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The Effect of Safety System on Production Indices

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ABSTRACT

Nowadays, in addition to implement the quality of management systems and environment management and due to the effects of safety and health issues on working processes, the organizations have also sought to acquire health and safety management systems. This descriptive–analytic and past reviewing study has been implemented based on five years (from 2006 to 2010) recorded documents and statistics information in food industrial. Information was collected based on the food industries checklists. The safety indices including risk evaluation, safety auditing, personnel safety training, investment in personal protection equipments, accident severity, accident frequency, accident frequency-severity and job decease repetition coefficient were used for determination of safety programs successfulness degree. Productivity indices such as human forces productivity, wastage amount, production per capita, personnel absence, personnel complaint, and production exploitation were for organizational productivity measurements. The results showed that, the safety programs implementation have positive impacts on mentioned productivity indices. So, there was a direct relationship between safety rules respect and work condition optimization which arouse productivity development in the organizations. Indices definition could be helpful for the safety system effectiveness and system continuous performance optimization.

Keywords: *Productivity, Safety management, Accidents, OHSAS-18001*

INTRODUCTION

National productivity increase causes to raise people life levels, inflammation decrease and national capacity creation in global markets. National productivity increase was the result of productivity increase in organizations, institutes and economical firms. We could consider its level as a criterion for improvement and development measurement of a country. Safety programs play an important role in the workforce productivity and product qualitative and quantitative indices.

Boden and Brody studied about economic expenditures investigation due to the job accidents by using insurance payments information to the worker, the elapsed time for returning to the work and its effects on the worker life quality and the bearing costs by employers. They concluded that job accidents had negative effects on the working life quality and employers' costs increase [1, 2]. Leigh et al. investigated the accidents as quantitative models and concluded that accidents prevention was one of the most influencing factors on the costs decline and productivity raise [3].

Safety program implementation is one of the most influencing factors on the productivity increase [4-6]. The negative effect of the working shift on the productivity is reported [7]. Some studies were done about the effects of ergonomic factors on satisfaction and job diseases [8]. A model for implementing the safety program was presented which was economical and cost effective [9]. Oxenburgh and Marlow studied invisible profits of the safety program and job health

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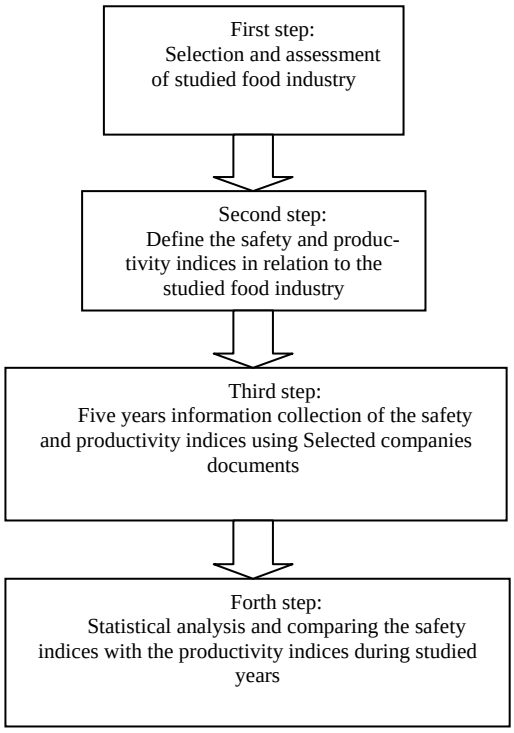

Fig 1. The steps of research

and the effects of these programs on financial processes and production quality as well as quantity [10].

Some studies defined productivity as an optimal usage of material resources, human forces, scientific facilities, and production costs decline, markets development, employment increase, efforts for increasing real wages and life standards optimization in a manner that it be useful for the worker, manager and general consumers [11-13]. Priority of the safety programs in the main policies of the organization cause to increase the productivity and raise the personnel's morale and their responsibilities. In addition, Hola concluded that, the greater the accidents, the more costs will become. It had negative effect on the firm economics [14].

The ordered and disciplinary systems of the work environment had positive influence on the safety programs successfulness and the workforce productivity [15]. The economical and financial and competitive performance of industry was affected by the safety management system [16]. Government role in optimization of the industry safety program was identified as regulatory and rules compilation [17].

Shalini believed that, there was relation between job accidents and productivity [18]. Some studies were done regarding the relation between the safety indices and systems structure with low flexibility and the result was expressed as increasing safety indices and system flexibility [19, 20]. Temperature of the work place could be affect on personnel productivity. Undesired conditions of the workplace were one of the factors which decline the workforce productivity [21].

