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Enhancing Manufacturing Productivity through Refined Work-Study Techniques: A Critical Review of Allowance Factors in Time Study

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ABSTRACT

This systematic review examines the critical role of allowance factors in enhancing work measurement accuracy within mechanical and industrial engineering domains. The study addresses inconsistencies in understanding and implementing allowances across various manufacturing and production environments. Through a comprehensive analysis of extant literature and industry practices, this research categorizes and evaluates the impact of diverse allowance types on productivity and operational efficiency in engineering settings. The investigation encompasses three primary allowance categories: constant (e.g., personal needs, basic fatigue), variable (e.g., abnormal posture, environmental factors), and special (e.g., unavoidable delays, policy-based considerations). These allowances are analyzed for their application and impact in industrial and mechanical engineering contexts. Based on the literature synthesis, a methodological framework for allowance determination and implementation is proposed. This framework comprises systematic observation, empirical data collection through time studies, statistical analysis, and validation processes specific to engineering applications. It aims to enhance the precision of allowance estimation in developing equitable work standards, influencing labor cost calculations, productivity metrics, and operational efficiency in manufacturing systems. This study highlights the importance of accurate allowance integration in work measurement methodologies for mechanical and industrial engineering. It provides a structured approach to allowance application, contributing to the advancement of work measurement techniques in complex manufacturing environments. Findings offer evidence-based recommendations for implementing robust allowance strategies, aimed at optimizing work measurement practices and fostering sustainable operational improvements. This research serves as a comprehensive resource for engineers and researchers seeking to enhance the accuracy and effectiveness of their work measurement methodologies. By synthesizing current knowledge and best practices in allowance factor application, this study bridges the gap between theoretical concepts and practical implementation, ultimately improving productivity and efficiency in manufacturing and production processes.

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1. Introduction

Work measurement is a fundamental aspect of industrial engineering, essential for optimizing productivity and ensuring operational efficiency. This process involves determining the time required for a qualified worker to complete a specific task at a defined performance level [1-3]. However, raw time measurements often fail to account for various inevitable delays and the necessity for rest and personal activities. Consequently, the integration of allowances in work measurement processes has become crucial [4]. Allowances represent additional time added to the standard time to account for factors affecting a worker's ability to perform consistently at the standard rate. These factors encompass fatigue, personal needs, and unavoidable delays among others [1,2]. The accurate estimation and application of allowances are critical in developing realistic and fair work standards, which subsequently influence labor costs, productivity metrics and overall operational efficiency.

Despite their significance, the methodologies for calculating and applying allowances are not consistently understood or implemented across various industries. This investigation seeks to bridge the existing knowledge gap by conducting a thorough examination of the various allowance types and their corresponding calculation methodologies that may influence work measurement within prevalent industrial settings. By addressing this technical information, this article seeks to contribute to the optimization of work measurement techniques and enhance the overall understanding of allowance integration in industrial fields. The case study presented in the article serves as a reference point for elucidating the work measurement practices employed at Company X.

2. Literature Review

2.1 Definition of Allowances

Allowances in work measurements constitute additional time appended to the basic time required for task completion. These adjustments account for various factors that can influence the overall efficiency and productivity of the work process [2,4]. Such factors may encompass scheduled and unscheduled breaks, personal needs, fatigue, equipment downtime and other disruptions that can occur during a work shift, potentially affecting a worker's ability to maintain a consistent pace and output [5]. The primary purpose of incorporating allowances into work measurements is to ensure that time estimates accurately reflect the true duration required for task completion, taking into consideration the multitude of factors that can impact worker performance.

The integration of allowances aims to establish time standards for tasks that are not only attainable but also representative of real-world working conditions. This practice acknowledges the human element in work processes, recognizing that workers are not machines and that their performance can be influenced by physical, mental, and environmental variables [2]. For instance, the inclusion of allowances can accommodate ergonomic considerations in repetitive tasks, thereby mitigating the risk of repetitive strain injuries and enhancing overall worker well-being.

2.2 Importance of Allowances in Work Measurement

Allowances in work measurements are critical components in the fields of industrial engineering and operations management. These allowances function as adjustments appended to the basic time to account for various factors that influence worker performance and well-being. Three (3) primary categories of factors contribute to worker fatigue: physical factors, mental and cognitive factors and environmental and work factors [1,6]. Table 1 presents a comprehensive overview of these fatigue-inducing factors. Given the multifaceted nature of factors contributing to worker fatigue, including physical, mental, cognitive, environmental and work-related elements, the application of allowances is essential in work measurements [6]. The incorporation of allowances ensures that the developed time standards are both realistic and attainable, as they account for the actual conditions under which workers perform their tasks. This approach serves to accurately reflect the true demands placed on workers and mitigate unrealistic expectations [4].

The integration of appropriate allowances in work measurements is fundamental to enhancing productivity and overall operational efficiency within organizations. These allowances account for factors that can induce worker fatigue, such as physical, mental, and environmental demands and provide for adequate rest and recovery periods [4,6]. This consideration contributes to worker safety, well-being, and job satisfaction, which in turn advances improved performance and sustained productivity enhancements. By incorporating realistic allowances into time standards, organizations can cultivate a work environment that enables workers to operate at optimal capacity. This approach ultimately leads to more effective workforce planning, enhanced process efficiency, and increased organizational competitiveness.

Table 1
Overview of fatigue-inducing factors [1]

Factors	Example of activities
Physical	i. Standing ii. Abnormal body position iii. Use of force iv. Expenditure of muscular energy
Mental and cognitive	i. Concentration and attention ii. Mental strain iii. Monotony and tediousness iv. Eyestrain
Environmental and work	i. Poor lighting ii. Noise iii. Fumes iv. Heat v. Atmospheric conditions

2.3 Type of Allowance

Work measurement studies incorporate critical adjustments to observed time through the use of allowances. These adjustments are essential for establishing realistic and attainable time standards by accounting for various factors that may influence a worker's performance but are beyond their control. The integration of allowances into observed time ensures that the resulting time standards are equitable and representative of actual working conditions. Allowances can be broadly categorized into two (2) main types: constant allowances and variable allowances, as illustrated in Figure 1 [2].

