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Effects of organizational macroergonomic compatibility elements over manufacturing systems' performance

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Abstract

This paper examines the effects of organizational macroergonomic compatibility elements over manufacturing systems performance from four companies located in the city of Ciudad Juárez, México. Current studies scarcely address the relationship that exists among the factors and their elements included in the Systems Engineering Initiative for Patient Safety (SEIPS) macroergonomic model and the benefits they may generate on manufacturing systems' performance. The SEIPS model includes macroergonomic factors such as person, organization, technology and tools, tasks, and environment, and it has been adapted for manufacturing systems. This paper is focused on the analysis of the relationship among the macroergonomic organizational elements (elements of the factor organization) included in the SEIPS model, and the benefits that these elements may generate on manufacturing systems performance using a structural equation modelling approach. Results indicate that macroergonomic organizational elements like organizational culture and organizational communication have a direct effect over clients and an indirect effect over the manufacturing processes and the growth of the companies. These results can offer some relevant and new knowledge to develop macroergonomic strategies for manufacturing systems in order to increase their competitiveness. Additionally, knowledge about direct and indirect effects derived from organizational elements over manufacturing systems greatly supports the design and improvement of these systems.

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1. Introduction

In an increasingly saturated market place, competitiveness of manufacturing systems should be guided, in part, by an analysis of macroergonomic factors, such as person, organization, technology, tasks and environment. A model that includes these factors is the Systems Engineering Initiative for Patient Safety (SEIPS) model [1, 2]. SEIPS model is a human factors systems approach that has been successfully applied in healthcare research and practice [1]. The SEIPS model can be adapted and applied on manufacturing systems because it serves as a useful framework for studying work systems change and design and it also provides a holistic view of a work systems rather than focusing on a single factor [1]. It also provides the elements the design of works systems, and its impact on the processes and outcomes. A complete description of SEIPS model can be found in [1, 2] for further reading.

Macroergonomics is the study of work systems, and it focuses on the achievement of a fully harmonized work system at both the macro- and microergonomic level [3]. Ergonomic compatibility is defined in this paper evoking the concepts of human–system and human–artefact compatibility introduced by Karwowski [4], which emanate from the need of having comprehensive treatment of compatibility in human factor discipline [5]. How well a work system is designed will determine how effective the work system will be [3]. Several authors such as [4-9] have written about ergonomic compatibility either at micro or macro level, nevertheless, there is no model available for validation and evaluation of this construct on manufacturing systems. Some macroergonomic elements from the original SEIPS model were classified as Organizational communication, Organizational culture, and Performance. Dependent variables are the Processes, Clients and the outcomes named as Growth.

2. Literature review

2.1 Macroergonomic compatibility

Macroergonomics is the study of work systems, and it focuses on the achievement of a fully harmonized work system at both the macro- and microergonomic level [3]. In ergonomics, “compatibility” has been expressed in an unstructured way, by matching it with the term ‘fit’ [7]. Macroergonomic compatibility is based on the theory of Karwowski [7] and symvatology [5]. Macroergonomic compatibility exists when a work system supports an appropriate interaction of the personnel subsystem and the technological subsystem, including its relationship with external environment characteristics [8].

2.2 Organizational culture

Organizational culture is “the tacit, unwritten rules for getting along in the organization; the ropes that a newcomer must learn in order to become an accepted member; the way we do things around here” [10]. It has been found that organizational culture has been related to organizational efficiency [11]; and that managers who had an identification to their own organization and the clients organization had significantly more loyal clients compared to project managers that do not have identification to their organization or the client organization [12].

2.3 Organizational communication

Organizational communication represents the way business, companies, enterprises, firms, institutions or groups communicate in their internal environment to their own member or employees and how the organization as a whole communicate with people (clients, customers, vendors, suppliers, stakeholders, media, general public etc.) outside its environment [13]. It is stated that good communication skills improve the organizational performance [14], and that an efficient communication at the workplace is significant for the success or failure of an organization [15], because this tends to motivate the employees to work cooperatively and more efficiently [16].

2.4 Teamwork

Teamwork is defined as the behaviors that facilitate team member interaction such as leadership, orientation, mutual performance monitoring, back up behaviors, and adaptability [17]. Some studies showed that teamwork may

influence the competitiveness of companies[18],and that companies that improve their teamwork activities obtain better performance and face with fewer problems and damage in their projects[19].