Looking at the safety from the productivity view could specify the importance of this case for everyone especially companies managers. Because many managers have yet to consider the safety investment as a part of the organizational overcharge costs. With verification of the safety programs positive impact on the productivity, we took steps on account of propagating safety culture in the organizations and present a scientific reason with regard to prioritize the safety programs in the organizations policies.

In this study, the safety programs impact on the organizational productivity was reviewed by using the safety indices and accidents and productivity.

MATERIALS AND METHODS

Algorithm of performance phases in this study is shown in Fig 1. Accordingly, we have started to assess original food industry which has OHSAS-18001 safety and health system in the first step. In the second step, the important indices of the safety and the productivity in relation to the food industry were defined. In the third step, the indices were measured based on the collected information in the assessed industries in five years during 2006 to 2010.

This study was descriptive-analytic one which reviewed past literature. The hypotheses which had examined in this study were as follows:

H_1: Safety programs implementation have positive impact on the workforce productivity.

H_2: Safety programs implementation have positive impact on the production quality.

H_3: Safety programs implementation have positive impact on the losses decline.

Table 1. Research questionnaire

Age:	Type of job: Worker □	Company name:
Years of services:	Manager □	Section name:

No.	Question	Yes	No
1	Do you know the IMS system?		
2	Is Environmental management system, one of the elements of IMS?		
3	Does the IMS focus on safety management system?		
4	Does the safety program caused to change your safety behavior?		
5	Did you use PPE in work place?		
6	Is PPE obligated in your work place?		
7	Do you agree with it?		
8	Have you had any work accident during 2005 to 2010?		
9	Do you agree with safety program?		
10	Is safety required in your work place?		
11	Has the safety program effect on your performance?		
12	Has the safety program effect on quantity?		
13	Has the safety program effect on quality?		
14	Has the safety program decreased workers complaint?		
15	Has the safety program effect on production cessation?		
16	Has the safety program effect on your injury?		
17	Have all of the workplace hazard identified?		
18	Have all of the workplace hazard controlled?		

H_4: Safety programs implementation have positive impact on personnel's complaints decrease.

H_5: Safety programs implementation have positive impact on the personnel's absence decrease.

H_6: Safety programs implementation have positive impact on the production results.

Questionnaire and checklist was used to collect information (Table 1).

The obtained information was ranked based on two time periods before and after the implementation of OHSAS-18001 system. Based on the obtained information, the safety indices and accidents were defined. Then, by using the production statistics and production losses, the productivity indices were defined and then were measured. We have used median statistics and standard deviation to present the results.

Correlation coefficient statistics have been used to specify the relation scale between accidents and safety and productivity indices of the organization. Then, *t*-test was used to analyze significance of the indices increase and decrease during 2006-2010. All the active food industries settled in Ilam are five companies in which the safety and health management system in this industry in 2008 have been implemented based on governmental centers emphasis. All the companies which have this system license and risk evaluation program license (HACCP) based on ISO-22000 standard and quality standards (ISO-9001) and environment (ISO-14001) have acted to increase successfulness level of the safety programs and risk evaluation programs implementation for declining the accidents in this year. The workers number in each company and demographics of the companies under study is showed in Table 2.

Table 2. Demographic of the companies under study

Company No.	Number of workers	Age average	Workers years of service Average	Marriage percentage	Unlettered percentage	Number of samples
1	120	29.0	12.3	96.0	6.5	45
2	98	28.0	11.1	95.0	5.4	38
3	115	27.7	9.8	94.5	8.1	56
4	270	26.1	7.5	94.4	7.3	86
5	165	25.3	6.7	93.7	5.8	78

Table 3. Demographic of the respondents

Company No.	Number of respondents	Age average	Workers years of service average	Job		Percent of respondents experienced accidents during 2005 to 2010
				Workers (%)	Managers (%)	
1	45	30.5	13.2	91.9	8.1	15.5
2	38	30.0	14.5	86.8	13.2	21.5
3	56	26.8	8.5	85.7	14.3	10.7
4	86	28.6	8.6	90.7	9.3	10.4
5	48	27.0	6.8	83.3	16.7	25.0

The identifications of people, who have filled the questionnaire, have been shown separately in Table 3. In sum, 303 individuals have been participated in this research. In order to determine the affectability and measure the safety system effect on the production and productivity, indices were defined by which can observe the safety system affectability and operation.

Productivity indices during the years 2006 to 2010 based on the programs and existing statistics in accounting and financial department and organization production and the safety indices during the years 2006 to 2010 based on the programs and existed statistics in the safety and health departments of the studied organizations have been assessed. In this relation a series of evaluations and assessments in a periodic manner were done by auditor of this standards and health safety attendants. They have been applied as one of the informational resources. All of effective variable on productivity in these companies (e.g.; salary, technology, budget, construction and number of employee) was not significantly changed (p<0.05). All of effective variable on productivity is shown in Table 4.