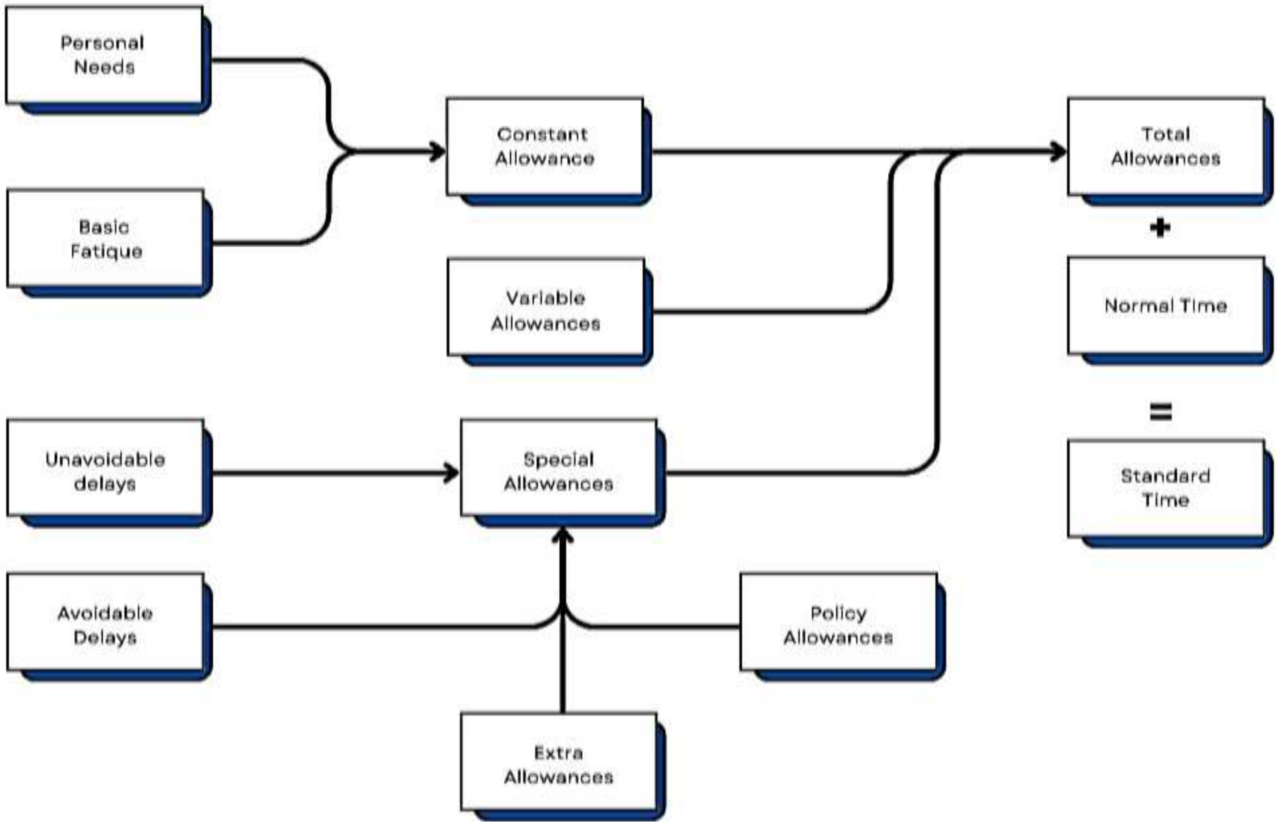

Fig. 1. Categorize of allowances: Constant allowances and variable allowances [2]

2.3.1 Constant allowance

Constant allowances, also referred to as basic allowances, encompass personal needs and basic fatigue considerations. These allowances are incorporated into the observed time in a time study to account for personal requirements and the fundamental effects of fatigue on worker performance. Constant allowances are applied uniformly across all tasks or operations, irrespective of the specific work being performed. Figure 2 illustrates the components of constant allowances, while Table 2 presents the constant allowance recommendations provided by the International Labor Organization (ILO) [7].

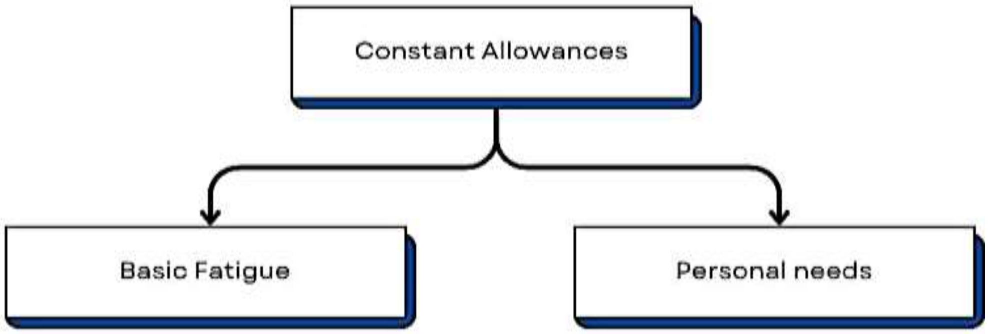

Fig. 2. Components in constant allowance (reproduce from Figure 1)

Table 2
Constant allowances recommendation by ILO [2,7]

Component	Men	Women
Personal needs	5	7
Basic fatigue	4	4
Total (%)	9	11

2.3.1.1 Personal needs

Personal allowances account for the time workers are required to attend to personal necessities, such as brief breaks for restroom use, hydration, or addressing minor personal matters that may arise during the course of work. These allowances recognize the legitimate personal requirements of workers and provide brief opportunities to address their needs. The incorporation of personal allowances enables workers to momentarily disengage from their tasks, potentially contributing to the maintenance of productivity, focus, and overall well-being throughout the workday.

2.3.1.2 Basic fatigue

The basic fatigue allowance acknowledges the fundamental impact of physical and mental fatigue on worker performance. This allowance is incorporated into the constant allowance to account for the gradual decline in productivity that may occur due to prolonged task engagement. It serves as a buffer, recognizing that worker performance may gradually diminish as fatigue accumulates over time. The basic fatigue allowance contributes to the accuracy of work measurement by reflecting the true time required to complete a task, considering the natural effects of physical and cognitive fatigue on a worker's ability to maintain consistent output.

2.3.2 Variable allowances

Variable allowances, also known as contingency allowances, are additions to the standard time in a time study that account for unpredictable or varying factors influencing worker performance. The purpose of variable allowances is to introduce flexibility into the standard time, accommodating conditions that may fluctuate from one work cycle to another. This ensures that the standard time provides a realistic estimate of the time required to perform a task under varying circumstances. Factors that may warrant a variable allowance include abnormal posture, muscular force exertion, atmospheric conditions, noise levels, illumination levels, visual strain, mental strain, monotony and tediousness. Figure 3 illustrates the components of variable allowances.

