Hindawi
Journal of Engineering
Volume 2019, Article ID 1316734, 6 pages
https://doi.org/10.1155/2019/1316734

Research Article

Determination of Allowance Time by Work Sampling and Heart Rate in Manufacturing Plant in Juárez México

Karen Y. Ferreira García, Jorge de la Riva Rodriguez, Jaime Sánchez Leal, Rosa M. Reyes-Martínez, and Arturo Woocay Prieto

Division of Postgraduate Studies and Research, Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez, Ciudad Juárez 32500, Mexico

Correspondence should be addressed to Jorge de la Riva Rodriguez; jriva@itcj.edu.mx

Received 10 December 2018; Accepted 10 February 2019; Published 13 March 2019

Academic Editor: Kamran Iqbal

We propose a methodology for determination of Allowance Time (AT), based on heart rate and work sampling of a production line composed of thirteen stations operated by four workers. The current production line presents a high rate of personnel turnover and absenteeism and with an AT value established by the company of 6.3%. The AT determination is of critical importance, given that through this the workers need to maintain their work rhythm at 100% during the entire workday without fatigue. The resulting allowance after the study was 15% instead of 6.3%, increasing the standard time and causing a decrease in personnel turnover and absenteeism and consequently increasing the production capacity and the reduction of costs.

1. Introduction

The traditional practices in Industrial Engineering involve supervising, managing, and linking the needs of the company to employees, in order to improve and optimize resources to increase efficiency, productivity, quality, and cost reduction. Among these practices is work study, a very common technique used by the Industrial Engineer to improve methods and work measurements in order to establish operations standard times. Hartani mentions the techniques for the determination of standard times [1], one of them being the work sampling. It is a specific approach to measuring labor productivity [2].

The traditional way to use the work sampling is to explore the content and the context of the activity during a work period during a period of time [3]. The work sampling is a technique that during the study makes a series of random observations about the resource employed (man, machine, or process) that are analyzed [4]. It is performed in those activities that do not have a work method and very consuming time activities and could be more than one monitored resource. This technique has been used to measure productivity in the construction area [2], automotive industry [3], brewing manufacture [5], and clothing industry [6], but it can actually be used to measure the efficiency of any company.

The standard time is determined from the real time affected by the rating of the operator performance and adding operator allowances for different causes that the operator may need during his working day. The type of work is an element that must be taken into account to define the Allowance Time (AT) [7]. Price proposes that the allowances time can be determined based on the metabolic cost [8] and the local muscle fatigue [9] where it exposes the factors involved in its determination. On the other hand, Mital divides its determination into empirical, based on static strength, based on heart rate, and based on energy expenditure; moreover, it shows the equations for each these categories [10]. Kroemer's proposed the necessity of matching the individual's energy capacity with the job demands capacity; they recommended the measurement of "standard" people reaction; however it is difficult to find those people [11]. Rohmert indicated that although there are several methods to define allowances, the determination is delegated to people with little skill and little experience to determine their value [12].

Personal and delay allowances are very important for every industry [6]. Having an incorrect standard time directly affects productivity, operators, and quality, among other metrics in the company. Establishing a lower standard time for workers, sacrificing AT, does not imply that the operators produce more but, on the contrary, the operator cannot maintain his rating of 100% during the working day; in addition, they accumulate fatigue day after day.

In the US Department of Labor's operations manual [13], it is stipulated that a time study should include time for personal needs and fatigue. The last one must be considered because fatigue occurs in all activities, and the objective is that the employees maintain a 100% rating for a defined period of time.

The International Labour Office (ILO) [14] stipulates that the percent allowances for personal needs are 5 or 7 percentage and 4 percentage dedicated to fatigue making a total of 9 and 11 percentages for men and women, respectively. In addition, it could be increased according to working conditions, due to standing work, abnormal postures, weight lifting, use of force, intensity of light, air quality, visual-hearing-sensory tension, and mental and physical monotony. The final allowance value is determined by the analyst's experience or the workers' perception, which is a subjective value.

A study was carried out on different jobs in the area of construction where the postures and types of work and psychological aspects produce an effect on the heart rate [15]. Likewise, external effects at work also impact the heart rate. The heart rate is a noninvasive method and easily monitored [16] and that is a very popular and cheap measure [17].

Therefore, heart rate monitoring was used to eliminate the subjectivity in this research. Given that the heart rate value will depend on age, gender, body postures, time of day, environment, physical condition, and muscle activity [18], recently, de la Riva [19] proposed a methodology to determine the percentage of AT based on heart rate measurements.