Definition of studied indices

Productivity indices (PI_1)
Production capitation index (PCI)

$$PCI = \frac{P_L}{N_P} \qquad (1)$$

P_L: production limpid (kg/1000)
N_P: number of full time employer

Human productivity index (HPI):

$$HPI = \frac{P_L}{H_P} \qquad (2)$$

P_L: production limpid (kg/1000)
H_P: hour total of personnel's work

Production rate index (PRI):

$$PRI = \frac{I}{O} \times 100 \qquad (3)$$

I = rate of product (kg/1000)
O = rate of raw material (kg/1000)

*The cost of production (CP)**

$$CP = \frac{I}{C} \qquad (4)$$

CP = cost of production
I = rate of product per day (kg/1000×day)
C = average of cost of product (dollars/day)
*- Supposing that the price of raw material and the cost of machine maintenance has been stable during the years 2006-2010.

Wastage rate index (WRI)

$$WRI = \frac{W_R}{P_L} \qquad (5)$$

W_R: wastage rate (kg/1000)
P_L: production limped (kg/1000)

Workers' complaints index (WCI):

$$WCI = \frac{N_C}{N_{FW}} \qquad (6)$$

N_C: number of personnel complaint per year
N_{FW}: number of full time employer

Table 4. The result of effective variable on production

No.	Variable	2006	2007	2008	2009	2010
1	Average of salary (million Rails)	540	590	620	690	720
2	Average of budget (million Rails)	1200	1210	1300	1350	1395
3	Average of Number of employee	154	154	156	160	160
4	Type of technology	Semi Automatic	Semi Automatic	Semi Automatic	Semi Automatic	Semi Automatic
5	Construction/ environmental	No change	No change	No change	No change	No change
6	Number of engine and tools	No change	No change	No change	No change	No change

Table 5. The indices which have been defined in this research

	Index	Name	Definition
Productivity indices	PCI	Production capitation index	Total production per year
	HPI	Human productivity index	The ratio of production limpid in relation to total personal work hours
	PRI	Production rate index	The ratio production rate in relation to raw material
	CP	Production cost	The ratio of product in relation to cost average of product unit
	WRI	Wastage rate index	The ratio of product in relation to production limped
	WCI	Workers' complaints index	The ratio of personnel complaint numbers in relation to the number of full time employer
	WAI	Workers absence index	The number of absence days ratio in relation to number of full time employer
Safety indices	STI	Personnel safety training index	The ratio of safety training hours in relation to trained personnel numbers
	PPEI	Personal protection equipment index	The ratio of personal protection equipment cost in relation to personnel numbers
	IFR	Injury frequency rate	Number of accidents in 200000 hours of work per year
	ISR	Injury severely rate	Lost days rates in 200000 hours of work per year
	AC	Accident cost	The cost of accidents per year
	FSI	Accident frequency-severity index	ISR and IFR was combined by this index
	TLIOF	Job lost time accidents and illness frequency coefficient	The frequency rate of job lost time due to accident or illness

Workers absence index (WAI):

$$WAI = \frac{D_A}{PN} \qquad (7)$$

D_A: number of days of absence
PN: number of full time employer

Safety indices (SI):

Personnel safety training index (STI)

$$STI = \frac{ES}{T_{EN}} \qquad (8)$$

ES = safety training hour per year
T_{EN} = trained personnel numbers

Personal protection equipment index (PPEI):

$$PPEI = \frac{PPEC}{EN} \qquad (9)$$

PPEC = personal protection equipment cost per year
EN = personnel numbers

Injury frequency rate (IFR):

$$IFR = \frac{AF \times 200000}{Eh} \qquad (10)$$

AF = accidents numbers
Eh = personnel individual per hour work numbers (N×40×50)

N: number of employer

Injury severely rate (ISR):

$$ISR = \frac{As \times 200000}{Eh} \qquad (11)$$

AS = lost days numbers
Eh = personnel individual per hour work numbers (N×40×50)

Accident cost (AC):

The cost of accident per year is "Accident Cost Index". This index was measured by calculated of the cost which recorded in accounting system.

Accident frequency-severity index (FSI):

$$FSI = \sqrt{\frac{ISR \times IFR}{1000}} \qquad (12)$$

IFR = injury frequency rate
ISR = injury severity rate

Time lost of job accidents and illness frequency coefficient (TLOIF):

$$TLOIF = \frac{Dt}{200000} \qquad (13)$$

Dt = total time lost of accidents and job illness
All of the indices were defined in Table 5.

