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Cost effectiveness of ergonomic redesign of electronic motherboard

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Abstract

A case study to illustrate the cost effectiveness of ergonomic redesign of electronic motherboard was presented. The factory was running at a loss due to the high costs of rejects and poor quality and productivity. Subjective assessments and direct observations were made on the factory. Investigation revealed that due to motherboard design errors, the machine had difficulty in placing integrated circuits onto the pads, the operators had much difficulty in manual soldering certain components and much unproductive manual cleaning (MC) was required. Consequently, there were high rejects and occupational health and safety (OHS) problems, such as, boredom and work discomfort. Also, much labour and machine costs were spent on repairs. The motherboard was redesigned to correct the design errors, to allow more components to be machine soldered and to reduce MC. This eliminated rejects, reduced repairs, saved US $581,495/year and improved operators' OHS. The customer also saved US $142,105/year on loss of business.

Keywords: Quality and productivity; Occupational health and safety; Industrially developing countries

1. Introduction

One of the major debates on the use of ergonomics in the factories in industrially developing countries (IDCs) is whether it is cost effective or not. Most of these factories are already facing great difficulty in surviving the competitive world market; hence, they cannot afford to introduce ergonomics to improve the working conditions of their workers. This is because they think that ergonomics is expenditure rather than an investment. This trend of thought is more common amongst the managers in IDCs, possibly because ergonomics is still very new to them (Sen, 1984, 1998; O'Neill, 2000).

There were many ergonomic studies conducted in Industrially Advanced Countries (IACs) that had proven the cost effectiveness of ergonomics. To name a few, Marcotte and Kessler (1997) did a 6-year study on a games manufacturing company and found that application of ergonomics to product design and manufacturing process had saved over US $1 million in direct manufacturing cost. Helander and Burri (1995) presented four case studies of ergonomics applied to electronic manufacturing which resulted in cost savings of approximately US $130 million. Abrahamsson (2000) did an ergonomic study on a Swedish steel factory to improve the quality, productivity, working environment and Occupational Health and Safety (OHS) of the workers; and found that the study yielded a good profit.

However, a very few cost effective studies had been conducted in IDCs, e.g. Sen and Yeow (1999) and Yeow and Sen (1999a, b, 2000) conducted four studies of ergonomic interventions on an electronic manufacturing factory in an IDC, which had saved approximately US $0.3 million/year on rejection costs and improved quality, productivity and OHS. To our knowledge, there has been no study conducted so far on the cost effectiveness of ergonomic redesign of electronic motherboard. For this reason, the present research undertook to investigate the cost effectiveness of the ergonomic redesign of electronic motherboard in a computer peripheral manufacturing factory, located in Malaysia, an IDC. The brief preliminary findings of this research were presented by Sen and Yeow (2001). The current paper presents the final findings.

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2. Method

2.1. Procedures

Initially, a plant walk-through was conducted with the production and engineering managers, engineers and supervisors. A general idea of the problems was identified in the discussion during the walk-through. After that, questionnaire interviews were conducted with 33 production operators. Later, direct observations (Drury, 1995a) were made on the production line to further investigate the problems. These were done through watching video recordings of the operators at work in every production process for three shifts. Operators were asked questions to further confirm the observations. Current and archival data (Drury, 1995b) from the production and cost accounting were retrieved and analysed to study the extent of the problems. Appropriate ergonomic interventions were implemented to solve the problems. Follow-up studies were then conducted to determine the effectiveness of the interventions.

2.2. Interview questionnaire design

Interview questionnaire was designed, tested and finalised using Sinclair's (1995) subjective assessment method. There were 13 open-ended and close-ended questions altogether, related to workstation design, work process, work environment, work difficulties, quality, productivity, OHS and motherboard design problems. The open-ended questions were used to explore the operators' work-related problems and to get suggestions to overcome them. The close-ended questions were used with Likert's 5-point scale to describe the intensity of specific problems highlighted earlier during the plant walk-through.

Interviews were conducted with one operator at a time and each interview took about 0.5–1 h to complete. The interviewer was knowledgeable of the electronic motherboard manufacturing process so that he could easily understand the operators' responses and record them in the questionnaire.

2.3. Interview participants

The 33 participants were female operators aged between 16 and 26 years, with the mean age of 19 years. They had at least 9 years of school education. They were all local operators, with an average experience of 2.3 years in the factory.

2.4. Materials

In the direct observations, a video camera (model GR-AX20 manufactured by JVC, Japan), and a video player, with the slow-motion playback functions, were used.

A high-powered microscope ($60\times$ magnification, manufactured by Cannon, Japan) with measuring scales was used to investigate the motherboard design problems.

2.5. Analysis

The data collected from the interviews were analysed for trends of problems related to work and OHS. Tasks analyses were conducted during the direct observations to further investigate the trends. Percentages of rejection rate, productivity, customer returns, loss of business, etc. and their associated costs were calculated from the production and cost accounting data to measure the magnitude of the problems and the extent of improvements, before and after the ergonomic redesign.

3. Results

3.1. Manufacturing processes

The motherboard went through five consecutive processes as follows:

1. *Solder paste depositing process*: The motherboard was inserted into a screen-printing machine that deposited solder paste on the connecting pads of the motherboard.
2. *Surface mounted component placement* (*SMTCP*) *process*: The motherboard (with solder paste) was transported by a conveyor belt into the SMTCP machine that mounted the surface mounted technology (SMT) components on the connecting pads. The motherboard was then transported by a conveyor belt into an oven where the solder paste was transformed into solder joints, connecting the components and the pads.
3. *Manual soldering* (*MS*) *process*: The wire leaded components were inserted on the motherboard and were hand soldered using soldering iron.
4. *Manual cleaning* (*MC*) *process*: The patches of solder flux on the motherboard were manually removed by brushing alcohol on the motherboard and wiping it with lint-free papers.
5. *Inspection and test process*: The motherboard was visually inspected for soldering defects and electrically tested for component failures.

3.2. Factory's problems

Previously, the factory and its customers were facing very high costs (see Table 1) attributed to the problems in manufacturing, such as, high rejects, poor quality,