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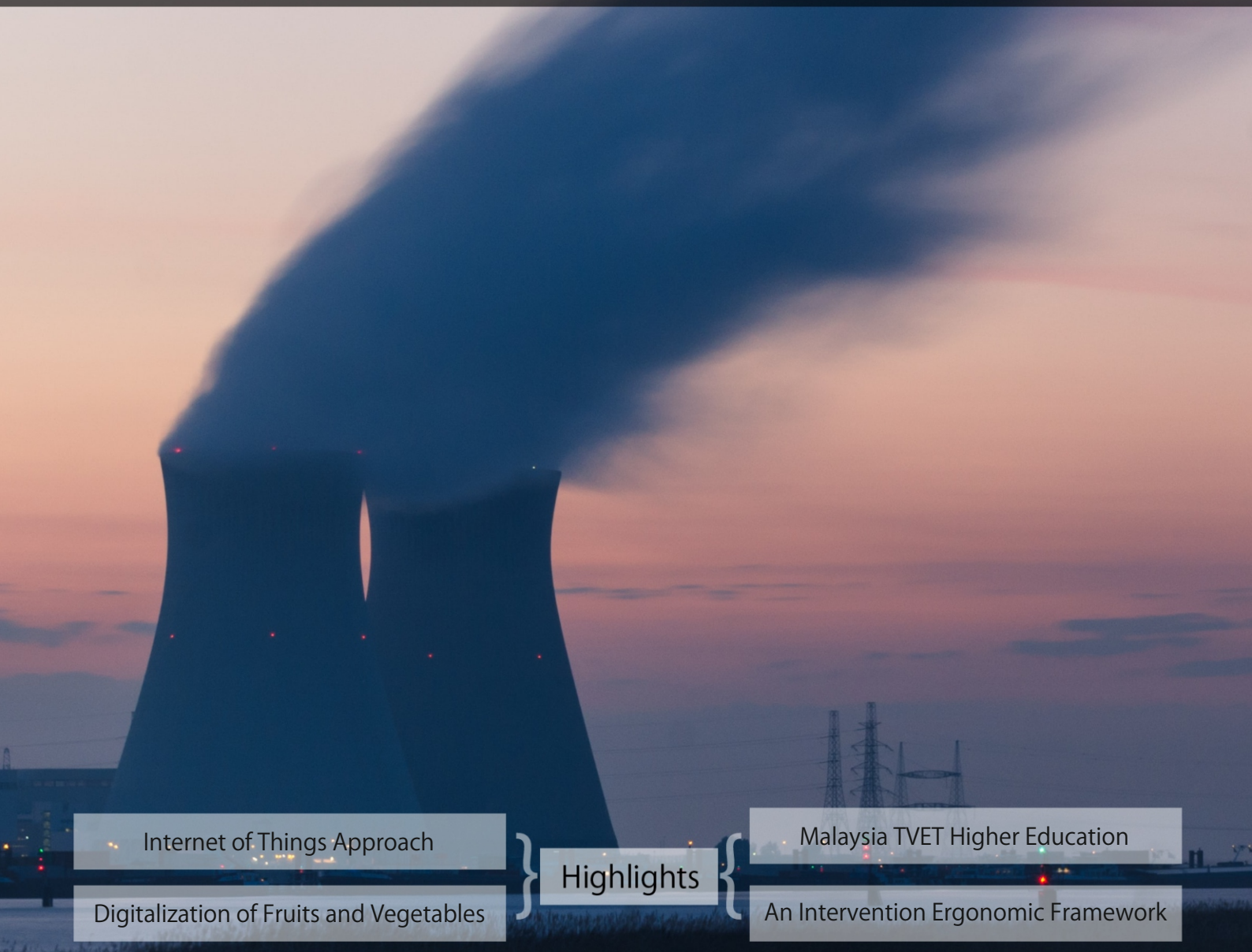

Internet of Things Approach

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

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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.*

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An Intervention Ergonomic Framework for Malaysia TVET Higher Education

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

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

I. 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

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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.

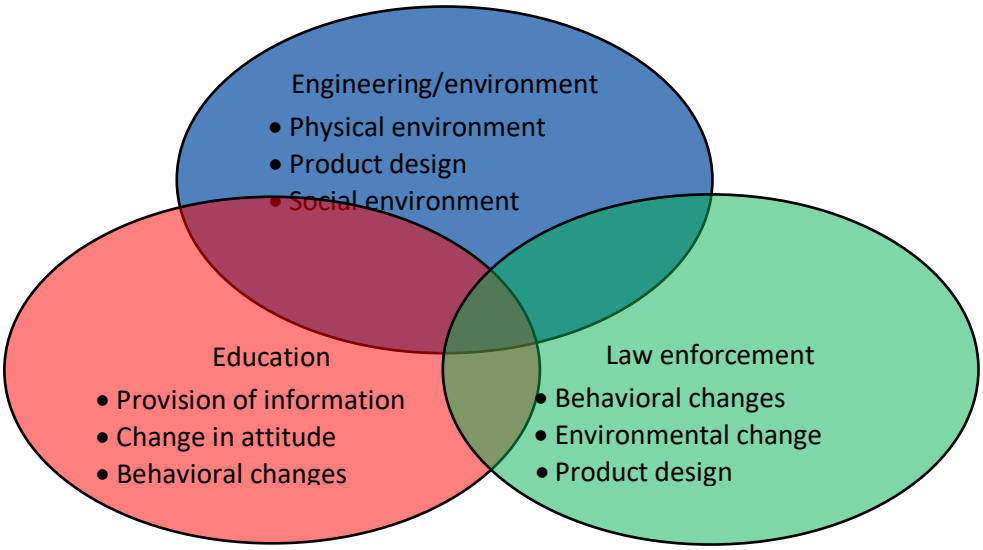

Figure 1: 3E model of injury prevention

Macro Ergonomics is a human-cantered 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-cantered 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.

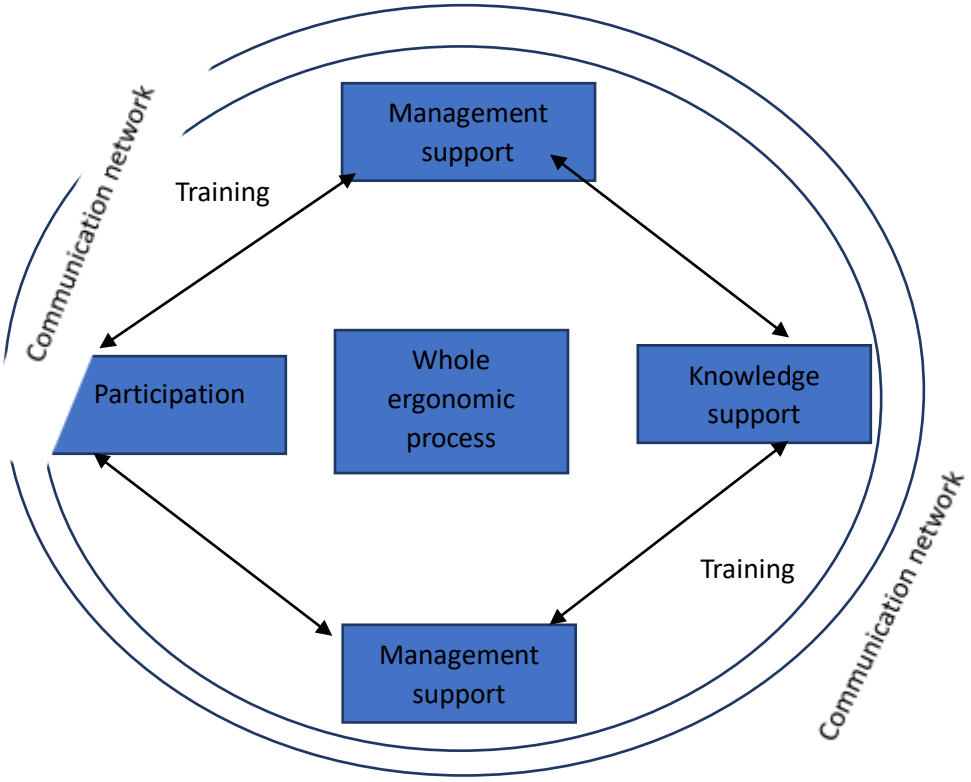

Figure 1: Overall evaluation model of ergonomics and intervention process

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 hazads, 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 creteria as one of the leading indicatiors 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 ang 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:

