A METHODOLOGY FOR HUMAN FACTORS UTILITY ANALYSIS
IN QUALITY INSPECTION WORKSTATION DESIGN

طريقة لتحليل فائدة العوامل الإنسانية
في تصميم محطة فحص الجودة

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ABSTRACT

This paper addresses a very critical issue relating human factor to the quality inspection workstation design. In lot of instances these workstations lack the consideration of human capabilities and limitations in their design, which could be included to enhance both the productivity and safety of the workplace and more importantly of the inspector, the paper presents a methodology which is easy to use and can be effectively applied to provide an analyt with a measure to compare the existing quality inspection station design utility with the utility of many number of alternate options having varying applications of human factors in their design. Also these new systems could be compared between each other. The major human factor features identified and included in the analysis are namely, the time available for inspection, lighting for task, inspector's vision and inspector's posture. The major goals identified are, improved inspector's detectability, better inspection consequence, improved product reputation and better inspection procedure and steps.
These goals are considered under productivity category whereas, three other goals are identified under health and safety category, these include the reduction of compensation costs, reduction of governmental fines and penalties and minimization of lost time due to injuries and accidents because of poor human factor considerations in the design of the station. In general this paper presents a very practical, hands on and easy methodology for human factor justification in redesigns of the existing quality inspection workstations.

INTRODUCTION

Quality inspection tasks requires extensive decision making from the inspections, even thought the decisions are generally simple but they have to make a number of decisions. As the inspector looks at every part, he or she has to decide if the required specifications are met and should the part be accepted or rejected. There is a good chance that the inspector may forget to look for a particular specification, especially, if the choices are many. This would result in the acceptance of defective items (Type I Error) or rejection of non-defective items (Type II Error). If both of these errors are reduced then the inspection performance will improve, which will result in increased productivity, customer satisfaction cost savings and better health and safety of inspector.

Human Factors Engineering aims to look at workplaces from a human angle and tries to improve the work environment for the human which in turn results in the increased productivity, safety and health of the worker. Some of the major human factor variables that can influence the performance of the quality inspector are also difficult to quantify due to their intangible nature, these variables are briefly described in the following section. A methodology is needed to quantify these variables to compare the total human factor utility of two or more systems.

(i). Time Available for Inspection

Inspection jobs are normally either paced or unpaced. In a paced line, the inspector has to detect several types of defects in a certain period of time resulting in both type I & II errors especially if the line is not designed properly or and the defects are too many or and the workplace is not designed properly. A human system can only at a certain speed which depends on individual's maximum physical and mental capacity. Unpaced tasks may be non productive or may cause unhealthy postures etc., therefore, a well designed workplace incorporating both the human abilities and limitations can improve the inspector's performance several folds.
(ii). Lighting

Improper lighting can make objects appear different, the light should preserve the color of objects especially for inspection type tasks. The optimum amount of light falling on the work area or the workplace is important in defect detectability, this light depends on light location, intensity, surface texture etc., also due to more energy cost consciousness the tendency to limit the illumination in factories can have serious effects on the inspection quality. Some of the relevant standards in lighting include the British code CIBS (1984) and American Code IES (1979).

(iii). Inspector’s Vision

The inspector’s vision is probably the most important factor in his/her ability to detect a defect, the visual acuity varies between individuals and can be measured to categorize the inspector’s ability to detect a defect.

(iv). Posture

A workplace that forces a person to take a poor posture because of improper table or chair heights, adjustments etc. can affect the performance, because the long term effects of these postures can cause static muscle loading which results in excessive fatigue and hence increased errors and slower reaction times.

In order to evaluate the benefits in terms of economics of implementing the human factor variables in the design of inspection workplaces, this paper addresses the above intangibles and include them in an economic analysis of including human factor variables in improving the existing work places or designing/procuring new inspection workplace. The methodology presented is general, so it has variety of applications, for e.g., the financial analyst in collaboration with human factor, safety or engineering personnel can rate different human factor variables on a subjective scale. Several researchers (Drury 74, Nelson and Barany 69, Wallack & Adams 69, Bloomfield 75) have addressed the issue of human factor relevance to quality inspection tasks. Flion and Fazer (1982) have addressed the costs associated with Type I Error in the inspection tasks, however, this paper aims at tackling this old problem with a fresh approach and helps to aid the analyst to justify the changes in a more meaningful way.

Proposed Methodology:

In order to deal with the human factor intangibles in a quality inspection task. A methodology is presented that could be used to evaluate the inspection workstations from human factors utility standpoint. The subjective scale for each critical factor is described in the following section. It should be noted that the scale of 1 to 100 is at par with the percentage of 1 to 100.

