areas, topics, and modelling techniques applied from the members of ORAHS presented/discussed at this meeting as exemplarily outlined in Sects. 2 to 6. We furthermore briefly outline trends for further research in this area.

2 Strategic health care policy making

Strategic health care management covers a wide range of application areas such as the establishment of health care systems/networks, as well as evaluation of health care programs and prevention strategies in which OR policy modelling plays an important role as illustrated at ORAHS 2020 (<https://orahs2020.univie.ac.at/>).

In the session on health care networks at ORAHS 2020, Brailsford et al. (2020a) outlined the importance of OR methods in decision making in health care and social care by overcoming barriers of implementation illustrated on a case study from the National Health Service in the United Kingdom. Tuson et al. (2020) assessed an Adverse Childhood Experiences program for Public Health Wales by using simulation and statistical analysis. Aspland et al. (2020) introduced to Sim.Pro.Model which is a useful tool for modelling, simulating, and visualizing clinical pathways as shown on a case study for supporting decision making at a Walsh cancer center. Vasilakis and Wood (2020) developed an open-source simulation tool to account for the requirements of end-users to help overcome poor uptake of OR in health care illustrated on the centralization of an acute stroke pathway.

Next, in the session on behavioral OR & policies in health care at ORAHS 2020, Oliveira et al. (2020) showed how important it is to involve stakeholders to develop OR tools for better health care policy making by using the Delphi method. Kazakov et al. (2020) investigated external reference pricing methods to improve drug access, affordability, and availability in the EU by using a hybrid agent-based and system dynamics simulation model to account for the behavior of essential market actors. Barrera Ferro et al. (2020) applied a Health Belief Model to explore the reasons for no-show behaviour in a cervical cancer screening program among low-income patients in Bogotá, Colombia to further improve an outreach program by using simulation.

In the session on health care modelling in developing countries at ORAHS 2020, Duque-Urbe et al. (2020) explored rules for advancing sustainability of supply chain management in hospitals. Chandra and Vipin (2020) analyzed well-performing supply contracts for a better provision of a rota virus immunization program in India by using mathematical models and expert opinions. Potgieter and Matter (2020) reported on improving epidemic response in the context of rural insufficient and unstable road infrastructure using a disease policy model and resource allocation techniques.

Furthermore, in the session on machine learning approaches applied to health care to better plan for and improve patient treatment at ORAHS 2020, interesting case studies were presented by colleagues from all over the world such as Koc University, Turkey (Demiray et al. 2020), Laboratoire Génie Industriel, CentraleSupélec, Gif-sur-Yvette, France (Santamaria-Acevedo 2020), and Stanford University, USA (Brandeau 2020).

Finally, one of the highlights of the e-conference was the “Round Table on Challenges in Health Care Prevention” which was moderated by Prof. Bernhard Schwarz from Medical University of Vienna, Austria who is also the head of the Karl Landsteiner Society, Austria. The further panalists included: Sally Brailsford (University of Southampton, UK), Margaret Brenadeau (Stanford University, USA), and Alexandra Schosser (BBRZ Med GmbH, Austria). They lively discussed areas of general prevention strategies, cancer prevention, psychiatric prevention, as well as COVID-19 prevention strategies with the e-audience.

In this special issue of CJOR, an health economic study entitled “The Benefit of an Ambulant Psychiatric Rehabilitation Program in Vienna, Austria: an Uncontrolled Repeated Measures Study” (Schosser et al. 2021) is included which was briefly presented in the round table session on prevention. The authors compared the effectiveness and cost measures of a ambulant psychiatric rehabilitation program on patients for the period of up to 12 months after discharge to the period of 12 months before admission to the intervention program based on self-reported catamnesis questionnaires using suitable statistical analyses in Vienna, Austria. The most important finding was that such an prevention program was especially beneficial for rehabilitation patients in earlier stages of psychiatric diseases who were still employed, indicating the need for early intervention in mental disorder.

To summarize, policy maker involvement in the development of applied OR models (e.g., Shetaban et al. 2020, Capan et al. 2017, Hulshof et al. 2012), behavioral OR (e.g., Brailsford et al. 2020b; Kunc et al. 2020; Donohue et al. 2018), hybrid OR modelling techniques (e.g., Brailsford et al. 2019; Xu et al. 2015), machine learning and data mining approaches (e.g., Ben-Israel et al. 2020; Malik et al. 2018), and sound prevention strategies (e.g., Silal 2021, Kong and Zhang 2018) proved the topics of highest importance for future OR applications in the field of strategic health care management.