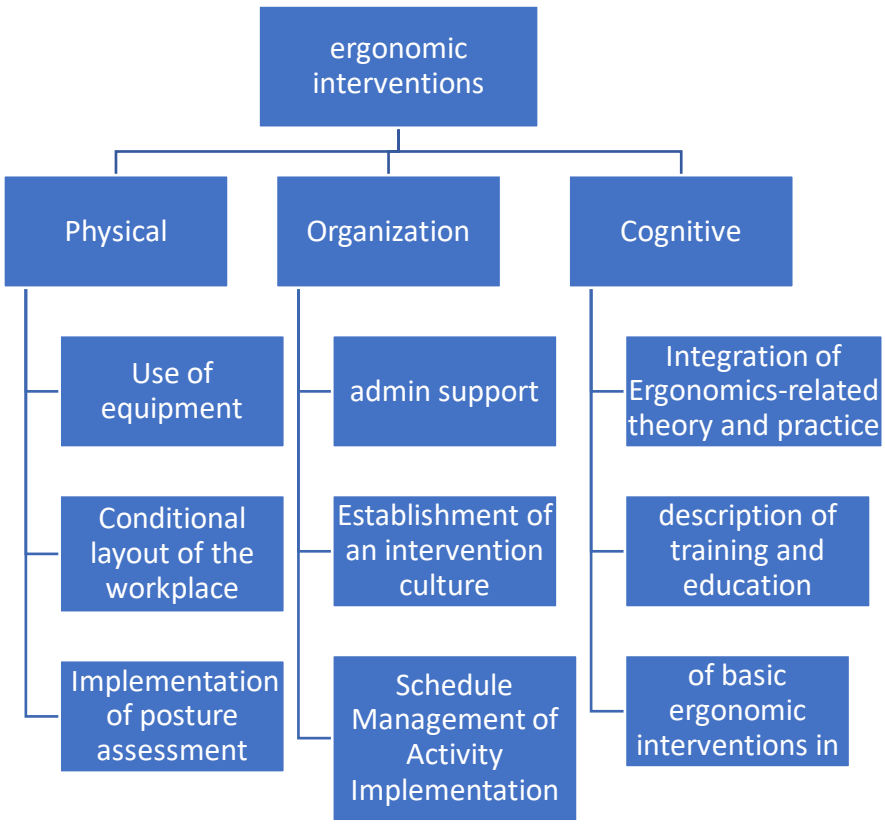

Figure 2: Recommendations Framework of ergonomic interventions

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.

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

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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.

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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

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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.

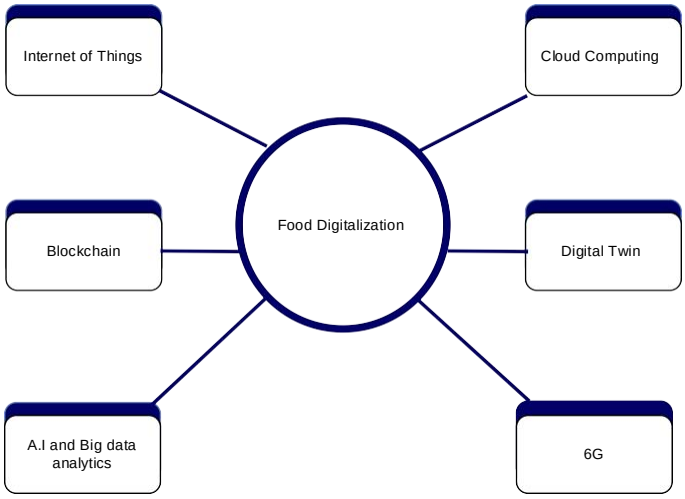

Fig. 1: Food Digitalization

The aim of this research is to examine plausible tactics for reducing food wastage 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].

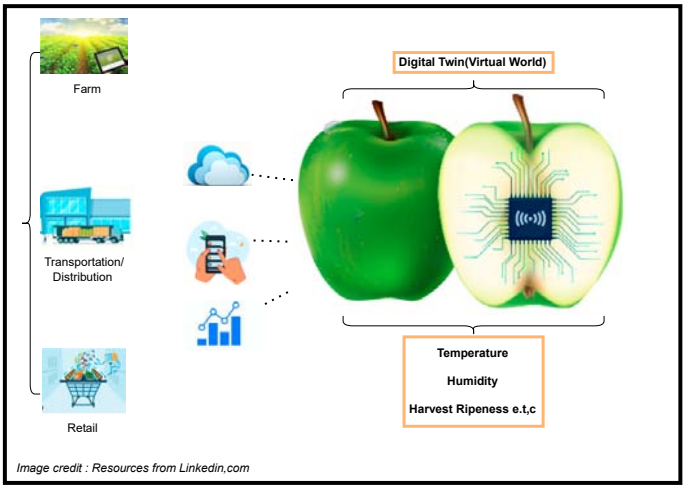

Fig. 2: Fruit Digital twin during postharvest supply chain

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 twinss 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.

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By Dr. Christos P. Beretas

Abstract- Cybersecurity in Programmable Logic Controllers (PLCs) is a critical component in ensuring the overall security and reliability of industrial control systems. PLCs are widely used in various industries to automate processes and control machinery. However, as PLCs become more interconnected with other systems and the internet, they are increasingly vulnerable to cyber threats. This abstract explores the importance of cybersecurity in PLCs and the potential risks associated with inadequate security measures. It highlights the various ways in which PLCs can be compromised, such as through malware attacks, unauthorized access, or physical tampering. This abstract discusses the potential consequences of a cyber-attack on PLCs, including disruption of critical infrastructure, loss of sensitive data, and potential harm to personnel. It also emphasizes the importance of implementing robust cybersecurity measures, such as encryption, access control, and regular security audits, to protect PLCs from cyber threats.

Keywords: *IoT, cybersecurity, beretas, vulnerabilities, hacking, industry 4.0, threats, critical infrastructure.*

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Finally, this abstract underscores the importance of prioritizing cybersecurity in PLCs to ensure the continued safety and reliability of industrial processes. Failure to adequately secure PLCs can have far-reaching consequences, making it imperative for organizations to invest in cybersecurity measures to safeguard their critical infrastructure.

Keywords: IoT, cybersecurity, beretas, vulnerabilities, hacking, industry 4.0, threats, critical infrastructure.

