

GLOBAL JOURNAL

OF RESEARCHES IN ENGINEERING: G

Industrial Engineering

Internet of Things Approach

Digitalization of Fruits and Vegetables

Highlights

Malaysia TVET Higher Education

An Intervention Ergonomic Framework

Discovering Thoughts, Inventing Future

VOLUME 24

ISSUE 1

VERSION 1.0

© 2001-2024 by Global Journal of Researches in Engineering, USA



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: G
INDUSTRIAL ENGINEERING

GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: G
INDUSTRIAL ENGINEERING

VOLUME 24 ISSUE 1 (VER. 1.0)

OPEN ASSOCIATION OF RESEARCH SOCIETY

© Global Journal of
Researches in Engineering.
2024.

All rights reserved.

This is a special issue published in version 1.0
of "Global Journal of Researches in
Engineering." By Global Journals Inc.

All articles are open access articles distributed
under "Global Journal of Researches in
Engineering"

Reading License, which permits restricted use.
Entire contents are copyright by of "Global
Journal of Researches in Engineering" unless
otherwise noted on specific articles.

No part of this publication may be reproduced
or transmitted in any form or by any means,
electronic or mechanical, including
photocopy, recording, or any information
storage and retrieval system, without written
permission.

The opinions and statements made in this
book are those of the authors concerned.
Ultraculture has not verified and neither
confirms nor denies any of the foregoing and
no warranty or fitness is implied.

Engage with the contents herein at your own
risk.

The use of this journal, and the terms and
conditions for our providing information, is
governed by our Disclaimer, Terms and
Conditions and Privacy Policy given on our
website [http://globaljournals.us/terms-and-condition/
menu-id-1463/](http://globaljournals.us/terms-and-condition/menu-id-1463/).

By referring / using / reading / any type of
association / referencing this journal, this
signifies and you acknowledge that you have
read them and that you accept and will be
bound by the terms thereof.

All information, journals, this journal,
activities undertaken, materials, services and
our website, terms and conditions, privacy
policy, and this journal is subject to change
anytime without any prior notice.

Incorporation No.: 0423089
License No.: 42125/022010/1186
Registration No.: 430374
Import-Export Code: 1109007027
Employer Identification Number (EIN):
USA Tax ID: 98-0673427

Global Journals Inc.

(A Delaware USA Incorporation with "Good Standing"; **Reg. Number: 0423089**)

Sponsors: *Open Association of Research Society*

Open Scientific Standards

Publisher's Headquarters office

Global Journals® Headquarters
945th Concord Streets,
Framingham Massachusetts Pin: 01701,
United States of America

USA Toll Free: +001-888-839-7392

USA Toll Free Fax: +001-888-839-7392

Offset Typesetting

Global Journals Incorporated
2nd, Lansdowne, Lansdowne Rd., Croydon-Surrey,
Pin: CR9 2ER, United Kingdom

Packaging & Continental Dispatching

Global Journals Pvt Ltd
E-3130 Sudama Nagar, Near Gopur Square,
Indore, M.P., Pin: 452009, India

Find a correspondence nodal officer near you

To find nodal officer of your country, please
email us at local@globaljournals.org

eContacts

Press Inquiries: press@globaljournals.org

Investor Inquiries: investors@globaljournals.org

Technical Support: technology@globaljournals.org

Media & Releases: media@globaljournals.org

Pricing (Excluding Air Parcel Charges):

Yearly Subscription (Personal & Institutional)
250 USD (B/W) & 350 USD (Color)

EDITORIAL BOARD

GLOBAL JOURNAL OF RESEARCH IN ENGINEERING

Dr. Ren-Jye Dzung

Professor Civil Engineering, National Chiao-Tung University, Taiwan Dean of General Affairs, Ph.D., Civil & Environmental Engineering, University of Michigan United States

Dr. Iman Hajirasouliha

Ph.D. in Structural Engineering, Associate Professor, Department of Civil and Structural Engineering, University of Sheffield, United Kingdom

Dr. Ye Tian

Ph.D. Electrical Engineering The Pennsylvania State University 121 Electrical, Engineering East University Park, PA 16802, United States

Dr. Eric M. Lui

Ph.D., Structural Engineering, Department of Civil & Environmental Engineering, Syracuse University United States

Dr. Zi Chen

Ph.D. Department of Mechanical & Aerospace Engineering, Princeton University, US Assistant Professor, Thayer School of Engineering, Dartmouth College, Hanover, United States

Dr. T.S. Jang

Ph.D. Naval Architecture and Ocean Engineering, Seoul National University, Korea Director, Arctic Engineering Research Center, The Korea Ship and Offshore Research Institute, Pusan National University, South Korea

Dr. Ephraim Suhir

Ph.D., Dept. of Mechanics and Mathematics, Moscow University Moscow, Russia Bell Laboratories Physical Sciences and Engineering Research Division United States

Dr. Pangil Choi

Ph.D. Department of Civil, Environmental, and Construction Engineering, Texas Tech University, United States

Dr. Xianbo Zhao

Ph.D. Department of Building, National University of Singapore, Singapore, Senior Lecturer, Central Queensland University, Australia

Dr. Zhou Yufeng

Ph.D. Mechanical Engineering & Materials Science, Duke University, US Assistant Professor College of Engineering, Nanyang Technological University, Singapore

Dr. Pallav Purohit

Ph.D. Energy Policy and Planning, Indian Institute of Technology (IIT), Delhi Research Scientist, International Institute for Applied Systems Analysis (IIASA), Austria

Dr. Balasubramani R

Ph.D., (IT) in Faculty of Engg. & Tech. Professor & Head, Dept. of ISE at NMAM Institute of Technology

Dr. Sofoklis S. Makridis

B.Sc(Hons), M.Eng, Ph.D. Professor Department of Mechanical Engineering University of Western Macedonia, Greece

Dr. Steffen Lehmann

Faculty of Creative and Cultural Industries Ph.D., AA Dip University of Portsmouth United Kingdom

Dr. Wenfang Xie

Ph.D., Department of Electrical Engineering, Hong Kong Polytechnic University, Department of Automatic Control, Beijing University of Aeronautics and Astronautics China

Dr. Hai-Wen Li

Ph.D., Materials Engineering, Kyushu University, Fukuoka, Guest Professor at Aarhus University, Japan

Dr. Saeed Chehreh Chelgani

Ph.D. in Mineral Processing University of Western Ontario, Adjunct professor, Mining engineering and Mineral processing, University of Michigan United States

Belen Riveiro

Ph.D., School of Industrial Engineering, University of Vigo Spain

Dr. Adel Al Jumaily

Ph.D. Electrical Engineering (AI), Faculty of Engineering and IT, University of Technology, Sydney

Dr. Maciej Gucma

Assistant Professor, Maritime Univeristy of Szczecin Szczecin, Ph.D.. Eng. Master Mariner, Poland

Dr. M. Meguellati

Department of Electronics, University of Batna, Batna 05000, Algeria

Dr. Haijian Shi

Ph.D. Civil Engineering Structural Engineering Oakland, CA, United States

Dr. Chao Wang

Ph.D. in Computational Mechanics Rosharon, TX, United States

Dr. Joaquim Carneiro

Ph.D. in Mechanical Engineering, Faculty of Engineering, University of Porto (FEUP), University of Minho, Department of Physics Portugal

Dr. Wei-Hsin Chen

Ph.D., National Cheng Kung University, Department of Aeronautics, and Astronautics, Taiwan

Dr. Bin Chen

B.Sc., M.Sc., Ph.D., Xian Jiaotong University, China. State Key Laboratory of Multiphase Flow in Power Engineering Xi'an Jiaotong University, China

Dr. Charles-Darwin Annan

Ph.D., Professor Civil and Water Engineering University Laval, Canada

Dr. Jalal Kafashan

Mechanical Engineering Division of Mechatronics KU Leuven, Belgium

Dr. Alex W. Dawotola

Hydraulic Engineering Section, Delft University of Technology, Stevinweg, Delft, Netherlands

Dr. Shun-Chung Lee

Department of Resources Engineering, National Cheng Kung University, Taiwan

Dr. Gordana Colovic

B.Sc Textile Technology, M.Sc. Technical Science Ph.D. in Industrial Management. The College of Textile? Design, Technology and Management, Belgrade, Serbia

Dr. Giacomo Risitano

Ph.D., Industrial Engineering at University of Perugia (Italy) "Automotive Design" at Engineering Department of Messina University (Messina) Italy

Dr. Maurizio Palesi

Ph.D. in Computer Engineering, University of Catania, Faculty of Engineering and Architecture Italy

Dr. Salvatore Brischetto

Ph.D. in Aerospace Engineering, Polytechnic University of Turin and in Mechanics, Paris West University Nanterre La D?fense Department of Mechanical and Aerospace Engineering, Polytechnic University of Turin, Italy

Dr. Wesam S. Alaloul

B.Sc., M.Sc., Ph.D. in Civil and Environmental Engineering, University Technology Petronas, Malaysia

Dr. Ananda Kumar Palaniappan

B.Sc., MBA, MED, Ph.D. in Civil and Environmental Engineering, Ph.D. University of Malaya, Malaysia, University of Malaya, Malaysia

Dr. Hugo Silva

Associate Professor, University of Minho, Department of Civil Engineering, Ph.D., Civil Engineering, University of Minho Portugal

Dr. Fausto Gallucci

Associate Professor, Chemical Process Intensification (SPI), Faculty of Chemical Engineering and Chemistry Assistant Editor, International J. Hydrogen Energy, Netherlands

Dr. Philip T Moore

Ph.D., Graduate Master Supervisor School of Information Science and engineering Lanzhou University China

Dr. Cesar M. A. Vasques

Ph.D., Mechanical Engineering, Department of Mechanical Engineering, School of Engineering, Polytechnic of Porto Porto, Portugal

Dr. Jun Wang

Ph.D. in Architecture, University of Hong Kong, China Urban Studies City University of Hong Kong, China

Dr. Stefano Invernizzi

Ph.D. in Structural Engineering Technical University of Turin, Department of Structural, Geotechnical and Building Engineering, Italy

Dr. Togay Ozbakkaloglu

B.Sc. in Civil Engineering, Ph.D. in Structural Engineering, University of Ottawa, Canada Senior Lecturer University of Adelaide, Australia

Dr. Zhen Yuan

B.E., Ph.D. in Mechanical Engineering University of Sciences and Technology of China, China Professor, Faculty of Health Sciences, University of Macau, China

Dr. Jui-Sheng Chou

Ph.D. University of Texas at Austin, U.S.A. Department of Civil and Construction Engineering National Taiwan University of Science and Technology (Taiwan Tech)

Dr. Houfa Shen

Ph.D. Manufacturing Engineering, Mechanical Engineering, Structural Engineering, Department of Mechanical Engineering, Tsinghua University, China

Prof. (LU), (UoS) Dr. Miklas Scholz

Cand Ing, BEng (equiv), PgC, MSc, Ph.D., CWEM, CEnv, CSci, CEng, FHEA, FIEMA, FCIWEM, FICE, Fellow of IWA, VINNOVA Fellow, Marie Curie Senior, Fellow, Chair in Civil Engineering (UoS) Wetland Systems, Sustainable Drainage, and Water Quality

Dr. Yudong Zhang

B.S., M.S., Ph.D. Signal and Information Processing, Southeast University Professor School of Information Science and Technology at Nanjing Normal University, China

Dr. Minghua He

Department of Civil Engineering Tsinghua University Beijing, 100084, China

Dr. Philip G. Moscoso

Technology and Operations Management IESE Business School, University of Navarra Ph.D. in Industrial Engineering and Management, ETH Zurich M.Sc. in Chemical Engineering, ETH Zurich, Spain

Dr. Stefano Mariani

Associate Professor, Structural Mechanics, Department of Civil and Environmental Engineering, Ph.D., in Structural Engineering Polytechnic University of Milan Italy

Dr. Ciprian Lapusan

Ph. D in Mechanical Engineering Technical University of Cluj-Napoca Cluj-Napoca (Romania)

Dr. Francesco Tornabene

Ph.D. in Structural Mechanics, University of Bologna Professor Department of Civil, Chemical, Environmental and Materials Engineering University of Bologna, Italy

Dr. Kitipong Jaojaruek

B. Eng, M. Eng, D. Eng (Energy Technology, Asian Institute of Technology). Kasetsart University Kamphaeng Saen (KPS) Campus Energy Research Laboratory of Mechanical Engineering

Dr. Burcin Becerik-Gerber

University of Southern California Ph.D. in Civil Engineering Ddes, from Harvard University M.S. from University of California, Berkeley M.S. from Istanbul, Technical University

Hiroshi Sekimoto

Professor Emeritus Tokyo Institute of Technology Japan Ph.D., University of California Berkeley

Dr. Shaoping Xiao

BS, MS Ph.D. Mechanical Engineering, Northwestern University The University of Iowa, Department of Mechanical and Industrial Engineering Center for Computer-Aided Design

Dr. A. Stegou-Sagia

Ph.D., Mechanical Engineering, Environmental Engineering School of Mechanical Engineering, National Technical University of Athens, Greece

Diego Gonzalez-Aguilera

Ph.D. Dep. Cartographic and Land Engineering, University of Salamanca, Avilla, Spain

Dr. Maria Daniela

Ph.D in Aerospace Science and Technologies Second University of Naples, Research Fellow University of Naples Federico II, Italy

Dr. Omid Gohardani

Ph.D. Senior Aerospace/Mechanical/ Aeronautical,
Engineering professional M.Sc. Mechanical Engineering,
M.Sc. Aeronautical Engineering B.Sc. Vehicle
Engineering Orange County, California, US

Dr. Paolo Veronesi

Ph.D., Materials Engineering, Institute of Electronics,
Italy President of the master Degree in Materials
Engineering Dept. of Engineering, Italy

CONTENTS OF THE ISSUE

- i. Copyright Notice
 - ii. Editorial Board Members
 - iii. Chief Author and Dean
 - iv. Contents of the Issue
-
- 1. An Intervention Ergonomic Framework for Malaysia TVET Higher Education. *1-9*
 - 2. Towards Digitalization of Fruits and Vegetables Supply Chain: Digital Twins and Internet of Things Approach. *11-20*
 - 3. Systems Energodynamic Approach as an Instrument of Increasing Efficiency of Engineering Developments. *21-34*
 - 4. Optimizing Smart Factories: A Data-Driven Approach. *35-50*
-
- v. Fellows
 - vi. Auxiliary Memberships
 - vii. Preferred Author Guidelines
 - viii. Index



An Intervention Ergonomic Framework for Malaysia TVET Higher Education

By Khairul Fahzan Bin Salleh & Politeknik Sultan Salahuddin Abdul Aziz Shah

Abstract- Fundamentally an intervention refers to an action that has an agenda and is aimed by the human being to create change (Midgley 2020) according to him if the intervention is an action aimed by the human being to create change, then systemic intervention is an action aimed at creating a change in the context of reflection to the system. The International Association of ergonomics (IEA) categorizes ergonomics into three specific domains: physical, organizational, and cognitive ergonomics. The physical domain is concerned with human anatomy, anthropometry, physiological and biomechanical characteristics associated with physical activity. The domain also consists of working environments and equipment, such as hand tools, workstations and lighting and ventilation in the workplace. The domain of the organization, referring to the concern for the optimization of work systems, including organizing and even work processes for example as a frequency of work, work cycle and rest, in addition to directing in performing work. The cognitive domain is related to mental processes, such as perception, memory, judgment, and motor response.

Keywords: *intervention, ergonomics, physical, organizational, cognitive.*

GJRE-G Classification: *FOR Code: 130202*



AN INTERVENTION ERGONOMIC FRAMEWORK FOR MALAYSIA TVET HIGHER EDUCATION

Strictly as per the compliance and regulations of:



RESEARCH | DIVERSITY | ETHICS

An Intervention Ergonomic Framework for Malaysia TVET Higher Education

Khairul Fahzan Bin Salleh ^α & Politeknik Sultan Salahuddin Abdul Aziz Shah ^σ

Abstract- Fundamentally an intervention refers to an action that has an agenda and is aimed by the human being to create change (Midgley 2020) according to him if the intervention is an action aimed by the human being to create change, then systemic intervention is an action aimed at creating a change in the context of reflection to the system. The International Association of ergonomics (IEA) categorizes ergonomics into three specific domains: physical, organizational, and cognitive ergonomics. The physical domain is concerned with human anatomy, anthropometry, physiological and biomechanical characteristics associated with physical activity. The domain also consists of working environments and equipment, such as hand tools, workstations and lighting and ventilation in the workplace. The domain of the organization, referring to the concern for the optimization of work systems, including organizing and even work processes for example as a frequency of work, work cycle and rest, in addition to directing in performing work. The cognitive domain is related to mental processes, such as perception, memory, judgment, and motor response. Therefore, the ergonomic interventions developed should cover all three ergonomic domains, namely physical, organizational, and cognitive. Good ergonomic interventions must be carried out prior to the occurrence or reporting of skeletal disorders. It is one of the proactive or preventive methods in ensuring the health of a community such as students, lecturers, and employees at a good level. However, corrective reactive actions still need to be maintained and taken seriously to curb the symptoms of skeletal disorders.

Keywords: *intervention, ergonomics, physical, organizational, cognitive.*

1. INTRODUCTION

Numerous studies have found that ergonomic factors associated with MSD symptoms (Ashley et al. 2008; Xie et al. 2016). Adjustment of physical, organizational, and cognitive ergonomic factors aimed at reducing the physical and mental burden on employees certainly reduces the risk of employees getting work-related MSDs, especially upper limbs, neck or both. Physical ergonomic interventions include providing workspaces and equipment based on the principles of employee ergonomics and anthropometry. This will reduce physical tension to the body's skeletal system, thereby automatically reducing the risk of injury. For example, the use of a separate keyboard was found to reduce the severity of MSD pain in computer users (Tittiranonda et al. 1999). Engineering interventions are part of physical ergonomic interventions such as the use of adjustable platforms to

prevent lifting from floor level can be used. Organizational ergonomic interventions consist of the optimization of working intervals with rest time for the skeletal system, thus indirectly reducing the risk of performing work in the long term. Among the examples is the extra rest time for tasks to lock data into the system (Wendsche & Lohmann-haislah 2016). In addition, exposure training to good ergonomic practices and principles (Baydur & Demiral 2016) is also part of the organization's ergonomic interventions. Administrative interventions focus on changing tasks or work designs such as the introduction of work rotation, or the implementation of safe work policies, such as at least two people required during large and heavy load lifts. Cognitive ergonomic interventions consist of improving mental abilities of processing such as perception, memory and logical considerations, in addition to that also motor response through work process modification as well as training that is a safe working practice as well as part of cognitive ergonomic interventions. This will directly reduce mental workload, increase reliability, and reduce errors. However, it may only have an indirect effect in reducing tension in the body's skeletal system physically. Behavioural interventions focus on individual behaviour. Behavioural interventions refer to focusing on fitness or strength levels. In line with the Guidelines on Ergonomic Risk Assessment at Work by the Department of Occupational Safety and Health, Ministry of Human Resource in 2017. Early detection of symptoms should be emphasized through sensory detection or skeletal discomfort.

Generally, polytechnic students will be burdened with a total of around 25 hours of formal learning per week depending on the credit hours taken for prime students. at least 4 hours of it is practical work. The implementation of this learning period continues for 14 weeks of lecture for each semester. The practice of welding engineering is one of the practical subjects for students who major in mechanical engineering, and it is a mandatory graduation requirement. Generally, students will take practical subjects for 3 semesters starting from semester 1 to 3 and will be connected with 2 semester as a semester 4 and 5 in project subjects. For the practical subject of welding, there are 3 mandatory tasks which are to continue meeting, connect the open 't' and continue the contact every semester. This 4-hour-a-week period requires students to perform their assignments properly and quality, as

Author α: e-mail: khairul.fahzan@gmail.com

there are certain rubrics that form the basis of the assessment, and the impact will be on the grade of value points that will be obtained at the end of the semester.

MSD can occur when performing repetitive tasks continuously, working in abnormal and awkward postures, doing heavy physical work, and using strong energy.

A common ergonomic hazard factor present during the welding process is a static and prolonged posture position, in addition to that when the posture is awkward and exposure to fumes. These ergonomic risk factors may cause MSD associated with welding activities. MSD is an injury and disease that affects the condition of muscles, nerves, tendons, ligaments, blood vessels and bones. As a result, the welder easily suffers from fatigue, lethargy, and suffering from injuries. Therefore, if the welder is not in a good level of fitness to perform the task, the quality of welding can also be affected. Poor welding quality occurs when there are defects in the welding area such as porosity, excessive splashing, incomplete connection, lack of penetration rate, excessive penetration, burning and bending (Waters & Dick 2015) (Jaffar et al. 2011) (Kalpakjian & Schmid 2009).

Static position refers to a person who is in the same position or posture in a period throughout the performance of work. In order to maintain a static posture while performing the task, this condition will cause muscle tension or fatigue which is a factor in the risk of MSD. The duration of the posture position of the body, the awkward position of the posture, and the level of energy used will affect the degree of risk of injury. Static position can also be referred to as static load.

Based on epidemiological studies, occupational factors can potentially increase the risk of musculoskeletal disorders. The frequency of musculoskeletal complaints varies significantly between different employment groups. Therefore, different occupational factors can cause different MSD pain.

Basically an intervention refers to an action that has an agenda and is aimed at by human beings to create change (Midgley 2020) according to Midgley also If an intervention is an action aimed by man to create change, then systemic intervention is an action aimed at creating a change in the context of reflection to the system. The International Association of ergonomics (IEA) catalyses ergonomics into three specific domains: physical, organizational and cognitive ergonomics. The physical domain is as concerned with human anatomy, anthropometry, physiological and biomechanical characteristics as they relate to physical activity. The domain consists of working environments and equipment, such as hand tools, workstations and lighting and ventilation in the workplace. The organization's domain focuses on job system optimization, including organization and work

processes, such as work frequency, work-break cycles, and directing in performing work. The cognitive domain is related to mental processes, such as perception, memory, decision-making and motor response. Therefore, the ergonomics interventions developed should cover all three ergonomic domains, namely physically, organizational and cognitive. Good ergonomic interventions must be carried out prior to the occurrence or reporting of skeletal disorders. It is one of the proactive or preventive methods in ensuring the health of a community such as students, lecturers and employees at a good level. However, reactive action in the form of correction should also be taken to curb the symptoms of skeletal disorders becoming more serious.

II. LITERATURE REVIEW

The 3 'E' injury prevention framework is a common injury prevention framework. Usually 3'E' will refer to Education, Engineering and Enforcement. The acronym 3 'E' refers to education which is related to knowledge and translation of skills, engineering i.e., environment and building materials and materials built and not built as well as enforcement i.e., compliance with OSH policies, laws and regulations related to OSH. The 3 E approach was created in 1923 by the director of the Kansas City Safety Council, Julien H Harvey, in his discussion on road traffic safety. Through the passage of time the 3 E approach has been expanded by including additional 'E' such as Exposure, exam, equality and even emergency. This framework actually focuses more on considering human behaviour.

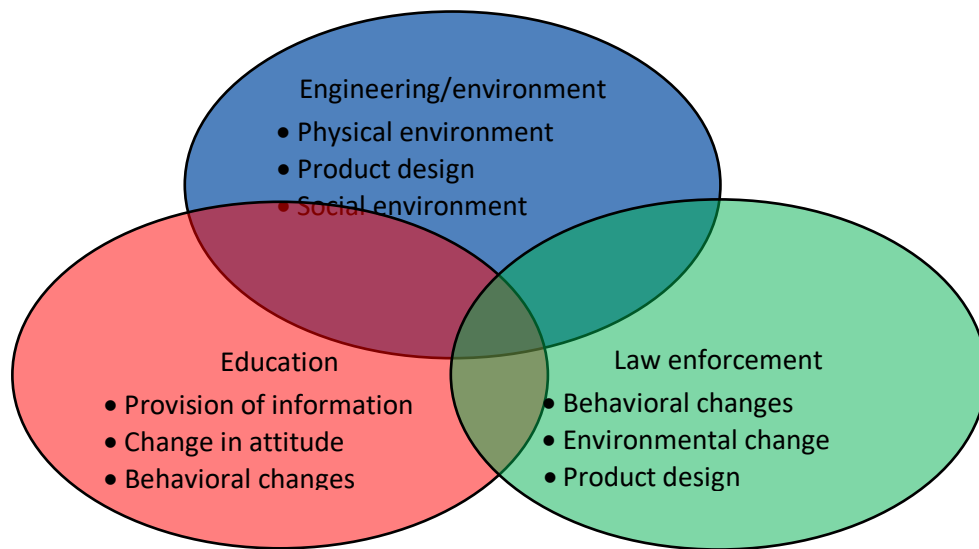


Figure 1: 3E model of injury prevention

Macro Ergonomics is a human-centered ergonomic because it considers the professional and psychosocial characteristics of employees in planning System work and then bring the design of the working system through the ergonomic design of specific jobs and related hardware and software interfaces. According to Hendrick and Kleiner (2001), macro-ergonomics is a top-down approach, a strategic approach to analysis, The main focus on macro-ergonomics is that the analysis and design of the working system will participate in a balanced manner. (Imada 2007). Macro-ergonomics human-centered and ergonomic participation are the main focus in macro-ergonomics involving workers at All organizational stage in the design process. (Hal W. Hendrick 2000) has defined several ergonomic 'levels'. These include:

- *Human machine: hardware ergonomics:* It mainly relates to physical characteristics and human perception to control designs, displays, seats, workstations and is used for the arrangement of related workspaces.
- *Human environment: environmental ergonomics:* It deals with the effects of various physical environmental factors, such as lighting, heat, cold, sound and vibration, human performance, and is used to design physical environments for humans.
- *Human software: cognitive ergonomics:* It is related to the way people think, conceptualize, and process information, and is used for software design.
- *Human work: work design ergonomics:* It is related to job design to ensure the correct workload and characteristics such as multitasking or having different meaningful things to do in work identity or a sense of job solidity, importance or autonomy or control of the perceived meaning of work over one's work, and feedback or knowledge of results.
- *Human organization: macro-ergonomics:* It relates to employee intermediaries with the organizational design of a more effective work system to use both personnel and technologies used in the system in responding to the external environment of the organization.

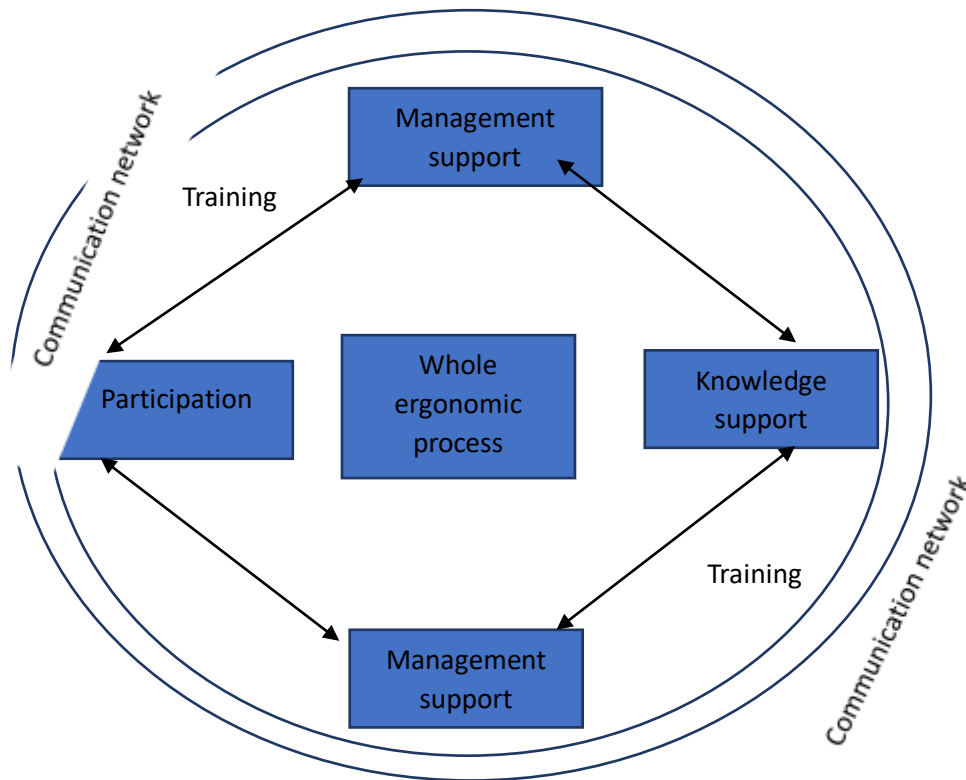


Figure 1: Overall evaluation model of ergonomics and intervention process

Since ergonomic interventions are a process of improvement in all aspects of the organization's activities, the appropriate model for implementing interventions should aim to include all aspects of the organization to address as many types of issues as possible. In general, these issues relate to technological innovation and organizational and environmental changes. From this point of view, (Hosseini et al. 2012), proposes as in Figure 2 for ergonomic interventions based on four principles:

- Management and logistics support,
- Knowledge support,
- HR participation and
- Motivation through evaluation, recognition and reward.

