AN INDUSTRY-BASED PERSPECTIVE OF MAINTENANCE OPERATIONS IN MAQUILADORAS

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ABSTRACT

This study empirically investigated the role and implications of industrial maintenance in the maquiladora industry. The response rate was 86% constituting 131 usable questionnaires. Additionally, several in-depth field interviews with experts of maquiladoras were conducted in order to gain insight into the results of the survey.

Equipment maintenance, maquiladoras, survey instrument, functional collaboration, and sources of maintenance problems.

INTRODUCTION

The maquiladora concept, also known as 'production sharing' and 'twin plants', emerged as a new model of manufacturing operations on the border between the United States and Mexico in the 1960s. This mode of manufacturing created tremendous interest among firms in the United States and subsequently among European and Asian firms. Many U.S. companies attempted to develop maquiladora operations to take advantage of low-cost Mexican labor, less restrictive Mexican labor laws and unions, and the ability to be close to newer markets. Dowlatshahi (2005) explained many details of the operational characteristics and the importance of maquiladora industries.

The main focus of TPM is on workers and managers who operate or maintain industrial equipment. This is essential for achieving effectiveness in the use of technology. The TPM is designed to maximize the effectiveness of the equipment by setting and maintaining the best relationships between people and machines.

Principles of Total Preventive Maintenance (TPM)

In order to effectively address and implement TPM, the following five principles must be considered:

1. Autonomous maintenance system. This requires seven steps and includes: initial cleaning of machines and production plants, carrying out counter-measures at the source of problems, developing cleaning and lubrication standards, implementing general inspection routines, effecting an autonomous inspection, and creating full autonomous maintenance.

2. Equipment improvement. The feedback from the previous step is essential for improving equipment. In this step, the maintenance department could work with designers and engineers to create new designs and applications for machines, if necessary. These designs and re-evaluations could include: discovering abnormalities, treating and eliminating abnormalities, setting optimal equipment conditions, maintaining optimal equipment conditions, and providing feedback to the design department.

3. Quality maintenance. Quality function should focus on eliminating accelerated deterioration, eliminating defects, operating machine profitability, and working as a team. This principle requires the identification of sources as well as proper elimination of defects.

4. Maintenance prevention. Preventive maintenance to the machines is like preventive medicine for humans. Preventive maintenance decreases the number of breakdowns and eliminates accelerated deterioration in order to extend the life of equipment. The preventive maintenance step requires planned a preventive maintenance program, evaluating the maintenance program, creating optimal design and operation of equipment, and finally making improvements in systems and work methods.

5. Education, training, and awareness. Training personnel is essential in order to implement and succeed in the TPM process. The personnel must be trained in different areas with different types of education. Some of these training programs include: introductory education, stepwise education (in which operators are jointly trained by production managers and maintenance engineers), inspection education, and routine education.

LITERATURE REVIEW, RESEARCH QUESTIONS, AND TOPIC JUSTIFICATION

The review of literature is designed to support the questions posed in the survey instrument.

Question number 1 of the survey instrument (Collaboration between the maintenance and other functional areas). Dilger (1997) stated that other departments such as the ones initiating work orders for preventive and predictive maintenance, equipment recording and tracking, inventory control, scheduling labor and resources, and purchasing are essential in the proper functioning of maintenance activities. Sivalingam (1997) argued that integrating all aspects of maintenance produces dividends, immediately and in the long term if good management practices are applied along with sound technical expertise. According to Sivalingam (1997) this functional integration could result in cost reductions of 35% or more. Some of these aspects or departments include: paradigm shifts, change, teamwork, training, asset management, warehouse/inventory control, corrective management, and purchasing. Cowley (2006) suggested that the use of data generated by computerized maintenance systems contributes to any serious effort to better interpret the financial side of the maintenance function.

Question number 2 of the survey instrument (Likely sources of maintenance problems (equipment, personnel, and management)). Antosiewicz (1996) defined equipment as the most likely source of maintenance troubles. He proposed various ways of combating equipment

failures. There are many other references where the focus of maintenance problems is placed on the equipment itself. Moore (1997) focused on teamwork, consensus building, and continuous improvement by operators and personnel. The author further stated that TPM principles call for one to avoid crises, foster teamwork, maximize capacity, minimize costs, and continuously improve processes for manufacturing. Bannister (1991) also focused on a team approach that combines the talents of machine operators, management, and the maintenance trades as the backbone of TPM. Vorster (2006) also stated that operators influence the field maintenance costs. Jordan and Gruber (2001) stated that training technicians and personnel on the correct ways to certify the machines and follow the appropriate procedures to better pinpoint problems in the machines have been highly beneficial for operators and the maintenance staff. Brown and McCabe (2005) contended that the best results are achieved by using a team of operators and maintenance personnel facilitated by an experienced moderator to provide objective guidance on failure modes, guide the discussion, and maintain pace and momentum in maintenance activities. Eade (1997) focused on employee involvement, training, and team activity in maintenance operations. The author cited a company whose employee involvement was designed to detect potential maintenance problems and stop them from occurring. On the other hand, Phillips (1997) focused on the role managers play in the upkeep and maintenance activities.