2.5 Organizational performance

Performance is the degree to which companies achieve their objective, and it is a competitiveness indicator for manufacturing systems[20, 21].Dess and Robinson [22]found that there is a positive correlation between global organizational performance and the growth in sales and return on assets in manufacturing systems, meanwhile Lee and Choi [20] discovered that there is a positive relation between organizational creativity and non-financial performance. Zacharatos, Barling [23] found a positive relation betweenhigh-performance work systems andoccupational safety.

2.6 Clients

Client is“any person or entity that employs or retains another person for financial or another compensation to conduct lobbying activities on behalf of that person or entity”[24]. Some studies indicated that the better the understanding of the clients, the better the competitive advantage of the firm[25, 26]. For example, it was foundthat by mean of the clients’ assessment, the construction projects can be improved[26],and when clients lack knowledge and experience, the projects may fail [27]. In manufacturing systems it is pointed out that clients can help to improve the process in different stages[28].

2.7 Process

Business process is defined universally, and it is described as a procedure relevant for adding value to an organization[29]. Studies revealed that manufacturing processes have an impact on manufacturing systems performance. For example, it was discovered that a reliable and continuously improving manufacturing process can be a key condition for ensuring long-term sustainability[30], and they influence the environmental impact of products[31].

3. Methodology

3.1 Questionnaire development

A questionnaire was developed to measure macroergonomic compatibility of manufacturing systems. It contains four sections: First section included questions about the name of the company, the type of manufacturing system used in the company, and the macroergonomic methods applied for the company. The second section included 92 items about macroergonomic practices applied in manufacturins systems, third section included 22 items about the frequency on which manufacturing systems applies macroergonomic practices, and fourth section included 18 questions about the benefits the enterprise enjoysfrom macroergonomic practices application.Appendix Ashows the Table with the items for each construct analyzed and the references from which they were obtained. Those items without references were items included by the authors.

The questionnaire should be answered on a Likert scale, which included values: 1) Totally disagree, 2) Disagree, 3) Neither agree nor disagree, 4) Agree, and 5) Totally agree. This scale was adopted because it was used in recent and similar studies in [32-34]. Questionnaire was applied in manufacturing systems in Ciudad Juarez, Chihuahua, Mexico. Surveyed people were employees of middle and senior management because they because they have knowledge about macroergonomic practicesapplied in theircompany, its deficiencies and opportunities for improvement. The method to apply the questionnaire includes the following steps: 1) contact at the management of the company, and 2) establish an appointment for questionnaire application. All middle and high management staff members were invited to voluntarily participate in the study.

3.2 Statistical questionnaire validation

A statistical questionnaire validation was performed. For each dimension, a Cronbach's alpha index was used, considering a minimum cutoff value of 0.7 [33]. Variables with a corrected total-item correlation value less than 0.3 were removed only if the Cronbach's alpha kept greater than 0.7. The average variance extracted (AVE) and the cross-factor loadings were used as indicator of discriminant validity and convergent validity [33]. The index of variance inflation factors (VIFs) was used to detect collinearity between latent variables [33], and the coefficient of Q-squared was used as a nonparametric measure of predictive validity [33].

3.3 Proposed hypothetical causal model

Once the final variables were defined and taking literature review as basis. The proposed hypotheses were:

- H₁**: Organizational culture in manufacturing systems has a direct and positive effect on Organizational communication.
- H₂**: Organizational culture in manufacturing systems has a direct and positive effect on loyalty of Clients.
- H₃**: Organizational communication in manufacturing systems has a direct and positive effect on the Teamwork.
- H₄**: Organizational communication in manufacturing systems has a direct and positive effect on Organizational performance.
- H₅**: Organizational communication in manufacturing systems has a direct and positive effect on loyalty of Clients.
- H₆**: Teamwork in manufacturing systems has a direct and positive effect on organizational Performance.
- H₇**: Teamwork in manufacturing systems has a direct and positive effect on manufacturing Process.
- H₈**: Organizational performance in manufacturing systems has a direct and positive effect on manufacturing Process.
- H₉**: Process has a direct and positive effect on Clients.
- H₁₀**: Processes have a direct and positive effect on the Growth of manufacturing systems.
- H₁₁**: Clients have a direct and positive effect on the Growth of manufacturing systems.

