# A METHODOLOGY FOR HUMAN FACTORS UTILITY ANALYSIS IN QUALITY INSPICTION WORKSTATION DESIGN

# طريقة لتحليل فائدة العوامل الانسانية فى تصميم محطة فحص الجودة

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ملخص البحث: يتناول هذا البحث موضوع العوامل الانسانية فى تصميم محطة فحص الجوده، حيث نجد أن هذه المحطات كثيرا مما تتخلف عن اخذ واعتبار القدرات والامكانيات ونواحى القصور البشرية في تصميمها، والتى ستدعم انتاجية وأمان المحطة أذا تم اعتبارها فى التصميم والأكثر من هذا اهميتها لعامل الفحص. ويقدم هذا البحث طريقة ومنهجا سهل الاستخدام ويمكن تطبيقه بكفاءة لامداد المحلل بمقياس لمقارنة الفائدة الناتجة من التصميم الحالى لمحطة فحص الجودة مع الفائدة الناتجة لكل من التصميمات البدائل الأخرى والتى تحتوى على تطبيقات متباينة للعوامل الإنسانية فى تصميمها. وباستخدام المنهج المقدم فى هذا البحث يمكن ايضا مقارنة التصميمات الجديدة مع بعضها البعض. وقد تم تحديد واستعمال المعالم الرئيسية للعوامل الانسانية وهى الوقت المتاح للفحص والاضاءة للعمليات وقوة ابصار عامل الفحص وكذلك وضعه. وايضا تم تحديد وتعريف الأهداف الرئيسية وهى: تحسين امكانية الفحص للعامل، وعواقب الفحص الأفضل وتحسين سمعة وشهرة المنتج وكذلك افضل اسلوب لخطوات الفحص وتم تحديد هذه الأهداف تحت مسمى فئة الانتاجية، بينما تم تحديد ثلاثة أهداف اخرى تحت مسمى فئة الصحة والأمان، وتشمل التقليل من تكاليف التعويض، والتقليل من الوقت الضائع نتيجة للحوادث والجروح التى تحدث بسبب افتقار تصميم المحطة للعوامل الانسانية. وعموما فإن هذا البحث يقدم منهجا وأسلوبا عمليا سهل التناول لادخال واعتماد العوامل الانسانية فى إعادة تصميم محطات ضبط الجوده

## ABSTRACT

**This paper addresses a very crictial issue relating human fector to the quality inspection workstation design. In lot of istance these worstations 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 provoied an analyat with a measure to compare the exsisting quality inapection 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 namly, 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 minimizstion of lost time due to injuries and accidents because of poor human factor consideeations 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

Qulity 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 individuals 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 workpiece 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 serioue 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 effect 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 ecnomics 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 existiong work places or designing/procuring new inspection workplace. The methodology presented is general, so it has variety of applicationa, for e.g., the financial analyst in collaboration with hunman 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. Ballon and Pazer (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 approech 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 intangiblee in a quality inspection task. A methodology is presented that could be used to evaluate the inspection workstations from human factors utilify standpoint. The subjective scale for each critical factor is decribed 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 worstations 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 wotrking day, and

(b) no two individual inspectors work at the same pace throught the working period.

Task durations in manual operated workstations are actually random veriable which can be approximated by normal distribuation (Dudley 1963). Based on the previoue facts end using a rating system for the operator comfort form 1% (worst condition or lowest comfort) to 100% (beat condition or highest comfort). It should be noted here that the zero precent for worst case was avoided mainly due to the fact that utility function may becoms 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 devision ( $\sigma$ ), the shortest time, i.e. "1" on the ecale of 1 to 100, corresponds to the most uncomfortable situstion for the operator or inspetor 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)

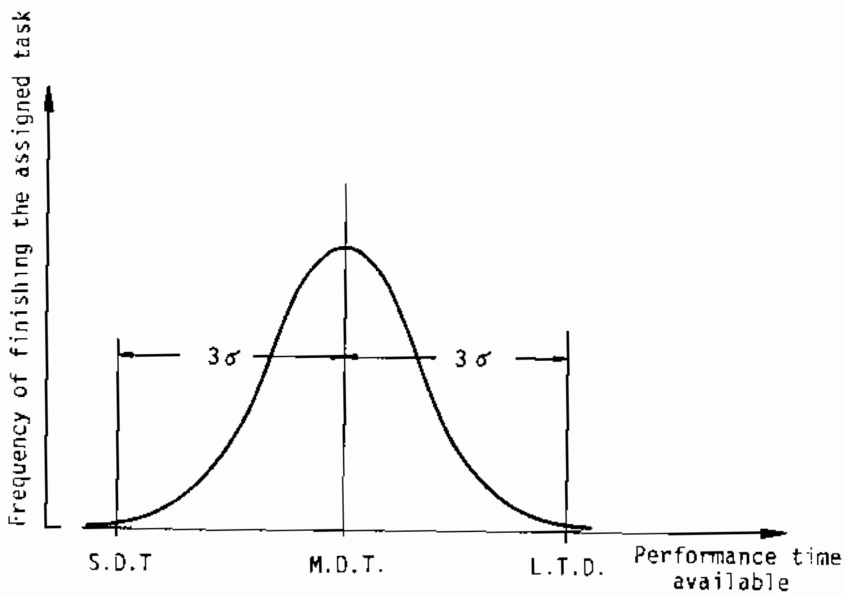


Fig.1: Normal distribution for inspection task performance.

