A Descriptive Study about the Integration of Ergonomic Attributes on the Selection of Advanced Manufacturing Technology -AMT-

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Resumen: Este artículo presenta un estudio descriptivo sobre la integración de la Ergonomía de compatibilidad de atributos (ECA) en la selección de la Tecnologia de Manufactura Avanzada (TMA) entre 30 personas que toman decisiones (TD) de las empresas del sector metal-mecánico situado en la zona fronteriza de Ciudad Juárez, México. La intención es aumentar el conocimiento sobre la consideración e importancia de los atributos ergonómicos en la adquisición de TMA. Además, fueron investigadas algunas de las características del personal que participa en su funcionamiento, la gestión y la toma de decisiones. Adicionalmente, se identificaron los procedimientos comunes de evaluación y selección de TMA; se da una clasificación de los equipos utilizados en estas empresas de acuerdo con el propósito de manufactura.

La metodología expone la ECA en un modelo de atributos múltiples y describe la ECA aplicada para recabar información sobre las características de la selección de la TMA, selección de proocesos utilizados en estas empresas. Los resultados muestran que la mayoría de las empresas realizan algún tipo de diagnóstico para la selección de AMT, pero frecuentemente se omiten o descuidan los atributos ergonómicos. Sin embargo, los TM reconocen que al tomar en consideracion los atributos ergonomicos en la selección de TMA puede proporcionar una ventaja estratégica al facilitar y promover condiciones operativas más seguras en estos lugares de trabajo y lograr una mejor aplicación de esta tecnología también. Asimismo, los resultados indican que es casi tan frecuente encontrar en estas empresas la tecnología CNC como la tecnología tradicional

y una tendencia cada vez mayor para incrementar las inversiones en tecnología de robots y prototipado rápido. Además, el genero masculino es predominante en el personal operativo y administrativo relacionado con TMA y el personal operativo promedia una antigüedad en un rango de 4-7 años.

Palabras clave: Ergonomia de Compativilidad de Atributos, Tecnología de Manufactura Avanzada, Toma de Decisiones, Encuesta de compatibilidad ergonómico para TMA

Abstract: This paper presents a descriptive study about the integration of Ergonomic Compatibility Attributes (ECA) on the selection of Advanced Manufacturing Technology (AMT) among 30 Decision Makers (DM) from enterprises of the metal-mechanical sector located in the borderland of Juarez City, Mexico. It is meant to increase knowledge about the consideration and importance of ergonomic attributes on the acquisition of Advanced Manufacturing Technology (AMT). Also, some characteristics of the personnel involved in its operation, management and the decision making processes were investigated. Additionally, common procedures for evaluation and selection of AMT were identified; a classification of the equipment used in these companies is provided according to the manufacturing purpose.

The methodology exposes the ECA in a multi-attribute model and describes the Ergonomic Compatibility Survey (ECS) applied for gather information about the characteristics of the AMT selection processes used in these companies. The results show that most of the companies do perform some kind of diagnosis for AMT selection, but ergonomic attributes are often omitted or neglected among them. However, DM recognize that ergonomic attributes consideration in AMT selection may provide a strategic advantage in the way it would facilitate and promote safer operative conditions in these workplaces, and a more successful implementation of this technology as well. Also, results explain that CNC technology is almost as frequent to find in these companies as traditional technology and a growing trend to increment the investments in rapid prototyping technology and robots can be observed. Additionally, male gender is predominant in the operative and management personnel related with AMT and operative personnel average seniority is in a range of 4-7years.

Keywords: Ergonomic Compatibility Attributes, Advanced Manufacturing Technology, Decision Making Processes, Ergonomic Compatibility Survey for AMT.

1. INTRODUCTION

This section presents the problem description, the objectives of this investigation and finally the justification and the scope.

1.1 Problem Description

According to the Metal-Mechanic Industry Directory 2008 (Directorio de la Industria Metal-Mecánica, DIMM, by its initials in Spanish) in Juarez City, there are approximately 200 companies in the field of Metal-Mechanic Industry, which represents an important source of jobs for the city. Thus, it is believed that there is substantial amount of workers engaged in the use of AMT. However, studies about the characteristics of the personnel and employees related with the operation and management of AMT and the integration of safety and ergonomic attributes in the decision making processes are scarce locally.