I. Introduction

A Programmable Logic Controller (PLC) is a critical component in industrial automation, controlling various processes and machinery in sectors such as manufacturing, energy, and transportation. As PLCs become increasingly interconnected within larger networks and integrated with other systems, the need for robust cybersecurity measures to protect these devices from cyber threats has become paramount. Cybersecurity in the context of PLCs involves safeguarding these devices from unauthorized access, data breaches, and malicious attacks that could compromise their functionality, disrupt operations, and potentially lead to physical harm or damage. With the growing interconnectedness of industrial systems and the rise of Industry 4.0, PLCs are becoming more vulnerable to cyber threats, as hackers target these devices to gain access to sensitive data, manipulate operations, or cause system failures. As such, organizations that rely on PLCs must implement comprehensive cybersecurity strategies to mitigate these risks and ensure the integrity, availability, and confidentiality of their industrial processes. This may involve measures such as network segmentation, access controls, encryption, regular software updates, and employee training on cybersecurity best practices.

II. PLC Cyber Threats

PLC (Programmable Logic Controller) systems are a critical component in industrial automation, used in various industries such as manufacturing, energy, and transportation. These systems are responsible for controlling and monitoring various processes, making them an attractive target for cyber threats. With the increasing connectivity of devices in industrial settings, PLC systems are becoming more vulnerable to cyber attacks. In recent years, there have been several high-profile incidents of PLC cyber threats, including the Stuxnet virus that targeted Iran's nuclear program in 2010. One of the main threats facing PLC systems is malware. Malware can infiltrate a system through various means, such as phishing emails, infected USB drives, or vulnerabilities in software. Once inside a system, malware can disrupt operations, steal sensitive data, or even sabotage equipment.

Another common cyber threat facing PLC systems is ransomware. Ransomware is a type of malware that encrypts a system's data, making it inaccessible until a ransom is paid. In the case of PLC systems, a ransomware attack can bring operations to a standstill, causing significant financial losses for the organization. Hackers can also exploit vulnerabilities in PLC systems to gain unauthorized access and manipulate processes. This can lead to equipment malfunctions, production delays, or even safety hazards. In some cases, hackers have targeted critical infrastructure, such as power plants or water treatment facilities, posing a significant risk to public safety.

To protect against PLC cyber threats, organizations must take proactive measures to secure their systems. This includes implementing strong

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cybersecurity protocols, such as regularly updating software, using firewall and antivirus protection, and conducting regular security audits. Training employees on cybersecurity best practices can also help prevent attacks. Additionally, organizations should consider implementing network segmentation to isolate critical systems from the rest of the network. This can help contain an attack and limit the damage caused by a breach. Regularly backing up data and developing a response plan in the event of a cyber-attack are also essential components of a robust cybersecurity strategy. PLC systems are increasingly facing cyber threats, posing a significant risk to industrial operations. By implementing strong cybersecurity measures and staying vigilant against emerging threats, organizations can better protect their PLC systems from cyber attacks and ensure the continued reliability and safety of their operations.

III. PLC Cyber Security

PLC (Programmable Logic Controller) Cyber Security has become a major concern as industrial control systems are increasingly interconnected and vulnerable to cyberattacks. PLCs are widely used in manufacturing plants, power plants, and various other industrial settings to control processes and equipment. These systems are critical to the operation of many industries and must be protected from cyber threats to prevent costly downtime and potential safety risks. One of the main challenges in securing PLCs is that they were not originally designed with cybersecurity in mind. Many older PLCs lack basic security features such as password protection, encryption, and secure communication protocols. This makes them easy targets for hackers who can exploit vulnerabilities to gain unauthorized access and disrupt operations. To address these vulnerabilities, industry experts recommend implementing several cybersecurity best practices for PLCs. These include:

- *Network segmentation:* Isolating PLCs from other networks can help prevent unauthorized access. Creating separate VLANs for PLCs and implementing firewall rules can limit communication between devices and networks.
- *Strong authentication:* Requiring complex passwords and using two-factor authentication can help prevent unauthorized access to PLCs. Changing default passwords and regularly updating credentials can also enhance security.
- *Regular software updates:* Keeping PLC firmware and software up to date is essential for patching security vulnerabilities. Manufacturers often release updates to address known cybersecurity issues, so it is important to install these patches as soon as they become available.
- *Access control:* Limiting access to PLCs to authorized personnel can help prevent insider threats. Implementing role-based access controls can ensure that only employees with the proper credentials can make changes to PLC configurations.
- *Monitoring and logging:* Monitoring network traffic and logging PLC activity can help detect suspicious behavior and potential cyberattacks. Intrusion detection systems and security information and event management (SIEM) tools can provide real-time alerts and analysis of security events.

Securing PLCs from cyber threats is essential to protect critical infrastructure and prevent costly disruptions. By implementing best practices for PLC cyber security, industrial organizations can reduce the risk of cyberattacks and ensure the safe and reliable operation of their systems. As cyber threats continue to evolve, it is important for industry stakeholders to stay informed about emerging threats and best practices for securing PLCs.

IV. PLC Cyber Attacks

A PLC, or Programmable Logic Controller, is a specialized computer used in industrial control systems to automate tasks such as manufacturing processes, power generation, and building automation. PLCs are widely used in critical infrastructure, making them an attractive target for cyber attacks. PLC cyber attacks have the potential to cause significant disruption and damage, as they can affect the operation of entire industrial systems. These attacks can be carried out by malicious actors seeking financial gain, political motives, or simply looking to cause chaos. There are several types of PLC cyber attacks that can be used to compromise industrial systems. One common method is to exploit vulnerabilities in the system's software or firmware. Hackers can use coding errors or security flaws to gain unauthorized access to the PLC and manipulate its functions.

Another type of attack is known as a *denial-of-service (DoS) attack,* where the PLC is overwhelmed with a flood of traffic, causing it to become unresponsive and potentially shutting down the entire system. This type of attack can be especially damaging in industries where downtime can result in significant financial losses. *Man-in-the-middle attacks* are also a concern when it comes to PLCs. In this type of attack, a hacker intercepts communication between the PLC and other devices on the network, allowing them to manipulate data or inject malicious code into the system.

To protect against PLC cyber attacks, organizations should implement various security measures, such as regularly updating firmware and software, using strong encryption protocols, and segmenting networks to limit the spread of an attack.

Additionally, training employees on cybersecurity best practices and implementing access controls can help prevent unauthorized access to PLCs. PLC cyber attacks pose a significant threat to industrial control systems and critical infrastructure. By understanding the different types of attacks and implementing robust security measures, organizations can better protect their PLCs from cyber threats and ensure the continued operation of their systems.

V. Industry 4.0 and PLC Security

Industry 4.0, also known as the Fourth Industrial Revolution, is characterized by the integration of digital technologies into manufacturing processes. This includes the use of artificial intelligence, the Internet of Things (IoT), big data analytics, and cloud computing to create smart factories that are more efficient, flexible, and interconnected than ever before. One key technology that plays a crucial role in Industry 4.0 is the Programmable Logic Controller (PLC). PLCs are used to automate industrial processes such as assembly lines, packaging machines, and robotic arms. They are essentially the brains of the operation, executing programmed instructions to control machinery and equipment in real-time. However, as Industry 4.0 continues to evolve, the security of PLCs has become a growing concern. With the increasing connectivity of industrial systems, PLCs are now more vulnerable to cyber attacks than ever before. Hackers can exploit vulnerabilities in PLCs to gain access to sensitive data, disrupt operations, or even cause physical harm to workers and equipment. To address these security risks, manufacturers must implement robust cybersecurity measures to protect their PLCs. This includes regularly updating firmware and software, enforcing strong password policies, segmenting networks, encrypting data, and monitoring for unauthorized access or suspicious activity. Furthermore, manufacturers should invest in training their employees on cybersecurity best practices and implementing a culture of security throughout the organization. It is crucial for all stakeholders, from engineers to executives, to understand the importance of PLC security and take proactive steps to protect against potential threats.