This case study was based on an actuators production line designed to manufacture five products for two different customers. It is important to mention that two of these products are considered very strenuous in the plant and the manufacturing process is complex; this process is performed on 13 machines with 4 operators (3 women and 1 man), distributed in 54.87 m^2 space, and with a producing rate of 170 pieces per hour. Currently, this line has a 71.46% efficiency. Other important data that must be considered in this study is personnel turnover, given that in this line there is a 13.45% weekly and a 6.75% daily absenteeism in the first and second shifts. Comparing other manufacturing lines, the plant presents low levels of personnel turnover and absenteeism, showing levels of 0.75% and 1.74%, respectively. In particular, the line that is being evaluated accounts for 13.4% of the monthly total turnover of the plant and 8.8% of the total absenteeism per month.

2. Materials and Methods

In this research, the continuous work sampling technique was used to register workers' activities and simultaneously take their heart rate using a Smart Heart Rate Bracelet (SHRB) [22] sensor in combination with a smartphone using HPlus Watch [23]. The methodology for determining the fatigue factor and personal needs consists of the following five steps.

First, the analyst or engineer documents in detail the operations performed by each of the operators involved in the study in order to determine the activities being performed and their progress on the task at the moment of the sampling.

Second, the work sampling and the acquisition of the heart rate information with the Smart Heart Rate Bracelet are started simultaneously. At the end of the day, the heart rate recorded with the Bracelet is cleared for each sampling time. The work sampling was performed for three days, every 5 minutes, during the entire working day for each worker. Table 1 shows a section of the work sampling made for one of the operators.

Third, a statistical analysis was performed, using MINITAB®, where the normality of the residuals of the heart rate measurements was verified by means of ANOVA using the Anderson-Darling criterion, obtaining a value of p-value = 0.005, which is less than 0.05 level of expected significance, which means that the data is not normal (Figure 1). In addition, the variance test was performed, yielding a p-value = 0.055 that is less than 0.3 (Figure 2); in according with Levene's Test, it is concluded that there is enough evidence to support that the variances are different.

Since it was not possible to show evidence that data was normally distributed, we proceeded to evaluate the residuals by means of the Kruskal-Wallis test. The results include adjustment for ties of heart rate data between two of the operators, and the medians' estimates of heart rate of the four operators are 96.00, 94.00, 98.00, and 97.00. Given that the values of p are less than the level of significance of 0.05, it is concluded that the medians of the heart rate are not all equal (Box 1).

Four, work sampling is related to the heart rate for each time activity and later on the heart rate is classified with the job severity according to Table 1 by Astrand and Rhodahl [20] for each activity. Table 2 shows the values of job severity of a work section by one of the operators. This step was performed for the three sampled days of each operator. Tables 3(a), 3(b), 3(c), and 3(d) show a summary from the frequencies obtained of the activity performed during the study of work sampling related to their level of job severity and in the last column the percentages corresponding to each level are included.

Five, allowances are determined for each operator with the help of the tables by Astrand and Rhodahl, the job severity of the tasks, and the allowances suggested by AHMSA [21] (reproduced here in Table 4) and given that both are compatible in the classification of job severity. The total percentage of tolerance is the sum of the values obtained from each level of job severity, obtained by multiplying the corresponding allowance (from the AHMSA table) and the percentage resulting from the summary of work sampling reflected in Tables 3(a), 3(b), 3(c), and 3(d). Table 5 contains the allowances for each classification and the total for the four employees.

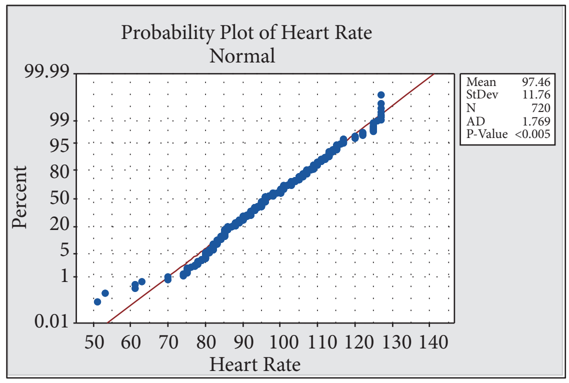

Figure 1: ANOVA test of the residuals during the heart rate study.