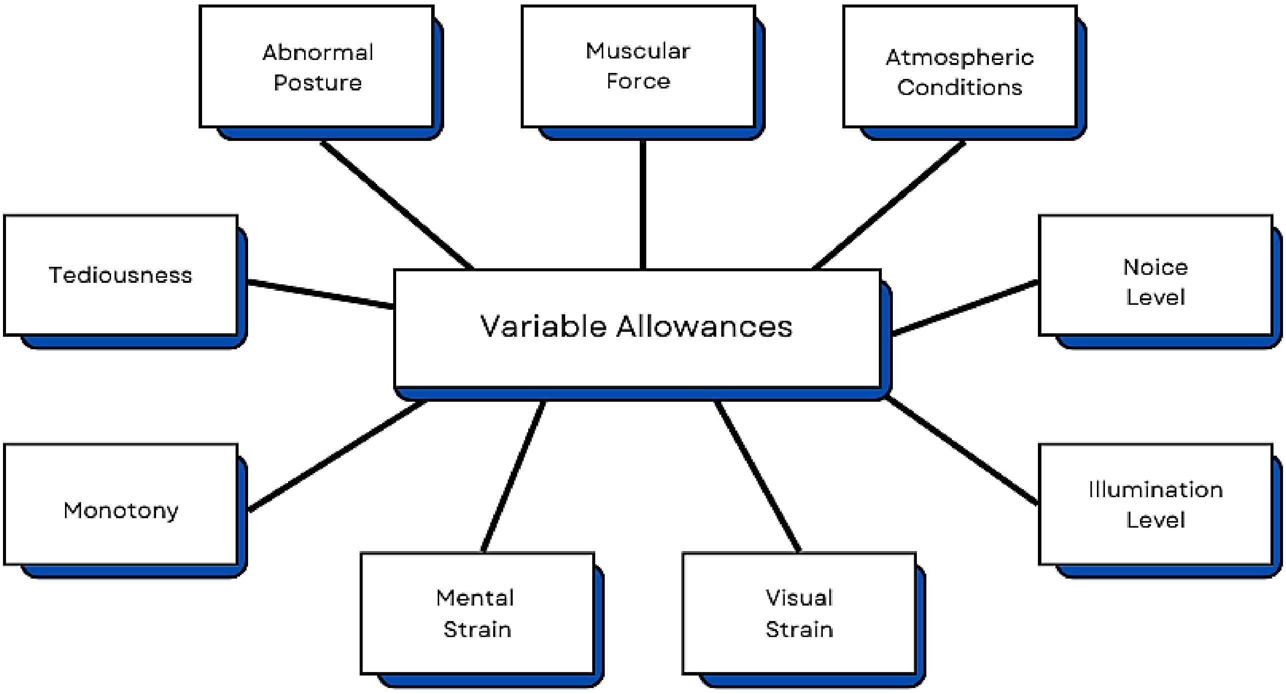

Fig. 3. Components of variable allowance

2.3.2.1 Abnormal posture

Abnormal postures refer to body positions or movements that deviate from ergonomic principles. These uncomfortable and potentially fatiguing postures can increase the risk of musculoskeletal disorders [8]. This allowance compensates for the additional effort and time required when workers must adopt awkward positions, such as prolonged sitting, standing or bending. Table 3 presents the ILO's recommended allowances for abnormal postures [7].

Table 3
ILO's recommended allowances for abnormal postures [2]

Posture	Men	Women
Standing	2	4
Slightly awkward	0	1
Awkward (bending)	2	3
Very awkward (lying, stretching)	7	7

2.3.2.2 Muscular force

The muscular force allowance accounts for variations in the physical effort required to perform a task. This allowance recognizes that the amount of force a worker exerts can vary based on factors such as the specific task, tools utilized, and physical demands [6,8,9]. It is applied when the required force fluctuates during task performance. Table 4 presents the ILO's recommended allowances for muscular force exertion [7].

Table 4
ILO's recommended allowances for muscular force exertion [2]

Weight lifted, in kg	Men	Women
2.5	0	1
5	1	2
10	3	4
12.5	4	6
15	6	9
20	10	15
25	14	-
30	19	-
40	33	-
50	58	-

2.3.2.3 Atmospheric conditions

The atmospheric conditions allowance accounts for the impact of environmental factors such as temperature, humidity, and weather on worker performance. Adjustments in the form of atmospheric conditions allowances are made to address the effects of these environmental factors on a worker's ability to perform tasks efficiently. Table 5 presents the ILO's recommended allowances for atmospheric conditions [7]. The ILO's allowance recommendations have been supplemented by more recent guidelines developed by the National Institute for Occupational Safety and Health (NIOSH) in 1986. These updated guidelines utilize the Wet-Bulb Globe Temperature (WBGT) and worker energy expenditure to calculate fatigue allowances [10]. This approach provides a more precise and scientifically grounded method for accounting for the impacts of environmental factors and physical exertion on worker productivity. The resulting allowances can be quantified through a least-squares regression, as expressed in Eq. (1).

$$A = e^{(-41.5+0.0161W+0.497\,WBGT)} \tag{1}$$

Where, RA is relaxation allowance, W is working energy expenditure (kcal/hr) and WBGT is wet-bulb globe temperature (°F).

Table 5
ILO's recommended allowances for atmospheric conditions [2]

Component	Men	Women
Well-ventilated or fresh air	0	0
Badly ventilated, but no toxic fumes or gases	5	5
Work close to furnaces severe, heat etc	5-15	-

2.3.2.4 Noise level

The noise level allowance compensates for the detrimental impact of high noise levels on worker efficiency and performance. This allowance is incorporated into the observed time to account for the reduction in concentration and productivity caused by distracting and stressful auditory stimuli. By including this allowance, the calculated standard time more accurately reflects the effects of working in a noisy environment. Table 6 presents the ILO's recommended allowances for various noise levels [7].

Table 6
ILO's recommended allowances for various noise levels [12]

Noise strain	Men	Women
Continuous	0	0
Intermittent-loud	2	2
Intermittent-very loud	5	5
High pitched-loud	5	5

In addition to the ILO allowance recommendations, permissible noise exposures can be employed to determine appropriate noise level allowances. The Occupational Safety and Health Administration (OSHA) has established permissible noise exposure limits for industrial workers. When the total daily exposure comprises multiple noise levels, the combined exposure can be calculated using permissible noise levels and specific equations, as shown in Eqs. (2) and (3). Table 7 illustrates the permissible levels based on exposure duration.