Question number 3 of the survey instrument (Major common losses of maintenance problems). The literature review pertaining to the six major and common sources of maintenance problems, as originally developed by Nakajima (1988), are outlined below:

1. Breakdowns and unplanned plant shutdowns. Gorman (1985) viewed breakdowns and shutdowns as the most common loss of maintenance problems costing as much as three times the cost of a well-planned preventive maintenance program. Ljungberg (1998) stated that TPM is necessary to assess the magnitude of different types of production losses. In many enterprises, the focus is directed toward major time losses due to breakdowns (performance losses) rather than minor losses in speed and time. Knezevic (1994) stated that the prediction of the duration of the downtime caused by maintenance presented a challenge for maintenance managers, because of possible revenue losses. The author further suggested the use of 'group replacement maintenance policy' where individual replacement tasks are performed simultaneously, sequentially, and combined. Skipper (2006) cited a company in which its focus and effort was on reducing failures or the actual number of events that a machine is considered down for unscheduled maintenance and/or failures.

2. Excessive set-ups, changeovers, and adjustments. Gerry and Buckbee (2006) cited a company that could not easily make direct adjustments to its main operations. Instead, the company could make adjustments to compression, fuel mix, operating procedures, and tire pressure to optimize short-term process performance. McIntosh *et al.* (1996) discussed the advantages of design-based solutions for changeovers over incremental, low cost, and team-based approaches, which emphasize organizational changes to the changeover. On the other hand, Mileham *et al.* (1999) focused on a set of rules derived from action research from different companies in order to reduce the changeover time.

3. Machine idling and minor stoppages requiring the attention of the operator. Williams (2003) stated that machine downtimes should be avoided so that operator's time and effort would not go

idle. According to Suehiro (1992) idling and minor stoppages stands for 20-30 per cent of Overall equipment Effectiveness (OEE) in most automated lines.

4. Running and then reducing the speed due to equipment malfunctions. Kalousdian (2006) showed a case where operating speed was used to check the bypass indicators. Then, the equipment was evaluated after a drop in operating speed. Anonymous (2003) showed through another case how operating speed affected the production rate of a given machine. According to Nakajima (1989), the father of TPM, the speed losses are much larger in equipment such as automated machinery, automated assemblers and automated packers.

5. Startup losses due to breakdowns and minor stoppages before the process stabilizes (process defects). Vorster (2006) suggested that repair costs, downtime and reliability, operating conditions, the operators themselves, and the quality of preventive maintenance influenced the actual results and the stabilization of the maintenance process. Chang *et al.* (2007) proposed an approach called 'maintenance opportunity' to mitigate the loss of production during scheduled maintenance activities by strategically shutting down equipment for short-time periods.

6. Quality defects and rework due to equipment malfunctioning. Jeske and Marlow (1997) focused on the proportion of defects in a manufacturing or service-oriented process. The author further noted that these defects were attributable to a specific root cause of equipment malfunctioning. The root-cause problem was then often used to dictate maintenance actions. Raouf (1994) argued that an efficiently maintained plant must produce the right quality and quantity of product to yield high capital productivity. The author further stated that TPM is required to avoid quality defects and achieve high capital productivity. Jordan and Gruber (2001) showed the interrelationships among effective maintenance programs, high reliability machine operation, and better quality parts with less downtime.

Question number 4 of the survey instrument (The role of ISO certification in maintenance). The role of equipment maintenance is crucial and a requirement in ISO certification. Tzelepis *et al.* (2006) empirically explored the role of ISO 9001 as a factor affecting technical and productive inefficiency of firms. The authors concluded that ISO 9001 decreased the level of technical inefficiency of firms. Jordan and Gruber (2001) stated that ISO 9000 companies must have their machines certified. The authors further stated that this certification is critically important to customers because the quality of parts produced depends on the quality of the company's equipment.

Maquiladoras are inherently manufacturing entities with major focus placed on the production of parts and products. The maintenance, upkeep, and effectiveness of industrial equipment are a more crucial issue for maquiladoras than many industries. The lack of equipment availability can adversely affect the entire maquiladora production. Therefore, exploring the role and impact of maintenance in maquiladora is a significant topic for research. This importance is enhanced by the fact that there is virtually no work conducted in this area.

