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ORIGINAL ARTICLE

Development and Validation of a Model for HSE Management Performance Assessment Based on the Resilience Engineering Approach (A Case Study in a Car Manufacturing Company)

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ABSTRACT

The performance evaluation of HSE based on updated analytical models such as Resilience Engineering particularly in automotive industries is crucial. This research aims to develop the evaluation of the HSE management performance model and incorporate Resilience Engineering principles with the emphasis on a futuristic approach rather than a retrospective one, as well as focusing on strengths issues instead of weaknesses in an organization. This study, as a cross-sectional analysis, carried out in an automotive industry. Four Resilience components were chosen based on the Hollnagel theory as the RE contribution factors. Then, using an expert panel, the main and sub-indices of environmental health safety indices were evaluated and validated via CVI and CVR method. In the consecutive step, the validated indices were made in the format of the questionnaire and finally compiled through the analytical results of the mentioned questionnaire. According to the resilience engineering factors weight were determined that the highest impact for the safety component and the least effect on the monitoring component. In the case of health, experience has the highest impact where prediction comes with the least impact; in the environmental dimension, prediction has the highest impact and monitoring has the least effect relevant to the explanation of the structures. Overall, for HSE performance management, forecasting and monitoring in the aspect of environmental dimension have the highest effect (0/18) and the lowest effect (0/07). In the current study, the performance of HSE management in three dimensions of safety, health and environment as well as four factors including forecasting, response, experience acquisition and monitoring that are derived from data-driven theory research approach is studied in the automotive industry. Based on the analysis results, health (0/40), safety (0/37) and the environment (0/33) have the highest impact in the formation of HSE performance management, respectively. On the other hand, these dimensions cover almost all aspects of HSE (R=1) in its measurement.

KEYWORDS: *Performance Evaluation, Resilience Engineering, Safety, Health, Environment, HSE, Automotive Industry*

INTRODUCTION

The development of new materials and technology, albeit increasing welfare, puts new risks ahead of mankind due to the increase in complexity, especially in process systems, which requires a sense of social public responsibility in implementing safety, health and environmental programs to protect human lives, the environment and national capitals.

The term Resilience implies flexibility and elasticity while having an inherent ability to deal with unexpected challenges and a flexible capability to adapt to these challenges [1]. Hence, in HSE Management System, resilience can be defined as the intrinsic ability of a system to adjust its performance, so that it can operate and keep its function in the anticipated and unpredictable conditions. [2-3].

The previous classical models relating to safety and health were based on the Newton - Cartesian assumptions on the basis of the causal relationships and their interaction, the symmetry between the past and the future and the Time-reversibility, linearity, degradability and resistance [5]. Unlike Newton - Cartesian machine, nowadays, systems are mostly dynamic, self-organised and resilient. In resilient systems, Newton - Cartesian models are incapable of investigating phenomena but relying on Holistic methods.

These expectations can be observed in the attitude proposed by Hollnagel et al. Based on his attitude, called Resilience Engineering, a new vision has been evolved connected to accidents and risk management. While risk management views were mostly retrospective and emphasized on the calculation of the probability of error and finding fault causes, Resilience Engineering is trying to pursue the ways to strengthen the organization through the creation of processes that are steady and yet flexible, able to monitor and review the risk models and take advantage of the organization's resources in the face of adverse events and economic pressures [6].

In Resilience Engineering, system safety assurance is not only based on intensive performance monitoring, regarding errors, or reducing violation of standards, but also on both positive and negative functions [3]. Resilience Engineering is a proactive attitude aimed at eliminating the existed constraints in the system.

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Besides, Resilience Engineering is a safety-oriented model of focusing on helping people that creates foresight spirit and forecasting different types of risk to overcome complications in conditions under pressure and attain successful paths. In RE, success and failure are seen as a similar phenomenon.

Woods was among the researchers who conducted a series of studies related to Resilience Engineering. The factors like the buffer capacity, proximity to the threatening boundaries of the system, tolerances, and interactions between system variables as the contributing factors are recommended by Woods.

According to the above subject, it is clear that resilience is the outcome of many process features, including technical aspects, organizational and managerial safety margins. Furthermore, in Woods's survey, five factors covering design, potential recognition, and responsive program in emergencies, human factor and safety management are known as the principal criteria in Resilience Engineering.

Woods has stated four applied concepts for Resilience Engineering: 1- reaction against the impact and return to the equilibrium state 2- resistance against the imported pressures 3- resilience against the fragility/brittleness 4- grid architecture capable of involving with unpredictable events. HSE management systems need to be proactive and reactive. In HSE management systems, risk changes are considered as a threat that is vital to be controlled [17].

Restricting those changes may result in a disruption to the organization's ability to achieve good results. The best method to deal with performance changes is to strengthen the positive outcome and reduce changes with negative consequences. Based on the above-mentioned notes, Resilience Engineering is considered to be a new attitude and also a new horizon in HSE systems that can be used to develop HSE.

In recent years, several studies have identified Resilience Engineering as a strategic concept for improving complex systems such as aviation industries [13], process industries [14-15],

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atomic industries [16], petrochemical industries [17-18] and medical and health systems [19]. However, various studies have been investigated to quantify and measure resilience. Among them, surveys done by GRECCO et al. [20] are to be mentioned, which used resilience indicators for monitoring and preventive safety measures in the manufacturing process of medicinal radiological issues [20].

In this survey, only assessment components were expressed and a method for quantitative assessment was unavailable. In a research conducted by Lengnick et al. (2009), resilience has been identified as an organization's agility developer that enables it to continue survival and growth in adverse conditions. In their thought, the organization's compressive capacity is a multidimensional set of procedures, behaviors, capability and mental models that traces dominant performance for the organization [9].