In addition to internal measures, manufacturers can also look to industry standards and regulations for guidance on PLC security. Organizations such as the International Society of Automation (ISA) have developed standards like ISA/IEC 62443 to help companies secure their industrial control systems, including PLCs. PLC security is a critical component of Industry 4.0 that cannot be overlooked. By taking proactive steps to secure their PLCs, manufacturers can ensure the safety, reliability, and efficiency of their smart factories in the digital age.

VI. Mitigate PLC Cyber Threats in Industry 4.0

As Industry 4.0 continues to revolutionize the manufacturing sector with its interconnected systems and smart technologies, the risk of cyber threats to Programmable Logic Controllers (PLCs) has become a growing concern. PLCs are computerized control systems that automate industrial processes, making them a critical component in the functioning of modern factories. However, their reliance on network connectivity also makes them vulnerable to cyber attacks that can disrupt operations, compromise sensitive data, and even pose a threat to worker safety. Mitigating PLC cyber threats is essential to ensure the smooth and secure functioning of Industry 4.0 environments. Here are some strategies that organizations can adopt to enhance the cybersecurity of their PLCs:

- *Implement robust access control measures:* Limiting access to PLCs to authorized personnel only is a crucial step in preventing unauthorized individuals from tampering with the system. Implementing strong authentication mechanisms such as multi-factor authentication and restricting network access to trusted devices can help minimize the risk of unauthorized access.
- *Regularly update and patch PLC firmware:* Manufacturers often release firmware updates and patches to address security vulnerabilities in their PLCs. Ensuring that these updates are promptly applied can help protect PLCs from known threats and ensure they are equipped with the latest security features.
- *Encrypt communication channels:* Encrypting communication channels between PLCs and other systems can help safeguard sensitive data from interception and manipulation by cyber attackers. Implementing protocols such as Secure Sockets Layer (SSL) or Transport Layer Security (TLS) can add an extra layer of security to PLC communication.
- *Monitor network traffic:* Monitoring network traffic for any unusual or suspicious activities can help detect potential cyber threats at an early stage. Implementing Intrusion Detection Systems (IDS) and Intrusion Prevention Systems (IPS) can help organizations identify and respond to security incidents in real-time.
- *Conduct regular security audits and assessments:* Regularly auditing and assessing the security posture of PLCs can help organizations identify potential vulnerabilities and weaknesses that may be exploited by cyber attackers. Conducting penetration testing and vulnerability assessments

can help organizations proactively address security gaps before they are exploited.

- *Educate employees on cybersecurity best practices:* Human error is often a significant factor in cybersecurity incidents. Educating employees on cybersecurity best practices, such as avoiding clicking on suspicious links or downloading unknown files, can help prevent inadvertent security breaches that could compromise PLC systems.

Mitigating PLC cyber threats in Industry 4.0 requires a comprehensive and proactive approach to cybersecurity. By implementing robust access control measures, regularly updating and patching firmware, encrypting communication channels, monitoring network traffic, conducting security audits, and educating employees on cybersecurity best practices, organizations can enhance the security of their PLC systems and minimize the risk of cyber attacks in the increasingly digitalized manufacturing landscape.

VII. Cybersecurity Best Practices

Cybersecurity is a critical concern for businesses of all sizes, and this is particularly true when it comes to protecting programmable logic controllers (PLCs) from cyber threats. PLCs are computer-based control systems that automate industrial processes, and they are often used in critical infrastructure such as power plants, water treatment facilities, and manufacturing plants. A cyber attack on a PLC could have serious consequences, including physical damage to equipment, loss of productivity, and even harm to employees. To minimize the risk of cyber attacks on PLCs, it is essential for businesses to implement best practices for cybersecurity. These practices can help to prevent unauthorized access, tampering, and other malicious activities that could compromise the integrity and security of PLCs. Here are some key best practices that businesses should consider when it comes to PLC cybersecurity:

- *Implement a robust network security strategy:* PLCs are often connected to corporate networks or the internet, making them vulnerable to cyber attacks. To protect PLCs from unauthorized access, businesses should implement strong network security measures, such as firewalls, intrusion detection systems, and secure VPN connections. It is also important to segment PLC networks from other corporate networks to limit the potential impact of a cyber attack.
- *Keep software and firmware up to date:* PLC vendors regularly release software updates and patches to address security vulnerabilities. Businesses should regularly update the software and firmware on their PLCs to ensure they are protected against the latest threats. It is also important to change default passwords and disable unnecessary services to reduce the risk of unauthorized access.
- *Restrict physical access to PLCs:* Physical access to PLCs should be restricted to authorized personnel only. Businesses should secure PLCs in locked cabinets or rooms, and limit access to individuals who have been properly trained in cybersecurity best practices. It is also important to monitor and log access to PLCs to detect any unauthorized activity.
- *Train employees on cybersecurity best practices:* Employees who work with PLCs should be trained in cybersecurity best practices, such as how to identify phishing emails, how to create strong passwords, and how to detect suspicious activity on the network. Businesses should also conduct regular cybersecurity awareness training to educate employees on the latest threats and how to mitigate risk.
- *Conduct regular security assessments:* Businesses should regularly assess the cybersecurity posture of their PLCs to identify and address any security vulnerabilities. This can be done through penetration testing, vulnerability scanning, and security audits. It is also important to monitor PLCs for any signs of suspicious activity, such as changes to configuration settings or unusual network traffic.

By implementing these best practices for PLC cybersecurity, businesses can reduce the risk of cyber attacks on their critical infrastructure. Protecting PLCs from cyber threats is essential for ensuring the safety, security, and reliability of industrial processes, and businesses should make cybersecurity a top priority in their operational and risk management strategies.

VIII. Conclusion

It is evident that cybersecurity for PLCs is a critical aspect of maintaining the security and stability of industrial systems. With the increasing interconnectedness of devices in industrial settings, the potential for cyber attacks on PLCs is higher than ever before. It is essential for organizations to implement robust cybersecurity measures to protect their PLCs from potential threats and vulnerabilities. By staying up-to-date on the latest cybersecurity best practices, conducting regular security audits, and investing in advanced security solutions, organizations can significantly reduce the risk of cyber attacks on their PLCs. Ultimately, a proactive approach to cybersecurity is crucial in ensuring the continued functionality and safety of industrial systems. It is imperative for organizations to prioritize PLC cybersecurity to safeguard their operations and prevent potentially catastrophic consequences.

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The Effect of Changes in External Factors on the Natural Frequencies of Large Objects

By V. S. Seleznev, A. V. Liseikin, I. V. Kokovkin & V. M. Solovyov

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The Effect of Changes in External Factors on the Natural Frequencies of Large Objects

V. S. Seleznev [α], A. V. Liseikin [σ], I. V. Kokovkin [ρ] & V. M. Solovyov [ω]

Abstract- This work is devoted to the development of the engineering seismic monitoring method created in GS RAS. In previous years, the "method of standing waves" was created and put into practice. It helps to separate natural oscillation modes of buildings and other engineering structures. The natural oscillations of hundreds of various objects (buildings, bridges, dams, etc.) had been studied and identified. We assumed that the physical condition of studied constructions could be controlled during exploitation by measuring the changes of natural oscillation frequencies. That would help to identify the appearance of defects in constructions, to prevent the risk of their destruction. However, it turned out that not everything is that simple: changes in frequency values are logically affected by changes in the environment around the studied objects. This article provides examples of these relations, influence of changes in environmental temperature, mass of objects and precipitation on the frequencies of natural oscillations.