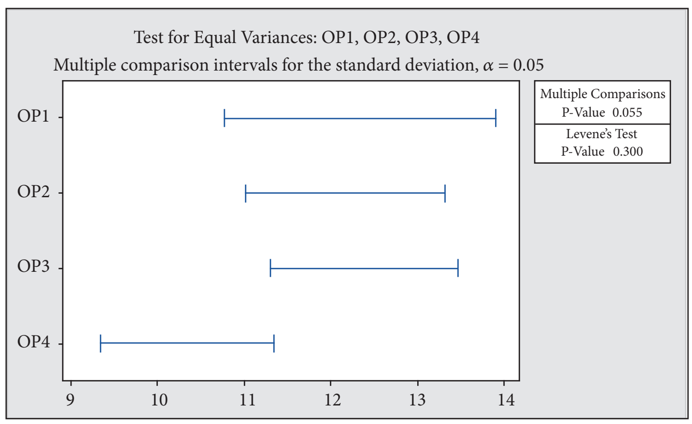

Figure 2: Variance test for heart rate study.

Table 1: Job severity classification according to Astrand and Rhodahl [20].

Job Severity	Vo_2 (l/min)	Heart Rate(beats/min)	Energy Consumption (Kcal/min)
Light	<0.05	<90	<2.5
Moderate	0.5-1.0	90-110	2.5-5
Heavy	1.0-1.5	110-130	5-7.5
Very Heavy	1.5-2.0	130-150	7.5-10
Extremely Heavy	>2.0	150-170	>10

Table 2: Section of work shift schedule selected for sampling, performed by one of the operators.

Work Sample			
Analyst:	KF	Date:	10/10/2017
Operation:	Production operator	Age:	41 years
Operator:	JM	Weight:	75 Kg
Time	Activity	Heart Rate	Job Severity
6:30 AM	Start shift	80	Light
6:35	Review the working conditions of the stations	80	Light
6:40	Fill the process audit sheet	80	Light
6:45	Working	86	Light
6:50	Working	95	Moderate
6:55	Working	101	Moderate
.	.	.	.
.	.	.	.
4:00 PM	End of the working day	90	Moderate

Table 3

(a) Operator "A" percentage of job severity obtained from the work sampling.

Job Severity	Heart Rate	Frequency											TOT	% Job Sev.
		RW	FF	W	WO	B	MS	WC	L	GY	ED	DW		
Light	<90	1	1	23	0	4	2	6	4	0	0	2	43	0.254
Moderate	90-110	2	2	83	2	1	0	0	7	3	5	0	105	0.622
Heavy	110-130	0	0	18	0	1	0	0	1	0	1	0	21	0.124
Very Heavy	130-150	0	0	0	0	0	0	0	0	0	0	0	0	0
												TOT	169	1.000

RW: review the working conditions of the stations, FF: full fill process audit sheet, W: working, WO: walk to the cafeteria, B: breakfast, MS: machine shutdowns, WC: bathroom, L: lunch, GY: work calisthenics, ED: end of the day, DW: drink water.

(b) Operator "B" percentage of job severity obtained from the work sampling.

Job Severity	Heart Rate	Frequency											TOT	% Job Sev.
		RW	FF	W	WO	B	MS	WC	L	GY	ED	DW		
Light	<90	1	1	48	0	0	2	5	6	0	4	3	70	0.37
Moderate	90-110	1	0	74	2	6	0	0	6	3	3	0	95	0.51
Heavy	110-130	1	2	17	1	0	0	0	0	0	0	1	22	0.12
Very Heavy	130-150	0	0	0	0	0	0	0	0	0	0	0	0	0
												TOT	187	1.00

(c) Operator "C" percentage of job severity obtained from the work sampling

Job Severity	Heart Rate	Frequency											TOT	% Job Sev.
		RW	FF	W	WO	B	MS	WC	L	GY	ED	DW		
Light	<90	3	2	35	0	3	5	5	4	0	5	1	63	0.35
Moderate	90-110	0	1	83	3	3	0	0	7	3	4	1	105	0.57
Heavy	110-130	0	0	13	0	0	0	0	1	1	0	0	15	0.08
Very Heavy	130-150	0	0	0	0	0	0	0	0	0	0	0	0	0
												TOT	183	1.00

(d) Operator "D" percentage of job severity obtained from the work sampling.

Job Severity	Heart Rate	Frequency												TOT	% Job Sev.
		RW	MC	FF	W	WO	B	MS	WC	L	GY	ED	DW		
Light	<90	1	22	1	5	2	4	3	3	4	0	1	1	47	0.24
Moderate	90-110	0	90	0	7	2	2	0	2	5	6	2	1	117	0.60
Heavy	110-130	2	15	2	5	2	0	0	1	3	0	1	1	32	0.16
Very Heavy	130-150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
													TOT	196	1.00

MC: movements of containers.