RESULTS

The questionnaire results showed that the safety programs had been effective in four under studied companies. The personnel have satisfied of these programs. However, one of the individual of these companies has complained of the safety program. The

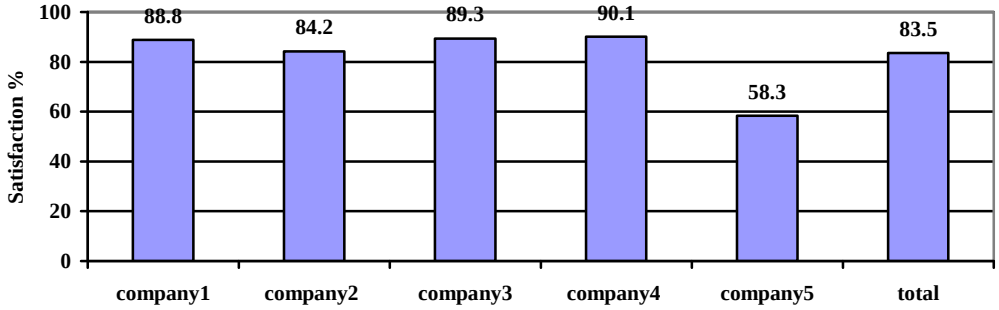

Fig 2. Personnel satisfaction percentage of the safety programs in under-studied companies

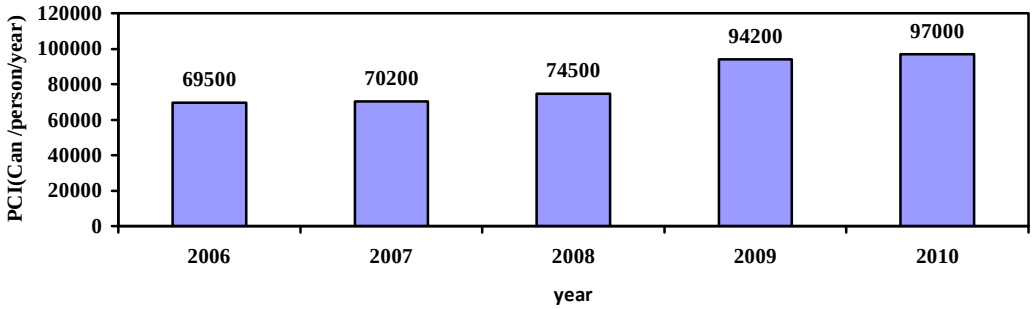

Fig 3. Yearly production capitation rate average during 2006-2010

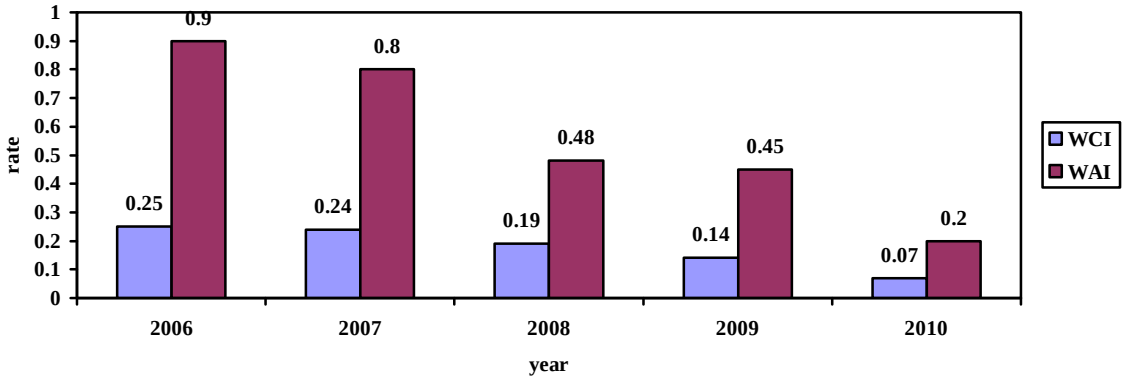

Fig 4. The related indices to human force performance during 2006-2010

survey showed that the 5th company personnel have participated in the safety program for horror. They had not believed them. However, personnel of other companies consider the program as a part of their work. As Fig 2, personnel agreement percentage in the 5th company compared to the other companies is lower.

As Fig 2 shows, in all under-studied companies, 83.5% of the personnel have had positive responses regarding the effectiveness of the safety system implementation.