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I. Introduction

Any building, bridge, dam, large construction object can be characterized by a set of natural oscillation modes. In seismology, these parameters are used to identify seismic stability of a construction. To understand what kind of vibrations could be endured by a construction during an earthquake (for the structure to remain), it is necessary to identify an accelerogram (i.e., identify accelerations during the earthquake in the construction location), conduct seismic microzoning (to understand how the upper part of the section would increase vibrations caused by an earthquake). Now, that we know these characteristics and oscillation modes of the object, we can solve the problem.

There are two known methods for determining the amplitude-frequency characteristics of buildings and structures. The first, knowing in detail a construction design, to calculate theoretically these characteristics. The second is to determine experimentally. For the second one the "standing wave method" was developed and passed extensive practical tests on various objects [Emanov et al., 2002]. Using this method, we can determine the natural oscillation modes up to an extremely accurate level. For example, at the Sayano-Shushenskaya HPP (SSH HPP) dam, about a dozen oscillation modes were identified at different levels of reservoir filling. Determining these modes is not an easy task and it requires observations of seismic oscillations at hundreds (sometimes up to thousands) of points. In this case, we get the data in a time slice. The oscillation modes have such parameters at the moment of measurement, but what happens after a while? Builders are well aware [Hsu et al., 2020] that oscillation modes (and their frequencies) can change when an object is covered with cracks. The same way you can check integrity of crystal glasses in a store, by hitting the glass with a pencil and listening to it ring. If there is a crack in the glass, the frequency of the sound will decrease, due to loss of structural integrity of the material. Likewise, we would like to develop a monitoring system for buildings and constructions that tracks changes in natural frequencies over time. Here, we can also choose two ways: the first is to measure natural oscillation modes periodically and compare them with the calculated ones, locating places of the greatest discrepancies and studying them in more detail. The second is to begin monitoring changes in frequencies of different modes of natural oscillations. In particular, we note that in any case it is impossible to immediately observe changes in some frequencies, without proving that these are the frequencies of natural oscillations. Without sufficient experience, it is very easy to miscalculate some monochromatic oscillations for natural frequencies.

Usually, while monitoring objects and surrounding areas, dozens of such oscillations are distinguished, some with high, and some with low quality factors. The first way is unfortunately quite expensive and can only be used for rather unique, very expensive objects. The second one is simpler and can be used by placing receivers not only inside a construction, but also at some reasonable distance from the location [Seleznev et al., 2012]. In this case, the object of study can be considered as a source of seismic vibrations. Imagine that this is a vibration source emitting not one, but a set of monochromatic oscillations equal to frequencies of natural oscillations. Based on the extensive experience of experimental and theoretical studies with powerful vibrators for more than

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40 years [Alekseev et al., 1982], such an assumption can greatly simplify the task of knowing how seismic vibrations propagate from a vibrator, what they depend on, and how to accumulate these vibrations. First, the accumulation of monochromatic oscillations at adjacent points, it is possible to obtain significantly different oscillations in amplitude, since the waves from the source to the receiver at two different points follow different paths. Second, the directivity characteristic of a vibrator emitting monochromatic signals is highly dependent on near-surface conditions; and a vibrogram obtained far from the source at the same point can be radically different even when the ground is frozen to 10 cm [Solovyov et al., 2017]. Finally, if oscillations from the source are significant in amplitude and it is possible to admit a nonlinear interaction of the source with the ground, multiple, semi-multiple and one and a half multiple frequencies may be identified [Seleznev et al., 2019]. When emitting to inhomogeneous soils, the amplitude of multiple harmonics can exceed several times the amplitude of the main harmonic [Seleznev et al., 2019].

The Main Conclusion: It is not worthwhile to monitor changes in the amplitudes of natural frequencies coming from the object of study, since it is necessary to take into account many factors, including the fact that the object under study is still not a controlled vibrator, and depending on the wind load, operating mechanisms and other noises, the amplitude of the emitted signal can vary significantly. This leaves us with the possibility of studying changes in natural frequencies. But what could they change from?

II. Theory/Calculation

Since any object can be described as a set of elements, including mass, damper and spring [Belostotsky et al., 2014a; Belostotsky et al., 2014b], the changes in natural frequencies emitted by the object will also depend on changes in the values of these parameters. Note, however, that significant change in frequencies, especially abrupt ones, could signal the destruction of the object. Below are several examples of engineering seismic monitoring of the large objects that show how natural frequencies can change with time.

Fig. 1 shows the SSH HPP dam, which has been studied by GS RAS specialists for more than a decade. It is a huge construction. The weight of the dam is approximately 20 million tons, the hydrostatic head on the dam is 18 million tons. In addition, the water level in the reservoir changes up to 40 meters every 6 months and, consequently, the added mass of the structure also varies. Researchers of the GS RAS have studied natural oscillation modes by the standing waves method for different fillings of the reservoir many times. Oscillations at hundreds of points in the body of the dam have been studied with three-component receivers. We now know which frequencies correspond to which modes of vibration (Fig. 2).

Fig. 1: The Sayano-Shushenskayadam (https://gelio.livejournal.com/)

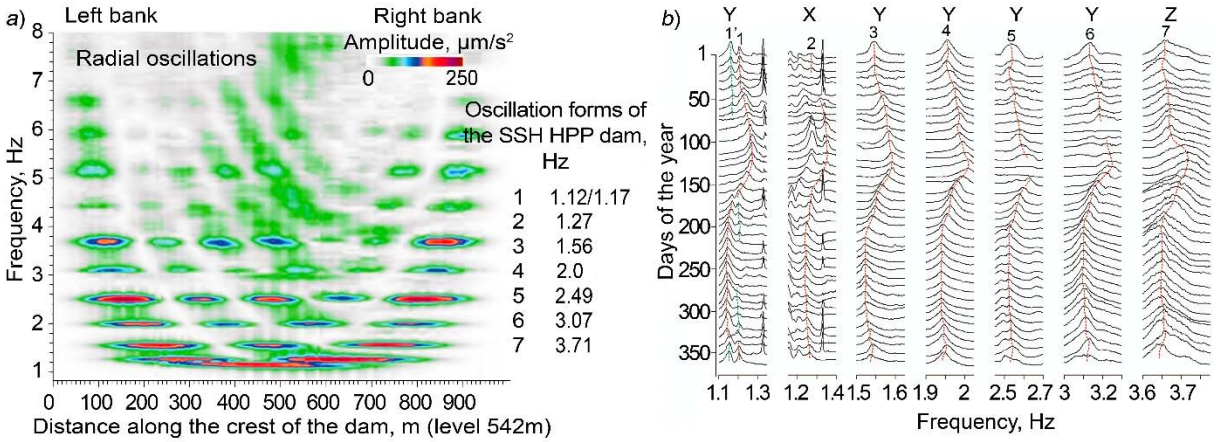

Fig. 2: Spectral field of standing waves in the SSH HPP dam (*a*) and averaged spectra of resonance frequencies at the SSH HPP dam for 2018 (*b*)

The seismological station, located at 4.5 km from the SSH HPP dam, has been carrying out digital registration of the seismic field for over 20 years. The possibility of identifying and tracking in time the frequencies of the first 7 modes of natural oscillations of the dam was investigated. It was determined that these frequencies are identified by the local maxima of amplitude spectrums of microseismic noise, recorded at the seismic station, averaged over 0.5-1.0 days [Liseikinet al., 2023]. If the length of the analyzed section of the seismogram is 200 seconds, the spectral resolution will be 0.005 Hz. Even taking into account the background noise, it is possible to determine the values of the natural frequencies with an accuracy of not less than 0.01 Hz.

