ORESTA

ISSN: 2620-1607

eISSN: 2620-1747

DOI: 10.31181/oresta190101s

OPERATIONAL RESEARCH IN ENGINEERING SCIENCES: THEORY AND APPLICATIONS

REGIONAL ASSOCIATION FOR SECURITY AND CRISIS MANAGEMENT - (RASEC)

EUROPEAN CENTRE FOR OPERATIONAL RESEARCH - (ECOR)

Volume 4, Issue 1

ISSN: 2620-1607

eISSN: 2620-1747

DOI: 10.31181/oresta190101s

Published: April 2021

OPERATIONAL RESEARCH IN ENGINEERING SCIENCES: THEORY AND APPLICATIONS

Publishers:

REGIONAL ASSOCIATION FOR SECURITY AND CRISIS MANAGEMENT - (RASEC)

EUROPEAN CENTRE FOR OPERATIONAL RESEARCH - (ECOR)

Address of editorial office:
Regional Association for Security and crisis management (RASEC) –
European centre for Operational research (ECOR)
Cerska 76a, 11000 Belgrade, Serbia
Tel. +38165-2503-213
e-mail: zeljkostevic88@yahoo.com, editor@oresta.rabek.org
http://oresta.rabek.org

CONTENTS

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 1-18
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https:// doi.org/10.31181/oresta2040101w

SYSTEM DYNAMIC MODELING OF RISK MANAGEMENT IN CONSTRUCTION PROJECTS: A SYSTEMATIC LITERATURE REVIEW

Endit Wardito[1], Humiras Hardi Purba[1] , Aleksander Purba[2*]

[1] Industrial Engineering Department, Mercu Buana University, Jakarta, Indonesia
[2] Civil Engineering Department, Lampung University, Lampung, Indonesia

Received: 26 June 2020
Accepted: 09 October 2020
First online: 28 January 2021

Review paper

Abstract. *This literature review discusses risk management research with System Dynamic modeling. Literature is reviewed by summarizing the research that has been done and examining research findings, research relationships, and research problems that require further research. The risk management paper with System Dynamic modeling (2000-2020) is reviewed by dividing risk into 3 groups, namely: internal risk, external risk, and project risk. Each group is further divided into technical risks and non-technical risks. The results of the study stated that risk management with System Dynamic modeling has not been widely used as evidenced by research (2000-2020); there are only 25 papers that match the keywords and can be written reviews. Ten internal risk papers include: project members, location risk, document risk & information. External risk papers are only found in 2 papers that discuss: weather risk and social risk, while the project risks are found in 13 papers discussing: cost risk, time risk, work quality risk, and construction risk.*

Keywords: *System Dynamic, Risk, Construction.*

1. Introduction

In research related to risk management, many approaches can be done, one of which is to use System Dynamic, Fuzzy Logic, or other methods. The System Dynamics approach is a simulation method in solving real problems to describe the relationship between variables in a complex system (Maryani et al., 2015). The System Dynamic (SD) can be used as a basis for simulating the effects of various risks on the project schedule to explore optimal measures to prevent prior risks (J. Wang & Yuan, 2016). System Dynamic (SD) can use dynamics and feedback to understand the structure and characteristics of a complex system so that it can help decision making (Yang & Yeh,

* Corresponding author
enditwardito@gmail.com (E. Wardito), humiras.hardi@mercubuana.ac.id (H. Hardi Purba), aleksander.purba@eng.unila.ac.id (A. Purba)

2014). System Dynamic can also be combined with other analytical methods such as Fuzzy; an integrated fuzzy-SD model can be applied to all BOT projects to determine the concession period (Khanzadi et al., 2012). The use of System Dynamics in construction projects has a good track record and has been used for a long time. In (Boateng et al., 2012), the SD method has been used extensively over the past 35 years on complex projects and has proven the track record of project management performance in the project life cycle. This review aims to examine risk management research using System Dynamic modeling to determine what can be accomplished using System Dynamic and to see Research GAP for further research.

2. Methodology

This review is based on a summary of the literature obtained online from trusted sources that discuss Risk Management using System Dynamic modeling, which is then reviewed and synthesized to provide the latest information. In research (Zavadskas et al., 2010), Risk was divided into 3 parts, namely: Internal Risk, External Risk, and Project Risk. Risk allocation structure is shown in Figure 1.

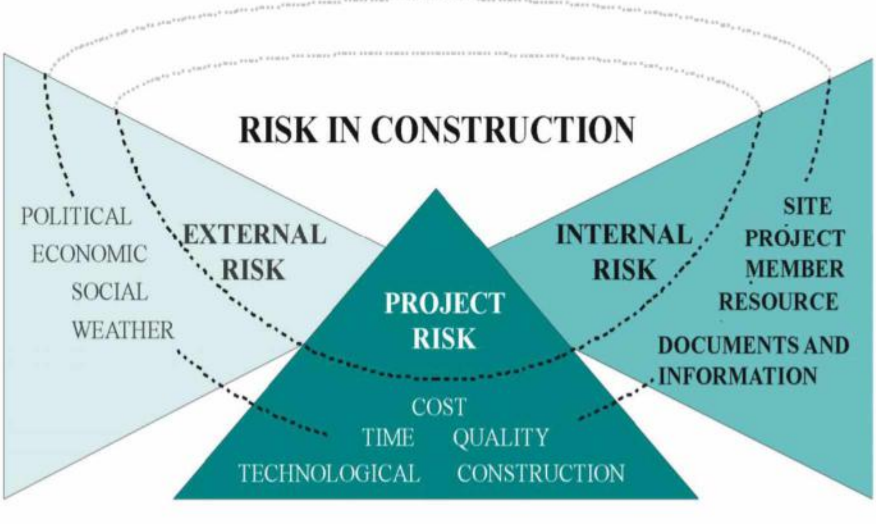


Figure 1. Risk allocation structure (Zavadskas et al. 2010)

Internal risks (intrinsic criteria): (1) Resource risk; (2) Project member risk; (3) Stakeholders Risks; (4) Designer Risk; (5) Contractor Risk; (6) SubContractor Risk; (7) Supplier Risk; (8) Team Risk; (9) Construction site risk; and (10) Documents and information risk. External risks (environmental criteria): (1) Political risk; (2) Economic risk; (3) Social risk; (4) Weather risk. Project risks (construction process criteria): (1) Time risk; (2) Cost risk; (3) Work quality; (4) Construction risk; and (5) Technological risk. The study method is shown in Figure 2.

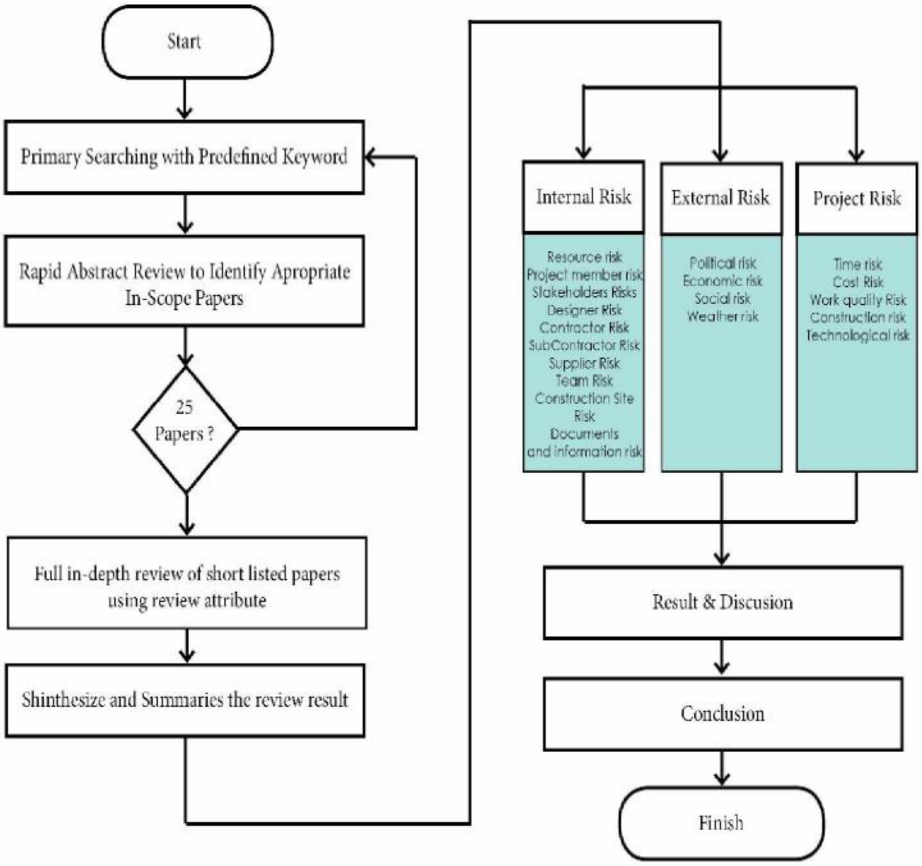


Figure 2. Study Framework: A Systematic Literature Review

3. Results

3.1. Summary of Results

The summary of the paper review related to risk management with System Dynamics modeling is shown in Table 1 (1.1-1.4).

Table 1.1. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
1.	(Love et al., 2002)	Project	Work Quality	Variation, rework, or both have a significant impact on the level of progress of the project, caused by: (1) Purchaser Changes; (2) Design Freezing; (3) Information management; (4) Building regulations; (5) Consultant fees; (6) Communication; (7) Coordination and integration of the project team; and (8) Training and skills development.
2.	(Nasirzadeh et al., 2008)	Project	Cost	Because of the more obvious negative side effects of the modified labor/equipment policy (MLEP), The quality is better than the overtime workforce policy (OTP) which experiences increased cost overruns.
3.	(Nasirzadeh et al., 2008)	Project	Cost	A large negative impact on project objectives in terms of cost overruns and project delays can be caused by machine breakdowns. The following alternative response scenarios for that risk: (1) use of overtime policy; (2) modification in labor/equipment policy; (3) use of subcontractors; (4) schedule changes.
4.	(Yi & Xiao, 2008)	Project	Cost	Project risks and costs by building a System Dynamics model are influenced by the allocation of stimulating costs between elements and elements between departments.
5.	(Han et al., 2010)	Internal	Construction Site	The relationship between the main indicators, safety culture, and organizational safety conditions and sensitivity analysis based on observing behavior towards the safety climate does not have a significant effect on the safety climate.
6.	(Mohamed & Chinda, 2011)	Internal	Construction Site	An organization with ad-hoc safety implementation (starting from the basic level of maturity of safety culture) must primarily focus on improving leadership attributes, in the context of safety, for rapid and successful progress to a higher level of maturity in the future.
7.	(Boateng et al., 2012)	External	Weather	Four weather conditions that have an impact on the project: (1) Snowfall; (2) High temperature; (3) Rainfall; and (4) Wind.
8.	(Khanzadi et al., 2012)	Project	Time	The proposed integrated fuzzy-SD model can be applied to all Built Operate Transfer (BOT) projects to determine the concession period.
9.	(Shin et al., 2014)	Internal	Team	Examine Three safety enhancement policies: (1) Provide incentives to workers, offer as early as possible for their safe behavior to be most effective; (2) Sharing accident information among workers; and (3) Helping workers experience accidents when sharing accident information.

Table 1.2. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
10.	(Y. Xu et al., 2012)	Project	Cost	Finally, the price of public private partnership (PPP) highway project concessions can be determined by the following formula: Finalprice = Basicprice* $(1+\lambda_1 - \text{PRS}_1 \frac{\lambda_2-\lambda_1}{\text{PRS}_2-\text{PRS}_1}$ Where: Final Price = Basic Price + Adjustment price Final price = $(1+\lambda)$ Basic Price $\text{PRS}_i = W_{ij} \times (R_{ij} - R_{oj})$ $\sum_{j=1}^{n} W_{ij} = 1$ where, PRS_i is the overall risk similarity between a reference case *i* and a target case; W_{ij} is the weighting of each risk factor; R_{ij} denotes the reference case *i*'s risk factor *j*, R_{oj} denotes the target case *n*'s risk factor *j*; $\sum_{j=1}^{n} W_{ij}$ denotes the summation of weighting of all risk factors.
11.	(Nasirzadeh et al., 2014)	Project	Cost	The optimal percentage of risk allocation is set at 46%. If the client accepts 46% of the risk consequences, the project costs will be minimized.
12.	(Yang & Yeh, 2014)	External	Politic-al	7 steps to solve environmental risk management problems systematically and efficiently. (Step 1) Verification of Stakeholders With Related Problems; (Step 2) Determine Important Issues Between Two Stakeholders; (Step 3) Draw the Important Causal Feedback Loop Diagram for Reference the Indicated Problem to the System Template; (Step 4) Building a Stock Flow System Dynamics Model Referring to the Causal Feedback Loop Diagram; (Step 5) Building a Framework Including a System Dynamics Model for Stakeholder Negotiations on related issues; (Step 6) Repeat Steps 2–5 until all Stakeholders are Involved; and (Step 7) List of Environmental Risks.
13.	(Jiang et al., 2015)	Internal	Team	A System dynamics model for the causation of unsafe behaviors (SD-CUB) produce correct behavior patterns. that is: (1) safety and production can support each other; (2) management conditions on the supervisory level are effective on the improvement of workers' safety awareness; (3) preventive actions are more effective than reactive actions on the enhancement of safety performance.

Table 1.3. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al, 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
14.	(Cunbin et al., 2015)	Internal	Team	The SD model of the transmission of risk elements that simulate the scope and depth of projects affected by human risk elements, we can illustrate as follows: (1) The theory of transmitting risk elements is introduced into the process that how human risk impacts construction and transfer projects, can carry out quantitative analysis at procedures and levels; (2) Schedules will temporarily disrupt elements of human risk; (3) If risks occur late, the right expansion saves more costs, while increasing the number of personnel cannot be completed on schedule; (4) Staff and general staff ratios will be considered. During the increase in technical staff, if it does not reduce construction speed, it will rework more, and form more waste; (5) When the proportion of key staff and general staff is more than standard, the workload of key staff is not saturated, while the risk of general staff increases.
15.	(Maryani et al., 2015)	Internal	Construc tion Site	The contractor must pay attention to the Components that make up K3 costs, namely: (1) Direct costs; (2) Indirect costs; (3) Training costs; (4) Consumption and non-consumables; (5) OSH equipment and inventory costs; (6) Prize and penalty fees; (7) Prevention costs; (8) Insurance fee; and (9) Costs outside of insurance coverage.
16.	(Boateng et al., 2016)	Project	Construc tion	Launched the Analytical Network Process (ANP) and System Dynamic (SD), (Integrated SD-ANP), to model the ease of design and construction of megaproject projects, SD-ANP model. The new framework is a superior solution for completing dynamics during design and construction megaprojects.
17.	(Nasir Bedewi Siraj, 2016)	Project	Construc tion	This paper develops FSD (Fuzzy System Dynamic) work commitments that will address many issues related to financial management by using higher funds that focus on risk issues, complex interactions between various risk factors, and dynamic effects.
18.	(Wang & Yuan, 2016)	Project	Time	There are six main risks, which are very important in influencing infrastructure project schedules, which include: (1) change request by the client; (2) project payment delays; (3) pressure due to tight project schedules; (4) site investigation information is not accurate; (5) loss of skilled labor, and (6) bad contractor management.
19.	(L. Xu et al., 2017)	Project	Documen ts and informati on	The Public-private partnership (PPP). This is a form of collaboration between one or more public and private sectors, which is long-term in nature. Based on the project's risk allocation mechanism, the risk factors system is summarized, divided into three sub-systems, including cooperation effectiveness sub-system, cooperation environment sub-system, and construction and operation sub-system.

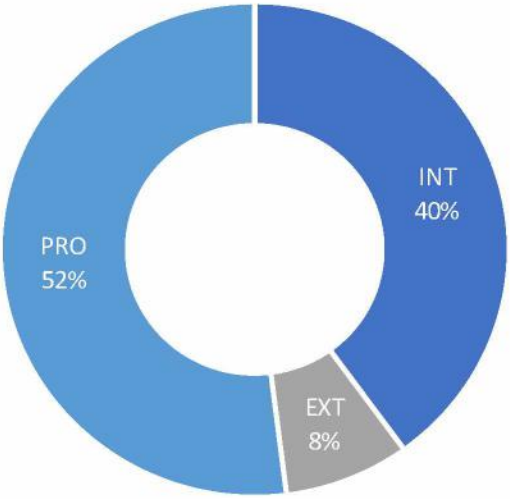
Table 1.4. Summary of Results, Risk Groups & Risk Criteria Based on (Zavadskas et al. 2010)

No.	Paper	Risk Group	Criteria (Risk)	Summary of Results
20.	(Mohammadi et al., 2018)	Internal	Constructi on Site	Four archetypes are developed to address the identified safety problems during the data collection process, including (1) Delay in design; (2) Number of subcontractors; (3) Project cost and safety; and (4) Supervisors and safety.
21.	(Ullah et al., 2018)	Project	Time	This study proves 59 CSF that affects CP. The results of a survey of 26 industry experts and 30 academics determined that Net Present Value (NPV), Project income (PI), Revenue stream (RS), Severity Involved Risks (SIR), Market situation (MS), and Investment Size (IS) were the most complicated aspects, with a minimum of 8% usage by MS and IS, and a maximum of 29% generated by NPV.
22.	(X. Xu et al., 2018)	Project	Time	The hybrid dynamic model developed was applied in the bridge engineering project to analyze the impact of the four risks selected on schedule. The results are as follows: (1) the degree of influence of risk on performance schedules varies across the project timeline; (2) the effect of risk may have a different rating when the risk occurs at different stages; (3) the effect of multiple risks on a schedule may be more significant than the simple amount of each risk.
23.	(Mohammadi & Tavakolan, 2019)	Internal	Constructi on Site	The simulation model presented in this paper can be used to: (1) identify changes in safety performance results during project time; (2) evaluate the effect of various factors on the results of safety performance; (3) make new policies or corrective actions to respond to changes in the project correctly.
24.	(Nasir & Hadikusumo, 2019)	Project	Document s and informati on	That Owner & Contractor relationships could be managed with integrated contract management activities both before and during the construction stage. The preconstruction stage has more potential to influence contractual relationships than the construction stage. The best result was found when all of the previously mentioned policies (preconstruction stage policies, and construction stage policies) were implemented together.
25.	(Mortazavi et al., 2020)	Project	Constructi on	Ten Diagrams are selected and analyzed, The Results are: (1) 10-Fold Increase in Lack of Budget Coefficient; (2) 10-Fold Increase in the Coefficient of Delays in the Project Implementation; (3) 10-Fold Increase in Claim Coefficient; (4) 10-Fold Increase in the Incomplete Design Coefficient; (5) 10-Fold Increase in the Coefficient of Employing Poor-Quality Second-Class Contractors; (6) 10-Fold Increase in the Coefficient of Low Labor Productivity; and (7) 10-Fold Increase in the Coefficient of Employing Unskilled Labor.

3.2. Risk Group

Based on Table 1 (Sections 1-3) of the Resume Review Paper, it can be concluded that: papers discussing Internal Risk include 10 Papers (40%), 2 papers (8%) discuss

External Risks, and 13 papers (52%) discuss Project Risks. The results of the grouping appear in Figure 3.



Internal Risk	INT	10	40%
External Risk	EXT	2	8%
Project Risk	PRO	13	52%

Figure 3. Risk Group Count

3.3. Risk Criteria

Based on Table 1 (Sections 1-4) in the discussion Continue Review paper, it can be concluded that the Risk Criteria discussed are as shown in Table 2. The grouping results are then sorted by the number of papers discussing the most Risk Criteria, as well as in Table 3. Furthermore, the discussion of the papers according to Risk criteria will be discussed in more detail.

Table 2. The Most Researched Risk Criteria

Risk Group	Risk Criteria	Count
Internal Risk	Construction site risk	5
Project Risk	Cost risk	5
Project Risk	Time risk	4
Internal Risk	Team risk	3
Project Risk	Construction risk	3
Internal Risk	Documents and information risk	2
Exsternal Risk	Political risk	1
Exsternal Risk	Weather risk	1
Project Risk	Work quality	1

Table 3. Risk Criteria Count

Risk	Count	Percentage
Internal Risk	10	40%
Resource Risk	0	0%
Project member risk	0	0%
Stakeholder Risk	0	0%
Designer Risk	0	0%
Contractor Risk	0	0%
Sub Contractor Risk	0	0%
Supplier Risk	0	0%
Team Risk	3	12%
Construction site risk	5	20%
Documents and information risk	2	8%
Exsternal Risk	2	8%
Political Risk	1	4%
Economical Risk	0	0%
Social Risk	0	0%
Weather Risk	1	4%
Project Risk	13	52%
Time risk	4	16%
Costruction risk	5	20%
Work quality	1	4%
Construction risk	3	12%
Technological Risk	0	0%
Total	25	100%

4. Discussion

4.1. Internal Risk, Team Risk

Team risk refers to problems associated with project team members, which can increase uncertainty about project outcomes, such as team member turnover, staff improvement, inadequate knowledge among team members, collaboration, motivation, and team communication problems (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 3 papers that discussed the Internal Risk for Team Risk Criteria. Construction accidents are caused by unsafe actions (e.g. Behavior or activities of someone who deviates from the safe procedure that is normally accepted) and/or unsafe conditions (for example, hazard or unsafe physical environment). Relatively little is known about eliminating unsafe construction workers' actions. Three safety improvement policies are examined: (1) Providing incentives to workers to make their safe behavior most effective if offered as early as possible, (2) Sharing accident information among workers can help reduce accident incidents, and (3) Helping workers feel an accident when sharing accident information because they assess the risk an accident is based on how likely it is to occur. Difficulties experienced by people in changing their habits and interests related to safety and safety in construction companies. This will be effective for sharing audiovisual accident information (Shin et al., 2014). Unsafe construction workers getting the direct cause of construction accidents, but the causes are not well understood (Jiang et al., 2015). This study discusses the modeling of System Dynamics to understand the systematic construction of unsafe construction. The SD-CUB model was developed to facilitate understanding of how the system optimizes. The SD-CUB model produces correct behavior patterns. The test model also implies that: (1) safety and production can truly support each other; (2) management conditions at the supervisory level are effective in increasing employee safety awareness; (3) preventive measures are more effective than reactive measures to improve safety performance. The characteristics of human resources are complex and flexible, predicting and controlling risks resulting from human resources is more difficult than other risk factors (Cunbin et al., 2015). In the research, the aim is to achieve effective construction objectives, then develop an SD Model to transmit elements of human resources during the construction project. The SD model of the transmission of risk elements that simulate the scope and depth of projects affected by human risk elements, we can illustrate as follows: (1) The theory of transmission of risk elements is incorporated into the process that how human risk impacts on construction and transfer projects, can carry out quantitative analysis at procedures and levels, (2) Schedules will disrupt while human elements of risk occur, (3) If risks occur late, the right expansion saves more costs, while increasing the number of personnel cannot be completed on schedule, (4) Staff and general staff ratios will be considered. During the improvement of technical staff, if it does not reduce the speed of construction, it will process more, and form more waste, and (5) When general staff risks occur, the proportion of key staff and general staff is more than standard, the workload of the main staff is not saturated, while general staff increased.

4.2. Internal Risk, Construction Site Risk

It means that construction site risk is workplace accident exposure that is inherent like the work and is considered best by contractors and their insurance and safety advisors (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 5 papers that discussed the Internal Risk for Site Construction Risk Criteria. Strong safety culture in companies and the influence of superior Main indicators for safety culture: (1) Worker's behavior; (2) Employee perception; (3) Schedule of delays; (4) Participation of the Safety Committee management; (5) Meetings; (6) Toolbox talks; (7) Safety education; (8) Inspection of superiors; (9) Worker involvement; (10) Inspections at work; (11) Danger; (12) Competence; and (13) Safety training. By integrating all concepts into the System Dynamics model, it is activated to analyze the feasibility of using key indicators previously understood, factors related to safety culture, and improving them on organizational safety. The relationship between the main indicators, safety culture, and organizational safety conditions and sensitivity analysis based on observing behavior towards the safety climate does not have a significant effect on the safety climate (Han et al., 2010). The construction of safety culture and the interaction between five key construction safety culture enablers, as well as the potential of each enabler on the organization's safety objectives during a certain period (Mohamed & Chinda, 2011). The following are 5 Key Enablers in a Construction Project: (1) Leadership; (2) Policies and Strategies; (3) People; (4) Partnerships and Resources; (5) Process. Organizations with ad-hoc safety implementation (starting from the basic level of safety culture maturity) must primarily focus on improving leadership attributes, in the context of safety, for rapid and successful progress to a higher level of maturity in the future.

Work accidents can be caused by members of the supply chain, i.e. parties involved in development projects, from management to workers, work environment, and work pressure related to targets, costs, quality, and time. Accidents will have an impact on costs, especially K3 costs (Maryani et al., 2015). The components that makeup OHS costs that require contractor attention are: (1) direct costs; (2) indirect costs; (3) training costs; (4) consumption and non-consumables; (5) Cost of OSH equipment and supplies; (6) prize and penalty fees; (7) prevention costs; (8) insurance costs; (9) costs outside the insurance coverage.

Repeated behavioral patterns in work safety management continuously have four archetypes identified, namely: (1) design delays; (2) number of subcontractors; (3) project costs and security; and (4) supervisors and safety. Each archetype is discussed at different stages of dynamic complexity, behavior over time, and the point of leverage to show how to deal with archetypes (Mohammadi et al., 2018). In construction projects caused by system failures, not just because of a single factor such as an unsafe problem or condition (Mohammadi & Tavakolan, 2019). Therefore, the construction of safety must be investigated using a systematic view that can think of the complex nature of reporting. Construction projects are also often canceled from the schedule issued and decided from the pressure caused by contract or client deadlines. Therefore, good project managers are needed for dynamic change. The simulation results in this paper can be used to: (1) identify changes in safety performance results during project time; (2) evaluate the effect of various factors on the results of safety performance; (3) make new policies or corrective actions to respond to changes in projects correctly.

4.3. Internal Risk, Documentation & Information Risk

Document and information risk assumptions include: contradictions in documents; pretermission; law and communication. Changing order negotiations and pending dispute resolution are significant risks during project construction. Communication is very important throughout all construction periods and after completing construction work (Zavadskas et al., 2010). The results showed that, during the specified period (2000-2020), there were 2 papers that discussed the Internal Risk for Documentation & Information Risk Criteria. The Public-private partnership (PPP) is a form of collaboration between one or more public and private sectors, which is long-term in nature. Based on the project's risk allocation mechanism, the risk factors system is summarized, divided into three sub-systems, including cooperation effectiveness sub-system, cooperation environment sub-system, and construction and operation sub-system. By setting the System Dynamics model, it can be concluded that government efficiency and contract document conflicts are key elements. In conclusion, the conflict of contract documents and the efficiency of the project company must be strictly controlled in this project (L. Xu et al., 2017). Another paper has examined the Contract Documents Between Owners and Contractors in a Construction project as a facilitating and integrated way to facilitate owner-contractor (O/C) relations in construction projects. This paper focuses more on discussing Policy in Pre-Construction Phase Policy, Construction Phase Policy & Combined Policy. Police Simulation in Pre-Construction Stage: (1) Standard value; (2) Procedure for selecting the right contractor; (3) Proactive contracting process; (4) Contractor involvement in design; (5) Quality of the written clause; (6) Abnormal low bids. Police Simulation in Construction: (7) Bureaucracy and politics deadline; (8) Late payment progress; (9) Efficient reporting; (10) Adequate scheduling system; (11) Adjustments to adequate and fair compensation. Police Simulation in Combined Police: (12) Policy 2 + 3 + 4 + 5 + 6; (13) Policies 7 + 8 + 9 + 10 + 11; and (14) 12 + 13 Policy. The Study Results state: The hostile nature of the O/C relationship has been a matter of concern and can lead to poor relationships in the construction contract, which causes a bad relationship in the contract. This study reveals that the development of the O/C relationships can be better understood if it regulates management approval for a combination of several improvements and balances. O / relationship can be managed with good contract management activities before and during construction. The pre-construction stage has a greater potential to influence contractual relations than the construction stage. The best results are found when all the policies mentioned earlier (pre-construction stage policies, and construction phase policies) are implemented together (Nasir & Hadikusumo, 2019).

4.4. External Risk, Political Risk

Political risk is a change in government laws regarding the legislative system, regulations, and policies as well as inappropriate administrative systems, etc. (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the External Risk for Political Risk Criteria Environmental risks arise from external forces that can easily place a project outside management's control. To avoid the influence of external forces, it is necessary to understand the problems between the project and external stakeholders. Seven processes are proposed using the SD Model to solve environmental risk management problems in a systematic and efficient manner. In the case study, there are seven steps to solve the problem of environmental risk management systematically, and efficiently. Step 1: Kernel Stakeholder Verification with the relevant Problem; Step 2: Determine Meaningful Issues Between Two Stakeholders; Step 3: Draw the Feedback Loop Diagram Cause of Cause for Reference Problems Indicated for System Archetypes; Step 4: Build a Dynamics Model of the Stock-Flow System by Referring to the Causal Feedback Loop Diagram; Step 5: Build a Frame Including a System Dynamics Model for Negotiations among Stakeholders for the Problem Indicated; Step 6: Repeat Steps 2–5 Until All Stakeholders Are Involved; Step 7: Make a List of Environmental Risks. This process allows project managers to reduce the negative impact of project threats (Yang & Yeh, 2014).

4.5. External Risk, Weather Risk

In connection with a very abnormal problem, the contractor is risking because it affects the construction method that can be agreed by the contractor (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the External Risk for Weather Risk Criteria. The effect of critical weather conditions (CWC) and addressing their direct impact on construction activities is very important for contractors, clients, and affected communities (P Boateng et al., 2012). The reason is that SD is used to model delays and cause cost overruns for the results of weather phenomena. Four weather conditions that impact the project: (1) Snow falling; (2) High temperature; (3) Rainfall; (4) Wind.

4.6. Project Risk, Time Risk

Time risk can be determined by assessing construction delays, technology, and for all jobs (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 4 papers that discussed the Project Risks for Time Risk Criteria. The Project BOT Financing using System Dynamic modeling is integrated with Fuzzy. It chooses the integrated fuzzy-SD model that can be applied to all BOT projects to determine the concession period (Khanzadi et al., 2012). Effects of Risk Schedule Delay are generated. There are six main risks (Wang & Yuan, 2016) which are very important in influencing infrastructure project schedules, which include: (1) changes in demand by clients; (2) project payment delays; (3) pressure from tight project schedules; (4) the information from the site investigation is inaccurate; (5) loss of skilled labor, (6) poor contractor management. Another paper has examined the planning scheduling problems in infrastructure project management. This study is a research modeling, System Dynamic (SD) and discrete event simulation (DES). The results are as follows: (1) the degree of influence of risk on the performance schedule varies across the project schedule; (2) risk effects can have different ratings when risks occur at different stages; (3) the effect of various risks on a schedule may be more significant than the simple amount of each risk. SD-DES modeling that can be used easily compares models for real reflection, performs various sensitivity and analysis analyzes and determines the results of more effective comparisons (X. Xu et al., 2018). The System Dynamic (SD) approach to provide deep understanding of the critical success factors (CSF) that determine the project concession period (CP) and model it for local use. This study proves 59 CSF that affects CP. The survey results from 26 industry experts and 30 academics determined that Present Value (NPV), Project income (PI), Revenue stream (RS), Severity Involved Risks (SIR), Market situation (MS), and Investment Size (IS) is the most complicated aspect, with a minimum use of 8% by MS and IS, and a maximum of 29% generated by NPV (Ullah et al., 2018).

4.7. Project Risk, Cost Risk

Cost risk is the opportunity cost of the product that goes up because it ignores management (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 5 papers that discussed Project Risks for Cost Risk Criteria. Overtime employment policies result in more significant swelling costs and poor quality compared to modification of labor/equipment policies (MLEP) due to their more prominent negative side effects (Nasirzadeh et al., 2008). This time, they discussed the risk of engine damage that can cause a large negative impact on project objectives in terms of cost overruns and project delays (Nasirzadeh et al., 2008). The following alternative response scenarios for this risk: (1) use of overtime policy; (2) modification in labor/equipment policy; (3) use of subcontractors; and (4) schedule changes. Another paper analyzed the optimal percentage of risk allocation determined at 46% (Nasirzadeh et al., 2014). The output of the model shows that if the client receives 46% of the risk consequences, the project costs (client costs) will be minimized.

The price of highway project concessions, as a result, the price of PPP highway project concessions can be determined by the following formula (Y. Xu et al., 2012):

$$\text{Final price} = \text{Basic price}^* \left(1+ \lambda_1 - \text{PRS}_1 \frac{\lambda_2 - \lambda_1}{\text{PRS}_2 - \text{PRS}_1}\right) \quad (1)$$

Where:

Final Price = Basic Price + Adjustment price

Final price = (1 +λ) Basic Price

$\text{PRS}_i = W_{ij} \times (R_{ij} - R_{oj})$

$\sum_{j=1}^{n} W_{ij} = 1$

where, PRS_i is the overall risk similarity between reference case i and a target case;

W_{ij} is the weighting of each risk factor;

R_{ij} denotes the reference case i's risk factor j, R_{oj} denotes the target case n's risk factor j;

$\sum_{j=1}^{n} W_{ij}$ denotes the summation of weighting of all risk factors.

The Stimulation of cost allocation between elements and elements between departments influence project risk and costs by building a System Dynamics model (Yi & Xiao, 2008). Allocation ratio is shown in Table 4. From the output results, when the allocation ratio is 0.6: 0.3: 0.1, cost savings reach the maximum of 2707 (2704) and the risk reaches the minimum of 0.28 (0.27). When the probability of the project risk occurrence is 0.27 or 0.28, it is in the supportability scope.

Table 4. Allocation ratio (Yi & Xiao, 2008)

	Allocation ratio		
Bonus: environment cost: training cost	0.6: 0.3: 0.1	0.45: 0.35: 0.2	0.3: 0.4: 0.3
Risk	0.28 (0.27)	0.30 (0.29)	0.32 (0.31)
Saved cost	2707 (2704)	2622 (2619)	2521 (2518)
Time (week)	10.5 (10.75)	10.5 (10.75)	10.5 (10.75)

4.8. Project Risk, Work Quality Risk

Construction delays and additional costs for contractors are due to the quality of the work that is damaged and easily creates disputes regarding deflection obligations. (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there was only 1 paper that discussed the Project Risks for Work Quality Risk Criteria. Matters that have a significant impact on the level of project progress that can cause variation, rework, or both (Love et al., 2002), namely: (1) Buyer Changes; (2)

Freezing of Design; (3) Information management; (4) Building regulations; (5) Consultant fees; (6) Communication; (7) Coordination and integration of the project team; (8) Training and skills development.

4.9. Project Risk, Construction Risk

Construction risk refers to the Risks involved in construction delays, changes in work, and construction technology (Zavadskas et al., 2010). The results show that, during the specified period (2000-2020), there were 3 papers that discussed the Project Risks for Construction Risk Criteria. The 10 diagrams selected and analyzed to identify and assess risks, and to develop predictive models for feedback behavior and to illustrate the effects of risks to each other in bridge construction projects (Mortazavi et al., 2020), The results are: (1) 10-Fold Increase in Lack of Budget Coefficient; (2) 10-Fold Increase in the Coefficient of Delays in the Project Implementation; (3) 10-Fold Increase in Claim Coefficient; (4) 10-Fold Increase in the Incomplete Design Coefficient; (5) 10-Fold Increase in the Coefficient of Employing Poor-Quality Second-Class Contractors; (6) 10-Fold Increase in the Coefficient of Low Labor Productivity; and (7) 10-Fold Increase in the Coefficient of Employing Unskilled Labor. The Analytical Network Process and System Dynamic, (Integrated SD-ANP) are used to model the ease of design and construction of megaproject (Prince Boateng et al., 2016). The new framework is a superior solution for completing dynamics during design and construction megaprojects. Another paper develops FSD (Fuzzy System Dynamic) work commitments that will address many issues related to financial management using higher funds that focus on risk issues, complex interactions between various risk factors, and effects dynamic (Nasir Bedewi Siraj, 2016).

5. System dynamic Software

Out of 25 Papers Regarding Risk Management with System Dynamic modeling, 12 papers used VENSIM software while the other 13 papers do not explain the use of System Dynamic Software. Recent research (Mortazavi et al., 2020) also uses VENSIM Software for System Dynamic Modeling.

6. Future Research

Some of the papers reviewed mostly did not inform future research, only (Boateng et al., 2016) that proposed future research would look at risks such as Social, Technology, Economics, Ecology, and Politics (STEEP) in construction projects. This research was later published in 2016 by the same author**.** In Table 3, there are many risks that have not been studied with System Dynamic, and this can be used as a research gap for further research. The Research gap for the Internal risk group: Resource risk; Project member risk; Stakeholder risk; Designer risk; Contractor risk; Sub Contractor risk; and Supplier risk. The Research gap for the External risk group: Economical risk; and Social risk. The research gap for the Project risk group: technological risk.

7. Conclusion

The results of the study stated that risk management with System Dynamic modeling has not been widely used as evidenced by research (2000-2020); there are only 25 papers that match the keywords and can be written reviews. Ten Internal risk papers include: project members, location risk, document risk & information. External risk papers are only found in 2 papers that discuss: weather risk and social risk, while the project risks are found in 13 papers discussing: cost risk, time risk, work quality risk, and construction risk. The most widely used software is VENSIM.

The Internal Risk group: System Dynamic Modeling helps systematically understand unsafe behavior structures that result in correct behavior patterns; Dynamic Modeling System is also able to simulate the scope and depth of projects affected by human risk elements; using the System Dynamic on the main indicators of safety culture allows to analyze the appropriateness of the use of key indicators and factors related to safety culture, and improve organizational safety; Work accidents can be caused by parties involved in a development project, from management to workers, work environment, and work pressure related to targets, costs, quality and time. Accidents will have an impact on costs, especially K3 costs; in the PPP Project, the use of System Dynamics can conclude that government efficiency and contract document conflicts are key elements; in the contact relationship between Owner and contractor (O / C), Dynamic Systems are used for Police Simulation at Pre-Construction Stage.

The External Risk Group: The problem between the project and external stakeholders must be understood to avoid the influence of external forces. Dynamic systems can be used for studies that allow project managers to systematically and efficiently reduce the negative impacts of project threats; Meanwhile, to deal with weather risk, SD is used to model delay and cause cost overruns due to weather phenomena.

The Project Risk group: Time-related System Dynamic Modeling can be integrated with Fuzzy which can be used in all BOT Financing Projects to determine the concession period; Dynamic systems can also be integrated with Discrete Event Simulation (DES) to be able to compare real reflection models, perform various models and sensitivity testing and determine the results of a more effective comparison; Regarding costs, the Dynamic Systems Project can support policies relating to overtime, additional employees or additional equipment; in Job Quality Risk using a dynamic system capable of identifying project progress and rework or both; Construction Risk uses a dynamic system to identify and assess risk, and to develop predictive models for feedback behavior and to describe the effects of risk; Dynamic Systems can also be integrated with Network Process Analytics (ANP) to model the ease of megaproject design and construction; In addition, Fuzzy System Dynamic Integration is able to solve many problems related to financial management using higher funds which focus on risk issues, complex interactions between various risk factors, and dynamic effects.

Reference

Boateng, P, Chen, & Ogunlana, S. (2012). A Conceptual System Dynamic Model To Describe the Impacts of Critical Weather Conditions in Megaproject Construction. *Journal of Construction Project Management and Innovation*, *2*(1), 208–224.

Boateng, Prince, Chen, Z., & Ogunlana, S. (2016). A dynamic framework for managing the complexities of risks in megaprojects. *International Journal of Technology and Management Research*, *1*(5), 1–13. https://doi.org/http://dx.doi.org/10.1016/j.clinbiochem.2014.12.004

Cunbin, L., Yunqi, L., & Shuke, L. (2015). Human resources risk element transmission model of construction project based on System Dynamic. *Open Cybernetics and Systemics Journal*, *9*, 295–305. https://doi.org/10.2174/1874110X01509010295

Han, S. U., Lee, S. H., & Peña-Mora, F. (2010). System Dynamics modeling of a safety culture based on resilience engineering. *Construction Research Congress 2010: Innovation for Reshaping Construction Practice - Proceedings of the 2010 Construction Research Congress*, 389–397. https://doi.org/10.1061/41109(373)39

Jiang, Z., Fang, D., & Zhang, M. (2015). Understanding the causation of construction workers' unsafe behaviors based on System Dynamics modeling. *Journal of Management in Engineering*, *31*(6). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000350

Khanzadi, M., Nasirzadeh, F., & Alipour, M. (2012). Integrating System Dynamics and fuzzy logic modeling to determine concession period in BOT projects. *Automation in Construction*, *22*, 368–376. https://doi.org/10.1016/j.autcon.2011.09.015

Love, P. E. D., Holt, G. D., Shen, L. Y., Li, H., & Irani, Z. (2002). Using systems dynamics to better understand change and rework in construction project management systems. *International Journal of Project Management*, *20*(6), 425–436. https://doi.org/10.1016/S0263-7863(01)00039-4

Maryani, A., Wignjosoebroto, S., & Partiwi, S. G. (2015). A System Dynamics Approach for Modeling Construction Accidents. *Procedia Manufacturing*, *4*(Iess), 392–401. https://doi.org/10.1016/j.promfg.2015.11.055

Mohamed, S., & Chinda, T. (2011). System Dynamics modelling of construction safety culture. *Engineering, Construction and Architectural Management*, *18*(3), 266–281. https://doi.org/10.1108/09699981111126179

Mohammadi, A., & Tavakolan, M. (2019). Modeling the effects of production pressure on safety performance in construction projects using System Dynamics. *Journal of Safety Research*, *71*(November), 273–284. https://doi.org/10.1016/j.jsr.2019.10.004

Mohammadi, A., Tavakolan, M., & Khosravi, Y. (2018). Developing safety archetypes of construction industry at project level using System Dynamics. *Journal of Safety Research*, *67*, 17–26. https://doi.org/10.1016/j.jsr.2018.09.010

Mortazavi, S., Kheyroddin, A., & Naderpour, H. (2020). *Risk Evaluation and Prioritization in Bridge Construction Projects Using System Dynamics Approach*. *25*(2007), 1–13. https://doi.org/10.1061/(ASCE)SC.1943-5576.0000493

Nasir Bedewi Siraj, A. R. F. (2016). Construction Research Congress 2016 2039. *Fuzzy System Dynamics for Modeling Construction Risk Management*, *1990*, 2039–2049. https://doi.org/10.1061/9780784479827.203

Nasir, M. K., & Hadikusumo, B. H. W. (2019). System Dynamics Model of Contractual Relationships between Owner and Contractor in Construction Projects. *Journal of Management in Engineering*, *35*(1). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000666

Nasirzadeh, Farnad., Abbas, Afshar., Mostafa, K. (2008). System Dynamics Approach for Construction Risk Analysis. *International Journal of Civil Engineering*, *6*(2), 120–131.