It is well known that managers and DM face the problem of selection of many AMT alternatives; and there are multiple attributes involved in making a good decision, so it is difficult to consider all in their totality. In this way, this research pretends to explore the integration of ECA on the selection of AMT among 30 DM in local industries and to promote the consciousness about the benefits of ergonomics' implementation.

1.1.1 Objectives

The objectives that arise in this work are divided into three specific and one general goal, which are explained below:

1.1.1.1 General Objective

Increase knowledge about the consideration of ergonomic attributes on the acquisition of Advanced Manufacturing Technology (AMT) by means of a descriptive study and the application of the ECS to 30 DM in local companies.

1.1.1.2 Specific Objectives

Describe some important characteristics of the personnel involved in its operation, management and in the decision making processes for AMT acquisition.

Identify common procedures for evaluation and selection of AMT.

Provide a classification of the equipment used in these companies according to the manufacturing purpose.

Increase knowledge about the reasons they may or may not include ergonomic and safety attributes on their decision making processes.

1.1.2 Justification and Scope

This research will provide information to managers and investors of the Metal Mechanic Industry about the integration of ergonomic attributes on the selection of AMT, which may have been previously obviated. According to Helander (2006), companies that take into account the ergonomic attributes on the selection process of AMT will result in safety, productivity and satisfaction of their workers.

This work was made in the Metal Mechanic Industry in Ciudad Juarez, Mexico, where an ECS was applied to DM to know some characteristics of their planning and selection processes of AMT and the personnel involved in such processes.

2. LITERATURE REVIEW

Ergonomic and safety aspects are significant for the design and operation of complex manufacturing systems like the ones related with AMT. These are being under estimated for the control of injuries and safety problems in the Manufacturing Industry (Karwowski, 1990, 2005). According to the Bureau of Labor Statistics of the United States, the Mexican Social Security Institute (IMSS), the European Agency for Safety and Health at Work, and the Report of Labor and Social Trends in Asia 2006 nowadays the Manufacturing Industry occupies one of the top five industries with the highest number of injuries, illnesses, days away from work, along with other important statistics worldwide. Additionally, in Mexico the operation of tools and machines is one of the top five occupations that report the highest numbers of these events also. However, there are difficulties to relate these events with the operation of AMT, due to insufficient information and

lack of attention to this topic (Maldonado, 2009). Important authors recognize that even when AMT was introduced among others reasons to reduce safety risks and hazards for humans, new and more critical ergonomic and safety risks have been detected since its introduction in manufacturing processes (Nicolaisen, 1995; Karwowski et. al., 1988; Karwowski and Salvendy, 2006; Sugimoto et. al., 1985).

In this way, managers and DM may have underestimated Human Factors and Ergonomics attributes in their decision in the way priority is given to other factors. Also they are unaware of these attributes and their benefits. Such ignorance has serious consequences for companies and their workers, since the operators work under physical and mental stress, eventually develop musculoskeletal trauma disorders and injuries for life, which represents large losses for jobs and businesses (Prado, 2001).

3. METHODOLOGY

The methodology presents the description of ECA and the ECS.

3.1 Ergonomic Compatibility Attributes

Ergonomic Evaluation of AMT is not an easy topic since ergonomic requirements (attributes) are not clearly determined in the literature and disperse, also it implies quantitative and qualitative aspects and its complexity and vagueness make an even harder problem to resolve. For Karwowski (2005), advanced technologies with which human interaction constitute complex systems that require a high level of integration, he considers that Ergonomic Compatibility Attributes of AMT have to focus in the design integration of the interactions between hardware (computer-based technology), organization (organizational structure), information system, and people (human skills and training). This was the foundation of the literature search, but also Corlett and Clark (1996) ergonomic guide for machine design was used. In this way, ergonomic compatibility evaluation main attributes (ECMA) for AMT, were divided into five parts: human skills and training compatibility (A11), physical work space compatibility (A12), usability (A13), equipment emissions (A14) and organizational requirements (A15). The main attribute A11 includes two sub-attributes: skill level compatibility (A111) and training compatibility (A121). The main attribute A12 includes five sub-attributes: access to machine and clearances (A121),

horizontal and vertical reaches (A122), adjustability of design (A123), postural comfort of design (A124), physical work and endurance of design (A125). The main attribute A13 includes seven sub-attributes: controls design compatibility (A131), controls' physical distribution (A132), visual work space design (A133), information load (A134), error tolerance (A135), man machine functional allocation (A136), design for maintainability (A137). The main attribute (A14) includes four sub-attributes: temperature (A141), vibration (A142), noise (A143), residual materials (A144). The main attribute (A15) includes two sub-attributes: rate of work machine compatibility (A151) and job content machine compatibility (A152).