Fig. 1 shows the proposed hypothetical causal model.

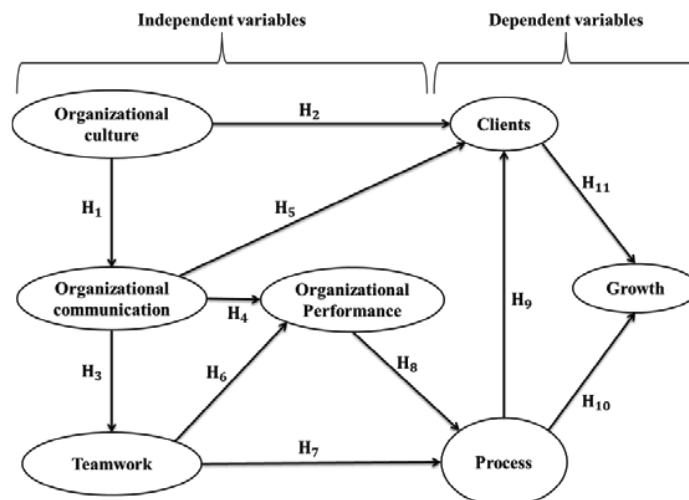


Fig. 1 The proposed hypothetical model.

3.4 Analysis of structural equation model

A relationships analysis among the dimensions was performed to test the relationships defined in Fig. 1. The analysis was performed by mean of structural equation model (SEM). This analysis was made by using the software WarpPLS⁴, which uses algorithms based on partial least squares (PLS), and it is widely recommended for small sample size [33].

The average path coefficient (APC), average R-squared (ARS), and average variance inflation factor (AVIF) were used to evaluate the model. For the APR and ARS all relationships with a $P < 0.05$ were considered significant, otherwise, they were removed. For the AVIF, five is the maximum acceptable value [33]. The direct effect was used to validate the hypotheses depicted in Fig. 1.

4. Results

4.1 Questionnaire application

The questionnaire was applied in four manufacturing systems, with the following results: 41 individuals in two manufacturing systems, 34 individuals in a third manufacturing system, and 42 individuals in the last one, comprising a total sample of 158 individuals

4.2 Statistical questionnaire validation

The variables of work schedules, social relationships, and supervisory and management style were removed during the questionnaire validation. After the model was tested in WarpPLS®, only the item “Safety inspections are performed regularly” of the dimension of Organizational culture was removed. The other final dimensions keep with the initial number of items.

The APC and the ARS were both greater than zero, and the P values were less than 0.001, therefore the relationships were significant. The TenenhausGoF (GoF) value was 0.465, and the model had a large overall explanatory power and predictive quality [35]. The AVIF and the average full collinearity variance inflation factor (AFVIF) values were both less than 3.3. The values of Sympton’s paradox ratio (SPR), R-squared contribution ratio (RSCR), and statistical suppression ratio (SSR) are all equal to 1, therefore all the paths in the model are in the correct direction and the predictor latent variables have a positive contribution to R-squared. The value of nonlinear bivariate causality direction ratio (NLBCDR) was 1, and then hypothesized directions of causality were correct.

Reliability of the survey is good, since the Cronbach’s alpha value was greater than 0.7 in all analyzed dimensions. In addition, the AVE values were greater than 0.5 in all dimensions, and then the survey had discriminant and convergent validity. All R-squared values were greater than 0.02. The VIF values were less than 3.3, and then there were no problems of collinearity between latent variables. Finally, all Q-squared values were greater than zero, and then the nonparametric predictive validation is good.

4.3 Effects among variables

Fig. 2 shows the significant direct effects. The values expressed in β are dependence measurement values and represent standardized values. P values are the values for the significance hypothesis test.

