An Intelligent Incentive Model Based on Environmental Ergonomics for Food SMEs

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Abstract. In this study, an intelligent incentive model based on environmental ergonomics in food small and medium-sized enterprises (SMEs) was developed. Environmental ergonomics was defined as the impact of temperature and relative humidity within a certain range on a worker's heart rate during work. Optimum environmental ergonomics are highly required as a basic standard for food SMEs to provide fair incentives. Recommendable parameters from a genetic algorithm and fuzzy inference modeling were used to model customized incentives based on optimum heart rate, workplace temperature and relative humidity before and after working. The research hypothesis stated that industries should optimize their workload and workstation environment prior to customizing incentives. The research objectives were: 1) to recommend optimum environmental ergonomics parameters for customized incentives; 2) to determine the incentives at workstations of SMEs based on optimum environmental ergonomics parameters and fuzzy inference modeling. The optimum values for heart rate, workstation temperature and relative humidity used were based on recommendable values from the genetic algorithm. An inference model was developed to generate decisions whether a worker should receive an incentive based on a calculated index. The results indicated that 84.4% of workers should receive an incentive. The results of this research could be used to promote the concept of ergonomics-based customized incentives.

Keywords: *fuzzy inference; genetic algorithm; heart rate; incentive index; workstation temperature.*

1 Introduction

The uncertainty of environmental ergonomics contributes significantly to workload, productivity, and job performance in the work systems of small and medium-sized enterprises (SMEs). Hakenes and Katolnik [1] state that the workstation environment contributes to variation in productivity and job performance. Environmental ergonomics is defined as the dynamic impact of the workstation environment on the health, convenience, and productivity of

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human workers [2]. In food SMEs, it is defined as the impact of temperature and relative humidity within a certain range on the worker's heart rate during the working day. Food operation and processing influences the variation of temperature and relative humidity. Characteristics of SMEs are flexible job scheduling and multi-tasking job descriptions. In Indonesia, the wages are determined based on the standard of each region. The incentives are required to provide additional income and a stimulus to increase productivity. Incentives are seen as an essential factor to stimulate worker performance [3]. Angelova, *et al.* [3] compared two incentive schemes based on the relationship between incentive and performance. Incentives have assisted industries in pursuing job rotation [1]. Also, incentives have a relationship with work practice and training [4].

Worker incentives in food SMEs can be affected by environmental ergonomics. Value-added processes in food SMEs such as boiling, frying, baking, and steaming require precise environmental control of the agricultural raw material. On the other hand, the worker ergonomics conditions are profoundly affected by the environment. Since environmental ergonomics are involved in the complex relationship between worker ergonomics conditions and workstation environment, the customized incentives in food SMEs should be precisely calculated. An intelligent approach could be a significant solution to define the dynamic impact of environmental ergonomics on the determination of the precise incentive.

Genetic algorithm and fuzzy inference are proposed to model environmental ergonomics-based incentives. An ideal workstation environment is highly required as a basic standard for food SMEs to provide appropriate incentives. This can be indicated by optimum parameter conditions. Genetic algorithm modeling is required to recommend the optimum parameter values for environmental ergonomics. This concept is based on the hypothesis that industries should optimize their workload and workstation environment prior to customizing incentives. Zou and Lei [5] stress the importance of involving information technology in determining production system performance precisely. Gong, *et al.* [6] have used an interactive genetic algorithm to evaluate user fatigue problems.

The optimum environmental ergonomics parameters should be modelled using fuzzy inference to generate the decision whether a worker should receive an incentive or not. Fuzzy inference models have been applied to some applications in work systems. Kolomvatsos, *et al.* [7] used the type-2 fuzzy inference system to identify contextual data stream mapping. Zhou, *et al.* [8] developed a fuzzy application to decision making on assessment criteria for job satisfaction in industry. Hsu [9] used a fuzzy knowledge system for disassembly process planning. Garcia-Nunez, *et al.* [10] defined the relationship between a mental model and fuzzy rules. Chen, *et al.* [11] developed fuzzy rule interpretation. Based on a literature review, none of these researches were applicable to a customized incentive model for food SMEs. The hybrid model of genetic algorithm and fuzzy inference proposed here is a significant contribution to ergonomics and human factors.