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \leq 1 \quad (2)$$

Where, D is noise does (decimal value), C time spent at specified noise level (hours) and T is permissible time (hours)

$$RA = 100 \times (D - 1) \quad (3)$$

Table 7
OSHA permissible noise levels [11]

Noise level (dBA)	Permissible time (hr)	Noise level (dBA)	Permissible time (hr)
80	32	110	0.5
85	16	115	0.25
90	8	120	0.125
95	4	125	0.063
100	2	130	0.031
105	1		

2.3.2.5 Illumination levels

The illumination allowance accounts for the impact of lighting conditions on worker performance. Inadequate lighting can induce visual strain and impair task effectiveness [12]. This allowance is particularly relevant for tasks that are highly sensitive to lighting conditions, such as those involving small details or precision instruments. Table 8 presents the ILO's recommended allowances for various illumination levels [7]. A study examining the relationship between illumination levels and the performance of practical visual tasks indicated that performance improved with higher illumination levels, as evidenced by decreased task completion times and increased accuracy [13]. These findings suggest that proper illumination is crucial for optimizing task performance, with higher illumination levels generally leading to better outcomes. Table 9 presents result that closely align with the ILO allowances, providing a basis for evaluating illumination levels when determining illumination allowances.

Table 8
ILO's recommended allowances for various illumination levels [2]

Light conditions	Men	Women
Slightly below recommended	0	0
Well below	2	2
Quite inadequate	5	5

Table 9
Modeled times result for illumination levels [13]

Illumination (fc)	Modeled time (sec)	% Change from 75 fc	ILO category	Allowance (%)
75	207.3	-	Recommended	0
50	210.0	1.3	Slightly below	0
30	213.9	3.2	Well below	2
20	217.2	4.8	Well below	2
15	219.8	6.0	Inadequate	5
10	223.6	7.9	Inadequate	5

2.3.2.6 Visual strain

Visual strain allowances account for the additional time required for tasks that demand prolonged, intense visual focus, such as reading fine print, inspecting small parts or performing precision work. These visually demanding tasks can lead to ocular fatigue, reduced focus and decreased productivity. The visual strain allowance level is contingent upon the task's visual requirements. Incorporating a visual strain allowance ensures that the standard time reflects the effects of visual discomfort. Table 10 presents the ILO's recommended allowances for visual strain [7].

Table 10
ILO's recommended allowances for visual strain [2]

Visual stresses	Men	Women
Fairly fine work	0	0
Fine or exacting	2	2
Very fine or very exacting	5	5

In addition to the ILO allowance recommendations, more specific values can be determined by target detectability, as initially quantified by Blackwell in his visibility curves. Blackwell's visibility curves can be modeled using Eq. (4) [14]. This equation facilitates the determination of visual strain allowances by utilizing the percentage of targets detected. Blackwell's model defines absolute target detection ability, which can subsequently be used to establish allowances for visual strain. Table 11 presents allowances based on Blackwell's percentage of targets detected.

$$\%Det = 81 \times C^{0.2} \times L^{0.45} \times T^{-0.003} \times A^{0.199} \quad (4)$$

Where, %Det is % targets detected (0-100%), C is contrast (0.001-1.80), L is background luminance (1-100 foot-Lamberts), T is viewing time (0.01-1 sec) and Ais visual angle (1-64 arc min).

Table 11
Allowances based on Blackwell's percentage of targets detected [14]

% targets detected	Condition of tasks or works	Allowance (%)
95	Task with no significant problems	0
50-95	Fine or exacting work	2
≤ 50	Very fine or very exacting work	5

2.3.2.7 Mental strain

The mental strain allowance compensates for cognitive fatigue caused by tasks requiring complex decision-making, detailed attention, problem-solving or extended focus. This allowance recognizes individual variations in the ability to maintain mental focus and applies to work that demands sustained attention and cognitive processing, such as intricate assembly, data analysis, quality control and programming. Table 12 presents the ILO's recommended allowances for mental strain [7].

Table 12
ILO's recommended allowances for mental strain [2]

Visual stresses	Men	Women
Fairly complex process	1	1
Complex or wide span of attention	4	4
Very complex and complicated	8	8

2.3.2.8 Monotony

Monotonous tasks characterized by limited variety can lead to mental fatigue and reduced attention, potentially decreasing worker efficiency. The allowance level varies based on the task's repetitiveness, with highly repetitive and unvaried tasks requiring a higher allowance. Recognizing and addressing the impact of monotony can contribute to improved worker motivation and overall performance. Table 13 presents the ILO's recommended allowances for monotony [7].

Table 13
ILO's recommended allowances for monotony [2]

Visual stresses	Men	Women
Low	0	1
Medium	1	4
High	4	8

2.3.2.9 Tediousness

The tediousness allowance compensates workers for the negative effects of repetitive, monotonous, or cognitively demanding tasks. Work that requires sustained attention with little variety can reduce worker efficiency over time. This allowance accounts for the mental fatigue caused by such tasks, recognizing and mitigating the impact of mental strain on worker productivity. Table 14 presents the ILO's recommended allowances for tediousness [7].

Table 14
ILO's recommended allowances for tediousness [2]

Visual stresses	Men	Women
Rather tedious	0	0
Tedious	2	1
Very tedious	5	2

2.3.3 Special allowances

In addition to constant and variable allowances, special allowances play a crucial role in the comprehensive calculation of total allowances in work measurements. These special allowances are designed to address specific situations and contingencies that may arise during task execution. The components of special allowances include unavoidable delays, avoidable delays, extra allowances, and policy allowances, as illustrated in Figure 4.