Fig. 3 shows the graph of change in the natural frequency of the 4th mode of dam oscillation at the SSH hydroelectric power station (as the most informative) and changes in the water level in the reservoir. It is clearly seen that in this case the main element (from the triad of mass, damper, spring) affecting the frequency values is the added mass of water. Smaller changes are also related to the mass of ice that freezes and breaks off the dam [Liseikin et al., 2023].

Why is it necessary to study the changes in natural frequency in detail? In the book "The Dam of the Sayano-Shushenskaya Hydroelectric Power Plant. State, Processes, Forecast" V. V. Tetelmin writes: "The safety problems of the SSH HPP dam are becoming more urgent and acute from year to year. Movements in the dam have not subsided, the base decompaction has been in progress, the contact seam has been opening, the arch stresses in concrete have been growing, the cracks in concrete of the pressure edge have not been stopped. Stress in the turbine water pipes and spiral chambers have also been growing. At the same time, specialists have not yet identified the reasons for such a deterioration in the dam" [Tetelmin, 2011].

Note that everything that V. V. Tetelmin writes about, affects the natural frequency values. To monitor and study such changes, it is necessary to increase measurements accuracy. This is quite possible, it is only necessary to increase the analysis interval on the seismogram, and put the recording station closer to the HPP in order to increase the signal-to-noise ratio. Note that it is not necessary to place the station at the HPP itself, since the method we use implies remote analysis, besides it is a dangerous construction with restricted access.

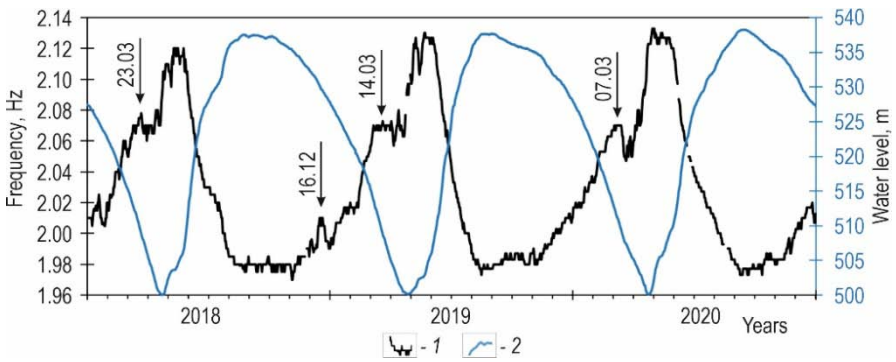

Fig. 3: Change in time of the fourth mode`s frequency of natural oscillations of the Sayano-Shushenskaya HPP dam (1) with a change of the water level in the reservoir (2). Dates (23.03) highlight changes in natural frequency that are not related to changes in water level

Another example of natural frequencies changing was obtained during an engineering seismic investigation of a residential 14-storey brick building in Novosibirsk. On the top floor of the building, a seismological station with a three-component 4.5 Hz seismic receiver had been continuously recording seismic data for two years. The directions of the seismic receiver axes are as follows: X - directed along the narrow part of the building, Y - along the long part of the building, Z - vertical. After analyzing the data for all the components, the X component was the most representative, which we will consider next. Fig. 4 shows the spectrogram for June 2022 and January 2023, and Fig. 5 shows the spectrum averaged over 12 hours (from 10:00 01/07/2023 to 10:00 01/08/2023).

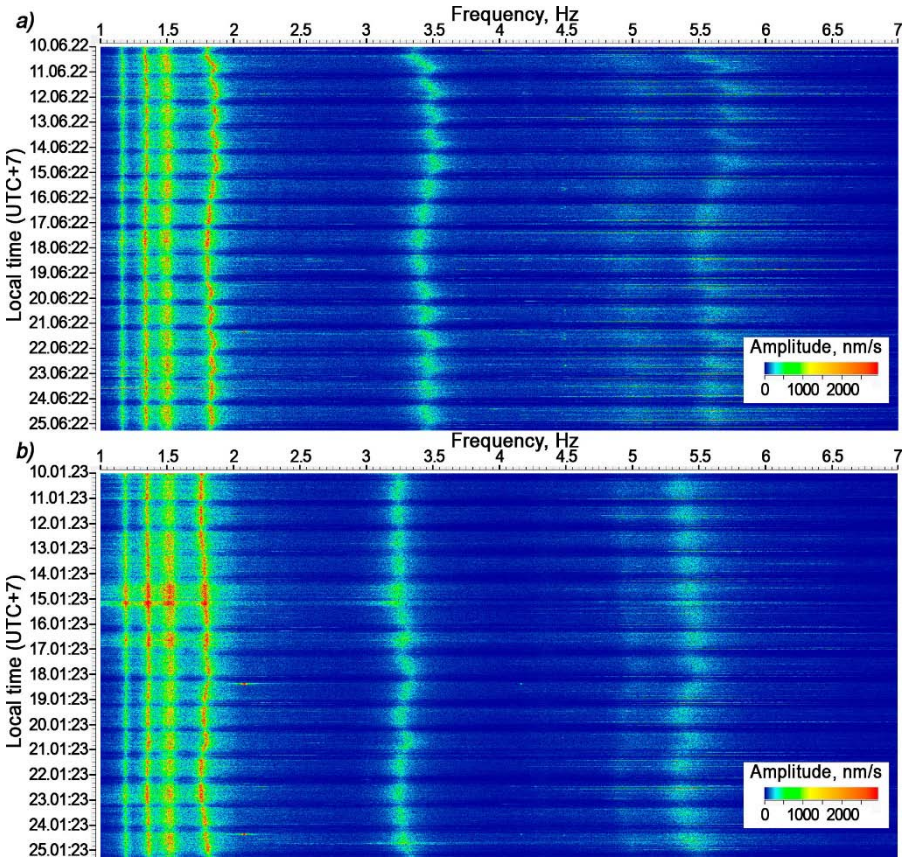

Fig. 4: Fragments of spectrograms for June 2022 (*a*) and January 2023 (*b*), X-components

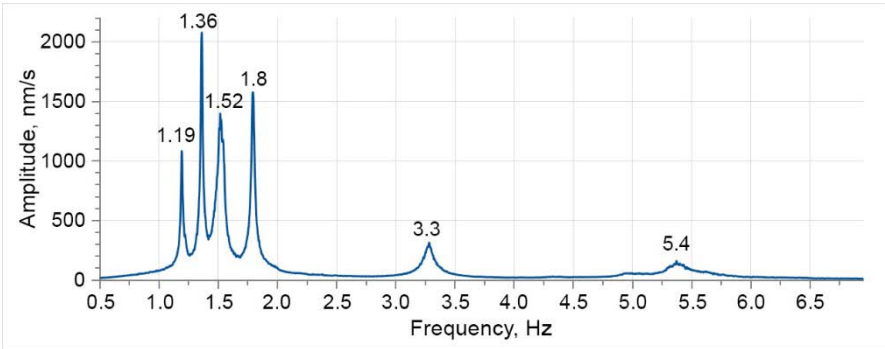

Fig. 5: Averaged spectrum for 12 hours from 01/07/2023 10:00 pm to 01/08/2023 10:00 am, X-component

A special determination of oscillation modes by the standing waves method was not carried out here. However, evidence that the selected frequencies are the natural frequencies of the building can be provided by a simultaneous increase in vibration amplitudes at these frequencies during strong wind gusts (Fig. 4) or an earthquake of $M = 7.8$ that occurred in southern Turkey on February 6, 2023 (Fig. 6). The earthquake was very strong and it was possible to identify it using deconvolution, even when using a 4.5 Hz seismic receiver for registration. The earthquake appears only in the first frequencies. Therefore, we will only look at the spectrogram up to 3 Hz. Fig. 6 shows that in the initial part of the earthquake recording, where there are waves

with periods of about 1 Hz, resonant excitation occurs at the natural frequencies of the building vibration and their amplitude increases by about 3 times.