In another study conducted by Borekci et al. (2014) the influence of organizational culture and organizational resilience was examined on perilous sub-contractors' risk-taking versus safe contractors. In this study, data were collected quantitatively in two stages through the investigation of the documents. The findings indicated that the sub-contractors have a high performance orientation, avoided high uncertain orientation and high orientation existed in the non - risky category and sub-contractors comprising high structural trust, the organizational capability and process continuity are also categorized in the same group [10].

Also, in a study conducted by Kantur et al. (2012) a model presented the resilience engineering contribution factors. The model presented in this study is able to integrate and incorporate various factors in different studies aimed at strengthening organizational resilience. The main finding was so that if an organization is developed in resilience aspect while a negative disruption occurs in the organization routines, the resilient organization can improve its status through adjusting itself to the change and contribute to the restructuring of the damaged items [13].

Moran and the colleagues have also presented a model in which leadership and resilience are introduced as a tool to enhance the sustainability of the organization. In this study, resilience was defined as an effective and efficient adaptation to challenges, learning through issues to result in success for future situations and growth and progress. It has been stated that resilience has a complex process that consists of increasing awareness, adopting ownership, participation in education and action [15].

In another study done by Bernard et al., a model related to the organization's resilience response to events and threats has been designed. The findings of this study indicate that in risky and uncertain situations, promotion of the organization's resilience features may increase the organization's achievement against risk. Therefore, the resilient organizations are less vulnerable to facing accidents and environmental discontinuities [18].

In a survey by Bhamra, et al., a model has been presented which clarified a connection between the organization's capacity and the vulnerability of the organization. In this manner, vulnerability is a capacity to sustain the system structure while resilience refers to the improvement and reconstruction following the emergence of disturbances and turmoil. Vulnerability refers to the degree of vulnerability due to exposure to threats and disorders, and resilience is defined as a vulnerability sub-system that affects business performance in critical situations through enhancing the ability of vulnerability [12].

Francis and Bekera developed a mathematical model to quantify resilience in the emergency conditions where the variables had the capability of evaluation, recovery time, adsorption capacity, and adaptive capacity while it cannot determine the resilience of the whole system [21]. In the study conducted by Azadeh et al. (2005), a novel concept called integrated resilience engineering (IRE) was developed. It refers to the components such as redundancy, self- organizing, loss tolerance and teamwork which can be identified as the strengths of the research [22]

All the mentioned studies tried to define a known level of resilience in the organizations but not an integrated model for the three components of safety, health, and environment which has been existed so far. This study aims to present a comprehensive model in HSE in the automotive industry that can be used extensively with partial changes in other industries.

METHODS

The present study is derived from a cross-sectional analysis, which was carried out in the automotive industry in order to evaluate HSE based on the Resilience Engineering (RE) and prioritization of different processes concerning RE components. The studied population/society is the automotive industry (Figure 1). For data collection, field studies, interviews and questionnaires were used. In the first stage of the study, in order to evaluate HSE performance through the help of library studies and the use of specialized sites and relevant organizations as well as the brainstorm, 197 indices were listed as the primary or raw ones; then, 20 experts and specialist were selected as the panel team. Eventually, 55 indices were selected in HSE area and categorized into four classes namely monitoring, forecasting and experience gain as well as three groups including safety, hygiene and environment. In the second step, a model was evaluated using the structural equation and compiled least square approach modeling.

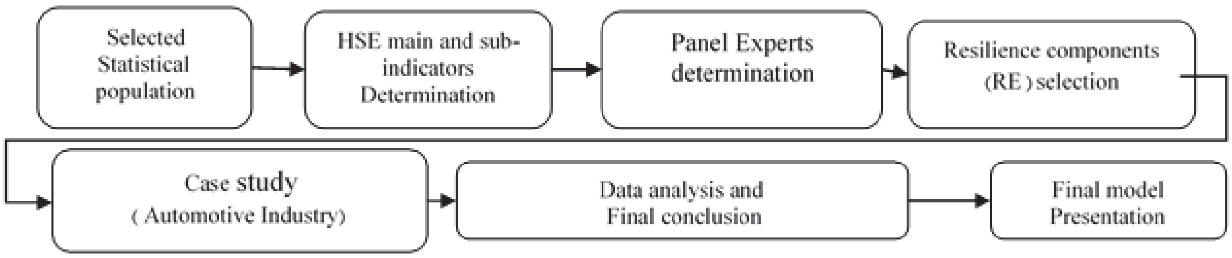

Fig 1. Research Method

First Stage

HSE indicators determination:

To determine HSE indicators in the view of Resilience Engineering, a library study has been conducted and related indices to resilience were extracted. Next, through brainstorming and HSE team specialists, some other indices were found and added to the indices obtained from the library study. The results of the library studies and brainstorming with respect to the opinion of the expert panel were reviewed and the effective factors in RE were determined.

Experts Panel Formation:

After determining HSE indicators in the second phase, the validation indicators were made to the selected indicators in the voice of the experts group. The panel of experts is formed including the ones who are experienced and skillful in HSE; furthermore, other expertise quotes who were not specialized in HSE field but have relation with HSE and environmental health issues were also considered to make it more comprehensive. There are extensive scientific levels and a wide range of experiments in which it may be classified into three groups including scientific and academic professors, scientific and experienced experts (work experience in the industry), and experts in management and engineering disciplines.

Moreover, to improve the scientific quality level of the panel, a wide range of experts with diverse opinions in the panel must be entered. In other words, the composition of the 20-member team of experts was composed of experts in HSE, human resource planning, production, and Pars Khodro production line (the specifications of the team of experts are shown in Figure 2). Three meetings were held with the presence of the expert team, in which the whole concept and objectives of the research in Resilience Engineering concepts, experts' opinions about the initial indicators were discussed.