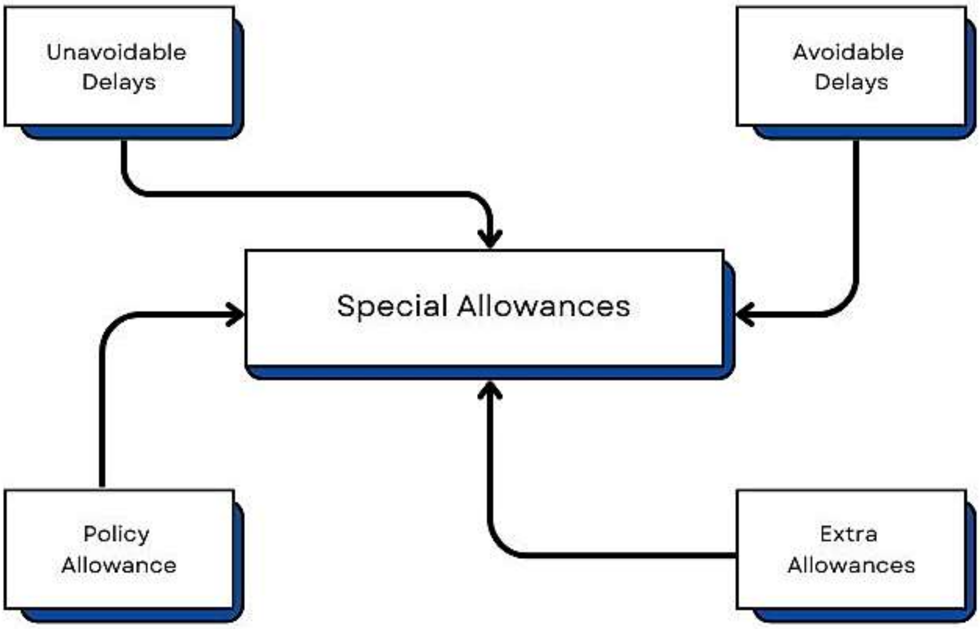

Fig. 4. Components of special allowances (reproduced from Figure 1)

2.3.3.1 Unavoidable delays

Unavoidable delays are interruptions that occur despite the best efforts to prevent them and are beyond the worker's control. These delays can significantly impact productivity and must be accounted for to ensure realistic time standards. Examples of unavoidable delays include:

i. Machine breakdowns: Equipment failures that halt production until repairs are made.
ii. Material shortages: Waiting for materials or components needed to continue work.
iii. Environmental conditions: Unforeseen weather conditions affecting outdoor tasks.

2.3.3.2 Avoidable delays

Avoidable delays, unlike unavoidable ones, result from factors that could potentially be mitigated or managed with improved planning and organization. While these delays should ideally be minimized, they still need to be considered in work measurements. Examples include:

i. Worker errors: Time lost due to mistakes that require correction or rework.
ii. Poor workflow management: Delays caused by inefficient task sequencing or inadequate supervision.
iii. Inefficient work methods: Use of outdated or suboptimal techniques that slow down task completion.

2.3.3.3 Extra allowances

Extra allowances are additional time allocations made for specific circumstances that are not regularly encountered but can occur occasionally. These allowances are essential for ensuring that workers are not unfairly penalized for rare but necessary activities. Examples include:

i. Training periods: Time needed for workers to learn new processes or equipment.
ii. Safety procedures: Time required for mandatory safety checks and compliance with health and safety regulations.
iii. Administrative tasks: Time spent on paperwork or other non-productive activities that are essential to the job.

2.3.3.4 Policy allowances

Policy allowances are determined by organizational policies and management decisions that impact how work is performed. These allowances reflect the strategic priorities and operational philosophies of the organization. Examples include:

i. Scheduled breaks: Additional breaks beyond the standard rest periods as mandated by company policy.
ii. Union agreements: Extra time allowances negotiated as part of labor agreements with unions.
iii. Incentive programs: Time adjustments related to performance incentives and productivity targets.

2.4 Summarization of Recommended Allowances by ILO

The ILO has provided a comprehensive set of recommended allowances that should be carefully considered and incorporated into work measurement studies. Table 15 below provides a comprehensive list of recommended allowances suggested by the ILO for work measurement studies.

Table 15
Recommended allowance by ILO [2,7]

Component	Men	Women
Abnormal posture:		
i. Standing	2	4
ii. Slightly awkward	0	1
iii. Awkward (bending)	2	3
iv. Very awkward (lying, stretching)	7	7
Muscular force (lifting, pulling, or pushing):		
i. 2.5 kg	0	1
ii. 5 kg	1	2
iii. 10 kg	3	4
iv. 12.5 kg	4	6
v. 15 kg	6	9
vi. 20 kg	10	15
vii. 25 kg	14	-
viii. 30 kg	19	-
ix. 40 kg	33	-
x. 50 kg	58	-

Atmospheric conditions:		
i. Well-ventilated or fresh air	0	0
ii. Badly ventilated, but no toxic fumes or gases	5	5
iii. Work close to furnaces severe, heat etc	5 -15	-
Noise levels:		
i. Continuous	0	0
ii. Intermittent-loud	2	2
iii. Intermittent-very loud	5	5
iv. High pitched-loud	5	5
Illumination levels:		
i. Slightly below recommended	0	0
ii. Well below	2	2
iii. Quite inadequate	5	5
Visual strain:		
i. Fairly fine work	0	0
ii. Fine or exacting	2	2
iii. Very fine or very exacting	5	5
Mental strain:		
i. Fairly complex process	1	1
ii. Complex or wide span of attention	4	4
iii. Very complex and complicated	8	8
Monotony:		
i. Low	0	1
ii. Medium	1	4
iii. High	4	8
Tediousness:		
i. Rather tedious	0	0
ii. Tedious	2	1
iii. Very tedious	5	2

3. Measurement of Allowance Factors: An Industry-Based Case Study

3.1 Flowchart of Allowances Measurements

The assessment of allowances for workstations necessitates a multifaceted approach to ensure that such allowances accurately reflect the myriad factors influencing worker performance and well-being. This systematic methodology enables organizations to establish rigorous and reliable time standards, thereby facilitating effective workforce planning, enhancing productivity and optimizing operational efficiency. The implementation of this structured process is instrumental in developing a comprehensive understanding of the temporal requirements associated with various tasks, ultimately contributing to the development of more precise and equitable work standards. Figure 5 presents a flowchart illustrating the process of measuring allowances at Company X, serving as a case study.