Cheshmehgaz, *et al.* [12] used a fuzzy genetic algorithm to develop a model related to the accumulated risk of monotonous body postures that could lead to work-musculoskeletal disorders. Tsuchiya, *et al.* [13] initially combined a genetic algorithm with a fuzzy rule induction method. Our literature review convinced us that recommendable values from a genetic algorithm and fuzzy inference are applicable to developing an intelligent incentive model based on environmental ergonomics for food SMEs. The novelty of this study is to determine customized incentives based on an optimum trade-off between environmental ergonomics and the workstation environment in the production process of food SMEs. The research objectives were: 1) to recommend optimum parameters for environmental ergonomics for customized incentives; 2) to determine the incentives at workstations of food SMEs based on optimum environmental ergonomics parameters and a fuzzy inference model. The research benefit is to provide a precise and customized incentive platform based on specific characteristics of environmental ergonomics in the production system of food SMEs.

2 Material and Methods

Figure 1 shows the research methodology to develop the intelligent incentive model. In the first step, a conceptual model was developed to approach a real system of customized incentives. In the second step, the parameters of environmental ergonomics were determined, i.e. heart rate, workstation temperature, and relative humidity. Heart rate (HR) was selected as workload parameter due to its applicability in representing the working methods in food SMEs [15,16]. Temperature and relative humidity were selected as consistent value to represent the various indoor environments in food SMEs [15,16]. In the third step, the workstation incentive index was determined based on the environmental ergonomics parameters. Finally, the recommendable values were obtained from the genetic algorithm and the fuzzy inference model to determine the customized incentive. Further steps can be defined as follows:

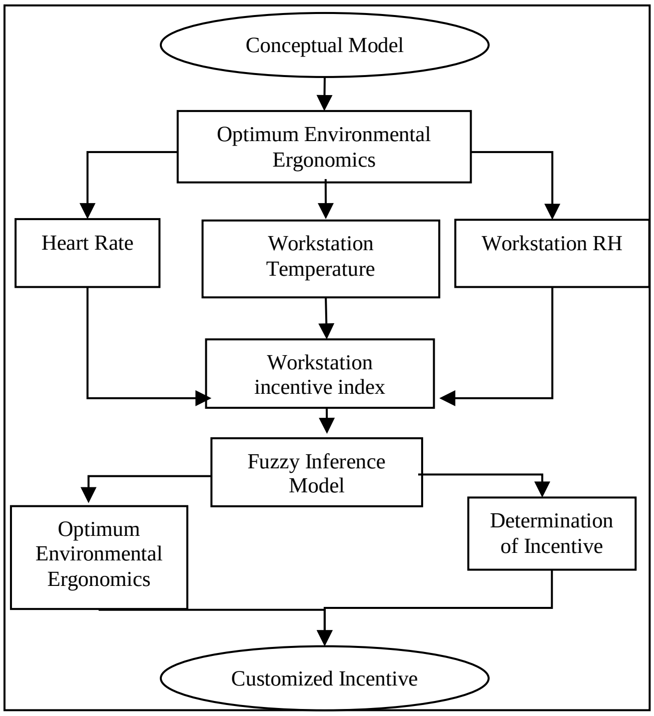

Figure 1 Research methodology.

2.1 Conceptual Model

A customized incentive is a work incentive in the form of an additional percentage of the standard wage that is determined based on the relationship between workers and their workstation environment. A workstation is a working group consisting of interaction between worker, tool, workstation environment, and material. Food SMEs in the Special Region of Yogyakarta were used as the database. 390 datasets were analyzed. The conceptual model defines that the customized incentive is influenced by heart rate, temperature, and relative humidity before and after working in a workstation (Figure 2). The customized term is indicated by an incentive index.

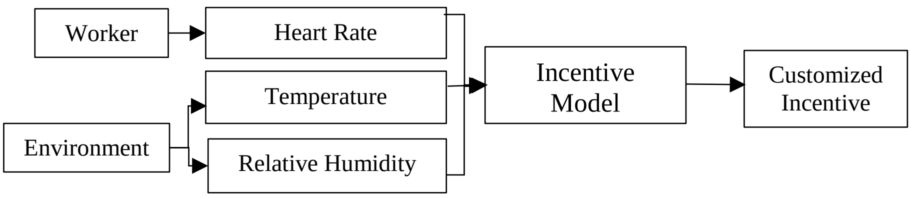

Figure 2 Conceptual model of customized incentive.

2.2 Optimum Environmental Ergonomics

The optimum environmental ergonomics parameters were determined using recommendations from a reference in genetic algorithm research [17] and were confirmed by our literature review [14,15]. The environmental ergonomics data were stored in a database. A genetic algorithm model was used to search the optimum values for heart rate, workstation temperature and relative humidity based on a target temperature of 30 °C [17].