Five years information in relation to the safety indices based on the statistics of safety and industry health department documents and files and five years information in relation to the productivity based on the statistics of production and safety department documents and files were studied and then were analyzed after admeasuring and averaging understudied industries indices. Fig 3 was showed the obtained results of indices study related to the production. As can be seen from Fig 3, production capitation index rate during three years after implementation of OHSAS-18001 system have raised. Regarding to unchanged individuals' structure, machineries and materials, these changes have been attributed to the implemented safety and health. The greatest change rate is one year after the implementation in 2009. This case identifies the effect of the safety and health systems on the production. The statistics results showed that there was a significance

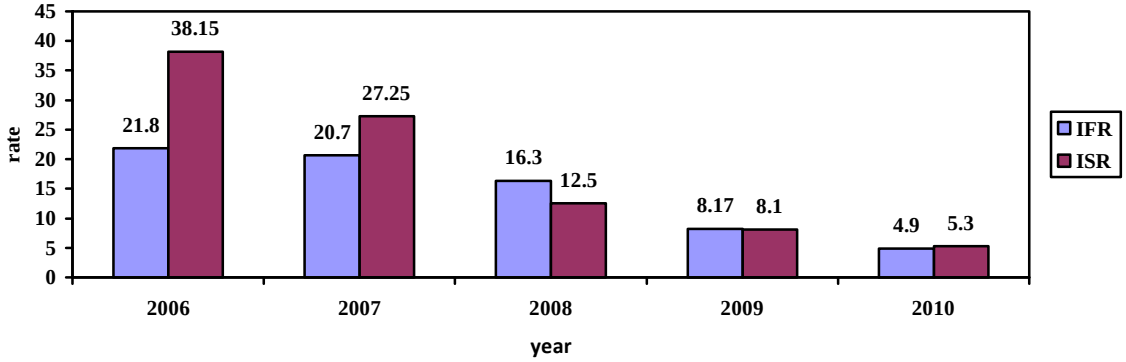

Fig 5. The changes of related indices to the accidents during 2006-2010

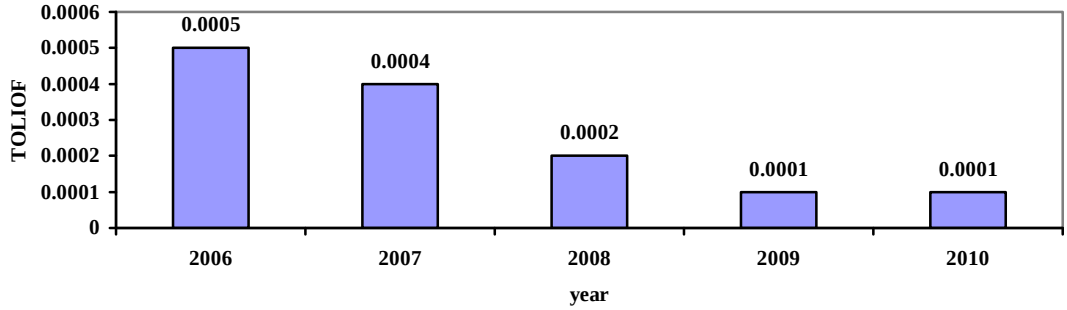

Fig 6. TOLIOF index changes during 2006-2010

difference between average production in the years before the implementation of OHSAS-18001 system and after it.

Moreover, related index to product fault and second degree production in 2009 with implementing OHSAS 18001 system, show more relative index. This procedure continues to the year 2010. The results of this section showed that the rate of PRI in were 44.8, 45.2, 45.7, 47.4 and 47.6 during the years 2006 to 1010. The statistics results showed that there was a significance difference between production degree rate in the years before the implementation of OHSAS-18001 system and after it (p<0.05).

The result of the Production Wastage showed that the WRI index rate were 0.06, 0.055, 0.03, 0.03 and 0.02 during the years 2006 to 2010. The statistics results showed that there was a significance difference between production degree rate in the years before the implementation of OHSAS-18001 system and after it (p<0.05). The related indices to the performance of human force and job satisfaction have been shown in Fig 4. In this regard, two indices WAI and WCI were defined. As can be seen from the figure, absence procedure and the complaints of the organization in 2008 which is the year of implementing OHSAS-18001 system have had relative decline. It can be attributed to OHSAS-18001 system for non existence of change in companies' organizational structure. Regarding OHSAS-18001 system structure which was concentrated on human force, so it was expected that the effect of this system on the indices related to human force performance is greater than the related indices to production. This case was presented in Fig 4 so these changes were established in 2008 in which the safety and health system implemented.

The results was showed that the cost of production in deferent years were deference. This index was decreased during the years 2006-2010. The results of the production rate cost were 2000, 2050, 1980, 1920 and 1892 kg/1000 during the years 2006 to 2010. In this section of study, the result was showed that there is not a significant difference between the costs of production in the years before the implementation of OHSAS-18001 system and after it (p>0.05).