3.2 Ergonomic Compatibility Survey

An Ergonomic Compatibility Survey (ECS) was designed for collect the information of the evaluation of AMT alternatives. The ECS has two versions; one of these versions was designed to be answered by experts and the other one to be answered by DM. For this work it will be analyzed the second version (DM). DM' subjective opinions were needed. The ECS consists on 72 questions but for the effects of this work only the first 22 questions were analyzed covering the sufficient information to make a descriptive study.

3.2.1 Companies' General Data

The general data of the companies is requested in the first section of the ECS. Information includes average occupation and the respective gender. Also the workers' average age for each gender is requested and workers' average seniority to each gender. Finally, the kind of AMT used in the company is inquired.

3.2.2 Characteristics of the Planning and Selection Process of Advanced Manufacturing Technology (AMT)

This part includes 17 questions. This section aims to know some characteristics of the planning process for the acquisition of ATM in the company and who participate in the decision making. The first 3 questions refer to who makes the final purchasing decision of AMT. The next 3 questions refer to how the AMT is identified and how the selection process is carried out. Finally, through the last 13 questions the integration of ergonomic and safety attributes on the selection process of AMT can be observed.

4. RESULTS

This section presents the results obtained of the ECS described above.

4.1 Results of Companies' General Data

This section shows the results of general data company.

4.1.1 Gender and average occupation

Companies of the survey occupy mainly male workers in all positions. According to the survey, male gender is preferable due to the nature of the work and the applied force that is required in some activities. The majority of female personnel found in these companies usually have administrative positions. Figure 1 shows these results. Additionally, average occupation is of 46 workers among the participating companies.

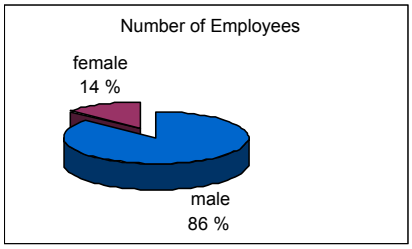

Figure 1. Gender of employees in the Metal Mechanical Sector

4.1.2 Average age of employees

Figure 2 shows that male workers employed have on average 29.76 years of age and female workers have on average of 30.80 years of age.

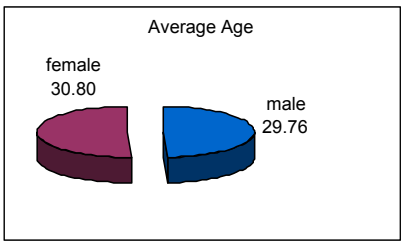

Figure 2. Employees' average age in the Metal Mechanic Sector

4.1.3 Average Seniority of employees

Figure 3 shows that the average seniority of male workers is 6.79 years while female workers have average seniority of 4.03 years. This results show also that male gender is still being preferable above female gender in these companies.

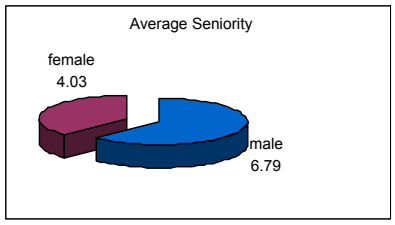

Figure 3. Average seniority in the Metal Mechanical Sector

4.1.4 Equipment Used in the Metal Mechanical Sector Companies

Participating companies present a variety of equipment. Equipment was classified into seven categories according to the manufacturing purpose: CNC Technology, Cutting Technology, Traditional Technology, Molding of Plastic Technology, Cleaning and Treatment of Metals Technology, Welding Technology, and Others.