1. TIME AVAILABLE FOR INSPECTION

Work performance duration at manual operated workstations is not actually the average performance time. The performance time per each working cycle will vary because:

(a) The working pace of each individual inspector varies throughout the working period or working day, and
(b) no two individual inspectors work at the same pace through the working period.

Task durations in manual operated workstations are actually random variables which can be approximated by a normal distribution (Dudley 1963). Based on the previous facts and using a rating system for the operator comfort form 1% (worst condition or lowest comfort) to 100% (best condition or highest comfort), it should be noted here that the zero present for worst case was avoided mainly due to the fact that utility function may become zero and also a perfectly worst workplace is very uncommon. Knowing the parameters of the task duration distribution such as the population mean \( \mu \) and its standard deviation \( \sigma \), the shortest time, i.e. "1" on the scale of 1 to 100, corresponds to the most uncomfortable situation for the operator or inspector to perform the assigned task, where the shortest duration is the available time for the inspector to complete the assigned task, i.e. 100 on the scale of 1 to 100. (fig. 1)

![Normal Distribution for Inspection Task Performance](image)

**Fig. 1. Normal distribution for inspection task performance.**

S.D.T = Short duration time \( \{ \geq \mu - 3\sigma \rightarrow 1\% \} \)

L.O.T = Longest duration time \( \{ \geq \mu + 3\sigma \rightarrow 100\% \} \)

M.D.T = Median duration time \( \{ \approx \mu = 50\% \} \).

Using normal distribution tables, the percentage of comfort which corresponds to any duration time available for the operator can be determined as follows:

\[
Z = \frac{X_t - \mu}{\sigma}
\]

where,

- \( Z \) = Standardized normal value
- \( X_t \) = Time available for inspector
- \( \mu \) = The population mean (station mean performance time),
- \( \sigma \) = The population standard deviation.

The percentage of comfort (area under the normal distribution curve) corresponds to the \( Z \)-value can be generated.
2. LIGHTING

On a scale of 1 to 100, where 100 is the best and 1 the worst, each division in the scale represents a one percent deviation in any direction from the standard for lighting for a particular workstation setup. For e.g. 5% deviation would represent a subjective scale number of 95.

3. INSPECTOR'S VISION

The inspector with a perfect vision would represent the best (100) and the one with the worst vision represent the worst (1). The visual acuity or ability to see can be obtained on a standard optometric testing device or from inspector's medical records.

4. Posture

A posture can be rated from the worst (1) to the best (100) depending on the extended reaches of body parts, excessive static or dynamic muscle work, improper or proper table and chair designs etc. The posture during inspection tasks can be rated based on the established human factor and biomechanics principles.

A methodology to incorporate intangible or qualitative factors is applied to the human factor in inspection station design problem. Utility over cost ratio could be used to deal with this problem. This idea came from benefit over cost ratio concept, but since the benefits are not so easily determined, therefore utility theory is used in this regard.

A model is presented in this paper, the basic parts of this utility model are described as follows:

Methodology Layout, Notation and Equations

Features $F_j$ (as described above)

I. Time available for inspection (Rating = $F_1$).
II. Lighting (Rating = $F_2$).
III. Inspector's Vision (Rating = $F_3$).
IV. Posture (Rating = $F_4$)
Goals $G_j$ (as described above)

1. Productivity: (Rating = $G_{1}$).
   A. Improved inspector’s detectability (Rating = $G_{11}$).
   B. Better inspection consequences: Product sorting and rectification (Rating = $G_{12}$).
   C. Improve product/Industry reputation (Rating = $G_{13}$).
   D. Better inspection procedure and steps (Rating = $G_{14}$).

2. Health and Safety: (Rating = $G_{2}$).
   I. Minimize worker compensation (Rating = $G_{21}$).
   II. Minimize Governmental fines or penalties (Rating = $G_{22}$).
   III. Reduce lost time due to unsafe or unhealthy events leading to accidents or injuries (Rating = $G_{23}$).

The layout template for the methodology is described in the following section. Also the Productivity & Safety categories are rated on a scale of 1 to 100% so that the sum of all categories with productivity and safety should be exactly 100%, where 100% represents the best and 1% the worst.

The notation for tables 1 and 2 are described as follows:

Notation and Equations

$F_i$ Feature $i$ Rating $i = 1,2,3,...,N$
$G_j$ Goal $j$ Rating $j = 1,2,...,J$
$k$ Goal category $k = 1,2,3,...,K_j$
$G_{jk}$ Category $k$ of goal $G_j$ (No. of categories $K_j$ can be different from goal $G_j$).
$K_j$ Number of categories of goal $G_j$
$U_{Fi}$ Utility of feature $i$ for all stated goals

OTHER:

$U_{F1}$ Time available utility
$U_{F2}$ Lighting utility
$U_{F3}$ Inspector’s vision utility
$U_{F4}$ Posture utility
$G_{1}$ Productivity Goal
$G_{1k}$ Productivity goal categories rating $k = 1,...,K_1$ where $K_1$ is the category number
$G_{2}$ Health and Safety Goal
$G_{2k}$ Health and safety categories rating $k = 1,...,K_2$ (where $K_2$ is the category number)
THFU Total human factor utility
THFC Total human factor cost
THFU/THFC Total human factor utility over cost ratio.
Table 1

<table>
<thead>
<tr>
<th>$g_j$ (Rating)</th>
<th>$c_j$ (j=1,2,3,...,n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_1$</td>
<td>$g_{11}$  $g_{12}$  $g_{13}$  $g_{14}$</td>
</tr>
<tr>
<td>$f_2$</td>
<td>$f_{21}$  $f_{22}$  $f_{23}$  $f_{24}$</td>
</tr>
<tr>
<td>$f_3$</td>
<td>$f_{31}$  $f_{32}$  $f_{33}$  $f_{34}$</td>
</tr>
<tr>
<td>...</td>
<td>...  ...  ...  ...</td>
</tr>
<tr>
<td>$f_n$</td>
<td>$f_{n1}$  $f_{n2}$  $f_{n3}$  $f_{n4}$</td>
</tr>
</tbody>
</table>

$u_{f_1} = f_1 \left( k^1_{1k} g_{1k} + k^2_{1k} g_{2k} + k^3_{1k} g_{3k} + \ldots k^m_{1k} g_{mk} \right)$

$u_{f_2} = f_2 \left( k^1_{2k} g_{1k} + k^2_{2k} g_{2k} + k^3_{2k} g_{3k} + \ldots k^m_{2k} g_{mk} \right)$

$u_{f_3} = f_3 \left( k^1_{3k} g_{1k} + k^2_{3k} g_{2k} + k^3_{3k} g_{3k} + \ldots k^m_{3k} g_{mk} \right)$

$u_{f_n} = f_n \left( k^1_{nk} g_{1k} + k^2_{nk} g_{2k} + k^3_{nk} g_{3k} + \ldots k^m_{nk} g_{mk} \right)$
### Table 2

<table>
<thead>
<tr>
<th>Goal Categories Rating</th>
<th>Features Rating</th>
<th>Productivity Goal ((G_1))</th>
<th>Health and Safety Goal ((G_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(G_{11})</td>
<td>(G_{12})</td>
<td>(G_{13})</td>
<td>(G_{14})</td>
</tr>
<tr>
<td>(F_1)</td>
<td>(F_{11})</td>
<td>(F_{12})</td>
<td>(F_{13})</td>
</tr>
<tr>
<td>(F_{2})</td>
<td>(F_{21})</td>
<td>(F_{22})</td>
<td>(F_{23})</td>
</tr>
<tr>
<td>(F_{3})</td>
<td>(F_{31})</td>
<td>(F_{32})</td>
<td>(F_{33})</td>
</tr>
<tr>
<td>(F_{4})</td>
<td>(F_{41})</td>
<td>(F_{42})</td>
<td>(F_{43})</td>
</tr>
</tbody>
</table>

\[ u_{F_1} = F_1 \left( \sum_{k=1}^{3} G_{1k} \right) \]
\[ u_{F_2} = F_2 \left( \sum_{k=1}^{3} G_{2k} \right) \]
\[ u_{F_3} = F_3 \left( \sum_{k=1}^{3} G_{1k} \right) \]
\[ u_{F_4} = F_4 \left( \sum_{k=1}^{3} G_{2k} \right) \]

\[ \text{THFU} = \sum_{i=1}^{4} u_{F_i} = \sum_{i=1}^{4} F_i \left( \sum_{k=1}^{3} G_{1k} + \sum_{k=1}^{3} G_{2k} \right) \]
Table 1: describes the general matrix arrangement of various features and goals as a general case, it also presents general equations for calculating the utility of a particular feature (UFc) and also the total human factor utility (THFU). Table 2: gives a more specific description based on the four features presented in this paper and limits itself to productivity and safety goals, however, the subcategories of goals left as general.

Utility equation for each feature is presented along with an equation of total human factor utility.

Discussion and Conclusions:

The enhancement of productivity, health and safety of a quality inspection workplace critically depends on the consideration of human variable in various aspects. The main issue with the management of most industries is the cost justification with respect to the utility of the new changes.

The methodology presented in this paper can assist the management to make more objective decisions with quick and easy interpretation of the analysis results, however, it is very important that the ratings be obtained carefully with the involvement of concerned individuals, professionals, and departments to minimize the bias or subjective error in the final results. It is also important that the cost component be obtained after close consultation with the costing departments. In the presence of reasonable data and ratings, the output of the methodology helps in aiding the decision maker to make a decision about a given manual in inspection workstation with better authority.

References