In the following, according to the experts' opinions, some indices were excluded from the group of initial 197 ones and some others were integrated and the exact number of 55 indicators were chosen as the final indicators in the three areas of safety, health, and environment. The validity and reliability of the final indices were realized using CVI and CVR and Cronbach's alpha techniques and eventually, 48 indices were selected based on which the questionnaire was designed and distributed among the statistical population (Pars Khodro company) and the results were used in developing the HSE performance evaluation model.

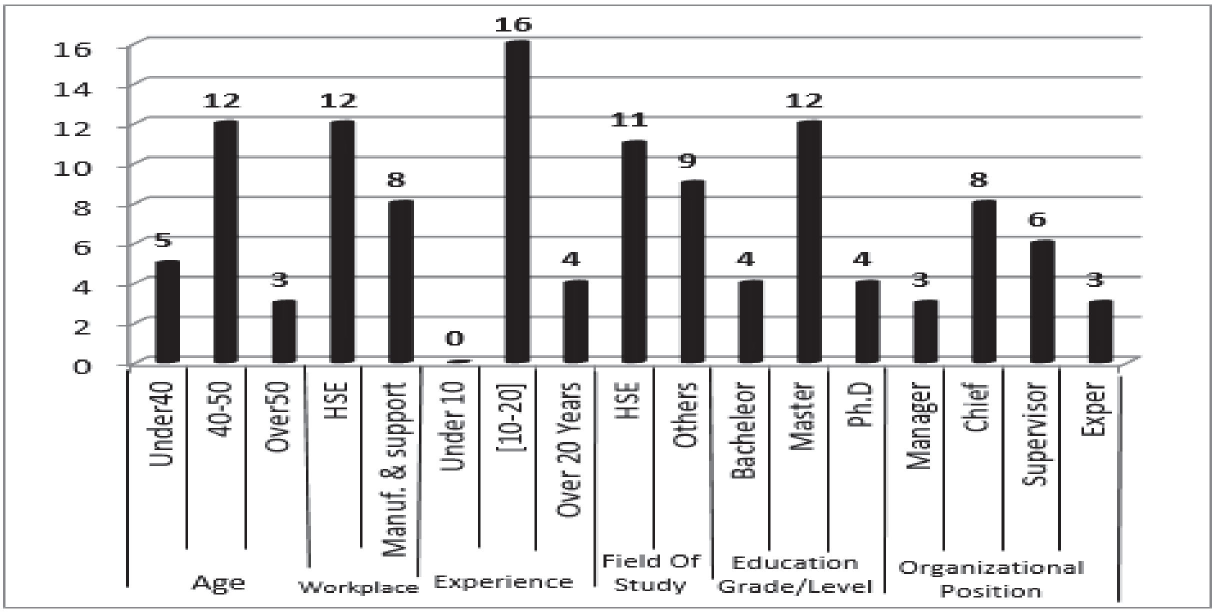

Fig 2. Number and demographic characteristics of members of the expert panel

Second Stage:

Having consolidated the HSE indices in three dimensions of safety, health and environment as well as four groups: forecasting components, response, experience acquisition and monitoring that are extracted data-driven by research method approach, the dimensions and extracted components were defined and evaluated through the modeling approach and partial least squares (PLS) approach to develop the optimal model.

The evaluation of the models is done using PLS in two stages:

*Reliability and validity of the measured model.

* Structural model assessment

At the beginning of our work, this process attempts to assess the measurement models. PLS estimation evaluates the validity and reliability of the measurements in terms of the criteria proposed of the model evaluates in the reflexive and developmental outer models. While sufficient evidence of validity and reliability of the scale - based models can be obtained, we can evaluate the structural model (intrinsic) [23].

Findings:

In this section, we initially evaluate the HSE indices measurement tools based on the Resilience Engineering. Thereafter their weight and significance through inferential statistics as follows were surveyed. Finally, by presenting the importance-performance matrix, some proposals were recommended for higher level of management in order to improve the current situation.

Validity:

To investigate and test the validity of the measurement instrument, the convergent and Discriminant validity index has been used.

Convergent validity:

The Average Variance Extracted (AVE) by Fornell and Larcker is proposed as an index for the convergent validity and internal credibility in the reflective measuring model. This index shows the correlation between a structure and its measured reagent. According to this criterion, the average variance extracted (AVE) must be at least 0.5.

Table 1: Convergent Validity (AVE)

Dimensions	Structure and measurement index	AVE
Safety	Reaction	0.63
	Monitoring	0.60
	Forecasting	0.65
	Experience	0.74
Health	Reaction 2	0.48
	Monitoring 2	0.60
	Forecasting 2	1.00
	Experience 2	0.55
Environment	Reaction 3	1.00
	Monitoring 3	0.65
	Forecasting 3	1.00
	Experience 3	1.00

Diagnostic or Discriminant Validity:

This validity is indeed complementary to the discriminant validity which indicates the differentiation of a latent construct with other indicators in the same structural model. In structural equation modeling with the PLS approach, there are two criteria to measure the diagnostic (discriminant) validity. One criterion is Fornell and Larcker cross – sectional and another one is the Transverse load test. According to Fornell and Larcker 's criterion, a latent structure-in comparison with other structures-should contain more dispersion among its agents so that it can be said that the structure has a high diagnostic validity (Fornell and Larcker,1981). In the transverse load test, the load value of each reagent should be greater than the load value on the other structures.