Nasirzadeh, Farnad. Abbas, Afshar. Mostafa, Khanzadi. Susan, H. (2008). Integrating System Dynamics and fuzzy logic modelling for construction risk management. *Construction*

Management and Economics, *26*(11), 1197–1212. https://doi.org/10.1080/01446190802459924

Nasirzadeh, F., Khanzadi, M., & Rezaie, M. (2014). Dynamic modeling of the quantitative risk allocation in construction projects. *International Journal of Project Management*, *32*(3), 442–451. https://doi.org/10.1016/j.ijproman.2013.06.002

Shin, M., Lee, H. S., Park, M., Moon, M., & Han, S. (2014). A System Dynamics approach for modeling construction workers' safety attitudes and behaviors. *Accident Analysis and Prevention*, *68*, 95–105. https://doi.org/10.1016/j.aap.2013.09.019

Ullah, F., Thaheem, M. J., Sepasgozar, S. M. E., & Forcada, N. (2018). System Dynamics Model to Determine Concession Period of PPP Infrastructure Projects: Overarching Effects of Critical Success Factors. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *10*(4). https://doi.org/10.1061/(ASCE)LA.1943-4170.0000280

Wang, J., & Yuan, H. (2016). System Dynamics Approach for Investigating the Risk Effects on Schedule Delay in Infrastructure Projects. In *Journal of Management in Engineering* (Vol. 33, Issue 1). American Society of Civil Engineers (ASCE). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000472

Xu, L., Meng, ; Xianwei, Cao, Y., & Candidate, P. D. (2017). *Multivariate Analysis of PPP Project Risk Based on System Dynamics*.

Xu, X., Wang, J., Li, C. Z., Huang, W., & Xia, N. (2018). Schedule risk analysis of infrastructure projects: A hybrid dynamic approach. *Automation in Construction*, *95*(November 2017), 20–34. https://doi.org/10.1016/j.autcon.2018.07.026

Xu, Y., Sun, C., Skibniewski, M. J., Chan, A. P. C., Yeung, J. F. Y., & Cheng, H. (2012). System Dynamics (SD) -based concession pricing model for PPP highway projects. *International Journal of Project Management*, *30*(2), 240–251. https://doi.org/10.1016/j.ijproman.2011.06.001

Yang, C. C., & Yeh, C. H. (2014). Application of System Dynamics in Environmental Risk Management of Project Management for External Stakeholders. *Systemic Practice and Action Research*, *27*(3), 211–225. https://doi.org/10.1007/s11213-013-9283-y

Yi, T., & Xiao, G. (2008). Applying System Dynamics to analyze the impact of incentive factors' allocation on construction cost and risk. *Proceedings of the 7th International Conference on Machine Learning and Cybernetics, ICMLC*, *2*(July), 676–680. https://doi.org/10.1109/ICMLC.2008.4620490

Zavadskas, E. K., Turskis, Z., & Tamošaitiene, J. (2010). Risk assessment of construction projects. *Journal of Civil Engineering and Management*, *16*(1), 33–46. https://doi.org/10.3846/jcem.2010.03

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 19-37
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https:// doi.org/10.31181/oresta2040115h

AN INVESTIGATION OF FIVE GENERATION AND REGENERATION INDUSTRIES USING DEA

Malek Hassanpour

Department of Environmental science, UCS, Osmania University, Telangana State, India

Received: 04 November 2020
Accepted: 03 January 2021
First online: 20 February 2021

Research paper

Abstract: *The data envelopment analysis (DEA) has employed to figure out the efficiency of various engineering projects in the Environment Impact Assessment (EIA) plan and Post-EIA. The procedure allocated to comprise the input and output variables within industries by the present study. The study was used both weighing systems of the Friedman test and the CRiteria Importance Through Intercriteria Correlation (CRITIC) model in the estimation of DEA. The objective of the research sought to find the efficiency of industries for the time interval before the establishment of industries and in the screening step of identification of projects. The findings manifested a classification of industries based on the DEA model and in both weighing systems. Using different weighing systems creates different categories via DEA. Overall, the DEA model is an essential decision-making model in the screening step of EIA.*

Keywords: *Industries, Recycling, EIA, Screening, Projects, Assessment*

1. Introduction

The first use of plastic films in agriculture applications dates back to 1948. In recent years, with the increasing population and the declining trend of water resources, many countries have made extensive efforts to apply drip irrigation systems to avoid the risks associated with water shortages in agricultural production, modern agriculture, and water use (Jha 2016; Usman et al., 2016). Plastics have used in various applications in agrarian usages. Perhaps that is why polymer films, as one of the plastic applications in this field, are interpreted as a revolution that can be extended by expanding their use in all regions of the world to solve many problems related to drought and depletion of water resources. The main applications of polymer plastic films in agriculture are divided into the following. (1) Mulch films (2) Greenhouse and tunnel coverings (3) Silage packaging films (4) Solarizing films (5) Geo-membranes, etc. From all these applications, greenhouse and tunnel coatings are the largest in terms of quantity consumption. The thickness of films used in this application is usually between 80 to 220 micrometers. They have used in one to

* Corresponding author.
Malek.hassanpour@yahoo.com (M. Hassanpour).

seven layers depending on the existing technologies in the countries. More than 80% of this market has accommodated by films made of Light Density Poly-Ethylene (LDPE), Ethylene Vinyl Acetate, and Ethylene Butyl Acrylate (Difallah et al., 2018). Today, the lifespan of these coatings varies between 6 months to ten years depending on the geographical location of the region, the polymers used in the greenhouse, and the formulation of various film stabilizers. The European standard DIN EN 13206 has provided guidelines in thermoplastic coatings for use in agriculture and horticulture for measuring the lifespan, dimensions, mechanical properties, light, and the degree of impermeability of infrared waves. The greenhouse and tunnel coating market is a particular market that requires significant investments in massive extrusion lines to produce vast films. Most of these films are produced by the blowing film process. Problems in stabilizing these large bubbles are one reason why LDPE is used in the production of these films, instead of LLDPE, due to the lower strength of the melt. In such cases, when co-extrusion lines are used, the technical complexity and quantity of investment increase significantly. The polymer films and coatings are affected by light, temperature, and chemical degradation during use. Therefore, they need requirements that are strongly dependent on environmental parameters for a long lifespan. Environmental parameters encompass the type of structure, its design, height, air conditioning, geographical parameters (sunlight and its intensity, temperature, rainfall, altitude, etc.), and chemicals used in the products (Jumanne, 2016). It is impossible to achieve all these properties without the use of special additives and the generation of multilayer structures. That is why in recent years the tendency of developed countries has been more towards producing films of five layers and higher. With the development of metallocene catalyst technology, and plasma reactors, new generations of plastics materials, known as enhanced polymers and polymers made up of chemical vapor deposition, were introduced. This generation of plastic products has extraordinary properties compared to ordinary plastics due to their modern manufacturing technologies. These properties include high melt strength, impact resistance, excellent perforation resistance, high transparency, and unique thermal properties. These particular properties make modern plastic products ideal materials for such applications that require high performance (Kado et al., 2004; Peeters et al., 2014).

Another application of plastic materials in the framework of Polyvinyl Chloride (PVC) films are also discussed in this study is their use in the production of drippers in the sprinkler irrigation system, for which many industries have developed in Iran. Drip irrigation is the slow dispersion of water on the surface or under the soil in the form of separate, continuous, narrow streams or delicate sprays through droppers located along the water transfer line. The recent studies of the International Committee on Irrigation and Drainage for the issues of drip irrigation show that one of the main difficulties in drip systems is the clogging of drippers in all countries of the world. The issue of obstruction is either due to the lack of use of water of good quality or improper selection of the treatment system, which results in uneven distribution of water along the sub-pipes. Thus, it reduces irrigation efficiency. The risk of clogging the drippers also increases the cost of maintaining and operating the system, including controlling the drippers and replacing or repairing them (Taylor and Zilberman, 2017; Gutiérrez et al., 2013; Wang et al., 2016; Raju et al., 2012).

The agricultural waste has proliferated and vast quantities of agrarian straw and animal waste produced during recent years. So, investigations suggested setting up an effective recycling program via supporting and encouraging governmental policies

(Gutiérrez et al., 2013; Wang et al., 2016). The annual reports indicate that India has generated around 400 million tons of agrarian waste (Raju et al., 2012). Agrarian waste has been used in many applications, even utilized to remove dyes from wastewater by Bharathi and Ramesh (2013). The use of agricultural waste has applauded to generate bioethanol in various studies and cardboard in the current study (Hossain et al., 2008). Therefore, the industrial projects of discussed options posed to assess in EIA.

One of the most essential instruments on which to consider environmental considerations in the planning system is the EIA. Today, in many countries, the EIA is one of the most critical strategic instruments of environmental management. To integrate environmental considerations in the planning and developing process at the highest levels, EIA is considered as the most essential decision-making instrument. The environmental assessment in the service of sustainable development leads to progress towards sustainability and, consequently, improved the indicators of sustainable development including all economic, social, institutional, and environmental dimensions. Protecting the environment, in which future generations should thrive in social life, is a public duty. It is necessary to raise awareness about this plan. It is essential to act strategically, not in the tactical field.

In general, environmental assessment is defined as a method by which a correct understanding of the position, role, function, and effects of any natural or human-made phenomenon in the environment is formed. Thus, it is possible to determine the circumstances of the assessment that is related to the environment, its interaction, and the kind of processes and reactions between them. According to the International Union of Impact Assessment, EIA is a plan to reduce biophysical, social, and other impacts associated with the proposed development before the primary decision and executive action. Analyzing the effects is a coherent scientific tool used to identify, summarize, and organize information related to the environmental impacts of policies, programs, and plans. In strategic & environmental assessment, the analysis and evaluation phase is one of the most critical parts of EIA studies. In this section, the current situation and predicted effects on physical and chemical, biological, socio-economic, and cultural environments are reviewed and analyzed. In fact, in this section, all information and forecasts, (both qualitatively and quantitatively), are standardized and presented in reviews and reports. In this section, according to the description of study services, to understand the significant and essential effects, all impacts are examined and analyzed according to their intensity, importance, and nature so that decisions be made based on them. Today, there are several methods for evaluating and analyzing the effects of implementing policies and programs, each of which has its advantages and disadvantages (IEEM, 2006). Being able to implement these policies and practices may be contrary to today's conditions or nature. However, arrangements can be made for the necessary precautions and measures to be taken.

The purpose of the monitoring program is to obtain information that identifies the effects and consequences of the various policies, programs, and activities. The monitoring program should provide a complete description of the techniques used. Regarding sampling methods, the essential equipment should be presented in the monitoring program. Therefore, it is indispensable that experts of environmental assessment and other relevant staff in various fields and disciplines must be recruited in this team who can evaluate the multiple dimensions of strategic decisions, policies, and programs with a macro perspective. The following data are related to the project screening step according to the EIA plan to underpin the efficiency score of five industries in Iran (Vallero, 2004; Hassanpour, 2020; Dubey and Dai, 2006; Bahrami et al., 2016; Mansour and Kesentini, 2008). Our studies declare that there is no similar study investigating the efficiency of Iranian industries in the screening step of the EIA plan across Iran. The motivation of the present research gets back to existing difficulties in the way of recently developed and outlined enterprises due to the sanctions approved against the Iranian government. The objective of the paper was to figure out the efficiency of industries based on recent prices for the input and output variables of industries in the market of Tehran, Iran.

2. Literature review

The efficiency assessment based on the DEA model takes into consideration the input and output variables. DEA model measures productivity performance based on financial indicators. In this model, if we add other inputs and outputs (net sales, net profit margin, net profit/equity, net profit / total assets, etc.) to the model, different results may occur. For this reason, we can achieve the desired results based on the selected data in the model. Statistics can sometimes provide us with this.

The division of output to input values releases the DEA rank. For example, the sustainability of suppliers has assessed via the Fuzzy DEA model. By the way, the variables allocated in 15 rows in inputs and outputs variables (Zhou et al., 2016). The input and output variables introduced to the DEA model based on the constant return to scale encompassed total outlays, CO_2 dissipation, the number of stations, weekly turn up, and the number of users in the investigation of two rail lines holding six and sixty stations in London, respectively (Taboada and Han 2020). Chinese industries underwent an efficiency assessment using the DEA model in seven years. It has been classified based on efficient and inefficient industries in the provinces (Xiong et al., 2017). A study addressed the DEA model as a potent instrument in economic prosperity assessment at national levels in energy and environment (Sueyoshi et al., 2017). The precision and reality of the DEA model (slacks-based measures) have investigated with other models. The comparison was reported with enough validity (Shermeh et al., 2016). The DEA model has been taken into consideration the efficiency and performance assessment of seven Indian chemical industries. The findings classified efficient industries with an efficiency border range of the lowest to highest, around 0.713 to 1, respectively (Anthony et al., 2019). A study introduced a type of DEA model in assessing the seven operational research techniques in business tax. The model succeeded in offering responses of efficient industries and was extendable to similar models in this regard (Santos et al., 2018). The efficiency assessment of wind turbines resulted in finding the inefficient cases regarding input variables of wind speed, wind power density, anemometer tower, and wind frequency and tower height and output variables of space between turbines, their directions, and the number of turbines in China (Niu et al., 2018). Bulak and Turkyilmaz, (2014) evaluated 744 Turkish suppliers at the efficiency level in a full list of input and output criteria and variables. The footprint of significant air pollutants emitted into the atmosphere by industrial sectors has assessed via the DEA model in European Union (Zurano-Cervello et al., 2018). In evaluating the agricultural enterprise, the DEA model assigned to release the efficiency score based on financial indicators. The excellent ranking system developed in the following calculations (Fenyves et al., 2015). The performance assessment of both Turkish and Chinese companies used the DEA model to detect the ranks, and, in the estimation, the canonical correlation analysis employed as a weighing system. The classification of efficient and inefficient industries paved the way for comparing the companies between two countries (Bayyurt and Duzu, 2008). The DEA- returns to scale model has assigned to assess the efficiency score of air transport sectors in 30 provinces in a matrix of 3×3 input and output variables in 2017 in china. According to the results, the majority of sectors appeared with full efficiency or very close values to the top efficiency border (Song et al., 2020).

Andrejić and Kilibarda (2016) employed the Principal Component Analysis - DEA model for figuring out and improving the efficiency of distribution channels of products regarding 16 inputs and 17 outputs variables. The reasons for failure, efficiency fall, and circumstances of efficiency rise have discussed and offered options for expansion and improvement in the efficiency of distribution channels. The results pointed out to improvement of efficiency in four sections within the distribution channels. Blagojević et al., (2020) used the Fuzzy Analytical Hierarchical Processes – DEA model to investigate the performance of nine freight transport railways by selecting five main criteria. The border of efficiency determined in a range of around 0.242 to 1 in both systems of CCR and BCC. A study applied both models of CCR and BCC of the DEA model and correlation analysis for determining the efficiency of five automotive companies based on financial statements in Europe. Findings revealed total efficiency for the mentioned cases (Papouskova et al., 2020). DEA model based on returns to scale in both systems of CCR and BCC has examined to realize and classify thirty-five Indian small and medium-sized industries in facing lean and sustainability-oriented innovation. The score of efficiency placed the industries in a certain interval of 0.832 to 1, and most of them were efficient. A combination of both orientations helps the industries move towards sustainability (De et al., 2020). In Brazil, the logistics modes of some projects outlined in transport and cargo handling operation have taken into consideration via the DEA-CCR model consist of 12 alternatives, four inputs, and one output variable from 2008 to 2012. The results emerged with full efficiency for all years of study except for 2010. By the way, it offered some improvement options to escalate the efficiency score and impede falling in efficiency reported (Lepchak and Voese, 2020). By a combination of the Entropy-Fuzzy PIPRECIA-DEA model and the presence of six inputs and five outputs, decisions have made in the field traffic safety of nine railways in Bosnia and Herzegovina. Due to significant low efficiency and high risk in safety, two alternatives were held back in the following calculations. The sensitivity analysis has conducted to verify the findings by alteration in quantities of variables in a variety of scenarios (Blagojevic et al., 2020). The DEA-CCR model has taken into consideration for determining the efficiency of airlines due to a significant decline in efficiency score during the pandemic of Covid-19 in Asia. It used three inputs and three outputs key variables in the study. The findings proved a significant decline in the performance and efficiency of airlines. To evaluate the monthly performance of the egg generation in a poultry house, integration of DEA (Slacks-Based Measure)-CRITIC-gray model has applied. A sample of 8000 chickens selected to breathe in proper conditions of feed and maintenance to evaluate the efficiency in various months of the year (15 months) in Çukurova. In the study, three inputs and two outputs variables composed the framework of the data matrix to assess. A sensitivity analysis has done using four models of multi-criteria decision-making to examine the validity of results. The final examination had shown a different classification in models for efficiency score (Kucukonder et al., 2019).

To figure out the efficiency score, the DEA model has been considered in a variety of researches pertaining to financial variables and indicators during a specific time interval in the studies conducted by Arab et al., (2015), Kettiramalingam et al., (2017), Raithatha and Komera (2016), Bagh et al., (2016) in the field of Indian manufacturing companies, an Indian cement industry, executive compensation relation between Indian companies and fifty Pakistani companies on the stock market respectively.

3. Methodology

3.1. Screening of projects

By the current study, the initial data were picked up from the screening step of industrial projects by evaluator teams and were investigated to estimate the efficiency of industries (according to Figure 1). To estimate the efficiency of industries via DEA model was assumed 270 working days per year. The variables were multiplied in the working days. To calculate the costs was used the daily prices in the market of Tehran, Iran.

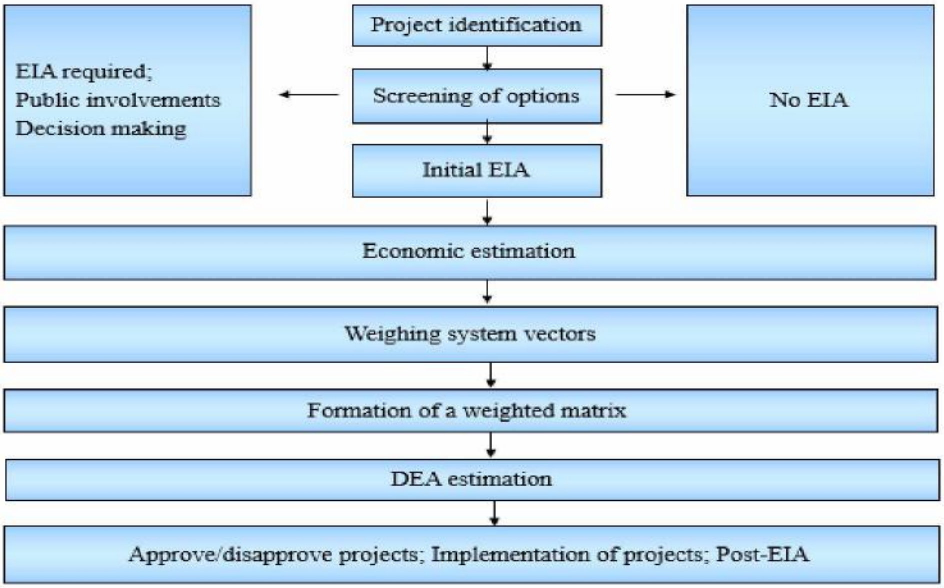


Figure 1. The evaluation steps of EIA in Iran and procedure conducted

3.2. Weighing system of Friedman test

When the normal distribution of groups is individually uncertain for us, we use the Friedman test as one of its essential applications. The blocks of values in the matrix are independent, and data are non-parametric. It is similar to the F test that indicates the samples of groups allocated together. It is also able to classify groups hierarchically. The homogeneity of average weights between values in the Friedman test depends on low fluctuations in data introduced into software for further processing (Biju and Prashanth, 2017; Eisinga et al., 2017). The existing Friedman test in the SPSS software was used to estimate the values of weights in the present study. There are a few empirical equations to describe the method, but this research has ignored to include them.

3.3. Weighing system of CRITIC

The use of the weighing system of CRITIC is encouraging because of its wide application in studies. It is classified in the list of correlation methods. The criterion Xij consists of the membership function rij, which converts the existing quantities into an interval [1-0] to present the ideal point. The data matrix is configured with elements of rij with a standard deviation (σj) for the individual vector after translating the initial values. The values of weights are calculated for the assumed criteria by values of Cj (Vujicic et al., 2017).

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad (1)$$

$$Cj = \sigma_j \sum_{j=1}^{m} (1 - r_{ij}) \quad (2)$$

$$W_j = \frac{C_j}{\sum_{j=1}^{m} C_j} \quad (3)$$

3.4. Traditional DEA model

The main application of the DEA model relies on distinguishing the efficient and inefficient alternatives (industries in this research). The framework of the DEA model has been defined based on the division of the sum of weighted outputs variables to the sum of weighted inputs variables according to equation 4. The inputs and outputs variables were the costs of materials, the salary of employees, energy consumed, and industries' products for five industries in the present study, respectively. The vectors of both weighing systems of Friedman test and CRITIC were introduced into a matrix of data to sum the final values as productivity of alternatives. Then the maximum value of productivity was selected to release the efficiency score (Sergi et al., 2020).

$$Ekk = \frac{\sum_{r=1}^{s} Urk\ Yrk}{\sum_{i=1}^{m} Vik\ Xik} \quad (4)$$

Regarding an allocation of n DMUs (alternatives) to be investigated, and individual DMU j (j=1,...,n) generates s various outputs via applying m different inputs, which are realized as Yrj (r = 1,...,s) and Xij (I = 1,....,m) respectively. To find out the efficiency (E) score of DMU k needs a division of the weighted sum of outputs over the weighted sum of inputs according to equation 4. By the way, Vk =(V1k,...., Vmk) and Uk = (U1k,...., Usk) are input and output weighing vectors to evaluate DMU k, as Urk and Vik are multipliers of the inputs and outputs, respectively (Vujicic et al., 2017; Hassanpour, 2020).

4. Result and discussion

To start describing the applied processes in five generation and regeneration industries (Drip irrigation system, Mobile sprinkler for the home lawn, PVC film generation, cardboard generation of agricultural waste, and plastic waste recycling industries), was displayed their flow diagrams as below (Figures 1.1 to 1.5).

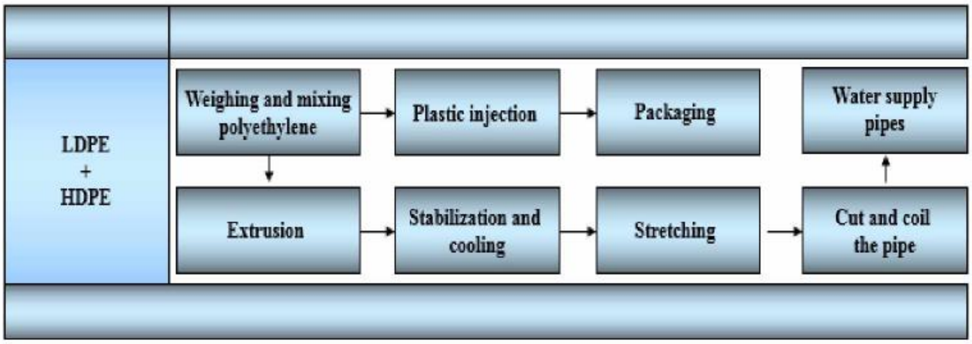


Figure 1.1. Diagram of layout units of drip irrigation system manufacturing in Iran

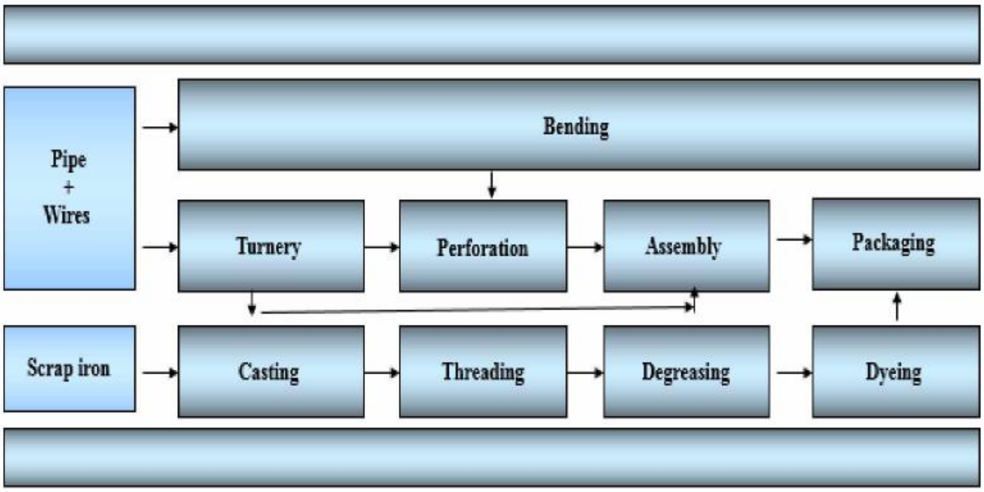


Figure 1.2. Diagram of layout units of mobile sprinkler generation industry for the home lawn in Iran

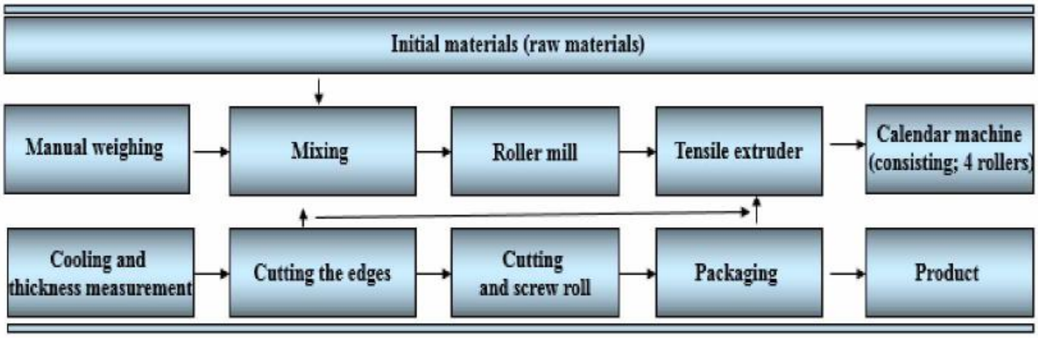


Figure 1.3. Diagram of layout units of PVC film generation industry for the agricultural use in Iran

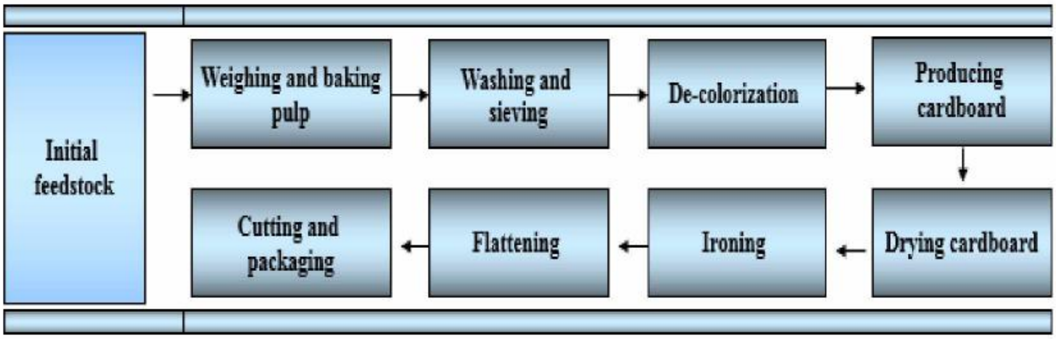


Figure 1.4. The steps of cardboard generation of agricultural waste

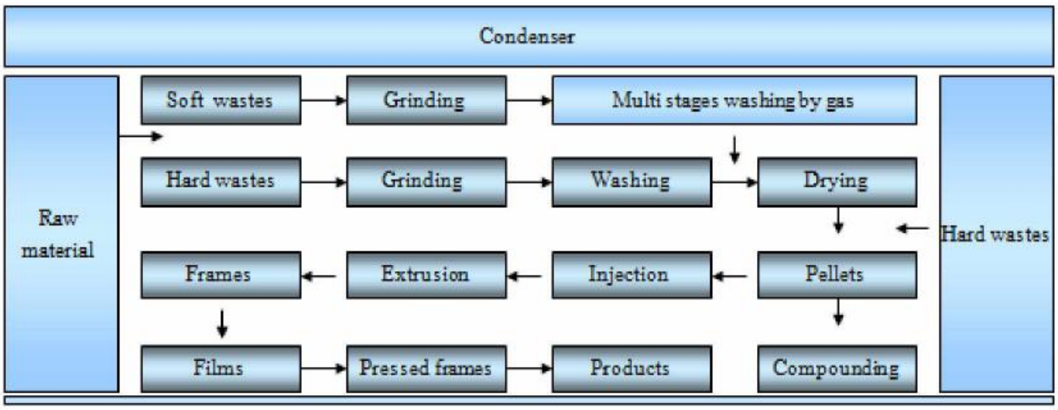


Figure 1.5. The layout units of recycling of the plastic wastes

4.1. Drip Irrigation System Manufacturing Industry (DISMI)

In a drip irrigation system, the required water is transferred to the plants through a pipe and passing through different device components. This system typically includes a motor pump, a cyclone, a sand filter, a fertilizer tank, a control center, an optical filter, the main pipe, a water pipe, and a dripper. Its wide application is for farms, gardens, and greenhouses. The production steps of drip irrigation components (pipes and dripper) are as follows: (1) Polyethylene and additive materials are weighed and mixed in a blender (2) The output mixture enters into the extruder and takes the desired shape when it is leaving the extruder. (3) The pipe enters into the stabilizing bath, which is closed, and its pressure by the vacuum pump is slightly less than the atmospheric pressure. After leaving the tub, the pipes enter into the cold water. (4) This unit has two rows of conveyor-like plastic strips, placed at the bottom and top of the pipe, and pull it with friction force so that the pipe does not wrap after leaving the mold. (5) The pipe is cut to the desired length with a circular saw. When the pipe is cut, the saw moves with high speed in the direction of the pipe. After cutting, the tubes are assembled on the spool. (6) The impeller is made of plastic. (7) Each of the 22 emitters is placed in a cardboard box in dimensions of 200 cm^3, according to Figure 1.1. The annual requirements of DISMI have displayed in Table 1.

Table 1. Annual requirements of DISMI (nominal capacity 1000 No+383.9t)

The materials and equipment	Total annual rates	$
Materials demands		
HDPE	173t	204998
LDPE	224t	
Pigment with the soot of 40%	16.600t	
Single-layer of cardboard boxes	31250 No	
Products		
Dripper (according to standard 8072 and 8074 DIN); Water supply pipe with a tolerable pressure of 10 atmospheres made of LDPE, heat resistance up to 80 and withstand cold up to -70 Ċ with specific characteristics in the national standards of Iran, numbers 1331; Water supply pipe with a tolerable pressure of 110 atmospheres and made of HDPE, heat resistance up to 80 and withstand cold up to (-70) Ċ with specific characteristics in the national standards of Iran, numbers 1331 and 2178	1000 No; 233.37t; 150.56t	4830572
Employees		
Staff	52 persons	83200
Energy consumption		
Required water	4590 m^3	21062
Power consumed	47520 kW	
Required fuel (Stoves)	1350 Giga joule	

4.2. Mobile sprinkler for home lawn

The home lawn sprinkler is a mobile piece and works with municipal water pressure, and is used to irrigate lawns and gardens to a limited extent. The sprinkler is classified as all-metal, all-plastic, and semi-plastic, which in this design, the type of semi-plastic was selected. It is made of cast iron in base and elbow, an aluminum fountain, and a plastic hose. It is designed in such a way that the fountain with water pressure in addition to spraying water in droplets, rotates around, and the elbow provides the possibility of irrigation under the beam. The stages of production of grass sprinklers are as follows: (1) Lathing: The parts of the sprinkler mold, which are made of hexagonal profiles, wire, and aluminum pipes, are threaded according to the necessary processes of the lathing, drilling, and incorporating steps. (2) Bending: The aluminum fountain tube will require a superior bending to perform the mechanism of circulation with underwater pressure where manual bending is used. (3) Drilling: Fountain pipe and cap need holes for spraying water, which is used to make a hole. (4) Assembly of sprinkler parts: First, the cap is screwed on the fountain pipe, and then the pipes are closed inside the revolving base and then the feeder base and ribbed seal are installed on the revolving base. (5) Casting: Scrap iron is used for the production of the base of cast iron and elbow as a melting process which is prepared by a furnace and a mold. (6) The threading of the base and the elbow for installing the fountain is created in the product by a lathe. (7) The base and the elbow are degreased to be ready for dyeing. (8) Dyeing is done with a pistol. (9) Packaging: The last stage of production is the packaging of three sets of sprinklers, elbow base, and hose head inside the plastic and cardboard boxes, according to Figure 1.2. The annual requirements of mobile sprinkler generation industries for the home lawn applications have displayed in Table 2.

Table 2. Annual requirements of mobile sprinkler generation industries for a home lawn application (nominal capacity of 81000 No)

The materials and equipment	Total annual rates	$
Materials demands		
Scrap metals	26700 kg	15000
Al wires, d=20 mm	290 kg	
Al pipes, d=22 mm	290 kg	
Hexagonal Al	6100 kg	
Al pipes	4700 kg	
Al wire	1t	
Plastic labels	81000 No	
Dye	3120 kg	
Cardboard boxes 10*15*15 cm^3	81000 No	
Nylon bags	81000 No	
Packaging carton in sizes of 45*45*50 mm^3	1800 No	
Plastic pipe heads	81000 No	
Plastic washer, external d= 19 mm	81000 No	
Steel washer, internal d= 21 mm	81000 No	
Products		
A mobile sprinkler which works with municipal water pressure, with a fountain made of AL, and a plastic hose head. It has good resistance to water in terms of erosion	81000 No	81000

and abrasion.		
Employees		
Staff	9 persons	14400
Energy consumption		
Required water	1620 m^3	7439.3
Power consumed	14040 kW	
Required fuel (Stoves)	2160 Giga joule	

4.3. PVC film for agricultural use

The steps for generating the PVC films in agricultural use are explained in the following (1) Raw materials are weighed in proportion to the required. (2) These required PVC materials, emollients, and other additives which are required for mixing are introduced into the mixer. To achieve uniformity, the mixture is vigorously re-mixed by transferring into a strong mixer. (3) The mixture is conducted by a conveyor to a two-roller mill to perform another stage of mixing. The mixture is fed to the secondary two-roller mill to re-mix the constituents. (4) The mixed material is disembogued to the extruder. (5) Using a conveyor belt, the mixture is transferred into a cylinder consisting of 4 rollers to bring the thickness to the dimensions referred as PVC film. (6) The temperature of the PVC film is reduced by passing through the dryer. The thickness of the PVC film is estimated via a measuring device which works based on beta rays. (7) For the PVC film to be rolled in terms of dimensions, its sides are cut, and its waste is returned to the initial mill. (8) PVC film is wrapped in a roll using the machine and the desired length. (9) The resulting rolls are packed using Kraft paper, according to Figure 1.3. The annual requirements of PVC film generation industries for agricultural use have displayed in Table 3.

Table 3. Annual requirements of PVC film generation industries for agricultural use in Iran (nominal capacity 21600000 m²)

The materials and equipment	Total annual rates	$
Materials demands		
PVC	3672t	416834.3
Shaping materials	55t	
Stabilizer	73t	
Additives	37t	
Paper in sizes of 0.5*2 m for packaging purposes	220000 No	
Products		
PVC film, width = 1.8 m, thickness = 0.5-0.1 mm, the average weight of each m^2 of PVC film = 92 g, the weight of each meter of PVC film = 170 g	21600000 m^2	7714285.714
Employees		
Staff	46 persons	73600
Energy consumption		
Required water	270 m^3	1708.5
Power consumed	55620 kW	
Required fuel (Stoves)	27270 Giga joule	

4.4. Cardboard generation of agricultural waste

Cardboard is a type of plywood that, due to the required strength and flexibility, is mainly used in the packaging industry, and each square meter should consist of more than 180 grams. The process of producing cardboard from agricultural waste is explained. (1) Weighing: Raw materials (agricultural waste and chemicals) are weighed to a certain proportion. (2) Baking pulp: Chemicals with agricultural waste are placed in a baking dick and are prepared at a lower temperature of 100 °C (3) Washing the pulp: The pulp is coming out of the cooking pot is washed with water inside a washing cylinder in three steps. (4) Sieving the pulp: After mixing and diluting, the clean pulp is pumped to centrifugal filters, and heavier particles like sands are separated from the pulp. The dryness percentage of the pulp is increased to about 100% by the thickening system. (5) De-colorization system: The pulp is mixed with chlorine solution in a blender with a retention time of 45 minutes. Then it is conducted to the chlorine washing system. After re-dilution with hypochlorite solution, it is transferred to the final rinse and is transferred to the cardboard-making machine in several stages of de-colorization. (6) Cardboard making: After passing through the de-colorization system, the paste is transferred to the cardboard making machine by a pump, and after withstanding the hammer pressures for separating the water from the suction pulp, it is sent to the drying part. (7) Dryer: After the pulp passes through the cardboard-making machine, it is sent to the dryer tunnel, and inside this tunnel, hot air hits the cardboard and makes the cardboard to be dried. (8) Ironing: since the cardboard loses its smoothness after leaving the dryer and its surface becomes uneven, in addition to flattening the surfaces by ironing with the pressure, it compresses the fibers and increases the strength of the cardboard. (9) Cardboard cutting: After ironing the cardboard, the cardboard's dimensions are equalized by the cutting machine, and it reaches the desired dimensions. (10) Packing: 100 pieces of cardboard are cut (80 by 120 cm^2) and placed inside the packing plastics. The annual requirements of cardboard generation industries of agricultural waste have displayed in Table 4.

Table 4. Annual requirements of cardboard generation of agricultural waste (nominal capacity of 1350 Kg)

The materials and equipment	Total annual rates	$
Materials demands		
Agricultural waste	2700t	111926.22
NaOH	10800 kg	
$NaCO_3$	5400 kg	
Hypochlorite sodium	5400 kg	
LDPE	44400 m^2	
Products		
The cardboard consists of 50-90% cellulose according to Iranian standard number 1411	1350t	1400000
Employees		
Staff	46 persons	73600
Energy consumption		
Required water	9180 m^3	42170
Power consumed	85320 kW	
Required fuel (Stoves)	11070 Giga joule	

4.5. Plastic waste recycling industries

The steps for recovering plastic waste are as follows (1) Waste classification: After collection, plastic waste should be classified according to the type of materials such as polypropylene and polyethylene, softness, and hardness. (2) Crushing and grinding the scrapes in less than one inch. (3) Washing: Particles can be cleaned in water washing machines. It can be used either the sodium carbonate or ordinary detergent powders for this purpose. (4) Dehydration and drying in a heated oven. (5) Granulation: To prepare the pellets of plastic particles to use in downstream processes or to mix with first-hand materials, clean pellets of plastic particles must be in the form of granules, according to figure 1.5. The annual requirements of plastic waste recycling industries of agricultural waste have displayed in Table 5.

Table 5. Requirements of the plastic wastes recycling industry

The materials and equipment	Total annual rates	$
Materials demands		
LDPE	1000t	108571.43
$NaCO_3$ (0.5 g per kg wastes)	0.5t	
Products		
Granules of LDPE + LDPE milled	230t+400t	878787
Employees		
Staff	9 persons	14400
Energy consumption		
Required water	1620 m^3	7743
Power consumed	91530 kW	
Required fuel (Stoves)	2430 Giga joule	

4.6. DEA assessment

The Friedman test was used to calculate the weights of criteria along with the weighing system of CRITIC. According to the t-test analysis, there is no significant difference between the obtained weights in both systems. Table 6 shows the values of weights in weighing systems.

Table 6. The values of weights in weighing systems

Industries/criteria	Materials demand	Products	Employees	Energy consumption
Friedman test				
Wj	3	4	2	1
Weighing system of CRITIC				
Wj	0.044233462	0.943349249	0.007437201	0.004980089

According to Table 7, the obtained results in the DEA score consist of a range between zero to one for the inefficient to efficient borders respectively. The number 1 denotes the fact that the industry is working with top efficiency and below that goes far from the efficiency border. The less value in the DEA score, the less efficiency will have emerged.

Table 7. DEA score and rank

Industries/criteria	Productivity	DEA score	DEA rank
	Based on the Friedman test		
(1)	24.07893766	1	1
(2)	3.988217525	0.165630959	5
(3)	22.05008681	0.915741679	2
(4)	10.66364713	0.442862026	3
(5)	9.703456899	0.402985258	4
	Based on the CRITIC system		
(1)	465.4	1	1
(2)	94.6	0.203288049	5
(3)	383.137	0.823245193	2
(4)	231.364	0.497131417	3
(5)	167.538	0.359988748	4

Drip irrigation system (1), Sprinkler generation (2), PVC film generation (3), Cardboard generation of agricultural waste (4), Plastic wastes recycling (5)

The t-test analysis had shown a significant difference ($p\text{-value} \leq 0.028$) for the criterion of employees in comparison with other variables (criteria) such as materials demand, product, and energy consumption. The null hypothesis test summary via a one-sample Kolmogorov Smirnov test retained the null hypothesis for the variables. But the same hypothesis had revealed a significant difference around 0.002 among four variables via related samples Friedman's two-way analysis of variance by ranks and the distribution of materials demand, product, employee, and energy consumption was the same.

Due to a significant rise in the price of raw materials required by industries, dependence on procuring raw materials of industries (in many cases), and devaluation of the Iranian currency, there is a need for a significant rise in the price of industrial products. On the other hand, due to the decrease in purchasing power, the industries will move towards inefficiency. With a slight increase in the selling price of the products of the industries, the efficiency score will decrease too. Also, with the rise in employees' salaries in the industry, there will be a further decrease in efficiency of industries. So, the stakeholders tend to either reduce the salaries of employees or lay off the number of employees. Due to the variability in energy consumption in units with the same nominal capacity, the results are not comparable to operating companies. Because the initial estimates in the project screening phase will change with the pattern of energy consumption in the industry after the construction of the industries. The quantity of energy consumption can be the same, but the costs will vary depending on the type of energy applied. On the other hand, finding industries with the exact specifications will raise the lack of cooperation from managers. To prove the fall and rise in efficiency score of industries before and during the period of sanction we can only rely on reports of inflation rate in Iran. The inflation rate and the rise in the price of goods are monthly announced by the in-charge bodies in Iran. To estimate the efficiency score of industries was used real data. Conducting a sensitivity analysis via manipulated and sophisticated data for the costs of energy & materials streams before and during the period of sanction will make the real results meaningless. The other limitations of the present research refer to the provision of initial data, the collaboration of in-charge organizations with the research centers, fluctuations in the market for the costs of materials & energy demands in industries, and raising the daily prices.

5. Conclusion

The present research attempted to find the efficiency of 5 industries based on the input variables of materials demand, employees' number, energy consumed, and the output variable of products generated. The DEA method applies to industries with the same nominal capacity. It can allocate them in a particular decision-making situation concerning the fact that the whole inventory of availability is the same for them in the screening step. But the efficiency will be changed for the same industries with different nominal capacities. It means by assessing an industry from one particular group, we can decide for the same group of industries with the same nominal capacity. On the other hand, we are aware the running technologies are the same among certain groups and stakeholders used the same processes and technologies in their manufacturing units in Iran. Any development and progress will happen in the post-EIA after the complete establishment of industries, and the efficiency will change according to a rise in the variables interfering in DEA estimation and during a time interval (years) of operation. However, it needs to point out that due to the ongoing pandemic prevalence of Covid-19 in our world, the efficiency scores of all sectors are decreasing. This situation is valid for the global economy. This fact should be taken into account as well as the current situation in Iran.

Future studies can be discussed for changing the actual prices of input and output variables and can be compared with existing reports to find the significant differences and conduct a sensitivity analysis in a variety of scenarios. Using novel models of DEA either individually or integrated with other multi-criteria decision-making models is also encouraging to find efficient enterprises. The tabulated data can be used to estimate the financial statements of mentioned industries and develop any financial estimation model in this regard. Also, the sustainability of industries can be taken into consideration by selecting various criteria from concepts presented by the text in decision-making theory.