3 Health economic applications

Health economics uses various quantitative methods to investigate a wide variety of economic issues in the health sector. The papers presented in the health economics sessions at the ORAHS 2020 conference reflected this diversity.

An important branch of research in health economics is the measurement of health preferences using discrete choice experiments (DCEs). The corresponding research results are used, for example, to assess supply and demand and the pricing of various health services. Kleij et al. (2017) provided a systematic literature review of DCEs in primary health care, while Larsen et al. (2021) analyzed the evolution of DCEs, among others, for designing mental health services for patients and providers. Col-lacott et al. (2021) and Sugitani et al. (2020) reviewed the frequent use of DCEs in oncology to investigate patients’ preferences. In a recent study, Michaels-Igbokwe et al. (2021) d, among others, on age-specific characteristics of designing, implementing, and analyzing DCEs in assessing the preferences of children and adolescents. From a methodological perspective, Bahrampour et al. (2020) provided an overview of the various methods to perform DCEs. Janssen et al. (2017) and Quaife et al. (2018)

reviewed the (external) validity and reliability of DCEs. At the ORAHS 2020 conference, Zweifel (2020) discussed the use of DCEs in the context of costly innovation in health care. In the related paper (Zweifel, 2021), which is part of this issue, he seeks to justify using the economic criterion "provision of health care according to the preferences of current and potential patients" for guiding decisions concerning the adoption of costly innovation in health. For measuring these preferences, he highlights the use of DCEs to derive the willingness to pay (WTP) values that can be pitted against the extra cost of innovative therapies. The broad application across different medical disciplines and the constant methodological development illustrate the importance of preference measurement in supporting clinical and economic decisions (see, e.g., Khan et al., 2021).

Another relevant health economics research stream was devoted to designing optimal contracts among differently informed contractual partners with varying and potentially conflicting interests. Contract theory aims to improve the performance of a health (sub)system by incentivizing the efficient use of scarce resources on the supply and demand side while simultaneously guaranteeing the (sub)system's quality and effectiveness. There is vibrant literature on the effects of differently designed contracts on the supply, demand, quality, and accessibility of medical services, pharmaceuticals, and other health care products and services. Fainman and Kucukyazici (2020) provided a review of studies investigating the effect of financial incentives and payment mechanisms for service providers on accessibility, quality, efficiency, and integration and collaboration in health care. De Walque (2020) addressed the demand side by examining the effectiveness of various financial incentives to avoid unhealthy behavior. Antonanzas et al. (2019) offered an in-depth literature review of various risk-sharing contracts in healthcare settings. In their paper, the authors referred, among others, to an overview by Zaric et al. (2013). The latter reviewed theoretical papers on risk-sharing and examined the effects on the behavior of pharmaceutical companies and social welfare. In his keynote at the ORAHS 2020 conference, Zaric (2020) highlighted the importance of contract theory for health care policy. He presented principal-agent models on risk-sharing contracts in the pharmaceutical sector and gain-sharing agreements in the hospital sector. He also provided insight into the effects of incentive payments for Canadian doctors to provide after-hours primary care on hospital emergency department utilization. Megiddo et al. (2020) illustrated an extension to current health technology assessment methods that incorporate externalities associated with technological innovations. Their model enables the assessment of the societal value of innovative technology, which is considered an essential element in price negotiations. Barlow et al. (2020) discussed a UK pilot program that decomposed total payment for an antibiotic into a fixed lump sum and a sales-related component in a related presentation. The authors proposed a mathematical model that explicitly considered a flat and volume-based compensation component to estimate the societal impact of such a subscription payment system.