The target temperature was decided based on effective temperature control in food SMEs [15]. The evaluation process calculated the fitness value of each chromosome using the fitness function of an artificial neural network [15,16]. If the stopping criterion was fulfilled, the optimal environmental ergonomics parameters were determined based on the best fitness value [17].

2.3 Workstation Incentives Index

The worker incentive index was adapted from the SME affective index [14]. The SME index was determined based on a comparison between the optimum heart rate and environmental ergonomics parameters [14]. The output was a customized incentive index, which indicates the incentive percentage.

The worker incentive index was defined as follows:

$$I_w = \frac{\frac{I_{RH0}}{I_{RH1}} + \frac{I_{T0}}{I_{T1}}}{I_{HR}} \times 100 \tag{1}$$

2.4 Fuzzy Inference Model

Fuzzy inference rules were set to classify workers' incentives based on the relationship between optimum heart rate, temperature and relative humidity before and after work, as recommended by reference research on genetic algorithms [17]. In this study, an open source software application, Fuzzy Inference System Professional (Fispro) version 3.5, was used [18,19].

The general process of fuzzy inference is performed on 3 (three) processes: fuzzification, rule-based system, and defuzzification. The fuzzification process is a process that converts numerical values (or crisp values) to a fuzzy input (linguistic values). The rule-based system is used to formulate the conditional statements that comprise the fuzzy logic. The defuzzification process is the reverse process of fuzzification. It converts the fuzzy values into crisp values.

3 Results and Discussions

3.1 Optimum Environmental Ergonomics

The result of genetic algorithm optimization was used to recommend the optimum values shown in Table 1 [17]. The parameter of light intensity in Ushada, *et al.* [17] was not used in this study due to the high variation of its values, which could constitute a bias when customizing the incentive. Ushada, *et al.* [15] confirmed the bias of light intensity at the workstation. The optimum heart rate was recommended at 121 beats/minute, the workstation temperature at 30 °C and the RH range at 60-67%. Heart rate workload can be optimized using work method management [14]. The work station environment can be optimized using a controlled environment system [15]. Table 1 shows the optimum environmental ergonomic values for food SMEs as a basic standard for providing fair incentives [17].

Table 1 Recommended environmental ergonomics for customized incentives.

Parameters	Values
HR (beats/minute)	121
T_0 (°C)	30
T_1 (°C)	30
RH_0 (%)	60
RH_1 (%)	67

The recommended heart rate confirmed the classification by AIHA in Kolus, *et al.* [20,21]. AIHA in Kolus, *et al.* [20,21] classifies workload as follows: 1) sitting (60 to 75 beats per minute); 2) very light (65 to 75 beats per minute); 3) light (75 to 100 beats per minute); 4) moderate (100 to 125 beats per minute); 5) heavy (125 to 150 beats per minute); 6) very heavy (150 to 175 beats per minute); and 7) extremely heavy (more than 175 beats per minute). The classification indicates a moderate workload when the heart rate ranges from 100 to 125 beats per minute. The recommendable values from the genetic algorithm were slightly different from another result that used simulated annealing [14]. The recommended heart rate was 69.58 beats per minute (light workload). The different results were caused by the high variation in the light intensity parameter in the previous result.

The recommended T_0 and T_1 confirm the standard temperature range for a transit room of 27 to 30 °C [15,22]. A transit room is the most approximate standard for food SMEs since it does not require an additional air conditioner or fan [15]. In addition, National Standard of Indonesia (SNI) No. 16-7063-2004 confirms a temperature of 30 °C as a recommendable value for workload [23]. The recommended temperature was confirmed by the review of Zomorodian, *et al.* [24], who state that a range of 26.6 to 30.70 °C can be categorized as the higher limit of the optimum temperature in a building. Ushada, *et al.* [15]

concluded that the optimum temperature before and after working in the workstation of food SMEs was 30 °C. The RH range was confirmed by Regulation of Ministry of Health No. 1077 from the year 2011 [25]. The recommendable values were between 40% and 60%. The value of 67% is tolerable since after working, the workstation temperature is higher than before. The recommendable values using the genetic algorithm confirmed the previous result using simulated annealing [14]. The recommended RH was between 40.64% and 59.80% [14].