***ACKNOWLEDGMENT*:** This research was considered as part of the Ph.D. research work (Entitled; Evaluation of 405 Iranian Industries). The funding information does not apply to the present paper. Any opinions, findings, and conclusions expressed in this publication are those of the author and necessarily reflect the current views and policies.

References

Anthony, P., Behnoee, B., Hassanpour, M., Pamucar, D. (2019). Financial performance evaluation of seven Indian chemical companies, Decision Making: Applications in Management and Engineering, 2(1), 19-37.

Arab, RO., Masoumi, SS., Asoumi, BA. (2015). Financial Performance of the Steel Industry in India: A Critical Analysis. Middle-East Journal of Scientific Research, 23(6), 1085-1090.

Andrejić, M., Kilibarda, M. (2016). A framework for measuring and improving efficiency in distribution channels. International Journal for Traffic and Transport Engineering, 6(2), 137 – 148.
Bharathi, KS., Ramesh, ST. (2013). Removal of dyes using agricultural waste as low-cost adsorbents: a review. Appl Water Sci, 3, 773–790.
Bahrami, A., Soltani, N., Pech-Canul, MI., Gutierrez, CA. (2016). Development of metal-matrix composites from industrial/agricultural waste materials and their derivatives. Critical reviews in environmental science and technology, 0(0), 1-66.
Bulak, ME., Turkyilmaz, A. (2014). Performance assessment of manufacturing SMEs: a frontier approach. Industrial Management & Data Systems, 114(5), 797-816.
Bayyurt, N., Duzu, G. (2008). Performance Measurement of Turkish and Chinese Manufacturing Firms: A Comparative Analysis. Eurasian Journal of Business and Economics, 1 (2), 71-83.
Bagh, T., Nazir, MI., Khan, MA., Khan, MA., Razzaq, S. (2016). The Impact of Working Capital Management on Firms Financial Performance: Evidence from Pakistan. International Journal of Economic and Finance, 6(3), 1097-1105.
Blagojević, A., Vesković, S., Kasalica, S., Gojić, A., Allamani, A. (2020). The application of the fuzzy AHP and DEA for measuring the efficiency of freight transport railway undertakings. Operational Research in Engineering Sciences: Theory and Applications, 3(2), 1-23.
Blagojevic, A., Stevic, Z., Marinkovic, D., Kasalica, S., Rajili, S. (2020). A Novel Entropy-Fuzzy PIPRECIA-DEA Model for Safety Evaluation of Railway Traffic. Symmetry, 12, 1479, 1-23.
Biju VG, Prashanth CM. (2017). Friedman and Wilcoxon's evaluations comparing SVM, bagging, boosting, K-NN and decision tree classifiers, JACSM, 9(1), 23-47.
Difallah, W., Benahmed, K., Bounnama, F., Draoui B, Saaidi A. (2018). Intelligent Irrigation Management System. International Journal of Advanced Computer Science and Applications, 9(9), 429-433.
Dubey, VN., Dai, JS. (2006). Complex Carton Packaging with Dexterous Robot Hands", Chapter 29 the book: Industrial Robotics: Programming, Simulation and Application, 583-594. Germany.
De, D., Chowdhury. S., Dey, PK., Ghosh, SK. (2020). Impact of Lean and Sustainability Oriented Innovation on Sustainability Performance of Small and Medium-Sized Enterprises: A Data Envelopment Analysis-based framework, 219, 416-430.
Eisinga, R., Heskes, T., Pelzer, B., Grotenhuis MT. (2017). Exact p-values for pairwise comparison of Friedman rank sums, with application to comparing classifiers. BMC Bioinformatics, 18, (68), 2-18.
Fenyves, V., Tarnóczi, T., Zsidó, K. (2015). Financial Performance Evaluation of agricultural enterprises with DEA Method. Procedia Economics and Finance, 32, 423 – 431.
Gutiérrez, J., Villa-Medina, JF., Nieto-Garibay, A., Porta-Gándara, MÁ. (2013). Automated irrigation system using a wireless sensor network and GPRS module. IEEE Trans Instrum Measur, 63(1), 166–176.
Hossain, ABMS., Saleh, AA., Aishah, SS., Boyce, AN., Chowdhury, PP., Naqiuddin, M. (2008). Bioethanol Production from Agricultural Waste Biomass as a Renewable Bioenergy Resource in Biomaterials. Biomed Proceedings, 21, 300–305.
Hassanpour, M. (2020). Evaluation of Iranian Chemical Industries. International journal of chemistry materials research, 8(1), 26-48.

Jha, G. (2016). A Review on Drip Irrigation using Saline Irrigation Water in Potato (Solanum tuberosum L.). Journal of Agro-ecology and Natural Resource Management, 3(1), 43-46.

Jumanne, MK. (2016). Applicability of drip irrigation for smallholder farmers: A case study of the Horticultural industry in Tanzania. Presented in Partial Fulfillment of the Requirement for the Degree Master of Science in the Graduate School of the Ohio State University, 1-70.

IEEM. (2006). Guidelines for ecological impact assessment in the United Kingdom. Institute of Ecology and Environmental Management, 1-67.

Kado, S., Sekine, Y., Nozaki, T., Okazaki, K. (2004). Diagnosis of atmospheric pressure low-temperature plasma and application to high efficient methane conversion. Catalysis Today, 89(1-2), 47–55.

Kettiramalingam, AY., Sowmiya, K., Sangeetha, P. (2017). Financial performance analysis of select cement companies. Intercontinental journal of finance research, 5(4), 15-27.

Küçükönder, H., Demirarslan, CP., Burgut, A., Boğa, M. (2019). A Hybrid Approach of Data Envelopment Analysis Based Grey Relational Analysis: A Study on Egg Yield. Pakistan J. Zool, 51(3), 903-912.

Lepchak, A., Voese, SB. (2020). Evaluation of the efficiency of logistics activities using Data Envelopment Analysis (DEA). Gestão & Produção, 27(1), e3371, 1-20.

Mansour, LB., Kesentini, I. (2008). Treatment of effluents from cardboard industry by coagulation–electro flotation. J. Hazard. Mater, 153(3), 1067-1070.

Niu, D., Song, Z., Xiao, X., Wang, Y. (2018). Analysis of wind turbine micro siting efficiency: An application of two-subprocess data envelopment analysis method. Journal of Cleaner Production, 170, 193-204.

Peeters, JR., Vanegas, P., Tange, L., Houwelingen, JV., Duflou, JR. (2014). Closed-loop recycling of plastics containing Flame Retardants. Resources, Conservation and Recycling, 84, 35– 43.

Papouskova, K., Telecky, M., Cejka, J. (2020). Process efficiency analysis of selected automotive companies in Europe. Communications, 22(4) 20-27.

Peoples, J., Abdullah, MA., Satar, NM. (2020). COVID-19 and Airline Performance in the Asia Pacific region. Version 1; peer review: 1 approved with reservations]. Emerald Open Research, 2:62, 1-17.

Raju, GU., Kumarappa, S., Gaitonde, VN. (2012). Mechanical and physical characterization of agricultural waste reinforced polymer composites. J. Mater. Environ. Sci, 3 (5), 907-916.

Raithatha, M., Komera, S. (2016). Executive compensation and firm performance: Evidence from Indian firms. IIMB Management Review, 28, 160–169.

Sueyoshi, T., Yuan, Y., Goto, M. (2017). A literature study for DEA applied to energy and environment. Energy Economics, 62, 104–124.

Shermeh, HE., Najafi, SE., Alavidoost, MH. (2016). A novel fuzzy network SBM model for data envelopment analysis: A case study in Iran regional power companies. Energy, 112, 686-697.

Santos, SP., Belton, V., Howick, S., Pilkington, M. (2018). Measuring organizational performance using a mix of OR methods. Technological Forecasting & Social Change, 131, 18–30.

Sergi, SB., D'Aleo, V., Arbolinoc, R., Carlucci, F., Barilla, D., Ioppolo, G. (2020). Evaluation of the Italian transport infrastructures: A technical and economic efficiency analysis. Land Use Policy, 99, 104961.

Song, M., Jia, G., Zhang, P. (2020). An Evaluation of Air Transport Sector Operational Efficiency in China based on a Three-Stage DEA Analysis. Sustainability, 12, 4220, 1-16.
Taylor, R., Zilberman, D. (2017). Diffusion of Drip Irrigation: The Case of California. Applied Economic Perspectives and Policy, 39(1), 16–40.
Taboada, GL, Han L. (2020). Exploratory data analysis and data envelopment analysis of urban rail transit. Electronics, 9, 1270, 1-29.
Usman, KM., Muhammad, T., Majid, M., Ali, SM., Shilan, R., Alireza, M., Sergey, P. (2016). Drip irrigation in Pakistan: status, challenges and future prospects. Russian Journal of Agricultural and Socio-Economic Sciences, 8(56), 114-126.
Vujicic, MD., Papic, M., Blagojevic, MD. (2017). Comparative Analysis of Objective Techniques for Criteria Weighing in Two MCDM Methods on Example of an Air Conditioner Selection. TEHNIKA –MENADŽMENT, 67, 3, 422-429.
Vallero, DA. (2004). Environmental Contaminants: Assessment and Control. Elsevier Academic Press, Burlington, MA, 1-820.
Wang, B., Dong, F., Chen, M., Zhu, J., Tan, J., Fu, X., Wang, Y., Chen, S. (2016). Advances in recycling and utilization of agricultural wastes in China: Based on environmental risk, crucial pathways, influencing factors, policy mechanism. The Tenth International Conference on Waste Management and Technology (ICWMT), Procedia Environmental Sciences, 31, 12 – 17.
Xiong, B., Li, Y., Song, M. (2017). Eco-efficiency measurement and improvement of Chinese industry using a new closest target method. International Journal of Climate Change Strategies and Management, 9(5), 666-681.
Zhou, X., Pedrycz, W., Kuang, Y., Zhang, Z. (2016). Type-2 fuzzy multi-objective DEA model: An application to sustainable supplier evaluation. Applied Soft Computing, 46, 424–440.
Zurano-Cervello, P., Pozo, C., Mateo-Sanz, JM., Jimenez, L., Guillen-Gosalbez, G. (2018). Eco-efficiency assessment of EU manufacturing sectors combining input-output tables and data envelopment analysis following production and consumption-based accounting approaches. Journal of Cleaner Production, 174, 1161-1189.

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 38-66
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta2040123t

MODELING AND ANALYSIS OF LEAN MANUFACTURING STRATEGIES USING ISM-FUZZY MICMAC APPROACH

Mohit Tyagi [1], Dilbagh Panchal [1]*, Deepak Kumar [2], R. S. Walia [3]

[1]Department of Industrial and Production Engineering, Dr B R Ambedkar National Institute of Technology Jalandhar, Punjab, India
[2] Department of Mechanical Engineering, Delhi Technological University, Delhi, India
[3] Department of Production and Industrial Engineering, PEC University, Chandigarh, India

Received: 01 December 2020
Accepted: 12 February 2021
First online: 20 February 2021

Original scientific paper

Abstract: *The current research work deals with an identification of different lean strategies and extraction to relevant strategies after discussion with experts and gives the answer of a question "how lean manufacturing strategies can help the organization to enhance the efficiency of the organization with great effectiveness?" In this research work, thirty-six lean strategies have been identified and out of which thirteen lean strategies were filtered in respect of highly importance value by factor analysis using software SPSS 21. Further, to identify and analyze the inter-relationship among filtered strategies, an Interpretive Structural Modeling (ISM) with Fuzzy Matriced' Impacts Croise's Multiplication Applique'e a UN Classement (MICMAC) approach has been used. Fuzzy MICMAC help to understand the dependence and driver's power of the lean strategies. The mutual importance of extracted strategies has been discussed through developing the ISM model and the individual assessment of each strategy with each of the other strategies has been derived using the Fuzzy MICMAC approach.*

Key words: *Lean Manufacturing System (LMS), Lean Strategies; Factor Analysis, SPSS 21, ISM Methodology, Fuzzy MICMAC*

1. Introduction

In the present scenario, it has been observed that the manufacturing firms are facing many challenges worldwide like quality, productivity, time management etc. To overcome these challenges forced the world's manufacturing firms to develop new manufacturing methods and concepts in the competitive market. Among them one of the main concepts is execution of lean manufacturing strategies in the production system. The concept of lean manufacturing system (LMS) was initiated by a Japanese automobile industry Toyota in mid-20th century was well known for production

* Corresponding author: Dilbagh Panchal
e-mail addresses: mohitmied@gmail.com (M. Tyagi), panchald@nitj.ac.in (D. Panchal), dk18102010@gmail.com (D. Kumar), waliaravinder@yahoo.com (R. Walia)

system. The aim of Toyota Production system was to enhance and raise the productivity with cost-reduction of the product by reducing waste or non-value added ventures (Womack et al., 1990; Srinivasaraghavan & Allada, 2006). It defines the production process and procedures to improve the working environment of the shop floor consequently it also helps in increasing the overall productivity of company (Narasimhan et al., 2006; Kusrini et al., 2014). It can provide the essential extended term performance to automobile companies by refining the organization of cost effectiveness, elimination of wastage and also environmental risks over the improvement of experiences for endless organizational progress. Lean manufacturing can implement the various set of activities for better performance of a company (Yusup et al., 2015; Al-Tit, 2017). There are different techniques generally accessing in the industry for effective outcomes. Application of lean manufacturing strategies can lead to continuous improvement in industrial field. The concept of lean can be implemented in any business organization along with the industries. Different types of tool are being used from past several decades in order to get error free production from production unit. It is a tool that provides effective results to withstand the competition in prevailing different segments in the market aiming to remove all others unnecessary parameters from production unit (Schiele & McCue, 2010). It uses very small inventory for manufacturing of product at high productivity. That's why, it can be seen as a very popular tool or technique used by most of big industries and firms.

Lean management is meant for respect of humanity, it does not under estimate the capacity of people working in the company. Moreover, it will help people to be more effective and appreciate their work. Lean management maintains the production and levelise all stages of production in the company (Ahlstrom, 2004; Nenni et al., 2014). Many errors occur during production like breakdown, lot reject etc. it can provide the framework to remove all these errors during the production. It can analyze the production procedure to find out the causes occur during production. Lean can help in maintaining the documentation of work process or procedure of production and establish the standards of the manufacturing for the company for present and future production (Jasti & Kodali, 2016). Many articles have focused on lean manufacturing strategies and lean integrated production system (Hackman & Wageman, 1995; McKone et al., 2001). This research purposes to pinpoint several lean strategies and features through comprehensive textual review to analyze them through interpretive structural modeling (ISM). A model based on ISM technique is developed to frame the immediate connection between various considered strategies. Then the fuzzy MICMAC technique is performed to measure the inter-dependent power of different lean strategies. The results of present effort will assist the managers to improve the efficiency of their firm in this competitive market.

In the current study, an ISM approach with fuzzy MICMAC analysis has been applied due to its various importances over the other MCDM approaches. This approach provides a model based on that the dependence and driving nature of any factor/measures/strategies which is missing with the application of other MCDM approaches. Furthermore, the MICMAC analysis under uncertain environment (fuzzy) provide the cluster based analysis through four sectors (dependent, independent, linkage or individual) which provides a platform to the manager or policy makers to emphasize on strategies or factors according to the policy notion of the concerned organization.

The organization of this research article is as follow: section one gives a brief introduction on the various lean strategies and their importance in present manufacturing scenario, section two encloses the inclusive literature review and the based that important lean strategies have been extracted, section three illustrates the methodology which has been applied on the selected strategies in order to obtain the interrelationship among them, the conclusion drawn from the present research and its managerial implications in manufacturing environment have been expressed in section four and five respectively. In the last, section six shows the limitation and future scope of the present study.

2. Literature review

The goal of LMS is to reduce inventory and increase human efficiency and handling industrial stocks which are in accordance to consumer needs and the products are manufactured effectively and efficiently (Bhim et al., 2010). Increasing resource effectiveness by excluding superfluous consumption denotes the logical extension from lean manufacturing to lean and manufacturing. A simulation based methodology for monetary valuation was studied by Greinacher et al., (2015) of lean and green manufacturing organizations as non-monetary green parameters. Thus, economical efficiency is an indispensable evaluating factor in the application of lean and green manufacturing strategies. Salleh et al., (2012) Studied the forming process for simulation of combined total quality management along with lean manufacturing activities. Wahab et al., (2013) established a theoretical model to evaluate leanness in manufacturing unit. In this research, a concept based model for leanness element in the manufacturing unit has been made and deliberate in two prime levels i.e. dimensions and factors. Additionally, the model also demonstrations how lean parameters of an organization or manufacturing system co- relating different forms of wastes. Hartini & Ciptomulyono (2015) examined the effect of lean and sustainable production system to improve organization performance. Onyeocha et al., (2015) worked on assessment of multi-product lean manufacturing system with assembly and changing demand.

Many of the suggestions recommended that lean production system is favorable for sustainable production system; most influentially, it would help in perspective environment and cost-effective aspects. Duraccio et al., (2014), Arslankaya & Atay (2015) observed and apply the maintenance management with the lean manufacturing methods at the maintenance workshop for removing the losses caused by breakdowns in order to improve production and motivate the personnel. Youssouf et al., (2014) worked on the optimization of strategies lean Six Sigma. Lean manufacturing with ergonomic working environment in the automobile sector is another very effective concept to enhance the working condition, improve productivity, improving production processes, and eliminate the waste (Berlin et al., 2014; Dos Santos et al., 2015). The key area of ergonomics is to improve and relate the man alteration methods to their work and competent and harmless ways in order to enhance the welfare, safety, health, prosperity and thus to accumulate efficiency and productivity of the organization (Dul & Neumann, 2009). Mohammaddust et al., (2017) developed the robust lean model for alternative risk mitigation strategies. Rohani & Zahraee (2015) studied lean manufacturing technique termed as Value Stream Mapping (VSM) for enhancing the assembly line of an industry. To attain this goal, lean strategies were applied in order to construct VSM for identification, disposal of wastages and improved performance of the organization. Susilawati et al., (2015) used the fuzzy logic based process to quantify the level of lean activity in industry.

Mandal & Deshmukh (1994) researched about the vendor selection procedure of the company dependent on different parameters using ISM. ISM methodology is a very popular technique to define the direct relationship among different enablers or barriers. Lee et al., (2011) analysed that the Lean manufacturing is very popular technique in the field of production system from past several decades. Kanban system among them is the most important lean manufacturing principles for lean production system along with reduced cost and marginal inventories. The objectives are (i) to define the working of the KANBAN system successfully across organizations globally and (ii) categorizing factors obstructing small and medium enterprises from executing Kanban in lean manufacturing system (Rahman et al., 2013). Shah & Ward (2003) observed the outcomes of three dependent issues, plant dimensions, plant life and unionization position, on the chance of applying different manufacturing industrial practices that are main facets of LMS. Lee et al., (2011) analyzed the process-advantages, expenses, and threats for identifying techniques by making use of integrated ISM and fuzzy analytic order of procedure. Shuaib et al., (2016) studied on enablers of smart organization and developed the integrated ISM model with fuzzy MICMAC. Dewangan et al., (2015) examined the enablers for advancement of innovation in the Indian manufacturing segment and direct relationship has been analyzed among different enablers with help of ISM and fuzzy MICMAC. Charan et al., (2008) explored the barriers in supply chain performance measurement system and implementation in Indian context. ISM technique to analysis the enablers and barriers of green supply chain management (GSCM) has been used by many researcher, some of them are as follows (Diabat & Govindan, 2011; Gorane & Kant, 2013; Faisal, 2010; Mudgal et al., 2010; Singh et al., 2010; Talib et al., 2011; Tyagi et al., 2015; Wang et al., 2015; Tyagi et al., 2017). Kannan et al. (2009) applied the combined study of ISM and fuzzy TOPSIS approach to examine and considering the 3-P reverse logistic providers. Diabat & Govindan (2011) have suggested the ISM approach to examination the drivers influencing the application of GSCM. Prasad et al., (2020) developed a novel framework based on lean manufacturing concept for continuous improvement in Indian textile industry. Palang & Dhatrak (2020) implemented Define, Measure, Analysis, Improve and Control (DMAIC), Failure Mode and Effect Analysis (FMEA), Industry 4.0 and Kaizen approaches for developing the lean manufacturing concept based model in order to improve the productivity of the industry. Yadav et al., (2020) proposed hybrid Fuzzy Analytical Hierarchy Process (FAHP) - Decision Making Trial and Evaluation Laboratory (DEMATEL) approaches based lean manufacturing concept for enhancing the improvement capabilities of companies under developing economies. Guillen et al., (2020) proposed a structured methodology based on lean manufacturing principles for improving facility management. Tortorella et al., (2021) proposed lean automation based model for examining improvement pathway of an industry.

From the reviewed literature it has been noted that the application of ISM-MICMAC approaches was not yet been reported by any researcher in order to identify and analyze the inter-relationship among filtered strategies for the considered lean manufacturing case. To bridge this, gap the current work presents the application of

ISM-MICMAC approaches based framework to enhance the efficiency of the considered organization.

3. Research Methodology

On the basis of discussion with experts and literature review lean manufacturing strategies were identified and a developed questionnaire was floated among the experts for the collection of the data. Factor analysis was performed, and appropriate strategies were filtered and further brainstorming session was conducted for their acceptance or rejection. After the acceptance of filtered strategies ISM and fuzzy MICMAC approaches were applied and analysis was carried for reaching appropriate decision. The flow diagram on the research work plan denoted in figure 1 is carried out in unique view. However, a step by step explanation of ISM approach is also given below.

The interpretive structural modeling (ISM) used to create a composite system into an envisioned ordered arrangement. It is used for studying and solving complex problems to help in decision-making (Warfield, 1974; Jain & Raj, 2015). It is based on computer-assisted method that usually used to conclude the multiplex situations by providing a sensible and reasonable path of action (Kannan et al., 2009).

Initial phase of the ISM method is used to pin-point lean strategies, drivers or other alternatives, which concerns the research complication. Then a theoretically feasible derived relation is selected (Thakkar et al., 2006).

ISM methodology involves several steps as follows (Kannan &Haq, 2007; Sharma & Garg, 2010).

Identify and enlist the diverse strategies of lean manufacturing system.

I. Creating a relative relationship between different lean manufacturing strategies.

II. Development of a fundamental self-interaction matrix (SSIM) to lean manufacturing strategies which show interactions among lean manufacturing strategies under the ambit.

III. Creating reachability matrix using SSIM and then transitivity of the matrix is evaluated.

IV. A flow chart is drawn on the basis of reachability matrix.

V. Interpret the subsequent relationship digraph into an ISM by switching lean strategies with statements

Verify for conceptual difference and essential improvements made and contextual correlation was developed among diverse lean manufacturing strategies.

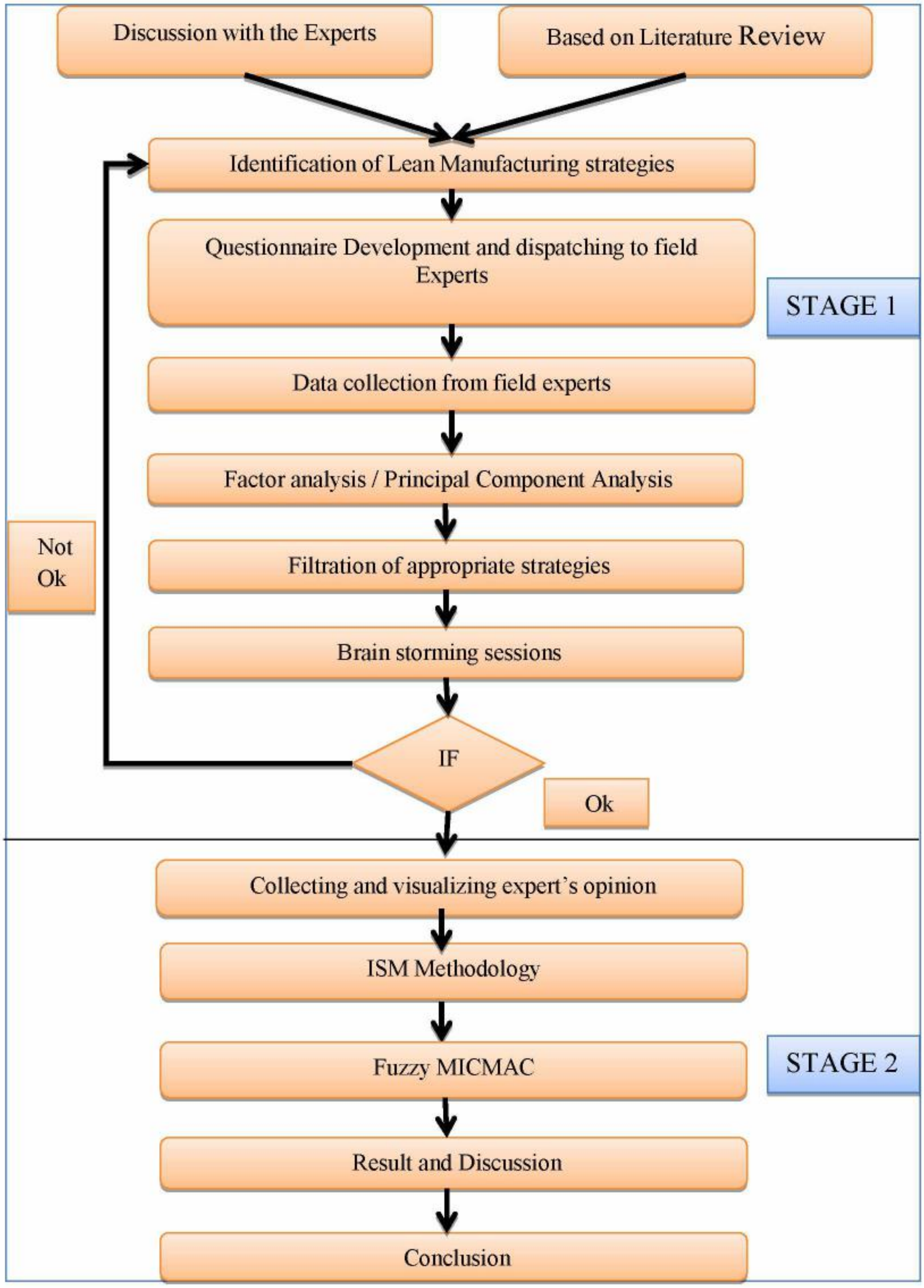


Figure 1. Flow chart illustrating research direction

4. Proposed research methodology implementation based results

In accordance to the literature survey and after consultation with the field professionals, thirty-six lean manufacturing strategies were acknowledged. Then, a questionnaire was designed using Google form and forwarded on Google doc. Numerous views of different field professionals were collected. To analyze the lean strategies, the experts from Indian automobiles companies situated near Delhi NCR and academicians from several organizations were communicated for the view of lean manufacturing strategies. encompassing expertise in the field of manufacturing and strategies formulation have been considered to collect their opinions regarding the implementation of lean strategies in Indian automobile companies in order to improve their performance. To analyze the lean strategies, an ISM approach with fuzzy MICMAC has been applied, for the same qualitative input from the experts (four groups having five to six experts in each group) have been taken to develop the structural self-interaction matrix. Here concept of fuzzy set is used to consider the vagueness of the collected data for high accuracy in the decision results. Before implementing the ISM approach, a factor analysis has also been carried in order to extract the significant strategies based on their factor loading values.

Factor analysis (FA) is a dynamic means for statistical mitigation and conveying the nearby events of diverse strategies by deciding the normal elements in view of the account of perceived correlations (Hayton, 2004). Primarily, a questionnaire has been designed by5-point Likert type scale for thirty-six lean strategies and was send to the one hundred and fifty field professionals to gather their view regarding the significance of lean strategies. Out of one hundred and fifty, fifty-seven replies were acknowledged, which reveals the 38% response rate. When the response rate is greater than 30%, it is appropriate to execute the reliability examination as suggested by Malhotra & Grover (1998).

The received stats are deemed as reliable, only if the cronbach alpha coefficient(α)ranges from0.7to 1. Gliem & Gliem (2003) mentions the rules as follows: $\alpha > 0.9$ signifies Outstanding, $\alpha > 0.8$ signifies Good, $\alpha >0 .7$ signifies Satisfactory, $\alpha > 0.6$ signifies Questionable, $\alpha > 0.5$ signifies Poor, and $\alpha < 0.5$ signifies Unacceptable". In the present research work, score of the cronbach alpha coefficient comes as 0.794, hence the collected data can be considered as reliable. Then factor analysis is done for the clarification of appropriate lean strategies by same software. Table 1 shows cumulative variances of different lean strategies and thirteen lean strategies contributed to about 77.648 % of the total variance and have eigen values greater than threshold value of 1. The component matrix was observed to extract thirteen lean strategies based on the variable loaded in the software. The listed of extracted lean strategies is shown in table 2. To understand the dominance thirteen extracted lean strategies over the total identified strategies a scree plot has been structured, as shown in Figure 2. The scree plot makes an elbow after the thirteenth component, which means that each succeeding factor accounts for smaller and smaller accounts of the total variance.

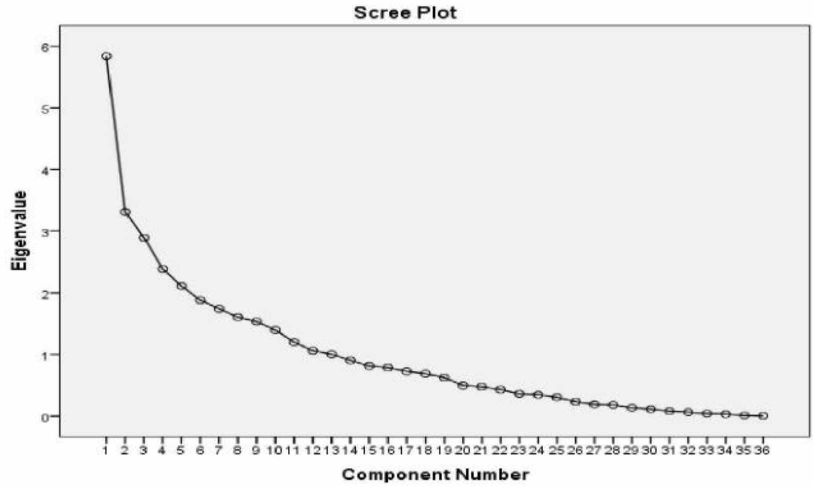


Figure 2 Scree graph for different components

Table 1 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	5.838	16.216	16.216	5.838	16.216	16.216	2.764
2	3.311	9.196	25.412	3.311	9.196	25.412	2.745
3	2.894	8.038	33.450	2.894	8.038	33.450	2.608
4	2.386	6.628	40.078	2.386	6.628	40.078	2.557
5	2.107	5.854	45.932	2.107	5.854	45.932	2.547
6	1.882	5.229	51.161	1.882	5.229	51.161	2.420
7	1.741	4.836	55.997	1.741	4.836	55.997	2.220
8	1.604	4.456	60.453	1.604	4.456	60.453	1.971
9	1.533	4.258	64.712	1.533	4.258	64.712	1.750
10	1.396	3.878	68.590	1.396	3.878	68.590	1.742
11	1.198	3.329	71.919	1.198	3.329	71.919	1.595
12	1.060	2.946	74.865	1.060	2.946	74.865	1.578
13	1.002	2.784	77.648	1.002	2.784	77.648	1.458
14	.903	2.510	80.158	-	-	-	-
15	.814	2.261	82.419	-	-	-	-
16	.786	2.184	84.603	-	-	-	-
17	.727	2.019	86.622	-	-	-	-
18	.688	1.911	88.533	-	-	-	-
19	.625	1.735	90.268	-	-	-	-
20	.497	1.380	91.648	-	-	-	-
21	.476	1.323	92.971	-	-	-	-
22	.431	1.197	94.168	-	-	-	-

23	.361	1.002	95.170	-	-	-	-
24	.346	.962	96.131	-	-	-	-
25	.305	.848	96.980	-	-	-	-
26	.233	.649	97.628	-	-	-	-
27	.190	.529	98.157	-	-	-	-
28	.180	.501	98.658	-	-	-	-
29	.135	.375	99.034	-	-	-	-
30	.112	.312	99.346	-	-	-	-
31	.081	.225	99.571	-	-	-	-
32	.065	.180	99.751	-	-	-	-
33	.041	.115	99.866	-	-	-	-
34	.032	.089	99.955	-	-	-	-
35	.011	.031	99.986	-	-	-	-
36	.005	.014	100.000	-	-	-	-

Table 2 Extracted lean strategies

Sr. No.	Lean Strategies	Sources
S1.	Line improvement activity	(Salleh et al., 2012; Chai et al., 2012)
S2.	Ability to adjust capacity rapidly within a short time period	(Stecke& Kim, 1988; Ward &Duray, 2000)
S3.	Alternative supply chain networks	(Harland, 1996; Hugo &Pistikopoulos, 2005; Mohammaddust et al., 2017)
S4.	Focus on Market orientation	(Venkatraman&Ramanujam, 1987)
S5.	Development programs or past performance record	(Brown & Cousins, 2004)
S6.	Proper machine utilization	(Nordin et al., 2010)
S7.	Minimizing Work in progress	(Riezebos et al., 2009; Onyeocha et al., 2015)
S8.	Ability to provide innovation design	(Zhao et al., 2006; Le Dain et al., 2011)
S9.	Recycling of raw materials and defective parts	(Thierry et al., 1995; Wang et al., 2008)
S10	Higher collaboration for better production planning	(Seifert, 2003; Kenne et al., 2007; Chinprateep&Boondiskulchok, 2010)
S11.	Monitoring the implementation schedules step by step	(Ballard & Howell, 1998; Guo et al., 2015; Soroush, 2015)
S12.	Training of employees to develop multi skills	(Wang et al., 2008; Heimerl&Kolisch, 2010)
S13.	Handling of appropriate variations in customer orders	(Anand& Ward, 2004)

Now, after extracting the significant lean manufacturing strategies, a step by step implementation of ISM approach has been made as given below:

4.1 Structural self-interaction matrix (SSIM)

The SSIM is used to understand the related relationship between the diverse identified lean strategies in table 3 by making use of professional's view. The matrix delivers the pair-wise connection of each lean strategy. The signs [V, A, X and O] are applied for linking of lean strategies (a, b).

V - Strategy 'a' will assistance to enhance strategy 'b'

A -Strategy 'a' will assistance to enhance strategy 'b'

X -Strategy 'a' and 'b' will assistance to enhance each other

O - Strategy 'a' and 'b' are independent

Table 3 SSIM lean strategies

S.no.	Lean Strategies	13	12	11	10	9	8	7	6	5	4	3	2	1
S1.	Line improvement activity	V	A	A	A	O	V	V	V	A	V	A	A	-
S2.	Ability to adjust capacity rapidly within a short time period	V	A	A	A	O	A	V	X	O	A	A	-	
S3.	Alternative supply chain networks	V	O	A	O	X	A	V	V	O	A	-		
S4.	Focus on Market orientation	V	V	V	A	V	V	O	V	V	-			
S5.	Development programs or past performance record	V	A	V	X	V	V	V	V	-				
S6.	Proper machine utilization	A	A	A	A	O	O	V	-					
S7.	Minimizing Work in progress	O	A	A	A	V	A	-						
S8.	Ability to provide innovation design	X	A	A	A	O	-							
S9.	Recycling of raw materials and defective parts	A	A	O	O	-								
S10	Higher collaboration for better production	V	A	V	-									

	planning			
S11.	Monitoring the implementation schedules step by step	X	A	-
S12.	Training of employees to develop multi skills	V	-	
S13.	Handling of appropriate variations in customer orders	-		

4.2 Reachability matrix

The formulation of the initial reachability matrix is the subsequent stage in ISM methodology. The transformation into initial reachability matrix as depicted in table 4 is obtained by the dual linking of the lean strategies in SSIM given in table 3 by means of binary system. The transformation is prepared with the assistance of the below mentioned rules:

When (a, b) in the set implies V, assign the value of (a, b) within the reachability matrix as 1 and assign the (b, a) value as 0.

When (a, b) in the set implies A, assign the value of (a, b) within the reachability matrix as 0 and assign the (b, a) value as 1.

When (a, b) in the set implies X, assign the value of (a, b) within the reachability matrix as 1 and assign the (b, a) value as 1.

When (a, b) in the set implies O, then assign the (a, b) result within the reachability matrix as 0 and assign the (b, a) value as 0.

Table 4 Initial reachability matrix

Sr. no.	Lean Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13
S1.	Line improvement activity	1	0	0	1	0	1	1	1	0	0	0	0	1
S2.	Ability to adjust capacity rapidly within a short time period	1	1	0	0	0	1	1	0	0	0	0	0	1
S3.	Alternative supply chain networks	1	1	1	0	0	1	1	0	1	0	0	0	1
S4.	Focus on Market orientation	0	1	1	1	1	1	0	1	1	0	1	1	1
S5.	Development programs or past	1	0	0	0	1	1	1	1	1	1	1	0	1

	performance record													
S6.	Proper machine utilization	0	1	0	0	0	1	1	0	0	0	0	0	0
S7.	Minimizing Work in progress	0	0	0	0	0	0	1	0	1	0	0	0	0
S8.	Ability to provide innovation design	0	1	1	0	0	0	1	1	0	0	0	0	1
S9.	Recycling of raw materials and defective parts	0	0	1	0	0	0	0	0	1	0	0	0	0
S10	Higher collaboration for better production planning	1	1	0	1	1	1	1	1	0	1	1	0	1
S11.	Monitoring the implementation schedules step by step	1	1	1	0	0	1	1	1	0	0	1	0	1
S12.	Training of employees to develop multi skills	1	1	0	0	1	1	1	1	1	1	1	1	1
S13.	Handling of appropriate variations in customer orders	0	0	0	0	0	1	0	1	1	0	1	0	1

By applying the transitivity rule the initial matrix was converted into final matrix in table 5, which suggests that the lean strategy 'L' is interrelated to 'M' and 'M' is interrelated to 'N', it is considered that L will be interrelated to N. The set that indicates the transitivity is noticeable with the symbol (*).

Table 5 Final reachability matrix

Sr. no.	Lean Strategies	1	2	3	4	……..	9	10	11	12	13	S.P
S1.	Line improvement activity	1	1*	1*	1	……..	1*	0	1*	1*	1	12
S2.	Ability to adjust capacity rapidly within a short time period	1	1	0	1*	……..	1*	0	1*	0	1	9

S3.	Alternative supply chain networks	1	1	1	1*	....	1	0	1*	0	1	10
S4.	Focus on Market orientation	1*	1	1	1	....	1	1*	1	1	1	13
S5.	Development programs or past performance record	1	1*	1*	1*	....	1	1	1	0	1	12
S6.	Proper machine utilization	1*	1	0	0	....	1*	0	0	0	1*	6
S7.	Minimizing Work in progress	0	0	1*	0	....	1	0	0	0	0	3
S8.	Ability to provide innovation design	1*	1	1	0	....	1*	0	1*	0	1	9
S9.	Recycling of raw materials and defective parts	1*	1*	1	0	....	1	0	0	0	1*	7
S10	Higher collaboration for better production planning	1	1	1*	1	....	1*	1	1	1*	1	13
S11.	Monitoring the implementation schedules step by step	1	1	1	1*	....	1*	0	1	0	1	10
S12.	Training of employees to develop multi skills	1	1	1*	1*	....	1	1	1	1	1	13
S13.	Handling of appropriate variations in customer orders	1*	1*	1*	1*	....	1	1*	1	0	1	12
		12	12	11	9	....	13	5	10	4	12	

4.3 Level partition

In order to filter out the reachability and antecedent sets, reachability matrix has been partitioned by applying the concept of level partition as shown in tables 6 and 7. In table 6, a complete process has been explained for level partition based on reachability and antecedent sets in respect of each filtered strategy.

However, in table 7, a complete summary of levels has been given. The reachability set includes the lean strategy itself along with lean strategies that it would affect while the antecedent set includes the lean strategy itself along with other lean strategies that may impact it. Then, different levels are obtained by the intersection for all lean strategies of these sets. The lean strategy whose reachability and antecedent set are identical, is placed in the uppermost level of the order. The uppermost level lean strategies are the ones that would not lead other lean strategies to overcome their own level in this order.

After identifying the topmost level of lean strategies, they are uninvolved in contemplation while the same procedure is reiterated to find out the successive levels. This method is applied till the level of each lean strategy is obtained. These levels play a major role in building the ISM model.

Table 6 Level partition (Iteration I)

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
S1.	1,2,3,4,5,6,7,8,9,11,12,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,3,4,5,6,8,9,11,12,13	-
S2.	1,2,4,6,7,8,9,11,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,4,6,8,9,11,13	-
S3.	1,2,3,4,6,7,8,9,11,13	1,3,4,5,7,8,9,10,11,12,13	1,3,4,7,8,9,11,13	-
S4.	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,4,5,10,11,12,13	1,2,3,4,5,10,11,12,13	-
S5.	1,2,3,4,5,6,7,8,9,10,11,13	1,4,5,10,13	1,4,5,10,13	-
S6.	1,2,6,7,9,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,6,9,13	-
S7.	3,7,9	1,2,3,4,5,6,7,8,9,10,11,12,13	3,7,9	I
S8.	1,2,3,6,7,8,9,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,8,11,13	-
S9.	1,2,3,6,7,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,6,7,9,13	I
S10	1,2,3,4,5,6,7,8,9,10,11,12,13	4,5,10,12,13	4,5,10,12,13	-
S11.	1,2,3,4,6,7,8,9,11,13	1,2,3,4,5,8,10,11,12,13	1,2,3,4,8,11,13	-
S12.	1,2,3,4,5,6,7,8,9,10,11,12,13	1,4,10,12	1,4,10,12	-
S13.	1,2,3,4,5,6,7,8,9,10,11,13	1,2,3,4,5,6,8,9,10,11,12,13	1,2,3,4,5,6,8,9,10,11,13	-

Table 7 Level partition (Final Iteration)

Lean Strategies	Reachability set	Antecedent set	Interaction	Level
S1.	1,2,3,4,5,6,8,11, 12,13	1,2,3,4,5,6,8,10,11,12, 13	1,2,3,4,5,6,8,11,1 2,13	II
S2.	1,2,4,6,8,11,13	1,2,3,4,5,6,8,10,11,12, 13	1,2,4,6,8,11,13	II
S3.	3,4,8,11,	3,4,5,8,10,11,12	3,4,8,11,	III
S4.	4,5,10,12	4,5,10,12	4,5,10,12	IV
S5.	4,5,10,	4,5,10	4,5,10	IV
S6.	1,2,6,13	1,2,3,4,5,6,8,10,11,12, 13	1,2,6,13	II
S7.	3,7,9	1,2,3,4,5,6,7,8,9,10,11, 12,13	3,7,9	I
S8.	8,11	3,4,5,8,10,11,12	8,11	III
S9.	1,2,3,6,7,9,13	1,2,3,4,5,6,7,8,9,10,11, 12,13	1,2,3,6,7,9,13	I
S10	4,5,10,12	4,5,10,12	4,5,10,12	IV
S11.	3,4,8,11	3,4,5,8,10,11,12	3,4,8,11	III
S12.	12	12	12	V
S13.	1,2,3,4,5,6,8,10, 11,13	1,2,3,4,5,6,8,10,11,12, 13	1,2,3,4,5,6,8,10,1 1,13	II

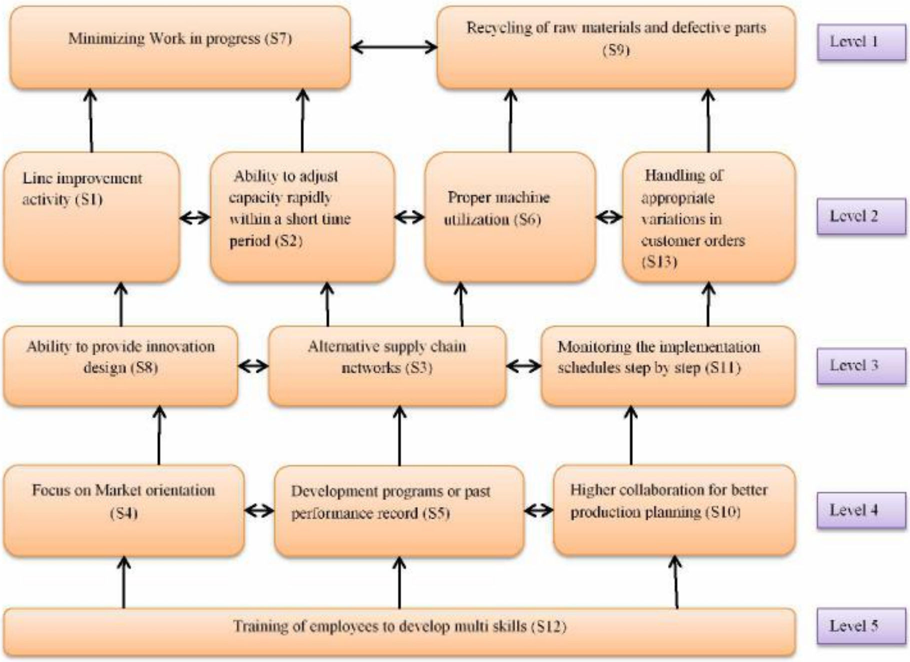


Figure 3 Model based on ISM

The above flow charts illustrated in figure 3 depicts the diverse lean strategies and their inter-dependence. In the flowchart, the adopted influential steps have been distributed into 5 levels for the progress of the organization. Training of employees to develop multi skills (S35) is most significant lean strategy which pushes all the former strategies which effect in positive incorporation of lean and every organization need to focus on this strategy. With continuous and systematic training, personnel become competent in new techniques that assist in building up several abilities which further help to steer the organization at higher level. The foundation of this ISM model is built up by level 5 strategies (S12).