Table 4: Allowance percentage taken from AHMSA manual [21].

Job Severity	Activities description	% Allowance
Light	Perform work that requires the use of small tools or lightweight material, which may include movements in restricted areas.	10
Moderate	Perform light physical work requiring the use of lightweight materials and tools: pull or push lightweight material, including bending, stretching or lifting.	15
Heavy	Perform moderately heavy work requiring the use of tools and materials that require considerable effort.	20
Very Heavy	Perform heavy work requiring the use of tools and equipment requiring extreme effort.	30

Table 5: Allowance percentage determined from the study for each operator.

Job Severity	% Allowance (AHMSA)	Operator A (1)	A (2)	B (1)	B (2)	C (1)	C (2)	D (1)	D (2)
Light	10	0.254	2.54	0.37	3.70	0.34	3.40	0.24	2.40
Moderate	15	0.622	9.33	0.51	7.65	0.57	8.55	0.60	9.00
Heavy	20	0.124	2.48	0.12	2.40	0.08	1.64	0.16	3.20
Very Heavy	30	0	0	0	0	0	0	0	0
TOTAL			14.35		13.75		13.59		14.60

Note: (1) % Obtained from job severity of the sampled periods (2) % Allowance according to job severity.

Kruskal-Wallis Test: RC versus Operador 1,2, 3,4

```
Kruskal - Wallis Test on RC
Op          N        Median        Ave Rank        Z
1           180      96.00         357.6           -0.21
2           180      94.00         316.8           -3.26
3           180      98.00         384.0           1.75
4           180      97.00         383.6           1.72
Overall     720                    360.5
H = 12.50   DF = 3   P = 0.006
H = 12.52   DF = 3   P = 0.006   (adjusted for ties)
```

Box 1: Kruskal-Wallis test nonparametric residuals test for the heart rate study.

3. Results and Discussion

The allowances obtained for this group of workers were 14.35, 13.75, 13.59, and 14.60, for operators A, B, C, and D respectively. The recommended tolerance is 15 %, given that a single tolerance value is usually used for the determination of standard time in a line or work area for both genders.

To verify the tolerance resulting from the methodology proposed in this article, the AT were determined using the ILO tables (1977) under the following premises: all operators work standing up and operators A, B, and C are women, for whom allowances consist of 7% for personal needs + 4% for fatigue + 4% for working standing giving a total of 15%. Worker D is male and his activities involve the use of force (packaging), so his tolerance turns out to be 5% personal needs + 4% for fatigue + 2% for working standing + 3% for lifting or use of force giving a total of 14%. Following the same arguments mentioned above, a single value is used for the four operators, which is 15%; this percentage exceeds by 8.7% the current value used in the company.

4. Conclusions

The proposed methodology in this paper eliminates analyst subjectivity for determining which factors should be taken into consideration from the allowance table already established, given that the heart rate involves the entire physical and psychological environment in which a task is performed. On the other hand, companies in some cases use allowance lower than those recommended, due to the erroneous belief that the increase in standard time may lead to less production, when in fact it is very likely that workers during the day are reducing their work rhythm due to fatigue. In addition, the daily accumulation of fatigue results in absenteeism and personnel turnover which is more detrimental than applying an adequate tolerance for determining the standard time.

One way to convince companies to use the appropriate allowance is through a cost analysis. The standard time of the line under study is designed with 21.14 second/piece or 18802 pieces /week, the proposed new standard time is 22.86 second/piece or 17364 pieces/week (i.e., 15% allowance), and there would be a loss of 1438 pieces/week, where a product at a cost of $ 17.75 USD represents a loss of $ 25,524.00 USD originates per week or $ 1,276,200.00 USD per year. However, the average real production is 16019 pieces/week much lower than the production capacity with the new allowance. On the other hand, production drops to 12797 pieces/week when operating with three people due to absenteeism. With the implementation of the new standard time with the correct AT, personnel turnover and absenteeism could be reduced, maintaining at least the average production with four operators which represent a gain of 3222 pieces/week or $ 57,190 USD per week or $ 2,859,500.00 USD per year.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

We are grateful for the financial support provided by Tecnológico Nacional de México/Instituto Tecnológico de Ciudad Juárez.

References

[1] L. Hartani, "Work Measurement approach to determinate standard time in in assembly line," *International Journal of Management and Applied Science*, pp. 192–195, 2016.

[2] S. Hajikazemi, B. Andersen, and J. A. Langlo, "Analyzing electrical installation labor productivity through work sampling," *International Journal of Productivity and Performance Management*, vol. 66, no. 4, pp. 539–553, 2017.