As it is shown in Figure 4, actually CNC Technology is almost as frequent to find as traditional Technology. Finally, a growing trend can be observed on equipment such as electrical discharge machines, flexible manufacturing cells, robots, robo-drills, and progressive die press found in the Others classification.

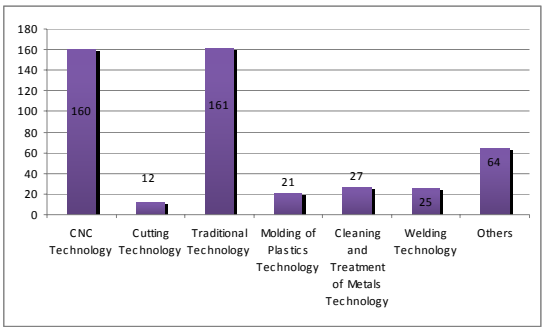

Figure 4. Classification of the Equipment Used in the companies

4.2 Important Characteristics of the Selection Processes for AMT acquisition.

This section shows the results of some characteristics of the planning and selection processes found in these companies.

4.2.1 Planning Processes for the acquisition of AMT in the Industry

Figure 5 shows that 77 % of the companies surveyed do perform some kind of planning processes for the acquisition of AMT; this indicates the relevance of a good decision making about AMT.

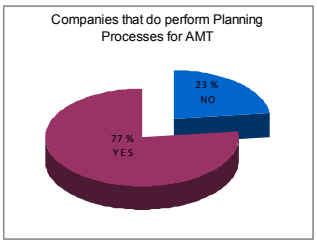

Figure 5. Percentage of Companies that do perform Planning Processes for AMT acquisition

In these companies, the planning processes performed for AMT acquisition are mainly part of engineering projects; this means that projects play an important role due to the specifications accomplishment on the selection of AMT. Also, in most of these companies the planning processes are executed only by the high management. Figure 6 shows the kind of personnel involved in the planning process for the acquisition of AMT.

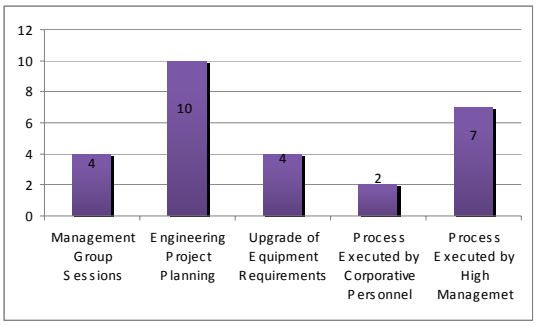

Figure 6. Planning Process Execution for AMT acquisition

Figure 7 shows that Executive and Administrative Personnel are mainly involved in the planning and selection processes; also in 35 % of the companies a group composed by executive, administrative and operative personnel conduct the decision for AMT acquisition.

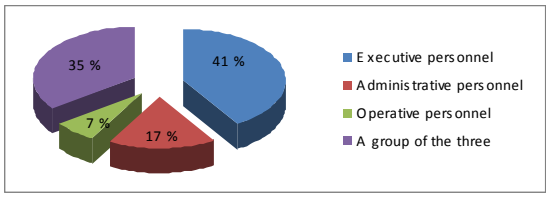

Figure 7. Personnel who participate on the Planning Process for AMT acquisition

Companies have different search methods for acquiring AMT. Some companies use two or three of this methods at the same time. Figure 8 shows that the use of internet web service and vendors casting are the most extended ways for search and acquire AMT, followed by benchmarking and equipment's exhibit. Also the use empirical knowledge is included in the Others category.

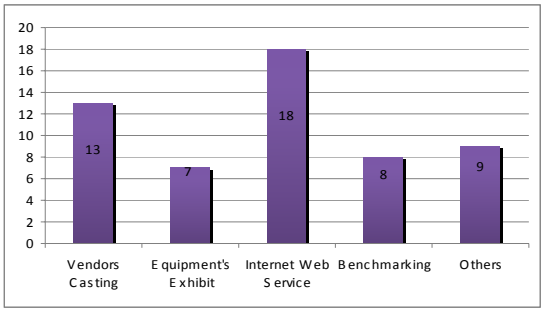

Figure 8. Searching Methods for AMT acquisition

4.2.2 Application of Evaluation Processes for the selection of AMT

Once the AMT has been identified, it is recommended to perform some kind of diagnosis processes to ensure that company's expectations are met and avoid high costs. Figure 9 shows most of the companies do perform some kind of evaluation or diagnosis processes for AMT selection.