Training of employees to develop multi skills (S12) escorts the three strategies at level 4 i.e. focus on market orientation (S4), development programs or past performance record (S5) and higher collaboration for better production planning (S10). These three strategies have solid connection among them based on the performance data of the past or improvement programs which plays a role in finding out the shortcomings of concluding products or new demands of consumers centered by concentrated on the inclination of the market. This would assist the manufacturing unit in teaming up with other personnel, hence enhancing productivity.

At level 3 strategies, alternative supply chain networks (S3), ability to provide innovation design (S8) and monitoring the implementation schedules step by step (S11) ushered by level 4. Regular training and Focusing on market orientation helps the employees to create the ability of innovative designing according to the demand that further come out to give alternative sully chain networks. This is also helps in monitoring the implementing schedules steps by steps. Level 2 drive the further four strategies i.e. line improvement activity (S1), ability to modify capacity quickly within a short time interval (S2), proper machine utilization (S6) and handling of appropriate variations in customer orders (S13).

Strategies at level 2 have very strong connectivity with each other. If there is proper machine utilization and improved line activity, it can create ability to adjust the capacity quickly within short period of time that helps to handle the variations in customers' orders.

Minimizing work in progress (S7) and recycling of raw materials and defective parts (S9) at first level directed by second level are the preferred products of the figures. Aforementioned two strategies acquiring the uppermost rank of this orderly representation make use of proper machine utilization and improved line activity results in minimizing work in process with minimal defective parts which gives desired best quality products and increases the productivity of the organization.

4.4 Fuzzy MICMAC analysis

MICMAC can be elaborated as "Matriced Impacts croises-multipication applique and classment" or in simple way it is define as "cross-impact matrix multiplication applied to classification" (Jain & Raj, 2016; Qureshi et al., 2008). This analysis involves the different steps as follows:

I: Creating the binary direct relationship matrix

II: Constructing the fuzzy direct reachability matrix

III: Producing the stabilized fuzzy MICMAC matrix

Here, fuzzy concept is used in order to consider the uncertainties or vagueness in the collected data useful for high accuracy in the decision results.

4.5 Creating the binary direct relationship matrix

To make the binary direct relationship matrix, it is required to transform the convectional MICMAC analysis into fuzzy MICMAC analysis using binary system (0 & 1). To make an analysis stronger through considering the uncertainty in the collected raw data, fuzzy set theory (Panchal & Kumar, 2014; Stojić et al., 2018; Chatterjee & Stević, 2019; Panchal et al., 2018; Panchal et al., 2019; Petrović et al.,2019; Đalić et al., 2020; Pająk, 2020; Kushwaha et al., 2020; Zavadskas et al., 2020) has been utilized. The binary direct relationship matrix is shown below in table 8.

Table 8 Binary direct relationship matrix

Sr. no.	Lean Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	**D.P**
S1.	Line improvement activity	0	0	0	1	0	1	1	1	0	0	0	0	1	**5**
S2.	Ability to adjust capacity rapidly within a short time period	1	0	0	0	0	1	1	0	0	0	0	0	1	**3**
S3.	Alternative supply chain networks	1	1	0	0	0	1	1	0	1	0	0	0	1	**6**
S4.	Focus on Market orientation	0	1	1	0	1	1	0	1	1	0	1	1	1	**9**
S5.	Development programs or past performance record	1	0	0	0	0	1	1	1	1	1	1	0	1	**8**
S6.	Proper machine utilization	0	1	0	0	0	0	1	0	0	0	0	0	0	**2**
S7.	Minimizing Work in progress	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
S8.	Ability to provide innovation design	0	1	1	0	0	0	1	0	0	0	0	0	1	**4**
S9.	Recycling of raw materials and defective parts	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
S10	Higher collaboration	1	1	0	1	1	1	1	1	0	0	1	0	1	**9**

	for better production planning														
S11.	Monitoring the implementation schedules step by step	1	1	1	0	0	1	1	1	0	0	0	0	1	**7**
S12.	Training of employees to develop multi skills	1	1	0	0	1	1	1	1	1	1	1	0	1	**10**
S13.	Handling of appropriate variations in customer orders	0	0	0	0	0	1	0	1	1	0	1	0	0	**4**
	Dependence power	6	7	4	2	3	9	9	7	7	2	5	1	9	

Table 9 Possibility of numerical values of the reachability

Possibility of reachability	No	Very low	Low	Medium	High	Very high	Complete
Value	0	0.1	0.3	0.5	0.7	0.9	1

4.6 Constructing the fuzzy direct reachability matrix

The values given in table 9 are made use in the binary direct relationship matrix for developing the fuzzy direct reachability matrix. The understanding of MICMAC analysis is augmented by making use of fuzzy theory which is why possibility of interaction is used to interpret the immediate connection among different lean strategies as represented in table 9. Therefore, fuzzy direct reachability is developed and as depicted in table 10.

Table 10 Fuzzy direct reachability matrix

S.no.	Lean Strategies	1	2	3	4	.....	9	10	11	12	13
S1.	Line improvement activity	0	0	0	0	…..	0	0	0	0	0.1
S2.	Ability to adjust capacity rapidly within a short time period	0	0	0	0	……	0	0	0	0	0.3
S3.	Alternative supply chain networks	0.3	0	0	0	…..	0.9	0	0	0	0.3
S4.	Focus on Market orientation	0	0.9	0.7	0	……	0.9	0	0.3	0	0.5
S5.	Development	0	0	0	0		0	0	0	0	0.1

	programs or past performance record					……					
S6.	Proper machine utilization	0	0	0	0	……	0	0	0	0	0
S7.	Minimizing Work in progress	0	0	0	0	……	0	0	0	0	0
S8.	Ability to provide innovation design	0	0	0	0	……	0	0	0	0	0
S9.	Recycling of raw materials and defective parts	0	0	0	0	……	0	0	0	0	0
S10	Higher collaboration for better production planning	0.5	0.5	0	0	…….	0	0	0.5	0	0.9
S11.	Monitoring the implementation schedules step by step	0.1	0.1	0	0	……..	0	0	0	0	0
S12.	Training of employees to develop multi skills	0.5	0.5	0	0	…….	0	0	0.5	0	0.7
S13.	Handling of appropriate variations in customer orders	0	0	0	0	……..	0.3	0	0	0	0

The subset values are given in table10 is used as the base for constructing stabilized fuzzy MICMAC matrix. Multiplication of the obtained matrix is done many a times unless the orders of dependence and driving power become constant. With reference to the mentioned theory, the result obtained could be a fuzzy matrix, after the multiplication of two fuzzy (Kandasamy et al., 2007) interval values. The Following multiplication method is used to get the required result for multiplying of two fuzzy matrixes,

MN = Max {min (mij, nij)}

Where, M = [mij] and N = [nij] are two fuzzy matrices.

For solving the above equation, the program is written in the 'C' language to attain the accuracy. The result obtained is illustrated in figure 4 and the required stabilized fuzzy MICMAC matrix is given in table 11.

```
Level-5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.9  0.5  0.3  0.3  0.5  0.9
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.7  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.9
  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.7
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.3  0.3  0.5  0.5
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.7  0.5  0.3  0.3  0.5  0.7
  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.9  0.5  0.3  0.3  0.5  0.5

Matrix Stabalised !!!
press ANY key to exit..._
```

Figure 4 Stabilized fuzzy MICMAC matrix

Table 11 Stabilized fuzzy MICMAC matrix

S.no.	Lean Strategies	1	2	3	4	......	9	10	11	12	13	Driving power
S1.	Line improvement activity	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.1**
S2.	Ability to adjust capacity rapidly within a short time period	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.1**
S3.	Alternative supply chain networks	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.1**
S4.	Focus on Market orientation	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.9	**6.9**
S5.	Development programs or past performance record	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.3**
S6.	Proper machine utilization	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.1**
S7.	Minimizing Work in progress	0.1	0.1	0.1	0.1	......	0.1	0.1	0.1	0.1	0.1	**1.3**
S8.	Ability to provide innovation design	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.9	**6.5**
S9.	Recycling of raw materials	0.1	0.1	0.1	0.1	......	0.1	0.1	0.1	0.1	0.1	**1.3**

	and defective parts											
S10	Higher collaboration for better production planning	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.7	**6.3**
S11.	Monitoring the implementation schedules step by step	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.1**
S12.	Training of employees to develop multi skills	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.7	**6.5**
S13.	Handling of appropriate variations in customer orders	0.5	0.5	0.5	0.5	......	0.5	0.3	0.3	0.5	0.5	**6.5**
Dependence power		**5.7**	**5.7**	**5.7**	**5.7**	**....**	**5.7**	**3.5**	**3.5**	**5.7**	**6.9**	

Stabilized matrix as shown in table 11 is categorized into four cluster in accordance to driving power and dependence power. The summing up values of rows in the stabilized fuzzy MICMAC matrix is driving power and summing up values columns in the stabilized fuzzy MICMAC matrix is the dependence power. The cluster representation is shown in figure 5.

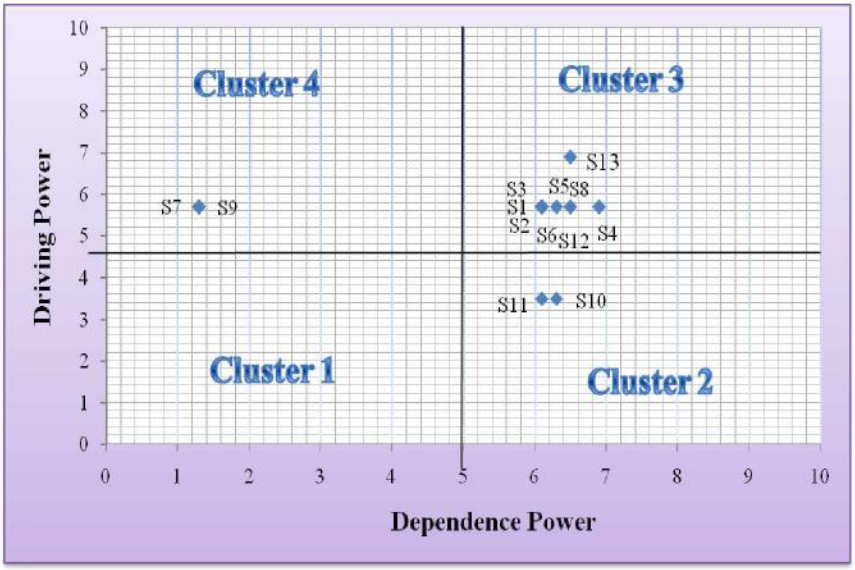


Figure 5 Driving and dependence power graph

Cluster 1: Lean strategies belonging to the particular group should have low driving and dependence power. Strategies in this group have no relation to each other. They are neither influence nor influenced by any others strategies. There is no lean strategy in our research that fall in this cluster. This is called autonomous cluster

Cluster 2: In this cluster, lean strategies are having low driving power and high dependence power. It characterizes lean strategies that are dependent on others strategies. The dependency of these lean strategies shows that they need all other lean strategies for the implementation of lean strategies into the system. Lean strategy (S7) minimizing work in progress and lean strategy (S9) recycling of raw materials and defective parts and are categorized in this cluster. This is called dependence cluster

Cluster 3: Lean strategies in this group are having very high driving power and high dependence power. This cluster denotes lean strategies which have very robust relation to each other's. Most of lean strategies in current research fall in this group. If there is a change in any lean strategy it will immediately affect the other lean strategy. Most of the lean strategies of present study fall in this cluster. Total eight strategies are categorized that are line improvement activity (S1), ability to adjust capacity quickly within a short time period (S2), alternative supply chain networks (S3), focus on Market orientation (S4), development programs or past performance record (S5), proper machine utilization (S6), ability to provide innovation design (S8), training of employees to develop multi skills (S12) and handling of appropriate variations in customer orders (S13). This is called linkage cluster.

Cluster 4: Lean strategies belonging to this group have low dependence power but very high driving power. Lean strategy which are categorized in this group are higher collaboration for better production planning (S10) and monitoring the implementation schedules step by step (S11). This is called Independent Cluster.

5. Managerial implications of the work

To prevail over the various tasks that emerge during production time and to improve the efficiency of their organization, managers require flexible attitudes to take the worthwhile decision for the growth of organization. The current research reveals that manager is required to emphasize on diverse lean strategies liable on the condition at different level. Training of employees is the primary need of the organization which accelerates the others strategies effectively in every field. Apart from this strategy, managers need to focus on secondary strategies at different level also as illustrated in figure 2. Driving and dependence graph illustrated in figure 3 would help the managers to decide whether the applied strategies are driving in nature or dependent on others. Most of strategies fall in cluster 3 managers have to focus more on this category. Strategies in this category are very crucial for application of lean manufacturing in the organization. Also, each and every strategy serves its role in the performance of the organization at its level. Therefore, this study helps the managers for implementation of various lean strategies into the organization.

6. Conclusion

It is understood that no single strategy is enough for implementation of lean manufacturing for enhancement of the efficiency organization. After factor analysis out of thirty-six lean strategies thirteen were extracted using software SPSS 21 and analyzed by structural modeling and then used to construct the ISM based model which helps to understand the direct relationship among various lean strategies. "Training of employees to develop multi skills(S12)" has been identified as the most crucial strategy which drives all the other strategies for the success of lean. Minimizing Work in progress (S7) and recycling of raw material and defective parts (S9) were level one, strategies whose success is dependent on other factors. Apart from the relationship among various lean strategies, it was also essential to express the role of individual strategy also. It was observed that most of the selected strategies have very high driving power and dependence power as well. No lean strategy was identified which fall in the autonomous cluster. Higher collaboration for better production planning (S10) and monitoring the implementation schedules step by step (S11) have been identified as the independent strategies which have high driving power and low dependence power. Also, minimizing work in progress (S7) and recycling of raw materials and defective parts (S9) were categorized in dependence cluster as they have low driving power and high dependence power. Organization across the globe now wants to make their system more define for every aspect. The present research contribution gives the optimistic correlation between different lean strategies to maintain their organization systematically. The present research assists the managers or industrialists in decision making for the implication of particular lean strategy during the production. The outcomes of this research may also be helpful for managers to comprehend the indirect and direct relationship among various lean strategies in order to provide a path to improve the efficiency of their enterprise in this competitive market. As an advantage of lean system in manufacturing organization, it is most valuable to identify and asses the importance of strategies related to lean system but it is not easy or feasible to implement the all strategies at a time in any industry or organization. For the same, a need arises to explore the strategies based on their dependence and driving behavior in order to implement and improve the lean manufacturing system of an organization. By keeping this view in mind, this study has been performed.

6.1 Limitations and future scope of the work

In this study, initially thirty-six lean strategies were identified on the basis of literature review; however, thirteen lean strategies have been extracted by using factor analysis. In ISM approach, there is no restriction in consideration on numbers of lean strategies, therefore more numbers of lean strategies can also be considered. Moreover, as the numbers of lean strategies increases, ISM model will become more complex. To drive the analysis, data have been gathered only from the automobiles industries situated at Delhi NCR. In future, data can also be gathered from the automobile industries situated at different locations of India and comprehensive study can also be implemented. To compare the outcomes of present research, the other multi-faceted decision building approaches like Fuzzy DEMATEL and SEM can be considered.

References

Ahlstrom, P. (2004). Lean service operations: translating lean Pro principles to service operations. International Journal of Services Technology and Management, 5(5-6): 545-564.

Al-Tit, A. A. (2017). Factors affecting the organizational performance of manufacturing firms. International Journal of Engineering Business Management, 9: 1-9.

Anand, G., & Ward, P. T. (2004). Fit, flexibility and performance in manufacturing: coping with dynamic environments. Production and Operations Management, 13(4): 369-385.

Arslankaya S & Atay H. (2015). Maintenance Manage and Lean Manufacturing Practices in a Firm Which Produces Dairy Products. Procedia-Social and Behavioral Sciences, 207: 214-224.

Ballard, G., & Howell, G. (1998). Shielding production: essential step in production control. Journal of Construction Engineering and management, 124(1): 11-17.

Berlin, C., Neumann, W. P., Theberge, N., &Örtengren, R. (2014). Avenues of entry: how industrial engineers and ergonomists access and influence human factors and ergonomics issues. European Journal of Industrial Engineering, 8(3): 325-348.

Brown, S., & Cousins, P. D. (2004). Supply and operations: parallel paths and integrated strategies. British Journal of Management, 15(4): 303-320.

Chai, S. F., Luo, S. J., & Zhang, L. J. (2012). Study on simulation of the main shaft production line. In Advanced Materials Research, 472: 2076-2079.

Charan, P., Shankar, R., & Baisya, R. K. (2008). Analysis of interactions among the variables of supply chain performance measurement system implementation. Business Process Management Journal, 14(4): 512-529.

Chatterjee, P., & Stević, Ž. (2019). A two-phase fuzzy AHP-fuzzy TOPSIS model for supplier evaluation in manufacturing environment. Operational Research in Engineering Sciences: Theory and Applications, 2(1): 72-90.

Chinprateep, S., & Boondiskulchok, R. (2011). Heuristic for integrated purchasing and production planning. European Journal of Industrial Engineering, 5(1): 64-80.

Đalić, I., Ateljević, J., Stević, Ž., & Terzić, S. (2020). An integrated swot–fuzzy piprecia model for analysis of competitiveness in order to improve logistics performances. FactaUniversitatis, Series: Mechanical Engineering, 18(3): 439-451.

Dewangan, D. K., Agrawal, R., & Sharma, V. (2015). Enablers for competitiveness of Indian manufacturing sector: An ISM-fuzzy MICMAC analysis. Procedia-Social and Behavioral Sciences, 189: 416-432.

Diabat, A., & Govindan, K. (2011). An analysis of the drivers affecting the implementation of green supply chain management. Resources, conservation and recycling, 55(6): 659-667.

Dos Santos, Z. G., Vieira, L., & Balbinotti, G. (2015). Lean Manufacturing and ergonomic working conditions in the automotive industry. Procedia Manufacturing, 3: 5947-5954.

Dul, J., & Neumann, W. P. (2009). Ergonomics contributions to company strategies. Applied ergonomics, 40(4): 745-752.

Duraccio, V., Forcina, A., Silvestri, A., & Bona, G. D. (2014). Assessment of the Effectiveness of Maintenance-oriented Design. International Journal of Engineering Business Management, 6: 6-19.

Faisal, M. N. (2010). Sustainable supply chains: a study of interaction among the enablers. Business Process Management Journal, 16(3): 508–529.

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education.

Gorane, S. J., & Kant, R. (2013). Supply chain management: modeling the enablers using ISM and fuzzy MICMAC approach. International Journal of Logistics Systems and Management, 16(2): 147-166.

Greinacher, S., Moser, E., Hermann, H., & Lanza, G. (2015). Simulation based assessment of lean and green strategies in manufacturing systems. Procedia CIRP, 29: 86-91.

Guo, Z., Ngai, E., Yang, C., & Liang, X. (2015). An RFID-based intelligent decision support system architecture for production monitoring and scheduling in a distributed manufacturing environment. International journal of production economics, 159: 16-28.

Guillen, D., Gomez, D., Hernandez, I., Charris, D., Gonzalez, J., Leon, D., & Sanjuan, M. (2020). Integrated methodology for industrial facilities management and design based on FCA and lean manufacturing principles. Facilities, 38 (7/8): 523-538.

Hackman, J. R., & Wageman, R. (1995). Total quality management: Empirical, conceptual, and practical issues. Administrative science quarterly, 40(2): 309–342.

Harland, C. M. (1996). Supply chain management: relationships, chains and networks. British Journal of management, 7(s1): S63-S80.

Hartini, S., & Ciptomulyono, U. (2015). The relationship between lean and sustainable manufacturing on performance: literature review. Procedia Manufacturing, 4: 38-45.

Hayton, J. C., Allen, D. G., & Scarpello, V. (2004). Factor retention decisions in exploratory factor analysis: A tutorial on parallel analysis. Organizational research methods, 7(2): 191-205.

Heimerl, C., & Kolisch, R. (2010). Work assignment to and qualification of multi-skilled human resources under knowledge depreciation and company skill level targets. International Journal of Production Research, 48(13): 3759-3781.

Hugo, A., & Pistikopoulos, E. N. (2005). Environmentally conscious long-range planning and design of supply chain networks. Journal of Cleaner Production, 13(15): 1471-1491.

Jain, V., & Raj, T. (2015). Modeling and analysis of FMS flexibility factors by TISM and fuzzy MICMAC. International Journal of System Assurance Engineering and Management, 6(3): 350-371.

Jain, V., & Raj, T. (2016). Modeling and analysis of FMS performance variables by ISM, SEM and GTMA approach. International journal of production economics, 171: 84-96.

Jasti, N. V. K., & Kodali, R. (2016). Validity and reliability of lean enterprise frameworks in Indian manufacturing industry. Proceedings of the institution of mechanical engineers, Part B: Journal of engineering manufacture, 230(2): 354-363.

Kandasamy, W. V., Smarandache, F., & Ilanthenral, K. (2007). Elementary fuzzy matrix theory and fuzzy models for social scientists. Infinite Study, Published by Automaton, Los Angeles, USA.

Kannan, G., & Haq, A. N. (2007). Analysis of interactions of criteria and sub-criteria for the selection of supplier in the built-in-order supply chain environment. International Journal of Production Research, 45(17): 3831-3852.

Kannan, G., Pokharel, S., & Kumar, P. S. (2009). A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. Resources, conservation and recycling, 54(1): 28-36.

Kenné, J. P., Gharbi, A., & Beit, M. (2007). Age-dependent production planning and maintenance strategies in unreliable manufacturing systems with lost sale. European Journal of Operational Research, 178(2): 408-420.

Kushwaha, D. K., Panchal, D., & Sachdeva, A. (2020). Risk analysis of cutting system under intuitionistic fuzzy environment. Reports in Mechanical Engineering, 1(1): 162-173.

Kusrini, E., Subagyo, & Masruroh, N. A. (2014). Good criteria for supply chain performance measurement. International Journal of Engineering Business Management, 6(9): 1-19.

Le Dain, M. A., Calvi, R., & Cheriti, S. (2011). Measuring supplier performance in collaborative design: proposition of a framework. R&d Management, 41(1): 61-79.

Lee, A. H., Kang, H. Y., & Chang, C. C. (2011). An integrated interpretive structural modeling–fuzzy analytic network process–benefits, opportunities, costs and risks model for selecting technologies. International Journal of Information Technology & Decision Making, 10(05): 843-871.

Malhotra, M. K., & Grover, V. (1998). An assessment of survey research in POM: from constructs to theory. Journal of operations management, 16(4): 407-425.

Mandal, A., & Deshmukh, S. G. (1994). Vendor selection using interpretive structural modeling (ISM). International journal of operations & production management, 14(6): 52-59.

McKone, K. E., Schroeder, R. G., & Cua, K. O. (2001). The impact of total productive maintenance practices on manufacturing performance. Journal of operations management, 19(1): 39-58.

Mohammaddust, F., Rezapour, S., Farahani, R. Z., Mofidfar, M., & Hill, A. (2017). Developing lean and responsive supply chains: A robust model for alternative risk mitigation strategies in supply chain designs. International Journal of Production Economics, 183: 632-653.

Mudgal, R. K., Shankar, R., Talib, P., & Raj, T. (2010). Modeling the barriers of green supply chain practices: An Indian perspective. International Journal of Logistics Systems and Management, 7(1): 81-107.

Narasimhan, R., Swink, M., & Kim, S. W. (2006). Disentangling leanness and agility: an empirical investigation. Journal of operations management, 24(5): 440-457.

Nenni, M. E., Giustiniano, L., & Pirolo, L. (2014). Improvement of manufacturing operations through a lean management approach: a case study in the pharmaceutical industry. International Journal of Engineering Business Management, 6(1): 24.

Nordin, N., Deros, B. M., & AbdWahab, D. (2010). A survey on lean manufacturing implementation in Malaysian automotive industry. International Journal of Innovation, Management and Technology, 1(4): 374.

Onyeocha, C. E., Khoury, J., & Geraghty, J. (2015). Evaluation of multi-product lean manufacturing systems with setup and erratic demand. Computers & Industrial Engineering, 87: 465-480.

Pająk, M. (2020). Fuzzy model of the operational potential consumption process of a complex technical system. Facta Universitatis, Series: Mechanical Engineering, 18(3): 453-472.

Panchal, D., & Kumar, D. (2014). Reliability analysis of CHU system of coal fired thermal power plant using fuzzy λ-τ approach. Procedia Engineering, 97: 2323-2332.

Panchal, D., Jamwal, U., Srivastava, P., Kamboj, K., & Sharma, R. (2018). Fuzzy methodology application for failure analysis of transmission system. International Journal of Mathematics in Operational Research, 12(2): 220-237.

Prasad, M. M., Dhiyaneswari, J. M., Jamaan, J. R., Mythreyan, S., & Sutharsan, S. M. (2020). A framework for lean manufacturing implementation in Indian textile industry. Materials Today: Proceedings, 33: 2986-2995.

Palange, A., & Dhatrak, P. (2021). Lean manufacturing a vital tool to enhance productivity in manufacturing. Materials Today: Proceedings: doi.org/10.1016/j.matpr.2020.12.193

Panchal, D., Singh, A. K., Chatterjee, P., Zavadskas, E. K., & Keshavarz-Ghorabaee, M. (2019). A new fuzzy methodology-based structured framework for RAM and risk analysis. Applied Soft Computing, 74: 242-254.

Petrović, G., Mihajlović, J., Ćojbašić, Ž., Madić, M., & Marinković, D. (2019). Comparison of three fuzzy MCDM methods for solving the supplier selection problem. Facta Universitatis, Series: Mechanical Engineering, 17(3): 455-469.

Qureshi, M. N., Kumar, D., & Kumar, P. (2008). An integrated model to identify and classify the key criteria and their role in the assessment of 3PL services providers. Asia Pacific Journal of Marketing and Logistics, 20(2): 227-249.

Rahman, N. A. A., Sharif, S. M., & Esa, M. M. (2013). Lean manufacturing case study with Kanban system implementation. Procedia Economics and Finance, 7: 174-180.

Riezebos, J., Klingenberg, W., & Hicks, C. (2009). Lean production and information technology: connection or contradiction? Computers in industry, 60(4): 237-247.

Rohani, J. M., & Zahraee, S. M. (2015). Production line analysis via value stream mapping: a lean manufacturing process of color industry. Procedia Manufacturing, 2: 6-10.

Salleh, N. A. M., Kasolang, S., & Jaffar, A. (2012). Simulation of integrated total quality management (TQM) with lean manufacturing (LM) practices in forming process using Delmia Quest. Procedia Engineering, 41: 1702-1707.

Schiele, J. J., & McCue, C. P. (2010). A framework for the adoption of lean thinking within public procurement. International Journal of Procurement Management, 3(4): 379-396.

Seifert, D. (2003). Collaborative planning, forecasting, and replenishment: How to create a supply chain advantage. AMACOM Div American Mgmt Assn.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. Journal of operations management, 21(2): 129-149.

Sharma, R., & Garg, S. (2010). Interpretive structural modeling of enablers for improving the performance of automobile service centre. International Journal of Services Operations and Informatics, 5(4): 351-372.

Shuaib, M., Khan, U., & Haleem, A. (2016). Modeling knowledge sharing factors and understanding its linkage to competitiveness. International Journal of Global Business and Competitiveness, 11(1): 23-36.

Singh, B., Garg, S. K., Sharma, S. K., & Grewal, C. (2010). Lean implementation and its benefits to production industry. International journal of lean six sigma, 1(2): 157-168.

Singh, R. K., Sharma, H. O., & Garg, S. K. (2010). Interpretive structural modeling for selection of best supply chain practices. International Journal of Business Performance and Supply Chain Modelling, 2(3): 237-257.

Soroush, H. M. (2015). Scheduling with job-dependent past-sequence-dependent setup times and job-dependent position-based learning effects on a single processor. European Journal of Industrial Engineering, 9(3): 277-307.

Srinivasaraghavan, J., & Allada, V. (2006). Application of mahalanobis distance as a lean assessment metric. The International Journal of Advanced Manufacturing Technology, 29(11-12): 1159-1168.

Stecke, K. E., & Kim, I. (1988). A study of FMS part type selection approaches for short-term production planning. International Journal of Flexible Manufacturing Systems, 1(1): 7-29.

Stojić, G., Sremac, S., & Vasiljković, I. (2018). A fuzzy model for determining the justifiability of investing in a road freight vehicle fleet. Operational Research in Engineering Sciences: Theory and Applications, 1(1): 62-75.

Susilawati, A., Tan, J., Bell, D., & Sarwar, M. (2015). Fuzzy logic based method to measure degree of lean activity in manufacturing industry. Journal of Manufacturing Systems, 34: 1-11.

Talib, F., Rahman, Z., & Qureshi, M. N. (2011). An interpretive structural modelling approach for modelling the practices of total quality management in service sector. International Journal of Modelling in Operations Management, 1(3): 223-250.

Thakkar, J., Deshmukh, S. G., Gupta, A. D., & Shankar, R. (2007). Development of a balanced scorecard, An integrated approach of interpretive structural modeling (ISM) and analytic network process (ANP). International Journal of Productivity and Performance Management, 56(1): 25-59.

Thierry, M., Salomon, M., Van Nunen, J., & Van Wassenhove, L. (1995). Strategic issues in product recovery management. California management review, 37(2): 114-136.

Tyagi, M., Kumar, P., & Kumar, D. (2015). Analysis of interactions among the drivers of green supply chain management. International Journal of Business Performance and Supply Chain Modelling, 7(1): 92-108.

Tyagi, M., Kumar, P., & Kumar, D. (2017). Modelling and analysis of barriers for supply chain performance measurement system. International Journal of Operational Research, 28(3): 392-414.

Tortorella, G. L., Narayanamurthy, G., & Thurer, M. (2021). Identifying pathways to a high-performing lean automation implementation: An empirical study in the manufacturing industry. International Journal of Production Economics, 231: 107918.

Venkatraman, N., & Ramanujam, V. (1987). Measurement of business economic performance: an examination of method convergence. Journal of management, 13(1): 109-122.

Wahab, A. N. A., Mukhtar, M., & Sulaiman, R. (2013). A conceptual model of lean manufacturing dimensions. Procedia Technology, 11: 1292-1298.

Wang, G., Wang, Y., & Zhao, T. (2008). Analysis of interactions among the barriers to energy saving in China. Energy Policy, 36(6): 1879-1889.

Wang, Z., Subramanian, N., Gunasekaran, A., Abdulrahman, M. D., & Liu, C. (2015). Composite sustainable manufacturing practice and performance framework: Chinese auto-parts suppliers′ perspective. International Journal of Production Economics, 170: 219-233.

Ward, P. T., & Duray, R. (2000). Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy. Journal of operations management, 18(2): 123-138.

Warfield, J. N. (1974). Developing interconnection matrices in structural modeling. IEEE Transactions on Systems, Man, and Cybernetics, 1: 81-87.

Womack, J.P., Jones D.T. & Roos D. (1990). The machine that changed the World: The triumph of lean Production. New York: Rawson Macmillan.

Youssouf, A., Rachid, C., & Ion, V. (2014). Contribution to the optimization of strategy of maintenance by lean six sigma. Physics procedia, 55: 512-518.

Yusup, M. Z., Mahmood, W. H. W., & Salleh, M. R. (2015). Basic formation in streamlining lean practices in manufacturing operations-a review. International Journal of Advanced Operations Management, 7(4): 255-273.

Yadav, G., Luthra, S., Huisingh, D., Mangla, S. K., Narkhede, B. E., & Liu, Y. (2020). Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies. Journal of Cleaner Production, 245: 118726.

Zavadskas, E. K., Turskis, Z., Stević, Ž., & Mardani, A. (2020). Modelling procedure for the selection of steel pipes supplier by applying fuzzy AHP method. Operational Research in Engineering Sciences: Theory and Applications, 3(2): 39-53.

Zhao, X., Flynn, B. B., & Roth, A. V. (2006). Decision sciences research in China: a critical review and research agenda—foundations and overview. Decision Sciences, 37(4): 451-496.

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 67-81
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta2040127s

USE OF THE RISK ANALYSIS APPROACH IN THE SERBIAN ARMY INTEGRATION PROCESS AGAINST COVID-19

Nikola Simić*[1], Miladin Stefanović[2], Goran Petrović[3], Aleksandar Stanković[3]

[1] The Serbian Army, Logistics training centre, Kruševac, Serbia
[2] Faculty of Engineering, University of Kragujevac, Serbia
[3] Faculty of Mechanical Engineering, University of Niš, Serbia

Received: 29 September 2020
Accepted: 03 January 2021
Published: 23 February 2021

Research paper

Abstract: *Current developments have contributed to organisations paying increasing attention to protecting resources, employee safety, and applying quality products and services. There is a need for increasing the application of standards that define the way of managing quality, safety at work, risk, and many others. One such organisation is the Serbian Army, a complex centralised system that requires integrating these standards, and often stricter, in all fields of its activities. The current situation in the world, and therefore in Serbia, is sufficient motivation for the project provided by this paper. This project aims to show the integration of risk management systems and occupational safety systems, through the level of protection and exposure of members of the army to the virus infection COVID-19 during the implementation of emergency tasks, by defining risks and proposing additional measures to reduce the level of risk and increase the protection of military personnel.*

Keywords: *virus infection, risk, safety management, emergencies, Serbian Army*

1. Introduction

The development of the most critical events in the 21st century has confirmed that the survival of nations and citizens will increasingly depend on the security of the essential functions of society. The ability to protect the population, ensure the functioning of government and civil society institutions, maintain critical infrastructure, and the democratic principles of functioning of state institutions are under enormous pressure in the face of crises. As no crisis is an isolated event "per se," awareness and readiness to counter non-military threats are focused on analysing complex security policy fields based on different management systems, which imposes the need for so-called integrated management systems (IMS). Because of this complexity, the identification and analysis of threats usually

* Corresponding author.
nikolasimicva@hotmail.com (N. Simić), miladin@kg.ac.rs (M.Stefanović), pgoran@masfak.ni.ac.rs (G.Petrović), aleksandar.stankovic@masfak.ni.ac.rs (A.Stanković)

involve assessing multiple risks and studying scenarios of a limited number of situations identified as potentially risky or catastrophic (Jørgensen et al., 2006). At present, risk assessments and crisis management concepts differ significantly in many countries and are conducted in the broader context of risk and crisis management. The primary and indisputable responsibility for protecting citizens and the fundamental values of society lies with the states. By improving awareness and understanding of the risks faced by states, decision-makers have a better position to agree on preventive measures to be taken and to prepare to avoid the most severe consequences of natural and human-made disasters. In the context of the responsibility of the state to prevent and resolve the effects of crises, special responsibility lies with the army, with an assessment of the comparative advantage of the military over other state bodies, but also the functional needs and opportunities for an effective response to non-military security threats (Karović et al., 2010). One such security threat is certainly the pandemic caused by the COVID-19 virus infection. It represents a new type of "enemy" that the Serbian Army has not yet encountered in its history. Therefore, this research becomes more exciting and encourages and motivates further courses of study. The analysis of various scenarios, which represent the core of the study, is focused on determining all assumptions, possibilities, risks, and prospects for the use of units of the Serbian Army, based on risk assessment, on showing the level of exposure to viral infection in military missions. As a result of this project, the preparedness, level of exposure, and protection of Serbian Army members' are highlighted, and shortcomings are spotted. Possible ways are considered for further suppression and security, while this paper gives new additional measures of security and safety of members in some future similar non-military threats.

2. Covid-19 review and application of the Serbian Army in non-military security threats through swot analysis

COVID-19 is a disease caused by a coronavirus. Coronaviruses are viruses that circulate among animals, but some of them can spread to humans. After they pass from animal to human, humans can distribute viruses among themselves. For example, the coronavirus of the respiratory syndrome SARS originates from the Viverridae, an animal from the order of beasts related to cats. Discovered in China in 2003, it is genetically closely related to the COVID-19 virus, and the two viruses have similar characteristics. In eight months, 33 countries reported more than 8,000 cases of SARS. Then one in ten infected people died of SARS. COVID-19 is SARS-CoV-2. It was detected in China, the city of Wuhan, Hubei Province, at the end of 2019, the first case on November 17, 2019. year (Ma Josephina, 2020), while the first case in the territory of Serbia arose on March 6, 2020. year (Government of Serbia, 2020). It is a new strain of coronavirus that has not been detected in humans before.

Although the virus originates from animals, it now spreads from person to person (human-to-human transmission). The virus is mainly transmitted by droplets when sneezing and coughing. Preliminary research indicates that the average incubation period is 5-6 days, with a maximum of up to 14 days (Chu et al., 2020). Although people are most contagious when they have symptoms (similar to seasonal flu symptoms - fever, sneezing, cough, muscle aches, fatigue). There are indications that some people can transmit the virus even though they have no signs or before symptoms appear, which is not uncommon with other viral infections. In severe cases, severe pneumonia, acute shortness of breath syndrome, sepsis, and septic shock occur, which can cause the patient's death. Older people and people with chronic diseases (such as high blood pressure, heart disease, diabetes, liver disorders, and respiratory diseases) have a higher risk of developing more severe forms of this disease. However, the exposure to this infection is not decreased for emergency and state services, including members of the Serbian Army.

The Serbian Army is an organised armed force that defends the country from armed threats from outside and performs other missions and tasks, following the Constitution, law, and principles of international law that regulate the use of force (Law on the Serbian Army, 2019). The President of the Republic or the Minister of Defense, upon the authorisation of the President of the Republic, may decide that the Serbian Army shall assist the competent state body, i.e., organisation, the body of autonomous provinces and local self-government units, at their request, for protection of life and safety of people and property, for other reasons determined by law (Official Gazette of the Republic of Serbia, 2019). After the war in the 1990s, the Serbian Army actively participated in implementing the third mission of the army, i.e., assisted civilian authorities in the event of natural disasters, technical-technological and other accidents. The military usage for civilian purposes could be noticed during firefighting actions on several occasions in recent years, then during the floods of 2014 and 2019, and during the migrant crisis to help civilian structures conduct migrants through the territory Serbia. However, the situation that caused the second state of emergency in the country in the 21st century after the prime minister's assassination in 2003 showed that the modern army had not encountered such a threat so far. The last time army was used in such a case, former JNA, in this territory was in 1972, during the smallpox epidemic "Variola Vera," on securing temporary hospitals. The necessary measures applied by JNA members were protective masks and steeled discipline, and the intensification of hygiene (Radovanovic, 2017). The situation with the disease at that time did not seem to bring any experience, so the Serbian Army entered the fight against COVID-19 practically unprepared. Until the declaration of emergency on March 15, 2020, activities and tasks in the Serbian Army were going according to plan (Official gazette of the Republic of Serbia, 2020).

Table 1. SWOT analysis

Strengths – S	**Weaknesses - W**
The medical and health care system is gradually improving - the Military Medical Academy.	The COVID-19 epidemic has spread to many regions in a short period.
Comprehensive progress of the military health system in terms of taking measures. (Blumenthal et al., 2020).	Rumours of wider disinformation
Rapid and efficient cooperation of joint prevention and control of the military and civilian structures. (Blumenthal et al., 2020).	Serbia's population density is 98.1 in / km^2
	Lack of aid and labour supplies (Ebrahim, 2020)
	Lack of equipment and accommodation (Rimmer, 2020)
	The public is upset and lacks awareness.

Opportunities – O	**Threats - T**
New research COVID-19 (Salvatore et al., 2020)	Impact on the daily life, work, and psychology of employees (Barnes & Sax, 2020)
Further improvement and inspection of the health system in the army (Blumenthal et al., 2020)	Impact on the national economy (Salvatore et al., 2020)
Opportunities for education for infectious diseases and gaining new experiences in combat (Blumenthal et al., 2020)	Possible virus carriers to their families

Namely, for such a case of non-military security threat, there is no plan in the army. All forces are focused on helping civilian structures in extinguishing fires, assistance during floods, and select units of atomic-biological-chemical defence that are engaged in case of CBRN accident. In a way, the unpreparedness for "fighting" against COVID-19 is understandable. Hence the solution to why lessons and experiences were not learned from the epidemic of the 1970s.

Concerning the previous, SWOT analysis presents the situations, which refers to the assessment of various strengths (S), weaknesses (W), opportunities (O), threats (T), and other factors that affect a particular topic. It comprehensively, systematically, and accurately describes the scenario in which the issue is situated. This helps to formulate appropriate strategies, plans, and countermeasures, based on the results of the assessment (Jasiulewicz-Kaczmarek, 2016). This method can be used to identify favourable and unfavourable factors and conditions, target current problems, identify challenges and threats, and formulate strategic decision-making plans. This SWOT analysis (Table 1) of COVID-19 is based on the experience of the reaction to the SARS epidemic from 2003, and the data as a basis are taken from the annual health statistics - China for 2019 and adjusted for R. of Serbia (China Health Statistics Yearbook, 2019).