Table 2: Discriminant Validity

	Reaction	Reaction 2	Reaction 3	Monitoring	Monitoring 2	Monitoring 3	Forecasting	Forecasting 2	Forecasting 3	Experience	Experience 2	Experience 3
Reaction	۰.۷۹۴											
Reaction 2	۰.۵۹۷	۰.۶۹۳										
Reaction 3	-0.072	-0.198	۱									
Monitoring	۰.۴۵۷	۰.۵۶۱	-0.119	۰.۷۷۷								
Monitoring 2	۰.۵۱۱	۰.۶۸۲	-0.164	۰.۶۶۸	۰.۷۷۲							
Monitoring 3	۰.۱۴۳	-0.002	۰.۲۸۸	۰.۱۳۴	۰.۱۵	۰.۸۰۴						
Forecasting	۰.۲۷۲	۰.۲۱۷	۰.۰۷۷	۰.۲۵۴	۰.۳۳۷	۰.۵۲۹	۰.۸۰۷					
Forecasting 2	۰.۳۲۶	۰.۴۰۴	-0.058	۰.۴۱۴	۰.۴۷۵	-0.052	۰.۲۹۴	۱				
Forecasting 3	۰.۰۰۵	-0.06	۰.۲۱۱	۰.۱۴۳	۰.۰۳۱	۰.۷۴۹	۰.۳۶۲	-0.142	۱			
Experience	۰.۱۱۱	۰.۲۵۶	۰.۳۷	۰.۲۷۵	۰.۲۶۶	۰.۱۹	۰.۲۶۱	۰.۱۸۸	۰.۱۴۷	۰.۸۵۹		
Experience 2	۰.۳۹۸	۰.۶۳	-0.139	۰.۴۶۸	۰.۵۶۱	-0.014	۰.۱۴۴	۰.۳۵۳	-0.107	۰.۰۸۵	۰.۷۴	
Experience 3	۰.۳۵۶	۰.۵۹۸	-0.051	۰.۲۸۱	۰.۴۲۹	-0.013	۰.۱۷۷	۰.۴۰۲	-0.005	۰.۱۸۷	۰.۵۲۸	۱

Since the AVE square root value of each structure is higher than the correlation value between the structure which is located in the lower and right cells of the main diagonal, it can be claimed that the model structures have more interaction with their reagents rather than other structures. In other words, the measurement instrument is not overlapped for definition and explanation of the structures and thus the discriminant validity (diverges) of the model was approved. The transverse load test also confirms the convergent validity.

Reliability:

The reliability of the measurement tool was measured in two parts. One part is related to the reliability of each reflective indicator and its corresponding structure represented by factor load and the other is composite reliability (PC) which defines the internal correlation of the measuring tool. The appropriate reliability value for each indicator with its corresponding structure and composite reliability is a minimum of 0.7 [24].

Reagents Reliability:

Researchers believe that a latent variable must explain a considerable portion of the dispersion of any reagent (usually at least 60 %). Therefore, the absolute value of the correlation between a structure and each of the measured variables (i.e., the absolute value of the standardized output load) should be greater than (≈√۰/۵) ۰/۷. Table 1 shows the reliability of the reagents.

Table 3: Discriminant Validity- Factor Load

Dimension	Structure and measurement index	Factor Load
HEALTH	***Reaction***	---
	The number of participants / complainant referring due to illness or weakness is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۷۰
	The percentage of staff periodic examinations coverage is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۸۰
	The percentage of employees with job restrictions is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۸۷
	Monitoring	---
	The percentage of production employees with musculoskeletal problems is considered to be one of the resilience monitoring indicators.	۰/۷۷
	The general rate of absence due to work Illness and work-related accidents is considered to be one of the resilience monitoring indicators.	۰/۶۸
	The percentage of diagnosed work-related illnesses is considered to be one of the resilience monitoring indicators.	۰/۸۵
	Measuring the percentage of risks under the control of industrial health and ergonomics is considered to be one of the resilience monitoring indicators.	۰/۸۴
	The percentage of employees exposed to hazardous chemicals and carcinogens is considered to be one of the resilience monitoring indicators.	۰/۷۴
	The percentage of staff periodic examinations coverage is an influential index in monitoring resilience indicators.	۰/۷۷
	Forecasting	---
	The percentage of employees exposed to harmful factors in the workplace is an influential index in forecasting resilience indicators.	۰/۸۳
	The percentage of non-conformity in ergonomic checklists is an influential index in forecasting resilience indicators.	۰/۸۵
	The number of ergonomic risks at three levels: high, medium and low is an influential index in forecasting resilience indicators.	۰/۷۴
	Experience	---
	The percentage of people transfer having with illness / occupational disease is the cause for gaining Experience related to Resilience.	۰/۸۶
	The degree of ergonomic risks H and M reduction in production shops (ERP) is the cause for gaining Experience related to Resilience.	۰/۸۹
	The degree of industrial health risks reduction including H level is the cause for gaining experience related to Resilience.	۰/۸۳
SAFETY	***Reaction 2***	---
	The percentage of personnel encouraged in terms of safety to total personnel is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۷۰
	The percentage of safety committees meeting held per month is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۷۱
	The number of high safety committees held is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۶۲
	The percentage of work stoppage to the issued safety work permit is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۶۳
	The number of safety warnings issued to contractors is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۸۰
	The percentage of qualified contractors with safety license to Total contractors is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۷۱
	The percentage of compliance with environmental pollution laws is considered to be one of the influential indices on appropriate reaction and improve resilience.	۰/۶۶