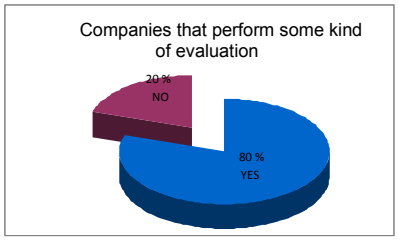

Figure 9. Companies that perform some kind of evaluation

Among these companies, the processes are supported by experts in the first place; then by the use of checklists and standardized corporative formats, only a few use some specialized software; and one company uses only the experience (Figure 10). Companies that omit evaluation processes assume that the requirements are included by default in the equipment.

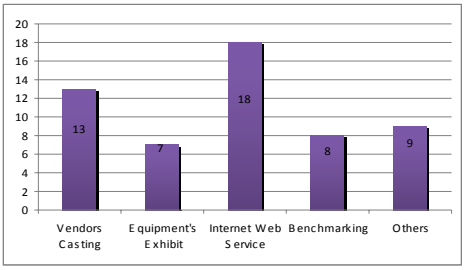

Figure 10. Diagnosis Methods for the selection of AMT in the Metal Mechanic Sector

These results show that most companies recur to experts to enhance their decisions.

4.2.3 Ergonomic Attributes on the Planning Process

Figure 11 shows that slightly more than a half of the surveyed companies that do apply some kind of evaluation process also consider ergonomic attributes on the selection of AMT. It is inferred by the attitude shown by managers and DM during interviews that 45% of them are unaware of the ergonomic attributes that may be involved in the evaluation, even some of them had not even heard about the topic.

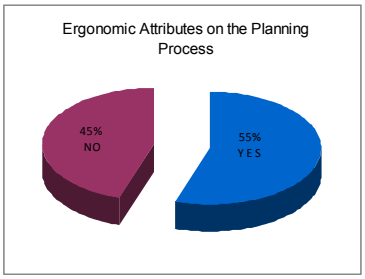

Figure 11. Ergonomic Attributes on the Planning Process

Ergonomic attributes included in the diagnoses of the equipment were diverse, but it was emphasized that all managers are looking for comfort for their operative personnel through proper postures and less effort. It was also important for managers the adjustability of the equipment. Additionally, usability of the equipment is required since they look for easiness of use in equipment and tools, also, Compatibility with Human Skills and Training seems to be the most important ergonomic attributes for DM on the selection of AMT according to Maldonado (2009).

About DM who do not consider ergonomic attributes in the diagnoses, they argue that the priority on AMT must be on the technical aspects, costs and lead times. Also the main reason to do so is the lack of knowledge about Ergonomics and the need of a pragmatic model or method that facilitates their integration in decision making.

On the other hand, safety attributes are included in the evaluation processes in almost all companies. Among the 30 companies surveyed, only one refused to include safety attributes in the diagnosis. Figure 12 shows this fact. It is deduced that safety attributes are much better known than Ergonomic Attributes among DM.

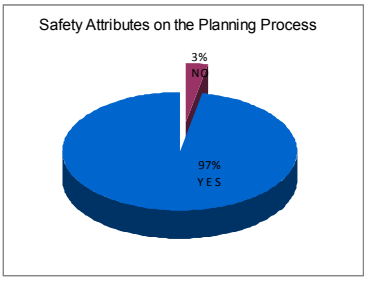

Figure 12. Safety Attributes on the Planning Process

In this research, most of the companies recognized that the integration of ergonomic attributes can become a strategic advantage for competitiveness; and for DM the combination of ergonomics and safety attributes would enhance the implementation of AMT, therefore it is easier to derive the benefits that both aspects generate. Figure 13 shows this fact.