The result of this study section is showed in Fig 5. This result showed that the safety system has not affected directly on Production rate cost. Related statistics to the safety indices show that accidents statistics in under-studied industries during the years 2006-2010 have had descending trend. Because the effect of the safety systems usually show themselves in medium-term periods; there was an expectation that accidents numbers and its indices have been showed one year after the implementation of these systems. The results of related indices assessment to the accidents have been shown in Fig 5. The statistics results showed that there was a significance difference between the

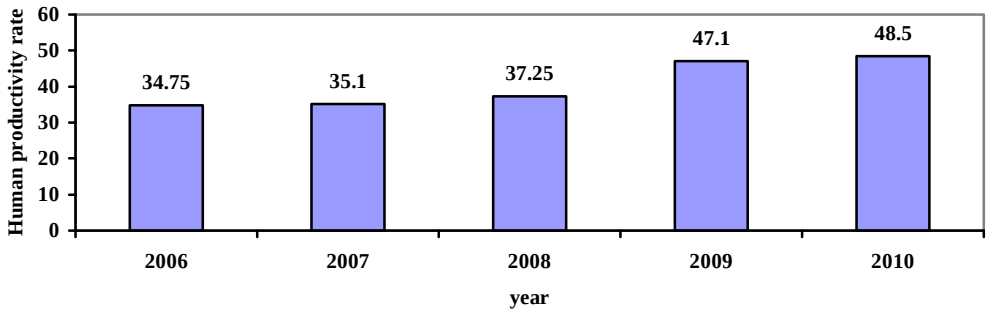

Fig 7. Human productivity index average during 2006-2010

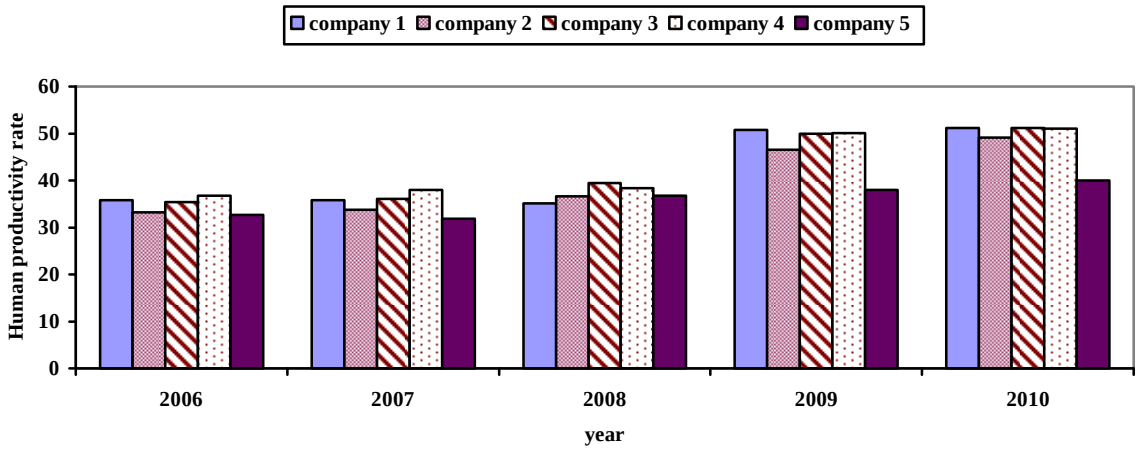

Fig 8. Human productivity index in under-studied industries during the years 2006-2010

accidents indices in the years before the implementation of OHSAS-18001 system and after it (p<0.05).

FSI index was defined to compare the safety performance which its results were 0.82, 0.67, 0.43, 0.1and 0.04 during 2006 to 2010. As can be seen from this result, FSI index has been declined after the implementation of the safety and health management system and it identifies positive impact of the system on the accidents. The statistics results showed that there was a significance difference between the average production in the years before the implementation of OHSAS-18001 system and after it (p<0.05). TOLIOF index was one of the other related indices to the organization safety performance which the results of it have been presented in Fig 6.

The statistics results showed that there was a significance difference between the rate of TOLIOF in the years before the implementation of OHSAS-18001 system and after it (p<0.05).

The cost of accident in under studied industries was decreased during the years 2006-2010. The result showed that the cost of accident average was 10 thousand Dollars in 2006 but this rate was 7.2 thousand dollars in 2010. One of the impacts of OHSAS-18001 system was management attitude change about the safety issues. The rates of PPEI were 14.2, 15, 18.3, 22.25 between years 2006 and 2010 and 30 thousand dollars per year. The statistics results showed that there was a significance difference between PPEI index in the years before the implementation of OHSAS-18001 system and after it (p<0.05). Person per hour index and safety training were defined and its results have been showed that the person per hours was increased between 2006 and 2010. As the rates of this index were 4, 4, 6, and 9 in 2006 to 2010 and 12 hours per person per year. Because training has cultural origin in the management, this case increases by the system performance and management development. The statistics results showed that there was a significance difference between STI index in the years before the implementation of OHSAS-18001 system and after it (p<0.05).

