G Model
RECYCL-3312; No. of Pages 9
ARTICLE IN PRESS
Resources, Conservation and Recycling xxx (2016) xxx–xxx
Contents lists available at ScienceDirect
Resources, Conservation and Recycling
journal homepage: www.elsevier.com/locate/resconrec

Full length article

Allocating human resources in organizations operating under crisis conditions: A fuzzy input-output optimization modeling framework

K.B. Aviso[a], A.P. Mayol[b], M.A.B. Promentilla[a], J.R. Santos[c], R.R. Tan[a,*], A.T. Ubando[b], K.D.S. Yu[d]

[a] Chemical Engineering Department, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines
[b] Mechanical Engineering Department, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines
[c] Department of Engineering Management and Systems Engineering, The George Washington University, WA 20052, USA
[d] School of Economics, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines

ARTICLE INFO

Article history:
Received 28 April 2016
Received in revised form 16 July 2016
Accepted 16 July 2016
Available online xxx

Keywords:
Resilience
Fuzzy optimization
Human resource allocation
Crisis operations
Input-output model

ABSTRACT

Ensuring the resilience of industrial systems to perturbations is a vital strategy for climate change adaptation to maintain sustainable consumption and production. Business decision-making models are essential in providing rational support for choices made by managers and industry practitioners under crisis conditions that may result from climatic disruptions. To date, most of the techniques proposed in the literature focus on the disruptions of physical resources that propagate through supply chain linkages; nonetheless, a significant research gap remains on mitigating impacts caused by disruptions in workforce availability. In this work, a fuzzy input-output optimization model is developed for allocating scarce labor resources within a business enterprise or organization. This model uses the input-output framework to take into account organizational interdependencies that exist among workers or departmental units, to ensure minimal loss of vital services delivered to external clients. The model is demonstrated using two illustrative case studies. The first case study involves medical staff deployment in a hospital during a pandemic event; while the second case study involves allocation of personnel in a business process outsourcing firm during an adverse weather event. The examples illustrate how the proposed fuzzy input-output optimization model can provide decision support for practitioners in industry, in order to mitigate the impacts of human resource shortage on business continuity during a crisis.

1. Introduction

Atmospheric CO_2 concentration has reached historic record levels, even as emission rates continue to grow due to global economic and demographic trends (Steffen et al., 2015). Links between greenhouse gas (GHG) emissions and climate change are already well-established, and now necessitate adaptation strategies to be integrated into sustainability measures (IPCC, 2014a). Meanwhile, sustainable consumption and production (SCP) is one of the holistic strategies being proposed to curb environmental impacts by considering both upstream (production) and downstream (consumption) ends of industrial systems (Tseng et al., 2013). Current trends in sustainability literature suggest the need to synchronize climate change mitigation and adaptation efforts through the development and use of business decision-making models. For example, Wedawatta and Ingirige (2012) studied how flood risks threaten business continuity, particularly in small and medium-sized enterprises (SMEs), while Constable and Chrysostomidis (2015) explored the implications of climate change adaptation framework on project management. It has thus been argued by Kuruppu et al. (2014) that research efforts need to be intensified on various aspects of climate change adaptation in the private sector.

It is important for organizations to be prepared to deal with climatic impacts that threaten operational continuity; hence, researchers should provide support to practitioners through business decision-making models for various aspects of enterprise operations. Climate change adaptation literature has heavily focused on disruptions in the supply of physical resources. For example, water resources are expected to be affected by climate change, with resulting implications for water supply planning (Papadaskalopoulou et al., 2015). Furthermore, research on water reuse and recycling has intensified (Alkaya and Demirer, 2015; Garcia and Pargament, 2015; Xu et al., 2015), with some effort

* Corresponding author.
E-mail addresses: raymond.tan@dlsu.edu.ph, natdnomyar@gmail.com (R.R. Tan).

http://dx.doi.org/10.1016/j.resconrec.2016.07.009

Nomenclature

Indices

i	Service provider department i
j	Service receiver department j

Model parameters

$\boldsymbol{\alpha}$	Fractional workload vector
β_i	Maximum allowable reduction for net output of work for department i
$\mathbf{A}$	Technical coefficient matrix/workforce interaction matrix with elements a_{ij}
$\mathbf{e}$	Net output of work vector with elements e_i, which provides the number of personnel in department i that interacts with the external environment
e_{i0}	Net output of work for department i during normal operating conditions
e_i^L	Minimum level of net output of work for department i during crisis conditions
m	Arbitrary large number
P_{ij}	The number of personnel from department i that contributes to department j
$\mathbf{t}$	Total workload vector with elements t_j, contains the total number of personnel needed by a department to satisfy internal and external requirements
$\mathbf{t}_0$	Initial level of total workload
t_j	Total number of personnel needed by department j
$\mathbf{x}$	Total output vector with elements x_j which represents the total output of sector j
$\mathbf{y}$	Final demand vector with elements y_i which indicates the final demand for sector i
z_{ij}	Input requirement of sector j from sector i