3.2 Determination of Incentive

In this study, Mamdani fuzzy logic was used to classify the worker incentives. Fuzzy inference was built with 5 (five) inputs, i.e. heart rate (HR), relative humidity before work (RH_0), relative humidity after work (RH_1), temperature before work (T_0), temperature after work (T_1). The output was the customized worker incentive. Each input and output had two member functions. The member functions for input were ‘optimum’ and ‘not optimum’, whereas for output they were ‘incentive’ and ‘no incentive’. These member functions were built based on the recommendable values of the genetic algorithm [17]. The range values for each input and output are indicated in Table 2.

Table 2 Input parameter values.

Input Parameters	Minimum Values	Maximum Values
Heart rate	66	123
Temperature before work	25	32
Temperature after work	27	30
Relative humidity before work	59	69
Relative humidity after work	30	69

Each input and output parameter had two member functions based on the recommendable values of the genetic algorithm [17]. The member function for each parameter is shown in Figures 3 to 7. By using these 5 (five) parameters, 32 probabilities of the rule were obtained. The fuzzy rules for the decision on the incentive shown in Table 3 were developed based on the relationship between these parameters. The inputs were the environmental ergonomic parameters. The output was the classification of the worker as ‘incentive’ or ‘no incentive’. The relationship was developed based on the knowledge from our previous research [14-16]. The relationship of the input in the fuzzy rules was partly derived from an experiment in a confined room, simulating various experimental designs based on hardware lighting, fan, air conditioner, and ventilation [15]. Besides that, it was also partly derived from field measurement in various food SMEs [16]. The relationship of the output of the fuzzy rules was derived from the SME worker affective index [14].

Table 3 Fuzzy rules.

No	HR	RH_0	RH_1	T_0	T_1	Output
1	√	√	√	√	√	Incentive
2	√	√	√	√	×	Incentive
3	√	√	√	×	√	No Incentive
4	√	√	√	×	×	No Incentive
5	√	√	×	√	√	Incentive
6	√	√	×	√	×	Incentive
7	√	√	×	×	√	No Incentive
8	√	√	×	×	×	No Incentive
9	√	×	√	√	√	Incentive
10	√	×	√	√	×	Incentive
11	√	×	√	×	√	No Incentive
12	√	×	√	×	×	No Incentive
13	√	×	×	√	√	Incentive
14	√	×	×	√	×	Incentive
15	√	×	×	×	√	No Incentive
16	√	×	×	×	×	No Incentive
17	×	√	√	√	√	No Incentive
18	×	√	√	√	×	No Incentive
19	×	√	√	×	√	No Incentive
20	×	√	√	×	×	No Incentive
21	×	√	×	√	√	No Incentive
22	×	√	×	√	×	No Incentive
23	×	√	×	×	√	No Incentive
24	×	√	×	×	×	No Incentive
25	×	×	√	√	√	No Incentive
26	×	×	√	√	×	No Incentive
27	×	×	√	×	√	No Incentive
28	×	×	√	×	×	No Incentive
29	×	×	×	√	√	No Incentive
30	×	×	×	√	×	No Incentive
31	×	×	×	×	√	No Incentive
32	×	×	×	×	×	No Incentive

Notes:
√ = Optimum
× = Not optimum

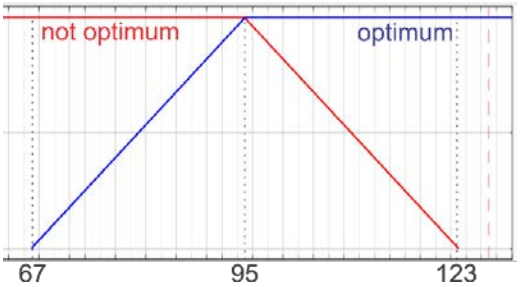

Figure 3 Fuzzy membership for heart rate parameter.

The fuzzy membership in Figure 3 indicates that the criteria values of not optimum for heart rate were below 95 (light workload [20,21]). The fuzzy values were between 67 (very light workload [20,21]) and 95 (moderate workload [20,21]). The optimum values were over 95, while the fuzzy values were between 95 and 123. These results accord with the standard value in AIHA in Kolus, *et al.* [20,21], where the moderate workload ranges from 100 to 125.

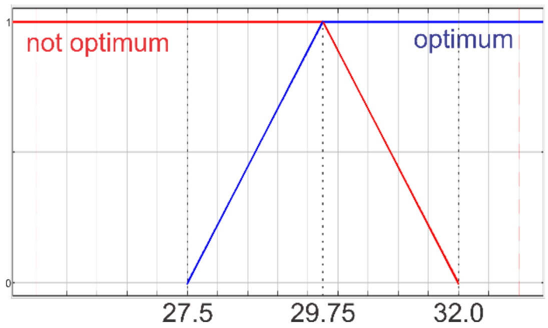

Figure 4 Fuzzy membership for workstation temperature before working.