ENVIRONMENT	***Monitoring 2***	---
	Accident indicator is considered to be one of the influential indices monitoring related to Resilience.	٠/٧٨
	The Percentage of compliance with rules and regulations is considered to be one of the influential indices monitoring related to Resilience.	٠/٧۵
	The Percentage of safety equipment usage is considered to be one of the influential indices monitoring related to Resilience.	٠/۶٩
	The Percentage of issue solved in safety committee to total items presented is considered to be one of the influential indices monitoring related to Resilience.	٠/٨۶
	Forecasting 2	---
	The number of high, medium and low safety risks affects the prediction resilience components.	---
	Experience 2	
	The number of stakeholders ‘complaints per year is the cause for gaining experience related to Resilience.	٠/٧٠
	The percentage of done/closed corrective action to total corrective action issued is the cause for gaining experience related to Resilience.	٠/٧٢
	The percentage of reporting pseudo-events to all personnel is the cause for gaining experience related to Resilience.	٠/٧٩
	The percentage of total pseudo-events to total events is the cause for gaining experience related to Resilience.	٠/٧٨
	The percentage of issues solved in safety committees to total items presented is the cause for gaining experience related to Resilience.	٠/۵٩
	The amount of budget dedicated to safety issues to the total budget of the company is the cause for gaining experience related to Resilience.	٠/٨۴
	Reaction 3	---
	Personnel Environmental training is considered to be one of the influential indices on appropriate reaction and improve resilience.	---
	Monitoring 3	---
	Amount of normal and industrial waste per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٨٣
	The amount of special waste per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٧٨
	The amount of energy consumption per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٨١
	Yearly CO2 emission per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٨٠
	The percentage of recycled waste is considered to be one of the influential indices monitoring related to Resilience.	٠/٨٣
	The amount of disposable tableware per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٧۵
	Yearly SO emission per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٧٧
	A4 paper consumption per production is considered to be one of the influential indices monitoring related to Resilience.	٠/٨۶
	Forecasting 3	---
	HSE Man-Hour training affects the prediction resilience components.	---
	Experience 3	
	The percentage of environmental accidents to total accidents is the cause for gaining experience related to Resilience.	---

According to the results of Table 1, the factor loading of each reagent for all structures of the research, except some reagents and monitoring in reaction 2, is more than the proposed bound (0 / 7). Considering these reagents, if the composite reliability and validity of their structure are more than the determined bound, they remain in the model. As shown in Tables (4-5) and (4-6), the composite reliability and convergent validity of the structure of reaction 2 and monitoring 2 are more than 0.7 and 0.5, respectively. Therefore, these reagents remain in the model.

Composite reliability:

This index does not computes the reliability of the structure in absolute value but relevant to their correlation. Composite reliability more than 0 / 70 indicates the one-dimensional block.

Table 4. Structures Composite reliability

Dimension	Structure and measurement index	CR
Safety	Reaction	۰/۸۴
	Monitoring	۰/۹۰
	Forecasting	۰/۸۵
	Experience	۰/۸۹
Health	Reaction 2	۰/۸۷
	Monitoring 2	۰/۸۵
	Forecasting 2	۱/۰۰
	Experience 2	۰/۸۸
Environment	Reaction 3	۱/۰۰
	Monitoring 3	۰/۹۴
	Forecasting 3	۱/۰۰
	Experience 3	۱/۰۰

According to Table 2, the composite validity coefficient of all structures in the research is greater than the proposed bound (0.7), so the reliability of the instrument size is confirmed.

The main components Evaluation:

In this study, to assess three components of safety, health and environment, the significance of their weight and the alignment test was used.

Table 5. Each dimension's weight in the formation of the corresponding structure

	HSE Performance Management	Safety	Health	Environment
Reaction		٠.٤٠٥		
Reaction	۰.۱۴۹			
Reaction1			۰.۳۴۵	
Reaction1	۰.۱۳۸			
Reaction2				۰.۲۴۱
Reaction2	۰.۰۸۰			
Monitoring		٠.٢١٤		
Monitoring	۰.۰۷۸			
Monitoring1			۰.۲۶۷	
Monitoring1	۰.۱۰۷			
Monitoring2				۰.۲۱۳
Monitoring2	۰.۰۷۰			
Forecasting		٠.٤٣٠		
Forecasting	۰.۱۵۸			
Forecasting1			۰.۲۱۸	
Forecasting1	۰.۰۸۷			
Forecasting2				۰.۵۵۱
Forecasting2	۰.۱۸۲			
Experience		٠.٢٩٧		
Experience	۰.۱۰۹			
Experience1			۰.۴۰۴	
Experience1	۰.۱۶۲			
Experience2				۰.۴۶۵
Experience2	۰.۱۵۴			

As seen in Table 5, in the safety aspect; forecasting, reaction, experience and monitoring weigh, 0/43, 0/21, 0/30, 0/40, respectively. So, in terms of the safety structure explanation, forecasting has the highest impact where monitoring is in the lowest level.

In the health aspect; forecasting, reaction, experience and monitoring weigh 0/27, 0/40, 0/34, 0/22, respectively, so experience gain has the highest impact where forecasting is in the lowest level in the health structure explanation.

In the environment aspect; forecasting, reaction, experience and monitoring weigh 0/47, 0/24, 0/21, 0/55, respectively, so forecasting has the highest impact where monitoring is in the lowest level in the environment structure explanation.

Overall, for HSE performance management, forecasting and monitoring relevant to the environment aspect has the highest impact (۰/۱۸)and lowest impact (۰/۰۷).

As seen in Table 6, the weights are positive and significant. Therefore, each reagent has its part in the transfer of meaning and the concept of Developmental structure.