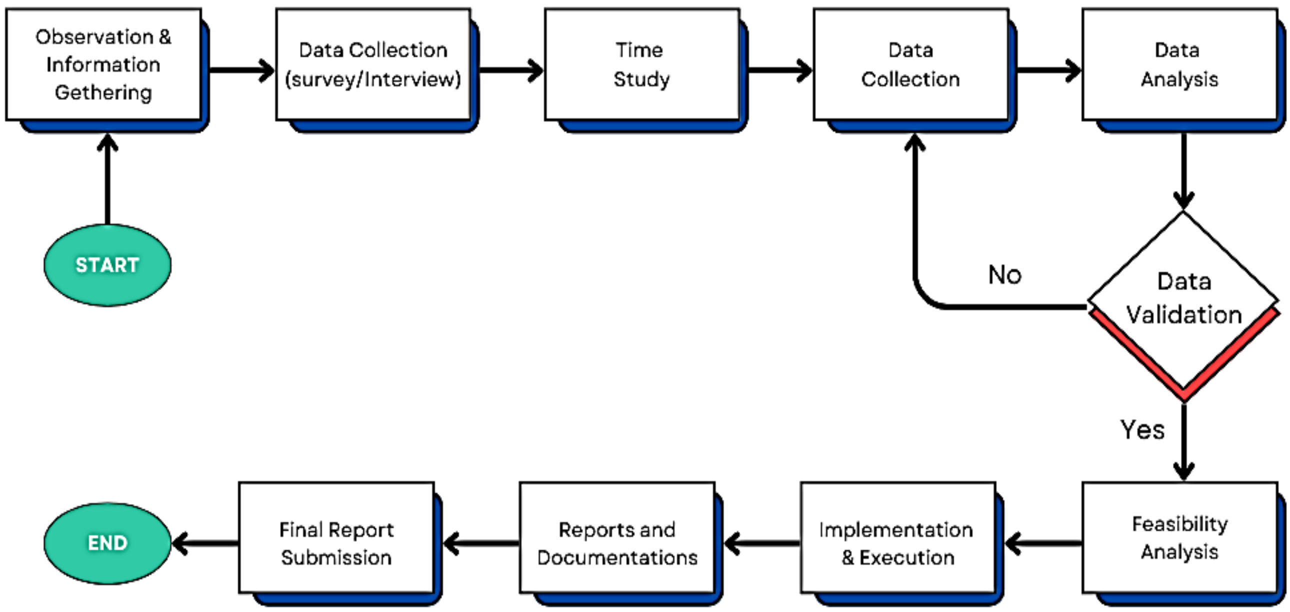

Fig. 5. Flowchart of allowances measurements

3.1.1 Observation and information gathering

The foundational step in determining allowances in work measurements involves observation and information gathering. This phase encompasses the collection of both qualitative and quantitative data pertaining to the work environment, processes, and workers. The objective is to acquire a comprehensive understanding of work tasks, conditions and factors influencing performance, thereby identifying potential areas necessitating allowances [15]. This process entails a thorough examination of the work environment, including physical layout, equipment and prevailing conditions [16,17]. Tasks are analyzed to discern their nature and complexity, while workers are observed during task performance to note variations in performance, interruptions and delays.

3.1.2 Surveys and interviews

Surveys and interviews serve as essential tools for collecting subjective data from workers and supervisors regarding their experiences, challenges, and perceptions related to work tasks and the work environment. This qualitative data collection process is crucial for garnering insights that may not be readily apparent through observation alone [18]. Understanding the subjective aspects of work facilitates the identification of factors such as task difficulty, fatigue, interruptions, and delays, which are critical for establishing accurate and fair work measurement standards [19,20]. Table 16 presents examples of survey and interview questions. The responses are subsequently analyzed to identify common themes and issues that may necessitate allowances, leading to the development of more accurate and equitable work measurement standards, ultimately enhancing productivity and worker well-being.

Table 16
Examples of surveys and interview questions

Survey questions	Interview questions
i. On a scale of 1 to 10, how difficult do you find the tasks you perform daily?	i. Can you describe a typical workday and any challenges you face?
ii. How often do you experience fatigue during your work shift?	ii. How does the work environment affect your ability to perform tasks efficiently?
iii. What types of interruptions or delays do you encounter most frequently?	iii. What strategies do you use to manage fatigue and maintain productivity?
iv. How satisfied are you with the current work environment and conditions?	iv. Are there any specific changes you would suggest improving work conditions and efficiency?

3.1.3 Time study preparation

Prior to collecting task times for work elements, several preparatory steps must be undertaken. This phase requires researchers to thoroughly define work elements for workstations, outline the detailed workflow and sequence of operations, and meticulously prepare appropriate tools, forms and documentation for accurately recording the necessary time data [21,22]. By clearly identifying critical work components, mapping process flow, and ensuring the availability of proper data collection mechanisms, researchers establish the foundation for a comprehensive and reliable time study [23,24]. Table 17 presents an example template for data collection, including essential information required for the time study method.

Table 17
Example of work elements for a production process [24]

Workstation	Work element	Work element description	Precedence	No. of operators
1	A	Move part from waiting bay to touch up and cleaning workstation.	-	1
	B	Touch up and cleaning process.	A	3
	C	Checked and move part to waiting bay.	B	1
2	D	Settings and stamping process.	C	2
	E	Move part to quality check workstation.	D	1
3	F	Settings and final inspection process.	E	3
	G	Move part to waiting bay.	F	1

3.1.4 Data collection

The preceding processes, including surveys, interviews, and time study preparation, are utilized to collect task times for each work element across all workstations. Task times are measured using a stopwatch for individual work elements at each workstation [25,26]. Data accuracy is ensured through the use of calibrated stopwatches and adherence to standard work procedures [5]. The collected data is systematically organized and comprehensively documented to facilitate thorough analysis and understanding of work processes and factors impacting worker productivity [27,28]. Table 18 provides an example of collected data.

Table 18
Example of task times collected by using stopwatch

Work element	Time taken (sec)										
	1	2	3	4	5	6	7	8	9	10	Avg
A	8.22	9.32	10.28	6.93	6.81	7.41	10.41	6.97	8.3	7.95	8.26
B	47.71	48.84	167.69	111.52	92.48	120.07	61.5	92.85	92.30	76.57	91.15
C	8.99	6.95	13.96	7.26	6.68	15.74	6.68	9.46	6.63	8.88	9.12
D	479.47	292.31	259.48	101.81	160.98	81.09	72.12	101.13	104.33	62.99	171.57
E	9.92	13.72	12.27	6.32	9.83	11.24	7.84	9.59	6.79	9.73	9.73
F	66.72	115.79	134.14	96.36	66.23	117.42	102.81	204.36	65.18	60.2	102.92
G	7.04	10.26	7.04	7.58	7.49	7.06	14.08	16.65	13.1	13.24	10.35

3.1.5 Data analysis

Data analysis in work measurement allowance is a critical phase involving the processing and interpretation of collected data to derive meaningful insights and conclusions. The collected data is analyzed to identify trends, patterns and factors influencing task performance and necessary allowances [19,22]. Average task times serve as references in determining suitable allowances based on workers' performance ratings and workstation conditions [20,21,29]. This approach enables a comprehensive analysis of factors impacting worker productivity and the appropriate allowances to be incorporated into time standards [26]. Table 19 illustrates an example of allowance distribution based on categories. After determining appropriate allowances for each work element, standard time can be calculated by incorporating the newly determined allowances and average performance rating of the worker, using Eq. (5).

$$\text{Standard time} = \frac{\text{Normal time}}{(1-\text{Allowance})} \tag{5}$$

Where normal time × performance rating.