The fuzzy membership in Figure 4 indicates that the criteria values of not optimum for workstation temperature before working were below 27.5 °C, while the fuzzy value was between 27.5 and 29.75 °C. The optimum values were more than 29.75 °C, while the fuzzy values were between 29.75 and 32 °C. The results confirm RMEMR [22] and SNI [23], which recommend temperatures between 27 and 30 °C. A value of 32 °C is tolerable since it is the upper threshold of the fuzzy value.

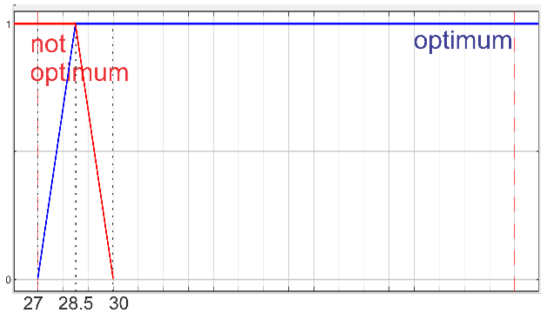

Figure 5 Fuzzy membership for workstation temperature after working.

The fuzzy membership in Figure 5 indicates that the not optimum values of workstation temperature after working were below 27 °C, while the fuzzy values were between 27 °C and 28.5 °C. The optimum values were over 28.5 °C, while the fuzzy values were between 28.5 °C and 30 °C. The results confirm

RMEMR [22] and SNI [23], which recommend temperatures between 27 and 30 °C.

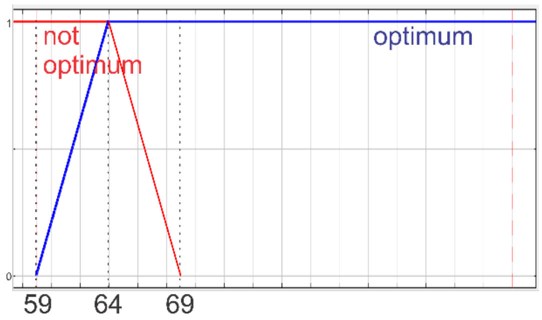

Figure 6 Fuzzy membership for workstation relative humidity before working.

The fuzzy membership in Figure 6 indicates that the not-optimum criteria values for the relative humidity at the work station before working were below 59%, while the fuzzy values were between 59% and 69%. The optimum values were over 64%, while the fuzzy values were between 64% and 69%. The results confirm the recommendable value of Regulation of Ministry of Health No.1077 from the year 2011 with the range between 40 and 60% [25]. A value of 69% is tolerable since it is below the upper threshold of the fuzzy value.

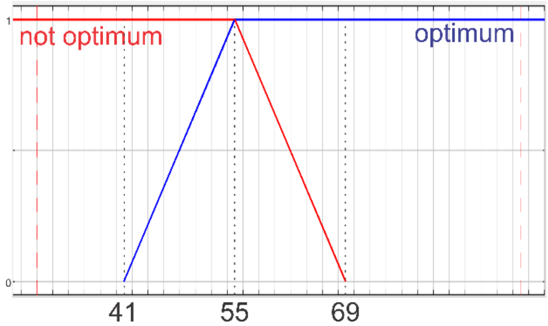

Figure 7 Fuzzy membership for workstation relative humidity after working.

The fuzzy membership in Figure 7 indicates that the criteria values of not optimum for the relative humidity at the work station after working were below 41%, while the fuzzy values were between 41% and 55%. The optimum values were over 55%, while the fuzzy values were between 55% and 69%.

The results confirm the recommendable values of Regulation of Ministry of Health No. 1077 from the year 2011 with the range between 40 and 60% [25].

A value of 69% is tolerable because it is below the upper threshold of the fuzzy value.

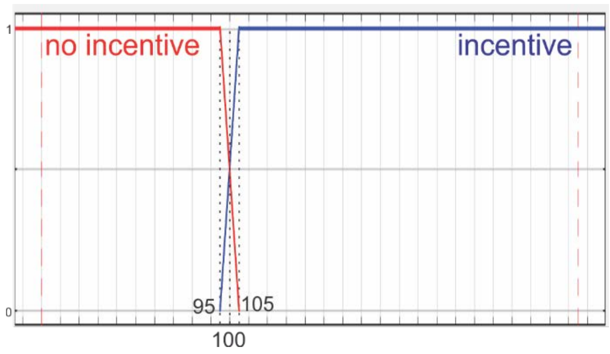

Figure 8 Fuzzy membership for incentive index.