The need to use scarce resources efficiently while simultaneously guaranteeing and improving health services provision effectiveness has also fueled considerable interest in applying multi-objective optimization models, control theory, and performance measurement methods in the health sector. In their ORAHS 2020 presentation, Neuvonen and Dillon (2020) proposed decision programming to optimize

a screening program for the early detection of colon cancer. With the mathematical model developed by the authors, they optimize the cut-off level of a specific screening program in a particular target population by minimizing direct costs and maximizing the reduction of incidence and mortality rates. Freiberger et al. (2020) presented a sophisticated dynamic optimal control framework that considers stochastic health shocks in life-cycle models that enabled the authors to obtain analytic pre- and post-shock expressions for consumption and health investment profiles. Sommersguter-Reichmann (2020) concentrated on the incorporation of quality in nonparametric frontier efficiency studies, which have attracted considerable attention since the seminal works of Farrell (1957), Charnes et al. (1978), as well as Färe and Knox Lovell (1978). The extensive bibliographies (e.g., Seiford 1996; Emrouznejad and Yang 2018), general and health-related reviews (e.g., Peykani et al., 2021, Mergoni and Witte 2021, Hollingsworth 2008, Cantor and Poh 2017, O'Neill et al. 2008, Kohl et al. 2019) and special issues (e.g., Emrouznejad et al. 2019; Emrouznejad 2014; Jablonsky et al. 2018) underpin the dynamic publication activity in this field. The author found that many studies assume that structural quality affects inefficiency distribution. At the same time, they presume that process and outcome quality predominantly impact the efficiency frontier (Sommersguter-Reichmann, 2021).

4 Health care workforce scheduling care

At the ORAHS 2020 (<https://orahs2020.univie.ac.at/>), planning of home health care services as well as outpatient chemotherapy planning and clinical rostering constituted important OR application areas in health care.

4.1 Planning of home health care services

Home health care (HHC) services are of vital importance for the health care system of many countries (Rest and Hirsch 2021). The number of people requiring HHC services is increasing in industrialized countries due to demographic transformation, changes in the family structure, the trend to grow old at home, or the usually lower cost than intramural care. Several recent literature reviews on HHC as Fikar and Hirsch (2017), Hirsch (2017), Cissé et al. (2017), Grieco et al. (2020), or Di Mascolo et al. (2021) give a comprehensive overview on this topic.

At the ORAHS 2020 some presentations dealt with HHC planning, e.g., Ramalhinho Lourenco et al. (2020), who propose models to optimize integrated HHC and home social care, and evaluate the cost and service quality impact of introducing synchronization in the whole system, or Salman et al. (2020), who focus on dynamic prioritized HHC routing and scheduling. The paper “Insights and decision support for home health care services in times of disasters” by Rest and Hirsch (2021) studies the impacts of various disasters (i.e., epidemics, blackouts, heatwaves, and floods) on the HHC system, using the concept of Causal-Loop-Diagrams. DSS is presented and applied to real-world data from a HHC service provider in Vienna, in order to numerically analyze the impacts of the COVID-19 pandemic that hit Austria in spring

2020. The DSS is based on a Tabu Search metaheuristic that specifically aims to deal with the peculiarities of urban regions. The impact of disasters on HHC planning has been covered in just a few papers as Trautsamwieser et al. (2011), Rest et al. (2012), or Rest and Hirsch (2015) before. Rest and Hirsch (2021) also provide solutions, if HHC nurses use time-dependent public transport (i.e., bus, tram, train, or underground) instead of an individual transport mode as car or bike. This has only been highlighted in a few preceding journal papers as Hiermann et al. (2015) or Rest and Hirsch (2016). Moreover, it is important to consider sustainability issues in HHC planning (Voegl and Hirsch 2018). The presentation of Reyes et al. (2020) considered an integrated mobility concept for HHC services and not time-critical patients, who need to be transported to medical facilities, in order to reduce driving distances of the employed vehicles and to support the use of more environment friendly transport modes as public transport.

4.2 Outpatient chemotherapy planning and clinicians rostering

The paper "Master chemotherapy planning and clinicians rostering in a hospital outpatient cancer centre" by Carello et al. (2021), deals with a highly relevant and fairly complicated real-world tactical level planning problem. The problem addressed arises in outpatient cancer centers where different pathologies and oncologist specialties share the main resources. The problem aims at assigning consultation rooms and days to the treated pathologies and setting the medical agendas. Different criteria are considered. The problem is formulated as a multi-objective lexicographic optimization model and solved by sequentially optimizing a sequence of MIP models. The paper shows that the different stakeholders' perspectives can be efficiently optimized and that a rolling horizon approach can be fruitfully applied over a one-year planning horizon. The practical orientation of the research is reinforced by the use of real data and the cooperation of hospital managers and oncologists. Carello et al. (2021) mention that the literature on outpatient chemotherapy activities is sparse compared to other areas of application with similar features, such as multi-appointment scheduling in healthcare (Marynissen et al. 2019). A literature review on operations research techniques applied throughout cancer care services can be found in Saville et al. (2019). Moreover, the review paper of Lamé (2016) provides an overview on outpatient chemotherapy planning.