[3] T. Martinec, S. Skec, T. Savsek, and M. M. Perisic, "Work sampling for the production development: A case study of a supplier in European automotive industry," *Advances in Production Engineering & Management*, vol. 12, no. 4, pp. 375–387, 2017.

[4] F.-S. Liou, J. D. Borcherding, and Members ASCE, "Work sampling can predict unit rate productivity," *Journal of Construction Engineering and Management*, vol. 112, no. 1, pp. 90–103, 1986.

[5] B. G. Mwanza and C. Mbohwa, "Application of work study for productivity Improvement: A case study of brewing company," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, pp. 296–305, Kuala Lumpur, Malaysia, March 2016.

[6] S. Gunesoglu and B. M. Meric, "The analysis of personal and delay allowances using work sampling technique in the sewing room of a clothing manufacturer," *International Journal of Clothing Science and Technology*, vol. 19, no. 2, pp. 145–150, 2007.

[7] A. Coronado, H. Romandia, A. Ramírez et al., *Determination of Allowances for Standard Time, Final Assembly Manufacturing Engineering*, Ford Motor Company, Hermosillo, Sonora, México.

[8] A. D. F. Price, "Calculating relaxation allowances for construction operatives - Part 1: Metabolic cost," *Applied Ergonomics*, vol. 21, no. 4, pp. 311–317, 1990.

[9] A. Price, "Calculating relaxation allowance for construction operatives -Part 2: Metabolic cost," *Applied Ergonomics*, vol. 21, no. 4, pp. 318–324, 1990.

[10] A. Mital, R. R. Bishu, and S. G. Manjunath, "Review and evaluation of techniques for determining fatigue allowances," *International Journal of Industrial Ergonomics*, vol. 8, no. 2, pp. 165–178, 1991.

[11] K. Kroemer, H. Kroemer, and K. Kroemer-Elbert, *Ergonomics How to Design for Ease and Efficiency*, Prentice Hall, New Jersey, 2nd edition, 2000.

[12] W. Rohmert, "Problems in determining rest allowances. Part 1: Use of modern methods to evaluate stress and strain in static muscular work," *Applied Ergonomics*, vol. 4, no. 2, pp. 91–95, 1973.

[13] FOH, U.S. Department of Labor, "Chapter 64, revision 713#, Field operations handbook, Washington, DC, U.S.A, 2016.

[14] International Labor Organization, *Introduction to The Work Study Italy*, International Labor Office Geneva, Sagraf Naples, Italy, 3rd edition, 1977.

[15] F.-L. Chang, Y.-M. Sun, K.-H. Chuang, and D.-J. Hsu, "Work fatigue and physiological symptoms in different occupations of high-elevation construction workers," *Applied Ergonomics*, vol. 40, no. 4, pp. 591–596, 2009.

[16] E. M. Goffeng, K.-C. Nordby, M. P. Tarvainen et al., "Fluctuations in heart rate variability of health care workers during four consecutive extended work shifts and recovery during rest and sleep," *Industrial Health*, vol. 56, no. 2, pp. 122–131, 2018.

[17] J. Malchaire, F. R. d'Ambrosio Alfano, and B. I. Palella, "Evaluation of the metabolic rate based on the recording of the heart rate," *Industrial Health*, vol. 55, no. 3, pp. 219–232, 2017.

[18] G. Rodas, P. Carballido, J. Ramos, and L. Capdevila, *Variability of Heart Rate: Concept, Measurements and Relationship with Clinical Aspects (I)*, vol. XXV, No.123, Ministry of Education and Science, Barcelona, Spain, 2008.

[19] J. de la Riva, A. I. Garcia, R. M. Reyes, and A. Woocay, "Methodology to determine time allowance by work sampling using heart rate," *Procedia Manufacturing*, vol. 3, pp. 6490–6497, 2015.

[20] P.-O. Astrand and K. Rodahl, *Textbook of Work Physiology*, McGraw Hill, New York, USA, 3rd edition, 2003.

[21] AHMSA, Altos Hornos de México S.A, "Manual of Procedures for Time Study of Production Work and Maintenance", Department of Industrial Engineering, p. 13, México, 1967.

[22] SHRB. Shenzhen Zhimeide Technology Co, Smart watch user manual, https://fccid.io/2AL5W-DFIT/User-Manual/User-Manual-3395108, 2018.

[23] HPlus Watch. 2018 H+ 2.27.0, https://play.google.com/store/apps/details?id=com.richtechie.hplus, 2018.