Thus, ergonomic intervention is a process developed by managers, staff and members of the working group through contact. Another element of the model is feedback, prepared and designed on the basis of four principles of this model. Corresponding communication systems and networks are established between those involved in the intervention to establish this framework to ensure continuity. Training is also seen as a core element of the model, as ergonomic interventions begin and end with training. Ergonomic training and knowledge is an ongoing process in which the state of intervention of ergonomic knowledge is

provided in the system (Abarghouei, Nasab, 2012). Training allows the transmission of organizational knowledge and helps participants understand how to use certain ergonomic interventions in different working groups. In addition, training ensures a deep understanding of how to actually implement a step or decision that is not ergonomic. Ergonomic intervention is a long-term process and it requires the constant support of management. Feedback becomes important when it is the only indicator of the measures that have been implemented fulfilling the original goal. Feedback should be in the form required by a particular group. "The management system should encourage working team members to be active and continue to participate. Therefore, for a successful and continuous intervention process, the evaluation and monitoring system should be considered (Hosseini et al. 2012). The intervention process should be evaluated at regular intervals by a management-certified assessment team to confirm the progress of the intervention. Along with a robust evaluation system, good progress needs to be encouraged and praised. Those involved in this intervention should be encouraged to collaborate among members of the organization. Typically, activities cause increased production, improvement in quality of work, improvement of health, safety and satisfaction of staff and job safety (Abarghouei, Nasab, 2012). In order

to improve intervention results and effectiveness, management needs to provide adequate support for all measures and implementation efforts. The main thing is that top management must turn ergonomically related work procedures into a significant part of the organizational culture. Communication between top management and employees can bring the possibility of avoiding certain risks and quickly addressing all the issues and job risks that frighten the organization.

This model has a systemic structure because all of the above elements are interconnected and operate together with the aim of ensuring efficient ergonomic interventions.

III. DATA AND FINDING

In order to ensure that this intervention is reliable and able to achieve the Desire as a leading indicator, the views of the welding experts comprising academics and practitioners should be considered.

a) Cohen Kappa Test

The study protocol questions as listed in Table 3.5 of the interview question protocol. Where it is built through the results of intervention theories such as the intervention model developed in the previous section.

Table 1: The value of the cohen kappa index and the consent scale

Cappa value	Scale of consent
Below 0.00	Very weak
0.00-0.20	Weak
0.21-0.40	Moderately weak
0.41-0.60	Simple
0.61-0.80	Good
0.81-1.00	Very nice

The value of *Cohen Kappa* can be calculated by referring to the following formula:

$$K = \frac{f_a - f_c}{n - f_c}$$

Based on the following formula, the calculation of the Cohen Kappa reliability index for ergonomic intervention interviews at TVET institutions in Table 3.12 such as following:

Where:

K – Coefficient value

fa – Frequency of consent

fc – Frequency of 50% expected agreement

N – Number of units assessed by consent

Based on the following formula, the calculation of the Cohen *Kappa reliability index* for ergonomic intervention interviews at TVET institutions in Table 3.12 such as following:

Table 2: Data Cohen Kappa (K) between expert panels

Cohen Kappa (K) test					
			2		Total
			yes	no	
1	yes	Count	10	1	11
		Expected Count	6.5	4.5	11.0
	no	Count	0	6	6
		Expected Count	3.5	2.5	6.0
Total		Count	10	7	17
		Expected Count	10.0	7.0	17.0

Table 3: Kohan Kappa Analysis

Symmetric Measures					
		Value	Asymp. Std. Error ^a	Approx. Tb	Approx. Sig.
Measure of Agreement	Kappa	0.876	0.119	3.640	0.000
N of Valid Cases		17			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					

b) *Ergonomic Intervention Questions*

1. Is there ergonomic training or ergonomic intervention program to students of your institution
2. What is the level of success of the program in your institution now
3. Who should be involved in ergonomic intervention programmes or ergonomic training
4. What is the most important element in the development of ergonomic training or ergonomic intervention programs to students
5. What are the data or studies conducted on your institution in relation to MSD injuries
6. If students are given adequate training and are aware of ergonomic hazards, can MSD injuries in your institution be avoided
7. In the context of ergonomic programmes in tvet institutions, student behaviour is a factor that contributes to ergonomic injury (MSD) during practice
8. Should a comprehensive ergonomic intervention programme be applied in the syllabus related to the workshop
9. What exposure to ergonomic interventions is required for students to leave work after the end of employment
10. Is there a need in integrating theoretical and practical related ergonomic interventions in any subject during study
11. What is the main content needed in ensuring that ergonomic interventions deliver good results
12. Do tvet institutions require a suitable ergonomic intervention program for the entire tvet system (1 system fit to all)
13. Other things to include in the development of the ergonomic intervention program to be developed

The result of the expert's view states that 11 items are accepted for use as interview protocols to informants i.e. items 1 and 2 in the informant background as well as items 1,2,3,4,6,7,8 and 13. Although there are differences of opinion between experts on item 5 on the part of the ergonomic intervention, the item is still used in obtaining data from informants for interview sessions. Last 6 items were dropped i.e. items 3 and 4 on the informant background as well as item 9,10,11,12 for the ergonomic intervention section. In total only 11 items are applied to the interview protocol conducted to the informant with 10 items agreed on a basis, 1 item there is a difference of opinion between the expert as a whole and 6 items disagree and be dropped.

Table 1 showing the results of Cohen Kappa's reliability agreement. According to expert assessment for ergonomic intervention interviews. For this purpose, the researcher employs the services of two field experts who are assumed to be sufficient to see consent weighting as suggested by Cohen (1960). The

assessment, found that the coefficient value (K) of 0.746. The value shows a good consensus level between experts 1 and 2 at the level of 5% understanding. In addition, (Bogdan & Biklen 2003) Declaring supervisor verification is one of the forms of data reliability methods. The supervisor's verification can also help in terms of the regularity of the studies carried out. For this study, both the method of validity and reliability was implemented, namely through the calculation of the alpha coefficient of Cronbach and the review of the supervisor.

c) *Proposed for Implementation Ergonomic Interventions of Malaysia TVET Institutions*

The findings of the interview from the informant, found that ergonomic interventions need to be comprehensive in addition to meeting the criteria as one of the leading indicators for osh ergonomic interventions can be broken down into 3 phased clusters i.e. physical, organizational, and cognitive. This is in line with the framework that has been planned at the previous stage.

i. *Physical Ergonomic Interventions*

This intervention specialises directly in the prevention of work-related MSDs, especially those at high risk of the neck, back and thighs. Among the ergonomic interventions that can be implemented are through the approach.

- Implementation of posture assessment
- Use of technology
- Workplace layout and conditional environment

Through the approach of implementing posture assessment in the early stages. Enabling students and citizens of TVET institutions involved in the commission of work to be detected or prevented before the occurrence of skeletal disorders (MSD) among the proposed instruments is the use of posture assessment when performing REBA work. The assessment of this posture is not just a data analysis but it will be able to provide a different point of view to the perpetrator by knowing the appropriate posture position while carrying out welding work. For the use of technology, the initial intention was to minimize the risks to the implementer including the use of appropriate self-protection devices such as gloves that are able to provide a comfortable grip, anti-tremor and grip perfectly. In addition, the design of the workplace should be suitable for the work performer, for example, it can be adjusted according to the height and suitable workspace and not too large to prevent the perpetrator from placing side workpieces and causing twisted body.

The layout of the workplace and the conducive environment refer directly to the terms of lighting, ventilation and noise sources. Appropriate lighting is able to help with good posture while performing the proposed lighting work for the workshop is around 300

lux according to the recommendations from DOSH in the 2008 workplace lighting guidelines. This is because the executor does not need to bend to carry out the work to see the results of the completed work. As is generally known the workshops are mostly hot works involving heat especially welding work therefore a good ventilation system is indispensable. The use of natural ventilation alone may not be sufficient to ensure that the fumes produced during the work of the welding are not sucked into the lungs. Therefore, the use of effective ventilation such as the use of LEV to trap fumes and fans for surrounding ventilation is very helpful. The last is noise related, basically the welding workplace will be designed by isolating between one welder and the other using a permanent or temporary barrier. The issue is that when there is noise, the noise reflecting onto the barrier can double and this can cause the noise to pass the threshold of 85dba. Therefore, the arrangement of welders in the workplace on a non-adjacent basis can reduce the risk of welders by imprisoning from noise sources. The use of sound soaking.

ii. Organizational Ergonomic Interventions

Organizational ergonomic interventions are broken down into two levels of administrators and implementers. Slightly different from physical intervention, it is private in nature. But for organizational ergonomic interventions it is group in nature. Among the preventive measures or organizational interventions that can be implemented are;

- Early exposure of ergonomic education and training
- Management support for ergonomic interventions
- Management of skeletal risk during the implementation of work

Through the approach Early exposure of ergonomic education and training can provide new dement to the need for occupational disease prevention. The fact is that there are tvet institutions that are able to implement exposure as early as semester 1 of diploma studies through the application of OSH subjects. However, this initial exposure is theoretical learning only and does not succeed in integrating with physical training. Among the essences that should be present in such ergonomic education and training are ergonomic theory, good posture, effects and consequences of skeletal disorders of the body and most important is to self-assess the current state of sensation of body disorder. To support the concept of prevention, the executor should be able to obtain early exposure to education and to ergonomic interventions. When they know they will be conscious when they are aware that they will control and avoid the risk of self-awareness This is an important element to shape an individual's attitude. These social attitudes or values include effective aspects (feelings towards an object), behaviour (the tendency to act on behaviour).

Ergonomic intervention education and training should be carried out regularly. ini to ensure that they are able to change from attitude to culture. Referring to this pearl of the word "*practice makes perfect*" gives the impression that the exercises performed continuously will produce results that Perfect. The same goes for developing individual skills requires early exposure and continuous training to students to be better prepared with the realm of work. Efficacy research is also very important and needs to be carried out to prevent such matters from achieving objectives and not waste. a checklist of ergonomic interventions should be available to facilitate the evaluation and effectiveness of ergonomic interventions in line with this concept of plan, do, check and follow-up action (PDCA) because ergonomic interventions are dynamic and always need improvement.

Management support for ergonomic interventions is very significant in ensuring that ergonomic interventions are successful. The establishment of a policy of ergonomic intervention and safe work should be accelerated. With the existence of this intervention policy, it demonstrates management's commitment. It will be followed by the provision of provisions that support ergonomic interventions and the acquisition of supporting equipment to ergonomic intervene and bodily injury. Often the program in TVET institutions are zero exclusively for students only or for employees only or for management only. For ergonomic interventions it should be inclusive regardless of the person's background and level. This is due to occupational diseases not only towards students or employees but to all. Among the factors of the feasibility of ergonomic interventions is through physical and financial support from management.

The last for organizational intervention is the management of the risk of using the skeleton during the implementation of the work. The management can implement the work implementation schedule by applying the concept of micro breaks, or the frequency of every 10 minutes of work will be given a short break of about 30 seconds. This break refers to a passive state (no activity) nor active rest (a combination of rest with stretching or light exercise). Not least the start of a working session with a meting toolbox as well as exercise activities and brief stretching to prepare the body physically and mentally to perform the task. In addition, the distribution of hand bills or pocket-sized safe work leaflets is capable of self-warning. Changes from sop standard operating procedure to safe operating procedure are also preventive measures or ergonomic risk mitigation measures.

Generally, when an organization achieves a level of self-awareness, it will indirectly stimulate the culture of ergonomic interventions.

iii. *Cognitive Ergonomic Interventions*

The last ergonomic intervention is a congenital ergonomic intervention. it is the best of these interventions, this because this intervention involves the whole institution. Not just the management or the employees or the students. It is collective and comprehensive, between and contained in the cognitive ergonomic intervention is to establishment of a culture of intervention.

Applying a culture of intersensitivity and safe work is not easy. In general, basic and mid-level interventions i.e. physical and organizational ergonomic interventions should be achieved in whole or in part. The establishment of specialized officers who manage OSH matters, especially occupational diseases such as MSD disorder problems, are also among the factors that are seen to be a catalyst for the culture of the intervention. Many workplaces only chant a culture of safe work but when it comes to occupational diseases no one takes care or even takes indifferent action. Apart from that recognition is also able to help the culture of intervention bloom in TVET institutions. In contrast to the approach by always showing tvet citizens with punishment is better approach positively through internally and externally implemented. There have been many organizations that have implemented the recognition of OSH such as the government through national council for occupational safety and health (NCOSH) and department of occupational safety and health (DOSH)

as well as non-governmental organizations such as the MALAYSIAN SOCIETY FOR OCCUPATIONAL SAFETY & HEALTH (MSOSH) association. Evaluation of occupational diseases such as skeletal gagging (MSD) problems at the end of the study should be carried out in order to ensure that the workforce produced by TVET institutions is certified healthy and able to enter the job market. Therefore, students are not only provided with academic transcripts, but occupational disease-free testimonials can also be included. Creating a holistic occupational disease reference center for TVET institutions is also capable of enhancing the image of TVET institutions. This reference center is not just to store data on occupational diseases but to be a training center for the same use in different TVET institutions of the ministry to raise awareness of occupational diseases especially in ergonomic issues, regardless of the development of the syllabus, selection of workplace design and the implementation of ergonomic interventions. The operation of this reference center can be with the industry in achieving the reduction of occupational diseases in the future.

IV. RESULT

a) *Intervention Framework Recommendations*

The findings of ergonomic interventions in practical work in TVET institutions can be formulated in Figure 3 as follows:

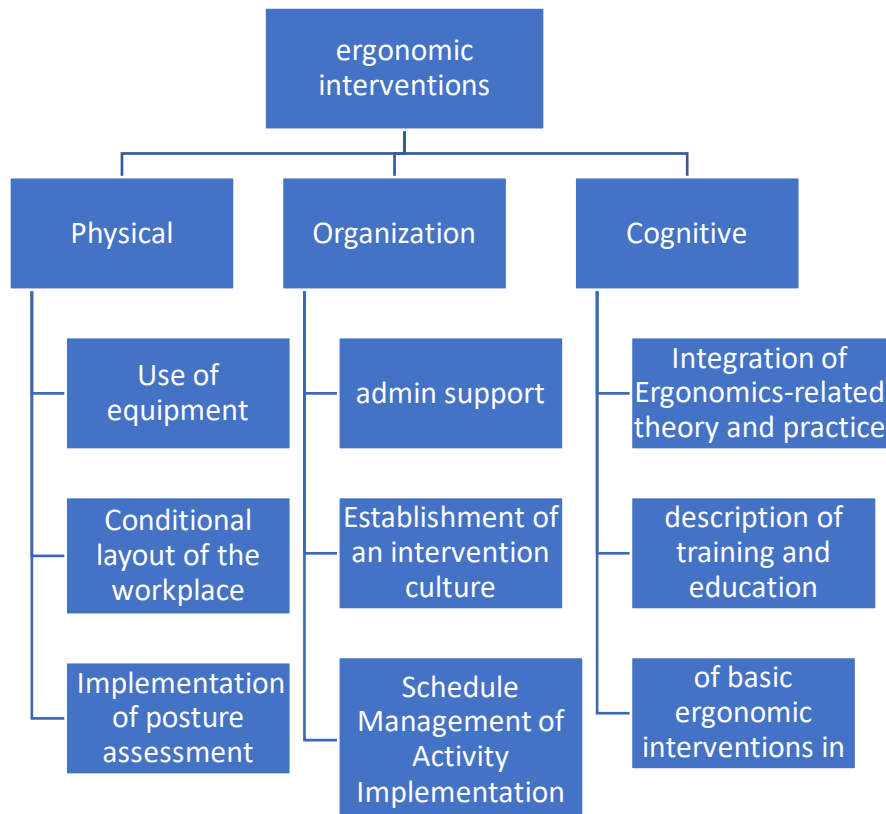


Figure 2: Recommendations Framework of ergonomic interventions

Generally, ergonomic interventions can be attributed to 3 large clusters by including physical, organizational and cognitive interventions. This ergonomic intervention also represents certain levels of level 1 physical ergonomics i.e. basic, moderate-level level organizational ergonomic interventions and high level 3 organizational interventions.

V. CONCLUSION

In order to create a comprehensive intervention program, it is necessary to fill it with all three clusters. However, it is given a level due to the difficulty and impact of the implementation on the organization. For example, a physical ergonomic intervention at a basic level focuses only on the perpetrator but the impact is only on one sub-unit within the institution. The most difficult the implementation method but the easier it is to see the overall change, very importantly if an institution only implements a basic ergonomic intervention, it does not mean that it does not carry out the intervention activity but it is not enough and it is best to start with the basic level and be followed up with the next level to get a good intervention effectiveness.

The implementation of this ergonomic intervention is not mandatory. Must be implemented as a whole but it should be implemented according to the suitability of the place. It is in line with the implementation of ergonomic guidelines in the workplace in the Occupational Safety and Health Act 1994 on a voluntary basis. Perhaps sometime these guidelines will be made mandatory.

REFERENCES RÉFÉRENCES REFERENCIAS

- Ashley, C. D., Luecke, C. L., Schwartz, S. S., Islam, M. Z. & Bernard, T. E. 2008. Heat strain at the critical WBGT and the effects of gender, clothing and metabolic rate. *International Journal of Industrial Ergonomics* 2008(38): 640–644.
- Abarghouei, N. S. & Nasab, H. H. 2012. An ergonomic evaluation and intervention model: Macro ergonomic approach. *International Journal of Scientific & Engineering Research*, 2(3): 1-7.
- Baydur, H. & Demiral, Y. 2016. Effects of participatory ergonomic intervention on the development of upper extremity musculoskeletal disorders and disability in office employees using a computer. *Journal of Occupational Health* 2016:1-20.
- Bogdan, R. C. & Biklen, S. K. 2003. *Qualitative Research for Education*. Needham Heights: Allyn and Bacon.
- Cohen, J. 1977. *Statistical Power Analysis for the Behavioural Sciences*. New York: Academic Press.
- Harvey, P. D. 2019. Domains of cognition and their assessment. *Dialogues in clinical neuroscience* 21(3): 227–237.
- Hal W. Hendrick. 2000. The technology of ergonomics. *Theoretical Issues in Ergonomics Science* 1(1): 22–33.
- Hosseini, H., Abarghouei, N. S. & Nasab, H. H. 2012. An ergonomic evaluation and intervention model: Macro ergonomic approach. *International Journal of Scientific & Engineering Research* 2(3): 1-7.
- Imada, A. S. 2007. *Meeting Diversity in Ergonomics*. Amsterdam:Elsevier Ltd.
- Jaffar, N., Abdul-Tharim, A. H., Mohd-Kamar, I. F. & Lop, N. S. 2011. A literature review of ergonomics risk factors in construction industry. *Procedia Engineering* 2011(20): 89–97.
- Kalpakjian, S. & Schmid, S. R. 2009. *Manufacturing Engineering And Technology Sixth Edition In SI Units*. Singapore: Prentice Hall.
- Midgley, G. 2020. Science as systemic intervention: some implications of systems thinking and complexity for the philosophy of science. *Philosophy of Science Systemic Practice and Action Research* 2(16):77-97.
- Tittiranonda, P., Rempel, D., Armstrong, T. & Burastero, S. 1999. Effect of four computer keyboards in computer users with upper extremity musculoskeletal disorders. *American Journal Of Industrial Medicine* (35): 647–661.
- Waters, T. R. & Dick, R. B. 2015. Evidence of health risks associated with prolonged standing at work and intervention effectiveness. *Rehabilitation Nursing* 40(3): 148–165.
- Wendsche, J. & Lohmann-haislah, A. 2016. The impact of supplementary short rest breaks on task performance – A meta-analysis. *Sozialpolitik* 2016(2): 1–24.
- Xie, Y., Szeto, G. P. Y., Dai, J. & Madeleine, P. 2016. A comparison of muscle activity in using touchscreen smartphone among young people with and without chronic neck–shoulder pain. *Ergonomics* 59(1): 61–72.



This page is intentionally left blank



Towards Digitalization of Fruits and Vegetables Supply Chain: Digital Twins and Internet of Things Approach

By Ayodeji Falayi, Anuoluwapo Ayeni, Bukola Adebayo & Abdullahi Abdullahi

Federal University of Technology

Abstract- The consumption of fruits and vegetables is known to confer numerous health benefits to individuals, owing to their remarkable nutrient density as agricultural produce. Rapid decay of perishable items leads to a reduction in quality and nutrient content. Additionally, these items are highly susceptible to spoilage. The implementation of cold chain technologies has resulted in a reduction of quality loss experienced by fruits and vegetables during their transportation from the farm to the consumer. Despite efforts to minimize waste, a considerable proportion (50%) of fresh agricultural products is still lost during the processes of packaging, pre-cooling, transportation, and storage. The quality loss experienced by perishable foods like fruits and vegetables during packaging, storage, and transit along the cold chain is the primary focus of this article. Existing research points to digital twins and the Internet of Things (IoT) as two possible technological intervention paths for linked supply chains. Using a digital twin, or a virtual clone of a farm, has the potential to increase productivity and efficiency while decreasing resource use.

Index Terms: digital twins, food-supply chain, internet of things.

GJRE-G Classification: FOR Code: 070106



TOWARDS DIGITALIZATION OF FRUITS AND VEGETABLES SUPPLY CHAIN: DIGITAL TWINS AND INTERNET OF THINGS APPROACH

Strictly as per the compliance and regulations of:



Towards Digitalization of Fruits and Vegetables Supply Chain: Digital Twins and Internet of Things Approach

Ayodeji Falayi ^α, Anuoluwapo Ayeni ^σ, Bukola Adebayo ^ρ & Abdullahi Abdullahi ^ω

Abstract- The consumption of fruits and vegetables is known to confer numerous health benefits to individuals, owing to their remarkable nutrient density as agricultural produce. Rapid decay of perishable items leads to a reduction in quality and nutrient content. Additionally, these items are highly susceptible to spoilage. The implementation of cold chain technologies has resulted in a reduction of quality loss experienced by fruits and vegetables during their transportation from the farm to the consumer. Despite efforts to minimize waste, a considerable proportion (50%) of fresh agricultural products is still lost during the processes of packaging, pre-cooling, transportation, and storage. The quality loss experienced by perishable foods like fruits and vegetables during packaging, storage, and transit along the cold chain is the primary focus of this article. Existing research points to digital twins and the Internet of Things (IoT) as two possible technological intervention paths for linked supply chains. Using a digital twin, or a virtual clone of a farm, has the potential to increase productivity and efficiency while decreasing resource use. The provision of approximative assessments of food temperatures after harvest is one example of how the Internet of Things (IoT) could help with quality monitoring and management. The aforementioned advancements will facilitate the detection and mitigation of supply chain challenges that have the potential to undermine the freshness and quality of perishable goods. The objective of this research is to present a conceptual model for the integration of supply chain in urban food systems, with a specific focus on digital technology interventions. Furthermore, this study aims to provide insights into the potential areas of investigation for future research on the digitization of the food supply chain.

Index Terms: digital twins, food-supply chain, internet of things.

I. INTRODUCTION

One of the primary global challenges pertains to the assurance of food security for the expanding global populace, while simultaneously ensuring sustainable development in the long run. As per the Food and Agriculture Organization's report, it is

imperative for the agricultural and food sectors to expand in order to cater to the global populace, which is estimated to reach approximately 10 billion by the year 2050 [54]. The matter of food security, sustainability, productivity, and profitability has gained greater significance owing to the rise in global population and the market's inclination towards elevated product quantity and quality standards. Moreover, the agricultural industry is facing mounting economic pressures, as well as challenges related to labor, the environment, and climate change [17]. In recent years, there has been a widespread consideration of the integration of smart technologies and techniques to enhance efficiency [27].

Investments in food packing, transportation, and storage are severely depleted when food is lost in the postharvest supply chain [21]. Approximately a quarter to a third of the food produced worldwide is lost during the transition from on-farm production to storage at retail establishments, primarily due to inadequate chain management and spoilage [3]. Fresh agricultural produce, such as fruits and vegetables, frequently undergoes significant losses (up to 30% per year) during postharvest handling [15]. Reducing food insecurity from these perishable goods can be achieved by drastically reducing losses from physical biochemical, physiological and microbiological degradation processes. Losses sustained by fruits and vegetables along the postharvest supply chain can be reduced through the use of cutting-edge technology. If these losses could be reduced, more perishable fruits and vegetables would be made available. [38].

The incorporation of refrigeration is a crucial factor in improving the caliber of freshly harvested agricultural products and prolonging their shelf life, thereby facilitating their sufficient distribution to a progressively urbanized global population [49]. It is important to note that a significant proportion of perishable commodities, comprising over 90%, have not yet been subjected to refrigeration. Insufficient refrigeration infrastructure or limited access to energy sources results in a loss of perishable goods that surpasses 20%. The production processes entail significant amounts of energy and water wastage, coupled with the release of carbon dioxide emissions [33]. The implementation of sustainable cold chain

Author α: Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
e-mail: ayodejifalayi@gmail.com

Author σ ρ: Department of Business Analytics and Technology Management, Towson University, Towson, USA.

Author ω: Department of Computer Science, Arab Academy for Science, Technology, Maritime Transport Alexandria, Egypt.
e-mail: madibo04@gmail.com

technologies is crucial due to their ability to enhance resource efficiency, optimize product quality preservation, and minimize food waste caused by external factors [12].

Numerous investigations have been carried out concerning the postharvest cold chain of fruits and vegetables, with the aim of acquiring a more profound understanding of how to tackle the technological and developmental obstacles linked to it. The utilization of refrigerated containers set at a temperature of 4°C resulted in a decrease in the degradation of both mass and nutritional qualities of various fruits, such as strawberries, raspberries, red currants, drupes, cherries, and sour cherries, when compared to their storage at ambient temperature [16]. Various packaging techniques have been employed to mitigate the deterioration of quality in cherry tomatoes, kiwifruits, guava, mushrooms, cucumbers, and berries throughout the cold chain procedures. The techniques encompass active modified atmosphere packaging (MAP) [7], nano-composite based packaging (NCP) [34], polypropylene/polyethylene bags, and edible coating. Oxygen scavengers, ethylene absorbers, moisture regulators, and intelligent packaging are just some of the components that have been included into modern active packaging systems. In order to accomplish its goal, the latter makes use of modern technologies including chemical sensors, temperature and gas indicators, barcodes, and radio frequency identification devices (RFID) [56]. This techniques have been devised with the objective of enhancing the safety and maintaining the quality of recently harvested agricultural commodities.

Multiple factors, including slow metabolism, extended shipment duration [55], a wide variety of fruits and vegetables, and insufficient use of advanced packaging materials [32] and monitoring technology [45], contribute to the rising rates of food loss in the postharvest supply chain of these products. In the realm of cold chain logistics, it is frequently observed that there are notable variations in temperature and relative humidity at different stages throughout the transportation of commodities [55]. The diverse characteristics of refrigeration machinery, food attributes, and packaging materials frequently result in notable fluctuations in the approach air velocity of distinct types of fruits and vegetables [36]. Variations in these variables could potentially affect the final decrease in mass, overall quality, and remaining shelf life of recently gathered agricultural produce.

In recent decades, a variety of technological advancements have been implemented to improve the efficiency of the agricultural and food distribution system. The implementation of innovative solutions has become necessary due to the emergence of novel challenges resulting from demands in emerging markets, regulatory changes, and cost considerations.

In contemporary times, there has been a noteworthy emphasis on tackling the improvement of productivity by means of proficient and cohesive intelligent technologies and methodologies, including digital twins (DTs) and Internet of Things (IoT). Fig 1 depicts novel technologies used in food system. The interdependence of the physical and virtual domains is reliant on the progress of the digital twin technology [30]. This specific component enables the transfer of information among systems that coexist in virtual as well as physical environments. The information obtained from the tangible system is analyzed and applied to revise the condition of the digital system. Furthermore, the virtual system provides feedback that is transmitted to the physical realm. The process of choosing connection components is dependent on various factors such as the source, type, and size of data, the speed of data transmission, and the minimum time gap between data acquisition and responses. The amalgamation of wireless and Internet of Things (IoT) techniques has been utilized to create digital simulations of agricultural systems, which enable the connection between the tangible and intangible realms. The ability to simulate multiple operations and anticipate critical scenarios in advance enables swift response and process adaptation, thereby enhancing resilience.