The study of the natural frequencies of the building showed that the frequency values change almost constantly over time, as can be clearly seen in Fig. 4.

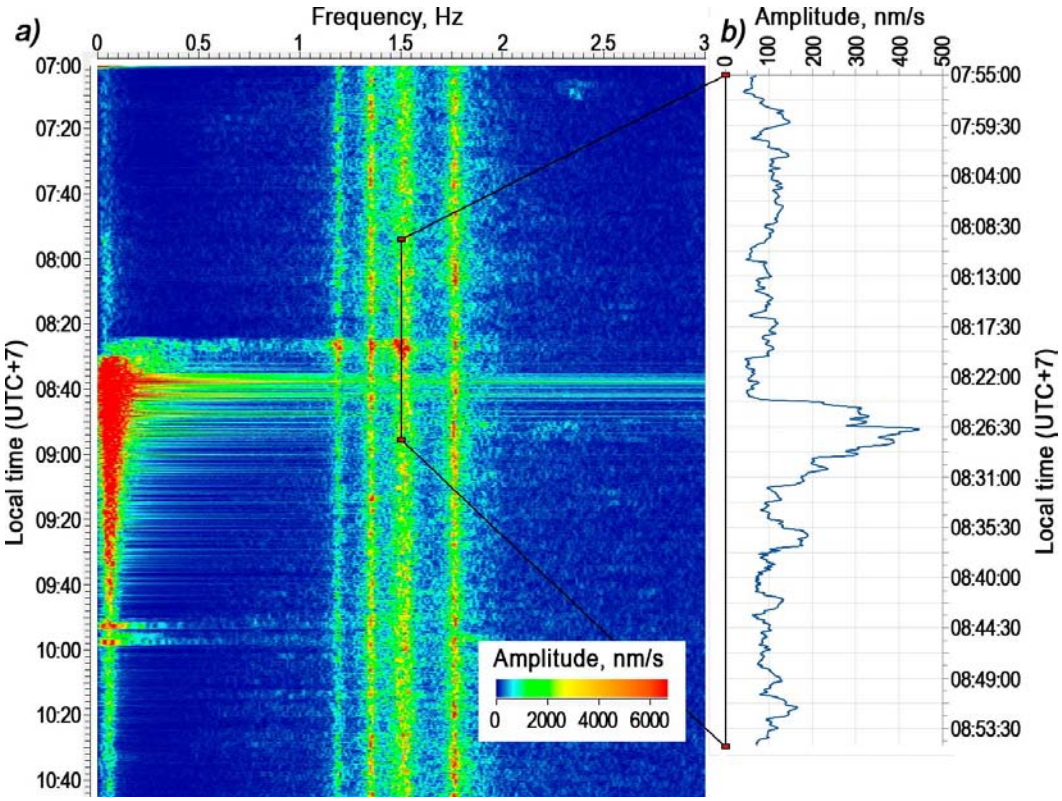

Fig. 6: Spectrogram of the Turkish earthquake on February 6, 2023, X-component (a). Graph of change in the oscillation amplitude at a frequency of 1.45 Hz in time (b)

In the spectrograms in Fig. 4, obtained in the summer and winter months, the first 6 natural frequencies and their changes over time are clearly visible, as well as in the averaged spectrum in Fig. 5, where only the first four have the largest amplitudes. Some works [Cai et al., 2021] show that natural frequencies can be changed with temperature changes. In order to understand what these changes are connected with, we made graphs of changes in frequency of the fourth mode of natural oscillations (it has a high amplitude and sufficient fluctuations), variations in air temperature and the amount of precipitation, presented in Fig. 7 and Fig. 8.

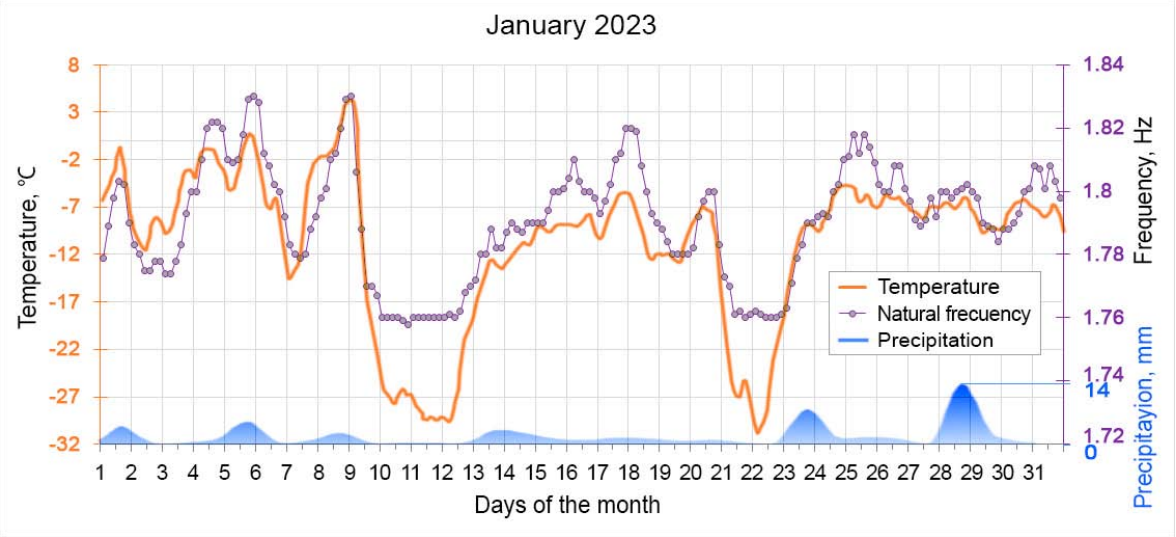

Fig. 7: Graphs of temperature changes, the frequency of the fourth mode of natural oscillations of the building and the level of precipitation in January 2023, X-component

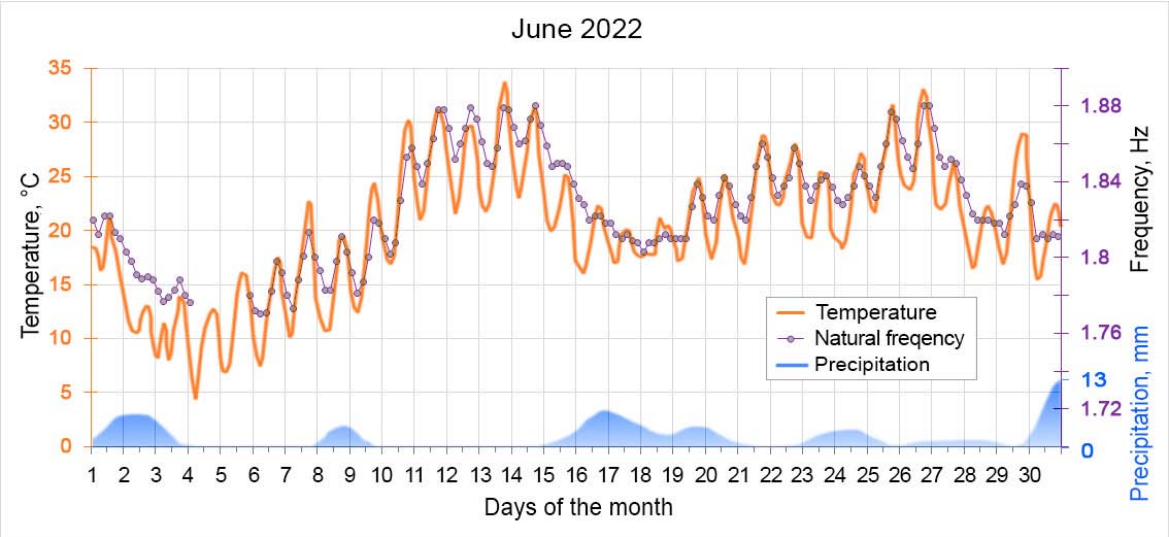

Fig. 8: Graphs of temperature changes, the frequency of the fourth mode of natural oscillations of the building and the level of precipitation in June 2022, X-component