Evaluating the Multiple alignment degree among developmental reagents, Variance Inflation Factor (VIF) or negligible difference could be used. Statistical analysis showed a multiple alignment critical level for VIF higher than 5 indicates. As shown in Table 7, the VIF amount is lower than the proposed bound [5]. Therefore, the validity of the Developmental measurement model is confirmed.

Table 6. Weights' Significance

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Safety < Reaction	۰.۴۰۵	۰.۴۱۰	۰.۰۶۹	۵.۸۵۰	۰.۰۰۰
HSE Performance Management < Reaction	۰.۱۴۹	۰.۱۵۰	۰.۰۲۷	۵.۵۴۱	۰.۰۰۰
Health < Reaction 1	۰.۳۴۵	۰.۳۵۰	۰.۱۰۱	۳.۴۲۱	۰.۰۰۱
HSE Performance Management < Reaction 1	۰.۱۳۸	۰.۱۳۹	۰.۰۴۰	۳.۴۷۷	۰.۰۰۱
Environment < Reaction 2	۰.۲۴۱	۰.۲۴۳	۰.۰۵۵	۴.۳۹۹	۰.۰۰۰
HSE Performance Management < Reaction 2	۰.۰۸۰	۰.۰۸۱	۰.۰۱۹	۴.۱۴۳	۰.۰۰۰
Safety < Monitoring	۰.۲۱۴	۰.۲۰۳	۰.۰۶۷	۳.۲۰۱	۰.۰۰۱
HSE Performance Management < Monitoring	۰.۰۷۸	۰.۰۷۴	۰.۰۲۵	۳.۱۱۹	۰.۰۰۲
Health < Monitoring 1	۰.۲۶۷	۰.۲۵۸	۰.۰۹۶	۲.۷۹۳	۰.۰۰۵
HSE Performance Management < Monitoring 1	۰.۱۰۷	۰.۱۰۳	۰.۰۳۹	۲.۷۷٤	۰.۰۰٦
Environment < Monitoring 2	۰.۲۱۳	۰.۲۰۹	۰.۰٥۳	۳.۹۹٦	۰.۰۰۰
HSE Performance Management < Monitoring 2	۰.۰۷۰	۰.۰٦۹	۰.۰۱۸	۳.۸٦۰	۰.۰۰۰
Safety < Forecasting	۰.٤۳۰	۰.٤۲۷	۰.۰۸۳	٥.۱۷۱	۰.۰۰۰
HSE Performance Management < Forecasting	۰.۱٥۸	۰.۱٥٦	۰.۰۳٤	٤.٦۷۷	۰.۰۰۰
Health < Forecasting 1	۰.۲۱۸	۰.۲۱۹	۰.۰۷٥	۲.۹۱٥	۰.۰۰٤
HSE Performance Management < Forecasting 1	۰.۰۸۷	۰.۰۸۷	۰.۰۲۹	۲.۹۸۰	۰.۰۰۳
Environment < Forecasting 2	۰.٥٥۱	۰.٥٥۲	۰.۰۹٦	٥.۷۳۷	۰.۰۰۰
HSE Performance Management < Forecasting 2	۰.۱۸۲	۰.۱۸۳	۰.۰۳٤	٥.۳٦۱	۰.۰۰۰
Safety < Experience	۰.۲۹۷	۰.۲۹۲	۰.۰۹۳	۳.۲۰۹	۰.۰۰۱
HSE Performance Management < Experience	۰.۱۰۹	۰.۱۰٦	۰.۰۳۳	۳.۲۸۹	۰.۰۰۱
Health < Experience 1	۰.٤۰٤	۰.۳۹٦	۰.۰۸۱	٥.۰۰۹	۰.۰۰۰
HSE Performance Management < Experience 1	۰.۱٦۲	۰.۱٥۷	۰.۰۳٤	٤.۷۲٤	۰.۰۰۰
Environment < Experience 2	۰.٤٦٥	۰.٤٦۱	۰.۰۹٥	٤.۸۷۱	۰.۰۰۰
HSE Performance Management < Experience 2	۰.۱٥٤	۰.۱٥۳	۰.۰۳۳	٤.٦۰۲	۰.۰۰۰

Table 7. Level 1 multiple alignment degree

	VIF
Reaction	۱.۲۸۱
Reaction1	۳.۲۰۲
Reaction2	۱.۰۶۸
Monitoring	۱.۲۴۸
Monitoring1	۱.۴۲۰
Monitoring2	۱.۰۹۱
Forecasting	۱.۶۱۸
Forecasting1	۲.۴۱۲
Forecasting2	۲.۳۱۷
Experience	۱.۷۸۲
Experience1	۱.۵۹۶
Experience2	۲.۲۷۴

Table 8. Level 2 multiple alignment degree

	HSE Performance Management
Safety	2.736
Health	2.498
Environment	3.319

Structural model evaluation

Path coefficient:

The structural path whose signal agrees with the prior algebraic symbol of assumptions; a partial empirical validity is implied about the relations between the latent variables to the theoretical assumptions. The paths whose algebraic notations are contrary to expectation will not support the assumptions that have already been formed. The path coefficients have been shown in Table 8.

The coefficients between the internal components and the HSE performance management structure represent the weight of each component.

Table 9. Path coefficient Model (Weight)

	HSE Performance Management
Safety	0.367
Health	0.401
Environment	0.331

According to the above tables, health component has more weight in explaining HSE performance management. On the other hand, the environment has a lower impact on HSE management performance.

Table 10. Path coefficient significance

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
HSE Performance Management < Safety	0.367	0.366	0.022	17.040	0.000
HSE Performance Management < Health	0.401	0.397	0.016	24.410	0.000
HSE Performance Management < Environment	0.331	0.332	0.022	15.007	0.000

Path coefficient significance:

As can be seen, the paths weights are meaningful, so the impact of these dimensions is confirmed in HSE performance management

The coefficient of determination:

The basic criterion for the evaluation of endogenous latent variables is the coefficient of determination (R^2). The values of R^2 were equal to 0.19, 0.33, 0.67 in PLS models which were considered to be significant, moderate and weak, respectively.