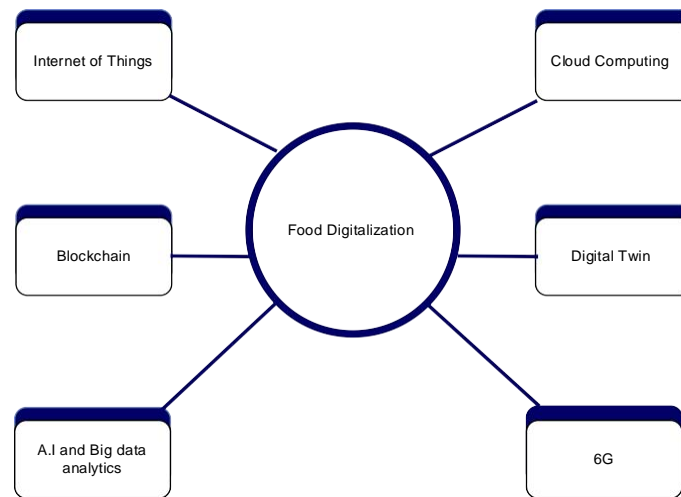


Fig. 1: Food Digitalization

The aim of this research is to examine plausible tactics for reducing food waste in the postharvest supply chain of fruits and vegetables. The present study centers on the contemporary developments in monitoring and optimizing cold chain systems with the aim of reducing quality degradation in fruits and vegetables throughout their packaging, transportation, and storage processes. This research investigates the application of nascent technologies, including the Internet of Things (IoT) and digital twins, in mitigating food waste. Next, we discuss a potential outlook developed to lessen food waste throughout the entire packaging, warehousing, and distribution process.

a) Internet of Things (IoT) Technology in the Postharvest Supply Chain of Fruits and Vegetables

The Internet of Things (IoT) is a subject of ongoing interest due to its capacity to intelligently and efficiently perceive the environment via a network of intelligent devices, and facilitate a range of intelligent applications [39]. The Internet of Things (IoT) has been designed to facilitate intelligent applications, including but not limited to smart cities, smart transportation, smart homes, smart vehicles, smart hospitals, and smart agriculture [6]. The Internet of Things (IoT) is comprised of a series of interconnected networks of tangible objects that are equipped with embedded technology designed to detect, transmit, and engage with either their internal conditions or the surrounding external environment [18]. IoT enables uninterrupted interconnectivity and communication among individuals, objects, and entities, irrespective of their temporal or spatial constraints. As per the European Commission Information Society, the Internet of Things (IoT) is distinguished by a multitude of objects that exhibit comparable and virtual identities, and possess the capability to interconnect and interact with one another in a smart setting through advanced interfaces, all while operating within the confines of social, economic, and user contexts [22]. The fundamental components that

facilitate a conventional Internet of Things (IoT) system comprise Radio Frequency Identification (RFID) [44], printed sensors [19], web services, Machine-to-Machine (M2M) communication [35], Wireless Sensor Network (WSN) [23], imaging systems [43], multi-sensors [14], cloud computing, blockchain technology [51], albeit not always in conjunction.

The food industry has shown a notable inclination towards the utilization of IoT in recent times, primarily for the purpose of product tracking [4], traceability [25], and environmental condition monitoring such as temperature [46], humidity [20], weight loss [20], and overall quality loss in the postharvest supply chain. This is evident from various studies conducted on the subject. The food industry has shown considerable interest in utilizing this technology for the development of intelligent packaging [28]. The implementation of intelligent packaging entails the utilization of a variety of sensors, including biosensors, printed sensors, chemical sensors, and gas sensors, as well as indicators such as time-temperature indicators [20], freshness indicators [52], gas indicators [57], and integrity indicators [37]. These tools are employed to detect alterations in the biological, chemical, or gaseous composition of fresh produce that has been packaged. RFID tags with built-in sensors can monitor changes in temperature, carbon dioxide levels, light exposure, fruit and vegetable pH, and other variables along the post-harvest supply chain. Using the timely data collected by the package system, the relevant parties in the logistics network might be made aware of any incident that might endanger the packing material or the perishable produce inside.

As demonstrated by Chen et al.,2020 [11], IoT in various cold chain processes generates a sizable amount of real time data, which can enable novel computational approaches like big data analytics and artificial intelligence. The aforementioned information is set to aid various supply chain actors in managing and



developing cold chain technologies to reduce quality loss. It will also help stakeholders make educated choices in regards to food safety. However, there is still not enough use of the Internet of Things (IoT) in the administration of cold chain technology to reduce fruit and vegetable spoilage during transport.

Karim et al., 2018 [20] show that the Internet of Things (IoT) has been used to track and monitor temperature and food quality changes during the transportation of product such fruits and vegetables. Integrating sensors for things like temperature, humidity, light exposure, and global positioning system (GPS) is a key part of using IoT technology in product transportation. These sensors are used at various points in the distribution chain for perishable goods like fruits and vegetables. The sensors are positioned in the containers to monitor changes in air temperature, air velocity, light exposure, and relative humidity along the cold chain. The use of sensor data fusion, in particular soft sensors, allows for this to be accomplished. The gadgets link wirelessly to computers in order to improve supply chain communication with control centers, manufacturers, and other key participants. The collected information can serve as baseline information for future studies examining the effects of different preparation methods on food properties as satiety, freshness, shelf life, and flavor. It should be emphasized that numerous sensors, such as chemical sensors, biosensors, imaging systems, Enose, spectroscopy, and AIR, can be utilized to instantly assess alterations in the qualitative attributes of fresh produce at any point in the postharvest supply chain. With the help of IoT sensors, controllers can keep tabs on the operational conditions of food and make educated judgments. Taking any one of these measures might drastically cut down on wasted food. IoT's potential as a reliable and long-term solution to lowering food waste has been bolstered by the falling prices of wireless software and hardware as well as digital sensors, all of which can now be integrated into the shipping, packing, and storage of food.

b) *Digital Twin in Food Supply Chain*

Digital farming techniques have the potential to enhance post-harvest processes by mitigating losses, optimizing food processing, storage conditions, marketing, and transportation through effective monitoring. The implementation of digital solutions enables the real-time monitoring of the agri-food supply chain, thereby enhancing its robustness and resilience [31]. Additionally, it aids in reducing food waste and losses [5].

- 1) *Implementation of Digital Twin:* The primary and essential step in the implementation of digital twins entails the identification of physical entities. The concept of a "physical entity" is a relative construct that refers to the concrete product or system that a virtual design thinking model replicates in the real

world. This may comprise a spectrum of nomenclatures, including but not limited to "vehicle", "component", "product", "system", "artifact", and the like. Digital twins of fruits, farms, and supply chain networks are commonly observed in the agri-food supply chain. To create a virtual entity, it is imperative to produce a digital depiction that precisely mirrors the tangible features, traits, behaviors, and guidelines of the corresponding actual entity. Moreover, service platforms play a crucial role in the execution of models. For optimal performance of the virtual entity, it is essential to provide it with authorization to access cloud-based applications, data, and information.

There is a growing trend among supply chain professionals to incorporate real-time data, as well as demographic data sourced from various stakeholders within the supply chain, in order to obtain valuable insights into logistics. The aforementioned data can be employed to monitor the paths taken by trucks, distribution centers, sales locations, and customers, among other factors, in order to improve the understanding of the supply chain. The data mentioned above can be easily integrated into databases, such as the Enterprise Resource Planning (ERP) database and the production system. This integration process can aid in the development of a digital twin through the utilization of a simulation tool. Furthermore, it is worth noting that digital twins possess the ability to utilize data obtained from transportation management systems and customer relationship management systems. Incorporating internal data from actors' systems with external data sources, such as weather, traffic, and competitors' prices, is a feasible alternative. The factors mentioned above form the basis for creating digital twins of the supply chain. These digital twins aim to construct a model that is both accurate and precise, enabling the performance of analyses and simulations that depend on reliable data. Achieving maximum efficiency in the implementation of supply chain digital technologies requires the essential prerequisites of astute analysis and the integration of data that is both abundant and of superior quality. The adoption of supply chain digital transformation necessitates certain fundamental prerequisites. These include visibility and transparency, frequent updates, data collection and analysis, simulation capabilities, decision support capabilities for planning, and the ability to manage disruptions.

- 2) *Implementation Steps:* Digital twin methodologies have been employed in post-harvest processing to provide ongoing monitoring of the products and revise the processing stages [29]. A digital twin utilized in post-harvest processes refers to a virtual model that is constructed to represent harvested agricultural products [?]. This model is generated

through the collection and analysis of pertinent information obtained from the products. The digital twin concept of food processing [29], encompasses several components. Firstly, data is collected from a physical system, specifically a food process operation, through the use of sensors that measure various properties and variables of both products and environmental parameters [50]. Secondly, an IoT platform is utilized to facilitate sensor communication, data storage, big data analytics, high-performance computing, and connection to the digital twin assets. In order to execute digital twin scenarios within the agri-food supply chain, a variety of sensors have been utilized. Temperature and gas sensors have been employed for the purpose of monitoring the state of fresh products throughout the logistics and storage phases, as well as for representing inventory and grain quality as it moves through a plant. Lastly, a simulation platform is

employed to optimize, test, and validate models using input data from the physical system, and to provide decision support in the virtual realm. To optimize food processing through the creation of digital twin models, it is imperative to incorporate precise data that accurately reflects the production processes involved in the product, such as equipment and labor, and to construct realistic models that account for all existing boundaries and obstacles [1]. According to a report by Defraeye et al., 2021 [?], a digital replica of a mango fruit was created to model and assess the thermal and related biochemical characteristics of the fruit during its journey through the post-harvest supply chain. The development of the digital twin concept involved the incorporation of environmental air temperature as input, and the emulation of real supply chain conditions through mechanistic finite element models [13].

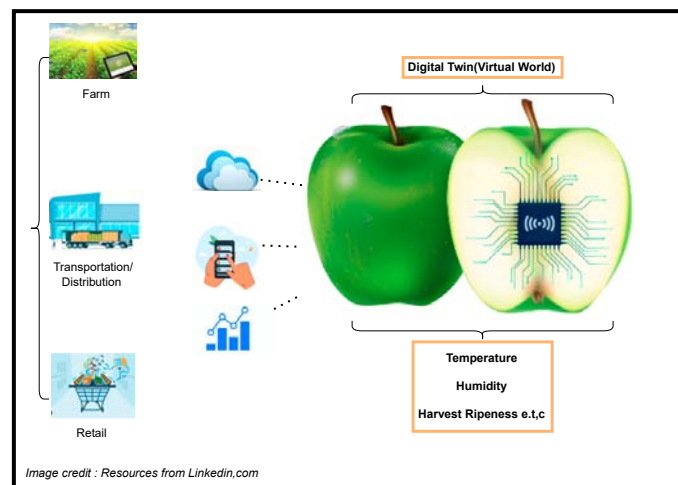


Fig. 2: Fruit Digital twin during postharvest supply chain

Furthermore, the digital twin took into account the effects of increased air velocity on the longevity of storage, duration of the cold chain, and temperature of air during delivery, with regards to the quality of the fruit [42]. Implementation of digital twin technology enables the monitoring and prediction of temperature-dependent fruit quality losses, leading to enhanced refrigeration and logistic processes, ultimately resulting in a reduction of food losses [47]. According to Verboven et al., 2020 [47], implementation of digital twin technology has the potential to enhance the post-harvest lifespan of horticultural products. Additionally, it can be utilized to predict the shelf-life of agricultural products during the cold chain process. The extant digital twin paradigm has the potential to facilitate the monitoring of products, logistics, and marketing decisions for both food consumers and business owners [24]. Nonetheless, further refinement of this concept is required to incorporate additional biochemical and physical

attributes. According to Burgos et al., 2021 [10], The digital twin that has been created encompasses several key components. Firstly, it incorporates a network that is informed by knowledge derived from a range of sources, such as customers, suppliers, and factories. Secondly, it includes a number of parameters that are relevant to production, transportation, warehouses, sourcing, shipment costs, and policies. Finally, the digital twin incorporates a variety of operational parameters, including demand, quality, target inventory, and vehicle capacity. The study revealed that the digital twin that was created has the potential to be utilized for the purpose of optimizing, simulating, and analyzing the modifications in the operation and performance of the food supply chain.

As per the findings Verboven et al., 2020 [47], digital twin models in the post-harvest domain can be classified into three categories, namely mechanistic, statistical, and intelligent models. However, the study

suggests that mechanistic digital twin models based on physics principles are more effective in assessing the quality of fresh agricultural produce compared to the other two categories. According to Shoji et al., 2022 [41], digital twins based on physics were created for 331 shipments of four types of fruits (namely cucumber, eggplant, strawberry, and raspberry) in cold chain environments. The utilization of digital twin concepts has revealed that the pre-delivery quality of fruits may be impacted by a range of factors, resulting in a potential reduction of approximately 43-85%. In recent years, the utilization of digital solutions has led to enhancements in post-harvest processing. The digital twin paradigm is gaining increased attention in post-harvest food processing as it offers the potential for predicting future product quality and reducing costs. Future studies may involve the development of a digital twin for post-harvest processes [?]. This twin would serve to model, optimize, represent, and characterize various design and operational parameters, including quality, safety, ingredients, shelf-life, and product status. Such considerations are essential for researchers in this field [47]. The implementation of digital twins entails a variety of phases, including defining the procedures, recognizing pertinent data sources, selecting suitable technology, constructing models, coordinating the system in real-time, performing simulations, refining the process, and evaluating the outcomes [9]. Furthermore, there exist alternatives that can facilitate the expansion and enhancement of the system. Several methodologies are available to address planning-related inquiries, including those related to determining the quantity to procure, transport, or manufacture. When engaging in modeling, it is recommended to create the digital twin with a primary emphasis on achieving long-term goals. Furthermore, it is imperative that the framework enables the modeling and analysis of alternative processes, optimization of asset performance, and prediction of future events [26].

The utilization of prescriptive, predictive, and advanced analytics in harnessing digital supply chain twins to influence decision-making has a wide range of potential applications, encompassing both strategic and operational domains. By incorporating models, operations, and assets, simulations and optimizations can be conducted to acquire valuable insights, assess various potential scenarios, or adapt to unexpected disruptions. The dissemination of results throughout the organization is crucial to ensure that all levels are informed of the suitable courses of action. The application of various parameters to the digital twin of cloud computing's simulation module facilitates the prediction of future events in the physical supply chain. Ultimately, it is crucial that digital twin exhibit the ability to be extended to incorporate multiple entities, thus enhancing comprehensive supervision across the entire spectrum of supply chain activities. Enterprises possess

the capacity to establish linkages with suppliers and consumers that extend beyond their internal operations. The enhancement of Digital twins performance can be achieved through the integration of supplementary real-time data points derived from internal sources, third-party entities, and industry groups. Fresh-produce supply chains can benefit greatly from digital twins due to their ability to estimate the remaining shelf life days based on the produce's physical, biochemical, microbiological, or physiological states reaction. The digital duplicate can be used to stamp a "use by" date on each box or pallet of agricultural goods. Consumers can use this date as a guide while shopping for groceries in an effort to waste less food. Consumers may become confused when such ideas are combined with a use-by date (or expiration date). Each shipment's digital twin provides retailers and consumers with useful information that can be put to use. Using physics-based digital twins has advantages over traditional methods, such as providing average fruit pulp temperatures rather than just point measurements and allowing for the simultaneous evaluation of several other quality parameters that are sensitive to temperature. With such precise tracking of perishable goods' quality over time, it might be possible to pick fruit when it's at its peak of flavor and aroma and monetary value.

3) *Challenges for Digital Twins Implementation:* The incorporation of Digital Technologies (DTs) into the agricultural and food sectors remains a challenging endeavor. The deployment of Internet of Things (IoT) technology in agricultural systems encounters notable obstacles, primarily stemming from the requirement for an uninterrupted power source to sustain operations. While it is true that alternative energy sources, such as solar and wind, have the potential to fulfill energy requirements, their adoption may result in a significant escalation in expenses. The absence of dependable internet connectivity in geographically isolated and sparsely populated regions presents an added obstacle. Sufficient broadband capacity is a prerequisite for ensuring the efficient transmission of data in accordance with the prescribed service requirements. Furthermore, it is imperative to provide farmers with guidance regarding the integration of fundamental computer systems and tablets, along with a comprehensive understanding of the Internet of Things (IoT).

The task of creating an up-to-date and all-encompassing depiction of the supply chain through mapping presents a formidable undertaking in practice. As noted by Wagg et al., 2020 [48], the concurrent validation of all parameters of model output presents an extra difficulty in the application of digital twinnss within supply chain contexts. In addition, stakeholders involved in the cold chain, such as retailers, necessitate empirical

substantiation to endorse the advantages of implementing particular digital technologies with regards to the extension of product lifespan. Regrettably, the undertaking of pilot studies to obtain such validations can be both financially and temporally arduous. The execution of the system is confronted with additional obstacles related to insufficient methodology and standards, insufficient data governance, and challenges in gathering and retaining large datasets [53].

As noted by Shahzad et al., 2022 [40], the absence of established modeling standards for digital twins can result in compatibility challenges when integrating models that have been developed independently. This study encountered several noteworthy obstacles, such as the creation of a data acquisition system, synchronization difficulties, modeling a multifaceted system, limited knowledge, hesitancy of companies to embrace technology, and difficulties in constructing, comprehending, administering, and simulating real-time modifications within the system. The utilization of digital twins is confronted with obstacles such as the amalgamation of heterogeneous domains of expertise and the availability of sufficient data. According to Bhatti et al., 2021 [8], the implementation process may encounter various hindrances such as alterations pertaining to management education and knowledge dissemination, precise depiction, data precision, expenses, safeguarding of intellectual property (including apprehensions regarding data ownership, identity verification procedures, and user access control), cyber security, and compatibility. In addition, the incorporation of Digital Twins within the agricultural industry is impeded by ethical considerations, along with possible societal and safety consequences [2].

4) *Potential Applications of Digital Twins in Food Systems: Food Traceability:* Many postharvest supply chains lack full transparency, but recent blockchain initiatives aim to remedy this. In this case, the digital twin can play an important role in documenting the postharvest journey of the fruit and telling its biological tale. The use of digital twins would improve cargo tracking by revealing instances of improper hygrothermal management. The data generated by the digital twin may be safely stored and easily accessed by all parties involved thanks to blockchain technology's elegant digital thread storage mechanism. In turn, computational statistics or machine learning approaches can leverage the ledgers of digital twin populations to pinpoint present bottlenecks and optimize the supply chain.

Supply Cooling Chain: Thermal sensors have the potential to predict not only the ambient temperature and humidity, but also the fruit pulp temperature and its consequential impact on quality attributes throughout

the fruit. This includes the loss of moisture, which can result in a decrease in the weight of the fruit that is available for sale. Accelerometer sensors enable the computation of thermal damage potential at extreme temperatures, including chilling injury, and mechanical damage resulting from bruising. In order to furnish this functionality, it is necessary to augment the digital twin with submodels that account for these processes and their corresponding quality standards. This enhanced comprehension proves valuable in the remote analysis of the reactions of perishable food items in every consignment across the refrigerated supply chain. This facilitates timely identification of issues and the consequent execution of preemptive measures. Enhancing the dependability of cold chain notifications constitutes a measure in this regard. Digital twins have the potential to be utilized for the purpose of real-time monitoring and management of cold chain operations in the future. Digital twins have the potential to be employed in prospective endeavors, such as forecasting alterations in food quality based on available data regarding the anticipated conditions of the cold chain and working environment. The integration of digital twins and model predictive control algorithms can enable their performance to resemble that of a weather forecasting model. Furthermore, digital twins have the potential to enhance the protection of importers and exporters against accusations of mishandling the shipment by providing supplementary information to regulatory bodies, such as plant-quarantine or invasive-species inspection services.

II. CONCLUSION

Many perfectly edible fruits and vegetables are lost before they even reach the consumer because of poor postharvest handling. Refrigeration is commonly recognized as the most effective way for extending the storage life of perishable items. This study digs into the postharvest cold chain for fresh produce and how cutting-edge technology is being used to reduce spoiling and ensure a safe food supply. Processing of perishable commodities is highly dependent on Internet of Things monitoring and control, which improves decision making for many parties involved.

Perishable items' quality can be tracked with each shipment, and their shelf life can be predicted with the help of digital twins. The goal of this research was to assess the current state of digital twin implementation within the framework of the contemporary agri-food supply chain. This analysis sheds light on the efficiency of the supply chain as a whole, including its performance, resource allocation, cooperation, and information exchange. It examines the region's advantages, classifications, levels of inclusion, key components, and procedural stages, as well as the problems encountered during implementation. The agri-



food supply chain stands to benefit from digital twins by boosting transparency, decreasing bottlenecks, being better prepared for the unexpected, and optimizing what is currently in place. Until the scientific community agrees on what a digital twin actually is, terms like "digital twin," "digital model," and "digital shadow" will continue to be used interchangeably. Furthermore, both theoretical and applied work in the agri food sector are still in their infancy. A deeper comprehension of how new technologies might be applied would assist future studies of the cold chain for freshly produced agricultural items.

REFERENCES RÉFÉRENCES REFERENCIAS

1. K Agalinos, ST Ponis, E Aretoulaki, G Plakas, and O Efthymiou. Discrete event simulation and digital twins: review and challenges for logistics. *Procedia Manufacturing*, 51:1636–1641, 2020.
2. Zaheer Allam and David S Jones. Future (post-covid) digital, smart and sustainable cities in the wake of 6g: Digital twins, immersive realities and new urban economies. *Land use policy*, 101:105201, 2021.
3. Santosh Anand and MK Barua. Modeling the key factors leading to post harvest loss and waste of fruits and vegetables in the agri-fresh produce supply chain. *Computers and Electronics in Agriculture*, 198:106936, 2022.
4. Mohammad Iqbal Saryuddin Assaqty, Ying Gao, Xiping Hu, Zhaolong Ning, Victor CM Leung, Quansi Wen, and Yijian Chen. Private blockchain-based industrial iot for material and product tracking in smart manufacturing. *IEEE Network*, 34(5):91–97, 2020.
5. Muhammad Ayaz, Mohammad Ammad-Uddin, Zubair Sharif, Ali Man sour, and El-Hadi M Aggoune. Internet-of-things (iot)-based smart agriculture: Toward making the fields talk. *IEEE access*, 7:129551–129583, 2019.
6. Pierfrancesco Bellini, Paolo Nesi, and Gianni Pantaleo. Iot-enabled smart cities: A review of concepts, frameworks and key technologies. *Applied Sciences*, 12(3):1607, 2022.
7. Saiqa Aziz Bhat, Danish Rizwan, Sajad Ahmad Mir, Shoib Mohmad Wani, and FA Masoodi. Advances in apple packaging: A review. *Journal of Food Science and Technology*, pages 1–13, 2022.
8. Ghanishtha Bhatti, Harshit Mohan, and R Raja Singh. Towards the future of smart electric vehicles: Digital twin technology. *Renewable and Sustainable Energy Reviews*, 141:110801, 2021.
9. Diego M Botín-Sanabria, Adriana-Simona Mihaita, Rodrigo E Peimbert García, Mauricio A Ramírez-Moreno, Ricardo A Ramírez-Mendoza, and Jorge de J Lozoya-Santos. Digital twin technology challenges and applications: A comprehensive review. *Remote Sensing*, 14(6):1335, 2022.
10. Diana Burgos and Dmitry Ivanov. Food retail supply chain resilience and the covid-19 pandemic: A digital twin-based impact analysis and improvement directions. *Transportation Research Part E: Logistics and Transportation Review*, 152:102412, 2021.
11. Yinong Chen. Iot, cloud, big data and ai in interdisciplinary domains, 2020.
12. Tamiris Pacheco da Costa, James Gillespie, Xavier Cama-Moncunill, Shane Ward, Joan Condell, Ramakrishnan Ramanathan, and Fionnuala Murphy. A systematic review of real-time monitoring technologies and its potential application to reduce food loss and waste: Key elements of food supply chains and iot technologies. *Sustainability*, 15(1):614, 2022.
13. Thijs Defraeye, Giorgia Tagliavini, Wentao Wu, Kevin Prawiranto, Seraina Schudel, Mekdim Assefa Kerisima, Pieter Verboven, and Andreas Buhlmann. Digital twins probe into food cooling and biochemical quality changes for reducing losses in refrigerated supply chains. *Resources, Conservation and Recycling*, 149:778–794, 2019.
14. Doaa Mohey El-Din, Aboul Ella Hassanien, and Ehab E Hassanien. Information integrity for multi-sensors data fusion in smart mobility. *Toward Social Internet of Things (SloT): Enabling Technologies, Architectures and Applications: Emerging Technologies for Connected and Smart Social Objects*, pages 99–121, 2020.
15. Wen Xia Ling Felicia, Kobun Rovina, Md Nasir Nur'Aqilah, Joseph Merilyn Vonnice, Kana Husna Erna, Mailin Misson, and Nur Fatimah Abdul Halid. Recent advancements of polysaccharides to enhance quality and delay ripening of fresh produce: A review. *Polymers*, 14(7):1341, 2022.
16. Yunting Feng, Kee-hung Lai, and Qinghua Zhu. Green supply chain innovation: Emergence, adoption, and challenges. *International Journal of Production Economics*, page 108497, 2022.
17. Gudrun Franken and Philip Schutte. Current trends in addressing environmental and social risks in mining and mineral supply chains by regulatory and voluntary approaches. *Mineral Economics*, 35(3-4):653–671, 2022.
18. Sukhpal Singh Gill, Minxian Xu, Carlo Ottaviani, Panos Patros, Rami Bahsoon, Arash Shaghghi, Muhammed Golec, Vlado Stankovski, Huaming Wu, Ajith Abraham, et al. Ai for next generation computing: Emerging trends and future directions. *Internet of Things*, 19:100514, 2022.
19. Nenad Gligoric, Srdjan Krco, Liisa Hakola, Kaisa Vehmas, Suparna De, Klaus Moessner, Kristoffer Jansson, Ingmar Polenz, and Rob Van Kra nenburg. Smarttags: Iot product passport for circular

- economy based on printed sensors and unique item-level identifiers. *Sensors*, 19(3):586, 2019.
20. AB Karim, AZ Hassan, MM Akanda, and A Mallik. Monitoring food storage humidity and temperature data using iot. *MOJ Food Process Technol*, 6(4):400–404, 2018.
 21. Yasanur Kayikci, Sercan Demir, Sachin K Mangla, Nachiappan Subramanian, and Basar Koc. Data-driven optimal dynamic pricing strategy for reducing perishable food waste at retailers. *Journal of Cleaner Production*, 344:131068, 2022.
 22. Guido Noto La Diega. *Internet of Things and the Law: Legal Strategies for Consumer-centric Smart Technologies*. Taylor & Francis, 2022.
 23. Hugo Landaluce, Laura Arjona, Asier Perallos, Francisco Falcone, Ignacio Angulo, and Florian Muralter. A review of iot sensing applications and challenges using rfid and wireless sensor networks. *Sensors*, 20(9):2495, 2020.
 24. Kendrik Yan Hong Lim, Pai Zheng, and Chun-Hsien Chen. A state-of-the-art survey of digital twin: techniques, engineering product lifecycle management and business innovation perspectives. *Journal of Intelligent Manufacturing*, 31:1313–1337, 2020.
 25. Jun Lin, Zhiqi Shen, Anting Zhang, and Yueting Chai. Blockchain and iot based food traceability for smart agriculture. In *Proceedings of the 3rd international conference on crowd science and engineering*, pages 1–6, 2018.
 26. Mengnan Liu, Shuiliang Fang, Huiyue Dong, and Cunzhi Xu. Review of digital twin about concepts, technologies, and industrial applications. *Journal of Manufacturing Systems*, 58:346–361, 2021.
 27. Weihua Liu, Shangsong Long, and Shuang Wei. Correlation mechanism between smart technology and smart supply chain innovation performance: A multi-case study from china's companies with physical internet. *International Journal of Production Economics*, 245:108394, 2022.
 28. Mirjana Maksimović, Vladimir Vujović, and Enisa Omanović-Miklić anin. Application of internet of things in food packaging and transportation. *International Journal of Sustainable Agricultural Management and Informatics*, 1(4):333–350, 2015.
 29. Tsega Y Melesse, Matteo Bollo, Valentina Di Pasquale, Francesco Centro, and Stefano Riemma. Machine learning-based digital twin for monitoring fruit quality evolution. *Procedia Computer Science*, 200:13– 20, 2022.
 30. Stefan Mihai, Mahnoor Yaqoob, Dang V Hung, William Davis, Praveer Towakel, Mohsin Raza, Mehmet Karamanoglu, Balbir Barn, Dattaprasad Shetve, Raja V Prasad, et al. Digital twins: a survey on enabling technologies, challenges, trends and future prospects. *IEEE Communications Surveys & Tutorials*, 2022.
 31. Ruchi Mishra, Rajesh Kumar Singh, and Nachiappan Subramanian. Impact of disruptions in agri-food supply chain due to covid-19 pandemic: contextualised resilience framework to achieve operational excellence. *The International Journal of Logistics Management*, 33(3):926–954, 2022.
 32. DG Mogale, Abhijeet Ghadge, Naoufel Cheikhrouhou, and Manoj Kumar Tiwari. Designing a food supply chain for enhanced social sustainability in developing countries. *International Journal of Production Research*, pages 1–21, 2022.
 33. Florin Nenciu, Iustina Stanciulescu, Horia Vlad, Andrei Gabur, Ovidiu Leonard Turcu, Tiberiu Apostol, Valentin Nicolae Vladut, Diana Mariana Cocarta, and Constantin Stan. Decentralized processing performance of fruit and vegetable waste discarded from retail, using an automated thermophilic composting technology. *Sustainability*, 14(5):2835, 2022.
 34. Taskeen Niaz, Saima Shabbir, Tayyaba Noor, and Muhammad Imran. Active composite packaging reinforced with nisin-loaded nano-vesicles for extended shelf life of chicken breast filets and cheese slices. *Food and Bioprocess Technology*, 15(6):1284–1298, 2022.
 35. Ramjee Prasad, Vandana Rohokale, Ramjee Prasad, and Vandana Rohokale. Internet of things (iot) and machine to machine (m2m) communication. *Cyber security: The lifeline of information and communication technology*, pages 125–141, 2020.
 36. Sneh Punia Bangar, Monica Trif, Fatih Ozogul, Manoj Kumar, Vandana Chaudhary, Milan Vukic, Maharishi Tomar, and Sushil Changan. Recent developments in cold plasma-based enzyme activity (browning, cell wall degradation, and antioxidant) in fruits and vegetables. *Comprehensive Reviews in Food Science and Food Safety*, 21(2):1958–1978, 2022.
 37. Abderahman Rejeb, Karim Rejeb, Suhaiza Zailani, Horst Treiblmaier, and Karen J Hand. Integrating the internet of things in the halal food supply chain: A systematic literature review and research agenda. *Internet of Things*, 13:100361, 2021.
 38. Barrientos Barraza Rodolfo, Odar Chang Pedro Rodrigo, and Garcia Lopez Yvan Jesus. Digital twins application in the post-harvest supply chain of fruits and vegetables: A systematic review of the literature. In *IEOM Soc. Int. Proc. Int. Conf. Ind. Eng. Oper. Manag. Istanbul.*, pages 118–130, 2022.
 39. Iqbal H Sarker, Asif Irshad Khan, Yoosef B Abushark, and Fawaz Alsolami. Internet of things (iot) security intelligence: a comprehensive overview, machine learning solutions and research directions. *Mobile Networks and Applications*, pages 1–17, 2022.