Table 19
Example of allowances distribution based on categories

Work element	Constant		Variable						Total
	P	Fg	S	Fc	A	Men	Mono	T	
A	5	4	2	1	0	0	0	0	12
B	5	4	2	1	2	1	0	0	15
C	5	4	2	1	0	0	0	0	12
D	5	4	2	1	2	1	0	0	15
E	5	4	2	1	0	0	0	0	12
F	5	4	2	1	2	0	0	0	14
G	5	4	2	1	0	0	0	0	12

Note: P= Personal, Fg= Fatigue, S= Standing, Fc= Force, A= Attention, Men= Mental, Mono= Monotony, T= Tediousness

3.1.6 Validation of allowances and standard time

The subsequent step involves validating the calculated standard time and allowances. This validation process is crucial to ensure that time standards and allowances accurately reflect actual work conditions and worker performance [30]. By conducting this validation, organizations can confirm that the calculated standards and allowances are realistic, achievable, and representative of the real-world work environment and worker capabilities. This step helps to validate the reliability and applicability of the work measurement findings, ultimately leading to more effective workforce planning, process improvement, and enhanced overall productivity. Common validation methods include [31,32]:

i. Pilot studies: Conducting trial runs or pilot studies to test the applicability of established time standards and allowances in real-world scenarios. This allows organizations to assess how well the standards align with the actual work environment, worker capabilities, and task requirements.
ii. Worker feedback: Soliciting feedback from workers who will be performing the tasks to ensure the time standards and allowances are realistic and achievable. Workers' firsthand experiences and insights can help ensure the standards are aligned with the actual work environment and worker capabilities.

3.1.7 Feasibility analysis

The final step before implementing standard allowances involves a thorough assessment of the feasibility and practicality of implementing the calculated time standards and allowances. This evaluation examines the potential impact of proposed changes on the organization's operations, resources and overall business objectives [27]. The feasibility analysis considers operational implications, financial considerations, and the organization's readiness to adopt new time standards and allowances [31]. This includes assessing the impact on production processes, workflow, resource utilization, cost implications, employee acceptance, training needs and policy or procedural changes required for successful implementation [9,16].

3.1.8 Implementation of standard allowance

Following the validation of time standards and allowances and completion of the feasibility analysis, the final step is to implement the new standards within the organization. Implementation should be carefully planned and executed to ensure a smooth transition and maximize potential benefits. This process should involve a well-structured change management strategy that effectively communicates the rationale and details of the changes to all affected employees. The implementation plan should address potential challenges, provide comprehensive training, and incorporate feedback mechanisms to monitor the adoption and effectiveness of the new standards.

4. Conclusions

In conclusion, the analysis and application of appropriate allowances in work measurements constitute a critical component of effective workforce planning and process improvement. By adopting a comprehensive approach encompassing data collection, analysis, validation and feasibility assessment, organizations can establish robust and reliable time standards that accurately reflect the realities of the work environment and account for various factors impacting worker productivity. The implementation of these standard allowances can yield significant benefits, including improved workforce planning, enhanced productivity, and more effective process improvement initiatives. Key considerations in this process include a thorough understanding of work activities, systematic data collection, rigorous analysis of allowance factors, worker feedback, and a feasibility analysis to ensure the proposed changes are operationally and financially viable. By adopting this holistic approach, organizations can optimize their work measurement practices, enhance efficiency and drive sustainable improvements in their operations.