Finally and regarding the obtained results, human productivity index was measured. As we can see from Fig 7, HPI index had been faced with an ascending trend during the years after the implementation of OHSAS-18001 system. It was expected that this trend continues with less proportion during coming years. The greatest growth was in 2009. The statistics results showed that there was a significance difference between PHI index in the years before the implementation of OHSAS-18001 system and after it (p<0.05).

The HPI index calculation results of each under-studied industry have been represented separately in Fig

Table 6. Correlations between different outcomes

Safety \ Productivity	PCI	PHI	PRI	WRI	WCI	WAI
EI	0.991**	0.990**	-0.970**	-0.995**	-0.981**	-0.952*
STI	0.998**	0.975**	-0.984**	-0.986**	-0.998**	-0.912*
RAI	0.992**	0.966**	-0.974**	-0.972**	-0.999**	-0.898*
PPEI	0.998**	0.982**	-0.980**	-0.996**	-0.988**	-0.932*
FRI	-0.998**	-0.963**	0.981**	0.980**	0.998**	0.891*
SRI	-0.997**	-0.972**	0.987**	0.983**	0.998**	0.905*
FSRI	-0.865	-0.935*	0.899*	0.930*	0.831	0.959**
TLOIF	-0.941*	-0.926*	0.969**	0.956*	0.921*	0.873

**Correlation is significant at the 0.01 level ($p< 0.01$).

*Correlation is significant at the 0.05 level ($p< 0.05$).

8. As can be seen from Fig 8, the safety effect was not the same in all the industries. And a meaningful positive effect was not observed in some of them. The industry situation evaluation showed that management responsibility in relation to risk decrease and control and investment on the safety training and individual protection equipments have the lowest rate in these companies. Analysis results presented that there was not a significant difference between PPEI and STI indices in these five companies ($p>0.05$).

The obtained results of statistics analysis between the safety and productivity and production indices presented that correlation coefficient between the safety indices and the productivity indices with regard to collected data, have been represented in Table 6.

It was observed that there was a direct relationship between the safety indices development and optimization including the assessments, personnel safety training, controlled risk evaluation and personal protection equipment usage rate with developing and optimizing the workforce productivity and production capitation indices. There was a reversed relationship between these indices with personnel's complaints indices, wastages rate and production exploitation. Moreover, there was a reversed relationship between the accidents indices and workforce productivity and production capitation indices. Having decline the accidents, human force productivity and production capitation increase. The accidents indices had direct relationship with other productivity indices like wastages rate, personnel's absence rate, personnel's complaint and product exploitation. That was, the more these indices, wastages rate indices, personnel absence, personnel complaint and product exploitation will become greater and vice versa.

DISCUSSION

The results showed that there was a significance relationship between productivity rate and safety indices so that the more precise implementation the greater productivity become. Shikdar and Sawaqed studied health and safety program impacts on job satisfaction and diseases. The findings presented those weak ergonomic factors at work environment cause to increase personnel's' complaints and absence and to decrease the productivity [8]. Folkard and Tucker investigated the accidents and the risks of night shift and its effects on the productivity [7].

The results were negative effect of the working shift on the productivity. Safety program was affected on shift working and the last on productivity. They suggested the correct implementation of the safety programs and activity in standards framework to minimize the working shift driven effects [7]. One of the effects of safety program was quality and quantity increasing. Oxenburgh and Marlow studied invisible profits of the safety program and job health and the effects of these programs on financial processes and production quality and quantity. The results of this study contributed to the positive effects of the safety programs on the financial processes and the production quality and quantity [10]. Other effects of safety program that showed in this study, was a decrease in cost of production (e.g. wastage rate and material waste).

Also, Shikdar and Sawaqed claimed that the safety and health issues could be effect on product and productivity. A significant correlation ($p<0.01$) was found among productivity indicators and health and organizational attributes. Lack of skills in ergonomics and training, communication and resources were some of the factors contributing to the poor ergonomic conditions and consequent loss of worker productivity and reduced health and safety in these industries [8]. This result was the same as the result of the research. In an study which was done by Beatriz (2009) about the safety management system effect on competitive performance and industries financial and economical performance, the safety management system positive impact on company economical and financial performance optimization and the safety programs competitive priority have been presented. It is also specified that not only safety programs cause to decline job accidents but also could affect on the personnel's attitude and their job satisfaction. These accidents create by accident decline and safety culture [16].

In a study, the government roles in optimization of the industry safety program were identified as regulatory and rules compilation. It expressed the safety position in optimal usage of the material resources and human forces in a scientific manner, increasing personnel's life quality, production costs decline, production quality increase, on time repairing and

maintenance and value creation for clients. It explained that the main part of machineries' halting is because of the accidents, breakdowns outbreak and their technical defect [17].