40. Muhammad Shahzad, Muhammad Tariq Shafiq, Dean Douglas, and Mohamad Kassem. Digital twins in built environments: An investigation of the characteristics, applications, and challenges. *Buildings*, 12(2):120, 2022.
41. Kanaha Shoji, Seraina Schudel, Daniel Onwude, Chandrima Shrivastava, and Thijs Defraeye. Mapping the postharvest life of imported fruits from packhouse to retail stores using physics-based digital twins. *Resources, Conservation and Recycling*, 176:105914, 2022.
42. Chandrima Shrivastava, Tarl Berry, Paul Cronje, Seraina Schudel, and Thijs Defraeye. Digital twins enable the quantification of the trade-offs in maintaining citrus quality and marketability in the refrigerated supply chain. *Nature Food*, 3(6):413–427, 2022.
43. Daichi Suzuki and Yukio Kawano. Flexible terahertz imaging systems with single-walled carbon nanotube films. *Carbon*, 162:13–24, 2020.
44. Weng Chun Tan and Manjit Singh Sidhu. Review of rfid and iot integration in supply chain management. *Operations Research Perspectives*, 9:100229, 2022.
45. Vasileios Tsoukas, Anargyros Gkogkidis, Aikaterini Kampa, Georgios Spathoulas, and Athanasios Kakarountas. Enhancing food supply chain security through the use of blockchain and tinyml. *Information*, 13(5):213, 2022.
46. Oscar Urbano, Angel Perles, Cesar Pedraza, Susana Rubio-Arreaez, María Luisa Castelló, María Dolores Ortola, and Ricardo Mercado. Cost effective implementation of a temperature traceability system based on smart rfid tags and iot services. *Sensors*, 20(4):1163, 2020.
47. Pieter Verboven, Thijs Defraeye, Ashim K Datta, and Bart Nicolai. Digital twins of food process operations: the next step for food process models? *Current Opinion in Food Science*, 35:79–87, 2020.
48. DJ Wagg, Keith Worden, RJ Barthorpe, and Paul Gardner. Digital twins: state-of-the-art and future directions for modeling and simulation in engineering dynamics applications. *ASCE-ASME J Risk and Uncert in Engrg Sys Part B Mech Engrg*, 6(3), 2020.
49. Hongyu Wang, Xiaolei Wang, Apurbo Sarkar, and Lu Qian. Evaluating the impacts of smallholder farmer's participation in modern agricultural value chain tactics for facilitating poverty alleviation—a case study of kiwifruit industry in shaanxi, china. *Agriculture*, 11(5):462, 2021.
50. Jinjiang Wang, Lunkuan Ye, Robert X Gao, Chen Li, and Laibin Zhang. Digital twin for rotating machinery fault diagnosis in smart manufacturing. *International Journal of Production Research*, 57(12):3920–3934, 2019.
51. Qin Wang, Xinqi Zhu, Yiyang Ni, Li Gu, and Hongbo Zhu. Blockchain for the iot and industrial iot: A review. *Internet of Things*, 10:100081, 2020.
52. Gunawan Witjaksono, Almur Abdelkreem Saeed Rabih, Noorhana bt Yahya, and Sagir Alva. Iot for agriculture: food quality and safety. In *IOP Conference Series: Materials Science and Engineering*, volume 343, page 012023. IOP Publishing, 2018.
53. Sjaak Wolfert, Lan Ge, Cor Verdouw, and Marc-Jeroen Bogaardt. Big data in smart farming—a review. *Agricultural systems*, 153:69–80, 2017.
54. Shahla M Wunderlich and Natalie M Martinez. Conserving natural resources through food loss reduction: Production and consumption stages of the food supply chain. *International Soil and Water Conservation Research*, 6(4):331–339, 2018.
55. Vinay Surendra Yadav, AR Singh, Angappa Gunasekaran, Rakesh D Raut, and Balkrishna E Narkhede. A systematic literature review of the agro-food supply chain: Challenges, network design, and performance measurement perspectives. *Sustainable Production and Consumption*, 29:685–704, 2022.
56. Beibei Ye, Jian Chen, Linglin Fu, and Yanbo Wang. Application of nondestructive evaluation (nde) technologies throughout cold chain logistics of seafood: Classification, innovations and research trends. *LWT*, 158:113127, 2022.
57. Zhilong Yu, Dongyun Jung, Soyoun Park, Yaxi Hu, Kang Huang, Barbara A Rasco, Shuo Wang, Jennifer Ronholm, Xiaonan Lu, and Juhong Chen. Smart traceability for food safety. *Critical Reviews in Food Science and Nutrition*, 62(4):905–916, 2022.



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: G
INDUSTRIAL ENGINEERING

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Systems Energodynamic Approach as an Instrument of Increasing Efficiency of Engineering Developments

By I. N. Dorokhov & Doc. V. Etkin

University of Chemical Technology of Russia

Abstract- It is shown that the systems energydynamic approach, which takes into account the local heterogeneity of a natural object, significantly expands the capabilities of thermodynamic analysis and radically changes the conclusions of all fundamental theories based on hypotheses, postulates and model ideas about the mechanism of natural phenomena.

Keywords: crisis of physics, paralogisms, systems approach, new principles, gravity, oscillator, resonant selective interaction, synthesis of sciences, convergence.

GJRE-G Classification: LCC Code: QC73



SYSTEMS ENERGDYNAMIC APPROACH AS AN INSTRUMENT OF INCREASING EFFICIENCY OF ENGINEERING DEVELOPMENTS

Strictly as per the compliance and regulations of:



RESEARCH | DIVERSITY | ETHICS

© 2024. I. N. Dorokhov & Doc. V. Etkin. This research/review article is distributed under the terms of the Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0). You must give appropriate credit to authors and reference this article if parts of the article are reproduced in any manner. Applicable licensing terms are at <https://creativecommons.org/licenses/by-nc-nd/4.0/>.

Systems Energodynamic Approach as an Instrument of Increasing Efficiency of Engineering Developments

I. N. Dorokhov ^α & Doc. V. Etkin ^σ

Abstract- It is shown that the systems energodynamic approach, which takes into account the local heterogeneity of a natural object, significantly expands the capabilities of thermodynamic analysis and radically changes the conclusions of all fundamental theories based on hypotheses, postulates and model ideas about the mechanism of natural phenomena.

Keywords: crisis of physics, paralogisms, systems approach, new principles, gravity, oscillator, resonant selective interaction, synthesis of sciences, convergence.

I. INTRODUCTION

The current state of natural science and theoretical physics clearly demonstrates what can be referred to as “epistemological inversion”. As R. Feynman figuratively expressed it, it became preferable to “guess equations without paying attention to physical models or physical explanation” of a particular phenomenon. Speculative models and postulates are increasingly replacing experimental facts as the basis for the modern edifice of science. Scientists are no longer burdened by the fact that their theories do not clarify reality, they no longer aim to understand cause and effect relationships. Phenomena explanation is no longer the primary function of science. Therefore, there are more and more statements about the modern crisis of theoretical physics.

The bifurcation of natural science, which occurred between the 19th and 20th centuries, led to the emergence of new branches of classical science. The first is the special and general theory of relativity and quantum mechanics (QM). The second is general systems theory and computer science. The third is the transformation of classical (equilibrium) thermodynamics into the thermodynamics of irreversible processes and energodynamics. At present, the results of mutually complementary development of these three branches are obvious. The first one led to the appearance of the atomic weapons, ITER, TOKAMAK, CERN. The second one led to the personalization of

computers, global informatization and digitalization. The third one led to the personalization of energy consumption, which is struggling to break through.

A. Einstein believed that thermodynamics was a science of principles, and its conclusions would never be refuted, and this idea corresponds to the fact that thermodynamics is the recognized “queen of sciences.” The uniqueness of thermodynamics as a systems science is that its starting points naturally lead to the existence of hidden energy carriers, such as electric charge, the nature of which is still not clear, or ether, previously excluded from consideration. The energodynamic concept of a material energy carrier and the generalized law of conservation of energy open up the possibility of quantitatively assessing the result of the transformation of energy from one form to another in conditions of incomplete information about its mechanism. This is where the key to understanding and practical use of the vast factual material accumulated in natural science lies, which cannot be explained by modern science [1]. The purpose of this article is to show a real way to overcome the crisis of theoretical physics by transforming classical thermodynamics into a theory of principles based on a systems approach.

II. METHODOLOGICAL FEATURES OF THE SYSTEMS ENERGODYNAMIC APPROACH

It refers to a comprehensive methodology, which involves combining systems analysis with the highest level of thermodynamics — energodynamics, which expands it to any non-static processes and any forms of energy. The systems approach uses the concept of a system as a set of elements, which has integrity due to system-forming relationships. The property of integrity is reflected in the philosophical thesis of nonadditivity of the whole, which was recognized as early as Aristotle and Plato: the whole is greater than the sum of its parts. Integrity combines the properties of structuredness, self-organization and emergence of the system. Structuredness manifests itself in the hierarchical structure of the system, self-organization — in the occurrence and development of structures in an initially homogeneous environment, emergence — in the spontaneous occurrence of new properties in the system. Gravity, movement,

Author ^α: D. Mendeleev University of Chemical Technology of Russia, Moscow. e-mail: indorokhov@yandex.ru

Author ^σ: Togliatti State University, Advisor to the Vice-Rector for Science. e-mail: v_a_etkin@bezeqint.net

emergence of new elements and chemical compounds, and so on are manifestations of these properties in nature. [2-11].

The universal characteristic of an energodynamic system is energy, which is the most general function of its state. Its derivatives determine all other properties of the system by independent arguments. Energy acts as a link between various processes occurring in a thermodynamic system — mechanical, thermal, chemical, electromagnetic, nuclear processes, etc. The basis of energodynamics is the law of conservation and transformation of energy, which has no limitations [12-18].

The analysis is of a deductive nature (from the general to the particular) and relies solely on experience-validated data on natural phenomena, i.e., phenomenology. The systems approach does not exclude from consideration those internal (hidden from the observer) system-forming relationships, through which the system as a whole acquires new properties that its individual parts (elements) did not have and without which the system cannot function fully. Deductive analysis is more challenging for the researcher, yet it allows the results of inductive analysis to be critically evaluated (verified) and therefore brings it closer to reality. For instance, energodynamics does not exclude the study of internal (including dissipative) processes, that classical mechanics usually neglects, limiting itself to “conservative” systems. The discovery of the impossibility to restore the system-forming properties, which were lost when the system was split into volume or mass elements during its analysis, by further integration was “the most profound and the most fruitful that physics has experienced since the time of Newton” [19], according to A. Poincaré.

The energodynamic system is vaster than the mechanical system. Elements of a mechanical system are material points, and elements of an energodynamic system are real processes and their coordinates are material carriers of various forms of energy — the so-called energy carriers. Whereas in mechanics the coordinates of position and velocities of individual material points serve as generalized coordinates of the system state, in energodynamics the coordinates are numerical characteristics of material energy carriers Θ_i and displacements R_i of their centers in relation to equilibrium, characterizing the system as a whole. The energy U is an extensive characteristic of the system and is a single-valued function of the extensive energy coordinates $U = U(\Theta_i, R_i)$. For example, in energodynamics, a mechanical process is characterized by mass and displacement of the center of mass, a thermal process is characterized by entropy and displacement of its center; a chemical process is characterized by the amount of a component and displacement of its center; an *electrodynamics* process is

characterized by charge and displacement of its center, etc.

The presentation of mechanics in theoretical physics courses is based on the postulates of homogeneity and isotropy of space and homogeneity of time, as well as Lagrange's variational principle of least action, a special case of Gauss's principle of least constraint [20], which is more general. The authors [20] have admitted that space is not homogeneous and isotropic with respect to an arbitrary frame of reference. Thus, if a body does not interact with any other bodies, it does not mean that its various positions and orientations in space are mechanically equivalent. This non-equivalence is clearly manifested when it comes to spatially heterogeneous media, which are anisotropic since a number of properties depending on the gradients of any potentials varies in different directions.

The transition to the energy coordinates of the state (Θ_i, R_i) supplemented by the axiom of process heterogeneity, leads inevitably to an absolute frame of reference [6]. The concept of an energodynamic system, being free from the postulates of homogeneity and isotropy of space and Galileo's principle of relativity, limited to linear and steady motion, is much broader than the concept of a mechanical system, thus, making the mechanical system a special case of an energodynamic system. For energodynamics, mechanics is an “equal” representative among all other, including non-mechanical forms of matter motions. With this view of mechanics, not only does it require a correction of all its laws, but it also provides a natural explanation of the principle of least constraint in mechanics mentioned above.

Being a consistently phenomenological theory, energodynamics relies on experience rather than on models of the mechanisms of natural processes. Its underlying principles are specified on the basis of experimental data on particular properties of the systems under study (including the so-called laws of Newton, Coulomb, Ampere, equations of condition, transfer, mass balance, charge, impulse, momentum, etc.) which are involved as additional single-valued conditions for the completion of the set of equations. Its equations are based on the formalism of differential and integral calculus and mathematical properties of the system energy as a characteristic function of a certain number of state variables reflecting the quantitative and qualitative aspects of the forms of motion under study. Therefore, the consequences of such a theory become fundamental truths within the applicability of single-valued conditions, whereas energodynamics itself becomes a “theory of principles” as Einstein put it [21].

It is known that all conservation laws were formulated for isolated systems. However, none of the fundamental disciplines can study such systems, since their conceptual system and mathematical apparatus are oriented to locally or globally homogeneous

(internally equilibrium) macro- or micro-subjects, which have no internal processes, so that any changes in their state are due solely to the action of external forces and external energy exchange. A breakthrough in this direction was made by the thermodynamics of irreversible processes (TIP) [22, 23], which emerged in the first third of the 19th century following quantum mechanics (QM) and the theory of relativity (TR). It enriched the theoretical thought of the 20th century with a number of new principles of general physical nature and made it possible to study the kinetics of internal relaxation processes that occur alongside the processes of external energy exchange in all study subjects without exception. TIP became the third of the above-mentioned theories of a revolutionary nature that changed the image of physics of the 20th century, which was celebrated by awarding Nobel Prizes to L. Onsager and I. Prigogin.

However, this theory was based on the principle of increasing entropy and therefore excludes from consideration the reversible component of real processes, which does not affect entropy. Meanwhile, the study of processes of useful transformation of energy was the main task of classical thermodynamics. The kinetics (power) of these processes is of primary interest to the engineer. There is a need to develop a unified theory of the rate of energy transfer and transformation, which would not exclude from consideration any (reversible or irreversible) component of real processes. Such a theory was proposed in the works of one of the authors of this paper and was called "thermokinetics" [13]. All its provisions were justified in a purely thermodynamic way (i.e., not involving hypotheses, postulates, modeling representations, and statistical-mechanical nature). Later it was generalized to the processes of transformation of any forms of energy and called "energodynamics" [14].

Unlike other fundamental disciplines, this theory considers isolated systems as the subject of study, which includes the entire complex of interacting (mutually moving) material subjects. Due to this, it is most consistent with both the systems approach and the deductive method of study (from the general to the particular) followed by classical thermodynamics [24]. Energodynamics is characterized by the refusal to use hypotheses and postulates in the foundations of the theory, idealization of systems and working bodies (contained in concepts such as "ideal gas", "equilibrium state", "reversible (quasi-static) process", etc.), as well as speculative models and ideas regarding the atomic and molecular mechanism of processes. Its special feature is the separation of the theoretical part, based solely on principles of general physical nature, from the applied part, using modeling representations, hypotheses and postulates. This allows it to preserve the main advantage of the thermodynamic method — the irreversible validity of its consequences within the

limits of applicability of the initial paradigm of natural science. This property is also preserved when the single-valued conditions involved in the applied part of the theory are also reliably established.

Energodynamics is based on two principles: distinguishability of real processes and their counterdirectivity. The first one establishes a necessary and sufficient number of energy arguments as the most general function of the properties of the subject of study (i.e., system). This principle is proved "by contradiction" based on the theorem stating that the number of degrees of freedom of a system (i.e., the number of independent parameters uniquely determining its state) is equal to the number of independent (specific, qualitatively distinguishable and irreducible to others) processes occurring in it. This principle prevents "underdetermination" or "overdetermination" of a system, i.e., it attempts to describe their state by a missing or redundant number of variables, which is the most common cause of fallacy in a majority of theories. Among the latter are those theories where the concept of homogeneity is initially assumed, excluding relaxation processes and everything related to non-equilibrium processes from consideration.

The second principle establishes the fact of opposite direction of non-equilibrium processes, which is the reason for the appearance of new properties in the system. It is sufficient to represent the value of any extensive parameter of the system Θ_i (its mass M , entropy S , electric charge Θ_e , impulse \mathbf{P} , its momentum \mathbf{L} , etc.) by integrals of its local $\rho_i = d\Theta_i/dV_i$ and average density $\bar{\rho}_i = \Theta_i/V$ using the expression

$$\Theta_i = \int_V \rho_i dV = \int_V \bar{\rho}_i dV,$$

Hence the identity directly follows:

$$\int_V d(\rho_i - \bar{\rho}_i)/dt dV \equiv 0, \quad (1)$$

which is observed only if the sign of velocity of any process $d(\rho_i - \bar{\rho}_i)/dt$ is opposite at least in some elements of its volume dV , i.e., when these processes are counterdirected. Such counterdirectivity of processes has a general physical nature, i.e., there are always such processes among those occurring in spatially heterogeneous systems, which cause opposite changes of its properties like the process of wave formation. This is evidence of the existence of a natural polarization of nature in the most common sense of this term. It can be considered a physical justification for the law of unity and struggle of opposites. If the properties of an energodynamic system do not differ from the average, then no processes in such a system are impossible. The opposites arise only as a result of deviations from the average value of any properties of the system. Herein lies the emergent nature of the energodynamic system. This property is inherent in all natural phenomena in big and small forms from micro-

to megaworld and serves as the basis of the universe. This property limits numerous fancies about the existence of matter and antimatter, particles and antiparticles, positive and negative energy, positive and negative charges, dark energy and dark matter, and so on and so forth. These two principles were sufficient to create a general theory for all fundamental disciplines, explained using unified concepts and terminology [14]. This approach was celebrated by winning the 1st World Science Championships in Dubai (August 2023) [2].

III. HETEROGENEITY PARAMETERS OF REAL PROCESSES AND THE LAW OF CONSERVATION AND TRANSFORMATION OF ENERGY

For the first time, energodynamics made it possible to study internal processes in locally heterogeneous and isolated systems due to the introduction of missing heterogeneity parameters. These parameters reflect the processes of redistribution of energy carriers Θ_i over the volume of system V in heterogeneous systems, as a result, their densities ρ_i in different parts of the system change in the opposite ways. This leads to a deviation of the position of the center \mathbf{R}_i of the value Θ_i from the equilibrium \mathbf{R}_{i0} (taken as a reference point), which are determined in a system of fixed volume V in a well-known way [14]:

$$\mathbf{R}_i = \Theta_i^{-1} \int \rho_i \mathbf{r} dV; \quad \mathbf{R}_{i0} = \Theta_i^{-1} \int \bar{\rho}_i \mathbf{r} dV, \quad (2)$$

where \mathbf{r} is a running (Eulerian) spatial coordinate.

It follows that when such a system deviates from a homogeneous ("internally equilibrium") state, a certain "distribution moment" of the energy carrier arises

$$\mathbf{Z}_i = \Theta_i (\mathbf{R}_i - \mathbf{R}_{i0}) = \int_V (\rho_i - \bar{\rho}_i) \mathbf{r} dV \quad (3)$$

with a ratio arm $\mathbf{R}_i - \mathbf{R}_{i0}$, referred to as the "displacement vector" [14]. Since there are no processes in the equilibrium \mathbf{R}_{i0} , \mathbf{R}_{i0} can be taken as the reference point of $\mathbf{Z}_i = \Theta_i \mathbf{R}_i$. Thus, the differential $d\mathbf{Z}_i$ can be represented as the sum of three independent components:

$$d\mathbf{Z}_i = \mathbf{R}_i d\Theta_i + \Theta_i d\mathbf{r}_i + d\boldsymbol{\varphi}_i \times \mathbf{Z}_i \quad (4)$$

where $\boldsymbol{\varphi}_i$ is the spatial (Eulerian) angle of the vector \mathbf{Z}_i ; $d\mathbf{r}_i$ is the shearing component of $d\mathbf{R}_i$ (at $\boldsymbol{\varphi}_i = \text{const}$).

Three components of $d\mathbf{Z}_i$ correspond to three independent categories of non-equilibrium processes: 1) emergence of energy carrier Θ_i in the system or its introduction through the system boundary ($d\Theta_i \neq 0$); 2) its redistribution over the system volume ($d\mathbf{r}_i \neq 0$); 3) reorientation of the energy carrier in space ($d\boldsymbol{\varphi}_i \neq 0$). As a result, any i -th form U_i of its own (belonging only to the system) energy¹ U generally becomes a function of three

independent parameters: $U_i = U_i(\Theta_i, \mathbf{r}_i, \boldsymbol{\varphi}_i)$. Thus, the total differential dU of the internal energy of the system as a sum of "partial" energies of all its forms $U = \sum U_i$ can be represented as an identity:

$$dU \equiv \sum_i \Psi_i d\Theta_i + \sum_i \mathbf{F}_i \cdot d\mathbf{r}_i + \sum_i \mathbf{M}_i \cdot d\boldsymbol{\varphi}_i, \quad (i=1,2,\dots,I), \quad (5)$$

where $\Psi_i \equiv (\partial U / \partial \Theta_i)$ — generalized potentials ψ_i , averaged over the volume of the system (absolute temperature T and pressure p , chemical potential of the k -th component of the system μ_k , its electric potential ϕ , gravitational potential ψ_g , etc.); $\mathbf{F}_i \equiv (\partial U / \partial \mathbf{r}_i)$ — generalized forces (external and internal, mechanical and non-mechanical, useful and dissipative); $\mathbf{M}_i \equiv (\partial U / \partial \boldsymbol{\varphi}_i)$ — moments of these forces.

Identity (5) represents the law of conservation and transformation of energy. According to this law, the energy of any natural system is divided into two parts — irreversible and reversible. The potentials of these two forms of energy differ insignificantly and are similar to the potentials of a calm and wavy ocean. Only the disturbed part, representing the wavy ripples of the ocean, is reversible. This part is characterized by the second and third sums in identity (5). Figuratively speaking, everything that is associated in nature with the energy of disturbed motion is a same fraction of the total energy of the global ocean of the Universe energy.

One of the most important advantages of the identity (5) is the elimination of the uncertainty of the energy concept and its definition as the most general function of the system properties characterizing its ability to perform any type of work. The identity (5) that connects the "conjugate" parameters Ψ_i and Θ_i , \mathbf{F}_i and \mathbf{r}_i , \mathbf{M}_i and $\boldsymbol{\varphi}_i$, defines them regardless of what caused their change: external energy exchange or internal (including relaxation) processes. This prevents the well-known problem of the emergence of thermodynamic inequalities at transition to non-static processes, where the change of these parameters is caused not only by external energy exchange, but also by internal (relaxation) processes. This eliminates a major obstacle to applying the mathematical apparatus of thermodynamics to other fundamental disciplines. For the same reasons, the identity (5) is applicable not only to isolated systems as a whole (for which the volume V is unchanged and all processes are internal), but also to any of its material components, phases or areas, where parameters Θ_i , \mathbf{r}_i and $\boldsymbol{\varphi}_i$ change also due to external energy exchange (heat transfer, mass transfer, diffusion, introduction of a charge into it, etc.).

In homogeneous systems ($\Psi_i = \psi_i$, $\mathbf{F}_i = 0$, $\mathbf{M}_i = 0$), the second and third sums of identity (5) vanishes, and it transforms into the combined equation of the 1st and 2nd principles of classical thermodynamics in the form of the generalized Gibbs relation [14], which

¹ It was called internal for a number of historical reasons.

describes the processes of equilibrium energy exchange of the system with the environment. After the introduction of time t as a physical parameter, the identity (5) formulated for isolated systems takes the form of the law of conservation of energy in its nonstationary form:

$$dU/dt \equiv \sum_i \Psi_i d\Theta_i/dt + \sum_i \mathbf{X}_i \cdot \mathbf{J}_i + \sum_i \mathbf{M}_i \cdot \boldsymbol{\omega}_i = 0, \quad (6)$$

where $\mathbf{X}_i = \mathbf{F}_i/\Theta_i = \nabla \psi_i$ – strengths of field of force, expressed by gradients of generalized potential ψ_i (energodynamic forces) averaged over the system volume; $\mathbf{J}_i = (\partial \mathbf{Z}_i / \partial t)$ – generalized impulses of energy carrier Θ_i , referred to as “flows”; $\boldsymbol{\omega}_i = d\boldsymbol{\phi}_i/dt$ – angular velocities of rotation (reorientation) of vector \mathbf{Z}_i .

In contrast to fundamental disciplines that study the processes of external energy exchange, this law provides an opportunity to consider internal processes in isolated (closed) systems, where the concepts of external energy, external forces, their work, momentum, etc. are meaningless. At the same time, energodynamics reveals the flow of three independent forms of internal work in such systems, performed respectively by “disordered” (scalar) forces, “ordered” (vector) forces and their moments. This radically changes the research methodology of all fundamental disciplines that do not consider internal processes, and makes it possible to move towards the study of internal processes determined by the above-mentioned system-forming connections.

IV. SYSTEMS APPROACH TO EQUILIBRIUM AND NON-EQUILIBRIUM THERMODYNAMICS

Of all the fundamental disciplines, classical thermodynamics, being a deductive and phenomenological theory based on the principles of excluded perpetual motion machine of the 1st and 2nd kind, met the requirements of a systems approach to the greatest extent. It provided numerous consequences related to different fields of knowledge and earned the status of “queen of sciences” as a theory “the consequences of which will never be refuted by anyone” [21]. However, as it appeared, it had some known paralogisms when going beyond the strict limits of the validity of its initial concepts of equilibrium and reversibility. Most of them were related to the concept of Clausius entropy, which he introduced as a coordinate of heat transfer that was also dependent on internal heat sources [18].

The theory of irreversible processes (TIP), which emerged on the basis of the principle of increasing entropy using statistical-mechanical considerations and a number of additional hypotheses, did not avoid paralogisms either [25]. I. Prigogin's local equilibrium hypothesis became the main one [23]. This hypothesis assumed the presence of equilibrium in the continuum elements (despite the relaxation processes occurring in them), the possibility of their description by the same set

of variables as in the homogeneous state (despite the presence of potential gradients), and the validity of all equations of equilibrium thermodynamics for them (despite their inevitable transition to inequalities). Despite its inconsistency, this hypothesis made it possible to find the basic values used by TIP theory. However, this deprived TIP of the completeness and rigidity inherent in the classical thermodynamic method. All attempts to overcome these difficulties proved unsuccessful due to the lack of a thorough adjustment of the conceptual foundations and mathematical apparatus of classical thermodynamics.

This problem was solved by introducing additional extensive \mathbf{Z}_i and intensive \mathbf{X}_i parameters of the nonequilibrium state [14], and these parameters changed not only the structure, but also the methodology of explanation of the basics of equilibrium and nonequilibrium thermodynamics. An unconventional consequence of this approach is the proof that the true “dividing line” is not between heat Q and work W^u , which are included in the same sum of identity (5), but between different sums of this identity, i.e., technical W^t and non-technical types of work W^u , the first ones being quantitative measures of the process of “energy conversion” (with a change in the form of energy), and the second ones — of energy transfer (without changing its form). These two types of work, referred to as “ordered” and “disordered”, differ not only in the tensor rank of their coordinates \mathbf{r}_i and Θ_i , but also in the presence or absence of the resulting overcome forces. The fact that “one work is different from the other” leads to the categorization of heat transfer as disordered work. This work is related to the transformation of the impulse of the system elements into a thermal impulse, which loses its vector nature due to thermal (chaotic) movement. Unlike entropy, thermoimpulse in thermally isolated systems can both increase and decrease, making it a true argument of internal thermal energy. Using it as an extensive measure of thermal motion instead of Clausius entropy S (as a coordinate of equilibrium heat transfer) makes it superfluous to interpret the latter as a measure of the thermodynamic probability of a state, which is incompatible with the concept of “entropy flux” used by TIP [26].