The processing of the received records was carried out using the software "SpectrumSeism", developed at the Seismological Brunch of GS RAS [Seleznev et al., 2021], which allows to convert seismic trace records into spectrograms. This makes it possible to determine how the amplitude-frequency composition of the record changes over time and to identify sources of oscillations of a particular frequency from the entire record. To obtain quantitative estimates, we generate graphs of changes in the amplitudes of oscillations at fixed frequencies by the short-time Fourier transform formula of the form:

$$A(\omega, t) = \frac{1}{T}\left|\int_{t-T/2}^{t+T/2} f(\tau)e^{-i\omega\tau}\, d\tau\right| \qquad (1)$$

where $f(\tau)$- recorded seismic signal, ω - frequency for which the graph is generated, t-running time, T-time interval (window) in which the amplitude is identified, |…|-modulus of a complex number. An important parameter in this method is the window length (T), which directly determines the time resolution of the graph. However, it is not allowed to reduce the window length too much, because this reduces the resolution by frequency.

In summary, since natural frequencies are determined by seismic noise, in order to select a useful signal from them with a sufficiently high accuracy, the received seismic record is divided into fragments (windows), for each of which an amplitude spectrum is formed and averaged, resulting in an averaged spectrum without of noise, where only regular signals are detected.

To select the values of natural frequencies, a large number of amplitude spectra of noise records

were accumulated, as a result, sequences of local maxima corresponding to natural frequencies appeared on the averaged spectra. Fig. 7 and Fig. 8 show data on the X-component, i.e. transverse vibrations of the building, with the following parameters for formula Eq. 1: T= 100s, window step is 50s. This means that we cannot study signals with duration less than 100s. At the same time, the frequency resolution is 0.01 Hz, so all signals on the seismogram with frequencies more than 0.01 Hz away from the frequency of the studied signal will not affect the result of amplitude determination according to formula Eq. 1. We chose the interval from 1.5 to 2 Hz (where one of the local maxima at a frequency of 1.8 Hz, taken as the natural frequency of the building of the fourth mode, is clearly traced); and the graphs of its current values were generated over the averaged spectrum every 4 hours for January 2023 (Fig. 7) and June 2022 (Fig. 8).

III. Results

Analyzing the variations of the curves shown in Fig. 7, we can note the following: precipitation practically does not effect changes in natural frequencies, even when about 40 cm of snow fell on January 28-29 (with the roof area of about 600 m^2, the total snow weight is about 10 tons and the building weight is about 10 thousand tons with a perimeter of 100m, a wall thickness of 1m and a height of about 40m). Besides the snow is periodically removed from the roof. The mass does not change significantly, but the damper and the spring change and it relates to the freezing of the brick wall. The structure of the building wall is shown schematically in Fig. 9. The inner part of the outer wall up to the 6th floor has a thickness of three bricks, from the 7th to the 14th floor - two. The insulation is foam with a thickness of 10 cm, then the outer facing part of the wall is one brick. The length of the brick is 25 cm.

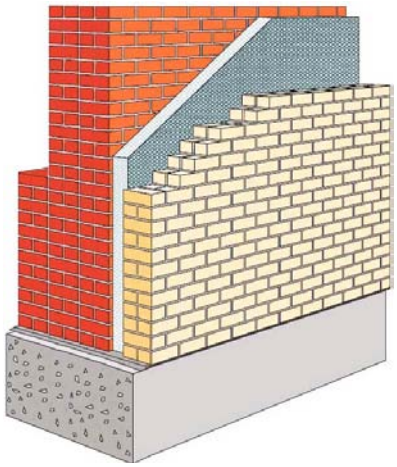

Fig. 9: Scheme of a brick wall of the building

In January 2023, there were severe frosts, and as the wall was freezing (Fig. 7), the natural frequency of the building also changed, but when the entire outer masonry was frozen to the foam, the changes in frequency stopped. Then the frequency began to change again until the moment when the temperature dropped to minus 20 degrees. Note that in winter the central heating in the building works, the colder it is outside, the more powerful the heating. This fact undoubtedly affects the natural frequencies in the form of local distortions, but does not have a significant impact on the overall picture because the indoor temperature remains almost the same. For a panel building, however, this influence is much more significant.

During the summer period, the change in the frequency of natural oscillations is also closely related to the change in temperature (Fig. 8), and there is a noticeable slight lag in the frequency change from the temperature change. This can be explained by the thermal inertia of the building materials.

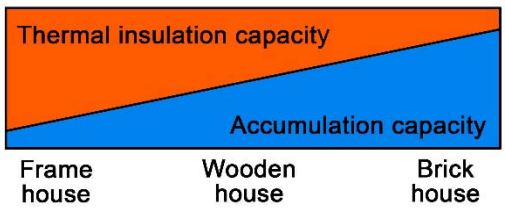

Fig. 10: Heat-insulating and storage capacity of different houses

The thermal insulation capacity of a brick house is the lowest, so it is always recommended to insulate it, and the accumulation capacity is the highest (Fig. 10). It will take a lot of energy and time to heat a brick house, but it will also cool down more slowly than other ones [Kharitonov, 2017]. Therefore, Fig. 8 shows that in the June 1-4 and June 15-19 periods, natural frequencies decrease more smoothly than temperature and daily temperature changes are less noticeable in frequency changes. It should be noted that the temperature data were taken from the meteorological station of the Novosibirsk State University, located approximately 600 meters from the 14-storey residential building on Akademika Koptyuga Prospect 7 under study, and the precipitation data - from the weather station located 12 km from the object, which could make some error in the final result.

IV. Conclusions

The analysis of the obtained research results shows that natural frequencies of buildings and constructions are not static values and can vary within certain limits. It is determined that in the studied brick building, with an increase in ambient temperature, the frequency of natural oscillations increases, and with its decrease, the frequency value also decreases.

The spectral-temporal analysis of long-term monitoring data at the Sayano-Shushenskaya HPP shows that it is possible to monitor changes in natural frequencies with an accuracy of not less than 0.01 Hz and a detail of the order of one measurement in half a day. Such accuracy and detail of measurements opens the way for solving many monitoring problems related to changes in the natural frequencies of the dam, which depend not only on a smooth change in the water level in the reservoir, but also associated with temperature changes, dam icing, changes in the sediment structure, erosion of the dam foundation and other reasons.

It should be noted that such an accuracy and detail of measurements were obtained according to the data of the seismological station located 4.5 km from the dam.

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Memberships

Fellows/Associates of Engineering Research Council

FERC/AERC Memberships

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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

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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.

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2. Drafting the paper and revising it critically regarding important academic content.
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Acknowledgments

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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.
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- First character must be three lines drop-capped.
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- 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.

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

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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.

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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.

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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

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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).

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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.

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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.

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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.

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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 though 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.

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Key points to remember:

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- 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.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	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
Introduction	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
Methods and Procedures	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
Result	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
Discussion	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
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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