At the ORAHS 2020, Penn (2020) gave a talk on the prisoner's dilemma in healthcare scheduling based on data for chemotherapies. A dedicated session on chemotherapy and radiotherapy scheduling at the ORAHS 2020 included presentations of Robbes et al. (2020) on the production of chemotherapies, of Duenas et al. (2020) on multicriteria decision analysis modelling in an outpatient chemotherapy service, and of Aringhieri et al. (2020a,b) on online algorithms for the radiotherapy patient scheduling problem. A recent paper by Braune et al. (2021) presents a model for planning appointment times for radiotherapy treatments with uncertain activity durations, several treatment rooms, and required preparation as well as exiting phases for each patient.

5 Health care operations management

Health care operations with the topics health care logistics as well as disease modelling constitute important OR application areas in health care covered by the ORAHS 2020 program (<https://orahs2020.univie.ac.at/>).

5.1 Health care logistics

Health care logistics addresses the efficient planning, scheduling, and control of different flows in the delivery of health care services. Such flows are related to patients, materials, and information. The use of OR plays a crucial role when managers want to optimize processes considering a patient centered approach, that is not only taking into account the economic efficiency but also considering the quality of care and patient satisfaction. Health care logistics covers a broad area of health services such as the emergency medical services (e.g., Aringhieri et al. 2017; Reuter-Oppermann et al. 2017), health facilities (e.g., Ahmadi-Javid et al. 2017), operating room planning (e.g., Samudra et al. 2016; Zhu et al. 2019), appointment scheduling (e.g., Marynissen et al., 2019), hospital management (Abe et al. 2016a,b,c), and disaster management (e.g., Özdamar et al. 2015; Farahani et al. 2020).

At the ORAHS 2020 more than six sessions covered the broad area of the health care logistics. Hosteins et al. (2020) presented a talk on bed management, an emerging topic in health care. Beds are an essential resource, which follows the patients, and must be adequately managed. Stock-outs could lead to severe consequences: delays, redirections or procedure cancellations. Therefore, reliable and robust bed management is fundamental for well-performing hospitals. Landa et al. (2018) studied how to improve the bed capacity planning and its coordination with the management of emergency and elective patient admissions. Kayis et al. (2020) studied the integrated scheduling of ORs and sterilization of reusable medical devices under stochastic surgery durations with the possibility of dynamic rescheduling, if needed, during the day. Dynamic rescheduling or real time management of operating rooms is new and promising area of research as reported by Duma et al. (2015, 2018).

The aim of the paper "Fairness in ambulance routing for post disaster management" by Aringhieri et al. (2021) is to find the best ambulance tours to transport the patients during a disaster in relief operations while considering fairness and equity to deliver services to patients in balance. The problem is formulated as a new variant of the team orienteering problem with hierarchical objectives to address also the efficiency issue. A new hybrid algorithm based on a machine learning and neighbourhood search has been developed. An extensive quantitative analysis proved the capability of the algorithm allowing also a comparison between the fair solution and the system optimum.

5.2 Disease policy modelling

The use of quantitative models can show how (infectious) disease progress over time and helping the development of public health interventions and policies such as mass vaccination. Children vaccination programmes have been discussed in two talks at the

ORAHS 2020: the first one presented a rule-based digital vaccination decision support for child immigrants immunization coordination in Sweden (Steen et al. 2020) while the second presented a cross-sectional survey for childhood vaccination in Viennese primary schools (Rauner et al. 2020).

The paper "Hospital preparedness during epidemics using simulation. The case of COVID-19", by Garcia de Vicuña et al. (2021) proposes a discrete event simulation model to support decision-making for the planning of hospital resource needs during pandemic waves. It also reports how it was employed on a daily basis to inform logistic health authorities and the lessons learnt from this successful application.