Energodynamics radically changed the methodology of nonequilibrium thermodynamics. TIP considers only the relaxation (purely dissipative) part of real processes. Instead, a new method of analyzing real processes was proposed on the basis of law (5) or (6) without excluding any (reversible or irreversible) part of them from consideration [14]. This became possible due to the identity (6), which allows finding the flows \mathbf{J}_i regardless of the reason they are due to — relaxation ($\mathbf{X}_i \cdot d\mathbf{Z}_i < 0$) or performing useful internal work “against equilibrium” in the system ($\mathbf{X}_i \cdot d\mathbf{Z}_i > 0$).

Finding flows \mathbf{J}_i and forces \mathbf{X}_i directly from the identity (6), made it superfluous to formulate

cumbersome equations of the mass, charge, momentum, energy and entropy balances for this purpose. This also excluded the arbitrariness characteristic of TIP in dividing the product $\mathbf{J}_i \mathbf{X}_j$ into factors with different meanings, values, and dimensions. This dramatically facilitated the application of the theory to various physicochemical processes and made it possible to propose a new method for their study. The essence of this method is to translate Onsager's laws from the matrix form-

$$\mathbf{J}_i = \sum_j L_{ij} \mathbf{X}_j \quad (7)$$

into a diagonal form with a smaller number of coefficients L_{ij} subject to experimental determination. This brought Onsager's laws closer to the equations of heat conduction, electrical conduction, diffusion, etc. Such a form did not need to apply the Onsager's symmetry conditions

$$L_{ij} = L_{ji}, \quad (8)$$

and allowed to reduce the number of coefficients L_{ij} from $n(n+1)/2$ in TIP to n while preserving all information about the "superposition effects" of heterogeneous flows \mathbf{J}_i and \mathbf{J}_j . Giving the transfer equations a diagonal form made the application of the Onsager reciprocity relations unnecessary, which significantly extended the scope of application of nonequilibrium thermodynamics owing to the violation of these relations in nonlinear processes. However, the possibility of applying nonequilibrium thermodynamics to non-static (occurring at a finite rate) energy conversion processes, which were previously considered in the so-called "non-dissipative" approximation, turned out to be even more important. This revealed the possibility of taking irreversibility into account in all fundamental disciplines [15].

The application of nonequilibrium thermodynamics to systems performing useful work has revealed the inapplicability of Onsager's "constitutive laws" (7) to such systems. The phenomenological laws of the process of energy conversion from the i -th form to the j -th one take the form in which their off-diagonal components ($i \neq j$) have the opposite sign:

$$\mathbf{J}_i = L_{ii} \mathbf{X}_i - L_{ij} \mathbf{X}_j \quad (9)$$

$$\mathbf{J}_j = L_{ji} \mathbf{X}_i - L_{jj} \mathbf{X}_j \quad (10)$$

These laws reflect the interrelation and counterdirectivity of flows \mathbf{J}_i and \mathbf{J}_j in the processes of conversion of any forms of energy. For such processes, the reciprocity relations (9), (10) have an antisymmetric character $L_{ij} = -L_{ji}$ and requires appropriate proof. Energo-dynamics leads to more general differential reciprocity relations [14]

$$(\partial \mathbf{X}_i / \partial \mathbf{J}_j) = (\partial \mathbf{X}_j / \partial \mathbf{J}_i) \quad (11)$$

Passing for linear processes into the Casimir anti-symmetry conditions $L_{ij} = -L_{ji}$ [27]. These relations required a TIP-independent and consistent thermodynamic justification of all positions of nonequilibrium thermodynamics. The consideration of counterdirectivity of flows at the input and output of the energy converter in relations (11) resulted in the development of original theory of similarity of processes of useful energy conversion. This theory proposed criteria of similarity of energy converters and universal dependences of coefficients of efficiency (COE) on the design perfection and operating mode of power plants. This has greatly improved the efficiency and practical benefits of thermodynamic analysis of thermal and non-thermal, cyclic and non-cyclic, forward and reverse machines in engineering calculations [14].

V. SYSTEMS APPROACH TO CLASSICAL MECHANICS

The presentation of mechanics usually begins with kinematics, which considers the motion of a point in space and time independently of the physical causes of that motion. At the same time, the concepts of motion trajectory, position of a point on it, its speed and acceleration are introduced by pure speculation. Only after that, the concepts of mass and momentum, which are the characteristics of a material point, are introduced, and the transition is made to the study of dynamics, which clarifies the reason for the emergence of this or that motion in various conditions and the laws to which it obeys.

At first glance, this structure of mechanics seems quite natural. However, as L. de Broglie fairly noted, this approach is based on the assumption that the results of abstract kinematic consideration can be further extended to the real motion of more complex mechanical subjects. Meanwhile, this is not always the case, and a systems approach to mechanics proves to be as useful as in other fundamental disciplines. From its perspective, the so-called "laws" of Newton's mechanics appear to be nothing more than postulates, which he called "definitions" for good reason. The limitations of these "definitions" are not always obvious and are sometimes revealed only when considering a more general range of problems [18]. This is, in particular, the Newtonian definition of force $F = dP/dt$ as the time derivative t of the scalar "momentum" $P = Mv$, which applies equally to both chaotic and directed motion. For the latter case, the concept of acceleration $\mathbf{a} \equiv d\mathbf{v}/dt$ became relevant to two fundamentally different processes: the change of the velocity modulus without changing its direction, and the change of the direction of the velocity vector without changing its absolute value. The concept of "centripetal acceleration" emerged when

a point rotates uniformly around a circle, i.e., in the absence of motion toward the center. This led to the well-known paralogism of Rutherford's model of the atom on the basis of the erroneous statement about the inevitability of the electron falling on the nucleus due to its emission of energy during accelerated motion, despite the constancy of its kinetic energy.

From the perspective of the systems approach, the shortcomings of other initial concepts of mechanics are revealed as well [28]. For example, it is well-known that the motion of a single material point in the absence of external forces acting on it will be rectilinear and uniform (Newton's law of inertia). However, the uniform motion of bodies of finite dimensions "by inertia" can be both translational and rotational. This means that the law of inertia should have been generalized to rotational motion long ago. In that case there would be no reason to deny the existence of predominant reference frames. These examples and a number of others demonstrate the appropriateness of considering mechanics as an equal branch of physical theory like energodynamics as a single doctrine of forces. This approach generalizes all three of Newton's laws: the 1st law (of inertia) — for rotational motion, the 2nd law (of forces) — for forces of any nature ($\mathbf{F}_i \equiv \partial U / \partial \mathbf{r}_i$), the 3rd law (equality of forces of action and reaction) - for the case of simultaneous action of forces of the i -th and j -th nature ($\mathbf{F}_i = -\Sigma \mathbf{F}_j$) [28]. Here it follows that the requirement of the directionality of the action and reaction forces, arising from Newton's 3rd law, applies only to the resulting forces \mathbf{F}_i .

However, it is even more important to find the law of gravity

$$F = G(Mm/r^2) \quad (12)$$

for the case of continuum media where it is impossible to distinguish neither "field-forming" M , nor "test" m bodies. Such a law can be obtained directly from the equivalence principle of mass M_0 and rest energy $U = M_0 c^2$ by A. Einstein or from the previously obtained expressions of the ether energy. Expressing this principle through the matter density ρ and energy ρ_u , we have $\rho_u = \rho c^2$. Then, the intensity $\mathbf{X}_g = \rho \mathbf{g}$ of the gravitational field \mathbf{F}_g is expressed through the matter density gradient $\nabla \rho$ by a simple relation [29]:

$$\mathbf{X}_g = c^2 \nabla \rho \quad \text{or} \quad \mathbf{g} = c^2 \nabla \rho / \rho. \quad (13)$$

This law is not a generalization of Newton's law of universal gravitation (12), it is an independent law, which has paradigm (ideological) significance, since it implies the existence of not only the forces of "pushing" ($\nabla \rho > 0$), but also the forces of repulsion ($\nabla \rho < 0$), as well as gravitational equilibrium ($\nabla \rho = 0$). It is also of no less importance that gravitational interaction forces \mathbf{X}_g

are the most significant of all kinds of forces at equal density gradients of energy carriers ∇p .

VI. SYSTEMS APPROACH TO QUANTUM MECHANICS

Nowadays it is difficult to imagine that the quantum-relativistic revolution could not have taken place if the apparatus of nonequilibrium thermodynamics had been developed in time, and instead of thermostatics the analysis of laws of radiation was based on thermokinetics. Back then, the idea of equilibrium with the cavity of the perfectly black body (PBB) would be replaced by the equality of flows of the absorbed and emitted energy that would immediately lead to understanding that the true radiation quantum is a wave modeled by PBB in the luminiferous medium, discrete both in time and in space. Then Planck's radiation law acquires a thermodynamic justification without involving Planck's postulate [30]. At the same time, the De Broglie relation expressing the wave-particle dualism is also proved, except that it does not refer to the wave properties of a particle, but to the particle-like properties of a soliton as a structurally stable wave. Then the position of E. Schrödinger becomes clear, as he believed until the end of his life that "what we take as particles are actually waves" [31]. According to energodynamics, radiation refers to ordered forms of energy exchange, therefore it must be described by the thermodynamic parameters of the process, not the state. Then the law of thermal radiation naturally follows from the concepts of classical physics without any preliminary postulates, but taking into account the fact that radiant energy is transferred by waves that are discrete in both time and space.

Furthermore, as follows from the principle of state determinism and the energy identity (5), each independent process inherent in the i -th form of energy U_i corresponds to a single state coordinate, i.e., a parameter that necessarily changes in the course of the process and remains unchanged in its absence. As it follows from the principle of counterdirectivity of processes, the deviation of such a value compared to the average value ($\rho_i - \bar{\rho}_i$) has the opposite sign, as Franklin believed with regard to electric charge. Consequently, the search for an antipode for each energy carrier (like an electron and a positron, a particle and an antiparticle, positive and negative mass, etc.) leads to a redefinition of the system.

Finally, if N. Bohr had followed the systems approach when studying the emission process, he would have considered as a subject of study the entire set of atoms, located in external force fields and oscillating with them, rather than a single atom. Thus, it would become apparent that the emission or absorption of energy by an atom could only occur when the energy state of the electrons was determined by the action of

external (non-central) forces \mathbf{F} . Therefore, the reason of quantization of the emission energy is not the instantaneous “jump” of the electron from one stable orbit to another, but is the reaction of the electron to the influence of the external force field on it.

Thus, the contradiction between classical and quantum mechanics declared at the beginning of the twentieth century does not actually exist. It disappears in the light of the energy-dynamic concept: changes in energy in nature are caused by a discrete flow of energy carriers in the form of single waves. This means that there is no specific quantum physics with its own special laws, but there is a branch of unified physics that studies discrete (wave) processes. In this case, the true quantum of radiation is an ordinary wave, clearly discrete in both time and space.

Thanks to this approach, it is possible not only to justify the law of formation of spectral series as a consequence of the presence of harmonics of oscillations, but also to obtain the Schrödinger steady-state equation, which does not require comprehension in terms of probability theory [31].

VII. SYSTEMS APPROACH IN ELECTROSTATICS AND ELECTRODYNAMICS

Electrodynamics as a fundamental discipline emerged from electrostatics, which studied the interaction of fixed charges. The Coulomb's law, established experimentally for two macroscopic charges of finite sizes but formulated for two point charges, is one of the initial principles of electrostatics. Hence, this formalization led to infinite values of force and energy when the distance between the charges was reduced to zero.

To eliminate this and other paralogisms, the use of the systems approach made it possible to formulate the mathematical apparatus of electrodynamics as a special case of the energodynamic identities (5) and (6) in their application to “current-carrying” systems [32]. The experimental Coulomb's law has the following form

$$F_e = (1/(4\pi\epsilon_0))[(qQ_e)/r^2], \quad (14)$$

where F_e — the modulus of the interaction force of charges q and Q_e ; ϵ_0 — the electrical permittivity of vacuum. It corresponds to the potential of the electrostatic field $\varphi(\mathbf{r})$ as a measure of its potential energy at a point of the field \mathbf{r} at a distance r from the “field-forming” charge Q_e :

$$\varphi(\mathbf{r}) = (1/4\pi\epsilon_0)(Q_e/r) \quad (15)$$

The potential $\varphi(\mathbf{r})$ characterizes the attenuation of the electric field as it moves away from the center of a fixed “field-forming” charge Q_e , but it does not provide an idea of the change in the field potential as a function

of the density φ_e of the charge in it e . At the same time, it is fundamentally important since the “primary cause” of the force $\mathbf{F}_e = -(\partial U_e/\partial \mathbf{r})_V$ is precisely the gradient of the electrostatic energy density $U_e = U_e(\rho_e)$, and the work W_e of moving the charge in the electrostatic field \mathbf{E} is solely due to the heterogeneity of the field $\rho_e = \rho_e(\mathbf{r})$. For this purpose, we shall distinguish in space a sphere of unit volume V_0 with radius $r_0 = \text{const}$ and charge density $\rho_e = Q_e/V$, on a surface of which the potential $\varphi(r_0)$ has the same value. Then the expression (15) can be represented as:

$$\varphi(\rho_e) = V_0/(4\pi\epsilon_0 r_0) \rho_e(\mathbf{r}) \quad (16)$$

Here, the potential \mathbf{r} is expressed as an implicit function of the field coordinate $\varphi(\rho_e)$, i.e., $\varphi(\rho_e) = \varphi[\rho_e(\mathbf{r})]$, and that preserves the meaning of the concept of the electrostatic field strength \mathbf{E} as a negative gradient of this potential. Taking into account the constancy of the expression in brackets (16), we have the following

$$\mathbf{E} = -\nabla\varphi(\rho_e) = -(V_0/(4\pi\epsilon_0 r_0))\nabla\rho_e$$

If we supplement the expression in brackets to the value of the potential of the sphere of unit volume $\varphi_0 = \rho V_0/(4\pi\epsilon_0 r_0)$ or, we find

$$\mathbf{E} = -\varphi_0 \nabla\rho_e/\rho_e \quad (17)$$

This relation expresses the field form of Coulomb's law. It describes the electrostatic field as a function of the density gradient $\nabla\rho_e$ of the charge distributed in the field ρ_e . This relation (17) differs from the Poisson equation

$$\nabla^2\varphi = 4\pi\epsilon_0\rho_e,$$

since it provides a direct relation between the electrostatic field and the local density of the “field-forming” charge ρ_e . It appears completely identical to Newton's law in its field form (13). It is fundamentally important that the generalized form of Newton's and Coulomb's laws (13) and (17) reveals the existence of forces of attraction and repulsion for energy carriers ρ_g and ρ_e of the same sign, demonstrating that this is not about them, but about their distribution in space. It is equally important that these laws reveal the existence of unstable equilibrium in gravitational and electric fields, prerequisite of this unstable equilibrium is the vanishing of the energy carrier density gradient:

$$\nabla\rho_g = 0 \text{ — gravitational equilibrium;}$$

$$\nabla\rho_e = 0 \text{ — electrostatic equilibrium.}$$

It should be noted that the existence of such equilibrium and the possibility of existence of fields with homogeneous distribution of masses and charges was

not implied by the classical laws of Newton and Coulomb, where the forces of attraction or repulsion vanished only at infinity.

The transition to electrodynamics is connected with the interpretation of the electric current as a flow (impulse) of charge $\mathbf{J}_e = Q_e \mathbf{v}_e$, conjugated with the electrodynamic force $\mathbf{X}_e = \nabla \mathbf{v}_e$. This force is a tensor in 2 dimensions and can be decomposed into a symmetric and antisymmetric part and a trace of the tensor which respectively form the vortex-free, vortex and scalar magnetic fields respectively. In this case, both torques and Nikolaev's forces arise, and there remains no room for statements that "the magnetic field does not perform work since the Lorentz forces are normally directed along the direction of motion" [33].

The understanding of the electromagnetic field (EMF) as a distribution in space of vectors \mathbf{E} and \mathbf{H} is fundamentally different from its interpretation by Maxwell as a medium carrying energy "after it has left one body and has not yet reached another one" [34]. It becomes clear why such "materialization" of EMF was not accepted by any of the researchers of that time and, in particular, by W. Thomson, who referred to this field theory as "mathematical nihilism". Indeed, the existence of EMF, "detached" from its source, led to a conflict with the law of conservation of energy, according to which the energy of EMF is equal to the sum $\epsilon_0 \mathbf{E}^2/2 + \mu_0 \mathbf{H}^2/2$, where \mathbf{E} and \mathbf{H} are the intensities of its electric and magnetic components; ϵ_0 and μ_0 are the "electric and magnetic permittivity" of vacuum. In an electromagnetic field, the intensities \mathbf{E} and \mathbf{H} change in-phase, which was proved by Faraday. Therefore, the EMF energy cannot remain constant when isolated from the sources. The transfer of electromagnetic oscillations in the environment discovered by Hertz did not provide a definite answer about the nature of the environmental oscillations themselves. They are not necessarily of electromagnetic nature. Hertz's experiments, revealing the transfer of electromagnetic oscillations in the environment from one body to another, didn't prove that the same kind of oscillations are inherent in the "luminiferous" medium itself. Such transfer can be realized as a result of conversion of electromagnetic energy of the source into the energy of density oscillations of the "luminiferous" medium with their inverse transformation into electromagnetic oscillations in the radiation detector. This was claimed by N. Tesla, who discovered a special kind of "radiant" ("cold") electricity in the ether [35].

VIII. SYSTEMS APPROACH IN BIOCHEMISTRY AND BIOPHYSICS

In biological systems, supplementary non-additive properties that require a systems approach are the following: the existence of "active transport" of matters (their transfer to the area of increased

concentration), the phenomenon of "conjugation" of chemical reactions (when some of them go in the direction opposite to the chemical equilibrium), their ability to "self-organization" (structure formation), and so on. All phenomena of this kind are anti-dissipative in their nature, and according to I. Prigogin's fair remark, this fact "flagrantly contradicts to thermodynamics". (I. Prigogin). Thereby, the thermodynamic analysis of biological systems encounters significant fundamental challenges [36].

One of the ways to overcome these challenges is to consider any biological cell as a complex (polyvariant) system. This approach requires considering its structure (spatial heterogeneity) to the same extent as in macrosystems. Therefore, all the observations made earlier with respect to extensive \mathbf{Z} and intensive \mathbf{X}_i non-equilibrium parameters of the systems under study are valid for this purpose.

The next step is the refusal to justify the laws of biophysics on the basis of the theory of irreversible processes, since the latter does not consider the reversible component of real processes [17]. The performance of useful work by a biological system is one of the main signs of its vitality. As it is known, the maintenance of the non-equilibrium state of biosystems is accomplished by supplying it with free (ordered) energy from the outside. Therefore, the exclusion of the processes of performing useful work as described by the second sum of identity (1) from consideration is the same as "splashing out the water and the child as well".

Under the systems approach, vector flows \mathbf{J}_i and forces \mathbf{X}_i are determined not on the basis of the expression for entropy "production" dS/dt (as it was proposed by I. Prigogin), but on the more general basis of the law of conservation of energy in the form (6). In this case, the product $\mathbf{J}_i \mathbf{X}_i$, which characterizes the power of the process, reflects not only the relaxation processes ($\mathbf{J}_i \mathbf{X}_i < 0$), but also the processes of removing the system from equilibrium by performing the internal work "against equilibrium" in it ($\mathbf{J}_i \mathbf{X}_i > 0$). In biological systems, the postulated Onsager-Prigogin linear kinetic laws (7), (8) are replaced by true «phenomenological» laws (9), (10) and (11), which have a reversible component (with the opposite sign of the off-diagonal components ($i \neq j$)). They proved to be valid for processes of "active transport" of matters in biological systems, as well as for "ascending diffusion" in alloys, for electrolysis, dissociation, "self-organization", and so on, i.e., for all processes where the work "against equilibrium" is performed.

The systems approach also makes it possible to eliminate the contradiction of TIP with the Curie principle, according to which the flows \mathbf{J}_i can depend only on thermodynamic forces \mathbf{X}_i of the same (or even) tensor. In particular, scalar chemical reactions referred to in TIP as $\sum_r A_r d\xi_r$ (where A_r is the standard chemical affinity of the r -th chemical reaction, ξ_r is the degree of



its completeness) cannot interact with metabolic processes of vector nature. Meanwhile, these are precisely the processes that play a key role in supporting the vital activity of biosystems. Prigogin's hypothesis of "steady-state conjugation", which he put forward to overcome this difficulty, appeared to be unsatisfactory, since the mentioned interrelation is also preserved in non-stationary behaviors that are typical of biological systems.

Once again, the systems approach becomes useful here. According to this approach, chemical reactions in cell membranes, flow reactors, fuel cells, Van't-Goff boxes, and so on also acquire a vector character, and in this case, the function of the thermodynamic force of the r -th chemical reaction is fulfilled by the value $\mathbf{X}_r = \nabla A_r \xi_r$, conjugated to the flow of reagents \mathbf{J}_r involved in it, which corresponds to the Curie principle [14].

Thus, the evidence reveals the limited applicability of the theory of irreversible processes to biological systems and the "inductive" construction of chemical physics and biophysics by extrapolating TIP to biological systems. In this regard, the crucial role is played by the replacement of entropic criteria of evolution by non-entropic ones, which are expressed directly by the moments of distribution of energy carriers \mathbf{Z}_i or by forces \mathbf{X}_i , capable of increasing and decreasing in real processes. Such criteria can reflect not only the proximity of the system to equilibrium (its involution), but also its removal from it (evolution) [17]: $d\mathbf{X}_i > 0$ (evolution); $d\mathbf{X}_i < 0$ (involution).

The introduction of more "physical" and intuitive criteria of evolution and involution provides an opportunity to reflect the behavior not only of the system as a whole ($\sum \mathbf{X}_i d\mathbf{Z}_i \neq 0$), but also of each degree of its freedom, i.e., it is more informative than entropy. It becomes obvious that the processes of "self-organization" in isolated systems ($dU = 0$) are the ordering of some (i -x) degrees of freedom due to the "disordering" of others (j -x) [17].

The systems approach enables to find a law of biological evolution that does not contradict classical thermodynamics. To achieve this, it is sufficient to compare the time it takes for a biosystem to reach a state of internal equilibrium in the presence and absence of evolutionary processes in it $\mathbf{X}_i d\mathbf{Z}_i > 0$. Then it becomes apparent that the evolutionary processes occurring in biological systems increase the duration of their reproductive periods. Therein lies the reason for the general orientation of the progressive evolution of biological systems, which is understood as a transition from simple to complex. Such a delay in achieving equilibrium in biosystems is close to the Darwinian idea of survival, and therefore it can be considered as an alternative to the rather straightforward idea of the "struggle for existence".

IX. SYSTEMS APPROACH TO THE ANALYSIS OF PHYSICAL VACUUM

Until recently, physics, thermodynamics, physical chemistry and other sciences have studied energy transfer in the real (structured) part of matter, which is no more than 5% of the Universe. However, the main energy transfer occurs in the remaining hidden mass of unstructured matter, which has only an oscillatory form of motion with a continual spectrum, which contributes to its invisibility (hence the term "dark" matter) [37]. Therefore, it is only natural to consider the environment in the form of unstructured matter (pre-matter) as a continual set of oscillators with a background frequency spectrum. Pre-matter oscillators are traveling waves that carry energy. Radiators, i.e., oscillators of matter represented as structured forms of baryonic matter (electrons, protons, neutrons, atoms, molecules, nanoparticles, plant cells and living organisms) transform the energy of pre-matter into its other forms as closed (standing) waves, which number is countable [5, 8]. The vibrations of the matter oscillators are transferred to the environment, modulating traveling waves in it with a spectrum different from the continual (background) one, making the structured matter visible ("light"). For an observer, structured matter is perceived by distinguishable radiations: light, thermal, electromagnetic, X-ray, chemiluminescence, photoluminescence, electroluminescence, radiant, torsion, microlepton, choral, biofields, and others.

The analytical model of the origin of matter oscillators in the form of electron, proton, and neutron from pre-matter was first developed by N. A. Magnitsky (2010) [38-40]. The mechanism of interaction of matter and pre-matter in the form of convolution of a traveling wave into a closed wave of doubled period is proposed, resulting in two elementary particles with rest mass and opposite spins. It is shown that the electron is the first simplest period-doubling bifurcation from an infinite cascade of bifurcations in accordance with the universal Feigenbaum-Sharkovsky-Magnitsky (FSM) theory [40]. According to this theory, the discovered elementary particles are far from exhausting the infinite set of elementary particles that can appear as a result of bifurcations in the nonlinear system of equations of the pre-matter motion dynamics. Hence, two important consequences follow: 1) structured matter emerges from unstructured matter continuously, as does the reverse spontaneous decay of baryonic matter as a result of radioactive emission; 2) attempts to experimentally detect both the simplest (most elementary) and the most complex of elementary particles are unpromising. Instead of the point elementary particle concepts considered in theoretical physics, the wave internal structure of elementary particles as well as atoms and molecules of matter is

justified. As a result, for the first time, an analytical description was given, reliably confirmed by experiments, of the structure of atoms of all chemical elements included in the table of D.I. Mendeleev from the positions of classical mechanics, whereas the table itself was returned to its original state [39], which had previously been distorted by numerous adjustments to the unsubstantiated postulates of the traditional quantum theory.

According to energodynamics, any wave (acoustic, hydraulic, electromagnetic, ether, etc.) is similar to a dipole, which determines the force nature of its interaction with the matter. Furthermore, the force manifests itself as a gradient of the amplitude-frequency potential [41]. Due to this, any interactions performed by oscillating intermediate medium, no matter how it is referred to (ether or field) also acquire a force nature, which is determined not by any special nature of acting forces, but by resonance amplification of energy exchange at the frequencies of natural oscillations of various structural elements of interacting agents. In energodynamics, this type of interaction is called resonant selective.

This interaction nature is confirmed by numerous phenomena of resonant absorption or emission observed in all fields of natural science. The resonant selective force interaction in the matter can be performed by the field of any oscillating scalar magnitude, i.e., it is not necessarily electromagnetic. In particular, the following can be considered: resonant absorption of energy of elastic or electromagnetic waves; "indifference" to atoms of a different "type", expressed in the concept of partial pressure; interaction of different chemical reagents in multiples defined for each of them; catalysis in chemical reactions; selective conductivity of membranes against different substances and solutions; selective absorption of certain substances by the surface of bodies; diffusion, osmosis, filtration of substances through semiconductor membranes; synchronization of radiation frequencies in lasers; selective interaction of proteins with RNA and selective effects of pharmaceuticals on the organism; preferential reproduction of certain ones and destruction of others in the processes of evolution, and so on and so forth.[42].

X. SYSTEMS APPROACH TO ASTROPHYSICS AND COSMOLOGY

At present, a true cosmological revolution is taking place, originated by the improvement of technical instruments of observational astronomy and characterized by an avalanche-like growth of new knowledge about the Universe. One of the fundamental results was the confirmation of the presence of two forms of matter in the Universe — observable and unobservable, referred to as ether, and after its

expulsion from physics — hidden mass, physical vacuum, dark matter, etc. As it was mentioned above, the "visible" mass is not more than 5% of the matter amount in the Universe, and most of it is "hidden" (dark) and is not involved in electromagnetic interactions. The latter means that among the four types of interaction known to science only gravitational interaction is the only one left for it, so it shall be considered as the main form of energy of the Universe. The transformation of gravitational energy into other forms, discovered as early as in Galileo's experiments, is the basis of all evolutionary processes occurring in it. However, in order to prove it, it is essential to find a "primary" material carrier of gravity, which has an all-pervasive ability and can transform into any other forms of matter of the Universe. At this point, the knowledge that has reached us from the depths of millennia proves to be useful. The knowledge is about the existence of invisible and intangible "subtle" matter, which originally filled all the available space. And from this "subtle" matter the "rough" matter, which has boundaries and is called substance, was formed by compaction. In ancient India this medium was called "Akasha", in Europe of the Middle Ages — ether, and in post-classical physics — "hidden mass", "physical ("cosmic") vacuum", "dark matter", "dark energy", etc. The modern paradigm classifies this form of matter as field matter, which differs from matter in its continuity (lack of structure). All known forms of matter in the universe arose from it. The main feature of the "field medium" is the absence of boundaries, i.e., the ability to occupy the entire space without any voids. This property means that it is an indispensable component of any material system and it is included in identities (5) and (6) along with other material components.

According to modern data, the density of the field medium ρ_0 is $\sim 10^{-27}$ g cm⁻³, which is by dozen orders of magnitude less than the density of white dwarf stars. This is evidence of the heterogeneity of the matter of the Universe and the validity of the principle of counter directivity, with all the following consequences. One of them implies the possibility to consider the identity (6) as an "equation of the Universe", especially since it describes the entire set of processes occurring in it, besides the relationship between the space-time curvature and the energy-momentum tensor. The main advantage of this "equation of the Universe" in comparison with the well-known Einstein-Hilbert-Friedman model is that it does not require any hypotheses and postulates, it does not contain any concepts unfamiliar to classical physics, it does not contradict the law of conservation of energy and does not impose upon the Universe the simultaneous occurrence of the same processes in all its areas ("multiverses"). On the contrary, it indicates the inevitability of the counterdirectivity of the processes of evolution ($dZ_i > 0$) and involution ($dZ_i < 0$) in different

areas of the Universe (galaxies and metagalaxies) and the possibility of simultaneous occurrence of such processes in the same areas of the Universe [17].