The fuzzy membership in Figure 8 indicates that the not optimum criteria values of for the incentive index were below 95, while the fuzzy values were between 95 and 100. The optimum values were over 100, while the fuzzy values were between 100 and 105. The results confirm our previous research [14], where the same recommendable affective index was below a value of 112.

The fuzzy inference model was tested by 390 worker datasets. The research results indicated that 84.4% of workers were recommended to receive an incentive and 15.6% not to receive an incentive. 160 workers were recommended to receive an incentive of 42.5%. The high percentage of recommended incentives indicates the possibility of a large number of overload workers in the SMEs. This was confirmed by our previous publication [26] where the amount of overload workers in the food SMEs exceeded the number of normal and underload workers. Ushada, *et al.* [26] developed an assessment method for integrated workload, which classifies workers as ‘overload’, ‘normal’ and ‘underload’. Overload and underload workers are identified based on a comparison of work proportion, utility and mood efficiency at each workstation. Overload workers are identified at work stations that have the lowest service rate and the highest utility. This overload could create a bottleneck [26]. Therefore, by providing an appropriate work incentive, overload workers can prevent bottlenecks.

Dam [27] confirms the research results in this paper that policy makers such as local governments should consider the effect of managerial incentives for SMEs. This could create a cumulative effect for manager of SMEs to consider the importance of customized worker incentives. Local governments should promote trainings to make managers more familiar with work incentives.

Jaworksi, *et al.* [28] confirmed the relationship between training satisfaction and incentives impacting the commitment of managers and workers in achieving industry goals.

The incentive percentage ranged between 3.1% and 92.5% based on the standard worker wages. The wide range of incentive percentages indicates that worker incentives at workstations in food SMEs is influenced by the environmental ergonomics parameters heart rate, workstation temperature, and relative humidity.

3.3 Implementation of Customized Incentive

In a recent development, the effect of information technology on work systems in industry is considered, called digital ergonomics [29]. The program enhances appropriate information technology application in SMEs based on tailored intelligent technology systems that are usually used by large companies.

An intelligent incentive model is used as an additional feature of Kansei Engineering-based Sensor for Agro-industry (KESAN) in an integrated ergonomic assessment system [30,31]. The role of management is to utilize an environmental ergonomics control system [32]. The actors in the environmental ergonomics system consist of human resource manager, data enumerator, team leader, worker, controller, and interpreter [32]. In some Indonesian SMEs, the human resource manager can be categorized as the SME's owner. The owner of the SME can retrieve the worker incentive database, monitor a career program, pursue ergonomic designs, monitor quality of life, pursue worker evaluation, determine periods of measurement, select the data enumerator and team leader [32]. Thus, it is expected that work incentives could impact workplace performance, as confirmed by Itri, *et al.* [33].

In a wider scope, an intelligent incentive model could be used to formulate collective-regional incentive standards among SME clusters. SME clusters consist of several single SMEs. Each single SME could pursue incentive measurement using a groupware system and a collaborative platform. Furthermore, the incentive could be smaller if the SME cluster collectively provides a comfortable work system and environmental ergonomics. SME clusters could share the initial implementation costs for an environmental ergonomics control system such as the as procurement of integrated workload sensor, indoor environment sensor, air conditioner, controller and interpreter.

4 Conclusions

This paper proposes an intelligent model for worker incentives using a fuzzy inference model and recommendable values from a genetic algorithm. Optimum values for the parameters heart rate, workstation temperature and relative humidity based on the recommendable values from the genetic algorithm were used. A worker incentive index was determined to indicate the incentive percentage. Fuzzy inference models were developed to generate the decision based on the worker incentive index whether a worker should receive an incentive or not. 390 datasets were used for testing the model. The research results indicated that 84.4% of workers were recommended to receive an incentive and 15.6% not to receive an incentive. The results can be used to promote the concept of customized incentives based on the effects of environmental ergonomics at workstations in food SMEs. In addition, it is recommended that industry should optimize their workload and workstation environment prior to introducing customized incentives.

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Nomenclature

Iw	=	workstation index
I_{RHO}	=	index of RH before working [14]
I_{RH1}	=	index of RH after working [14]
I_{T0}	=	index of temperature before working [14]
I_{T1}	=	index of temperature after working [14]
I_{HR}	=	index of heart rate before working [14]

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