Based on the presented SWOT analysis, it can be concluded that the defence forces are extraordinary mild and that the weaknesses are too many. It can also be added that the Serbian Army is spread over the entire territory. Due to the realisation of tasks, there is a need to connect personnel on specific charges, which was the case during the formation of a temporary hospital in the military institution "Morovic." The lack of protective equipment can be singled out as a fundamental problem because with the existing resources, members are not adequately protected under regulations (eg. Surgical masks in pharmacies do not have a long-lasting effect; according to some estimates, only 2-3 hours (Chu et al., 2020). Also, the chances that may only arise after a pandemic are reflected inexperience, not allowing the same omissions as during the epidemic of the 70s. As for threats, the most dangerous is related to the army members who are in an unenviable position, given their constant engagements and returns to their families after them. There is an increased risk of exposure to loved ones, regardless of government measures and curfews.

Based on the analysis, the fight against this type of "enemy" is shown in the following text. So far, the Serbian Army's application in the implementation of the third mission has shown that members of the army have not encountered this type of "enemy." Role insecurity is one of the daily tasks of members of the army. During the security, standardised equipment is used following standardisation documents that are even stricter than management systems' standards. The standardisation documents are the standards of defence of the Republic of Serbia (SORS), product quality regulations (PKP), and technical regulations in the field of protection (TPO) (Official military gazette, 2018).

The defence standard is a document that refers to specific items for the needs of defence and contains technical specifications and criteria that ensure that the material, products, processes, and services correspond to the purpose. The product quality regulation is a document that contains data important for quality in research, development, and production. At the same time, the TPO is a document related to facilities, devices, and plants for other processes, products, and services in the field of defence (Official military gazette, 2018). The Standards of Defense of the Republic of Serbia (SORS), formerly the Standards of National Defense (SNO), are applied to every means, weapon, equipment in use, like the ones in the following figures.

This case study will present three cases in the suppression of COVID-19, as follows:

- Provision of civilian hospitals, health centres, gerontology centres, and other public facilities of importance. During security, members were exposed to contact with staff employed in health facilities, controlled the entry and exit of patients, and performed their identification, as well as the passing of motor vehicles.
- Establishment of temporary "COVID" hospitals in sports halls and the military institution "Morovic." The engagement of members in the formation of temporary hospitals was realised in all significant hotspots. They showed the most significant efforts during the construction of the hospital at the Fair in Belgrade. With a minimum of equipment (surgical mask and gloves), the assessment was that the members were protected during this task's realisation.

Figure 1. A member of the army during the construction of the COVID hospital

- Specialised units of the army realised disinfection of public areas and buildings. The members of the CBRN units had the best protection, but also the most challenging task, because by the nature of their work, they were most exposed to chemical substances, and they were equipped with overalls, unique protective masks, and gloves at all times.

Figure 2. A member of the CBRN service on the task of disinfection

3. The methodological framework of the research

Research has the character of a theoretical-empirical procedure, where the design and implementation combine theoretical methods of scientific research and empirical methods.

Based on data from foreign and domestic literature, the descriptive method was used to present the viral pandemic situation as comprehensively as possible, both in the world and in the Republic of Serbia. When comparing the cases in which the army was engaged, a comparative analysis was used. The inductive-deductive method was used to draw lessons from foreign countries' experiences, primarily China and Russia. When generalising certain phenomena related to COVID-19 and the Serbian Army's use, the analytical-synthetic method was applied.

The scientific significance of this project work lies in the new theoretical approach in defining the army's role in combating similar non-military security threats and assisting decision-makers with the advantages of this research; those are new adequate measures in case of possible recurrence.

4. Case study

So far, the Serbian Army's application has shown that members of the army have not encountered this type of "enemy." This case study will compare the levels of risk of exposure of members of the Serbian Army to COVID 19 infection in three cases, by multicriteria decision using the TOPSIS method, where issues are defined as options (A) and risks (K), after which alternatives will be ranked. Appropriate conclusions will be drawn for better protection of employees during the performance of duties in these cases:

Case 1: Securing civilian hospitals, health centres, gerontology centres, and other critical public facilities. During security, members were exposed to contact with staff employed in health facilities, controlled the entry and exit of patients, and performed their identification, as well as the passing of motor vehicles.

Case 2: Establishment of temporary "COVID" hospitals in sports halls and the military institution "Morović." The engagement of members in the formation of temporary hospitals was realised in all significant hotspots. They showed the most significant efforts during the construction of the hospital at the Fair in Belgrade. With a minimum of equipment (surgical mask and gloves), the assessment was that the members were protected during this task's realisation.

Case 3: Disinfection of public areas and buildings carried out by specialised military units. The members of the CBRN units had the best protection, but also the most challenging task, because by the nature of their work, they were most exposed to chemical substances, and they were equipped with overalls, unique protective masks, and gloves at all times.

After defining the cases and gathering information on the dangers posed by a viral infection, a risk assessment follows. One of the simplest methods used is to determine the level of risk. Three levels of severity of consequences and three levels of Probability of occurrence are defined, and then the level of risk is specified based on these data (Table 2).

Table 2. Defining risk levels

Consequences / Probability	**Slightly Dangerous**	**Dangerous**	**Extremely Dangerous**
Probable event	MEDIUM RISK	HIGH RISK	VERY HIGH RISK
Rare event	LOW RISK	MEDIUM RISK	HIGH RISK
Sporadic event	VERY LOW RISK	LOW RISK	MEDIUM RISK

Based on the presented method of risk assessment and perception of the situation in the field, the risk assessment of the study case takes the Probability of events: Probable event, and based on the table, we see the consequences of events through a medium, high, and very high risk. A rare event is not taken as a reference, and also, the situation is not harmless, so a sporadic occurrence and a shallow risk are excluded (Čerepnalkovska, 2016). Based on the above, the risks and levels of risk are defined, which are shown in Table 3:

Table 3. Defining risks and levels - weighting coefficients

Risk		MEDIUM RISK	HIGH RISK	VERY HIGH RISK
Risk 1	Level of protection of members of the Armed Forces	1	3	5
Risk 2	Possibility of infection			
Risk 3	Possibility of possible transmission to other members of the Armed Forces			
Risk 4	Possibility of possible transmission to their families			
Risk 5	Presence of chemicals			
Risk 6	Possibility of unwanted contact and conflict			

Explanation of the level of risk (weighting coefficients) of the First Case:

- The protection of members of the Armed Forces was assessed as "very high risk" because members use only surgical masks N95 or AM-1002 and surgical gloves.
- The possibility of infection was assessed as "high risk" because members are exposed to potential patients at the entrance to public buildings, keeping a distance of 2 meters but with a personal identification check that requires a reduction in the prescribed space.
- The possibility of possible transmission was assessed as "very high risk" because members come to work after completing the task and then go to their homes. There is a possibility that they are potentially infected.
- Persons on this task are not exposed to excessive effects of disinfectant chemicals.
- The possibility of unwanted contact and conflict was assessed as "high risk" because there are situations in which potentially infected people refused to cooperate and were brought to the brink of physical confrontation.

Explanation of the level of risk (weighting coefficients) of the Second Case:

- The level of protection of members of the Armed Forces was assessed as "very high risk" because members use only a surgical mask, improvised mask, and surgical gloves or work gloves (Figure 1).
- The possibility of infection was assessed as "high risk" because the members are at a distance of fewer than 2 meters and a large concentration of people in one place.
- A possible transfer was assessed as "high risk" because members remain in contact after the task, during the rest and preparation for the next job but do not come into contact with their families.
- Persons on this task are exposed to a specific effect of chemicals during the disinfection of established hospitals, and this risk is assessed as "high risk."
- The possibility of unwanted contact and conflict was assessed as "medium risk" because there are no other persons than members of the Armed Forces to implement this task.

Explanation of the level of risk (weighting coefficients) of the Third Case:

- The level of protection of CBRN members was assessed as "medium risk" because they use special protective equipment for particular purposes (Figure 2).
- The possibility of infection is assessed as "high risk" because members do not come into direct contact with the infected or potentially infected.
- A possible transfer was assessed as "high risk" because they are in constant contact with each other and go to their families after work.
- People on this task are most exposed to chemicals during disinfection because in addition to the use of chemicals, it is necessary to do the same, and this risk is assessed as "very high risk."
- The possibility of unwanted contact and conflict was assessed as "medium risk" because there are no persons other than CBRN members to implement this task.

4.1. Technique for order preference by similarity to an ideal solution

The Technique for the Order Preference by Similarity to Ideal Solution (TOPSIS) was introduced by Hwang and Yoon (1981). The standard TOPSIS method is based on the concept that the best alternative should have the shortest Euclidian distance from the ideal solution, and at the same time, the farthest from the anti-ideal solution. TOPSIS method can be implemented using the following steps:

Step 1: Method starts with determination of a *Decision matrix* $X = (x_{ij})_{m \times n}$, in which element x_{ij} indicates the performance of alternative A_i when it is evaluated in terms of decision criterion C_j, (for $i = 1, 2, 3,..., m$ and $j = 1, 2, 3,..., n$):

$$X = \left[x_{ij}\right] = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \ldots & x_{mn} \end{bmatrix} \end{array} ; \quad (1)$$

Step 2: Determine the normalized decision matrix which elements are *rij*:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2}}, \quad (2)$$

Step 3: Obtain the weighted normalized decision matrix whose elements are v_{ij} by multiplying each column j of the normalized matrix by its associated weight w_j:

$$v_{ij} = r_{ij} \cdot w_j, \quad (3)$$

Step 4: Determine the positive ideal and the negative ideal solutions:

$$\begin{aligned} V^+ &= (v_1^+, v_2^+, ..., v_n^+) = \{(\max_i \{v_{ij} | j \in B\}), (\min_i \{v_{ij} | j \in C\})\} \\ V^- &= (v_1^-, v_2^-, ..., v_n^-) = \{(\min_i \{v_{ij} | j \in B\}), (\max_i \{v_{ij} | j \in C\})\} \end{aligned}, \quad (4)$$

Where B and C are associated with the maximisation and minimisation criteria sets, respectively.

Step 5: Calculate the separation measures (Euclidean metric) from the positive ideal solution and the perfect negative solution. The separation of each alternative from the perfect positive solution is given as:

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - V_j^+)^2} \tag{5}$$

The separation of each alternative from the negative ideal solution is given as:

$$S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - V_j^-)^2} \, . \tag{6}$$

Step 6: Calculate the *relative closeness* of the *i*-th alternative A_i to the positive ideal solution:

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{7}$$

The relative closeness P_i can have values between (0, 1), whereby $P_i = 0$ represents a negative ideal solution, while $P_i = 1$ stands for a perfect positive solution. According to P_i values, the alternatives can be ranked. The best option has the highest value, P_i, because it is the closest to the positive ideal solution.

Since the last part of the paper defines alternatives (A) and criteria (K), it is necessary to determine the weights of the bars (risk), based on an exchange of opinions with occupational safety officers, for the application of the TOPSIS method, according to the following:

- for K1 - 0.4 - is considered the most important because it is the protection of human lives;
- for K2 - 0.2 - presented as an important criterion because it entails other risks and possibilities of spreading the infection;
- for K3 - 0.1 - presented as a medium-important criterion because there is a possibility of spreading the disease to military circles;
- for K4 - 0.15 - presented as an essential criterion because employees, finishing their work, can spread the disease to their family members;
- for K5 - 0.1 - it is considered not very important because only select units of the army work with chemicals;
- for K6 - 0.05 - presented as the least important criterion because the cases are individual.

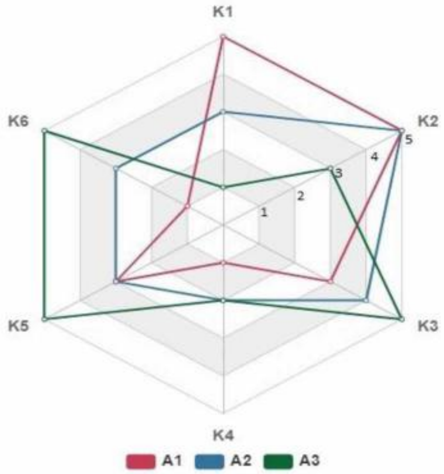


Figure 3. Defining risk levels by alternatives

The first step is the initial table-matrix of initial data with the assignment of coefficients, determination of values that are minimised and maximised, and assignment of weight values, which is shown in Table 4.

Table 4. Assignment of values and determination of max and min and weight values

	Criteria					
	K_1	K_2	K_3	K_4	K_5	K_6
	0.4	0.2	0.1	0.15	0.1	0.05
Alternatives	min	min	min	min	min	min
A_1	5	5	3	1	3	1
A_2	3	5	4	2	3	3
A_3	1	3	5	3	5	5

The values of the criteria are determined, where maximised-rewrite and minimised-convert to the max, as shown in Table 5:

Table 5. Criterion values obtained after minimisation and maximisation

	Criteria					
	K_1	K_2	K_3	K_4	K_5	K_6
	0.4	0.2	0.1	0.15	0.1	0.05
Alternatives	min	min	min	min	min	min
A_1	0	0	2	4	2	4
A_2	2	0	1	3	2	2
A_3	4	2	0	2	0	0

The next step is to determine the norm and to form a normalised matrix. The determination of weighted values follows this, and the obtained data are shown in Table 6:

Table 6. Weighted values

	Criteria					
	K_1	K_2	K_3	K_4	K_5	K_6
	0.4	0.2	0.1	0.15	0.1	0.05
Alternatives	min	min	min	min	min	min
A_1	0	0	0.089	0.111	0.070	0.044
A_2	0.178	0	0.044	0.083	0.070	0.022
A_3	0.357	0.2	0	0.055	0	0
Best max	0.357	0.2	0.089	0.111	0.070	0.044
Best min	0	0	0	0.055	0	0

Finally, the distance is calculated according to the shown values, and the alternatives are ranked, as shown in Table 7.

Table 7. The final ranking of alternatives

	Criteria						
	S^+		S^-		The similarity to the solution		RANK
A_1	0.1345	A_1	0.40987	A_1	0.7528		**1**
A_2	0.2006	A_2	0.27436	A_2	0.5775		**2**
A_3	0.4098	A_3	0.13454	A_3	0.2471		**3**

Based on the final rank of alternatives shown in Table 7, it is concluded that members of the Serbian army engaged in protecting hospitals and public institutions (alternative 1) were most exposed to COVID-19 infection. The risk of their disease is the most significant, primarily due to daily exposure to potentially infected persons. In contrast, the lowest possibility of infection was present in members of the CBRN service (alternative 3) because they possessed the highest protection level. Members of the army engaged in the formation of "covid" hospitals were ranked second because there was no one in their presence except themselves.

A graphical representation of the final rank of alternatives is shown in Figure 4.

Figure 4. Graphical representation of the final rank of alternatives by the TOPSIS method

5. Conclusion

This research showed the level of protection and risk of members of the Serbian Army. Which were engaged in three cases, with some new security, which motivated the authors to examine the level of maximum risk exposure and identifies gaps and shortcomings, and proposes additional measures based on the research results. Based on the case study and the application of multicriteria decision-making using the TOPSIS method, the results showed that military members are most exposed to the possibility of contracting COVID-19 virus infection, primarily due to low levels of protection and contact with potentially ill persons. CBRN members serve, thanks to their protective equipment and almost minimal contact with potentially infected people, they are the safest from the effects of a viral infection. Members in the second case who were engaged in the formation of "covid" hospitals were assessed with a medium level of risk due to their spatial distribution in places where no viral agents were present. Based on the research and case study, measures can be concluded and proposed to further prevent the spread of infection according to the following:

- Provide sufficient quantities of surgical masks to ensure the condition of replacement every two hours,
- At the entrance to human accommodation (for pedestrians and vehicles), install and maintain disinfection barriers in the complexes (NaClO, Pinosteril 200, Chlor, Alcohol 70%),
- Regularly disinfect the premises for housing and dining of people,
- Perform regular personal and collective hygiene and accommodation and eating people, i.e., before eating to control the personal hygiene of all persons,
- During the execution of hospital security tasks, avoid close contacts with persons who show signs of acute respiratory diseases and strictly adhere to all prescribed measures,
- Indirect communication with the civilian population, provide a distance of at least 2 meters,
- measure the members' temperature before performing the task, and send it to the ambulance if it occurs.
- Use protective equipment (gloves and visor) when making the disinfectant mixture,
- After engaging in tasks, disinfect personnel and equipment.

Experiences that can be gained during this project's development are that the approach to the problem must be more serious and meaningful. It is necessary to look retroactively and see that preparation didn't exist for this type of "fight" and that for some future situations, all the people should be in the machine in a state of emergency.

Acknowledgement

This research was financially supported by the Ministry of Education, Science and Technological Development of Serbia.

References

Barnes, M., Sax P. (2020). Challenges of "Return to Work" in an Ongoing Pandemic, New England Journal of Medicine 383(8), June 18, 2020, 779-786. https://doi.org/10.1056/NEJMsr2019953.

Blumenthal, D., Fowler, E., Abrams, M., Collins S. (2020). Covid-19 — Implications for the Health Care System, New England Journal of Medicine, July 22, 2020. https://doi.org/10.1056/NEJMsb202.

China Health Statistics Yearbook. (2019). ISBN: 9787567913233

http://news.hc3i.cn/art/201912/44108.html,

Accessed: 11.04.2020. y.

Chu, D., Akl E., and others. (2020). Physical distancing, face masks, and eye protection prevents person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis Open Access, Volume 395, Issue 10242, June 27 – July 3, 2020, 1973-1987. https://doi.org/10.1016/S0140-6736(20)31142-9.

Ebrahim, A. (2020). A global survey on changes in the supply, price, and use of illicit drugs and alcohol, and related complications during the 2020 COVID-19 pandemic, Published in MedRxiv, 2020, https://doi.org/10.1101/2020.07.16.20155341.

Government of Serbia. (2020), Coronavirus information.

www.covid19.rs/питања-и-одговори-о-болести-узрокован/,

Accessed: 07.04.2020. y.

Hwang, C.L. & Yoon, K. (1981). Multiple Attribute Decision-Making Methods and Applications. Springer-Verlag, New York. http://dx.doi.org/10.1007/978-3-642-48318-9.

Isaksson, R., Tosteby, J., Abrahamsson, S. (2010). Integrated Management Systems: advantages, problems, and possibilities, Conference Paper, January 2010.

Jasiulewicz-Kaczmarek, M. (2016). SWOT analysis for Planned Maintenance strategy—A case study, IFAC PapersOnLine 2016, 49, 674–679.

Jørgensen, et al. (2006). Integrated management systems - Three different integration levels, Journal of Cleaner Production 14 (8), 713-722.

Karović, S. et al. (2010). Risk management as a prerequisite for integrated system management in the organisation, Military Technical Courier 2010, 146–161.

Law on the Serbian Army ("Official gazette of the Republic of Serbia," бр. 116/2007, 88/2009, 101/2010 – etc., 0/2015, 88/2015 – decision US, 36/2018 i 94/2019) - Article 2, paragraph 2, necessary provisions.

Ma, Josephina. (2020). China's first confirmed Covid-19 case traced back to November 17, South China Morning Post. Archived on March 19, 2020.

Radovanovic, Z. (2017), Variola Vera - virus, epidemic, humans, Heliks, 2017, 129. ID: A166505.

Rimmer, A. (2020). Covid-19: Shielding doctors express concerns about returning to work. Published in The BMJ 370, on July 21, 2020. doi.org/10.1136/BMJ.M2918.

Salvatore, C.M., Han J.Y., Acker K., and others. (2020). Neonatal management and outcomes during the COVID-19 pandemic: an observational cohort study, The Lancet Child & Adolescent Health, 2020 October 4 (10), 721–727.

Published online 2020 July 23. https://doi.org/10.1016/S2352-4642(20)30235-2.

"Official gazette of the Republic of Serbia," no. 94/2019.

"Official gazette of the Republic of Serbia," no. 29/2020.

"Official Military Gazette," no. 24/2018.

Čerepnalkovska, S. (2016). A model for improving an integrated risk-based management system, Faculty of Technical Sciences, University of Novi Sad, 26-31.

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 82-98
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https:// doi.org/10.31181/oresta2040182c

SUPPLIER SELECTION PROCESS IN DAIRY INDUSTRY USING FUZZY TOPSIS METHOD

Tarik Cakar *[1], Burcu Çavuş [2]

[1] İstanbul Gelisim University, Engineering and Architect Faculty, Industrial Engineering Department, Turkey
[2] International Balkan University, Engineering Faculty, Industrial Engineering Department, North Macedonia

Received: 20 December 2020
Accepted: 12 February 2021
Published: 20 March 2021

Research paper

Abstract: *Supplier selection is one of the most critical processes within the purchasing function. Choosing the right supplier makes a strategic difference to an organization's ability to reduce costs and improve the quality of products by helping to select the most suitable supplier. Sütaş Dairy Company, which is entered to Macedonia market in 2012. In the dairy company, there is only one purchasing manager who selects the farmers. Importance weights of criteria are determined using his reference, and also the alternatives are evaluated according to each criterion. The most important criteria are product and other costs, the price is also playing an important role, but due to the small marketplace of Macedonia, the prices are almost the same in every region. To select the dairy supplier in Macedonia, Fuzzy TOPSIS technique is used. The main goal of using fuzzy logic in this study is to help decision-makers for identifying the importance of selection criteria and rank possible suppliers easily. Since the supplier selection process is a Multi-Criteria Decision Making (MCDM) problem, after identify the weights and rankings in a fuzzy environment, TOPSIS algorithm has been used in the rest of the problem. Finally, fuzzy TOPSIS methodology has been implemented successfully, and its result pointed out the most suitable suppliers.*

Keywords: *Supplier selection, Fuzzy TOPSIS, Dairy industry*

1. Introduction

In today's competitive world, supply chain management has a significance role in the companies' plan due to survive and stay competitive. Supply chain management is a management process that consists of getting raw materials by selecting the best supplier into the organization, work on the raw materials to produce end products, and also supply chain management involves customer satisfaction. Since the procurement of raw material is the first and vital step of supply chain management, we may say that supplier selection has a numerous significant place in supply chain

* Corresponding author.
tcakar@gelisim.edu.tr (T. Cakar), bcavus@ibu.edu.mk (B. Çavuş)

management. Also, organizations exist due to serve customers and satisfy their needs. Because if there is not any customer, the organizations can not survive anymore. Also, from another point of view, the businesses must stay competitive in the global marketing area not to lose their potential of consumers as well as their stakeholders. The common ground of all these goals of the organizations is passing through the select a suitable supplier. Because a well-selected supplier can affect all needs and objectives of any organization, accordingly this study focuses on the selecting the best supplier and represent the supplier selection process in the dairy industry.

Supplier selection is a cross-functional group decision-making problem where the decision-makers from different parts of an organization. It is providing a long-term decision process due to it affects firm's expectations from raw material to the end products and also regarding end products customers' satisfaction. The role of purchasing managers (buyers) has become very important because supplier selection is an essential task within the purchasing function. However, since the supplier selection is a cross-functional group decision-making process, it involves different company departments, not only purchasing manager. On the hand, the purchasing department is influenced by several sets of factors such as individual, interpersonal, organizational, and environmental. On the other, supplier selection is a complicated process that may involve several and different types of criteria, a combination of different decision models, group decision-making, and various forms of uncertainty. Therefore, the supplier selection process is one of multi-criteria decision making (MCDM) problems, and Techniques for order performance by similarity to ideal solution (TOPSIS), which is one of the known classical MCDM methods, may provide the basis for developing supplier selection models that can effectively overcome with these uncertainties. For this purpose, in this work TOPSIS method is applied with its fuzzy renewal.

Moreover, according to Benyoucef et al. (2003), there are two different aspects that characterize the supplier selection problem. The first aspect is the determination of a number of the suppliers by considering the characteristics of the company product and market and the second aspect is the selection of the best suppliers among existing alternatives. In this study, we consider the second aspect of the problem. Therefore, we assume that the number of suppliers to be selected are already given.

2. Literature review

According to Vinodh et al. (2011), supplier selection is a cross-functional group decision-making problem providing long-term decision for the company, and Mazaher et al. (2013) mentioned that objective of supplier selection is to identify suppliers with the highest potential for meeting a firm's needs consistently. Professionals believe that supplier selection is an essential task within the purchasing function. Therefore, the decision of supplier selection takes an essential place for the businesses. Supplier or vendor selection processes are complicated by reason of various criteria have to be taken into account while decision making. From the beginning of the 1960' s the analysis of criteria for the supplier selection and calculating their performance have been the focus of many academists, decision-makers, and purchasing managers.

Through define the selection criteria of suppliers, one of the most important study prepared by Dickson (1966). Dickson's studies has based on a questionnaire sent to 273 buying managers and directors who are members of the National Association of Purchasing Managers. As a result of this study, he identified 23 criteria that are still the main priorities of the supplier selection process and ranked concerning their importance. In the past, because cost reduction is the main priority for a decision-makers, the price was the key factor in choosing a supplier. However, the evolution of the industrial environment and hard competitive business world modified the degrees of the relative of these selection criteria and new criteria have to be taken into consideration by the decision-makers. For instance, Weber et al. (1991) examined 74 supplier selection articles, which were published from 1966 to 1990, and also covered the Dickson's study.

Literature is very rich about supplier selection. In the nineties, Ellram (1990) presented three principal criteria for supplier selection problem which are: 1) the financial statement of the supplier, 2) organizational culture and strategy of the supplier, and the last one 3) technological state of the supplier. Also, for each criterion, the author defined several sub-criteria. Like Ellram's principal criteria, Barbarosoglu and Yazgac (1997) proposed another three principal criteria: 1) the performance of the supplier, 2) technical capability and financial of the supplier, and 3) the quality system of the supplier, and each one have some sub-criteria.

Cherangi et al. (2004) conducted a cluster analysis of 110 research papers which are written in 1990-2001 regarding critical success factors. Cherangi et al. compared their literature review with the literature review of Weber et al. and updated the criteria. Ho et al. (2010) assessed the 78 articles which were published the international magazines in 2000-2008. Thiruchelvam and Tookey (2011) examined 46 new articles, articles were written for engineering and manufacturing departments and published in international scientific magazines from 2000 to 2011. From the recent studies, Johan and Jimmy (2011) presented a review that was structured by four main headings such as the supplier selection process, buying-specific factors, organizational factors, and inter-organizational factors, and each heading purposed sub-headings.

Supplier selection criteria for the identification of solution to problems to select the best supplier is the first and important step. However, after determining criteria, solution of the problem, in another word the process which leads to the best supplier, is important as much as criteria definition. Therefore, another literature review was prepared with respect to used methods in supplier selection. There has been wide labor to develop decision techniques and methods for supplier selection. Some previous reviews of these decision techniques have been prepared by Holt (1998), Ho et al. (2010), and Agarwal et al. (2011).

Holt (1998) presented an article about the contractor evaluation and selection modeling methodologies. Some of these methodologies are multiple regression, fuzzy set theory, multi-attribute analysis, and cluster analysis. The merits/demerits and previous/possible future applications of each methodology were also discussed. Ho et al. (2010) examined 78 articles in 2000-2008. In this study, several individual and integrated approaches are proposed to solve supplier selection problems. According to its result, the most common of the integrated approach is analytic hierarchy process- hierarchy process (AHP), and the most commons of the individual approach are data envelopment analysis (DEA), mathematical programming, and AHP. Agarwal et al. (2011) have prepared a literature review which involves 68 articles written from 2000 to 2011 which were about multiple-criteria decision making methods. As the result of Ho et al.'s study, this work also gave similar results and showed that the most commons of applied processes were DEA, mathematical programming, and AHP. Pearn et al. (2004) made sound the selection power analysis of the method using simulation and process capability. The certainty analysis provides useful information related to the sample size necessary for specified selection power. To tailor this method for in-plant applications and to select the better supplier and calculate the size of the difference between the two suppliers Pearn et al. (2004) developed a two-phase selection procedure.

Because supplier selection abounds in the literature, only several methods mentioned above. However, the methods have been classified a little bit differently but mostly the same in the literature. One of the literature review on supplier selection was prepared by Junyi et al. (2012). By using a methodological decision analysis in four aspects, including decision problems, decision-makers, decision environments, and decision approaches, they selected and reviewed 123 articles published in 2008-2012. To examine the research trend on uncertain supplier selection, they classified the articles into seven categories according to different uncertainties and 26 decision making techniques identified from three perspectives: Firstly, MCDM techniques, secondly, mathematical programming (MP) techniques, and the last one artificial intelligence (AI) techniques. Jadidi et al. (2009) used the TOPSIS method and multi-objective mixed integer linear programming in order to solve the complicated problem, which is used to define the optimum quantities among the selected suppliers. Rouyendegh et al. (2014) mentioned that supplier selection is mostly a complex multi-criteria problem which consists of qualitative and quantitative factors. Therefore to deal with optimal decision making for selecting the best supplier and allocating order, applied the method of integrated fuzzy TOPSIS and Multi-Choice Goal Programing (MCGP). Firstly they used a Fuzzy TOPSIS to determine uncertain and imprecise judgment of decision-makers and, for the final supplier selection and order allocation, applied the MCGP model. Tayyar et al. (2013) utilized AHP and VIKOR models to solve the problem of determining the best sub-contractor among those which sew the orders of the worldwide known brands in the clothing sector through MCDM models. In addition, Sachin and Ravi, (2014) utilized a two-step method to identify and rank the solutions of knowledge management (KM) adoption in the supply chain (SC) and overcome its barriers. At the first step, AHP was used to determine the weights of the barriers as criteria. At the second step, TOPSIS was applied to obtain final ranking of the solutions of KM adoption in SC. Also, Nydic and Hill, (1992) and Narasimahn, (1983) used AHP, and Akman and Aklan, (2006), fuzzy AHP to determine the best suppliers.

A study published by Yue, (2014) which aims to develop a new methodology for group decision-making (GDM) problems in an intuitionistic fuzzy environment. The weights of decision-makers were determined by using an extended TOPSIS technique. The individual decisions of decision-makers were then converted into the group decision of alternatives. Then the preference of alternatives was ranked by using an extended TOPSIS technique. In order to show the major technical advances in the applied model, comparisons between the proposed method and other methods were studied. Besides these approaches, three injection timing and three injector protrusion settings were tested to study engine performance and exhaust emissions. The experimental results were evaluated using two multi-criteria decision-making techniques AHP and TOPSIS and the optimal fuel type-injection timing-injector protrusion configuration was selected.

Another study proposed by Izadikhah, (2009) by applying the TOPSIS method to deal with fuzzy data for determining the best choice among all possible alternatives. In his approach, one of the Yager indices, which were used for ordering fuzzy quantities in [0, 1], was applied to identify the fuzzy ideal solution and fuzzy negative ideal solution. The result of Yager's index gave a procedure for choosing fuzzy ideal and negative ideal solutions directly from the data for observed alternatives. Then, he proposed the Hamming distance for calculating the distance between two fuzzy triangular numbers.

Demiral, (2013) used fuzzy linear programming in production planning among several optimization opportunities in the dairy industry. Several reasons, such as an uncertain supply of milk and demand of dairy products and the results of the fuzzy linear programming model are more realistic than a linear programming model and more profitable in terms of the firm, made preferred the fuzzy linear programming. Also, Guan et al. took into account uncertain milk supply, price–demand curves and contracting, and applied multistage stochastic programming to a production planning problem for Fonterra, a leading company in the New Zealand dairy industry. They described a model for uncertain milk supply and a model for Fonterra's supply chain. Then presented a multistage stochastic quadratic programming model and a decomposition algorithm to compute an optimal sales policy, which is tested in simulation against a deterministic policy. Jouzdani et al. (2013) proposed another study based on minimizing the costs of facility location, traffic congestion and transportation of raw/processed milk and dairy products under demand uncertainty by dynamic dairy facility location, and supply chain planning. They proposed a model which was dynamically incorporated possible changes in the transportation network, facility investment costs, the monetary value of time, and changes in the production process.

Zavadkas et al. (2020) studied on MCDM techniques for improving the sustainability engineering process. Markovic et al. (2020) proposed a novel integrated subjective-objective MCDM model for alternative ranking in order to achieve business excellence and sustainability. Gegovska et al. (2020) used Fuzzy-MCDM technics and Artificial Neural Networks for the green supplier selection process. Matic et al. (2019) applied a new hybrid MCDM model: sustainable supplier selection in a construction company. Puska et al. (2018) proposed a new way of applying interval fuzzy logic in group decision making for supplier selection. Stevic et al. (2016) applied an integrated Fuzzy AHP and TOPSIS model for supplier evaluation. Sahin et al. (2020) applied Fuzzy TOPSIS method for Dry Bulk Carrier Selection. Jain et al. (2018) used Fuzzy TOPSIS and Fuzzy AHP to select suppliers in the Indian automotive industry.

This study fills a gap in the literature by choosing a supplier in the dairy industry with a large number of specified criteria. Although milk suppliers are similar due to their structure, there are differences among them, such as capacity, systematic work, technical structure, etc. Determining these different criteria made it easier for us to decide among suppliers. This study determines the suppliers by solving a very complex decision problem using the Fuzzy-TOPSIS method according to ten different criteria.

3. TOPSIS Method and Its Fuzzy Extension

In supplier selection problems, according to the characteristics of products, there can be differences between product types, which are procured by a supplier. For instance, some product types of a supplier can be more expensive when classed the products with similar types of product of other suppliers. If we give an example in the dairy industry, the supplied product is milk, and it can have more fat than other suppliers` milk. Thus worth of a supplier can change with reference to each product it supplies. Therefore, the significance worth of each supplier with regard to relevant product is determined via fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

The classical TOPSIS is developed by Hwang and Yoon in 1981 as an alternative method to the ELECTRE method. As mentioned previously, TOPSIS is one of the MCDM methods, and it is based on calculating the distance of alternatives from the positive ideal solution and the negative ideal solution by using Euclidean distance approach. Therefore in the TOPSIS method ideal solution should have shortest distance from the positive ideal solution and the farthest distance from the negative solution in the geometric sense. In this method, the alternatives are compared by identifying weights for each criterion, secondly normalizing scores for each criterion, and lastly, calculating the distance between each alternative and the ideal alternative, which is the best score in each criterion. The meaning of ideal alternative is related to criteria. For instance, considering the cost decision maker should take the lowest alternative whereas for profit, the decision-maker should choose the highest value as an ideal alternative. The terms used in the TOPSIS are briefly defined as follows:

Criteria: Criteria/Attributes $(C_j, j = 1, 2, \ldots, n)$ should provide a means of evaluating the levels of an objective. Each alternative can be characterized by a number of criteria.

Alternatives: As mentioned in MCDM alternatives are synonymous with 'options' or 'candidates'. Alternatives $(A_i, i = 1, \ldots, m)$ are different from each other.

Criteria weights: Weight values (w_j) show the relative importance of each criterion to the others.

$$W = \{w_j \mid j = 1, 2, \ldots, n\} \tag{1}$$

Normalization: The purpose of normalization is to gain comparable scales, which allows comparisons across criteria and it transforms various criterion dimensions into non-dimensional criteria. To calculate the normalized value of x_{ij}, the vector normalization approach divides the rating of each attribute by its norm. The equation of x_{ij}, is in below:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1,...,m; \; j = 1,...,n. \tag{2}$$

TOPSIS method is consisting of six steps, and within the presented steps, it is benefited from the study of Hwang and Yoon (1981) and Yang and Hung (2007).

Step 1: Calculate normalized rating for each element in the decision matrix using the normalization the equation.

Step2: Construct the weighted normalized ratings. The weighted normalized value v_{ij} is calculated by equation below:

$$v_{ij} = w_{ij} r_{ij}, \; i = 1,...,m; \; j = 1,...,n. \tag{3}$$

New matrix generated from the multiplication of the normalized decision matrix by its associated weight.

Step 3: Determine the positive ideal (A^*), and negative ideal (A^-) solutions.

The positive ideal solution equation is;

$$A^* = \{v_1^*, ..., v_n^*\}, \tag{4}$$

where

$$v_j^* = \left\{(\max_i \; v_{ij} \mid j \in B), (\min_i \; v_{ij} \mid j \in C) i = 1,...,m\right\}. \tag{5}$$

The negative ideal solution equation is;

$$A^- = \{v_1^-, ..., v_n^-\}, \tag{6}$$

where

$$v_j^- = \left\{(\min_i \; v_{ij} \mid j \in B), (\max_i \; v_{ij} \mid j \in C) i = 1,...,m\right\} \tag{7}$$

where B is a set of benefit attributes (larger-the-better type) and C is a set of cost attributes (smaller-the-better type).

Step 4: Calculate the distance measures for each alternative. The distance between alternatives can be measured by the n-dimensional Euclidean distance.

The separation from positive ideal solution, A^* is given by the equation as in follow,

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \; i = 1,...,m. \tag{8}$$

Similarly, the separation from the negative ideal solution, A^-, is given by the equation below,

$$S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, \; i = 1,\ldots,m. \tag{9}$$

Step 5: Calculate relative closeness to the ideal solution C_i^* ;

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \; i = 1,\ldots,m. \tag{10}$$

In this step, the important point is that $0 \le C_i^* \le 1$ where C_i^* =0 when $A_i = A^-$, and C_i^* =1 when $A_i = A^*$

Step 6: Rank preference order and according to preference rank order of C_i^* the best satisfied alternative can be decided. Therefore, the best alternative is the one that has the closest distance to the ideal solution, which means the ideal solution is guaranteed to have the farthest distance to the negative ideal solution.

Further from the classical TOPSIS method, uncertainty of the decision making environment is regarded by the fuzzy evaluations included in the fuzzy TOPSIS process.

Similar to the TOPSIS approach, in the fuzzy TOPSIS, an optimal alternative that is nearest to the Fuzzy Positive Ideal Solution (FPIS) and farthest from the Fuzzy Negative Ideal Solution (FNIS). A detailed description and treatment of fuzzy TOPSIS are discussed by many academicians (for instance, see: Yang and Hung (2007), Govindan et al. (2013), Saghafian and Hejazi (2005), Kilic(2012, 2013) and etc.) and we have adapted from Dymova et al., (2013) and Kilic (2013) the relevant steps of fuzzy TOPSIS as presented below.

The definitions of the related symbols used in the equations are as follows.

The definitions of the symbols

K: The number of decision-makers

i: Alternative

j: Criterion

$\tilde{x}_{ij}$: The rating of alternative "*i*" with respect to criterion j.

$\tilde{w}_j$: The importance of criterion *j*.

$\tilde{r}_{ij}$: Normalized triangular fuzzy number

$\tilde{R}_{ij}$: Matrix of normalized triangular fuzzy number

$\tilde{v}_{ij}$: Weighted normalized triangular fuzzy number

$\tilde{V}$: A matrix consisting of weighted normalized triangular fuzzy numbers

(a_{ij}, b_{ij}, c_{ij}) : The lower, middle and upper values in the triangular fuzzy numbers indicating the rating of alternative "*i*" with respect to criterion "*j*"

(w_{ij}, w_{ij}, w_{ij}): The lower, middle, and upper values in the triangular fuzzy numbers indicating the importance of criterion *j*.

Step 1: In this step, the importance of criteria and the alternative ratings with respect to the criteria are evaluated by the decision-makers. Each criterion is evaluated according to linguistic variables as shown in Table 1, and each alternative is rated via Table 2.

Step 2: Table 1. shows Linguistic Variables and Fuzzy Triangular Numbers for Criteria Evaluation. Table 2. shows Linguistic Variables and Fuzzy Triangular Numbers for Criteria Evaluation. Alternative ratings $\tilde{x}_{ij}$ and criteria importance $\tilde{w}_j$ are computed by multiplying each data with their own weights.

Table 1. Linguistic variables for criteria evaluation

Linguistic variable	Fuzzy Numbers
Very Low(VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Medium low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium high (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1)
Very high (VH)	(0.9,1,1)

Table 2. Linguistic variables for alternative ratings

Linguistic variable	Fuzzy Numbers
Very Poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium Poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium Good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very Good (VG)	(9,10,10)

Step 3: Normalizing the decision matrix.

An appropriate and method logically justified method for normalization of fuzzy decision matrices was developed in Chen (2000), and if $(\tilde{x}_{ij},\ i=1,2,\ldots,m,\ j=1,2,\ldots,\text{n},)$ are triangular fuzzy numbers, then the normalization process can be performed by:

$$\tilde{R}=[\tilde{r}_{ij}]_{mxn} \quad \Rightarrow \quad \tilde{r}_{ij}=(r_{ij}^{L},r_{ij}^{M},r_{ij}^{U})=\left(\frac{a_{ij}}{c_j^{+}},\frac{b_{ij}}{c_j^{+}},\frac{c_{ij}}{c_j^{+}}\right), \quad i=1,\ldots\text{m}; \quad j\in K_b \tag{11}$$

where

$$c_j^+ = \max_i (c_{ij}); \quad j \in K_{b,} \tag{12}$$

if the criterion is a cost, the following equation is taken into consideration:

$$\tilde{r}_{ij} = (r_{ij}^L, r_{ij}^M, r_{ij}^U) = \left(\frac{a_i^-}{c_{ij}}, \frac{a_i^-}{b_{ij}}, \frac{a_i^-}{a_{ij}} \right), \quad i = 1, \ldots \text{m}; \quad j \in K_c \tag{13}$$

where

$$a_j^- = \min_i (a_{ij}); \quad j \in K_c. \tag{14}$$

Because fuzzy set is in [0,1] range, this normalization provides that $\tilde{r}_{ij} \subset [0,1]$ for all *i* and *j.*

Step 4: The weighted normalized the fuzzy decision matrix is obtained. The definitions of the related symbols used in the equations are as follows.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn} \qquad i = 1,2,\ldots,m, \quad j = 1,2,\ldots,\text{n}, \tag{15}$$

$$\tilde{v}_{ij} = \tilde{r}_{ij}.\tilde{w}_j \tag{16}$$

Step 5: Definition of fuzzy positive ideal solution and fuzzy negative ideal solution values.

$$\tilde{A}^+ = \{\tilde{r}_1^+, \tilde{r}_2^+, \ldots, \tilde{r}_n^+\} = \{\max_i \{(r_{ij}^L, r_{ij}^M, r_{ij}^U)\} \mid j \in K_m, \min_i\{(r_{ij}^L, r_{ij}^M, r_{ij}^U)\} \mid j \in K_u\}, \tag{17}$$

$$\tilde{A}^- = \{\tilde{r}_1^-, \tilde{r}_2^-, \ldots, \tilde{r}_n^-\} = \{\min_i\{(r_{ij}^L, r_{ij}^M, r_{ij}^U)\} \mid j \in K_m, \max_i \{(r_{ij}^L, r_{ij}^M, r_{ij}^U)\} \mid j \in K_u\}. \tag{18}$$

Step 6: The distances of each alternative from fuzzy positive and negative ideal solutions are calculated using the vertex method as follows:

$$S_i^* = \sum_{j \epsilon K_m}^{n} w_j(\tilde{r}_j^+ - \tilde{r}_{ij}) + \sum_{j \epsilon K_u}^{n} w_j(\tilde{r}_{ij} - \tilde{r}_j^-), \qquad 19)$$

$$S_i^- = \sum_{j \epsilon K_m}^{n} w_j(\tilde{r}_{ij} - r_j^-) + \sum_{j \epsilon K_u}^{n} w_j(\tilde{r}_{ij} - \tilde{r}_j^+) i = 1,2,\ldots,m, \; j = 1,2,\ldots,n. \tag{20}$$

$$S_i^* = \sqrt{\tfrac{1}{3}[(\tilde{r}_n^+ - \tilde{r}_{11})^2 + (\tilde{r}_n^+ - \tilde{r}_{21})^2 + (\tilde{r}_n^+ - \tilde{r}_{31})^2]} \qquad 21)$$

$$S_i^- = \sqrt{\tfrac{1}{3}[(\tilde{r}_{11} - \tilde{r}_n^-)^2 + (\tilde{r}_{21} - \tilde{r}_n^-)^2 + (\tilde{r}_{31} - \tilde{r}_n^-)^2]} \tag{22}$$

Step 7: The fuzzy closeness coefficient CC_i is computed as shown in the equation below, and the highest result is selected as the best alternative.

$$CC_i = \frac{S_i^-}{S_i^* + S_i^-} \quad i = 1,2,\ldots,m. \tag{23}$$

4. Application of Fuzzy-TOPSIS Method in Dairy Industry

In this section, we will apply fuzzy TOPSIS method in the supplier selection problem in the dairy industry. Sütaş dairy company is a newly built factory in Macedonia. The company produces packaged and pasteurized milk, yogurt, ayran (yogurt drink), and other milk products. Therefore there needs to be a daily milk supply, and to be competitive in the sector, and the company wants to choose the right suppliers and increase its efficiency. For this purpose, fuzzy TOPSIS method will be used for the selection of suppliers.