Another consequence of the systems energodynamic approach to the Universe is the validity of the bipolar law of gravity (8) with all its predictive capabilities [17]. According to this law, gravity is not an "innate property" of hidden matter, but it is due to the uneven distribution of its density in space. Furthermore, according to (8), the action of the gravitational forces \mathbf{F}_g at a given point of space is directed along the density gradient of the latent mass $\nabla \rho_0$ in it. This means that in the area $\rho_0 > \bar{\rho}_0$, any material point is subject to "pushing" forces acting towards the area of increased density, which intensify the field heterogeneity spontaneously arisen in it. On the contrary, where $\rho_0 < \bar{\rho}_0$, there are "repulsion" forces, aiming to "move apart" such areas. Similar to the behavior of grease spots on the water surface, this results in the emergence of "voids" and explains the "scattering" of galaxies from each other as they compact without increasing the already infinite space of the Universe. This made it possible to construct a theory of gravity that predicts the formation of local condensations of hidden matter as spherical solitons forming the nuclei of future atoms, the formation of spherical shells of atoms of various substances around them, their combination into molecules, gases, liquids, solids, and so forth up to galaxies and their clusters [43]. This evolutionary branch of the Universe matter circulation comes to an end when the compression forces of the star, weakening with increasing density ρ , can no longer restrain the growth of internal pressure under the influence of thermonuclear reactions. This is when the "supernova explosion" occurs, which means the beginning of its involution and decay up to the initial state.

Another most important consequence of law (13) is the acknowledgment of gravity as the strongest of all interactions. It follows from the fact that the proportionality coefficient c^2 in (13) is at its maximum near the hidden mass, decreasing in optically dense matter by its refractive index. For this reason, Coulomb forces are weaker than gravitational ones, especially since the density of charges in a matter ρ_e is less than its density ρ . This turns the hidden mass into the "fuel of the Universe", since the energy $c^2 \Delta M_0$ released during "condensation" (realification) is 931.5 MeV/a.m.u., which is orders of magnitude less than the heat release of thermonuclear reactions. The evidence of this is the higher temperature of the photosphere.

Other consequences of the law of gravity (8) are also experimentally verified: the character of their rotational curves due to the density gradient of the matter of spiral galaxies, the existence of autonomous gravity zones near the Earth and the Moon (gravity funnels with different sign $\nabla \rho_0$), the matter flowing over from one galaxy to another (with larger $\nabla \rho$) in the

absence of convergence of their centers, the concentric arrangement of star clusters at a certain distance from the central ones, indicating their gravitational equilibrium, etc. [17].

The consequences of the systems energodynamic approach question the scenario of the origin and death of the Universe, derived from the analysis of the well-known Einstein-Hilbert-Friedman equation of the Universe. Indeed, it is sufficient to present this equation in the form of an integral taken over space (taking into account the spatial heterogeneity of the Universe), as it becomes obvious that all the consequences of its analysis should be attributed only to some of its areas. The nonstationary behavior of the Universe as a whole, the counterdirectivity and non-synchronism of processes due to delayed perturbations become obvious as well as the possibility of functioning of the Universe unlimited by time and space, bypassing the equilibrium state [44].

XI. CONCLUSION

A system-energodynamic approach to the construction of fundamental disciplines on a unified basis is formulated. This allows us to get rid of many paralogsms caused by the inductive nature of the construction of physics, based on a postulative (model) approach to describing the mechanisms of natural phenomena. The combination of inductive and deductive research methods significantly expands the horizons of natural science, in particular, it enriches the methodological base of engineering disciplines, opening up new ways and methods for solving practical problems.

REFERENCES

1. Koltovoi N. A. Scientific research into anomalous phenomena. Book 1–14. Moscow. 2023. Electronic edition. URL: <https://koltovoi.nethouse.ru> (In Russian).
2. Dorokhov I. N., Etkin V. A. System-energydynamic approach as a means of overcoming the crisis of theoretical physics. 1 World Science Championship in Dubai (August 2023) // Bulletin of the International Academy of System Research. Computer science, ecology, economics. RKhTUim. D. I. Mendeleva, 2023. T.25. Part 2. S. 3–26. (In Russian).
3. Dorokhov I. N. Energy concept of the universe // Bulletin of the International Academy of System Research. Computer science, ecology, economics. RKhTUim. DI. Mendeleva, 2021. T.23. pp. 3–78. (In Russian).
4. Dorokhov I. N. System analysis of natural and technological processes: textbook, allowance. M.: RKhTUim. D. I. Mendeleva, 2022. – 260 p. (In Russian).

5. Dorokhov I. N. System-energydynamic analysis of natural and technological processes. – M. LENAND, 2023. – 336 p. (In Russian).
6. Dorokhov I. N. Inhomogeneity Axiom and Generalized Energy Conservation and Transformation Law. //ISSN 0040-5795. Theoretical Foundations of Chemical Engineering, 2023, Vol. 57, No. 3, pp. 327–337.
7. Dorokhov I. N. The Role of Energodynamics in the Scientific Bases of Chemical Technology. // ISSN 0040-5795. Theoretical Foundations of Chemical Engineering, 2023, Vol. 57, No. 5, pp. 563–580.
8. Dorokhov I. N. Energy dynamics of radiation and chemical bonding as a resonant-selective interaction.//ISSN 0040-5795. Theoretical Foundations of Chemical Engineering, 2023, Vol. 57, No. 6, pp. 708–719.
9. Dorokhov I. N. System-energydynamic approach to the convergence of natural sciences. // Bulletin of the International Academy of System Research. Computer science, ecology, economics. RKhtUim. D. I. Mendeleeva, 2023. T.25. Part 1. pp. 44–54. (In Russian).
10. Dorokhov I. N. Convergence of sciences as a result of the use of the apparatus of generalized functions in natural science. // Bulletin of the International Academy of System Research. Computer science, ecology, economics. RKhtUim. DI. Mendeleeva, 2022. T.24. pp. 24–49. (In Russian).
11. Kafarov V. V., Dorokhov I.N. System analysis of chemical technology processes. Basics of strategy. M.: Nauka, 1976. 500 p. (In Russian).
12. Etkin V. A. Fundamentals of energy dynamics. Togliatti: Publishing house Tol.PI, 1992.– 120 p. (In Russian).
13. Etkin V. A. Thermokinetics (thermodynamics of energy transfer and conversion processes). – Tolyatti: "Acad. business, 1999.– 228 pp. (In Russian); Etkin V. Thermokinetics (Synthesis of Heat Engineering Theoretical Grounds). - Haifa, Lulu Inc. Publ., 2010.– 334 p.
14. Etkin V. A. Energy dynamics (synthesis of theories of energy transfer and transformation) - St. Petersburg; "Science", 2008.- 409 pp. (In Russian).; Etkin V. Energodynamics (Thermodynamic Fundamentals of Synergetics). - N.Y., Lulu Inc. Publ., 2011.- 480 p.
15. Etkin V. A. Synthesis of the fundamentals of engineering disciplines (energy-dynamic approach to knowledge integration). – Lambert Acad. Publ., Saarbrücken, 2011, 290 pp. (In Russian); Etkin V. Energodynamics (Thermodynamic Fundamentals of Synergetics). - New York, 2011.- 480 p.
16. Etkin V. A. Theoretical foundations of fuel-free energy. Canada: Altaspera, 2013. 155 p. (In Russian).
17. Etkin V. A. Nontrivial consequences of energy dynamics. Haifa, 2020. LuluInc.(USA). 155 p. (In Russian).
18. Etkin V. Paralogisms of thermodynamics. Saarbrücken: Palmarium Ac. Publ., 2015. (In Russian).
19. Poincare A. Selected works. - M.: "Science", 1974. P. 429–433. (In Russian).
20. Landau L. D., Lifshits E.M. Theoretical physics. T.1. Mechanics. M.: Nauka, 1973. 208 p. T. 2. Field theory.: M.: Nauka, 1973. 504 p. (In Russian).
21. Einstein A. Creative biography // In the book "Physics and Reality". – M.: "Science", 1985. P. 131–166. (In Russian).
22. Onsager L. Reciprocal relations in irreversible processes. //Phys. Rev., 1931. – 237(14). P.405–426; 238(12). P.2265–2279.
23. Prigogine I. Introduction to thermodynamics of irreversible processes. – M.: "Publishing house of foreign, lit.", 1947. (In Russian).
24. Bazarov I.P. Thermodynamics. Ed. 4th. M.: Higher School, 1991. (In Russian).
25. De Groot S., Mazur R. Nonequilibrium thermodynamics. M.: Mir, 1964. (In Russian). De Groot S., Mazur R. Non-Equilibrium Thermodynamics: Amsterdam, 1962.
26. Etkin V. Thermoimpulse as a True Extensive Measure of Heat. // Global Journal of Research in Engineering: G Industrial Engineering, 23(1)2023. P.21-31.
27. Etkin V. A. Reciprocity relations of reversible processes. //Sib. Phys.-Techn. zhurn., 1(1993). 2117-2121. (In Russian); Etkin V. Reciprocal relations of irreversible processes. // Soviet Journal of Appl. Physics, 1(1993).P. 62-64.
28. Etkin V. A. Correction and generalization of the principles of mechanics. //Reports of independent authors, 51(2021). 84-104. (In Russian); Etkin V. A. Synthesis of Thermodynamics and Continuum Mechanics. //Global Journal of Science Frontier Research: A Physics and Space Science, 22(4).2022. Online ISSN: 2249-4626 & Print ISSN: 0975-5896.
29. Etkin V. A. Bipolar law of gravity. //Reports of independent authors, 53(2021). 144-156. (In Russian); Etkin V. Gravitational repulsive forces and evolution of the universe. // Journal of Applied Physics (IOSR-JAP), 8(6), 2016. 43-49 (DOI: 10.9790/4861-08040).
30. Etkin V. A. Rethinking the foundations of quantum mechanics.//Problems of modern science and education, 12(132).2018, 6–14. DOI from 10.20861/2304-2338-2018-132-003. (In Russian). Etkin, V. A. Rethinking Quantum Mechanics. /IOSR Journal of Applied Physics (IOSR-JAP),10(6).2018.1-8. DOI: 10.9790/4861-1006010108.



31. Schrödinger E. New paths in physics. – M.: Nauka, 1971. (In Russian).
32. Etkin V. A. Correction of electrodynamics from the perspective of energy dynamics. // Reports of independent authors. 34(2015).193-208. (In Russian).; V. A. Etkin. Correction of Electrodynamics in the Question of the Magnetic Field Work. //Journal of Applied Physics (IOSR-JAP), 9(5). 2017. 71-75 DOI: 10.9790/4861-0905037175.
33. Landau L. D., Livshits E.M. Theoretical physics. T.8. Electrodynamics of continuous media. – M., Nauka, 1982, p.166. (In Russian).
34. Maxwell J. K. Treatise on electricity and magnetism. – M.: Nauka, 1989, T.1,2. (In Russian).
35. Tesla N. Lectures. Articles. – M., Tesla Print. - 2003. 386 p. (In Russian).
36. Etkin V. A. Towards an energy-dynamic theory of evolution. // Danish Scientific Journal, 21(1), 2019 45-50; Etkin V. A. Elimination of the Contradiction between Thermodynamics and Evolution. // Global Journal of Science Frontier Research: A Phys. and Space Science, 22(6)2022.P. 45-56.
37. Etkin V. A. On Wave Nature of Matter // World Scientific News. 69. 2017. P. 220–235.
38. Magnitsky N. A. Mathematical theory of physical vacuum. // Proceedings of NewInflow. M.: Institute of Microeconomics. 2010. 24 p. (In Russian).
39. Magnitsky N. A. The theory of compressible oscillating ether. M.: LENNAND. 2021, 216 p. (In Russian).
40. Magnitsky N. A. Dynamic chaos theory. M.: URSS, 2022. 320 p. (In Russian).
41. Etkin V. A. On the potential and driving force of radiant heat transfer // Bulletin of the Haifa House of Scientists, 2010. T.XX. P.2–6. (In Russian).
42. Etkin V. A. On selective interaction / Bulletin of the House of Scientists of Haifa, 2012. T.29. P.2–8. (In Russian).
43. Etkin V. A. Criteria for the evolution of the Universe. // Problems of science, (2)38, 2019. 5-17. (In Russian); Etkin V. A. On the Dialectic Unity of Evolution and Involution. //Global Journal of Science Frontier Research: A. Physics and Space Science. 20(10)2020. P. 9-17.
44. Etkin V. A. Perpetual motion machine of the Universe. // Bulletin of the House of Scientists of Haifa, 52(2022). 4-19. (In Russian).; V. A. Etkin. Perpetual Movement of the Universe. //Aeronautics and Aerospace Open Access Journal, 6(2). 2022. P. 29–36.



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: G
INDUSTRIAL ENGINEERING

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Optimizing Smart Factories: A Data-Driven Approach

By Janne Heilala, Antti Salminen, Wallace Moreira Bessa & Jussi Kantola

University of Turku

Abstract- Since the first industrial revolution, the leading role of emerging technologies has been highlighted in modernizing the industry and developing the workforce. This study explores the impact of Industry 4.0 digital technologies on manufacturing competitiveness, focusing on Finnish SMEs within the EU with a sample ($n = 123$). It utilizes extensive 2022 European Manufacturing Survey (EMS22) data. Advanced statistical techniques reveal complex connections between automation, competitive edge on services, and innovation models, among other factors. Robust statistical methods, including component and reliability analyses, reinforced the findings. The conclusion offers critical insights and identifies areas for further research in combining innovative manufacturing practices with technology education.

Keywords: *industry 4.0; competitiveness and employment, supply chain contracts, human resources, training and competence development, business innovation model, digital services, digital elements, product related services, cybersecurity practices, key enabling technologies, organization concepts, relocation activities, factor analysis.*

GJRE-G Classification: FOR Code: 0915



Strictly as per the compliance and regulations of:



© 2024. Janne Heilala, Antti Salminen, Wallace Moreira Bessa & Jussi Kantola. This research/review article is distributed under the terms of the Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0). You must give appropriate credit to authors and reference this article if parts of the article are reproduced in any manner. Applicable licensing terms are at <https://creativecommons.org/licenses/by-nc-nd/4.0/>.

Optimizing Smart Factories: A Data-Driven Approach

Janne Heilala ^α, Antti Salminen ^σ, Wallace Moreira Bessa ^ρ & Jussi Kantola ^ω

Abstract- Since the first industrial revolution, the leading role of emerging technologies has been highlighted in modernizing the industry and developing the workforce. This study explores the impact of Industry 4.0 digital technologies on manufacturing competitiveness, focusing on Finnish SMEs within the EU with a sample ($n = 123$). It utilizes extensive 2022 European Manufacturing Survey (EMS22) data. Advanced statistical techniques reveal complex connections between automation, competitive edge on services, and innovation models, among other factors. Robust statistical methods, including component and reliability analyses, reinforced the findings. The conclusion offers critical insights and identifies areas for further research in combining innovative manufacturing practices with technology education.

Keywords: industry 4.0; competitiveness and employment, supply chain contracts, human resources, training and competence development, business innovation model, digital services, digital elements, product related services, cybersecurity practices, key enabling technologies, organization concepts, relocation activities, factor analysis.

I. INTRODUCTION

This study's central motive is to quantitatively assess the impact of Industry 4.0 digital technologies on manufacturing competitiveness, specifically within the context of European Union Finnish small and medium-sized enterprises (SMEs). The alignment within the EU's strategic priorities is to modernize industry. Preparing the workforce in education and training means examining how technologies like automation and robotics applications can be integrated and leveraged. By utilizing the European Manufacturing Survey 2022 (EMS22) dataset tailored to the Finnish manufacturing sectors, the study aims to gain granular insights into SMEs' adoption and use of the manufacturer's key enabling technologies. The quantitative analysis of survey data provides data-driven perspectives to inform decision-making for Industry 4.0 integration.

The manufacturing industry has undergone significant transitions over centuries, from the advent of steam power and assembly lines in the 1750s (Industry 1.0) to the rise of global supply chains and localized production goals (Industry 2.0), and then progressive automation and digitalization since the 1960s (Industry 3.0). These advances have been driven by innovation and connectivity needs (Heilala, 2022). Today's

environment demands extreme customization and efficiency. This motivates embracing technologies like automation and robotics, moving towards Industry 4.0. Such technologies are critical for European Union (EU) small and medium-sized enterprises (SMEs) to bolster competitiveness. The EU aims to strategically modernize industry and develop workforces for the future (Heilala, 2022).

This research utilizes the EMS, which has tracked Europe's industrial progression for two decades, offering a rich dataset. The EMS is an extensive survey conducted across European countries that collects key information on manufacturing strategies, technologies, and practices. It provides valuable insights into the state of the industry and how it is evolving amidst digital transformation and Industry 4.0 trends. The EMS adopts a broad perspective on manufacturing evolution, complementing the innovation-focused Community Innovation Survey (CIS) grounded in the OSLO framework (Consortium for the European Manufacturing Survey 2020; Dachs & Zanker, 2015; European Commission et al., 2015). The refined EMS22 survey shows, by each question, The quantified variables of a representative sample of 123 small firms. As per leveraging EMS data, the impact of digital transformation on competitiveness is analyzed. The analysis applies exploratory factor analysis, structural equation modeling, and logistic regression to evaluate variable relationships on testing proposed hypotheses to form the logistic regression model. Key results reveal complex interdependencies between innovation models, technologies, services, and performance. The discussion interprets these insights, outlining empirical connections found and limitations encountered. The statistically driven findings contribute to the discourse on digital competitive advantage, providing a modeling foundation for ongoing research into optimizing smart manufacturing implementation.

II. LITERATURE REVIEW - DECADE-LONG PERSPECTIVE

a) Analytical Review of Manufacturing Research Trends

Prior EMS-based studies have utilized diverse statistical methods to analyze the survey data. The scoping review includes component analysis, reliability analysis through alpha, rho, and omega, and exploratory and confirmatory analyses. Structural path analysis shows multivariate analysis for discriminant and convergent validity assessments to implement in response to information characterization. Prior studies

Author ^{α σ ρ ω} : University of Turku. e-mails: janne.p.heilala@utu.fi, jussi.kantola@utu.fi, antti.salminen@utu.fi, wallace.moreirabessa@utu.fi

have shown depth in trade (European Commission, 2016; Kinkel et al., 2015). The lookup followed the format 'TITLE-ABS-KEY ("manufacturing" AND "statistic method")' to identify publications similar in the metadata. Results were filtered by year (2013-2023) for trends in

Figure 1. The usage of each component's method used in manufacturing literature (2013-2023) needed to be more extensive. The internal structures' lower reliability frequency and the current research gap were identified.

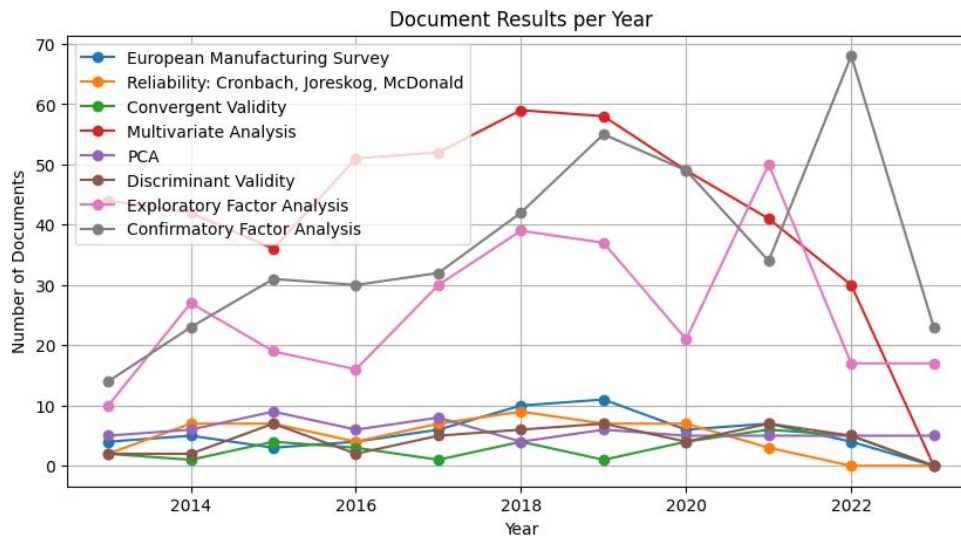


Figure 1: Trends for the Statistical Methods used in Manufacturing Method Studies (2013-2023) (Scopus 2023)

While the analysis criteria development established the management domain, the gap in examined publication trends is shown. The scope highlights increased utilization of exploratory and confirmatory factor analysis while other areas decline. The current study is aligned with the use of pre-defined variables from key themes from the EMS 2022 survey to fill the gap. The analysis incorporates a meta-level surfacing the variables from the EMS2022 survey across

categories, including competitiveness and employment metrics, supply chain contracts, human resources distribution, training initiatives, business innovation models, implementation of digital services, adoption of digital elements, provision of product-related services, cybersecurity practices, utilization of key enabling technologies, organization concepts, and prevalence of relocation activities abroad (Table 1).

Table 1: The study's classification development baseline adapts to EMS22 statements, testing if the practice is used for the context frameworks (EMS, 2022). The questions on the development of competitiveness and employment (DCES) are measuring manufacturing digitalization, acronymized as European manufacturing survey's (EMS's) key enabling technologies (KETs); organizational concepts (OCs) for relocation activities (RAs); digital services (DSs); cybersecurity practices (CPs) from the supply chain contract (SCCs) and resources (HR) perspectives. This shows that each of the factors explained is emerging in the experimental factor analysis addressed sample.

Category	Variables
Competitiveness and Employment	Annual turnover, number of employees, manufacturing capacity utilization, return on sales, investments in equipment and machinery, annual payroll as percentage of turnover, year of establishment.
Supply Chain Contracts	Manufacturers, suppliers, contract manufacturers.
Human Resources Distribution	University/college graduates, technically skilled workforce, trained workforce, semi-skilled and unskilled workers, trainees each segment indicating that practical skills and in-house training are highly valued in the workforce.
Training Initiatives	Task-specific training, cross-functional training, support in digital implementation, data security and compliance training, creativity, and innovation training.
Business Innovation Models	Distribution, access, maintenance service-based, high-performance computing, on-demand, sharing, performance, and turnkey innovative economies.
Digital Services Implementation	Customer contact platforms, digital standard solutions, automated customer interactions, remote access control elements, cloud and IoT solutions, big data analysis.
Digital Elements Adoption	Identification tags, sensor technology, interactive interfaces, real-time network connection, digital transformation technologies.

Product-Related Services Provision	Installation and start-up, maintenance and repair, training, remote support, design and project planning, prototype development, revamping and modernization, take-back services, software development.
Cybersecurity Practices	Data security awareness, software solutions, hardware solutions, organizational measures.
Key Enabling Technologies Utilization	Production control, automation and robotics, efficiency technologies, simulation, data analysis, additive manufacturing.
Organization Concepts	Organization of production, management, and control, such as lean management, quality circles, and continuous improvement processes highlight the significance of organizational culture and structure in driving performance and adaptability.

Sustainable manufacturing is the creative process of synergizing the supply chain components. The enhanced competitiveness is a sign of good manufacturing for maintaining operations. It is reflected in key EMS variables related to innovation. Innovativeness requires automating human capital development for efficiency (Chia-Yen & Andrew, 2015; Mehta et al., 2010). Aligning with Europe's 2020 strategy goals, the Scopus review has limitations to the latest EMS data. Studying and assessing relationships between digital transformation, competitiveness, and employment within Finnish manufacturing is a top priority (European Commission, 2014).

b) Research Hypothesizes

The review preliminaries show eight hypotheses developed to align with the analysis methods subsequently presented in the literature. The hypotheses show predictive relationships between EMS22 survey variables and manufacturing competitiveness and employment status for managing new natural law for technologist implications. The analysis tests hypotheses on the influence of EMS variables related to competitiveness and employment metrics (integer/binary), which are:

- H1. Business innovation model variables
- H2. Digital service implementation variables,
- H3. Digital element adoption variables,
- H4. Product-related service provision variables,
- H5. Cybersecurity practice variables,
- H6. Key enabling technology utilization variables,
- H7. Organization concept variables, and
- H8. Relocation activity variables, that

Have an explicit connection to Finnish manufacturers' competitiveness and employment. Anonymization was applied to model the small enterprises on the modeling path for a general overview. Competitiveness and employment status show the sample balanced challengingly with various sectors. The general model of the multivariate analyses between variables is usable for remote measurement of the firm floor-level relationships when fitted with normalized scores. The hypotheses assume the specific hypotheses of connections explore the exploratory

model and the bottom-level quotes to converge for discussion. Thus, the literature review of analysis methods considers exploratory factor analysis to assess the underlying factor structure. The measurement models against the survey data follow the factor structure evaluation. Structural path visioning shows the Tested hypothesized relationships advantaged to classify the sample. Reliability analysis for discriminant and convergent validity assessments validates the construct's internal validity. This EMS data derives the measure to manage small chains by a quantitative approach aligned with analyzed studies.

III. MULTI-ANALYTIC RESEARCH METHODOLOGY

Over time, the manufacturing studies trends from Scopus show applications to analyze manufacturing survey data. Findings of analyses type sorted (e.g., Kinkel et al., 2015; European Commission, 2016). A requirement to utilize factor analysis with structural path analysis is to establish an augmentation to explore relationships between variables from the latest EMS data. As such, explorative factor analysis is applied to assess the underlying factor structure with linear regression. The confirmatory on-path evaluation shows the measurement models on the survey data to the lagged binary correspondence. This was adapted to logistic regression with industry responses, reporting reliability to the causal treatment domain, see, e.g. (Wang et al., 2020; Gomila, 2021). For the detailed analysis, with the depth of linear analyses, utilizing logistic regression helped deal with binary data for drawing dedicated results. The grounding is considering traditional model fit indices for likelihoods. The accuracy on the analysis-dependent level is usually based on statistical principles (Hilbe, 2009; Casella & Berger, 2002; Hosmer Jr. et al., 2013). The approach offers coefficient interpretation in terms of associations between the variables studied. The regression path shows the hypothesized relationships influencing manufacturing competitiveness and employment component space. Reliability analysis shows internal consistency (Taber, 2016). discriminant and convergent validity validated in further models of measurement (Anderson & Gerbing, 1988).



IV. DATA-ANALYSIS

A sample (n=123) encompassed diverse industrial classifications to capture a breadth of product types and business models as classified (Heilala & Krolas, 2023). The data was acquired through Webropol's natural language collection tool and underwent cleaning to remove irrelevant responses (Webropol, 2022). The refined dataset was coded for frequency, reliability, and component analyses. Reliability analysis of the EMS2022 constructs was used to reveal internal consistency values. For reliable data, a partial technique across Industry 4.0 sectors established interpretable results (Bozgulova & Adambekova, 2023; Juariyah et al., 2020). Utilizing over 50 sub-items from the EMS22 survey represents a framework. Analysis of growth strategies in manufacturing, focusing on technologies, practices, and their impact on competition and employment industry-wide.

This spectrum of the manufacturing sector shows 'manufacturing of metal products and 'Manufacturing of machinery and equipment,' and the

software sector is most prominent. Industry sectors held a more miniature representation on each side for diversity and possibilities (Heilala & Krolas, 2023). The manufacturing industry studies have not been interested in industry-wide participatory studies (EMS, 2022; European Commission et al., 2015). Participation is included in the varied scope of industrial manufacturing, from factory assemblies to comprehensive lifecycle process assessments. Studies have usually served customers with platform requirements, such as within construction industry (He et al., 2018).

a) Convergent and Congeneric Reliability Levels

Component analysis was used for dimensionality reduction to measure the reliability of constructs. The Cronbach Alpha, Jöreskog's Rhô, and McDonald's omega were followed as in Table 2 (Taber, 2016). Alongside the analysis of several items (survey questions or statements used), the measures of internal consistency indicate a set of items' interrelation. A higher value suggests that the items measure the same concept.