Together with two other talks, this paper was part of the special session "Covid-19 Policy Modelling" at the ORAHS 2020, which was held not in parallel with other sessions. Rutherford et al. (2020) developed a two-stage queue network model to support planning requirements for access to mechanical ventilators by both COVID-19 and non-COVID-19 patients in British Columbia, Canada. Duma et al. (2020) presented a new problem called the daily swab test collection problem, which consists in organizing the daily collection of swab tests reaching the house of the contact(s) of a positive case detected the day(s) before through a digital contact tracing system.

6 Emergency services

Providing emergency care is a challenging task for all healthcare systems worldwide and the COVID-19 pandemic made it even more complex. In many countries, emergency medical services (EMS) care for emergency patients on the scene of the incident. While the Franco-German system emphasises the treatment at the scene, the Anglo-American system favours a fast transport to the hospital (Reuter-Oppermann et al. 2017). In hospitals, emergency departments (ED) are the gateway for all emergency patients seeking care, either when transported by an ambulance or arriving as walk-ins. At the ORAHS 2020 conference, four sessions directly targeted emergency services and the presentations are summarised in the following three subsections (<https://orahs2020.univie.ac.at/>).

6.1 Emergency medical services

Within EMS logistics, many different planning problems occur that can be addressed by operations research methods. These include locating ambulances and bases, workforce planning of paramedics and emergency doctors, dispatching ambulances or even helicopters or relocating ambulances during the day. A description of the planning problems as well as an overview of existing publications can be found, for example, in the reviews by Reuter-Oppermann et al. (2017) or Aringhieri et al. (2017).

During ORAHS 2020, four talks addressed different EMS topics. Pieter van den Berg (2020) discussed and analyzed modelling flaws in ambulance location models that use busy fractions, as for example the MEXCLP (Daskin, 1983). The dispatching of ambulances was addressed by Carvalho et al. (2020) as well as Olave-Rojas and

Nickel (2020). Worthington et al. (2020) investigated “optimal” service hours for helicopters and rapid response vehicles in the UK.

This issue contains one EMS-related paper by Matinrad and Reuter-Oppermann (2021) entitled “A review on initiatives for the management of daily medical emergencies prior to the arrival of emergency medical services “. The paper presents a review of the studies that are focused on the use of new types of resources, such as volunteers and drones, for daily medical emergency responses. These resources are used in daily medical emergencies if they can arrive earlier than emergency medical services. This work includes a total of 258 papers published in operations research/operations management and medical journals and conference proceedings. The paper investigates these studies from technical, logistical, and medical perspectives and gives an application-based and methodological overview.

6.2 Emergency departments

In order to provide the best possible care for emergency patients, it is not sufficient to analyse and improve the EMS and EDs individually. Instead, a system’s perspective is necessary and the complete rescue chain should be addressed. In countries like Canada or the UK, for example, ambulances often queue in front of the ED due to overcrowding, leading to very long turnaround times (Li et al. 2019). At ORAHS 2020, Reuter-Oppermann and Wolff (2020b) presented the design of an emergency navigator that supports the EMS in assigning emergency patients to hospitals (Reuter-Oppermann and Wolff 2020a).

Within ED related research, many publications apply simulation as their main methodology and reviews summarise the state of the art (e.g., Salmon et al. 2018; Furian et al. 2018). During ORAHS 2020, several speakers presented simulation models for emergency departments (Roma et al. 2020; Fabbri et al. 2020; Vanbrabant et al. 2020). Mayorga and Nambiar (2020) proposed a queuing model to study and improve the workload of nurses and the patients’ lengths of stay. Bijvank and Lee (2020) discussed the integration of care complexity levels into patient triage systems used in Canadian EDs.

6.3 Mass casualty incidents

Mass casualty incidents impose major challenges for EMS systems with treating many patients at the scene and transporting them to hospitals as well as for hospitals with many patients arriving at the same time in the ED. During the ORAHS 2020 conference, two talks specifically addressed mass casualty incidents. Li et al. (2020) discussed index policies for resource scheduling in emergency response. Christina Bartenschlager (2020) analyzed and compared existing and new triage algorithms for mass casualty incidents.

Funding Open access funding provided by University of Vienna.

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Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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