Firstly we defined criteria with purchasing manager of the company, who is an expert on purchasing function, and decide to select suppliers. Selection criteria have been determined by studying other similar supplier selection problems, and taking into account the specific structure of the dairy industry. The criteria are taken into consideration while supplier selection and they are as follows:

1. *Price:* The price of raw milk when buying from farmers, and each farmer gives different values due to their local costs. However, the prices in every region of Macedonia are almost the same.
2. *Product:* It is raw milk which is bought from suppliers. Also, it shows an alteration according to regions.
3. *On time delivery:* The delivered time of raw milk to the company from the first farmers.
4. *Capacity of supply:* The capacity of raw milk which suppliers daily produce.
5. *Performance history:* Performance history of suppliers.
6. *Conflict problem solving capacity:* It defines farmers' ability to solve problems such as the sickness of animals.
7. *Location:* The region where the suppliers are present. This criterion is considering to region of the supplier where the quality product can be supply. (i.e., air pollution, industrial area, capacity of farming and etc.)
8. *Transportation cost:* The company is buying raw milk from different cities. Therefore it causes costs, and we took into consideration.
9. *Technological capability:* It is the power of using technology.
10. *Other costs: All costs except transportation cost.*

Table 3. The evaluation for criterion importance weight

Criterion	Evaluation
Cr1 (Price)	MH
Cr2 (Product)	VH
Cr3 (On time delivery)	H
Cr4 (Capacity of supply)	MH
Cr5 (Performance history)	ML
Cr6 (Conflict problem solving capacity)	M
Cr7 (Location)	M
Cr8 (Transportation)	ML
Cr9 (Technological capability)	M
Cr10 (Other costs)	VH

After defining criteria, they are evaluated by using linguistic terms. Fuzzy linguistic terms of importance weight of the criteria are shown in Table 3. Alternative suppliers are determined as cities. There are six supplier cities, and their names as Skopje, Bitola, Kumanovo, Prilep, Kocani, and Tetovo-Gostivar. Tetovo and Gostivar are presumed as one supplier. The linguistic values of alternatives related to criteria are presented in Table 4.

Table 4. The evaluation of decision-makers for alternative ratings

Suppliers	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8	Cr9	Cr10
SKOPJE	MG	MG	G	G	MG	G	F	VG	F	MG
PRILEP	G	F	MG	MG	MG	MG	G	F	F	F
KUMONOVO	VG	MG	F	MG	F	MG	MG	G	F	F
BITOLA	MG	MG	MG	VG	G	G	MG	MP	MG	F
KOCANI	VG	MG	MG	F	F	MG	G	MG	F	F
TETOVA-GOSTIVAR	MG	G	VG	VG	VG	G	G	G	G	F

The linguistic terms of criteria are converted to triangular fuzzy numbers, and they will be used as weights in Fuzzy TOPSIS algorithm. Fuzzified criteria can be seen in Table 5.

Table 5. Fuzzy Weights of Criteria

Criterion	weights
Price	(0.5,0.7,0.9)
Product	(0.9,1.0,1.0)
On time delivery	(0.7,0.9,1.0)
Capacity of supply	(0.5,0.7,0.9)
Performance history	(0.1,0.3,0.5)
Conflict problem solving capacity	(0.3,0.5,0.7)
Location	(0.3,0.5,0.7)
Transportation	(0.1,0.3,0.5)
Technological capability	(0.3,0.5,0.7)
Other Costs	(0.9,1.0,1.0)

To prepare a decision matrix, the linguistic terms of alternatives are defined as triangular fuzzy numbers, which can be seen in Table 6. In the decision matrix, there are three cost criteria as well as seven benefit criteria, and they should be comparable values. For this purpose, each benefit criteria set, the highest value is taken, and all the other values are divided by this highest value.

Table 6. Fuzzy decision matrix and fuzzy weights of criteria

	Cr1	Cr2	Cr3	Cr4	Cr5
SKOPJE	(5,7,9)	(5,7,9)	(7,9,10)	(7,9,10)	(5,7,9)
PRILEP	(7,9,10)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)
KUMONOVO	(9,10,10)	(5,7,9)	(3,5,7)	(5,7,9)	(3,5,7)
BITOLO	(5,7,9)	(5,7,9)	(5,7,9)	(9,10,10)	(7,9,10)
KOCANI	(9,10,10)	(5,7,9)	(5,7,9)	(3,5,7)	(3,5,7)
TETOVA-GV	(5,7,9)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)
Weight	(0.5,0.7,0.9)	(0.9,1.0,1.0)	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.1,0.3,0.5)

	Cr6	Cr7	Cr8	Cr9	Cr10
SKOPJE	(7,9,10)	(3,5,7)	(9,10,10)	(3,5,7)	(5,7,9)
PRILEP	(5,7,9)	(7,9,10)	(3,5,7)	(3,5,7)	(3,5,7)
KUMONOVO	(5,7,9)	(5,7,9)	(7,9,10)	(3,5,7)	(3,5,7)
BITOLO	(7,9,10)	(5,7,9)	(1,3,5)	(5,7,9)	(3,5,7)
KOCANI	(5,7,9)	(7,9,10)	(5,7,9)	(3,5,7)	(3,5,7)
TETOVA-GV	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(3,5,7)
Weight	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.9,1.0,1.0)

For the cost sets, the lowest value is selected, and it is divided by the rest values. As a result of those calculations, a normalized fuzzy decision matrix is obtained. It is shown in Table 7.

Table 7. Fuzzy normalized decision matrix

	Cr1	Cr2	Cr3	Cr4	Cr5
SKOPJE	(0.56,0,71,1)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.5,0.7,0.9)
PRILEP	(0.5,0,56,0,71)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
KUMONOVO	(0.5,0.5,0.56)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)
BITOLO	(0.56,0,71,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
KOCANI	(0.5,0.5,0.56)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
TETOVA-GV	(0.56,0,71,1)	(0.7,0.9,1)	(0.9,1.0,1.0)	(0.9,1.0,1.0)	(0.9,1.0,1.0)
	Cr6	Cr7	Cr8	Cr9	Cr10
SKOPJE	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.1,0.1,0.11,)	(0.3,0.5,0.7)	(0.33,0.429,0.6)
PRILEP	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.143,0.2,0.33)	(0.3,0.5,0.7)	(0.429,0.6,1)
KUMONOVO	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.10,0.11,0.143)	(0.3,0.5,0.7)	(0.429,0.6,1)
BITOLO	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.2,0.33,1)	(0.5,0.7,0.9)	(0.429,0.6,1)
KOCANI	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.11,0.143,0.2)	(0.3,0.5,0.7)	(0.429,0.6,1)
TETOVA-GV	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.10,0.11,0.143)	(0.7,0.9,1.0)	(0.429,0.6,1)

The next step is the fuzzy TOPSIS method is to determine the weighted normalized fuzzy decision matrix. In this step, the normalized decision matrix is multiplied by the importance weights of criteria, as shown in Table 8.

Table 8. Fuzzy weighted normalized decision matrix

	Cr1	Cr2	Cr3	Cr4	Cr5
SKOPJE	(0.28,0.497,0.9)	(0.45,0.7,0.9)	(0.49,0.81,1.0)	(0.35,0.63,0.9)	(0.05,0.21,0.45)
PRILEP	(0.25,0.392,0.639)	(0.27,0.5,0.7)	(0.35,0.63,0.9)	(0.25,0.49,0.81)	(0.05,0.21,0.45)
KUMONOVO	(0.25,0.35,0.504)	(0.45,0.7,0.9)	(0.21,0.45,0.7)	(0.25,0.49,0.81)	(0.03,0.15,0.35)
BITOLO	(0.28,0.497,0.9)	(0.45,0.7,0.9)	(0.35,0.63,0.9)	(0.35,0.63,0.9)	(0.07,0.27,0.5)
KOCANI	(0.25,0.35,0.504)	(0.45,0.7,0.9)	(0.35,0.63,0.9)	(0.15,0.35,0.63)	(0.03,0.15,0.35)
TETOVA-GV	(0.28,0.497,0.9)	(0.63.0.9,1.0)	(0.63,0.9,1.0)	(0.45,0.7,0.9)	(0.09,0.3,0.5)
	Cr6	Cr7	Cr8	Cr9	Cr10
SKOPJE	(0.21,0.45,0.7)	(0.09,0.25,0.49)	(0.01,0.03,0.055)	(0.09,0.25,0.49)	(0.297,0.429,0.6)
PRILEP	(0.15,0.35,0.63)	(0.21,0.45,0.7)	(0.0143,0.06,0.071)	(0.09,0.25,0.49)	(0.387,0.6,1)
KUMONOVO	(0.15,0.35,0.63)	(0.15,0.35,0.63)	(0.01,0.033,0.05)	(0.09,0.25,0.49)	(0.387,0.6,1)
BITOLO	(0.21,0.45,0.7)	(0.15,0.35,0.63)	(0.02,0.099,0.1)	(0.15,0.35,0.63)	(0.387,0.6,1)
KOCANI	(0.15,0.35,0.63)	(0.21,0.45,0.7)	(0.011,0.0429,0.055)	(0.09,0.25,0.49)	(0.387,0.6,1)
TETOVA-GV	(0.21,0.45,0.7)	(0.21,0.45,0.7)	(0.01,0.033,0.05)	(0.21,0.45,0.7)	(0.387,0.6,1)

After calculation of weighted normalized decision matrix, fuzzy positive ideal solution ($\tilde{A}^{+}$) and fuzzy negative ideal solution ($\tilde{A}^{-}$) are determined. For fuzzy positive ideal solution the highest value of each benefit criteria column and the lowest value of each cost criteria column are taken into consideration. The determination of fuzzy negative ideal solution has a reverse situation and the values shown as follows:

$$\tilde{A}^{*} = [(0.25,0.25,0.25),(1.0,1.0,1.0),(1.0,1.0,1.0),(0.9,0.9,0.9),(0.5,0.5,0.5),(0.7,0.7,0.7),(0.7,0.7,0.7),(0.01,0.01,0.01),(0.7,0.7,0.7),(0.297,0.297,0.297)]$$

$$\tilde{A}^{-} = [(0.9,0.9,0.9),(0.27,0.27,0.27),(0.21,0.21,0.21).(0.15,0.15,0.15),(0.03,0.03,0.03),(0.15,0.15,0.15,),(0.09,0.09,0.09),(0.1,0.1,0.1),(0.09,0.09,0.09),(1.0,1.0,1.0)]$$

To calculate each alternative's distance from fuzzy positive ideal solution and fuzzy negative ideal solution Vertex method is used. The results are shown in Table 9 and Table 10.

Table 9. The distances from positive ideal solutions

	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8	Cr9	Cr10
S^* (SKOPJE, A^*)	0.426	0.37	0.31	0.35	0.31	0.35	0.45	0.0284	0.45	0.191
S^* (PRILEP, A^*)	0.343	0.54	0.44	0.45	0.31	0.38	0.32	0.0456	0.45	0.445
S^* (KUMONOVO, A^*)	0.158	0.37	0.58	0.45	0.35	0.35	0.38	0.0266	0.45	0.445
S^* (BITOLO, A^*)	0.402	0.37	0.44	0.35	0.28	0.35	0.38	0.0733	0.38	0.445
S^* (KOCANI, A^*)	0.158	0.37	0.44	0.56	0.35	0.35	0.32	0.0322	0.45	0.445
S^* (TETOVA-GV, A^*)	0.402	0.22	0.22	0.28	0.26	0.43	0.32	0.0266	0.32	0.445

Table 10. The distances from and negative ideal solutions

	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8	Cr9	Cr10
S^* (SKOPJE, A^*)	0.427	0.45	0.22	0.53	0.26	0.36	0.25	0.0284	0.25	0.191
S^* (PRILEP, A^*)	0.5	0.28	0.24	0.43	0.26	0.3	0.41	0.0456	0.25	0.445
S^* (KUMONOVO, A^*)	0.542	0.45	0.32	0.43	0.2	0.3	0.35	0.0266	0.25	0.445
S^* (BITOLO, A^*)	0.427	0.45	0.24	0.53	0.31	0.36	0.35	0.0733	0.35	0.445
S^* (KOCANI, A^*)	0.542	0.45	0.24	0.3	0.2	0.3	0.41	0.0322	0.25	0.445
S^* (TETOVA-GV, A^*)	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8	Cr9	Cr10

Using the total distance from fuzzy positive ideal solution and fuzzy negative ideal solution fuzzy closeness coefficient CC_i is computed as shown in below.

Table 11. Closeness coefficient and their rankings

	S^*	S^-	CC_i	Rankıng
SKOPJE	2.8094	2.963	0.5133	2
PRILEP	3.3806	2.65	0.4394	6
KUMONOVO	3.4016	2.794	0.4509	4
BITOLO	3.0683	3.059	0.4992	3
KOCANI	3.3172	2.639	0.4430	5
TETOVA-GOSTIVAR	2.5216	3.354	0.5708	1

After calculation of closeness coefficient, they are ranked from large to small values as in shown Table 11. Regarding the coefficient values, the best supplier is Tetova-Gostivar.

5. Conclusion

The supplier selection process is one of the most important activities in the supply chain management. In today's competitive world, a company or any organization should have right supplier selection methodology to provide a sustainable system. However, it is known that available information regarding supplier selection problems is often uncertain and changeable. Also, decision making for supplier selection becomes quite complicated because rather than the classical methods, which only focus on cost and profit, the supplier selection process is consisting of a wide range of factors such as product, quality, on time delivery time, etc. Moreover, the supplier selection process is a kind of multi-criteria decision making problem. Therefore, companies or organizations should have a strategic approach to choose the right suppliers considering all reasons that we mentioned. Using fuzzy logic may help to overcome these problems while facing in the decision making process and as an extension of multi-criteria decision making methodology, fuzzy TOPSIS is proposed in this study. The main purpose of the TOPSIS algorithm is to find the best solution; in other words, which solution is the closest to positive ideal solution at the same time the farthest from negative ideal solution. By combining these two methodologies the fuzzy TOPSIS is applied to the supplier selection process to determine the most preferable choice among all possible alternatives. In this research, the proposed method showed the best supplier is Tetova-Gostivar cities. According to this result, the company may pay more attention and invest to there for built new plantation or farms. In the future, A hybrid MCDM model can be used to select suppliers.

References

Agarwal, P.,S., Mishra M., Bag, V., M., and Singh, V. (2011), "A Review Of Multi-Criteria Decision Making Techniques For Supplier Evaluation and Selection", *International Journal of Industrial Engineering Computations*, 2:801–810.

Akman G. ve Aklan A. (2006), "Measurement of Supplier Performance at Supply Chain Management by Using Fuzzy AHP Method: a Study at Automotive Subcontractor Industry", *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi,* 5(9), 23-46.

Benyoucef, L., Ding, H., Xie, X. (2003), "Supplier selection problem: Selection criteria and methods", *Theme 4- Simulation et optimisation de systemes complexes,* No: 4726, INRIA

Chen, C.T. (2000), Extensions of the TOPSIS for Group Decision Making under Fuzzy Environment, *Fuzzy Sets and Systems*, 114, 1-9.

Demiral, M., F. (2013), "A Case Study at Dairy Industry with Fuzzy Linear Programming". *Suleyman Demirel University Journal of Faculty of Economics & Administrative Sciences , Vol. 18 Issue 2,* 373-397.

Dickson, W., G. (1966), "An Analysis of Vendor Selection Systems and Decisions", *Journal of Purchasing*, 2(1), 5-17

Dymova L., Sevastjanov P., Tikhonenko A. (2013), "An approach to generalization of fuzzy TOPSIS method". *Information Sciences* 238 149–162 pp. 151-152.

Gegovska, T,. Koker, R. And Cakar, T. (2020), "Green Supplier Selection Using Fuzzy Multiple-Criteria Decision Making Methods and Artificial Neural Networks", Computational Intelligence and Neuroscience, Vol 2020, Number: 8811834.

Guan Z., Philpott A., B. (2011), "A Multistage Stochastic Programming Model for the New Zealand Dairy Industry", *International Journal of Production Economics* Volume 134, Issue 2, 289–299

Ho, W., XU, X., and Dey, P. (2010), "Multi-Criteria Decision Making Approaches For Supplier Evaluation and Selection: A Literature Review", *European Journal of Operational Research,* 202:16–24.

Holt, G. D. (1998), "Which Contractor Selection Methodology?" *International Journal of Project Management,* 16(3), 153-164.

Izadikhah, M. (2009), "Using the Hamming Distance to Extend TOPSIS in a Fuzzy Environment." *Journal of Computational and Applied Mathematics* 231, 200-207

Jain, V., Sangaiah A.K., Sakhuja, S., Thoduka, N. And Aggarwal, R. (2018) "Supplier Selection Using Fuzzy AHP and TOPSIS: a Case Study in The Indian Automotive Industry", Vol.29, 555-564.

Jouzdani J., Sadjadi S. J., Fathian M. (2013), "Dynamic Dairy Facility Location and Supply Chain Planning Under Traffic Congestion and Demand Uncertainty: A Case Study of Tehran", *Applied Mathematical Modelling* Volume 37, Issues 18–19, 8467–8483

Kilic, H., S. (2012), "Supplier Selection Application Based on a Fuzzy Multiple Criteria Decision Making Methodology". *Online Academic Journal of Information Technology Summer Vol: 3 Num: 8*

Kilic, H., S. (2013), "An integrated approach for supplier selection in multi-item/multi-supplier environment". *Applied Mathematical Modelling* 37 7752–7763

Markovic, V., Stajic L., Stevic, Z. et al. (2020), "A novel Integrated Subjective-Objective MCDM Model for Alternative Ranking in order to Achive Business Excellence and Sustainability", SYMMETRY-BASEL, Vol. 12, Issue 1.

Matic, B., Jovanovic, S., Dillip, K. et al. (2019), "A new Hybrid MCDM Model: Sustainable Supplier Selection in a Construction Company", SYMMETRY-BASEL, Vol. 11, Issue 3.

Narasimahn R. (1983), "An Analytical Approach to Supplier Selection", *Journal of Purchasing and Management,* 19(4), 27-32.

Pearn, W. L., Wu, C.W. and Lin, H. C. (2004), "Procedure for supplier selection based on Cpm applied to super twisted nematic liquid crystal display processes," *International Journal of Production Research*, vol. 42, no. 13, 2719–2734,

Puska, A., Kozarevic, S., Stevic Z. and Stovrag, J. (2018), "A New Way of Appliying Interval Fuzzy Logic in Group Decision Making for Supplier Selection", Economic Computation and Economic Cybernetics Studies and Research, Issue 2, Vol. 52.

Rouyendegh, D., Babak, S., Thomy, E. (2014), "Supplier Selectio Using Integrated TOPSIS and Multi-Choice Goal Programing: a Case Study" *Procedia - Social and Behavioral Sciences 116, 3957 – 3970*

Sachin K. P., and Kant, R. (2014). "A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers", *Expert Systems with Applications* 41, 679–693.

Saghafian S. and Hejazi S.R., (2005). "Multi-criteria Group Decision Making Using A Modified Fuzzy TOPSIS Procedure", *International Conference on Computational Intelligence for Modelling, Control and Automation, and International Conference on Intelligent Agents, Web Technologies and Internet Commerce* 0-7695-2504-0/05

Sahin, B., Yip, T.L., Tseng, P-H., Kabak, M. And Soylu, A. (2020), "An Application of a Fuzzy TOPSIS Multi-Criteria Decision Analysis Algorithm for Dry Bulk Carrier Selection", Information, 11, 251.

Stevic, Z., Tanackov, I., Vasiljevic, M., Novarlic, B. and Stojic, G. (2016) "An Integrated Fuzzy AHP and TOPSIS Model for Supplier Evaluation", Serbian Journal of Management 11 (1), 15 – 27.

Tayyar N. and Arslan, P. (2013), "Selection of the Best Sub-Contractor in Clothing Sector Using AHP and VIKOR Methods", *CBU Sosyal Bilimler Dergisi* vol. 11, no. 1.

Thiruchelvam, S. and Tookey, J. (2011), "Evolving Trends of Supplier Selection Criteria and Methods", *International Journal of Automotive and Mechanical Engineering*, 4:437-454.

Vinodh, S., R. Anesh Ramiya, and S. G. Gautham, (2011), "Application of Fuzzy Analytic Network Process for Supplier Selection in a Manufacturing Organisation." *Expert Systems with Applications* 38: 272–280.

Weber, C. A., Current, J. R. and Benton, W. C., (1991), "Vendor Selection Criteria and Methods", *European Journal of Operational Research*, 50 (1):2-18.

Yang, T. C., Hung, C. (2007). "Multiple-attribute decision making methods for plant layout design problem" *Robotics and Computer-Integrated Manufacturing* 23 126–137

Yue, Z. (2014), "TOPSIS-based Group Decision-Making Methodology in Intuitionistic Fuzzy Setting", *Information Science.*

Zavadkas, E.K., Pamucar, D., Stevic, Z. et al. (2020), "Multi-Criteria Decision Making Techniques for Improvement Sustainability Engineering Process", Symmetry, Vol. 11, Issue 6.

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 99-114
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta2040199l

OCCUPATIONAL HEALTH AND SAFETY PERFORMANCE IN HIGH-RISE BUILDING PROJECTS IN PAKISTAN: A SYSTEMATIC LITERATURE REVIEW

Muhammad Tarique Lakhiar [1]*, Muhammad Tahir Lakhiar [2], Abd Halid Abdullah [1]

[1] Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia
[2] School of Engineering, Monash University, Subang Jaya, Selangor, Malaysia

Received: 09 February 2021
Accepted: 08 March 2021
First online: 20 March 2021

Review Paper

Abstract: *The building industry contributed an impressive share in Pakistan's growth sector, where the construction industry contributes almost 2.74% of the GDP of Pakistan. In most metropolitan cities, the trend of building multi-story structures is at increase. However, this construction industry is a prominent accident-prone industry where laborers generally work in an unsafe environment. These projects suffer from fatal and non-fatal accidents as labor health and security are not a prime aim in the construction industry despite all employees still dealing with safety issues. This research examines the Occupational safety and health (OSH) performance in High-rise building projects in Pakistan. This review focuses on adopting qualitative approaches, using the comprehensive literature approach for seeking current practice in health and safety and OHS laws in Pakistan's building industry. Finally, it proposes a realistic strategy for developing a safe environment at workplaces. Research indicates that Pakistan's construction sector should consider workers' safety as a priority, update and enforce safety laws at the workplace to enrich OHS conditions in the Pakistani construction sector.*

Keywords: *building industry, accident prevention, safety culture, fall protection system, Pakistan engineering council*

1. Introduction

Pakistan is considered one of the underdeveloped countries that have recently undergone instant development in building activities throughout the past decade, with almost 3 million laborers working in the building industry. However, building industry employees constitute 7.6% of the total workforce, whereas Construction

* Corresponding author
mtarique181@gmail.com (M. Tarique Lakhiar), mtl.eng17@gmail.come-mail (M. Tahir Lakhiar), abdhalid@uthm.edu.my (A. Halid Abdullah)

fatal and non-fatal accidents account for 17.3% of the entire crew (Pakistan Bureau of Statistics, 2018). Even with these frightening figures, few or no strenuous efforts are expended by government authorities or private agencies to improve Pakistani construction workers' safety conditions (Raheem and Hinze, 2012). Similarly, the majority of the opposing under-developing countries, around numerous hurdles and threats that Pakistan is experiencing to elevate and execute legislative system in the building sector. The existing safety acts in Pakistan are not exclusive to the building sector. They are accomplished by The Factories Act of 1934, the Workmen's Compensation Act of 1923, and the Minimum Wage Ordinance of 1961. These laws mainly deal with the work-related safety and health complications of industrial personnel.

Moreover, the health and safety clauses are generally made as part of contract documents in the Pakistan building industry. Still, they are commonly not imposed in reality because of carelessness and illiteracy amongst the workforces for their privileges, ensuing in inferior safety execution (Zahoor et al. 2016. Pakistan Bureau of Statistics (2018) has reported that about 36.6 % 36.7% of the whole manpower is utilized in the service sector (which includes the construction sector) (Figure. 1a), the construction sector of Pakistan is positioned third amongst the entire economic sectors and 1st amongst the service sectors relative to the share of reported occupational injuries/diseases (Figure. 1b). the governing authority is generally exhausted in executing the laws efficiently in underdeveloped countries like Pakistan.

Work dangers are not identified and either observed with not as much hazardous (Larcher and Sohail, 1999). Most underdeveloped countries have executed several safety regulating systems to minimize the frequency of accidents. The Governing organizations like OSHA in the USA and Hong Kong labor department are persistently endeavoring to attain 0 % of causality rate (Choudhry et al. 2009). Likewise, several safety encouragement plans are often publicized to lessen the frequency of accidents (Choudhry et al. 2008). In contrast, safety is not much properly considered in under-developing countries, such as Pakistan. Accident statistics are neither maintained nor regularly reported to the Government department (Raheem and Issa, 2016). Safety rules barely exist, the regulatory authority is mostly ineffective, and work hazards are not assessed accurately (Ali, 2006). The Pakistan Engineering Council (PEC), which is that the principal controlling agency for Construction in Pakistan, has not set detailed guidelines and safety regulations for the industry. Moreover, a major difference is observed between big and small contractors against their safety performance. Only the large firms have safety policies, conduct safety training, and appoint safety staff on their job sites (Raheem and Hinze, 2013).

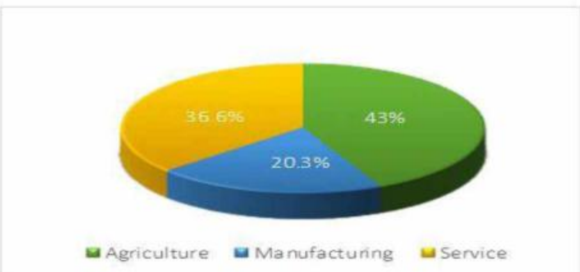


Figure 1a. Distribution of total labor force

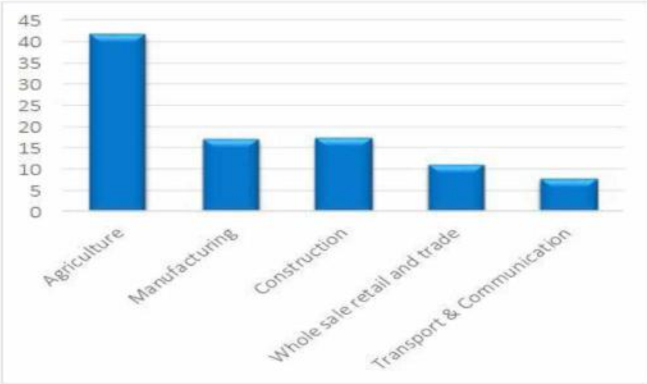


Figure 1b. Accidents relative to reported injuries/diseases

The construction workers usually face serious threats and safety issues while building high-rise structures. Building laborers are usually more subjected to falling, plant movement, heavy machinery, electroshock, and loud noises. The factors time, cost, and quality are often the key factors perceived to be ahead of safety. Health problems are still considered subordinate and take a back seat on the building site. Many organizations have not developed robust accident management plans but instead focusing on optimizing income. (Choudhry et al. 2008). Thus, laborers are more liable to face numerous hazards, such as harsh weather conditions and safety problems at high altitudes (dropping from elevation, colliding with items at workplace). These may be the reason for serious work-related wounds among building workers throughout the globe. Most building incidents happened due to a fall from a height, accompanied by electrocution and shifting activities (Zahoor et al. 2016). Lack of personal protective equipment (PPE), ineffective training, unrealistic construction time, and missing appropriate anchoring points are the main causes of falls from height at construction sites (Choudhry et al., 2014). In the last seven years, no noteworthy reduction in injury rate has been detected, as the injury rate remained nearly constant at over 14% (Pakistan Bureau of Statistics, 2018). Most occupational incidents in the Pakistani building industry are due to falls from a height, accompanied by uplifting activity, electric shocks, and hit by objects (Choudhry et al. 2014). However, building projects are still suffering from casualties even with the following safety criteria, mostly due to falling from height and electrocution (Choudhry et al. 2014). Whereas falling from height is the main cause of incidents that happen in the construction of tall buildings (Hassan, 2012). The main causes for safety non-compliance are generally summarized as; desire for earning more profit, misinterpretation that putting investment on safety raises the project budget, absence of a controlling authority, labors' unawareness, poor governing system, lack of safety training, and shortage of safety equipment's, political influence, and meeting deadlines (Farooqui, 2012).

2. Literature review

This study adopted a qualitative approach to analyze workplace safety and health performance in high-rise construction in Pakistan. It exposes the facts without tossing the information away. This study focused on a thorough analysis of the literature relating to workplace protection and health in high-scale Pakistan and their potential applications to improve occupational health and safety standards in the Pakistani buildings industry. It was intended to sum up the latest occupational safety and health efficiency of high-rise buildings in Pakistan and to review prevailing OHS laws and regulations and their application in the sector.

For a paper retrieval of the OHS performance in Pakistan, a systemic method involving three steps, as seen in Figure 2, has been adopted. A systematic desktop search was performed in Scopus under the 'article title/abstract/keyword' search area. The keywords for the search were safety culture, safety practices, construction safety, OHS, Pakistan. Their title/abstract /keyword section was deliberately picked to be for further review with these particular words. Other databases were also explored to access the relevant articles, such as Google, Scholar Science Direct, EBSCO, Scopus, Web of Science, and Google. In short, the best source for looking for the conference papers and proceedings was Google. A further step was to search the proceedings using the same search engines for 14 Global OSH conferences. For the next step, profiles were investigated in Research Gate, Academia, and Google Scholar to find out scholars who are intensively interested in OHS research in Pakistan. Consequently, the Snowball technique was eventually used for the finding of the corresponding articles by reviewing the reference portion of all the articles found. The papers that could not be downloaded were accessed via e-mail from the researchers.

Figure 2. Research methodology

2.1. Nature of the Construction Industry in Pakistan

Underdeveloped countries should focus on executing safety, health, and environmental management systems in the building industry to carry projects deprived of injuries and scale back worksite dangers. In developing countries, like Pakistan, the safety regulation hardly exists; and most of the laws are not suitable for building industry, and those laws are unsatisfactory, inefficient, or outdated. Generally, the administrative body is weak in imposing safety laws efficiently, and site hazards are either not evaluated at all or observed that these job risks are tolerable to worker safety (Ali, 2006). Various building firms across the globe are executing health, safety, and environmental management systems to prevent damages, eradicate illness, and offer a harmless work atmosphere on building projects. On the other hand, there is no legislative safety system in Pakistan to impose safety in the building industry without having any particular governing authority for OHS management, likewise OSHA in the USA (Choudhry et al. 2008). As the only regulatory body, the Pakistan Engineering Council (PEC) has yet to enforce health standards to be followed by construction stakeholders (Farooqui et al., 2007). However, PEC doesn't have the power and administrative authority to establish and enforce safety-related legislation. The majority of clients seek fast speed and high efficiency of building work in the region at the lowest feasible expense, and the project budgets do not specifically contain protection funds (Farooqui, 2012). The health efficiency of large and small contractors also varies considerably. Many of the major firms listed with the PEC in category C-A have detailed safety policies that offer some form of training to staff that retain safety personnel in their workplaces. Contrary to that, small firms usually do not have protection on their agenda, and there are dangerous environments on many building sites, and often injuries and fatalities occur to staff (Choudhry et al. 2008a). However, at different work sites of contractors, training programs for the safety of laborers haven't been introduced yet, no safety-related training conducted for entirely new workers, work-related risks never identified, and never called and conducted any safety meetings. Furthermore, the absence of immediate availability of medical services, inferior housekeeping, and unhygienic conditions tend to exist on isolated projects. Although safety clauses are included in contract documents, they are not strictly implemented. Likewise, construction firms are mostly failed to prescribe these clauses due to the non-existence of the regulatory authorities. PEC also organizes safety education seminars and obligatory short courses on continuing professional development (CPD), which are only available for engineers. However, no instruction for construction managers and staff are offered (Choudhry and Zahoor, 2016). The kind of work conducted at worksites in Pakistan are labor-intensive and relies entirely on the mostly nonprofessional and non-qualified workers, which usually poses an enormous risk of special damages (Farooqui et al. 2007a). Underdeveloped countries such as Pakistan are witnessing serious potential accidents due to intense work and rely heavily on professional and unskilled staff from diverse educational backgrounds. Similarly, the bulk of accidents in the Pakistani building industry are attributed to falls from height and a few more to lifts, electric shocks, and Safety training is the most neglected aspect in the construction industry. (Choudhry and Zahoor, 2016). Generally, laborers and managers have different opinions about accident reporting mechanisms. As explained by Masood et al. (2012), any accident that happened at the site is reported from the perspective of managers. Still, laborers possess a different belief and commonly not in agreement with the managers. Likewise, stakeholders are only concerned with productivity, while safety is not given much preference. Significant health and safety disparities among developing and under-developed nations contain inexistence, inadequate compliance, weak risk management, and lack of OHS awareness programs and safety regulations (Zahoor et al., 2017). This worsening condition contributes to serious worksite injuries and a significant shortage of site staff, reduced work morale, delays in building progress, and disputes between stakeholders (Haseeb et al. 2011). Building work is the country's riskiest task because it entails wounding and death on sites in Pakistan.

2.2. Status of Occupational Safety in the construction industry

In underdeveloped nations, health at work remains overlooked due to overlapping social, economic, and political problems. Following worldwide progress on OS&H problems, around 2.3 million deaths from workplace injuries and work-related disease are reported, 317 million suffer serious disabilities, and 160 million become sick, most of whom in less developing countries belong to rural regions (Azhar et al. 2015). Employees in less-developed nations have often had a large chance of injury/disease in jobs because of bad working standards and social security. In remote regions in less developed nations, the condition is much worse because of insufficient health care services. For less-developed nations, workplace injuries/diseases are a major expense to the national social insurance program (Rundmo and Hale, 2003). due to poor health safety infrastructure. Work accidents are the primary causes of an economic downturn (Brown, 2003). The ILO reports that the overall burden of work accidents and illnesses constitutes 4 percent of the national GDP on average (International Labor Organization, 2009). Proper social insurance programs are not integrated into less-developed countries, especially rural ones, and there is a reality of constraints and low-quality information; hence a standard data study is useful in assessing the efficiency of the country's occupational health safety systems (Smith, 2001). Moreover, in the least developed countries where workers are involved in dangerous jobs, mainly in agriculture, construction, fishing, and mining, work-related damage and death are greater (International Labor Organization, 2013). Social safety at low levels faces a high risk for adverse occupational exposure. According to the Pakistan Economic Survey 2013-14, Pakistan is the 10th largest country in the world in terms of the labor force, and its rural population accounts for 67.5% of the total population involved in agriculture activities (Pakistan Bureau of Statistics, 2014). Workers' health and safety in Pakistan are miserable due to several causes, for instance, inadequate healthcare services, Lack of relevant OHS regulations, and uneducated workers. Evidently, in Pakistan, no institutional program is in place to monitor incidents and causes associated with jobs. There is also a lack of obtainable statistics, meaning that most accidents are not reported to the Labor Department. OHS is not the country's highest priority because of a shortage of funding and the lack of technical skills. At the provincial level, the Saeed Ahmed Awan Centre for the development of Working Conditions & Environment and the Directorate General of Labor Welfare of Punjab province is responsible for offering medical and technical expertise for employee safety. Punjab recently revealed the first labor policy (Dawn News, 2015), and Baluchistan established an agreement on labor law and industrial reform (International Labor Organization, 2015). In addition, since the independence of Pakistan in 1947, the ILO has been collaborating with the government of Pakistan to resolve issues at work, workers' rights, and raise labor conditions. Pakistan has signed 36 ILO conventions, with eight of them were main agreements. Since thousands of employees are subjected daily to hazardous chemical compounds, Pakistan has a high prevalence of workplace diseases and injuries. Most workers are not aware of the distinction between preventive measures during their jobs. The majority of the workforce is not trained to cope with the threats presented by manufacturing and production processes. There are no clear safety laws for various industries throughout the country to cope with employees' health and security problems. The nation needs essential facilities and professional staff to provide OHS workforce services. A significant number of employees would also be in danger if possible; efforts to strengthen the OSH management are not made (Ahasan, 2001).

2.3. Causes and Effects of Occupational Accidents in the Construction Industry

Every year 3.7% of the labor in Pakistan undergo occupational injuries/diseases that result in the loss of working time (Pakistan Bureau of Statistics, 2008). Although its literacy rate of only 57.7 percent is reasonably acceptable, Pakistan is considered a country that lacks a security culture, mainly attributed to a lack of effective legislation (Farooqui, 2012). Most building industry injuries are caused by height dropping (Zahoor et al. 2016). The key causes of such incidents involve failure for fall security and sufficient anchorages on construction sites, insufficient preparation, excessive building time, and health ignorance among the workers (Choudhry et al., 2014). Drop from the top is the main cause of injuries, whilst other causes include electrical action, trapped between machines and objects (Nawaz et al. 2013). The ignored safety measures that trigger accidents in high-rise buildings are recognized as having no ear defenders, no boots, and no face masks if needed (Farooqui et al. 2008). The lack of coordination and comport ability, safety knowledge, consumer engagement, and health legislation are responsible for safety non-compliance (Khan, 2013). Significant reasons for safety violation are summed up: misunderstanding of the fact that safety improvements raise the costs of the project, ineffective regulatory bodies, political interference, unreasonable timelines, overtime, health ignorance, and lack of collaboration among employees (Raheem et al. 2011). Untrained employees and a higher unemployment rate are potential sources of injuries. These incidents lead to higher building costs, such as charging for the jobs of extra workers, temporary stoppages, and delays in time (Jafri, 2012). Moreover, accidents have adverse impacts on the morality of employees.

2.4. Safety Culture in the Construction industry of Pakistan

Safety culture (SC) is well-defined as the safety expectations, standards, and customs shared by the followers of an industry. It can be explicated that these fundamental values and standards that distress the performance of individuals in industries. Present pieces of training in management establishes that there is an intensifying acknowledgment of the effect of SC on variation execution accomplishment. For the disintegrated existence of the regulatory atmosphere and the erraticism of safety perception, the construction industry in Pakistan hasn't been able to develop a sound safety culture (Raheem et al., 2012). Though stakeholders/owners in the building industry in Pakistan are generally aware of protection objectives and their value to the sector, they do not have engagement, collaboration, experience, and knowledge of instruments to enforce the safety culture in their projects (Farooqui et al. 2008). Formal safety management practices between stakeholders/owners are rare, and thus incidents leading to loss of production, delays in development, and cost overruns occur in projects. It has also been concluded that, because of a lack of dedication and institutional processes, the managers, partners, and investors in the Pakistan building industry are not able enough to sustain a secure project. The key challenges encountered by contractors in introducing and enhancing protection are – in descending order of importance – the lack of the following: staff collaboration and behavior, experience and competence with protection management strategies, safety understanding and knowledge, owner involvement, and a safety regulatory system (Farooqui et al. 2008).

2.5. OHS training institutes in Pakistan

The Saeed Ahmed Awan Centre for Improvement of Working Conditions and Environment' in Lahore city of Punjab province; In Pakistan, it is a leading center offering professional services in the areas of OHS and the workplace environment founded by the Labour & Human Resource Department, Government of the Punjab, Pakistan. Several private institutes provide OHS training facilities on a commercial basis in Pakistan:

1. Pakistan Institute of Management (PIM) has established its offices in Karachi, Lahore, Islamabad, and Quetta. It is awarding diploma certificates of OSH after four months of training.

2. Pakistan Safety Institute (PSI) is a Karachi-based commercial organization providing training, auditing, and consulting services in the field of health and safety, fire safety, and construction safety.

3. Occupational Safety and Loss Prevention (OSALP) is a Lahore-based commercial organization, providing training in the fields of quality assurance, health, safety, security, and environment.

4. Safety Trends International (STI) is a Karachi-based private institute providing NEBOSH and IOSH training.

5. DESCON, a well renowned Lahore and Karachi based company, is providing OSH training to its employees at its DESCON Technical Institute (DTI). They also provide training on a commercial basis.

6. Occupational Training Institute (OTI) is based in Lahore and providing OSH training on a commercial basis.

7. Vivid Institute of Occupational Safety and Health (VIOSH) has its training offices in eight cities of Pakistan. It provides OSH training courses like OSHA, IOSH, NEBOSH, particularly in the construction and petroleum sectors.

8. Horizon Institute of Occupational Safety and Health (HIOSH) has established its branches in Lahore, Rawalpindi, Attock and Peshawar. It is providing training for IOSH and NEBOSH certifications.

9. Center of Risk, Safety, Health and Environment (CORE) is a Karachi based institute, providing training for NEBOSH International General Certification and for IOSH Managing Safely and IOSH Working Safely certifications.

In fact, as explained above, a variety of private companies offer OHS trainings on a commercial basis. This is essential to remember that construction employees are not strictly required to undergo any health training at workplaces because they are allowed to work on building projects without any health certification. Therefore, only construction workers who prepare for an overseas job are involved in receiving a safety training program.

3. Development of construction health and safety guidelines

Presently, Pakistan construction industry has not had any proper Occupational health and safety laws. Even though several OHS laws such as Workmen's Compensation Act 1923, Factories Act 1934, and Minimum Wage Ordinance, 1961 are established, they were basically applicable for over-all industries and do not specifically fulfil the criteria of safety compliance in the building industry. Therefore, a prominent need to modify the Factories Act 1934 or to generate completely advance safety legislation. Moreover, to improve the construction safety culture in the construction industry, current safety regulations, and safety performance, the Higher Education Commission of Pakistan collaborated with Department of State, USA under Pakistan-US Science and Technology Cooperation Program funded a capacity building project. The purpose of this project was to set up a knowledge-based Centre. The Construction Management and Safety Research Centre (CMSRC) was instituted at National University of Sciences and Technology (NUST) in 2012 to step up and encourage safety research in Construction, training and education to enrich safety rules and policies in building industry by engaging academia, public organizations, industry, regulatory agencies, and the regulatory bodies. The project team has submitted a request to the Ministry of Education, Training and Standards for Higher Education to set up the "Pakistan Occupational Safety and Health Agency (POSHA)". One of the functions of this department is to gather data on health and safety results on an annual basis. The plan is currently being reviewed by the appropriate department (Azhar et al. 2012).