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References
[1] Groover, Mikell P. *Work systems and the methods, measurement, and management of work*. Vol. 2007. Upper Saddle River, NJ: Pearson Prentice Hall, 2007.
[2] AFreivalds, Andris, and Benjamin W. Niebel. *Methods, standards, and work design*. Tsinghua University, 2009.
[3] Kiran, D. R. *Work organization and methods engineering for productivity*. Butterworth-Heinemann, 2020. https://doi.org/10.1016/B978-0-12-819956-5.00002-9
[4] Kiran, D. R. “Work measurement,” in *Work Organization and Methods Engineering for Productivity*, *Elsevier* (2020): 191-210. https://doi.org/10.1016/B978-0-12-819956-5.00014-5
[5] Meyers, Fred E. *Motion and time study: For lean manufacturing*. Prentice Hall, 2002.
[6] Kiran, D. R. “Chapter 4 – Factors affecting productivity.” *In Work Organization and Methods Engineering for Productivity, Butterworth-Heinemann* (2020): 45-61. https://doi.org/10.1016/B978-0-12-819956-5.00004-2
[7] Kanawaty, George, ed. *Introduction to work study*. International Labour Organization, 1992.
[8] Slama, Rim, Oussama Ben-Ammar, Houda Tlahig, Ilhem Slama, and Pierre Slangen. "Human-centred assembly and disassembly systems: a survey on technologies, ergonomic, productivity and optimisation." *IFAC-PapersOnLine* 55, no. 10 (2022): 1722-1727. https://doi.org/10.1016/j.ifacol.2022.09.646
[9] Lindhard, Søren Munch. "Applying work measurements to identify productivity potentials: the case of prefabricated concrete elements." *International Journal of Construction Management* 24, no. 15 (2024): 1668-1678. https://doi.org/10.1080/15623599.2023.2286115
[10] Centers for Disease Control, ed. *NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments*. National Institute on Drug Abuse, 2018.
[11] Sayler, Stephanie K., Benjamin J. Roberts, Michael A. Manning, Kan Sun, and Richard L. Neitzel. "Patterns and trends in OSHA occupational noise exposure measurements from 1979 to 2013." *Occupational and Environmental Medicine* 76, no. 2 (2019): 118-124. https://doi.org/10.1136/oemed-2018-105041
[12] Baron, Robert A., Mark S. Rea, and Susan G. Daniels. "Effects of indoor lighting (illuminance and spectral distribution) on the performance of cognitive tasks and interpersonal behaviors: The potential mediating role of positive affect." *Motivation and Emotion* 16, no. 1 (1992): 1-33. https://doi.org/10.1007/BF00996485
[13] Bennett, Corwin A., Anand Chitlangia, and Abhay Pangrekar. "Illumination levels and performance of practical visual tasks." In *Proceedings of the Human Factors Society Annual Meeting*, vol. 21, no. 4, p. 322-325. Sage CA: Los Angeles, CA: SAGE Publications, 1977. https://doi.org/10.1177/107118137702100413
[14] Blackwell, H. Richard. "Specification of interior illumination levels." *Illuminating Engineering* 54, no. 6 (1959): 317-353.
[15] Groeneveld, T., P. Ghafoorpoor, M. Huisken, and Sebastian Thiede. "Methodology for systematic design of cleanroom assembly workstations." *Procedia CIRP* 120 (2023): 410-415. https://doi.org/10.1016/j.procir.2023.09.011
[16] Ferreira García, Karen Y., Jorge de la Riva Rodriguez, Jaime Sánchez Leal, Rosa M. Reyes-Martínez, and Arturo Woocay Prieto. "Determination of allowance time by work sampling and heart rate in manufacturing plant in Juárez México." *Journal of Engineering* 2019, no. 1 (2019): 1316734. https://doi.org/10.1155/2019/1316734
[17] Ur Rehman, Ateeq, Muhammad Babar Ramzan, Muhammad Shafiq, Abher Rasheed, Muhammad Salman Naeem, and Matteo Mario Savino. "Productivity improvement through time study approach: a case study from an apparel manufacturing industry of Pakistan." *Procedia Manufacturing* 39 (2019): 1447-1454. https://doi.org/10.1016/j.promfg.2020.01.306
[18] Jones, Thomas L., M. A. J. Baxter, and Vikas Khanduja. "A quick guide to survey research." *The Snnals of the Royal College of Surgeons of England* 95, no. 1 (2013): 5-7. https://doi.org/10.1308/003588413X13511609956372
[19] Mahapatra, Aditya, Prabir Jana, and Bela Marthi. "Application of pre-determined motion time system to develop a standard data system for measuring work content of garments finishing operations." *Journal of Textile and Apparel, Technology and Management* 11, no. 4 (2020).

[20] Noelia Magnolia, Chipana Baca, Ruiz Villena Javier, and Díaz Díaz Marco Antonio, “Methods engineering application to improve the production in a textile company.” In *Proceedings of the 20th LACCEI International Multi-Conference for Engineering, Education and Technology*: *Latin American and Caribbean Consortium of Engineering Institutions* (2022). https://doi.org/10.18687/LACCEI2022.1.1.182
[21] Hartanti, Lusia Permata Sari. "Work measurement approach to determine standard time in assembly line." *Work Measurement Approach to Determine Standard Time in Assembly Line* 2, no. 10 (2016): 192-195.
[22] De la Riva, J., A. I. Garcia, R. M. Reyes, and A. Woocay. "Methodology to determine time allowance by work sampling using heart rate." *Procedia Manufacturing* 3 (2015): 6490-6497. https://doi.org/10.1016/j.promfg.2015.07.934
[23] Ahmad, Aida Husna, Shahrul Azmir Osman, Saliza Azlina Osman, M. F. A. Mohd-Azhar, Mohd Hazrein Jamaludin, and H. A. Abu-Bakar. "A comprehensive review: Analysing the pros and cons of assembly line balancing methods." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 44, no. 2 (2024): 72-88.
[24] Ahmad, A. H. *To Evaluate the production process of the packing department at manufacturing factory through time study techniques*. Batu Pahat, Johor, p. 1-109, 2024.
[25] Vílchez-Torres, Mylena Karen, Shonel Miguel Cáceres-Pérez, and Daniel Julio Castro-Pérez. "A stopwatch time study for an underground mining extraction." *Dyna* 88, no. 218 (2021): 152-158. https://doi.org/10.15446/dyna.v88n218.91738
[26] Marasabessy, Umar Rusli, Engelberto Astrides, Asih Ahistasari, Mohammad Arief Nur Wahyudien, and Mirga Maulana Rachmadhani. "Analysis of work measurement using the stopwatch time study method at PTEA." *Journal of Industrial System Engineering and Management* 2, no. 1 (2023): 23-31. https://doi.org/10.56882/jisem.v2i1.14
[27] Smirnova, G., R. Sabitov, N. Elizarova, Sh Sabitov, A. Eponeshnikov, and N. Maximova. "Measurability and feasibility of work in the management of an industrial enterprise in a flexible production environment." *IFAC-PapersOnLine* 55, no. 10 (2022): 1410-1415. https://doi.org/10.1016/j.ifacol.2022.09.588
[28] Sapkal, Tejaswini, Hari Vasudevan, and Rajendra Khavekar. "Application of Work Measurement to Reduce the Cycle Time in Manufacturing Firm: A Case Study." In *Proceedings of International Conference on Intelligent Manufacturing and Automation: ICIMA 2022*, pp. 69-75. Singapore: Springer Nature Singapore, 2023. https://doi.org/10.1007/978-981-19-7971-2_7
[29] Aft, Lawrence S. Work *measurement and methods improvements*. Hoboken, New Jersey, United States: John Wiley & Sons, Inc., 2000.
[30] Perumal, Puvanasvaran A., Karmegam Karuppiah, and Lim Eu Sheng. "Validation of improvement in changeover of die bond process using basic most technique." *Songklanakarin Journal of Science & Technology* 43, no. 5 (2021).
[31] Pearson, Nicole, Patti-Jean Naylor, Maureen C. Ashe, Maria Fernandez, Sze Lin Yoong, and Luke Wolfenden. "Guidance for conducting feasibility and pilot studies for implementation trials." *Pilot and Feasibility Studies* 6, no. 1 (2020): 167. https://doi.org/10.1186/s40814-020-00634-w
[32] Yasir, Muhammad, Abdul Majid, and Hassan Qudratullah. "Promoting environmental performance in manufacturing industry of developing countries through environmental orientation and green business strategies." *Journal of Cleaner Production* 275 (2020): 123003. https://doi.org/10.1016/j.jclepro.2020.123003