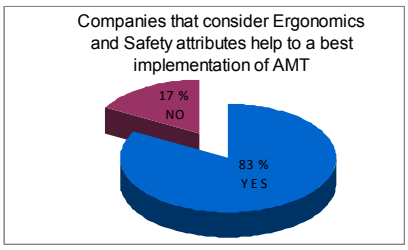

Figure 13. Companies that find a strategic advantage of Ergonomics

5. CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that most companies surveyed do perform some kind of planning and selection processes for AMT acquisition. However, the integration of ergonomic and safety attributes are usually neglected in the diagnosis and selection processes for acquiring AMT. The final decision about AMT acquisition is lead by the high management personnel and is strongly supported by experts. It was found appropriate by DM to increase their knowledge about the ergonomics aspects that can be taken into account to support their decision due to they consider Ergonomic and Safety attribute as a strategic advantage. The AMT which predominate in the

Metal Mechanic Sector in Juarez, Mexico has gradually been replacing traditional technology. Different practices for decision making about AMT among companies were studied, making clear that engineering projects are one of the most important reasons to replace or acquire equipment. Finally, it was analyzed the methods used by companies to identify and search AMT, where the internet web service was the method preferred by DM due to its convenience.

It is recommended to extend this study among macro enterprises which have higher occupation and may have records of accidents, injuries, days away from work and other events related with the operation of AMT. This may help to obtain more accurate results of the importance of the integration of ergonomic attributes on the selection of AMT.

6. REFERENCES

Corlett E. N. y Clark T.S. (1995). The Ergonomics of Workspaces and Machines, 2a. Edición, *Taylor and Francis*.

European Agency for Safety and Health. 2007. "Work ILO Facts European Agency for Safety and Health at Work", http://www.ilo.org/public/english/standards/relm/ilc/ilc90/pdf/rep-v-1.pdf.

Helander, M. (2006). A guide to human factors and ergonomics, 2nd Edition, *Taylor & Francis Group*, pp. 8.

IMSS. 2007. "Estadísticas laborales del Instituto Mexicano del Seguro Social", http://www.siicyt.gob.mx/siicyt/Principal.do?urlc=4,14.

Karwowski W. 1990. "Injury control and worker safety in integrated manufacturing systems", Unpublished Technical Report, Center for Industrial Ergonomics, University of Louisville, Louisville, Kentucky, United Sates of America.

Karwowski W. 2005. "Ergonomics and human factors: the paradigms for science, engineering, design, technology and management of human-compatible systems[1]", *Ergonomics*, Vol.48, No. 5, Pgs. 436-463.

Karwowski, W., Parsaei, H.R., Nash, D.L., and Rahimi, M. (1988). Human perception of the work envelope of an industrial robot, in Ergonomics of Hybrid Automated Systems, W. Karwowski, H. R. Parsaei, and M. R. Wilhem, Eds., Elsevier, Amsterdam, pp. 421-428.

Karwowski, W. and Salvendy, G. (2006). Handbook of human factors and ergonomics, John Wiley & Sons Inc., United States of America.

Labour and Social trends in Asean. 2007. "Labour and Social trends in Asean countries",http://www.ilo.org/public/english/region/asro/bangkok/library/download/pub07-04.pdf.

Maldonado Macías Aide Aracely, (2009). Tesis Doctoral, Instituto Tecnológico de Cd. Juárez. Diciembre 2009.

Maldonado Aide, Noriega Salvador, Díaz Juan J., (2009). Ergonomic Compatibility Survey for the Evaluation of Advanced Manufacturing Technology, Proceedings of the International Safety and Occupational Ergonomics Conference.

Nicolaisen. P. (1985). Occupational safety and industrial robots-present stage of discussion within the tripartite Group on robotic safety, in Robot Technology and Applications,-Proceedings of the 1st Robotics Europe Conference, Brussels June 27-28, 1984, K. Rathmill, P. MacConaill, S. O'Leary, and J. Brown, Eds., Springer-Verlag, Berlin, pp. 74-89.

Prado León, L. (2001). *Ergonomía y Lumbalgias ocupacionales.*

Sugimoto, N., and Kawaguchi, K. (1985). Fault-tree analysis of hazards created by robots, in Robot Safety, M. C. Bonney and Y.F. Yong, Eds, Spreinger-Verlag, KFS, Berlin, pgs.83-98.

U. S. Bureau of Labor Statistics. 2005. "Survey Occupational Injuries and Illnesse Summary Estimates Package (Appendix B)".