Table 11. The coefficient determination of model

	R Square	R Square Adjusted
HSE Performance Management	0.998	0.998

Considering that the coefficient for determining the performance of HSE performance management variable is approximately one; thus, safety, health and environment cover all its dimensions.

Examining the HSE performance management importance-performance matrix:

This matrix presents the importance and performance of each structure to explain the HSE performance management (see chart 2). The matrix makes a comparison between all indices' impact (Their importance), and indices' mean (performance) to determine the main crucial areas for improving the management activities. In particular, the results provide the possibility of identifying indicators with relatively high importance and low performance. Managers need to emphasize the structures that have high importance but in a weak performance.

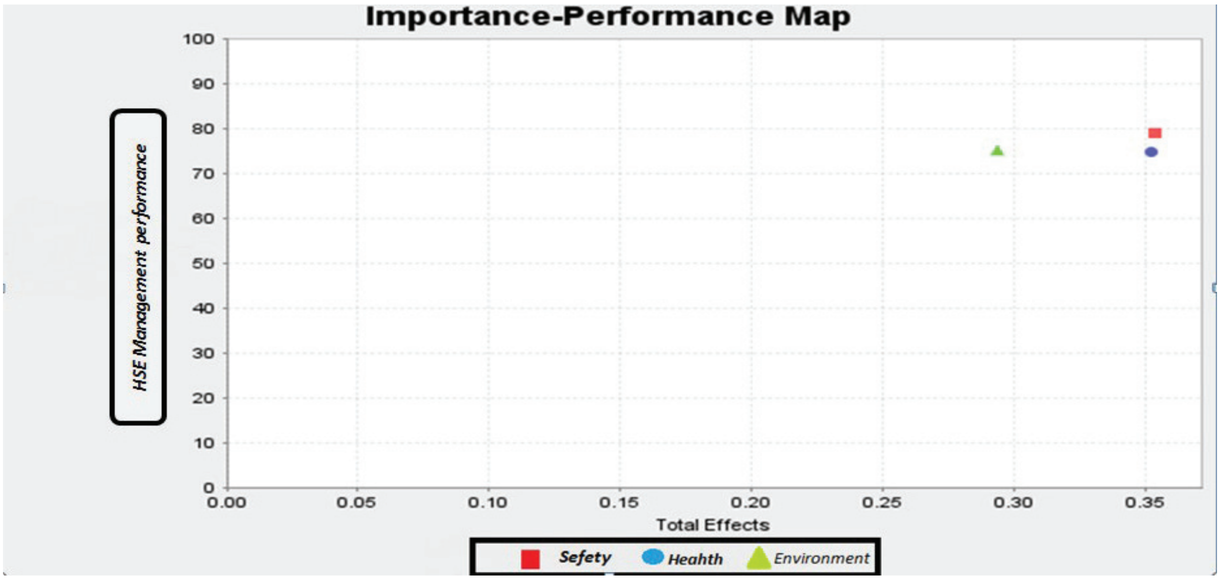

Fig 3. Importance-Performance Matrix in Structure level

With respect to the result of chart 2, safety and health are at a higher level of importance and the environment has lower importance. On the other hand, the performance of safety, health and environment is almost equal. Therefore, health, safety and environment should be consecutively at the center of attention. After reviewing HSE indices and resilience components by the experts' team, the results of the comparisons related to four main components were determined.

The weight and significance of each component of resilience have been presented in Table 12:

Table 12. Weight and significance of each resilience component

	Weight	T Statistics (|O/STDEV|)	Significance
Safety <- HSE Performance Management	۰.۳۶۷	۱۷.۰۴۰	۰.۰۰۰
Health <- HSE Performance Management	۰.۴۰۱	۲۴.۴۱۰	۰.۰۰۰
Environment <- HSE Performance Management	۰.۳۳۱	۱۵.۰۰۷	۰.۰۰۰
Reaction <- HSE Performance Management	۰.۱۴۹	۵.۵۴۱	۰.۰۰۰
Reaction 1 <- HSE Performance Management	۰.۱۳۸	۳.۴۷۷	۰.۰۰۱
Reaction 2 <-HSE Performance Management	۰.۰۸۰	۴.۱۴۳	۰.۰۰۰
Monitoring <- HSE Performance Management	۰.۰۷۸	۳.۱۱۹	۰.۰۰۲
Monitoring 1 <- HSE Performance Management	۰.۱۰۷	۲.۷۷۴	۰.۰۰۶
Monitoring 2 <- HSE Performance Management	۰.۰۷۰	۳.۸۶۰	۰.۰۰۰
Forecasting <- HSE Performance Management	۰.۱۵۸	۴.۶۷۷	۰.۰۰۰
Forecasting 1 <- HSE Performance Management	۰.۰۸۷	۲.۹۸۰	۰.۰۰۳
Forecasting 2 <- HSE Performance Management	۰.۱۸۲	۵.۳۶۱	۰.۰۰۰
Experience <- HSE Performance Management	۰.۱۰۹	۳.۲۸۹	۰.۰۰۱
Experience 1 <- HSE Performance Management	۰.۱۶۲	۴.۷۲۴	۰.۰۰۰
Experience 2 <- HSE Performance Management	۰.۱۵۴	۴.۶۰۲	۰.۰۰۰

Based on the results of the analysis, health (0.40), safety (0.37.5) and environment with (0.33) have the greatest impact in HSE performance management formation, respectively. On the other hand, these dimensions cover almost all aspects of HSE (R≈1) in its measurement. At lower levels of the model, in the safety aspect, prediction has the highest impact and monitoring has the lowest effect on the explanation of the safety structure. In the case of health, experience has the highest impact and prediction has the least effect on the explanation of health structure. In the environmental dimension, prediction has the highest effect and monitoring is at the lowest effect level on the definition of the environment structure. Overall for HSE, forecasting and monitoring relevant to the environmental dimension have the highest effect (0/18) and lowest effect (0.07). Then, the importance and performance of these dimensions and components were investigated for the current situation in the automotive industry. Based on the results, health, safety and environment should be the subject of priority to the managers and policymakers.