In order to better understand the importance of maquiladoras, the following information sheds some light. At least 17 states in the U.S. have major companies that are engaged in maquiladora trade and commerce (Michie 1987). The significance of maquiladoras to the Mexican economy

and to the U.S. economy cannot be overstated. The nearly 4,000 export manufacturers, including maquiladoras, employ more than one million people (Sowinski 2000). The maquiladora industry performed four percentage points above total industrial growth in 1997 and 1998 in Mexico, which is cited to become the number one maquiladora nation in the world (Carlsen 1998). Lindquist (2001) stated that the maquiladoras helped transform Mexico into one of the world's top 10 manufacturing countries. The author further stated that in 2000 the maquiladora output reached $83 billion, which is one-half of the total of Mexico's exports. The United States is on the receiving end of many of these exports. At the peak of employment at maquiladoras in 2000, nearly 1.3 million workers were employed by maquiladoras (Lindquist 2001).

The relevant issues in maintenance were studied through a survey instrument and extensive field interviews with experts in maquiladora plants in El Paso, TX and Juarez, Mexico. Based on the survey and 11 in-depth interviews of maintenance experts in 10 industries, statistical analyses were performed.

RESEARCH DESIGN

The study covered different industries, different experts in maquiladoras, and different aspects of industrial maintenance that were most relevant to maquiladoras. The questionnaire for this study was designed to be easy-to-read and understand. The questions were as concise and as clear as possible. In order to increase the response rate, difficult and complex questions were avoided. Also, respondent anonymity was offered to the respondents. This anonymity tended to increase the response rate as well as the veracity of the responses.

After a pilot study, the final questionnaire was completed with the assistance of university academicians and maquiladora practitioners. Because of the unique environment of the maquiladora industry, where both Spanish and English are spoken (and not necessarily fluently), two questionnaires were given to each individual at each company, one in each language. The contents of these questionnaires were exactly the same except for the language in which they were prepared. The respondent was asked to return the questionnaire in which he or she felt more comfortable answering. When appropriate, the five-point Likert scale was used.
The unit of analysis was at the company level. One questionnaire was delivered to an individual respondent at each company surveyed. No single company received more than one questionnaire. The questionnaires were targeted to medium- and upper-level management. The respondents were deemed to have direct and meaningful knowledge and involvement with the maintenance issues in their plants.

Data Collection

The study was targeted to manufacturing companies that belonged to the Asociación de Maquiladoras, A.C. (AMAC 2005) or Association of Maquiladoras in Ciudad Juarez and Ciudad Chihuahua, Mexico which border El Paso, Texas, representing the largest concentration of maquiladoras in Mexico. To conduct this study, questionnaires were distributed to the manufacturing members of the AMAC directory. From the AMAC (2005) database of

companies in Ciudad Juarez and Ciudad Chihuahua, Mexico, non-manufacturing-related companies, such as banks, custom brokers, lawyers, service organizations, etc. were initially excluded from the database. The response to the questionnaire was 86 percent; 152 questionnaires were distributed and 131 were returned. It was assumed that the high response rate was due to the fact that respondents were contacted initially by phone. After being contacted by phone, one questionnaire (in duplicate copies of English and Spanish) per company was delivered in person or by fax. Also the questionnaires were given to key contact personnel in the maquiladora industry, which were then distributed to appropriate personnel with knowledge of maintenance in their respective plants.

Classifications of Responses by Type of Industry

The classification of the industries is based on the main types of products that they manufacture. Table 1 presented the classification of industries surveyed.

Table 1. Number and percentage of respondents by type of industry

Type of industry	Number of responses	Percentage of responses	Cumulative percentage of responses
Electronic components	29	22.1%	22.1%
Consumer electronics	24	18.4%	40.5%
Automotive	21	16.0%	56.5%
Textile and apparels	11	8.4%	64.9%
Rubber and plastics	7	5.3%	70.2%
Metals and stamping	6	4.6%	74.8%
Medical	5	3.8%	78.6%
Paper and prints	5	3.8%	82.4%
Wood and furniture	4	3.1%	85.5%
Food and agricultures	3	2.3%	87.8%
Others	16	12.2%	100%
Total	131	100%	

By far the largest industries belonged to electronics components, consumer electronics, and automotive. These three types of industries accounted for 56 percent of the total industries surveyed. These mature industries were established in the El Paso-Juarez area during the late 1960s and early 1970s. Ancillary industries such as wood and furniture, food and agricultures, and metals and stamping showed some of the lowest response rates. These newer maquiladora industries emerged much later (late 1980s and early 1990s) in order to provide support for the plants already established. The number of these plants in the region was generally low.

ANALYSES, FINDINGS, AND ASSESSMENT OF THE RESULTS

The detailed analyses, findings, assessment of the results, future research directions, and references are available upon request from S. Dowlatshahi.