The economical costs assessment was resulted by job accidents and its impact on the worker's life quality and the bearing costs by employers concluded that job accidents have negative effects on working life quality and employers' costs increase. As it showed, there are many accidents in the organizations which impress organizations with direct and indirect costs [1, 2].

So, there was a direct relationship between safety rules respect and work condition optimization which arouse productivity development in the organizations. We specify the safety programs as one of the main factors in declining the accidents and its role in productivity indices. The results of this study were positive and successful impact of the safety programs on the accidents decline, personnel absence and complaint decline and this in turn affects on the productivity indices optimization like the production capitation, human forces productivity, wastages rate, accidents severely and frequently index and product exploitation.

The results showed that the safety system existence cannot ensure productivity increase. Indices definition could be helpful for the safety system effectiveness and system continuous performance optimization. It is important to say that there might be different indices definition in different industries. It is essential to investigate these cases in different industries.

CONCLUSION

Regarding the obtained results and to increase efficiency of the safety and quality and health management systems, following recommendations are presented:

1. We can monitor productivity optimization and control its changes by defining suitable performance indices in the safety and quality management systems.

2. The safety performance indices create an appropriate tool for management to control the safety unit performance and the role of safety in safety performance and productivity of servicing and manufacturing units' supervisors.

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REFERENCES

1. Boden L, Galizzi M. Economic consequences of workplace injuries and illnesses: lost earnings and benefit adequacy. *Am J Ind Med* 1999; 36(5): 487-503.
2. Brody B, Létourneau Y, Poirier A. An indirect cost theory of work accident prevention. *J Occup Accid.* 1990; 13: 256.
3. Leigh JP. The Costs of Injury to Victoria. Report no. 124, Monash University Accident Research Centre, 1997; pp 1-30.
4. Andreoni D. *The Cost of Occupational Accidents and Diseases*. ILO, Geneva, 1986; pp 223 -231.
5. Larsson TJ, Betts N. The Variation of Occupational Injury Cost in Australia: Estimates Based on a Small Empirical Study. *Saf Sci* 1996; 24: 143-155.
6. Dembe A. The social consequences of occupational injuries and illnesses. *Am J Ind Med* 2001; 40(4): 403–417.
7. Folkard S, Tucker P. Shift work, safety and productivity. *Occup Med* 2003; 53: 95-101.
8. Shikdar A, Sawaqed NM. Worker productivity and occupational health and safety issues in selected industries. *Comput Ind Eng* 2003; 45: 563-572.
9. Cowing MM, Pate-Cornell E, Glynn PW. Dynamic modeling of the tradeoff between productivity and safety in critical engineering systems. *Reliab Eng Syst Saf* 2004; 86: 269- 284.
10. Oxenburgh M, Marlow P. The Productivity Assessment Tool: Computer-based cost benefit analysis model for the economic assessment of occupational health and safety interventions in the workplace. *J Saf Res* 2005; 36: 209 – 214.
11. Rosekind MR. Underestimating the societal costs of impaired alertness: safety, health and productivity risks. Sleep medicine 6 suppl 2005; 1: 21-25.
12. Loomes G. How can we value health, safety and the environment? *J Econ Psychol* 2006; 27: 713 – 736.
13. Olson DL, Wu D. Review of Innovative CSR: From Risk Management to Value Creation. *J Cleaner Prod* 2010; 18(16): 1767-1768.
14. Hola B. General model of accident rate growth in the construction industry. *J Civ Eng Manage* 2007; 13(4): 255-264.
15. Wilpert B. Regulatory styles and their consequences for safety. *Saf Sci* 2008; 46: 371- 375.
16. Beatriz F, Jose montes P, Camilo J. Relation between occupation safety management and firm performance. *Saf Sci* 2009; 47: 980-991.
17. Shi X. Have government regulations improved workplace safety? A test of the asynchronous regulatory effects in china coal industry, 1995- 2006. *J Saf Res* 2009; 40(3): 207-213.
18. Shalini RT. Economic cost of occupational accidents: Evidence from a small island economy. *Saf Sci* 2009; 47: 973-979.
19. Ko MG, Kim KD. General relation between safety indices and structural stiffness of a fiexible barrier system. KSCE. *J Civ Eng* 2009; 13(5): 339-345.
20. Wu D, Olson DL. Introduction to special section on "Risk and Technology". *Technol Forecasting and Social Change* 2010; 77(6): 837-839.
21. Zhao J, Zhu N, Lu S. Productivity model in hot and humid environment based on heat tolerance time analysis. *Build Environ* 2009; 44: 2202-2207.