Table 2: Construct Reliability Levels Show Higher Reliability for Constructs, Abbreviations Explained Below, Indicating Strong Internal Consistency with High Measurement Accuracy

	Items	Cronbach's Alpha	Joreskog Rhô	McDonald's Omega	val.
DCES	4	0.900	0.803	0.867	62
BIMs	6(7)	0.765	0.530	0.505	59
DSs	6	<.50	<.50	<.50	88
PRS	17	.825	0.824	.839	105
DEs	5	.799	0.865	.812	106
CPs	4	<.50	<.50	<.50	105
KETs	18	0.951	0.595	0.755	123
OCs	11	0.803	0.889	0.659	120
RAs	3(4)	0.900	0.885	0.583	80

Several constructs in Table 2 exhibit poor reliability per the coefficient values below 0.5. In the stats table, DCES (developing competitiveness and employment stats) measures various aspects such as AT (annual turnover) and NE (numbers of employees) to the other factory specifics, showing high reliability in all coefficients and suggesting it is a well-measured construct. On the contrary, BIM (business innovation models) has moderate reliability, indicating the varying degree of integration that could be the first varying signal of innovation potential within firms. Surprisingly, DSs (digital services) exhibit poor reliability, raising concerns over the effectiveness of these measures in capturing companies' digital transition. PRS (product-related services) demonstrated robust reliability across all coefficients for services provided, reflecting customer relationship on maintenance services. The high-reliability scores were affirmed for DEs (digital elements). Poor reliability for CPs (cybersecurity practices) has indicated potential issues in consistently measuring how digital

infrastructure is safeguarded. Despite moderate reliability, KETs (key enabling technologies) benefit the omega display because it has a broad scope of moderate reliability measures regarding a few item combinations that align with each other. Similarly, but contrary to omega, OCs (organization concepts) present reliable measures contributing to firm efficiency and agility. Uniformity to globalization, RAs (relocation activities) exhibit varied reliability across coefficients. The first signal to the empty tabulations shows Heilala and Krolas (2023), who note that the carbon footprint in offshore locations needs to be more consistently optimized by reassessing certified systems.

b) Factor Analysis

Despite a few constructs having insufficient reliability for further analyses, another angle to considering partial exploratory factor analysis (PEFA) was taken. PEFA was an intriguing option to form over an established, validated framework of the survey metrics. The technique has been used across

manufacturing and other Industry 4.0 sectors, reliably increasing safety to select the analysis method (Bozgulova & Adambekova, 2023; Juariyah et al., 2020). Factor analysis provides insights into the multivariate relationships of survey instruments (Creswell, 2015; Edmonds & Kennedy, 2019). PEFA shows the interconnections between factors influencing the instruments (Matsunaga, 2010; Revelle, 2013). Rotation methods of Varimax and ProMax optimize factor separability (Matsunaga, 2010). The PEFA is shown in the Table 3 model DCES (developing competitiveness and employment situ) measures of annual turnover for 2019-2021 (AT19/21; m23a1, m23a2), employee numbers for 2019-2021 (NE19/21; m23b1, m23b2), capacity utilization for 2019-2021 (MCU19/21; m23h), return on sales for 2019-2021 (ROS19-21; m23i1-5), investments (m23f), payroll percentage (m23g), and establishment year (m23k) reflect financials, labor dynamics, asset efficiency. High turnover and employment correlate with competitiveness. Supply chain contract (SCC) types categorize operators as manufacturers (MFR; m03a1-a3), suppliers (SPLR; m03a4-a5), or contract manufacturers (CM; m03a6), capturing production system roles. Manufacturers' negative SCC correlation potentially signals inflexibilities, unlike positively correlated suppliers and contract manufacturers benefitting from dynamic agreements. Human resources (HR) distribution classifies graduates (m16a1), technical staff (sm16a2), trained workers (m16a3), semi/unskilled personnel (m16a4), and trainees (m16a5), measuring skills and qualifications. Graduates' negative HR correlation potentially reflects oversaturation, contrasting positives for vocational abilities. Business innovation models (BIM) like leasing (BIM1; m18a1), service contracts (BIM2; m18b1), output-based services (BIM3; m18c1), sharing models (BIM4; m18d1), availability guarantees (BIM5; M18e1), and turnkeys (BIM6; m18f1) integrate variably, signaling

innovation potential. Digital services (DS) include standards solutions (m18g1), automated customer processes (m18g2), remote access controls (m18g3), cloud/IoT applications (m18g4), and data analytics (m18g5), enabling digital transitions. Digital elements (DE) such as identification tags (m04a1), sensors (m04a2), interactive interfaces (m04a3), real-time connections (m04a4), and IoT integrations (m04a5) emphasize digitization's role. Product-related services (PRS) spanning installation (m15a1), maintenance (m15b1), training (m15c1), support (m15d1), consulting (m15e1), prototyping (m15f1), modernization (m15g1), takebacks (m15h1), and software (m15i1) maintain customer relationships. Cybersecurity practices (CP), including awareness (m11a1), data controls (m11a2), network solutions (m11a3), and protections (m11a4) safeguard digital infrastructure. Key enabling technologies (KET) from programming devices (m09a1) to simulation software (m09p1) drive innovation and sustainability. Organization concepts (OC) encompassing integration (m06a1), customer-focus (m06b1), pull-based control (m06c1), changeover optimization (m06d1), standardization (m06e1), visual management (m06f1), quality assurance (m06g1), innovation involvement (m06h1), performance incentives (m06i1), environmental management (m06k1), and energy management (m06l1) contribute to efficiency and agility. Relocation activities (RA), including off shoring production (m26a1) and R&D (m26b1) and back shoring production (m26c1) and R&D (m26d1) represent strategic footprint optimization. The commonalities indicate digitalization's integral role and human capital's nuance in competitiveness, demanding tailored management. This statistical portrait outlines the drivers of European manufacturing competitiveness, employment, innovation, and strategy amidst Industry 4.0 transformation. (EMS, 2022.).

Table 3: The Factor Loadings Offer a Multidimensional Perspective on the Interconnected Variables Influencing European Manufacturing as Discerned from the EMS22 Survey

EMS item	DCES	SSC	HR	BIM	DS	DE	PRS	CP	KETs	OCs	RA	COM
m23a1	.937											.878
m23b1	.915											.836
m23h	.389											.151
m23i1-5	.261											.068
m23a2	.932											.869
m23b2	.920											.846
m23h	.419											.175
m23f	.514											.264
m23g	-.451											.203
m23k	.676											.457
m03a1-a3		-.909										.826
m03a4-a5		.522										.273
m03a6		.564										.318

m16a1	-.927		.860
m16a2	.190		.036
m16a3	.211		.045
m16a4	.677		.458
m16a5	.357		.127
m18a1		.332	.110
m18b1		-.144	.021
m18c1		-.081	.007
m18d1		.794	.631
M18e1		.795	.631
m18f1		.785	.616
m19a		-.612	.375
M18g1		.538	.290
m18g2		.153	.023
m18g3		.570	.325
m18g4		-.560	.313
m18g5		-.612	.375
m04a1		.768	.356
m04a2		.727	.590
m04a3		.858	.528
m04a4		.785	.736
m04a5		.597	.616
m15a1		.681	.463
M15b1		.625	.391
m15c1		.654	.427
M15d1		.602	.362
M15e1		.550	.302
m15f1		.482	.232
m15g1		.622	.387
M15h1		.208	.043
M15i1		.577	.333
m15a2		.598	.358
m15b2		.643	.413
m15c2		.499	.249
m15d2		.506	.256
m15e2		.436	.190
m15f2		.276	.076
m15g2		.360	.130
m15h2		.089	.008
m11a1		-.318	.101
m11a2		.617	.381
m11a3		.725	.525
m11a4		.509	.259
m09a1		.446	.199
m09b1		.448	.201
m09c1		.259	.067
m09d1		.496	.246
m09e1		.537	.289
m09f1		.466	.218
m09a1		.481	.232
m09h1		.560	.313
m09i1		.588	.345
m09a1		.536	.287
m09r1		.562	.316
m09k1		.665	.443
m09l1		.552	.304
m09m1		.581	.337
m09n1		.584	.341
m09o1		.452	.204
m09p1		.608	.369
M09q*		.516	.266
m06a1		.609	.370
m06b1		.595	.355
m06c1		.482	.232
m06d1		.570	.325
m06e1		.647	.418
m06f1		.532	.283

m06q1	.480	.230
m06h1	.613	.375
m06i1	.552	.305
m06k1	.555	.308
m06l1	.393	.155
m26a1	.699	.488
m26b1	.749	.561
m26c1	-	.031
m26d1	.751	.564
z-standardized; *Extra		

Annual turnover and employee numbers (m23a1, m23a2, m23b1, m23b2) strongly correlate with the Competitiveness and Employment Status factor (DCES), underscoring their pivotal role in manufacturing prowess. Conversely, manufacturers (m03a1-a3) exhibit a negative relationship with Supply Chain Contracts (SSC), in contrast to the positive loadings for suppliers and contract manufacturers (m03a4-a6), revealing the complexities within supply chain dynamics. Human Resources (HR) are differentially impacted by the workforce composition, where graduates (m16a1) show a negative association, while technical, trained, semi-skilled, unskilled staff and trainees (m16a2-a5) present positive correlations, highlighting the multifaceted nature of human capital in this sector. The Business Innovation Models (BIM) spectrum (m18a1 to m18f1) demonstrates diverse associations, suggesting that innovation models integrate more seamlessly into the current industrial fabric. Digital Services (DS) and Elements (DE), illustrated by loadings for (m19a, m18g1 to m18g5, and m04a1 to m04a5), emphasize the growing importance of digitalization. Product-related services (PRS: m15a1 to m15h2), Cybersecurity Practices (CPs: m11a1 to m11a4), Key Enabling Technologies (KET: m09a1 to m09p1), Organization Concepts (OC: m06a1 to m06l1), and Relocation Activities (RA: m26a1 to m26d1) all display variegated correlations, indicating that specific practices, technologies, and strategies are differentially integrated and valued within the sector. Collectively,

these loadings serve as a statistical map outlining how various elements contribute to the overall competitiveness, employment landscape, innovative capacity, and strategic direction of European manufacturing firms.

c) Convergent and Discriminant Validity

However, the PEFAs Tucker-Lewis (Tucker & Lewis 1973) indicated only partial reliability, as from the reliability in Table 2 a few chapters back elaborated. For consistency, the potential removal of some variables is suggested. The limit must be raised to elaborate the unrelated contribution of interrelations of arithmetic sums of the companies' characteristics studied (Revelle, 2013)—correlation (R) analysis to Table 4 further explored relationships between variables of interest. The data normalization was applied to ensure compliance with the central limit theorem (Schober & Boer, 2018). This comprehensive analysis elaborates on variable relationships. Potential quadratic relationships were acknowledged. The quadratic or cubic terms are rare, highlighting the need for careful analysis to saturation (Robinson & Schumacker, 2009). The R shows that the internal reliability does not control the fluctuations of the company-dependent variables. There are no homogeneous groups unless market transformers are balanced in the manufacturing portfolio (Malik et al., 2023).

Table 4: R Magnitudes Average Extractions; the Factors are Z-Standardized

	ZDCES	ZBIMs	ZDSs	ZDEs	ZPRS	ZCPs	ZKETs	ZOCs	ZRAs
ZDCES	(0.25)								
ZBIMs	-0.063	(0.297)							
ZDSs	0.052	.324**	(0.283)						
ZDEs	.303**	.318**	0.219	(0.565)					
ZPRS	0.028	.419**	.371**	.658***	(0.41)				
ZCPs	0.007	0.256*	.910**	0.089	.205**	(0.317)			
ZKETs	.417***	-0.100	0.060	0.175*	0.047	0.042	(0.28)		
ZOCs	.418***	0.006	0.090	.248**	0.050	0.046	.655**	(0.31)	
ZRAs	0.077	0.022	0.085	.398***	.379**	0.023	.305**	0.214	(0.41)

Note: results do not have significant relation/not connect (n.s./n.c.), *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ and * $p < 0.1$.

Table 4 presents a matrix of R coefficients, which explores the relationships between pairs of z-scored variables representing different constructs (e.g., ZDCES, ZBIMs, ZDSs, etc.). Rs are showing the strength and direction of the relationships between constructs. The diagonal elements in parentheses indicate the average variance extracted for each construct, a measure of convergent validity that assesses the extent to which items of a construct are positively correlated. For instance, ZDEs and ZPRS have a robust positive correlation ($R = .658^{****}$), suggesting that as one construct increases, the other tends to increase as well, and this relationship is statistically significant at the $p < 0.001$ level. Similarly, ZCPs and ZDSs are highly correlated ($R = .910^{****}$), indicating a strong positive relationship with statistical significance.

d) Hypothesis Testing

Table 5 presents the results of hypothesis testing, adding depth to the cross-correlations by direct

multivariate measures to evaluate the fit of different models to the data. The models test specific hypotheses concerning the relationships between the introduced construct and other variables within the dataset. A high RMSEA (root mean square error approximation) suggests a poor fit between the model and the observed data, indicating the need for model revision. Despite model data fit limitations, the survey analysis is a complete, valid measure involving an extraordinary spectrum. The mediation model successfully depicted indirect effects on the resolution (Baron & Kenny, 1986; Frazier et al., 2004). For example, in biotechnology studies, multiple indices can be eliminated if a too-good fit becomes a highly restricted model (Lai et al., 2016).

Table 5: Uses Dof (Degrees of Freedom), χ^2 (Chi-Squared) Test, and P-Value for Model Evaluation. A P-Value < 0.05 Typically Rejects the Model Fit. Ratios χ^2/df , and RMSEA Show Fit Informing Questionnaire Validation

Models	DoF	χ^2	p-value	χ^2/df	RMSEA*	Hypotheses Result
BIMs	21	61.636	<.001	2.92	Medium	Accepted for BIM2, BIM6; Rejected for others
DSs	10	N/A	>.05	N/A	High	Rejected for all (5)
PRS	153	497.613	<.001	2.47	Medium	Accepted for PRSO3, PRSO8; Rejected for others
DEs	10	170.463	<.001	17.463	Medium	Accepted for all (5)
CPs	10	N/A	>.05	N/A	High	Rejected for all (4)
KETs	6	59.579	<.001	9.93	Null model	Accepted for PC, AR; Declined for SDA, ET
OCs						Accepted for all (3)
RAs						Rejected for all (4)

*Note Low (>.07), null model (>.20), medium (<.20) or High RMSEA (<.30).
N/A(not applicable): not computed; lack of data.

The hypotheses result column reflects hypothesis testing outcomes within each model for having relative model fit indices based on what we have (Schubert et al., 2017). The consideration of industry requirements culminates in certifying operating boundaries in the globally recognized framework for management. The question of accepting or rejecting the sample rather than removing the sample size could be based on p-values and fit indices like χ^2/df and RMSEA with high factor loadings applicable to be studied. This would elevate the indices results due to limited saturation. As per medium models were found in the BIMs (business innovation models), specific hypotheses such as BIM2 (access) and BIM6 (turnkey project) having supported; product-related service (PRS) show PRS3 (training) and PRS8 (recycling/lifecycle of a

product tracing); and for DE (digital elements) for all: DE1 (identification), DE2 (digital functions); DE3 (interfaces); DE4 (realtime-network); and DE5 (transformations). KETs (key enabling technologies) for AR (automation and robotics) with PC (production control) were supported, but other technologies like simulation, data analysis, and additive manufacturing were not. The OCs (organization concepts) spectrum showed affirmative. Table 5 shows that null modes were taken to the investigations to build a new model in discussion. The proposed automation and robotics technology management model was stable out of statistical biases. The industrial engineering management on automation and robotics robustness shows a technology model. Industrial Management's dilemma on perfect model fit corresponds to the highest

expectations (Hogeforster & Wildt, 2021). The chi-square is not definitive in determining fit indices in understanding industrialized imbalanced segregations with indications (West et al., 2012; Shi et al., 2019). The hypothesized per a priori model is in Figure 2—the path

drives key relationships. The figure's paths provide the research model's partial exploratory factor analysis elimination perspective. The figure proposes In-not corroborated linkage to avoid worsening the model fit.

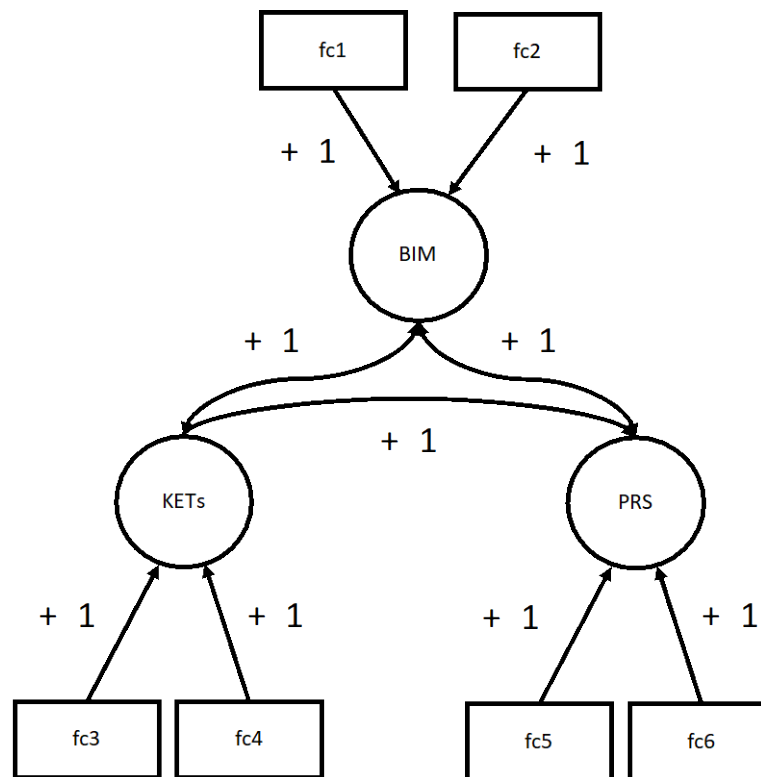


Figure 2. Has medium outlining for a null model for manufacturing survey results for discussion (arrows as causal hypotheses), focusing on contribution altogether, with BIMs with factors fc1-access and fc2-turn key innovation; KETs with factors fc3-automation and robotics and fc4-production control; and PRS, with factors fc5-online and fc6-maintenance provided —to achieve digital competitive advantage in Industry 4.0. Solid arrows depict validated causal connections between variables and factors, while double-headed arrows represent bidirectional correlations among BIMs, KETs, and PRS

e) Refining Empirical Variables

The refined structural multivariate hypothesis test shows evidence for support. Proposed relationships in the explorative research model are merged. Automation and robotics technologies computed dependent variables. Given the guess. Given their increasing prevalence in smart factories (Wang et al., 2020). This will allow testing of the integration between production control software and automated/robotic management. Per Manufacturing execution systems (MES, m09g1) and product lifecycle management (PLM, m09f1) selection to the independence of production control systems. The integral components of digital manufacturing infrastructure were explored (Lee et al., 2022). Shall MES and PLMs be selected for real-time data collection, monitoring, quality management, and product lifecycle data management (Zhong et al., 2021)? As per demonstration affirmative. The maintenance model into performance could also be critical for manufacturing operations review (Grieco et

al., 2022). The result identifies MES and PLM enabling the transformation forward for Industry 4.0 (Capgemini Research Institute, 2021).

V. EMPIRICAL RESULTS

a) Structural Concept

Per linear analysis: the depth included methods for causal links and chained handling of binary data, providing logic for advanced manufacturing (Heilala & Krolas, 2023). The logistic analysis is flexible per practice contract. Figure 3 shows that managed business innovation models (BIMs) and product-related services (PRS) can be abandoned. Industry 4.0 emphasizes manufacturing production control, automation, and robotics as key enablers. This framework for competitive advantage dynamics is in Figure 3.

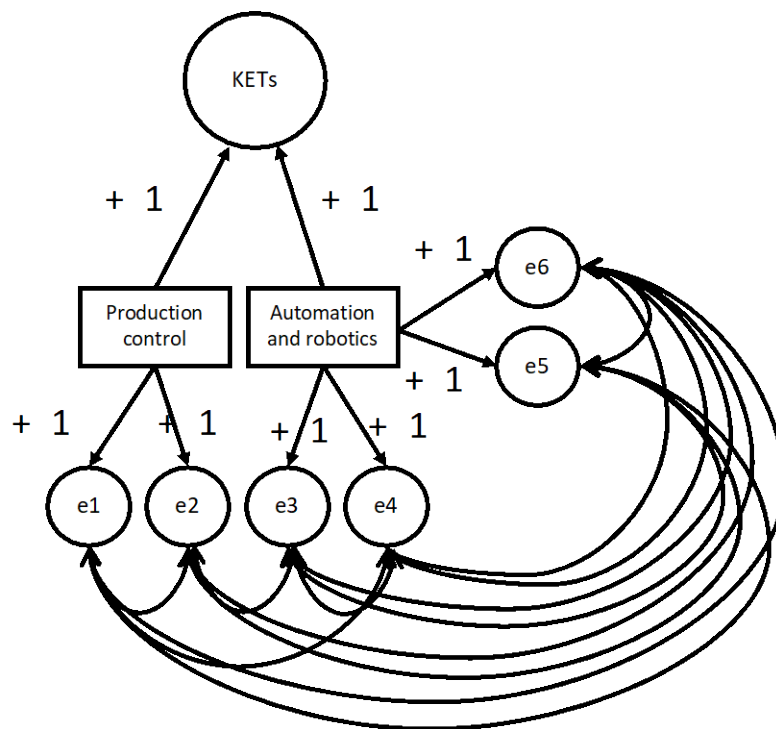


Figure 3: Structural Models Illustrate the a Priori Linear Relationships Between Automation and Robotics Production Control Endogenous Variables (E1-E6, M09, and M23-Series with Financial Management in EMS).

Exclusions of most of the factors were due to data constraints-imposed model. The boundary limitations for the power analysis on a small square are visible. Yielding lower RMSEA for fit between production control, automation, and robotics technologies. The correlates in m09-series endogenous variables e1 (f1) and e2 (g1), and connections to e3 (h1) and e4(i1) were highlighted. Integrating advanced technologies as foundational for Industry 4.0's competitive positioning evokes the primary hypothesis. The cross-sectional innovative servicing of robots and automation also

linkages with e5(q1) and e6(r1) can validate hypotheses. Confirmatory analysis suggests that innovative business practices leverage m09-series digital capability. This implies refined performance strategies resulting in manufacturer-minimum classification. The pathways of the manufacturer show solid arrows for empirically supported hypotheses, as regression ruling demonstrates. Growth stimulates advancement in other elements without the requirement for simulation. The selection variables support the theoretical hypotheses in Table 7 (Appendix A).

Table 7: The examination of a logistic regression model showing linear as detailed in Appendix A with A.1, merging various metrics of model performance with validation; A.2 measuring the model predicting correct outcomes; A.3-A.4 the model's accuracy to the relationship with result predictions

	Precision	Recall	F1-Score	Support		
	0.0	1.00	0.71	0.83	7	
	1.0	0.88	1.00	0.93	14	
	accuracy	0.90	21			
	macro	avg	0.94	0.86	0.88	21
weighted	avg	0.92	0.90	0.90	21	

The logistic regression predicts the fusion of automation technology with performance metrics. The characteristics of manufacturing classification accuracy elucidated precision to continue scientific discussions of applied regression's (Hilbe, 2009; Casella & Berger,

2002; Hosmer Jr et al., 2013). The analytical strategy's novelty shows reliability and discourse to literature to transform it into transformative innovation for engineering and financial management. Execution and lifecycle systems were chosen to represent the

production of automation and robotics. These are integral components of digital manufacturing infrastructure for sustainability (Lee et al., 2022). These systems offer comprehensive capabilities for real-time data collection, monitoring, quality management, and product lifecycle data management (Zhong et al., 2021). Past research shows similarities in shipbuilding (Sánchez-Sotano et al., 2019). Execution systems dimensioning without what operations are left to the heavy organization procedures irrelevant to manufacturers. Leading industry reports also identify results essential in digital transformation enablers for Industry 4.0 (Capgemini Research Institute, 2021). Regressions in measuring the literature confirmed a similar significant positive correlation between integrated execution on the production lifecycle, and it is being integral to finance.

VI. DISCUSSION

This study utilized path analysis and logistic regression to examine relationships between key manufacturing technologies and production outcomes. The analysis focused on widely adopted technologies and their interactions with automation and robotics. Positive correlations were found between these variables, validating hypothesized beneficial technology integration effects. While data limitations prevented confirmation of all proposed relationships, the statistically supported linkages represent essential findings for a refined model concentrating on validated connections to enable intelligent manufacturing performance.

The study also analyzed survey data assessing connections between digital transformation, manufacturing competitiveness, and employment in Finland. While hypothesis testing yielded mixed results, complex interrelationships, some business models and technologies exhibited clear positive ties to improved competitiveness. Furthermore, interactive interfaces, real-time networking, and digital transformation adoption are related to better competitiveness and employment scenarios (Moeuf et al., 2017). However, more than transparent or insignificant relationships were found for other variables like digital services, cybersecurity, simulation tools, and additive manufacturing (McNeish, 2018). These highlight areas needing further research before emphasis or investment.

VII. CONCLUSION

A statistical factorization outlined manufacturers' contributions from 2019 to 2021. The science gap reaches integration into European manufacturing competition, which concludes with execution and lifecycle management. According to the original hypotheses, growth has complex interdependencies. The inevitable other elements correspond to the

performance outcomes. However, the study cannot decide which principles of execution and lifecycle should prepare manufacturing. The standpoint on usable data constraints limited full confirmation. A partial overview supports every hypothesis. However, it is rare for a company to afford a complex system and business when manufacturing must be planned separately. A couple of more prominent companies with higher turnovers have higher integrative posts.

In conclusion, this study utilized statistical modeling to analyze the relationships for competitive manufacturing. Findings confirmed automation, robotics, and production control integration for performance. However, emerging technologies showed unclear impacts, requiring a reliable network. While small datasets set limitations preventing full spectral confirmation to all hypotheses reliably, responses contribute to future research and development. The database meta-analysis on the factor analysis' reliability reporting could be interesting to address in further studies. Factor analysis root means a square error has been outlined as heterogeneous, to which homogeneous generalization researchers aim to keep science differentiated from the actual practice. At the same time, others seem not to report indices. The indicative meta-analysis with regression test differentiates items and could open the industry trends, improving high indices.

REFERENCES RÉFÉRENCES REFERENCIAS

1. Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, 103(3), 411-423.
2. Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173-1182.
3. Bozgulova, R., & Adambekova, A. (2023). Cost accounting in the construction industry. *Central Asian Economic Review*, 6(3), 63-79.
4. Capgemini Research Institute. (2021). *Smart Factories @ Scale*. Referenced in 9.11.2023. <https://www.capgemini.com/wp-content/uploads/2019/11/Report-%E2%80%93-Smart-Factories-1-1.pdf>
5. Casella, G., & Berger, R. L. (2002). *Statistical inference*. Pacific Grove, CA: Duxbury.
6. Chia-Yen, L., & Andrew, J. (2015). Effective production: measuring of the sales effect using data envelopment analysis. *Annals of Operations Research*, 235(1), 1007-1032.
7. Consortium for the European Manufacturing Survey. (2020) COOPERATION AGREEMENT: European Manufacturing Survey December 2020 (Community Innovation Survey 2021).