Model variables

λ	Over-all level of satisfaction based on max-min aggregation
λ_i	Fuzzy goal satisfaction for department i
e_{if}	Personnel allocation for the net output of work for department i during crisis conditions
$\mathbf{t}_f$	Total workload level vector during crisis conditions

devoted to the development of quantitative tools (e.g., Krishna Priya and Bandyopadhyay, 2016; Lin et al., 2015) to aid in decision making. However, there is still a significant gap in the research literature on the development and use of similar business decision-making models for dealing with acute workforce shortage caused by climatic disruptions. Notably, significant volumes of disaster risk management literature have focused on restoration of critical infrastructure systems in the aftermath of disasters; in contrast, a disproportionate level of attention has been placed on the analysis of disaster impacts on workforce availability.[1] Hence, Santos et al. (2014) have underscored the vital role of human resources in ensuring continuity of operations of critical infrastructure and economic systems during adverse events. Such aspect of climate change adaptation needs to be addressed due to the vulnerability of human resources to various types of perturbations induced by climatic disturbances. Examples of human resource vulnerability due to climatic disturbances are adverse weather conditions that affect mobility; the spread of disease vectors that may trigger pandemic events; and droughts that may cause health problems due to unavailability of food and water, among others. Indeed, the IPCC (2014b) in its Climate Change Synthesis Report maintained with high confidence that: "The aspects of climate change with direct effects on stored terrestrial carbon include high temperatures, drought, and windstorms; indirect effects include the increased risk of fires, pest and disease outbreaks."

This work seeks to address the research question of how to provide effective decision support for managers to deal with disruptive events that result in a transient reduction in workforce availability. Thus, a novel fuzzy input-output (I-O) optimization model is developed for allocating human resources to business enterprises or organizations operating under crisis conditions. Unlike previous I-O models for human resources (e.g., Correa and Craft, 1999), the formulation proposed here is meant to prescribe optimal damage control responses to adverse events; by comparison, the previously developed I-O framework in Correa and Craft (1999) was limited to descriptive modeling capabilities only. The limitations of previously developed approaches creates a research gap, which can be addressed by developing an optimization model that can recommend to decision makers in industry the best reallocation of human resources during a crisis. The approach used is based on prior work for I-O systems at the economy-wide (Tan et al., 2015) or industrial complex (Tan et al., 2016) scales. Yu et al. (2016) developed an over-all index of satisfaction for economic output under climate change conditions; this model incorporates preference weights through a previously developed vulnerability index (Yu et al., 2014). The rest of this paper is organized as follows. The next section provides a brief literature review. The section that follows describes the model framework itself, with subsections for a formal problem statement, nomenclature, and mathematical formulation. Then, two representative case studies are explored to illustrate the model functionality; both examples deal with plausible real-life scenarios that may transpire as a result of climatic disruptions. The first case study deals with the allocation of medical personnel in a hospital during a pandemic event. The second case study then deals with the allocation of personnel in a business process outsourcing (BPO) firm during adverse weather conditions. Both of these sectors are typical examples of human resource-intensive activities that are highly reliant on workforce availability, and thus serve to demonstrate how the proposed model can provide recommendations for "damage control." Finally, conclusions and prospects for future work are discussed.

2. Literature review

Rational allocation of human resources during a crisis requires an understanding of the interdependencies between workers or between departmental units in an organization. Input-output (I-O) analysis provides an elegant and effective framework for modeling such linkages (Correa and Craft, 1999). I-O approach has been used in the analysis of relationships in hospitals (Correa and Parker, 2005), libraries (Correa and Correa, 1996) and government offices (Correa and Guajardo, 2001). Correa (2002) also proposed to extend the framework to general societal systems; however, with the exception of a recent paper on organizational influence by Hester and Adams (2013), there have been no developments on this class of applications of the I-O framework.

I-O models have traditionally been used for economic analysis (Leontief, 1936), and its mathematical foundations are outlined in the classic textbook by Miller and Blair (2009). Because of their inherent capability to reflect interdependencies that exist within complex systems, there is also extensive literature on the use of I-O models for the analysis of sustainable industrial systems, dating

[1] A recent web of science search for the pairing of the keywords "disaster" and "infrastructure" revealed more than 5500 articles, while only about 300 articles emerged from the pairing of "disaster" and "workforce." Similar trends can be observed using Scopus and Google Scholar.