4. Construction health and safety education and training

For the achievement of occupational health and safety programmes, successful OHS training is necessary as it enhances behavioral skills, associated information, and or attitudes and stimulates accident forecasting, particularly for new employees. To increase workplace OHS efficiency both at the level of the worker and the organization, management should develop a regular, rigorous health and safety curriculum for new workers and provide an instructor for them (Vredenburgh, 2002). Memon et al. (2013) suggest that management support, teamwork, effective supervision, safety education and training, regular safety meetings, effective communication, and setting realistic goals can effectively enhance the safety performance. Hassan (2012) suggests that the safety situation can be improved by the effective enforcement of OHS laws, incorporating safety credit points in the contractors' licensing, appointing safety inspectors for site monitoring, allocating sufficient safety budget, providing personal protective equipment (PPE), and effective safety training. While conducting surveys with three different questionnaires for the managers, workers and national culture, Mohamed et al. (2009) established a link between national culture and safety behavior (Mohamed et al. 2009). In addition, it has been suggested to use wireless sensors for intelligent real-time monitoring of workers in the confined spaces (Riaz et al. 2014). Raheem and Issa (2016) emphasize to incorporate more specific safety clauses in the contract documents and include safety plan as a mandatory part of the bidding process. They suggest starting with the safety induction training for all the workers, supervisors and managerial staff.

4.1. Accident reporting and investigation

Through background facts, injuries are caused by horrific incidents: machinery failures, unsafe working techniques, and poor maintenance. Updating people about such unpleasant incident would be useful in identifying reasons for minimizing the possibility of such incidence. To accomplish this aim, almost all misses, fatal and non-fatal accidents must be documented, it does not matter how minor they might appear. The accidents reporting phenomenon varies from company to company, as the procedures vary, so all information would be provided to administrators quickly so that the Incidents could be further investigated (Fahad et al. 2019). The effective method to track accidents is by a particular method of reporting. The method must provide a well-defined summary of incident, persons and work included, damages received, healthcare services given, and of the evidence provided if there is also, if possible, photos of the concerned region should also be added. Consequently, at every building site, it should always be demanded and assessed to maintain an injury record at the site where all forms of minor accidents including such cuts, damaging incidents such as attributing disabilities and fatalities has to be included and evaluated by the safety official (Fahad et al. 2019). Fortunately, the reporting of an injury is not sufficient to mitigate the chances of recurrence, and it must be determined as quickly as possible after an accident has been reported. The investigation process should be carefully examined to include all facets and concerns that have arisen in order to determine the root causes of incidents.

4.2. Temporary platform structure

Scaffolding is a temporary framework used in the design, renovation, and reconstruction of homes, bridges, and all other manmade structures to sustain a work team and materials. Scaffolding is a vital trade in the Construction of buildings by offering platforms that allow workers to maintain their job at a high altitude. Drop hazards are the leading cause of workplace accidents, responsible for almost half a year of all construction accidents. OSHA, (2002) reports that about 65 percent of contractors work on scaffolds each year. This could lead to hazardous conditions for construction staff and projects around the world without knowledge of the dangers of scaffolding. Get professionally qualified to recognize electrocution, fall, and dropping objects and techniques for treating these hazards when using a scaffold. The proper use of the scaffold must also be included in the training, how to handle materials, and the load capacity of the scaffold. Once you can use the scaffold, make sure that the qualified individual inspects the scaffold so that it is in good working order. When working on scaffolds, always use a sturdy, durable, non-skid work pair of boots and lanyard. If the scaffold is used inappropriately, please inform the supervisor straight away. Connect the machine to a secure level, which does not permit more than six feet of free fall before stopping (OSHA, 2002).

4.3. Personal protective equipment (PPE)

It is very necessary to wear PPE for workplace safety and for further various security reasons. It is designed for the defense of the body from disruptive impacts, electric threats, heating, and chemical agents for the wearer's whereas, wearer's apparel, masks, gloves, or other devices are produced to shield the body from injury. Personal protective equipment (PPE) is needed by the Occupational Safety and Health Administration (OSHA) in the United States to mitigate worker risks and hazards where engineering and administrative controls are inadequate to minimize such exposures to the required standard (OSHA, 2006). In addition, the building firm must define the statutory conditions for PPE in the construction sites and safety policy. The OHS manager will regularly review the needed volume of PPE on the job. OHS officials will perform routine checks for faulty PPE that are not in usage by staff. For review, replacement, and follow-up activities for the PPE, a checklist should be created. PPE used by all laborers of subcontractors must be checked and must meet the prime contractor's relevant requirements.

4.4. Fall protection system

Generally, workers would choose the fall safety systems that are more consistent with the job type. Flying objects are common at building sites as workers use power equipment or perform activities that include pressing, dragging, or prying (Keng and Razak, 2014). Then researchers like Hamid, Majid, and Singh (2008) reaffirmed that the most frequent form of the building site incident is caused by falling from a height or dropping objects. Incidents involving falling or flying objects may expose staff to minor injuries, like cuts and abrasions, and, rarely, even more, severe injuries, including concussions or blindness. More risks may be taken in accidents caused by falling items, particularly for workers who work under scaffolds or other places. In another study, the U.S. Department of Labor (DOL) reports falling as one of the main causes of traumatic workplace mortality, responsible for 8 percent of all trauma-related workplace deaths. For a fact, if a worker is 4 feet or taller, the worker would be at risk and will be secured. As a result, DOSH (2007) emphasized that fall protection equipment must be used and applied anywhere an individual would be at risk of falling by 2 meters.

5. Improving the existing regulatory infrastructure for worker health and safety

While construction activities have risen in the last decade, the Pakistani building industry is suffering largely because of the absence of a viable legislative framework due to unsafe working conditions. Owing to the delicate existence of the regulatory structure, temperamental and weak morale have become norms for the construction industry (Ali, 2006). The behavior of labor at the workplace reveals a significant challenge to the compliance of safety laws in Pakistan. Therefore, corporate control has marginal consequences, and the government pays no attention to health. Nawaz et al. (2013) recommend reformulating and implementing safety laws and by-laws, disseminating safety awareness, determining an accident reporting mechanism, and ensuring the provision of safety training as well as PPE to all the workers. In this connection, draft regulations to improve the existing health and safety legislative framework are submitted by Azhar and Choudhry (2016) to PEC for approval and implementation (Azhar and Choudhry, 2016). In order to improve safety standard in the building industry, researchers have recommended the PEC to: modify the contract documents, allocate explicit safety budget at the time of bidding, giving due weightage to safety performance in the processes of contractor licensing and renewal along with the professional credit points, and employ safety professionals on all the projects (Raheem and Hinze, 2013). In addition, the development of a database is emphasized to record the number of injuries/fatalities against the completed and ongoing construction projects at the industry level (Sheikh and Ali, 2013).

6. Conclusion

This paper addressed problems relating to the study of workplace safety and health performance in the construction of high-rise buildings in Pakistan. Furthermore, the difference in safety culture development in western nations and strategies and methods of encouraging the health and safety of buildings is also addressed. In order to minimize the occupational risk, a comprehensive analysis of the literature indicates that safety implementation in the construction sector of Pakistan should be considered. To ensure the OHS in Pakistan's construction industry, attempts must be made by both parties (Government and Entrepreneurs) to upgrade the working environment and to minimize risks for construction workers. Building safety and health research are in the development stage in Pakistan. There are also numerous articles that have been published in the area of OHS in Pakistan. It promises that several conferences are held annually to completely recognize and upgrade conditions in the construction sector; nonetheless, it is incredibly hard to obtain online details on these conferences. This situation makes it very hard for researchers to determine and understand working environments and recommend additional changes. This article is an attempt to examine and recognize Pakistan's health and safety practices. Study results show that construction companies are hesitant to disclose occupational incident-related records, aside from not showing and reporting workplace regulations that further jeopardize worker health and safety. Therefore, the selection criteria of PEC Contractors is based exclusively on financial potential, not success in health and safety. While in its legal contracts, PEC has incorporated safety clauses, due to the lack of administrative authorization, these are not enforced. To create alertness among its staff, PEC is also arranging CPD webinars and seminars; however, training of workers is not taken into account. Consequently, the following steps are recommended to PEC to increase OHS Knowledge at construction workplaces, thus PEC must launch safety awareness campaigns; set up regulating authority; develop clients' procurement and records of bids on the allocation of safety allowances; incorporate safety credit points into the evaluation criteria of the contractors, and establish a realistic system for reporting and investigating incidents.

References

Ahasan, M. R., & Partanen, T. (2001). Occupational health and safety in the least developed countries-a simple case of neglect. *Journal of Epidemiology, 11*(2), 74-80.

Ali, T. H. (2006). Influence of national culture on construction safety climate in Pakistan, PhD dissertation, School of Engineering and Built Environment, Griffith University, South East Queensland.

Azhar, N., Kang, Y., & Ahmad, I. (2015). Critical look into the relationship between information and communication technology and integrated project delivery in public sector construction. *Journal of Management in Engineering, 31(*5), 04014091.

Azhar, S., Behringer, A., Sattineni, A., & Mqsood, T. (2012). BIM for facilitating construction safety planning and management at jobsites. *Proceedings of the CIB-W099 international conference:* modelling and building safety, Singapore. pp. 10-11.

Azhar, Salman, and Rafiq M. Choudhry. (2016). Capacity building in construction health and safety research, education, and practice in Pakistan. *Built Environment Project and Asset Management.*

Brown, G. D. (2003). China's factory floors: an industrial hygienist's view. *International Journal of occupational and environmental health, 9*(4), 326-346, 2003.

Choudhry, R. M., & Zahoor, H. (2016). Strengths and weaknesses of safety practices to improve safety performance in construction projects in Pakistan. *Journal of Professional Issues in Engineering Education and Practice, 142*(4), 04016011.

Choudhry, R. M., Fang, D., & Ahmed, S. M. (2008). Safety management in Construction: Best practices in Hong Kong. *Journal of professional issues in engineering education and practice, 134*(1), 20-32.

Choudhry, R. M., Fang, D., & Lingard, H. (2009). Measuring safety climate of a construction company. *Journal of Construction Engineering and Management, 135*(9), 890-899.

Choudhry, R. M., Fang, D., & Rowlinson, S. (2008). Challenging and enforcing safety management in developing countries: A strategy. *International Journal of Construction Management, 8(*1), 87-101.

Choudhry, R. M., Tariq, B., and Gabriel, H. F. (2014). Investigation of fall protection practices in the construction industry of Pakistan. *CIB W099 International Health and Safety Conference, Achieving Sustainable Construction Health and Safety*, 2-3 June, Lund, Sweden, 211–220.

Dawn News. Punjab labour policy today. (2015). http://www.dawn.com/news/1179280/ Accessed 19 December 2020.

Farooqui, R. U. (2012). An exploratory study probing into the factors causing safety non-performance in the Pakistani construction industry. 45th Institute of Engineers Convention, Pakistan, 1–12.

Farooqui, R. U. (2012). An exploratory study probing into the factors causing safety non-performance in the Pakistani construction industry. *45th Institute of Engineers Convention, Pakistan*, 1–12.

Farooqui, R. U., Ahmed, S. M., & Saleem, F. (2007). Analysis of workplace injuries among Hispanic construction workers due to safety hazards. In Fifth *LACCEI International Latin American and Caribbean Conference for Engineering and Technology.* Developing Entrepreneurial Engineers for the Sustainable Growth of Latin America and the Caribbean: Education, Innovation, Technology and Practice Vol. 29.

Farooqui, R. U., Ahmed, S. M., and Lodi, S. H. (2008). Assessment of Pakistani Construction industry-current performance and the way forward. Journal for the Advancement of Performance Information and Value, 1(1), 51-72, 2008.

Farooqui, R. U., Ahmed, S. M., and Panthi, K. (2007). Developing safety culture in Pakistani construction industry—An assessment of perceptions and practices among construction contractors. Proc., 4th Int: *Conf on Construction in the 21st Century:*

Accelerating Innovation in Engineering, Management and Technology (CITC-IV), Griffith Univ., Gold Coast Campus, QLD, Australia, 420–437.

Farooqui, R. U., Saqib, M., & Ahmed, S. M. (2008). Assessment of critical skills for project managers in Pakistani construction industry. *In Proceeding of Conference on Construction in Developing Countries*. pp. 4-5.

Haseeb, M., Lu, X., Bibi, A., Dylan, M.-U., & Rabbani, W. (2011). Causes and effects of delays in large construction projects of Pakistan. *Kuwait Chapter of Arabian Journal of Business and Management Review, 33*(832), 1-25.

Hassan, S. A. (2012). Health, safety and environmental practices in the construction sector of Pakistan, Masters dissertation, Civil Engineering and Built Environment, Uppsala University, Uppsala.

Hinze, J., Hallowell, M., & Baud, K. (2013). Construction-safety best practices and relationships to safety performance. *Journal of Construction Engineering and Management, 139(*10), 04013006.

https://www.ilo.org/global/about-the-ilo/newsroom/media-centre/issue-briefs/WCMS_206117/lang--en/index.htm/ Accessed 18 December 2020.

https://www.pbs.gov.pksites/default/files/Labour%20Force/publications/lfs_Annual_2012_13/salient_features.pdf/ Accessed 19 December 2020.

International Labor Organization. Baluchistan province reaches consensus on labor legislation and labor policy. (2015). http://www.ilo.org/islamabad/info/public/pr/WCMS_357136/ langeen/index.htm/ Accessed 19 December 2020.

International Labor Organization. Health and safety at work: facts and figures. (2013).

International Labor Organization. World day for safety and health at work. (2009). https://www.ilo.org/safework/WCMS_108590/lang--en/index.htm/ Accessed 18 December 2020.

Jafri, S. F. (2012). Construction safety culture and promotion, conceptual approach based on the labor law of Pakistan, *IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), 1(*2), 24-27.

Keng, T. C., & Razak, N. A. (2014). Case studies on the safety management at construction site. *Journal of Sustainability Science and Management, 9*(2), 90-108.

Khan, M. I. (2013). Developing a safety culture in developing countries. *International Conference on Safety, Construction Engineering and Project Management (ICSCEPM),* Issues, Challenges and Opportunities in Developing Countries, August 19-21, Islamabad, 26-31.

Larcher, P., & Sohail, M. (1990). Review of Safety in Construction and Operation for the WS&S Sector. Loughborough University, UK.

Masood, R., Choudhry, R., Azhar, S., and Hinze, J. (2012). Mapping construction safety non-practice behavior with culture constructs. 3rd *International Conference on Construction in Developing Countries (ICCIDC–III)* Advancing Civil, Architectural and Construction Engineering and Management July 4-6, Bangkok, 320-327.

Memon, Z. A., Khatri, K. L., and Memon, A. B. (2013). Identifying the critical factor affecting safety program performance for construction projects within Pakistan construction industry. *Mehran University Research Journal of Engineering and Technology, 32*(2), 269-276.

Mohamed, S., Ali, T. H., and Tam, W. Y. V. (2009). National culture and safe work behaviour of construction workers in Pakistan, *Safety Science, 47*(1), 29-35.

Nawaz, T., Ishaq, A., and Ikram, A. A. (2013). Trends of safety performance in Construction and civil engineering projects in Pakistan. *Civil and Environmental Research,* 3(5),23-40.

OHSA. Occupational Health and Safety Act and Regulations 85 of 1993. (2006). https://store.lexisnexis.co.za/products/occupational-health-and-safety-act-no-85-of-1993-and-regulations-pocket-book skuZASKU9780639003078/details/ Accessed 20 December 2020.

OSHA. A Guide to Scaffold Use in the Construction Industry. (2002). https://www.osha.gov/Publications/OSHA3150/osha3150.html/ Accessed 19 December 2020.

Pakistan Bureau of Statistics. Labour Force Statistics. (2014).

Pakistan Bureau of Statistics. Labour Force Statistics. (2018). http://www.pbs.gov.pk/sites/default/files//Labour%20Force/publications/lfs2017_18/Anual%20Report%20of%20LFS%202017-18.pdf/ Accessed 16 December 2020.

Raheem, A. A., & Hinze, J. (2012). Reasons for the poor implementation of worker safety in the construction industry of Pakistan: A contractor's perspective. In *CIB W099 International Conference "Modeling and Building Health and Safety". Singapore.* pp. 54-63.

Raheem, A. A., & Issa, R. R. (2009). Safety implementation framework for Pakistani construction industry. *Safety Science, 82*, 301-314.

Raheem, A. A., and Hinze, J. W. (2013). Understanding the safety culture of construction companies in Pakistan by analyzing safety policy manuals. *International Conference on Safety, Construction Engineering and Project Management (ICSCEPM2013),* Issues, Challenges and Opportunities in Developing Countries, August 19-21, Islamabad,66-71.

Raheem, A. A., Hinze, J. W., Azhar, S., Choudhry, R. M., and Riaz, Z. (2011). Comparative analysis of construction safety in Asian developing countries, *6th International Conference on Construction in 21st Century (CITC-VI),* Construction Challenges in the New Decade, July 5-7, Kuala Lumpur, 623-630.

Raheem, A., and J. Hinze. (2013). Understanding the safety culture of construction companies in Pakistan by analyzing safety policy manuals. *Proceedings of the International Conference on Safety*, Construction Engineering and Project Management, Islamabad, August 19. Vol. 21.

Raheem, A., Hinze, J. and Azhar, S. (2012). Injury/fatality data collection needs for developing countries, Proceedings of the Third *International Conference on Construction in Developing Countries (ICCIDC-III),* Bangkok, July 4-6.

Riaz, Z., Arslan, M., Kiani, A. K., and Azhar, S. (2014). CoSMoS: A BIM and wireless sensor based integrated solution for worker safety in confined spaces. *Automation in Construction,* 45, 96-106.

Rundmo, T., & Hale, A. R. (2003). Managers' attitudes towards safety and accident prevention. Safety Science, 41(7), 557-574.

Shakri, Amirah Silmi Ahmad. (2016). A Study on Health, Safety and Environment (HSE) Practice by Private Contractors at Selected Service Residence Construction

Sites in Klang Valley. Diss. Jabatan Kejuruteraan Kimia, Fakulti Kejuruteraan, Universiti Malaya.

Sheikh, P., and Ali, T. H. (2013). Safety culture: A roadmap for sustainable safety. *International Conference on Safety, Construction Engineering and Project Management(ICSCEPM-2013),* Issues, Challenges and Opportunities in Developing Countries, August 19-21, Islamabad, 61-65.

Singh, S. P., Tripathy, D. P., & Ranjith, P. G. (2008). Performance evaluation of cement stabilized fly ash–GBFS mixes as a highway construction material. *Waste Management, 28*(8), 1331-1337.

Smith, G. S. (2001). Public health approaches to occupational injury prevention: do they work? *Injury Prevention* 1;7:i3-i10.

Taufek, F. H. B. M., Zulkifle, Z. B., & Kadir, S. Z. B. A. (2016). Safety and health practices and injury management in manufacturing industry, Procedia economics and finance, 35, 705-712.

Vredenburgh, A. G. (2002). Organizational safety: which management practices are most effective in reducing employee injury rates? *Journal of Safety Research, 33*(2), 259-276.

Zahoor, H., Chan, A. P., Masood, R., Choudhry, R. M., Javed, A. A., & Utama, W. P. (2016). Occupational safety and health performance in the Pakistani construction industry: stakeholders' perspective. *International Journal of Construction Management, 16*(3), 209-219.

Zahoor, H., Chan, A. P., Utama, W. P., Gao, R., & Zafar, I. (2017). Modelling the relationship between safety climate and safety performance in a developing construction industry. a cross-cultural validation study. *International journal of environmental research and public health, 14*(4), 351.

Zahoor, H., Chan, A.P.C., Utama, W.P. and Gao, R. (2016). A research framework for investigating the relationship between safety climate and safety performance in the Construction of multi-storey buildings in Pakistan. *Procedia Engineering*, Vol. 118, pp. 581-589.

Operational Research in Engineering Sciences: Theory and Applications
Vol. 4, Issue 1, 2021, pp. 115-135
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta20401156j

SELECTION OF FIRE POSITION OF MORTAR UNITS USING LBWA AND FUZZY MABAC MODEL

Željko Jokić*, Darko Božanić, Dragan Pamučar

Military Academy, University of Defence in Belgrade, Serbia

Received: 18 February 2021
Accepted: 26 March 2021
First online: 28 March 2021

Original scientific paper

Abstract: *The paper presents a hybrid model based on the LBWA method and the fuzzy MABAC method, applied when selecting firing positions' locations of the Serbian Army's mortar units. Using a questionnaire, the experts determined the criteria for choosing the firing position. The LBWA method is used to determine the weighting coefficients of the criteria, while the fuzzy MABAC method is used to determine the most favorable location of the firing position by choosing between six specific options - alternatives. By changing the value of the elasticity coefficients, the sensitivity analysis of the developed model was performed, and by applying the Spearman coefficient, it was determined that there is an ideal positive correlation of ranks.*

Key words: *LBWA, MABAC, fuzzy numbers, mortar units, firing position.*

1. Introduction

The entire twentieth and the beginning of the 21st century were marked by dizzying technological developments that could not but include the military industry. The impact of technological development on armaments and military equipment also conditioned a change in the armed conflicts' physiognomy. Modern combat conflicts are characterized by: sudden and rapid actions of forces from a distance, with mass use of armored and mechanized units and special forces on land, frequent use of helicopter landings, strong air support, and constant possibility and the threat of using weapons of mass destruction.

However, there are means of military equipment which, despite the stated technological development, have not undergone significant changes during all this time, and even without them, no major armed conflict can be imagined. From its appearance in 1904, in the Russo-Japanese War, to the present day, mortars have undergone small changes. They are produced in various calibers, of which the most common are 60 mm, 81-82 mm, and 120 mm, as traction or self-propelled. With the

* Corresponding author.
antras1209@gmail.com (Ž. Jokić), dbozanic@yahoo.com (D. Božanić), dpamucar@gmail.com (D. Pamučar)

possibility of shooting in a vertical path, they are suitable for shooting from bays, ravines, and from the back slope.

Mortar units are the basis of the infantry battalion's fire support in performing all types of combat operations. With their firepower and the possibility of quick maneuver, they can bring an advantage on the field, provided they are used correctly, which, above all, depends on the correct choice of the location of the combat schedule elements.

The article discusses the choice of the location of the battalion fire group fire position (BFG) formed by the company-platoon of 120 mm mortars. The ultimate goal of the article is to apply a model that will support the decision-maker in choosing the location of the firing position, which would significantly reduce the response time and the possibility of making an inadequate decision.

With the relatively newer LBWA method, the weight coefficients of the criteria for the selection of the location of the firing position (FP) will be determined. Experts in the subject area identified eight criteria, based on the applicable rules and instructions, on which the choice of the location of the firing position directly depends. The choice of the specific location of the firing position, between the six options, will be solved by applying the fuzzy MABAC method.

2. The place and role of mortars in contemporary combat actions

The 120 mm mortar is an accompanying infantry weapon, intended for neutralizing and destroying manpower and firepower, creating smoke curtains, blinding observation posts and firing points, illuminating battlefields, opening passages through wire barriers and minefields, and demolishing light fortification barriers at distances of about 6500 m (Military Encyclopedia, 1973). According to the formation of MB 120 mm, mortar companies or platoons are formed, depending on whether it is an infantry or mechanized battalion.

During combat operations, when operating within a battalion, a company-platoon of 120 mm mortars forms a battalion fire group of temporary composition. At the decision of the Commander, the battalion fire group may be attached to another unit or perform tasks for the needs of a higher unit. The tasks of the battalion fire group, during the execution of combat operations, derive from the purpose of the 120 mm mortar (Military Encyclopedia, 1973):

- neutralization and destruction of the enemy's manpower, firepower and fire support,
- fight against enemy landings,
- neutralization of enemy observation posts and observation posts,
- neutralization of enemy command posts and communication centers,
- demolition and destruction of field-type fortifications and opening of passages in obstacles,
- smoking and lighting of certain areas and rooms.

When conducting combat operations, BFG possesses elements of the combat schedule, which is part of the combat schedule of the battalion in which it operates, ie the unit it supports. The combat schedule of the BFG consists of an observation post, a firing position and a place of means of transport. The command part has an observation post, and the fire part has a fire position. Before possessing the stated elements of the combat schedule, the selection of optimal regions-locations for the execution of the obtained task is performed. As the topic of the paper is the choice of the location of the firing position in the future, the paper will not deal with the observation post.

The fire position (FP) is a region on the land where people, tools, ammunition and traction equipment are deployed in order to perform a fire task (Kurtov et al., 2014). According to the purposes, FP can be: basic, reserve, temporary, next and false, while according to the degree of shelter: sheltered, semi-sheltered and discovered (unprotected).

There are no works in the domestic and foreign literature that deal exclusively with the problem of choosing the firing position for mortar units. In addition to the rules and manuals that deal with mortars from the point of view of construction, some authors in works such as *Department of the Army* (2017), Jenzen-Jones (2015), consider mortars from the aspect of their application. The choice of the location of the basic VP for mortar units belongs to the group of location problems, which are considered in the literature in different ways, both by the type of location and by the applied methods. The problem of the location of military facilities was discussed by Karatas et al. (2019). Božanić & Pamučar (2010) select the location of the bridge crossing using Fuzzy logic. Also, Pamučar et al. (2019) select the optimal location for water barriers using the Interval-Valued Fuzzy-Rough Numbers and MAIRCA methods. Sennaroglu & Celebi (2018) use the AHP, PROMETHEE and VIKOR methods to select the location of the military airport. Pamučar et al. (2016) selected the firing position of the brigade artillery group in the defensive operation using a hybrid model fuzzy AHP - TOPSIS and a fabricated Satie scale. Hamurcu & Eren (2019) using multi-criteria decision-making using the AHP and TOPSIS methods select the best motorcycle route in Ankara. Stoilova (2020) using the AHP and SIMUS optimal railway route in case of an emergency. Liang et al. (2020) address the problem of route selection for perishable goods vehicles. Xu et al. (2020) solve a similar problem by multi-criteria analysis. Darbari et al. (2016) using multi-criteria analysis determine the optimal locations for the collection and disposal of recycled electrical equipment. Ortiz-Astorquiza et al. (2018) conduct a comprehensive overview of problems with the location of accommodation facilities. A similar problem is addressed by Küçükaydın & Aras (2020) using the Fuzzy C-means cluster. Contreras & O'Kelly (2019) address the problem of hub location when designing networks in transportation and telecommunications systems. The hybrid model AHP and PROMETHEE, Abdel-Basset et al. (2021) are used to select the location of coastal wind farms. Pan et al. (2021) are conducting a case study on the selection of the most suitable pedestrian overhead bridge location for the installation of elevators in Singapore using an adaptive Bayesian network.

3. Description of the method

The hybrid model, applied when solving the problem of choosing the location of FP mortars, consists of LBWA and fuzzy MABAC method. The LBWA method is used to determine the weight coefficients of the criteria, while the fuzzy MABAC method is used to determine the most favorable location of the mortars position. Figure 1 shows the scheme of the model.

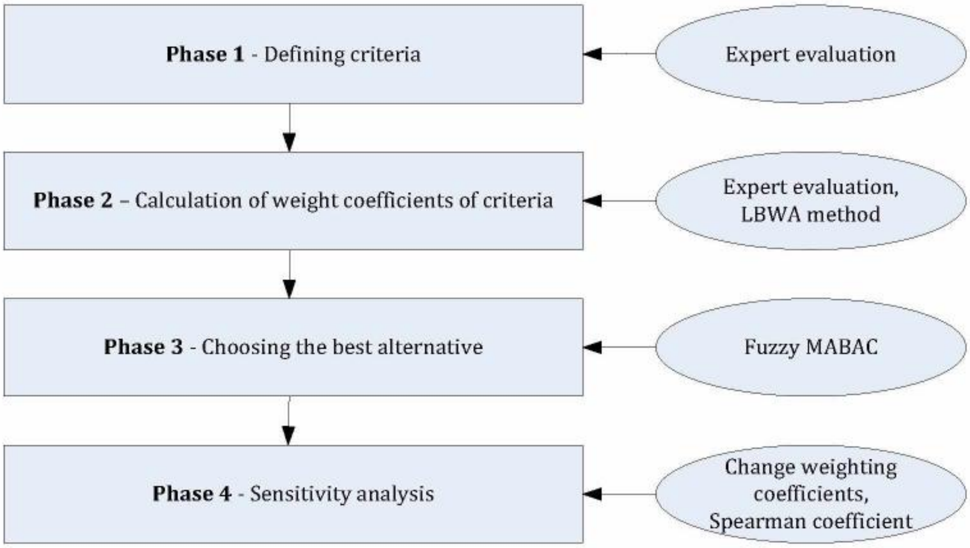


Figure 1. Model scheme

3.1. Level Based Weight Assessment (LBWA) model

The model of weight assessment based on levels (LBWA) was presented for the first time in their work by Žižović & Pamučar in 2019. Although a relatively new method, LBWA has so far been applied in several papers in solving various problems. After the first presentation of the method, Božanić et al. (2020) use a hybrid LBWA - IR-MAIRCA model of multi-criteria decision-making for weapon selection. Fuzzy LBWA – MACBETH – RAFSI was used to develop a multi-criteria model for the sustainable reorganization of the health system in the emergency situation caused by the COVID-19 pandemic (Pamučar et al., 2020b). The choice of the way passengers arrive at the airport in Istanbul was made, also by applying the fuzzy LBWA-WASPAS-H model (Pamučar et al., 2020a).

LBWA is a subjective model for determining weighting coefficients. Advantage of LBWA metod over other is in next keys (Žižović & Pamučar, 2019):

(1) Calculation of weighting coefficients can be realized with a small number of comparison criteria;
(2) A simple algorithm of the LBWA method;
(3) A simple mathematical apparatus is used to obtain the weighting coefficients;
(4) After realized comparisons of criteria, the coefficient of elasticity enables additional corrections of the values of weight coefficient.

Criteria must be defined before applying the LBWA method. If the number of criteria is denoted by *n*, then a set of criteria is available $S=\{C_1,C_2,\ldots,C_n\}$. After that, the LBWA method is approached through the following steps (Žižović & Pamučar, 2019):

Step 1. Determining the most significant criterion. The most important criterion is the one that, in the opinion of experts, has the greatest influence.

Step 2. Grouping the criteria by levels of significance in relation to the most significant criterion, according to the following:

Level S_1*:* From the set *S*, at the level of S_1, criteria are grouped that are of equal importance as C_1 or are up to twice less significant than C_1;

Level S_2*:* From the set *S*, at the level of S_2, the criteria are grouped exactly two times less significant than C_1 or are up to three times less significant than C_1;

Level S_3*: ...*

By applying the previously, the decision-maker is grouping criteria according levels of significance. If the significance of the criteria C_j marks with $s(C_j)$, wherein $j \in \{1, 2, \ldots, n\}$, then we have $S = S_1 \cup S_2 \cup \cdots \cup S_k$, where for each level $i \in \{1, 2, \ldots, k\}$, it is true that it is

$$S_i = \{C_{i_1}, C_{i_2}, \ldots, C_{i_s}\} = \{C_j \in S : i \le s(C_j) < i + 1\} \tag{1}$$

Also, for everyone $p, q \in \{1, 2, \ldots, k\}$ such that it is $p \neq q$ the intersection of the sets is $S_p \cap S_q = \varnothing$.

Step 3. Within the formed subsets, criteria according to significance are compared. Each criterion $C_{i_p} \in S_i$ from the set $S_i = \{C_{i_1}, C_{i_2}, \ldots, C_{i_s}\}$ is assigned an integer $I_{i_p} \in \{0, 1, \ldots, r\}$, that the most important criterion C_1 is assigned a number $I_1 = 0$. If it is C_{i_p} more significant than C_{i_q} than it is $I_p < I_q$, and if it is C_{i_p} of the same importance as C_{i_q}, than it is $I_p = I_q$. Expression (2) gives the maximum value of the scale for comparing the criteria r.

$$r = \max\{|S_1|, |S_2|, \ldots, |S_k|\} \tag{2}$$

Step 4. Based on the defined maximum value of the scale for comparing the criteria, coefficient of elasticity is determined $r_0 \in N$ which should satisfy the condition that $r_0 > r$.

Step 5. The calculation of the criterion influence function is realized in the following way:

$$f(C_{i_p}) = \frac{r_0}{i \cdot r_0 + I_{i_p}} \tag{3}$$

where *i* is the number of levels / subsets into which the criterion is classified, r_0 represents the coefficient of elasticity, while $I_{i_p} \in \{0, 1, \ldots, r\}$ represents the value assigned to the criterion C_{i_p} within the observed level.

Step 6. Calculation of optimal values of weight coefficients of criteria:

$$w_1 = \frac{1}{1 + f(C_2) + \cdots + f(C_n)} \tag{4}$$

The values of the weighting coefficients of the other criteria:

$$w_j = f(C_j) \cdot w_1 \tag{5}$$

where in $j = 2,3,\ldots,n$, and n the total number of criteria.

If expert decision-making is performed, as previously stated, after each expert determines the values of weighting coefficients, the aggregation of individual judgments according to the considered criterion (A_{ij}) is started (Blagojević et al., 2017). In the A_{ij} method, to obtain the group coefficient, the weighted geometric mean method is used, which is calculated as the *nth* root of the product of all elements of the data set using expression (6):

$$\overline{w}_{jC_1} = \sqrt[n]{w_{j1} * w_{j2} * \ldots * w_{jn}} = \sqrt[n]{\prod_{i=1}^{n} w_j} \tag{6}$$

where in $\overline{w}_{jC_1}$ combined weighting factor for the criterion C_1, w_{j1} expert weighting factor (E_1) and n number of weighting coefficients according to the given criterion.

3.2 Fuzzy sets

In classical set theory, the membership of elements in a set is estimated in a binary sense according to the bivalent condition - the element either belongs or does not belong to the set (Chatterjee & Stević, 2019). However, it is not always possible to make a clear division, especially of complex phenomena, which cannot be easily described by traditional mathematical methods, especially when the goal is to find an approximately good solution (Bojadziev & Bojadziev, 1996).

Modeling using fuzzy sets has been shown to be an effective way of formulating decision-making problems, where available input information is subjective or imprecise (Zimmermann, 1998). Fuzzy sets are sets whose elements have membership degrees. The theory of obscure sets was first introduced by Zadeh (1965), whose application enables decision-makers to deal effectively with uncertainties. Since then, fuzzy sets have been used by many researchers in solving various problems alone or in combination with other methods of multi-criteria decision-making. Thus, Kushwaha et al. (2020) and Panchal et al. (2019a, 2019b) use Fuzzy FMEA to assess risk and improve safety in various engineering systems. Also Pamučar et al. (2016) use Fuzzy Logic System of Type 2 to assess the risk of natural and other disasters in the Republic of Serbia while Božanć et al. (2015) in risk assessment when overcoming water obstacles in a defense operation. Similar to the previous one, Gopal & Panchal (2021) use the Fuzzy Lambda-Tau (λ-τ) approach in the dairy processing industry. The Lambda-Tau fuzzy method was also applied when determining the time interval of regular maintenance of a coal-fired thermal power plan (Panchal et al., 2020) as well as when analyzing the performance problems of a chemical process plan (Panchal & Srivastava, 2019).

Fuzzy sets are used mainly with triangular (TFN), trapezoidal and Gaussian fuzzy numbers. A fuzzy set Ã is a set of ordered pairs consisting of elements x of the universal set H and a certain degree of affiliation $\mu_{\tilde{A}}(h)$, shape $\tilde{A}=\{ (x, \mu_{\tilde{A}}(x)) \mid x \in X, \mu_{\tilde{A}}(x) \in [0,1]\}$(Zadeh, 1965). The membership function of the $\mu_{\tilde{A}}$ fuzzy set Ã is the mapping $\mu_{\tilde{A}}$: X → [0,1], where Ã is a subset of the universal set H.

Due to its fairly simple membership function, the triangular fuzzy number is one of the most commonly used fuzzy numbers, is defined by the following form:

$$\mu_{\tilde{A}} = \begin{cases} 1-\dfrac{m-x}{l}, & m-l \le x \le m \\ 1-\dfrac{x-m}{u}, & m \le x \le m+u \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

Fuzzy number is denoted as $\tilde{A}=(l,m,u)$. The value of m mark the basic value of the fuzzy number, a l deviation from the left, that is, u to the right of the modal value.

A very important concept associated with the application of fuzzy numbers is the dephasing process, which converts a fuzzy number into a real number. Several methods for performing dephasification can be found in the literature. The most widely used dephasification procedure is the centroid method, which is also known as the center of gravity or the Kwong method (Kwong & Bai, 2003). The triangular fuzzy of the number Ã = (l, m, u) is translated into a real number using the following expression:

$$M = \frac{(l+4*m+u)}{6} \tag{8}$$

3.3. Fuzzy MABAC method

<u>M</u>ulti-<u>A</u>ttributive <u>B</u>order <u>A</u>pproximation area <u>C</u>omparasion (MABAC)

The MABAC method is a reliable tool for rational decision-making (Pamučar & Ćirović, 2015). So far, it has been used in a large number of works independently or in one of the modifications. Alinezhad & Khalili (2019) in their book, among others, deal with the MABAC method. Sun et al. (2017) use the MABAC method to determine the priority of patient care. Using a modified rough method, AHP-MABAC, Sharma et al. (2018) determined the priority stations in the Indian Railways. Some authors combine the basic MABAC motor with fuzzy sets q-ROFS (Wang, 2020). Wei et al. (2019) apply the MABAC meter in ranking medical equipment suppliers. Božanić et al. (2016) applied the MABAC method in support of decision-making on the use of force in a defensive operation. Liang et al. (2019) use the MABAC method when assessing risk. Also, using this method, some authors selected the most suitable route of new lines in road and railway traffic (Luo et al., 2019). When defining the new interval-valued fuzzy-rough numbers (IVFRN) method, Pamučar et al. (2018) modified the BWM (Best – Worst method) and MABAC methods. Mishra et al. (2020) select a programming language using the MABAC method. Due to its consistency mentioned earlier, the MABAC method can be found in many more papers.

The fuzzy MABAC method solves the problem in three steps (Bobar et al., 2020):

Step 1. Forming the initial decision matrix ($\tilde{X}$).

The first thing is to do assessment *m* alternatives according to *n* criteria. Alternatives are shown in vector form $A_i = \left(\tilde{x}_{i1}, \tilde{x}_{i2} \ldots, \tilde{x}_{in}\right)$.

$$\tilde{X} = \begin{matrix} & C_1 & C_2 & \ldots & C_n \\ A_1 & \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ A_2 & \tilde{x}_{11} & \tilde{x}_{22} & & \tilde{x}_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{matrix} \tag{9}$$

Step 2. Normalization the initial matrix ($\tilde{X}$)

$$\tilde{X} = \begin{matrix} & C_1 & C_2 & \ldots & C_n \\ A_1 & \tilde{n}_{11} & \tilde{n}_{12} & \ldots & \tilde{n}_{1n} \\ A_2 & \tilde{n}_{11} & \tilde{n}_{22} & & \tilde{n}_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ A_m & \tilde{n}_{m1} & \tilde{n}_{m2} & \ldots & \tilde{n}_{mn} \end{matrix} \tag{10}$$

Elements of a normalized matrix ($\tilde{N}$) are determined by the equation:

a) For benefit (max) type criteria

$$\tilde{n}_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-} \tag{11}$$

b) For Cost (min) type criteria

$$\tilde{n}_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+} \tag{12}$$

Step 3. Calculate the elements from the weighted matrix ($\tilde{V}$).

$$\tilde{v}_{ij} = w_i * \tilde{n}_{ij} + w_i \tag{13}$$

n_{ij} is the elements of a normalized matrix ($\tilde{N}$), and w_i is the weighting coefficients of the criteria. Using equation (19) we receive a weighted matrix

$$\tilde{V} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \ldots & \tilde{v}_{1n} \\ \tilde{v}_{21} & \tilde{v}_{22} & \ldots & \tilde{v}_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ \tilde{v}_{m1} & \tilde{v}_{m2} & \ldots & \tilde{v}_{mn} \end{bmatrix} \tag{14}$$

Step 4. Determining the matrix of the approximate boundary area ($\tilde{G}$).

Boundary approximation area (BAA) is determined based on the expression:

$$\tilde{g}_i = \left(\prod_{j=1}^{m} \tilde{v}_{ij} \right)^{1/m} \tag{15}$$

After calculating the value $\tilde{g}_i$ for each criterion, a matrix of boundary approximate domains is formed $\tilde{G}$.

$$\begin{array}{c} \quad\; C_1 \quad C_2 \quad \dots \quad C_n \\ \tilde{G} = [\tilde{g}_1 \quad \tilde{g}_2 \quad \dots \quad \tilde{g}_n] \end{array} \tag{16}$$

Step 5. The calculation of the distance of the alternatives from the boundary approximate domain is obtained as follows:

$$\tilde{Q} = \begin{bmatrix} \tilde{q}_{11} & \tilde{q}_{12} & \dots & \tilde{q}_{1n} \\ \tilde{q}_{21} & \tilde{q}_{22} & & \tilde{q}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{q}_{m1} & \tilde{q}_{m2} & \dots & \tilde{q}_{mn} \end{bmatrix} \tag{17}$$

$$\tilde{Q} = \tilde{V} - \tilde{G} \tag{18}$$

Alternative A_i may belong to the boundary approximate domain ($\tilde{G}$), upper approximate area ($\tilde{G}^{+}$) or the lower approximate domain ($\tilde{G}^{-}$).

Belonging to an alternative A_i area of approximation ($\tilde{G}, \tilde{G}^{+}$ or $\tilde{G}^{-}$) is determined on the basis of the equation (19).

$$A_i \in \begin{cases} \tilde{G}^{+} & if \quad \tilde{q}_{ij} \succ 0 \\ \tilde{G} & if \quad \tilde{q}_{ij} = 0 \\ \tilde{G}^{-} & if \quad \tilde{q}_{ij} \prec 0 \end{cases} \tag{19}$$

Step 6. Ranking alternatives.

Through the sum of the distances of the alternatives from the boundary approach area ($\tilde{q}_i$) the calculation of the values of the criterion functions for alternatives was received. The final value of the criterion functions of the alternatives was received by calculating the sum of the elements of the matrix Q by rows.

$$\tilde{S}_i = \sum_{j=1}^{n} \tilde{q}_{ij}, \; j = 1,2,\dots,n, \; i = 1,2,\dots,m \tag{20}$$

4. Application of the hybrid model of multi-criteria decision making

The LBWA – Fuzzy MABAC hybrid model consists of four phases. In the first phase of the model, based on expert assessment, the criteria are defined. In the second phase, the calculation of the weight coefficients of the criteria is realized using expert assessment and the LBWA method. In the third phase, the best alternative is selected using the fuzzy MABAC method. The last phase includes the sensitivity analysis of the developed model and the correlation of ranks.

4.1. Criteria for choosing the firing position

In the first phase, the criteria are defined that in the further work directly affect the choice of the best alternative, ie. optimal locations for the firing position. Defining criteria and their weighting coefficients represents an important phase for decision-making models (Pamučar et al., 2016). Due to the complexity of the problem in defining the selection criteria, experts were hired. Experts identified eight criteria for the considered problem, which are listed from C_1 to C_8.

The criteria for selecting the location of the fire position (FP) of the battalion fire group (BFG), which is formed by a company of 120 mm mortars, were defined on the basis of expert opinion, and the data from the rules served as the basis for the survey.

The selection of the most favorable location of BFG is made on the basis of eight criteria:

C_1 - distance to the target, expressed in meters (ideal location is generally defined at 1/3 of the range of the weapon from the front end of its own forces when the unit is in attack, or 2/3 when in defense).

C_2 - the ability to observe the firing position by the enemy. In the professional literature, the stated criterion is defined as the shelter of the firing position, and on that basis, the division into sheltered, semi-sheltered and discovered (un sheltered) firing position was made. The detected firing position allows direct aiming at the target. On it the enemy can spot people and tools. The semi-sheltered firing position makes it impossible for the enemy to visually spot people, but it can detect it by smoke and flash when firing a mine. The sheltered firing position prevents the enemy from observing from the ground or detecting the firing position by the smoke and flash of a fired mine.