8. Creswell, J. W. (2015). *A concise introduction to mixed methods research*. Thousand Oaks, CA: SAGE Publications.
9. Dachs, B., & Zanker, C. (2015). *Backshoring of production activities in European manufacturing*. MPRA Paper, University Library of Munich, Germany.
10. Edmonds, W. A., & Kennedy, T. D. (2019). *An applied guide to research designs: Quantitative, qualitative, and mixed methods*. Thousand Oaks, CA: SAGE Publications.
11. European Manufacturing Survey (EMS). (2022). EMS22 questionnaire. In *European Manufacturing Survey 2022 Finland 2019-2021[Small Firms Harmonized Data set]*. 2022. University of Turku with Fraunhofer ISI.
12. European Commission, Directorate-General for the Information Society and Media, Zanker, C., Moll, C., Jäger, A. et al., *Analysis of the impact of robotic systems on employment in the European Union – Final report*, Publications Office, 2015, <https://data.europa.eu/doi/10.2759/516348>.
13. European Commission. (2014). *The impact of accounting rules and practices on resource efficiency in the EU*. https://europe.eu/environment/enveco/resource_efficiency/pdf/studies/accounting%20rules.pdf
14. European Commission –(2016) *Digitising European Industry: Reaping the full benefits of a Digital Single Market (COM(2016) 180 final)* https://s3platform.jrc.ec.europa.eu/documents/portlet_file_entry/20125/Digitising+European+Industry+%28DÉI%29+Strategy+19+4+2016.pdf/9a666a68-a064-7ea7-80fb-
15. European Commission (EC) -2016 *The Joint Harmonised EU Programme Of Business and Consumer Surveys: User Guide* given on March 2016 Referenced in 6 2 2022 http://ec.europa.eu/economy_finance/db_indicators/surveys/method_guides/index_en.htm.
16. Frazier, P. A., Tix, A. P., & Barron, K. E. (2004). Testing moderator and mediator effects in counseling psychology research. *Journal of Counseling Psychology*, 51(1), 115-134.
17. Gomila, R. (2021). Logistic or linear? Estimating causal effects of experimental treatments on binary outcomes using regression analysis. *Journal of Experimental Psychology: General*, 150(4), 700-709.
18. Grieco, A., Ouertani, M. Z., Pasini, P., & Lorenzini, L. (2022). Industry 4.0 and operations management: a systematic literature review based on citation network analysis. *International Journal of Production Research*, 60(18), 5660-5682.
19. He, W., Tan, K. H., Zhao, X., & Li, Y. (2018). An e-commerce platform for industrialized construction procurement based on BIM and linked data. *Sustainability*, 10(2613).
20. Heilala, Janne "Developing Competitiveness and Employment Situations on Manufacturing Key Enabling Technologies." *ISPIM Conference Proceedings*. Manchester: The International Society for Professional Innovation Management (ISPIM), 2022. 1–9. Print.
21. Heilala, J., Krolas, P. (2023). Locating A Smart Manufacturing based on Supply Chain Segregation. In: Vesa Salminen (eds) *Human Factors, Business Management and Society*. AHFE (2023) International Conference. AHFE Open Access, vol 97. AHFE International, USA.<http://doi.org/10.54941/ahfe1003899>.
22. Hilbe, J. M. (2009). *Logistic regression models*. CRC press.
23. Hogeforster, M., & Wildt, J. (2021). What performance indicators predict conversion success? A meta-analysis on web survey invitations. *Social Science Computer Review*, 39(6), 931-948.
24. Hosmer Jr, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied logistic regression (Vol. 398)*. John Wiley & Sons.
25. Juariyah, L., Subekti, P., & Junaedi, M. I. (2020). Factors analysis of employees' intention to stay in chemical manufacturing. *KnE Social Sciences*, 4(9), 183-192.
26. Kinkel, S., Kirner, E., & Jaeger, A. (2015). The effects of robot use in European manufacturing companies on production off-shoring outside the EU.
27. Lai K, Green SB. The Problem with Having Two Watches: Assessment of Fit When RMSEA and CFI Disagree. *Multivariate Behav Res*. 2016 Mar-Jun; 51(2-3):220-39. doi: 10.1080/00273171.2015.1134306. Epub 2016 Mar 25. PMID: 27014948.
28. Lee, J., Bagheri, B., & Kao, H. A. (2022). An in-depth review of Industry 4.0 research for operations and supply chain management: Current trends, opportunities and future directions. *Computers & Industrial Engineering*, 172, 107933.
29. Malik, Ali Ahmad & Masood, Tariq & Brem, Alexander. (2023). *Intelligent humanoids in manufacturing to address worker shortage and skill gaps: Case of Tesla Optimus*.
30. Matsunaga, M. (2010). How to factor-analyze your data right: Do's, don'ts, and how-to's. *International Journal of Psychological Research*, 3(1), 97-110.
31. McNeish, D. (2018). The thorny relation between measurement quality and fit index cut-offs in latent variable models. *Journal of Personality Assessment*, 100(1), 43-52.
32. Mehta, N., Verma, P., & Seth, N. (2010). Total quality management implementation in the Indian auto component industry: A case study. *Production Planning & Control*, 21(7), 692-703.
33. Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The industrial

- management of SMEs in the era of Industry 4.0. *International Journal of Production Research*, 56(3), 1118-1136.
34. Revelle, W. (2013). *Psych: Procedures for psychological, psychometric, and personality research*. Evanston, IL: Northwestern University.
 35. Robinson, J. P., & Schumacker, R. E. (2009). Interaction effects: Centering, variance inflation factor, and interpretation issues. *Multiple Linear Regression Viewpoints*, 35(1), 6-11.
 36. Sánchez-Sotano, A., Cerezo-Narváez, A., Abad-Fraga, F., Pastor-Fernández, A., & Salguero-Gómez, J. (2019). Trends of Digital Transformation in the Shipbuilding Sector. *IntechOpen*. doi: 10.5772/intechopen.91164.
 37. Scopus -2023 [Database] Elsevier B V Available from <https://www.scopus.com/> Accessed on 26th June 2023.
 38. Schober, P., & Boer, C. (2018). Correlation coefficients: appropriate use and interpretation. *Anesthesia & Analgesia*, 126(5), 1763-1768.
 39. Schubert, A.-L., Hagemann, D., Voss, A., & Bergmann, K. (2017). Evaluating the model fit of diffusion models with the root mean square error of approximation. *Journal of Mathematical Psychology*, 77, 29-45. <https://doi.org/10.1016/j.jmp.2016.08.004>
 40. Shi, D., Lee, T., & Maydeu-Olivares, A. (2019). Understanding the Model Size Effect on SEM Fit Indices. *Educational Psychology Measurement*, 79(2), 310-334. <https://doi.org/10.1177/0013164418783530>
 41. Taber, K. S. (2016). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, 48(6), 1273-1296.
 42. Tucker, L. R., & Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika*, 38(1), 1-10.
 43. Wang, J., Wang, X., & He, Y. (2020). Performance shaping factors dependence assessment through moderating and mediating effect analysis. *Reliability Engineering & System Safety*, 202, 107034.
 44. Webropol. (2022). Webropol services. <https://webropol.com>
 45. West S. G., Taylor A. B., Wu W. (2012). Model fit and model selection in structural equation modeling. In Hoyle R. H. (Ed.), *Handbook of structural equation modeling* (pp. 209-231). New York, NY: Guilford Press. [Google Scholar] [Ref list].
 46. Zhong, R. Y., Xu, C., Chen, C., & Huang, G. Q. (2021). Big data analytics for physical internet-based intelligent manufacturing shop floors. *International Journal of Production Research*, 59(2), 526-540.
 47. Zhong, R. Y., Xu, X., Klotz, E., & Newman, S. T. (2017). Intelligent manufacturing in the context of industry 4.0: A review. *Engineering*, 3(5), 616-630.

Appendix A: Evaluation of Logistic Regression Model Outcomes

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, classification_report

data = {'AT_m23a1': [-99, -99, -99, -99, 0, -99, -99, -99, 1, -99, -99, -99, -99, 113, 13, -99, -99, 1, 2.1, -99, 6, 6, 65, 8, 1, 2, -99, 29, 1, 16, 4, -99, 12, 4, 1, 7, 339, -99, 24, -99, 3, 59, 29, 24, 1, 10, 3, 10, -99, 70, 3, -99, 17, 2.4, 17, -99, -99, 3, 1, -99, 48, 2, 2.8, -99, -99, -99, 120, 10.8, -99, -99, 3.022, 0.6, 3, 45, 1.5, 1.2, -99, 1, -99, 5, 0.432, 4.7, 1, 9.7, 2, -99, -99, 1.2, 2, 12.397, 100, -99, 1.04, 2.2, -99, 32, 80, 220, -99, -99, 6, -99, 19.586, 11, -99, 6.26, 9.3, 6.4, 110, -99, 6, 1.7, -99, -99, -99, -99, 3.096, 6.2, 55, 0.4, 128, 82.295749 #... all others],
'AT_m23a2': [-99, -99, -99, -99, 0, -99, -99, -99, 1, -99, -99, -99, -99, 105, 11, -99, -99, 1, 1.6, -99, 7, 6, 60, 6, 1, 1, -99, 38, 1, 15, -99, -99, 11, 5, 0, 9, 326, -99, 22, -99, 20, 63, 24, 24, 1, 9, 2, 12, -99, 49, 2, -99, 15, 0.6, 15, -99, -99, 2, 1, -99, 32, 1, 2.7, -99, -99, -99, 120, 7.8, -99, -99, 3.275, 0.615, 3, 35, 1.5, 1.4, -99, 1, -99, 5, 0.158, 4.7, 0.64, 9, 2, -99, -99, 1.2, 1.8, 10.625, 110, -99, 0.1, 2.1, -99, 13, -99, 250, -99, -99, 6, -99, 16.694, 7, -99, 19.214, 7.3, 4.2, 120, -99, 4.5, 1.5, -99, -99, -99, -99, 4.865, 6, 50, 0.5, 108, 70.102277 #... all others],
'NE_m23b1': [-99, 15, 3, -99, -99, 15, 15, -99, 40, 30, 65, 18, 7, 14, -99, 250, 17, 108, 35, -99, 46, 19, 8, 53, 345, -99, 35, -99, 10, 177, 150, 54, 10, 42, 4, 55, -99, 220, 30, -99, 50, 21, 110, -99, -99, 6, 12, -99, 65, 19, 15, -99, -99, 43, -99, 300, 120, 230, -99, 20, 26, 3, 240, 11, 6, 12, -99, 100, 7, 17, 12, 57, 11, 20, -99, 17, 20, 65, 280, -99, 14, 10, -99, 65, 160, 500, -99, -99, 42, -99, 99, 60, -99, 51, 34, 76, 300, 200, 80, 12, -99, 75, -99, -99, 25, 43, 190, 4, 52, 75, 20, 120, 140, 90, 14, 54, -99, -99, 5, 47, 9, 4, 54, 5, -99, 45 #... all others],
'NE_m23b2': [-99, 12, 2, -99, -99, 14, 14, -99, 38, 28, 64, 18, 7, 13, -99, 240, 17, 105, 33, -99, 44, 18, 8, 51, 320, -99, 33, -99, 8, 175, 140, 52, 9, 40, 4, 53, -99, 210, 28, -99, 48, 20, 108, -99, -99, 5, 11, -99, 63, 18, 14, -99, -99, 40, -99, 290, 118, 220, -99, 19, 25, 2, 235, 10, 5, 11, -99, 96, 6, 15, 10, 55, 10, 18, -99, 16, 18, 63, 270, -99, 13, 8, -99, 62, 158, 480, -99, -99, 40, -99, 96, 58, -99, 50, 32, 73, 290, 190, 78, 11, -99, 70, -99, -99, 24, 40, 185, 3, 50, 73, 19, 116, 135, 88, 12, 52, -99, -99, 4, 45, 8, 3, 52, 4, -99, 42 #... all others],
```



```

'PLM_m09f1': [0, 1, 0, -99, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 1, 0, -99, 0, -99, 0, 0, 0, 0, 0, 0, 1, 0, -99, 1, 0, 1, 1, 0, 0,
1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 1, 1, 0, 0, -99, 0, 0, 0, -99, -99, 0, 0, 0, 0, -99, 0, 0, 1, 0, 1, 0, -99, 0, 0, 1,
-99, 0, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, -99, 0, 0, 0, 0, 0, 1, 0, 0, 0, -99, 0, 0, 1, -99, 1, 1 #... all others],
'MES_ofm09g1': [0, 0, 0, -99, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 0, 1, 0, 0, -99, 1, -99, 0, 1, 0, 0, 0, 1, 1, 1, -99, 0, 0, 0, 1, 0,
0, 1, 1, 1, 1, 0, 1, 1, 0, 0, 0, 1, 0, 0, 1, 0, 0, 1, 0, 0, -99, 1, 0, 0, -99, -99, 0, 0, 0, 0, -99, 0, 0, 0, 0, 0, -99, 1, 0,
1, -99, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1, 0, -99, 1, 0, 0, 0, 0, 0, 0, 0, 0, -99, 0, 0, 0, -99, 1, 0 #... all others],
'AR1_m09h1': [1, 1, -99, -99, 0, 1, -99, -99, -99, -99, 1, 0, -99, 1, -99, -99, 0, -99, -99, -99, -99, -99, -99, -99, 1, -99, 1, -99,
-99, 0, -99, -99, 1, -99, -99, -99, 1, -99, 1, -99, -99, -99, 1, -99, -99, 1, 0, -99, 0, -99, 1, -99, -99, -99, -99, -99, 1, -99, 1, 1, 1, 0, -99, 1, 0,
-99, -99, -99, 1, -99, 1, 1, -99, -99, 1, -99, -99, 1, 0, 1, 1, -99, 1, 0, -99, -99, -99, 1, -99, 1, 1, -99, -99, 0, -99, -99, -99, 1, -99, -99, 1, 1
#... all others],
'AR2_m09i1': [0, 0, -99, -99, 1, 0, -99, -99, -99, -99, 0, 0, -99, 1, -99, -99, 0, -99, -99, -99, -99, -99, -99, -99, 0, -99, 0, -99,
-99, 1, -99, -99, 0, -99, -99, -99, 0, -99, 0, -99, -99, -99, 0, -99, 1, 1, -99, 1, -99, 0, -99, -99, -99, -99, -99, 0, -99, 1, 0, 1, 1, -99, 1, 0,
-99, -99, -99, 0, -99, 0, 1, -99, -99, 0, -99, -99, 0, 1, 1, 0, -99, 1, 0, -99, -99, -99, 0, -99, 1, 0, -99, -99, 1, -99, -99, -99, 0, -99, 1, 1
#... all others],
'AR3_m09q1': [0, 0, -99, -99, 0, 0, -99, -99, -99, -99, 1, 1, -99, 0, -99, -99, 0, -99, -99, -99, -99, -99, -99, -99, 0, -99, 0, -99,
-99, 0, -99, -99, 1, -99, -99, -99, 0, -99, 0, -99, -99, -99, 0, -99, 0, -99, 0, -99, 0, -99, -99, -99, -99, -99, 0, -99, 0, 1, 0, -99, 0, 0,
-99, -99, -99, 0, -99, 0, 0, -99, -99, 0, -99, -99, 0, 0, 1, 1, -99, 0, 0, -99, -99, -99, 0, -99, 0, 0, -99, -99, 0, -99, -99, 0, -99, 0, 1
#... all others],
'AR4_m09r1': [0, 0, -99, -99, 0, 0, -99, -99, -99, -99, 0, 1, -99, 0, -99, -99, 1, -99, -99, -99, -99, -99, -99, -99, 0, -99, 0, -99,
-99, 0, -99, -99, 0, -99, -99, -99, 0, -99, 0, -99, -99, -99, 0, -99, 1, 0, -99, 0, -99, 0, -99, -99, -99, -99, -99, 0, -99, 0, 1, 1, -99, 0, 1,
-99, -99, -99, 0, -99, 0, 0, -99, -99, 0, -99, -99, 0, 1, 1, 1, -99, 0, 1, -99, -99, -99, 0, -99, 0, 0, -99, -99, 0, -99, -99, 0, -99, 0, 1
#... all others]]
df = pd.DataFrame(data)
df.replace(-99, pd.NA, inplace=True)
for col in df.columns:
    mode_val = df[col].mode()[0]
    df[col].fillna(mode_val, inplace=True)
X = df[['MES', 'AT_m23a1', 'AT_m23a2', 'NE_m23b1', 'NE_m23b2', 'AR1_m09h1', 'AR2_m09i1', 'AR3_m09q1', 'AR4_m09r1']]
y = df['PLM']
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
clf = LogisticRegression(max_iter=1000) # max_iter
clf.fit(X_train, y_train)
y_pred = clf.predict(X_test)

```

Figure A. 2: Receiver Operating Characteristic (ROC) Curve Demonstrating Outcome Predictive Efficacy

```

import numpy as np
from sklearn.metrics import precision_recall_fscore_support, roc_curve, auc
import matplotlib.pyplot as plt
import seaborn as sns
df = pd.DataFrame(data) # As given
df.replace(-99, np.nan, inplace=True)
df.dropna(inplace=True)
X = df[['PLM', 'MES']] # PLM & MES as features
y = df['AR1'] # Assuming for example, that 'AR1' is the target variable
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)
logreg = LogisticRegression()
logreg.fit(X_train, y_train)
y_pred = logreg.predict(X_test)
y_pred_proba = logreg.predict_proba(X_test)[: , 1]
accuracy = accuracy_score(y_test, y_pred)
precision, recall, f1, _ = precision_recall_fscore_support(y_test, y_pred, average='binary')
report = classification_report(y_test, y_pred)

```

```

print('Accuracy:', accuracy)
print('Precision:', precision)
print('Recall:', recall)
print('F1 Score:', f1)
print('Classification Report:\n', report)
fpr, tpr, thresholds = roc_curve(y_test, y_pred_proba)
roc_auc = auc(fpr, tpr)

```

Figure A.3: Histogram and Bar Plot Analysis Detailing Precision, Recall, and F1-Score for 'FF' and 'TF' Outcomes

```

# Plotted normalized data
data = { # 'Y': [5.5, 6.7, 8.8, 4.4], # Interface
        'AT_m23a1': [1, 2, 3, 4], # Growth for 2021
        'AT_m23a2': [2.1, 2.2, 2.3, 2.4], # Growth for 2019
        'NE_m23b1': [3, 3.1, 3.2, 3.3], # Size for 2021
        'NE_m23b2': [4, 4.1, 4.2, 4.3], # Size for 2019
        'AR1 m09h1': [5, 5.1, 5.2, 5.3], # Industrial robots for manufacturing adoption
        'AR2 m09i1': [6, 6.1, 6.2, 6.3], # Industrial robots for handling adoption
        'AR3 m09q1': [7, 7.1, 7.2, 7.3], # Mobile industrial robots adoption
        'AR4 m09r1': [8, 8.1, 8.2, 8.3], } # Collaborating robots adoption
df = pd.DataFrame(data)
# -99 missing removal
df = df[df.PLM != -99]
df = df[df.MES != -99]
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(10, 5))
ax[0].hist(df['PLM'], bins=3, edgecolor='black')
ax[0].set_title('PLM Distribution')
ax[0].set_xlabel('PLM Value')
ax[0].set_ylabel('Frequency')
ax[1].hist(df['MES'], bins=3, edgecolor='black')
ax[1].set_title('MES Distribution')
ax[1].set_xlabel('MES Value')
ax[1].set_ylabel('Frequency')
plt.tight_layout()
plt.show()
# Regression
sns.regplot(x='PLM', y='MES', data=df, logistic=True, ci=None) # logistic regression as data is binary
plt.title('Regression Plot between PLM and MES')

```

Figure A.4: Scatter Plot with Trend Line for Model Support Against 'Outcome' Categories

```

data = pd.DataFrame({ # Tabulated logistic training results
    'Outcome': ['FF', 'TF', 'Accuracy', 'Macro Avg', 'Weighted Avg'],
    'Precision': [1.00, 0.88, None, 0.94, 0.92],
    'Recall': [0.71, 1.00, None, 0.86, 0.90],
    'F1-Score': [0.83, 0.93, 0.90, 0.88, 0.90],
    'Support': [7, 14, 21, 21, 21]})
palette = {"FF": "#1f77b4", "TF": "#ff7f0e"}
plt.figure(figsize=(20, 6))
# Plot 1 for Precision, Recall, and F1-Score for FF and TF
plt.subplot(1, 2, 1) # 1 row, 2 columns, first subplot
bar_data = data[:2].melt(id_vars='Outcome', value_vars=['Precision', 'Recall', 'F1-Score'])
bar_plot = sns.barplot(x='variable', y='value', hue='Outcome', data=bar_data, palette=palette)

```

```
plt.ylim(0, 1.1)
plt.title('Precision, Recall, and F1-Score by Outcome')
plt.ylabel('Score')
plt.xlabel('Metric')
plt.legend(title='Outcome')
for container in bar_plot.containers:
    bar_plot.bar_label(container, fmt='%.2f', padding=3)
# Plot 2 for F1-Score for Accuracy, Macro Avg, and Weighted Avg
plt.subplot(1, 2, 2) # 1 row, 2 columns, second subplot
f1_data = data[2:].melt(id_vars='Outcome', value_vars=['F1-Score'])
f1_plot = sns.barplot(x='Outcome', y='value', data=f1_data)
plt.ylim(0, 1.1)
plt.title('F1-Score for Accuracy, Macro Avg, and Weighted Avg')
plt.ylabel('F1-Score')
plt.xlabel('Metric')
for container in f1_plot.containers:
    f1_plot.bar_label(container, fmt='%.2f')
plt.tight_layout()
```

GLOBAL JOURNALS GUIDELINES HANDBOOK 2024

WWW.GLOBALJOURNALS.ORG

MEMBERSHIPS

FELLOWS/ASSOCIATES OF ENGINEERING RESEARCH COUNCIL

FERC/AERC MEMBERSHIPS

INTRODUCTION



FERC/AERC is the most prestigious membership of Global Journals accredited by Open Association of Research Society, U.S.A (OARS). The credentials of Fellow and Associate designations signify that the researcher has gained the knowledge of the fundamental and high-level concepts, and is a subject matter expert, proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice. The credentials are designated only to the researchers, scientists, and professionals that have been selected by a rigorous process by our Editorial Board and Management Board.

Associates of FERC/AERC are scientists and researchers from around the world are working on projects/researches that have huge potentials. Members support Global Journals' mission to advance technology for humanity and the profession.

FERC

FELLOW OF ENGINEERING RESEARCH COUNCIL

FELLOW OF ENGINEERING RESEARCH COUNCIL is the most prestigious membership of Global Journals. It is an award and membership granted to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Fellows are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Fellow Members.



BENEFIT

TO THE INSTITUTION

GET LETTER OF APPRECIATION

Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.



EXCLUSIVE NETWORK

GET ACCESS TO A CLOSED NETWORK

A FERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Fellows can reach out to other members or researchers directly. They should also be open to reaching out by other.

[Career](#)[Credibility](#)[Exclusive](#)[Reputation](#)

CERTIFICATE

CERTIFICATE, LOR AND LASER-MOMENTO

Fellows receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

[Career](#)[Credibility](#)[Exclusive](#)[Reputation](#)

DESIGNATION

GET HONORED TITLE OF MEMBERSHIP

Fellows can use the honored title of membership. The "FERC" is an honored title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., FERC or William Walldroff, M.S., FERC.

[Career](#)[Credibility](#)[Exclusive](#)[Reputation](#)

RECOGNITION ON THE PLATFORM

BETTER VISIBILITY AND CITATION

All the Fellow members of FERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All fellows get a dedicated page on the website with their biography.

[Career](#)[Credibility](#)[Reputation](#)

FUTURE WORK

GET DISCOUNTS ON THE FUTURE PUBLICATIONS

Fellows receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career

Financial



GJ ACCOUNT

UNLIMITED FORWARD OF EMAILS

Fellows get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org.

Career

Credibility

Reputation



PREMIUM TOOLS

ACCESS TO ALL THE PREMIUM TOOLS

To take future researches to the zenith, fellows receive access to all the premium tools that Global Journals have to offer along with the partnership with some of the best marketing leading tools out there.

Financial

CONFERENCES & EVENTS

ORGANIZE SEMINAR/CONFERENCE

Fellows are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career

Credibility

Financial

EARLY INVITATIONS

EARLY INVITATIONS TO ALL THE SYMPOSIUMS, SEMINARS, CONFERENCES

All fellows receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

Exclusive



PUBLISHING ARTICLES & BOOKS

EARN 60% OF SALES PROCEEDS

Fellows can publish articles (limited) without any fees. Also, they can earn up to 70% of sales proceeds from the sale of reference/review books/literature/publishing of research paper. The FERC member can decide its price and we can help in making the right decision.

Exclusive

Financial

REVIEWERS

GET A REMUNERATION OF 15% OF AUTHOR FEES

Fellow members are eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get a remuneration of 15% of author fees, taken from the author of a respective paper.

Financial

ACCESS TO EDITORIAL BOARD

BECOME A MEMBER OF THE EDITORIAL BOARD

Fellows may join as a member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. Additionally, Fellows get a chance to nominate other members for Editorial Board.

Career

Credibility

Exclusive

Reputation

AND MUCH MORE

GET ACCESS TO SCIENTIFIC MUSEUMS AND OBSERVATORIES ACROSS THE GLOBE

All members get access to 5 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 10 GB free secure cloud access for storing research files.

ASSOCIATE OF ENGINEERING RESEARCH COUNCIL

ASSOCIATE OF ENGINEERING RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.



BENEFIT

TO THE INSTITUTION

GET LETTER OF APPRECIATION

Global Journals sends a letter of appreciation of author to the Dean or CEO of the University or Company of which author is a part, signed by editor in chief or chief author.



EXCLUSIVE NETWORK

GET ACCESS TO A CLOSED NETWORK

A AERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Associates can reach out to other members or researchers directly. They should also be open to reaching out by other.

Career

Credibility

Exclusive

Reputation



CERTIFICATE

CERTIFICATE, LOR AND LASER-MOMENTO

Associates receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

Career

Credibility

Exclusive

Reputation



DESIGNATION

GET HONORED TITLE OF MEMBERSHIP

Associates can use the honored title of membership. The "AERC" is an honored title which is accorded to a person's name viz. Dr. John E. Hall, Ph.D., AERC or William Walldroff, M.S., AERC.

Career

Credibility

Exclusive

Reputation

RECOGNITION ON THE PLATFORM

BETTER VISIBILITY AND CITATION

All the Associate members of AERC get a badge of "Leading Member of Global Journals" on the Research Community that distinguishes them from others. Additionally, the profile is also partially maintained by our team for better visibility and citation. All associates get a dedicated page on the website with their biography.

Career

Credibility

Reputation

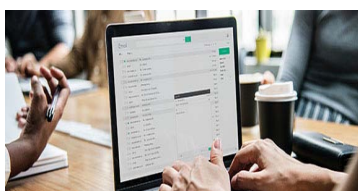
FUTURE WORK

GET DISCOUNTS ON THE FUTURE PUBLICATIONS

Associates receive discounts on the future publications with Global Journals up to 60%. Through our recommendation programs, members also receive discounts on publications made with OARS affiliated organizations.

Career

Financial



GJ ACCOUNT

UNLIMITED FORWARD OF EMAILS

Associates get secure and fast GJ work emails with unlimited storage of emails that they may use them as their primary email. For example, john [AT] globaljournals [DOT] org..

Career

Credibility

Reputation



PREMIUM TOOLS

ACCESS TO ALL THE PREMIUM TOOLS

To take future researches to the zenith, associates receive access to all the premium tools that Global Journals have to offer along with the partnership with some of the best marketing leading tools out there.

Financial

CONFERENCES & EVENTS

ORGANIZE SEMINAR/CONFERENCE

Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career

Credibility

Financial

EARLY INVITATIONS

EARLY INVITATIONS TO ALL THE SYMPOSIUMS, SEMINARS, CONFERENCES

All associates receive the early invitations to all the symposiums, seminars, conferences and webinars hosted by Global Journals in their subject.

Exclusive



PUBLISHING ARTICLES & BOOKS

EARN 30-40% OF SALES PROCEEDS

Associates can publish articles (limited) without any fees. Also, they can earn up to 30-40% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.

Exclusive

Financial

REVIEWERS

GET A REMUNERATION OF 15% OF AUTHOR FEES

Associate members are eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get a remuneration of 15% of author fees, taken from the author of a respective paper.

Financial

AND MUCH MORE

GET ACCESS TO SCIENTIFIC MUSEUMS AND OBSERVATORIES ACROSS THE GLOBE

All members get access to 2 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 5 GB free secure cloud access for storing research files.



ASSOCIATE	FELLOW	RESEARCH GROUP	BASIC
\$4800 lifetime designation	\$6800 lifetime designation	\$12500.00 organizational	APC per article
Certificate , LoR and Momento 2 discounted publishing/year Gradation of Research 10 research contacts/day 1 GB Cloud Storage GJ Community Access	Certificate , LoR and Momento Unlimited discounted publishing/year Gradation of Research Unlimited research contacts/day 5 GB Cloud Storage Online Presense Assistance GJ Community Access	Certificates , LoRs and Momentos Unlimited free publishing/year Gradation of Research Unlimited research contacts/day Unlimited Cloud Storage Online Presense Assistance GJ Community Access	GJ Community Access



PREFERRED AUTHOR GUIDELINES

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from <https://globaljournals.org/Template.zip>

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

BEFORE AND DURING SUBMISSION

Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

1. Authors must go through the complete author guideline and understand and *agree to Global Journals' ethics and code of conduct*, along with author responsibilities.
2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s) names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
5. Authors should submit paper in a ZIP archive if any supplementary files are required along with the paper.
6. Proper permissions must be acquired for the use of any copyrighted material.
7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

POLICY ON PLAGIARISM

Plagiarism is not acceptable in Global Journals submissions at all.

Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures



- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

AUTHORSHIP POLICIES

Global Journals follows the definition of authorship set up by the Open Association of Research Society, USA. According to its guidelines, authorship criteria must be based on:

1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

Copyright

During submission of the manuscript, the author is confirming an exclusive license agreement with Global Journals which gives Global Journals the authority to reproduce, reuse, and republish authors' research. We also believe in flexible copyright terms where copyright may remain with authors/employers/institutions as well. Contact your editor after acceptance to choose your copyright policy. You may follow this form for copyright transfers.

Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

PREPARING YOUR MANUSCRIPT

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.



Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

- a) A title which should be relevant to the theme of the paper.
- b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
- c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
- d) An introduction, giving fundamental background objectives.
- e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
- f) Results which should be presented concisely by well-designed tables and figures.
- g) Suitable statistical data should also be given.
- h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

- i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
- j) There should be brief acknowledgments.
- k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.



FORMAT STRUCTURE

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.



Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

PREPARATION OF ELETRONIC FIGURES FOR PUBLICATION

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

TIPS FOR WRITING A GOOD QUALITY ENGINEERING RESEARCH PAPER

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow [here](#).



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.



21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.



- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.



Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.



Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.



Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

THE ADMINISTRATION RULES

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

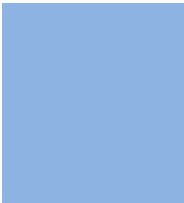


CRITERION FOR GRADING A RESEARCH PAPER (COMPILATION)
BY GLOBAL JOURNALS

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring





INDEX

A

Anthropometry · 1, 2
Arduous · 16
Astute · 13
Asymptotic · 5

B

Bolstered · 13

C

Clusters · 6, 9
Congenital · 8
Curb · 1, 2

D

Drupes · 11

E

Emulation · 14
Epidemiological · 2
Ergonomic · 1, 4, 6, 7, 8

F

Fumes · 2, 7

L

Lethargy · 2

P

Pallet · 15
Paradigm · 14, 15
Perpetrator · 6, 9
Pertinent · 14, 15
Preemptive · 16

R

Robust · 4

S

Spectroscopy · 13



save our planet



Global Journal of Researches in Engineering

Visit us on the Web at www.GlobalJournals.org | www.EngineeringResearch.org
or email us at helpdesk@globaljournals.org



ISSN 9755861

© Global Journals