DISCUSSION

The purpose of this research was to identify a model for evaluation of HSE performance management based on Resilience Engineering. The case study was conducted in an automotive industry in order to make it practical. In this research, the HSE performance management was surveyed in three main aspects including safety, health, and environment while 48 criteria were selected as sub-criteria and also four resilience components; forecasting, reaction, experience and monitoring which were extracted using theory research method in the automotive industry. Then, the dimensions and components extracted using the structural equation modeling approach and partial least squares (PLS) were evaluated in order to develop the optimal model. One of the strengths of this research was ranking primary and secondary indices, weighing and validating their influence as well as their impact on HSE performance management evaluation based on resiliency components that had not been addressed before. Also, based on Table 11 in the presented model, the coefficient of determination of main indices in the central structure was equal to 1 which indicates their full coverage of the central structure.

Likewise, in this study, to assess three components of safety, health and the environment, the significance of their weight and the alignment test was used. On the other hand, although the weight of health component is greater than the safety and environment in Table 9, it does not define priority. Because, on the basis of the importance-performance matrix (Chart 2), safety (0.40), health (0.37) and environment (0.33) were ranked which adapts to the study conducted [1]. This matter implies that in the automotive industry, in order to improve the resiliency level, the attention should be forwarded to the safety issues mostly and safety is to be considered as a value in the organization. On the other side, in the case of sub-components, observation (Table 12) expresses that in the aspect of safety, the highest impact goes to forecasting while the lowest is for monitoring while, experience and forecasting have the highest and lowest effect on health dimension, whereas in the environment aspect, the effects of forecasting and monitoring are in the highest and lowest levels.

Based on the results of analysis, among the three main indices of HSE central management structure (Table 12), the environment has the lowest effect. This can be attributed to the poor environmental structure of the organization, lack of integrity or environmental separation from safety and health.

In the following section, the analysis results indicate that, in the case of safety identification, safety risk identification is assessed desirably and due to the use of individual protection devices, implementation of the items is raised in the safety committees and indicators of events should be given more attention. In case of health, employees ' job rotation, and ergonomic risks assessment are assessed as desirable and the exposure of employees to harmful factors is one of the most important issues that have to be considered. In the environmental dimension, optimal environmental training was evaluated ideal and the focus of attention goes to the measurement of environmental pollutants, waste management, and energy consumption in the scale of production.

According to the above notes, we can conclude that the most important advantage of the developed model is that all of the main indices and sub-indices are evaluated such that alarms the necessary warnings to the management. Another advantage of the proposed model is to survey via integrated method including (qualitative - quantitative) and then analysis of the data by the PLS method.

To mention the constraints of the above research, lack of access to the scientific sources can be noted because of sanctions. Also, the reluctance of some individuals in answering the submitted questionnaires and multiple pursuits to deliver the completed questionnaires are pointed out which resulted in the research process delay.

CONCLUSION

With regard to the new topics in Resilience Engineering, this issue is evaluated relevant to HSE performance management in the automotive industry for the first time. In this study, using qualitative and quantitative methods possessing PLS technique, the evaluation of sub-indices and main indices of the central structure were carried out based on four resilience components. Based on the research results, the HSE performance evaluation model was developed including four levels. At the first level of the central structure known as the HSE performance management, the second level includes the main factors affecting central structure, the third stage goes to the criteria or components of resiliency and the fourth level consists of sub-criteria in the three areas namely safety, health and environment.

The results show that among sub-sub-criteria in the field of safety, the number of safety risks-in high, medium and low-levels has the most effect where the use of personal protective devices, compliance with the laws and safety regulations implemented in safety committees have less impact.

Also, the results of the survey showed that among the sub-indices of health field, ergonomics, and personnel with occupational disease have had a significant impact and less impact goes to employees facing with harmful factors at workplace. In the research results, in the field of environment, the effects of environmental education are the highest where the least effect belongs to the production of common wastes, specific wastes, energy consumption and SOX submission.

At the level of the main indices and according to research results (Chart 2), safety and health are more important than the environment.

Based on the results of analysis, safety, health and finally the environment component affected HSE management performance in resilience aspect, respectively. At the level of resilience components (Table 12) for safety, health and environment; forecasting, experience and forecasting; respectively have the highest effect and monitoring, forecasting and monitoring have less impact.

According to the results of this study, it seems that the environmental factors must be considered more in managerial planning to play a more efficient role in Resilience. In total, all of the main indices, sub-indices and components involved in the development of the model have been in a manner to cover the performance of HSE management. This assessment model can make safety, health, environmental performance more resistant in all automotive industries and also applicable in other industries with making slight changes, or defined as an efficient pattern for assessing their HSE performance. Likewise, based on the results of this research, managers and policymakers in automotive industries can play a more effective role in HSE status development. Based on the results of the survey and the developed model, all of the main indicators, sub-criteria and resilience components had the accuracy and correctness which covered the HSE management performance desirably.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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