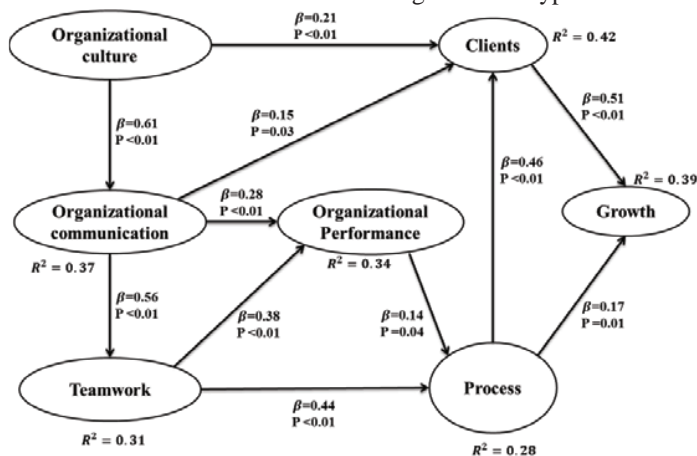


Fig. 2 Significant direct effects

The β values can be interpreted in the following way: for example, the relationship between Clients and Growth has a β value of 0.51, which means that when the first dimension increases its standard deviation in one unit, the second dimension goes up by 0.51. All β values can be interpreted in the same way in all other relations.

In the analysis of indirect effects and total effects, Organizational performance had no significant effects over Clients and Growth, while Teamwork had no significant effect over Process. All other effects were significant.

5. Conclusions

Organizational culture and Organizational communication are independent variables that indirectly influence the competitiveness of manufacturing enterprises. As dependent Clients play a significant role on the Growth of manufacturing systems.

The results in Fig. 2 can be written as follow:

- Macroergonomic compatibility of Organizational culture is required for macroergonomic compatibility of Organizational communication in manufacturing systems.
- Macroergonomic compatibility of Organizational communication is required for Macroergonomic compatibility of Teamwork in manufacturing systems.
- Macroergonomic compatibility of Organizational communication and Teamwork is required for macroergonomic compatibility of Organizational performance.
- Macroergonomic compatibility of Organizational culture, Organizational communication and good Process are required for satisfied Clients of manufacturing systems.
- Satisfied Clients and good Processes are required for the Growth of manufacturing systems.

All hypotheses were significant, and then we concluded that macroergonomic compatibility of organizational elements may provide competitive advantage for manufacturing systems performance.

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Appendix A

Table 1 References for questionnaire items

Item	Reference
Teamwork	
Employees perform the tasks in team	[36]
An employee receives support by the coworkers when he/she has doubts or difficulty to perform a task	[36]
Employees give ideas, opinions and suggestions which are respected	[37]
Employees receive feedback on their performance by coworkers and managers	[36]
Organizational communication	
Workers strive to maintain good coordination, collaboration and communication	[38]
Any employee can communicate to another employee regardless of the hierarchical level	[38]
Employees receive feedback in order to keep a good organizational communication	[38]
The company uses different forms of communication (visual, oral, auditory, written)	[38, 39]
Organizational culture	
Company's principles and values are clearly transmitted to the employees from the beginning	[39]
Employees know the objectives of the company	[39]
Employees strive to keep the company's principles and values	[39]
This company is in favor of the change	[39]
Division of work actually helps to achieve the company's goals	
A safety cultures is promoted among the employees	
Safety inspections are performed regularly	[39]
Work schedules	
Work schedules are comfortable and stable	[40]
Employees are early informed about these jobs that are going to demand extra time	[41]
Employees make their own decision-making the program of their tasks	[42]
Social relationships	
Employees can keep social relationships inside of the company	[42]
Employees interact with people outside the organization (clients, providers, etc.)	[36]
Employees keep cordial professional relationships	[36]
Employees share information among them	[36]
Employees can gather to talk about any topic	[36]
Supervisors are concerned about the welfare of the people who work for them	[42]
Supervisory and management style	
Tasks are supervised and monitored in order to improve the employees' performance	[42]
Managers provide continuously attention and support to the employees	[42]
Organizational performance	
Assessments of the employees' performance are made periodically	
Employees are encouraged to give their maximum effort	[39]
Employees' salary is commensurate with the tasks they do	[39]
All tasks performed are associated with incentives	[39]
Clients	
Needs and expectative of clients are considered	[43]
Clients are satisfied with the products they receive	[12]
Clients keep loyal with the company	[12, 44]
The number of clients has increased over the time	[44]
Processes	
The number of complaints by clients is very low	[45]
The number of defects is very low	[46]
Inventory levels are low	[46]
Productivity has increased over the time	[46]
Growth	
Productivity has improved	[46]
The number of employees has increased	
The variety of products has increased	[46]
The business has improved	