C_3 - masking conditions (terrain characteristics that enable successful masking of BFG and movement of parts or the whole BFG).

C_4 - soil bearing capacity - terrain characteristics on which the accuracy of shooting depends. When shooting from too hard ground, the ground bounces off the ground, while on soft ground it collapses, which requires additional soil reinforcement.

C_5 - the size of the parallax expressed in thousands of parts of the angle. The parallax of the target is the angle between the line of sight and the line of fire. If it is in the range from 0-00 to 3-00 it is small, from 3-00 to 5-00 it is medium and over 5-00 it is large.

C_6 - distance of the observation post from the firing position. The distance of the observation post from the firing position directly affects the duration and accuracy of the correction. The smaller the distance, the more precise the correction will be, and thus the faster it will be completed. Based on that, there is a division into near and far observatories. The observation post is close if it is within 10% of the shooting distance.

C_7 - access conditions. The approach conditions directly affect the speed of the firing position, and thus the time of preparation of the unit for opening fire. Having in mind the mass of individual parts of the 120 mm mortar, it is not at all negligible whether the tools can be brought by motor vehicle to the firing position or the handlers have to carry them by hand.

C_8 - distance to own units. The duration of the correction also depends on the distance of the firing position to one's own units. The closer the units are to the firing position, the easier it is to make a correction, and thus in a shorter time.

The set of criteria Cj consists of two subsets, a subset of the benefit type criteria, which means that a higher value of the criterion is more desirable, ie. better, denoted by C + and a subset of cost-type criteria, which means that a smaller value is more desirable, ie. better marked with C -. In this particular case, the subset of criteria C^+ includes criteria C_2, C_3, C_4 and C_7, while the subset of criteria C^- includes criteria C_1, C_5, C_6 and C_8.

The values of criteria C_1 and C_8 are shown as numerical values while the values of criteria C_2 are shown through a linguistic scale from 1 to 5 as seen in Table 1.

Table 1. Linguistic descriptors for criterion C_2

Linguistic descriptor	discovered (Ds)	semi-sheltered (SS)	sheltered (S)
Assigned numeric value	1	3	5

The values of criteria C_3, C_4, C_5, C_6 and C_7 are presented as fuzzy linguistic descriptors (table 2, table 3 and table 4).

Table 2.Fuzzy linguistic descriptors for criteria C_3, C_4, C_7

Linguistic condition	fuzzy number
Bad (B)	(0, 1, 3)
Good (G)	(2, 3, 5)
Excellent (E)	(4, 5, 5)

Table 3. Fuzzy linguistic descriptor for criterion C_5

Linguistic condition	Fuzzy number
Small (S)	(0, 2, 3.5)
Medium (M)	(2.5, 4, 5.5)
Large (L)	(4.5, 6, 7.5)

Table 4: Fuzzy linguistic descriptor for criterion C_6

Linguistic condition	fuzzy number
Close (C)	(0, 450, 600)
Remote (R)	(480, 640, 1000)

4.2. Calculation of weight coefficients of criteria using LBWA method

In the second phase, the calculation of the weight coefficients of the criteria is performed using the LBWA method, in the previously described manner. After the selection of the most important criteria by the experts, the determination of the weighting criteria is presented in this text. Determination of weighting coefficients is shown for one expert (E_1). As 11 experts participated in the research, in the end the aggregation of weight coefficients from all of them was performed and the weight coefficients were obtained, which were further used when choosing the firing position of the 120 mm mortar using the MABAC method.

Step 1: For the most important, the E_1 expert chose criterion C_2.

Step 2: The criteria are classified into three levels:

$S_1 = \{C_2, C_8\}$,

$S_2 = \{C_1, C_6, C_4\}$,

$S_3 = \{C_7, C_5, C_3\}$.

Step 3: Based on expression (2), the maximum value of the scale for comparing the criteria is defined

$r = \max\{|S_1|, |S_2|, |S_3| = 3$

Based on the comparison of criteria according to their significance, C_2 gets the value $I_2 = 0$ as the most significant criterion, while other criteria according to their importance in their sub-levels, get the following values:

S_1: $I_8=1$;

S_2: $I_1=1$, $I_6=2$, $I_4=4$;

S_3: $I_7=1$, $I_5=3$, $I_3=3$.

Step 4: Based on the defined maximum value of the scale for comparing the criteria $r = 3$, the coefficient of elasticity $r_0 = 4$ is defined.

Step 5: Using expression (3), the influence functions of the criteria were calculated:

$$f(C_2) = \frac{4}{1*4+0} = 1, \quad f(C_8) = \frac{4}{1*4+1} = 0.8,$$
$$f(C_1) = \frac{4}{2*4+1} = 0.444, \quad f(C_6) = \frac{4}{2*4+2} = 0.4, \quad f(C_4) = \frac{4}{2*4+4} = 0.333,$$
$$f(C_7) = \frac{4}{3*4+1} = 0.308, \quad f(C_5) = \frac{4}{3*4+3} = 0.267, \quad f(C_3) = \frac{4}{3*4+3} = 0.267$$

Step 6: Using expression (4), the weight coefficient of the most influential criterion was obtained

$$w_2 = \frac{1}{1+0.8+0.444+0.4+0.333+0.308+0.267+0.267} = 0.262$$

while the values of weight coefficients of the remaining criteria were obtained by applying the expression (5):

$$w_1 = 0.262*0.444 = 0.116,$$
$$w_3 = 0.262*0.267 = 0.209,$$
$$\ldots$$
$$w_8 = 0.262*0.8 = 0.209.$$

Based on the previous, the vector of expert weight coefficients (E_1) was obtained:

w_{j1}=(0.116, 0.262, 0.070, 0.087, 0.070, 0.105, 0.081, 0.209).

Using the expression (6), the aggregation of weight coefficients obtained from the experts was performed, on the basis of which a vector of weight coefficients was formed:

w_j =(0.187, 0.234, 0.072, 0.104, 0.094, 0.085, 0.067, 0.156).

After determining the weight coefficients of the criteria, it is possible to move on to the next phase of the model.

4.3. Choosing the best alternative using the fuzzy MABAC method

The third phase of the model involves selecting the best alternative for the firing position using the fuzzy MABAC method as described previously.

The paper discusses six potential locations-alternatives to the firing position of the mortar unit. The characteristics of the considered locations were obtained by the intelligence-reconnaissance work of the superior command.

Step 1. The first step is to form the initial matrix according to expression (9), which is shown in Tables 5 and 6.

Table 5 shows the initial decision matrix. Numerical and linguistic values are given for the considered alternatives according to the stated criteria.

Table 5. Initial decision matrix

Alt.	Criteria							
	C_1 (min)	C_2 (max)	C_3 (max)	C_4 (max)	C_5 (min)	C_6 (min)	C_7 (max)	C_8 (min)
A_1	5850	S	E	G	S	C	G	1000
A_2	4925	SS	G	E	M	R	E	950
A_3	3762	Ds	G	E	L	R	E	1250
A_4	4558	SS	B	G	M	C	G	1187
A_5	5321	S	E	B	S	C	B	1530
A_6	4789	S	G	G	L	R	G	1987
w_i	0.187	0.234	0.072	0.104	0.094	0.085	0.067	0.156

Linguistic values, in Table 6, are quantified into numerical ones. Criterion C_2 is shown as a real number after quantification while criteria C_3 to C_7 are shown as triangular fuzzy numbers.

Table 6. Quantification of the initial decision matrix

Alt	Criteria							
	C_1 (min)	C_2 (max)	C_3 (max)	C_4 (max)	C_5 (min)	C_6 (min)	C_7 (max)	C_8 (min)
A_1	5850	5	(4, 5, 5)	(2, 3, 5)	(0, 2, 3.5)	(0, 450, 600)	(2, 3, 5)	1000
A_2	4925	3	(2, 3, 5)	(4, 5, 5)	(2.5, 4, 5.5)	(480, 640, 1000)	(4, 5, 5)	950
A_3	3762	1	(2, 3, 5)	(4, 5, 5)	(4.5, 6, 7.5)	(480, 640, 1000)	(4, 5, 5)	1250
A_4	4558	3	(0, 1, 3)	(2, 3, 5)	(2.5, 4, 5.5)	(0, 450, 600)	(2, 3, 5)	1187
A_5	5321	5	(4, 5, 5)	(0, 1, 3)	(0, 2, 3.5)	(0, 450, 600)	(0, 1, 3)	1530
A_6	4789	5	(2, 3, 5)	(2, 3, 5)	(4.5, 6, 7.5)	(480, 640, 1000)	(2, 3, 5)	1987

Step 2. Normalization of initial matrix elements (*X*).

Normalization of elements from the confirmed initial decision matrix was performed using expressions (11) and (12), and the results are shown in Table 7.

Table 7. Normalized matrix (N)

Alt.	Criteria					
	C_1 (min)	C_2 (max)	C_3 (max)	...	C_7 (max)	C_8 (min)
A_1	0	1	(0.8, 1, 1)	...	(0.4, 0.6, 1)	0.952
A_2	0.443	0.500	(0.4, 0.6, 1)	...	(0.8, 1, 1)	1
A_3	1.000	0.000	(0.4, 0.6, 1)	...	(0.8, 1, 1)	0.771
A_4	0.619	0.500	(0, 0.2, 0.6)	...	(0.4, 0.6, 1)	0.771
A_5	0.253	1.000	(0.8, 1, 1)	...	(0, 0.2, 0.6)	0.441
A_6	0.508	1.000	(0.4, 0.6, 1)	...	(0.4, 0.6, 1)	0

Step 3. Calculation of elements from a weighted matrix (*V*).

The elements from the weighted matrix (*V*) are calculated on the basis of expression (13) which is shown in Table 8.

Table 8. Difficult normalized matrix (V)

Alt.	Criteria					
	C_1 (min)	C_2 (max)	C_3 (max)	...	C_7 (max)	C_8 (min)
A_1	0.187	0.468	(0.130, 0.144, 0.144)	...	(0.094, 0.107, 0.134)	0.305
A_2	0.270	0.351	(0.101, 0.115, 0.144)	...	(0.120, 0.134, 0.134)	0.312
A_3	0.374	0.234	(0.101, 0.115, 0.144)	...	(0.120, 0.134, 0.134)	0.267
A_4	0.303	0.351	(0.072, 0.087, 0.115)	...	(0.094, 0.107, 0.134)	0.277
A_5	0.234	0.469	(0.130, 0.144, 0.144)	...	(0.067, 0.080, 0.107)	0.225
A_6	0.282	0.469	(0.101, 0.115, 0.144)	...	(0.094, 0.107, 0.134)	0.156

Step 4. Determination of the boundary approximate domain matrix (G)

The boundary approximate area was obtained by applying expression (15), which is shown in Table 9.

Table 9. Boundary approximate domain matrix

BAA	Criteria					
	C_1 (min)	C_2 (max)	C_3 (max)	...	C_7 (max)	C_8 (min)
g_i	0.269	0.379	(0.104, 0.118, 0.139)	...	(0.096, 0.110, 0.129)	0.251

Step 5. Calculating the distance of the alternative from the area of the approximate boundary for the matrix elements (Q)

The distance of alternatives from BAA was obtained by applying expressions (18) and (19), Table 10.

Table 10. Matrix distance alternatives from BAA

Alt.	Criteria					
	C_1 (min)	C_2 (max)	C_3 (max)	...	C_7 (max)	C_8 (min)
A_1	-0.082	0.089	(-0.009, 0.026, 0.040)	...	(-0.035,-0.003, 0.038)	0.054
A_2	0.001	-0.028	(-0.038,-0.003, 0.040)	...	(-0.009, 0.024, 0.038)	0.062
A_3	0.105	-0.145	(-0.038,-0.003, 0.040)	...	(-0.009, 0.024, 0.038)	0.017
A_4	0.034	-0.028	(-0.067,-0.032, 0.012)	...	(-0.035,-0.003, 0.038)	0.026
A_5	-0.035	0.089	(-0.009, 0.026, 0.040)	...	(-0.062,-0.030, 0.011)	-0.026
A_6	0.013	0.089	(-0.038,-0.003, 0.040)	...	(-0.035,-0.003, 0.038)	-0.094

Step 6. Ranking alternatives.

To make it easier to represent the final rank of the alternatives using expression (8) the triangular fuzzy number is translated into a real number. According to expression (20), by calculating the sum of the elements of the matrix Q by rows, the final values of the criterion functions of the alternatives were obtained, which is shown in Table 11.

Table 11. Rank of alternatives by MABAC method

Alt.	Criteria								Q_j	Rank
	C_1 (min)	C_2 (max)	C_3 (max)	C_4 (max)	C_5 (min)	C_6 (min)	C_7 (max)	C_8 (min)		
A_1	-0.082	0.089	0.022	-0.002	0.027	0.012	-0.002	0.054	0.120	1
A_2	0.001	-0.028	-0.002	0.032	0.001	-0.011	0.021	0.062	0.077	2
A_3	0.105	-0.145	-0.002	0.032	-0.024	-0.011	0.021	0.017	-0.006	5
A_4	0.034	-0.028	-0.030	-0.002	0.001	0.012	-0.002	0.026	0.011	4
A_5	-0.035	0.089	0.022	-0.044	0.027	0.012	-0.028	-0.026	0.019	3
A_6	0.013	0.089	-0.002	-0.002	-0.024	-0.011	-0.002	-0.094	-0.032	6

Based on the obtained results, it is concluded that alternative A_1 is ranked first, ie that the ranking of alternatives is as follows: $A_1 > A_2 > A_5 > A_4 > A_3 > A_6$.

4.4. Sensitivity analysis

The fourth phase includes testing the sensitivity of the applied model, in order for the decision-maker to receive confirmation of the quality of the obtained solution, ie to determine how changes in the weight of criteria lead to changes in alternative ranks (Tešić & Božanić, 2018; Durmić et al., 2020). Checking the stability of the used methods of multi-criteria decision-making is an indispensable step in the process of developing a model to support decision-making (Pamučar et al., 2017). Stability was examined by changing the weight coefficients wi, ie by changing the value of the coefficient of elasticity r_0, whose value in the work is r_0 = 4. Table 12 shows the influence of the value of r_0 on the change in the rank of the alternative:

Table 12: Rank alternative depending on r_0

Alt.	$r_0 = 4$	$r_0 = 5$	$r_0 = 6\text{-}9$	$r_0 = 10\text{-}20$
A_1	1	1	1	1
A_2	2	2	2	2
A_3	5	5	5	4
A_4	4	4	3	3
A_5	3	3	4	5
A_6	6	6	6	6

Based on Table 12, it can be noticed that with the change of the weight coefficient, ie the coefficient of elasticity, the model shows stability. Three alternatives (A_1, A_2 and A_6) retain the rank regardless of the value of r_0 while the other alternatives suffer changes of rank for $r_0 = 5$, $r_0 = 6$ and $r_0 = 10$. For the values $r_0 = 7$, $r_0 = 8$ and $r_0 = 9$, the rank is identical as for $r_0 = 6$. Also, for $r_0 = 11\text{-}20$ the rank is identical as for $r_0 = 10$.

In order to establish the correlation of the ranks obtained by changing r_0, the Spearman coefficient was used as in expression (20):

$$S = 1 - \frac{6\sum_{i=1}^{n} D_i^2}{n(n^2 - 1)} \tag{21}$$

where D_i represents the difference of rank according to the given r_0 and rank in the corresponding r_0, and n the number of ranked alternatives. The Spiraman coefficient belongs to the value interval [-1,1] (Radovanović et al., 2020). When the ranks of the alternatives completely match the Spearman coefficient is 1 ("ideal positive correlation"), when the ranks are completely opposite the Spearman coefficient is -1 ("ideal negative correlation"), ie when S = 0 the ranks are uncorrelated. The values of the Spearman coefficient for the considered problem are shown in Table 13.

Table 13: Spearman coefficient values

	$r_0 = 4$	$r_0 = 5$	$r_0 = 6\text{-}9$	$r_0 = 10\text{-}20$
$r_0 = 4$	1	1	0.94	0.83
$r_0 = 5$		1	0.94	0.83
$r_0 = 6\text{-}9$			1	0.94
$r_0 = 10\text{-}20$				1

From the results shown in Table 13, it can be concluded that the values of the Spearman coefficient for all values of r_0 are extremely high, ie that there is an ideal positive correlation of ranks. There is no deviation from the ideal positive correlation as well as the negative correlation. Based on the above, it is possible to conclude that the model has sufficient sensitivity.

5. Conclusion

On a hybrid model based on the LBWA and fuzzy MABAC method, the paper explains the process of creating a multi-criteria decision model. Through a multi-criteria model, the paper solves the problem of choosing the location of the firing position for mortar units of company size MB 120 mm, which has not been considered in this way in the existing literature so far.

The paper describes in detail the steps of the LBWA and fuzzy MABAC methods. The experts determined eight criteria for influencing the choice of firing position. Further, the experts identified the most significant criterion, defined the levels of significance and determined the values of the criteria by levels. Part of the criteria, of the linguistic type, obtained numerical values using fuzzy linguistic and linguistic descriptors.

As the best choice-alternative, the MABAC method suggests the A_1 alternative. Alternative A_1 in relation to the others, has the largest battle of criteria belonging to the above approximate domain.

As the last phase, the sensitivity analysis of the presented model was performed in the paper, by changes in the weight coefficients of the criteria (by changing the coefficient of elasticity) from r_0 = 4 to r_0 = 20. The results of the analysis indicate sufficient stability of the model. The first-ranked alternative A_1 retains the first position regardless of the growth of the coefficient of elasticity r_0. Also, the Spearman coefficient has a great value, which shows that there is an ideal positive correlation of ranks.

Based on the existing literature, the LBWA method has not been combined with the MABAC method so far. Based on the results, presented in the model, it is concluded that the combination of these two methods gives consistent results. Further research should focus on testing the applied model through new problems, as well as the application of other methods to the existing problem.

The presented model of mortar firing position can have great application in military management. The application of the methods used significantly shortens the time in the decision-making process, which is very important in an uncertain environment.

References

Abdel-Basset, M., Gamal, A., Chakrabortty, R. K., & Ryan, M. (2021). A new hybrid multi-criteria decision-making approach for location selection of sustainable offshore wind energy stations: A case study. Journal of Cleaner Production, 280(2), 124462.

Alinezhad, A., & Khalili, J. (2019). New Methods and Applications in Multiple Attribute Decision Making (MADM). International Series in Operations Research & Management Science. Cham: Springer.

Blagojević, B., Srdević, B., Srdević, Z., & Zoranović, T. (2017). Group decision making using the analytic hierarchy process. Annals of Agronomy, 41(1), 30-39.

Bobar, Z., Božanić, D., Djurić, K., & Pamučar, D. (2020). Ranking and Assessment of the Efficiency of Social Media using the Fuzzy ANP-Z Number Model - Fuzzy MABAC. Acta Polytechnica Hungarica, 17(3), 43-70.

Bojadziev, G., & Bojadziev, M. (1996). Advances in Fuzzy Systems — Applications and Theory: Fuzzy sets, fuzzy logic, applications. World Scientific.

Božanić D., Slavković R., & Karović S. (2015). Model of Fuzzy Logic Application to the Assessment of Risk in Overcoming the Obstacles during an Army Defensive Operation, Vojno delo, 67(4), 240-260.

Božanić, D., & Pamučar, D. (2010). Evaluating locations for river crossing using fuzzy logic. Vojnotehnički glasnik/Military Technical Courier, 58(1), 129-145.

Božanić, D., Pamučar, D., & Karović, S. (2016). Application the mabac METHOD in support of decision-making on the use of force in a defensive operation, Tehnika, 66(1), 129-136.

Božanić, D., Randelović, A., Radovanović, M., & Tešić, D. (2020). A hybrid LBWA - IR-MAIRCA multicriteria decision-making model for determination of constructive elements of weapons, Facta Universitatis Series: Mechanical Engineering, 18(3), 399-418.

Chatterjee, P., & Stević, Ž. (2019). A two-phase fuzzy AHP - fuzzy TOPSIS model for supplier evaluation in manufacturing environment. Operational Research in Engineering Sciences: Theory and Applications, 2(1), 72-90.

Contreras I., & O'Kelly M. (2019). Hub Location Problems. In: Laporte G., Nickel S., Saldanha da Gama F. (Eds.), Location Science. Cham: Springer.

Darbari, J. D., Agarwal, V., & Jha, P. C. (2016). Multi Criteria Decision Making Model for Optimal Selection of Recovery Facility Location and Collection Routes for a Sustainable Reverse Logistics Network Under Fuzzy Environment. Recent Advances in Mathematics, Statistics and Computer Science, 29-39, doi.org/10.1142/9789814704830_0003.

Department of the Army. (2017). Mortars, Training Circular Washington No. 3-22.90.

Durmić, E., Stević, Ž., Chatterjee, P., Vasiljević, M., & Tomašević, M.. (2020). Sustainable supplier selection using combined FUCOM–Rough SAW model. Reports in mechanical engineering, 1(1), 34-43.

Gopal, N., & Panchal, D. (2021). A structured framework for reliability and risk evaluation in the milk process industry under fuzzy environment. Facta Universitatis Series: Mechanical Engineering https://doi.org/10.22190/FUME201123004G, (Online first).

Hamurcu, M., & Eren, T. (2019). An Application of Multicriteria Decision-making for the Evaluation of Alternative Monorail Routes, Mathematics, 7(1), 16.

Jenzen-Jones, N.R. (2015). Guided Mortar System. Research Note No. 3. Geneva: Small Arms Survey.

Karatas, M., Yakici, E., & Razi, N. (2019). Military Facility Location Problems: A Brief Survey. In Tozan, H., & Karatas, M. (Eds.), Operations Research for Military Organizations (pp.1-27). Hershey, PA: IGI Global.

Küçükaydın, H., & Aras, N. (2020). Gradual covering location problem with multi-type facilities considering customer preferences. Computers & Industrial Engineering, 147, 106577.

Kurtov, D., Božanić, D., & Pamučar, D. (2014). The choice of areas for firing position of Brigade Artillery Group in a defensive operation using the VIKOR method. In Proceedings of 17th DQM Internacional Conference (pp.705-710), Belgrade.

Kushwaha, D. K., Panchal, D., & Sachdeva, A. (2020). Risk analysis of cutting system under intuitionistic fuzzy environment, Reports in Mechanical Engineering, 1(1), 162-173.

Kwong, C. K., & Bai, H. (2003). Determining the importance weights for the customer requirements in QFD using a fuzzy AHP with an extent analysis approach. IIE Transactions, 35(7), 619-626.

Liang, W., Zhao, G., Wu, H., & Dai, B. (2019). Risk assessment of rockburst via an extended MABAC method under fuzzy environment. Tunnelling and Underground Space Technology, 83, 533-544.

Liang, Y., Liu, F., Lim, A., & Zhang, D. (2020). An integrated route, temperature and humidity planning problem for the distribution of perishable products. Computers & Industrial Engineering, 147, 106623.

Luo, S-Z., Liang, W-Z. (2019). Optimization of roadway support schemes with likelihood-based MABAC method. Applied Soft Computing. 80, 80-92.

Military Encyclopedia (Only in Serbian: Vojna enciklopedija). (1973). Belgrade: Military Paper Office.

Mishra, A.R., Chandel, A., & Motwani, D. (2020). Extended MABAC method based on divergence measures for multicriteria assessment of programming language with interval-valued intuitionistic fuzzy sets. Granular Computing, 5, 97–117.

Ortiz-Astorquiza, C., Contreras, I., & Laporte, G. (2018). Multi-level facility location problems. European Journal of Operational Research, 267(3), 791-805.

Pamučar, D, Božanić, D., & Kurtov, D. (2016). Fuzzification of the Saaty's scale and a presentation of the hybrid fuzzy AHP-TOPSIS model: an example of the selection of a brigade artillery group firing position in a defensive operation. Vojnotehnički glasnik/Military technical courier, 64(4), 966-986.

Pamučar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centres using Multi Attributive Border Approximation area Comparison (MABAC). Expert Systems with Applications, 42(6), 3016-3028.

Pamučar, D., Božanić, D., & Komazec, N. (2016). Risk Assessment of Natural Disasterts using Fuzzy Logic System Type-2, Management - Journal for Theory and Practice Management, 21(80), 23-32.

Pamučar, D., Božanić, D., & Milić, A. (2016). Selection of a course of action by Obstacle Employment Group based on a fuzzy logic system. Yugoslav Journal of Operations Research, 26(1), 75-90.

Pamučar, D., Božanić, D., & Randelović, A.. (2017). Multi-criteria decision making: An example of sensitivity analysis. Serbian Journal of Management, 12(1), 1-27.

Pamučar, D., Ćirović, G., & Božanić, D. (2019). Application of interval valued fuzzy-rough numbers in multi-criteria decision making: The IVFRN-MAIRCA model. Yugoslav Journal of Operations Research, 29(2), 221-247.

Pamučar, D., Deveci, M., Canıtez. F., & Lukovac, V. (2020a). Selecting an airport ground access mode using novel fuzzy LBWA-WASPAS-H decision making model. Engineering Applications of Artificial Intelligence, 93, 103703.

Pamučar, D., Petrović, I., & Ćirović, G. (2018). Modification of the Best–Worst and MABAC methods: A novel approach based on interval-valued fuzzy-rough numbers. Expert Systems with Applications, 91, 89-106.

Pamučar, D., Žižović, M., Marinković, D., Doljanica, D., Jovanović, V., S., & Brzaković, P. (2020b). Development of a Multi-Critria Model for Sustainable Reorganization of a Nealthcare System in an Emergency Situation Caused by the COVID-19 Pandemic. Sustainability, 12(18), 7504.

Pan, Y., Zhang, L., Koh, J., & Deng, Y. (2021). An adaptive decision making method with copula Bayesian network for location selection. Information Sciences, 544, 56-77.

Panchal D., Tyagi M., Sachdeva A., & Garg R.K. (2020) Reliability Analysis of Complex Repairable System in Thermal Power Plant. In: Ram M., & Pham H. (Eds.) Advances in Reliability Analysis and its Applications, Springer Series in Reliability Engineering (pp. 361-372). Cham: Springer.

Panchal, D., & Srivastava, P. (2019). Qualitative analysis of CNG dispensing system using fuzzy FMEA–GRA integrated approach. International Journal of System Assurance Engineering and Management, 10, 44–56.

Panchal, D., Chatterjee, P., Yazdani, M., & Chakraborty, S. (2019a). A Hybrid MCDM Approach-Based Framework for Operational Sustainability of Process Industry. Advanced Multi-Criteria Decision Making for Addressing Complex Sustainability Issues (pp. 1-13). Hershey, PA: IGI Global (Chapter 1).

Panchal, D., Singh, A. K., Chatterjee, P., Zavadskas, E. K. &, Keshavarz-G. M. (2019b). A new fuzzy methodology-based structured framework for RAM and risk analysis. Applied Soft Computing, 74, 242-254.

Radovanović, M., Randelović, A., & Jokić, Ž. (2020). Application of hybrid model fuzzy ahp - vikor in selection of the most efficient procedure for rectification of the optical sight of the longrange rifle. Decision Making: Applications in Management and Engineering, 3(2), 131-148.

Sennaroglu, B., & Celebi, G. V. (2018). A military airport location selection by AHP integrated PROMETHEE and VIKOR methods. Transportation Research Part D: Transport and Environment, 59, 160-173.

Sharma, K., H., Roy, J., Kar, S., & Prentkovskis, O. (2018). Multi Criteria Evaluation Framework for Prioritizing Indian Railway Stations Using Modified Rough AHP-Mabac Method. Transport and Telecommunication Journal, 19(2), 113-127.

Stoilova, S. (2020). An Integrated Multi-Criteria Approach for Planning Railway Passenger Transport in the Case of Uncertainty. Symmetry, 12, 949.

Sun, R., Hu, J., Zhou., J., & Chen. X. (2017). A Hesitant Fuzzy Linguistic Projection-Based MABAC Method for Patients' Prioritization. International Journal of Fuzzy Systems, 20, 2144-2160.

Tešić, D., & Božanić, D. (2018). Application of the MAIRCA method in the selection of the location for crossing tanks under water, Tehnika, 68(6), 860-867.

Wang, J., Wei, G., Wei, C., & Wei, Y. (2020). MABAC method for multiple attribute group decision making under q-rung orthopair fuzzy environment. Defence Technology, 16(1), 208-216.

Wei, G., Wei, C., Wu, J., & Wang, H. (2019). Supplier Selection of Medical Consumption Products with a Probabilistic Linguistic MABAC Method, International Journal of Environmental Research and Public Health, 16(24), 5082.

Xu, X., Grace Guo, W., & Rodgers, M. D. (2020). A real-time decision support framework to mitigate degradation in perishable supply chains. Computers & Industrial Engineering, 150, 106905.

Zadeh, L.A. (1965). Fuzzy sets. Information and control, 8(3), 338-353.

Zimmermann, H.J. (1998). Fuzzy Set Theory and Its Applications. Boston: Kluwer.

Žižović, M., & Pamučar, D. (2019). New model for determining criteria weights: Level Based Weight Assessment (LBWA) model. Decision Making: Applications in Management and Engineering, 2(2), 126-137.

CALL FOR PAPERS AND ARTICLE FORMATTING INSTRUCTIONS

The instructions to authors about the article preparation for publication in the *Operational Research in Engineering Sciences: Theory and Applications (ORESTA)* are based on the Act on scientific journal editing of the Ministry of Science and Technological Development of the Republic of Serbia, No 110-00-17/2009-01 of 9th July 2009. This Act aims at improving the quality of national journals and raising the level of their compliance with the international system of scientific information exchange. It is based on international standards ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 and ISO 5122 and their national equivalents.

ORESTA publishes high quality scientific papers that contribute significantly to the fields of operational research in engineering science. *Operational Research in Engineering Sciences: Theory and Applications* (ORESTA) is an international peer-reviewed journal covering main aspects of operational research in engineering sciences. ORESTA publishes high quality, scientific papers that contribute to the fields of operational research. The journal covers new theories, applications, and reviews of optimization methods, decision-making, stochastic models, mathematical programming, simulation, game theory, queueing systems, inventory, scheduling, project management, decision-support systems, artificial intelligence, neural network, fuzzy logic, expert systems.

Articles present new theoretical insights and developments, as well as real-world case studies illustrating the practical implementation of operational research models. Full experimental and methodical details must be provided so that the results can be reproduced.

This is a unique feature of *ORESTA* compared to other existing operational research journals, providing a means to explore new directions in engineering research in a interdisciplinary context. Overview papers from eminent scientists in significant fields of engineering that review the state-of-the-art in these fields, are also welcome.

Manuscripts for *Operational Research in Engineering Sciences: Theory and Applications* should be submitted online at www.oresta.rabek.org. The submitting author, who is generally the corresponding author, is responsible for the manuscript during the submission and peer-review process. The submitting author must ensure that all eligible co-authors have been included in the author list and that they all have read and approved the submitted version of the manuscript. To submit your manuscript, register and log in to the submission page.

Accepted File Formats

Authors must use the Microsoft Word template (www.oresta.rabek.org) to prepare their manuscript. Using the template file will substantially shorten the time to complete copy-editing and publication of accepted manuscripts. Accepted file formats are:

- *Microsoft Word:* Manuscripts prepared in Microsoft Word must be converted into a single file before submission. When preparing manuscripts in Microsoft Word, the ORESTA template file must be used. Please insert your graphics (schemes, figures, *etc.*) in the main text after the paragraph of its first citation.
- *Supplementary files:* May be any format, but it is recommended that you use common, non-proprietary formats where possible.

All necessary files have been uploaded:

Manuscript:

- Include keywords;
- All figures (include relevant captions);
- All tables (including titles, description, footnotes);
- Ensure all figure and table citations in the text match the files provided;
- Indicate clearly if color should be used for any figures in print; Supplemental files (where applicable).

Reproducing Published Material from other Publishers

It is absolutely essential that authors obtain permission to reproduce any published material (figures, schemes, tables or any extract of a text) which does not fall into the public domain, or for which they do not hold the copyright. Permission should be requested by the authors from the copyrightholder (usually the Publisher, please refer to the imprint of the individual publications to identify the copyrightholder). Permission is required for: Your own works published by other Publishers and for which you did not retain copyright; Substantial extracts from anyones' works or a series of works; Use of Tables, Graphs, Charts, Schemes and Artworks if they are unaltered or slightly modified and Photographs for which you do not hold copyright.

Permission is not required for: (1) Reconstruction of your *own* table with data already published elsewhere. Please notice that in this case you must cite the source of the data in the form of either "Data from..." or "Adapted from..."; (2) Reasonably short quotes are considered *fair use* and therefore do not require permission; (3) Graphs, Charts, Schemes and Artworks that are completely redrawn by the authors and significantly changed beyond recognition do not require permission.

In order to avoid unnecessary delays in the publication process, you should start obtaining permissions as early as possible. If in any doubt about the copyright, apply for permission. ORESTA cannot publish material from other publications without permission.

The copyright holder may give you instructions on the form of acknowledgement to be followed; otherwise follow the style: "Reproduced with permission from [author], [book/journal title]; published by [publisher], [year].' at the end of the caption of the Table, Figure or Scheme.

Publication Ethics Statement

The editors of this journal enforce a rigorous peer-review process together with strict ethical policies and standards to ensure to add high quality scientific works to the field of scholarly publication. Unfortunately, cases of plagiarism, data falsification, image manipulation, inappropriate authorship credit, and the like, do arise. The editors of *Operational Research in Engineering Sciences: Theory and Applications* take such publishing ethics issues very seriously and are trained to proceed in such cases with a zero tolerance policy.

Authors wishing to publish their papers in *Operational Research in Engineering Sciences: Theory and Applications* must abide to the following:

- Any facts that might be perceived as a possible conflict of interest of the author(s) must be disclosed in the paper prior to submission.
- Authors should accurately present their research findings and include an objective discussion of the significance of their findings.
- Data and methods used in the research need to be presented in sufficient detail in the paper, so that other researchers can replicate the work.

- Raw data should preferably be publicly deposited by the authors before submission of their manuscript. Authors need to at least have the raw data readily available for presentation to the referees and the editors of the journal, if requested. Authors need to ensure appropriate measures are taken so that raw data is retained in full for a reasonable time after publication.
- Simultaneous submission of manuscripts to more than one journal is not tolerated.
- Republishing content that is not novel is not tolerated (for example, an English translation of a paper that is already published in another language will not be accepted).
- If errors and inaccuracies are found by the authors after publication of their paper, they need to be promptly communicated to the editors of this journal so that appropriate actions can be taken.
- Your manuscript should not contain any information that has already been published. If you include already published figures or images, please obtain the necessary permission from the copyright holder to publish under the CC-BY license.
- Plagiarism, data fabrication and image manipulation are not tolerated.

Plagiarism is not acceptable in *Operational Research in Engineering Sciences: Theory and Applications* submissions.

Plagiarism includes copying text, ideas, images, or data from another source, even from your own publications, without giving any credit to the original source.

Reuse of text that is copied from another source must be between quotes and the original source must be cited. If a study's design or the manuscript's structure or language has been inspired by previous works, these works must be explicitly cited.

If plagiarism is detected during the peer review process, the manuscript may be rejected. If plagiarism is detected after publication, we may publish a correction or retract the paper.

Image files must not be manipulated or adjusted in any way that could lead to misinterpretation of the information provided by the original image.

Irregular manipulation includes: 1) introduction, enhancement, moving, or removing features from the original image; 2) grouping of images that should obviously be presented separately (e.g., from different parts of the same gel, or from different gels); or 3) modifying the contrast, brightness or color balance to obscure, eliminate or enhance some information.

If irregular image manipulation is identified and confirmed during the peer review process, we may reject the manuscript. If irregular image manipulation is identified and confirmed after publication, we may correct or retract the paper.

Our editors will investigate any allegations of publication misconduct and may contact the authors' institutions or funders if necessary. If evidence of misconduct is found, appropriate action will be taken to correct or retract the publication. Authors are expected to comply with the best ethical publication practices when publishing in *Operational Research in Engineering Sciences: Theory and Applications* journal.

Preparation of a Manuscript

- *Research manuscripts* should comprise:
  - Front matter: Title, Author list, Affiliations, Abstract, Keywords
  - Research manuscript sections: Introduction, Materials and Methods, Results, Discussion, Conclusions (optional).

- Back matter: Supplementary Materials, Acknowledgments, Author Contributions, Conflicts of Interest, References.

– *Review manuscripts* should comprise the front matter, literature review sections and the back matter. The template file can also be used to prepare the front and back matter of your review manuscript.
– *Abbreviations* should be defined in parentheses the first time they appear in the abstract, main text, and in figure or table captions.
– *SI Units* (International System of Units) should be used. Imperial, US customary and other units should be converted to SI units whenever possible.
– *Equations*: If you are using Word, please use either the Microsoft Equation Editor or the MathType add-on. Equations should be editable by the editorial office and not appear in a picture format.
– *Research Data and supplementary materials*: Note that publication of your manuscript implies that you must make all materials, data, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information.

Front Matter

These sections should appear in all manuscript types
– *Title*: The title of your manuscript should be concise, specific and relevant. When decision making model names are included, the abbreviated name rather than full name should be used.
– *Author List and Affiliations*: Authors' full first and last names must be provided. The initials of any middle names can be added. The PubMed/MEDLINE standard format is used for affiliations: complete address information including city, zip code, state/province, country, and all email addresses. At least one author should be designated as corresponding author, and his or her email address and other details should be included at the end of the affiliation section..
– *Abstract*: The abstract should be a total of about 200 words maximum. The abstract should be a single paragraph and should follow the style of structured abstracts, but without headings: 1) Background: Place the question addressed in a broad context and highlight the purpose of the study; 2) Methods: Describe briefly the main methods or treatments applied. Include any relevant preregistration numbers, and species and strains of any animals used. 3) Results: Summarize the article's main findings; and 4) Conclusion: Indicate the main conclusions or interpretations. The abstract should be an objective representation of the article: it must not contain results which are not presented and substantiated in the main text and should not exaggerate the main conclusions.
– *Keywords*: Three to ten pertinent keywords need to be added after the abstract. We recommend that the keywords are specific to the article, yet reasonably common within the subject discipline.

Research Manuscript Sections

– *Introduction*: The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance, including specific hypotheses being tested. The current state of the research field should be reviewed carefully and key publications cited.

Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the main conclusions.

– *Materials and Methods*: They should be described with sufficient detail to allow others to replicate and build on published results. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited. Give the name and version of any software used and make clear whether computer code used is available. Include any pre-registration codes.
– *Results*: Provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.
– *Discussion*: Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible and limitations of the work highlighted. Future research directions should also be mentioned. This section may be combined with Results.
– *Conclusions*: This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

Back Matter

– *Supplementary Materials*: Describe any supplementary material published online alongside the manuscript (figure, tables, etc.). Please indicate the name and title of each element as follows Figure S1: title, Table S1: title, etc.
– *Acknowledgments*: All sources of funding of the study should be disclosed. Clearly indicate grants that you have received in support of your research work and if you received funds to cover publication costs.
– *Author Contributions*: Each author is expected to have made substantial contributions to the paper and has approved the submitted version. Authorship must include and be limited to those who have contributed substantially to the work.
– *Conflicts of Interest*: Authors must identify and declare any personal circumstances or interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results. If there is no conflict of interest, please state "The authors declare no conflict of interest."
– *References*: References must be numbered in order of appearance in the text (including table captions and figure legends) and listed individually at the end of the manuscript. Include the digital object identifier (DOI) for all references where available.

References

Citation in text

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

Web references

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Data references

This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

Text: Citations in the text should follow the referencing style used by the American Psychological Association.

List: references should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

Examples:

Reference to a journal publication:

Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2010). The art of writing a scientific article. Journal of Scientific Communications, 163, 51–59.

Reference to a book:

Strunk, W., Jr., & White, E. B. (2000). The elements of style. (4th ed.). New York: Longman, (Chapter 4). *Reference to a chapter in an edited book*:

Mettam, G. R., & Adams, L. B. (2009). How to prepare an electronic version of your article. In B. S. Jones, & R. Z. Smith (Eds.), Introduction to the electronic age (pp. 281–304). New York: E-Publishing Inc.

Reference to a website:

Cancer Research UK. Cancer statistics reports for the UK. (2003). http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ Accessed 13 March 2003.

Reference to a dataset:

[dataset] Oguro, M., Imahiro, S., Saito, S., Nakashizuka, T. (2015). Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, v1. https://doi.org/10.17632/ xwj98nb39r.1.

Journal abbreviations source

Journal names should be abbreviated according to the List of Title Word Abbreviations.

Preparing Figures, Schemes and Tables

- File for Figures and schemes must be provided during submission in a single zip archive and at a sufficiently high resolution (minimum 1000 pixels width/height, or a resolution of 300 dpi or higher). Common formats are accepted, however, TIFF, JPEG, EPS and PDF are preferred.
- All Figures, Schemes and Tables should be inserted into the main text close to their first citation and must be numbered following their number of appearance (Figure 1, Scheme I, Figure 2, Scheme II, Table 1,).
- All Figures, Schemes and Tables should have a short explanatory title and caption.
- All table columns should have an explanatory heading. To facilitate the copy-editing of larger tables, smaller fonts may be used, but no less than 8 pt. in size. Authors should use the Table option of Microsoft Word to create tables.
- Authors are encouraged to prepare figures and schemes in color (RGB at 8-bit per channel). There is no additional cost for publishing full color graphics.

Supplementary Materials and Software Source Code

Data Availability

In order to maintain the integrity, transparency and reproducibility of research records, authors must make their experimental and research data openly available either by depositing into data repositories or by publishing the data and files as supplementary information in this journal.

Computer Code and Software

For work where novel computer code was developed, authors should release the code either by depositing in a recognized, public repository or uploading as supplementary information to the publication. The name and version of all software used should be clearly indicated.

Supplementary Material

Additional data and files can be uploaded as "Supplementary Files" during the manuscript submission process. The supplementary files will also be available to the referees as part of the peer-review process. Any file format is acceptable, however we recommend that common, non-proprietary formats are used where possible.

References in Supplementary Files

Citations and References in Supplementary files are permitted provided that they also appear in the reference list of the main text.

Publishers:
Regional Association for Security and crisis management (RASEC) –
European Centre for Operational research (ECOR)

Graphic design
Mihailo Aleksić

Copy editing
Marija Starčević, RABEK

Supporting institutions:
Faculty of architecture, civil engineering and geodesy, University of Banja Luka and Serbian OR Society, the Member of IFORS

Financial support:
Regional Association for Security and crisis management (RASEC) –
European Centre for Operational research (ECOR)

Printing:
C-Štampa, Radomira Markovića 27, 11000, Belgrade
www.cprint.rs
e-mail: cprint.stampa@gmail.com

Printed in 30 copies

Frequency:

CIP - Catalogisation in the publication:
National Library of Serbia, Belgrade

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

62

OPERATIONAL Research in Engineering Sciences : Theory and Applications / editor-in-chief Željko Stević. - [Štampano izd.] . - Vol. 4, issue 1 (2021)- . - Belgrade : Regional Association for Security and crisis management : European Centre for Operational research, 2020- (Belgrade : C štampa). - 25 cm

Tri puta godišnje.
ISSN 2620-1607 = ORESTA. Operational Research in Engineering Sciences. Theory and Applications (Štampano izd.)
COBISS.SR-ID 270766604

UDC: National Library of Serbia, Belgrade