S.D.T = Short duration time $\{> \mu - 3\sigma \rightarrow 1\%\}$

L.D.T = Longest duration time $\{= \mu + 3\sigma \rightarrow 100\%\}$

M.D.T = Mean duration time $\{= \mu = 50\%\}$.

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

$$Z = \frac{X_i - \mu}{\sigma}$$

where,

$Z$ = Standardized normal value

$X_i$ = 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 distribuation 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 woud 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 reted from the worst (1) to the best (100) deperding on the extended reaches of body parts, excessive static or dynamic muscle work, improper or proper table and chair designs ect. The posture during inspection tasks can be reted besed on the established human factor and biomechanics principles.

A methodology to incorporate intangible or qualitative factors is appliad to the human factor in inspection stetion 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 eesily 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 $F_i$ (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 detectabily (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. (Reting = $G_{14}$ ).

**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 Productivy & 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 $(k=1,2,3,...K_j)$

$G_{jk_j}$ 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 $G_j$

$U_{F_i}$ Utility of feature i for all stated goals

## OTHER:

$U_{F_1}$ Time available utility

$U_{F_2}$ Lighting utility

$U_{F_3}$ Inspector's vision utility

$U_{F_4}$ 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 categgories reting$(k=1,...K_2)$where $K_2$ is the category number

THFU Total human factor utility

THFC Total human factor cost

$\frac{THFU}{THFC}$ Total human factor utility over cost ratio.

Table 1

GOALS (Rating) $G_j$ $(j=1,2,3,....J)$

| | $G_1$ | | | | | $G_2$ | | | | | | $G_J$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $F_i$ | $G_{11}$ | $G_{12}$ | $G_{13}$ | $G_{1k}$ | $F_i \sum_{k=1}^{K_1} G_{1k}$ | $G_{21}$ | $G_{22}$ | $G_{23}$ | $G_{2K_2}$ | $F_i \sum_{k=1}^{K_2} G_{2k}$ | ... | $G_{J1}$ | $G_{J2}$ | $G_{J3}$ | $G_{JK_J}$ | $F_i \sum_{k=1}^{K_J} G_{JK}$ | $F_i \sum_{k=1}^{J} \sum_{k=1}^{K_J} G_{Jk}$ |
| $F_1$ | $F_1G_{11}$ | $F_1G_{12}$ | $F_1G_{13}$ | $F_1G_{1k_1}$ | $F_1 \sum_{k=1}^{K_1} G_{1k}$ | $F_1G_{21}$ | $F_1G_{22}$ | $F_1G_{23}$ | $F_1G_{2k_2}$ | $F_1 \sum_{k=1}^{K_1} G_{2k}$ | ... | $F_1G_{J1}$ | $F_1G_{J2}$ | $F_1G_{J3}$ | $F_1G_{JK_J}$ | $F_1 \sum_{k=1}^{K_J} G_{JK}$ | $F_1 \sum_{j=1}^{J} \sum_{k=1}^{K_J} G_{jk}$ |
| $F_2$ | $F_2G_{11}$ | $F_2G_{12}$ | $F_2G_{13}$ | $F_2G_{1k_1}$ | $F_2 \sum_{k=1}^{K_1} G_{1k}$ | $F_2G_{21}$ | $F_2G_{23}$ | $F_2G_{23}$ | $F_2G_{2k_2}$ | $F_2 \sum_{k=1}^{K_2} G_{2k}$ | ... | $F_2G_{J1}$ | $F_2G_{J2}$ | $F_2G_{J3}$ | $F_2G_{JK_J}$ | $F_2 \sum_{k=1}^{K_J} G_{JK}$ | $F_2 \sum_{j=1}^{J} \sum_{k=1}^{K_J} G_{jk}$ |
| $F_3$ | $F_3G_{11}$ | $F_3G_{12}$ | $F_3G_{13}$ | $F_3G_{1k_1}$ | $F_3 \sum_{k=1}^{K_1} G_{1k}$ | $F_3G_{21}$ | $F_3G_{23}$ | $F_3G_{23}$ | $F_3G_{2k_2}$ | $F_2 \sum_{k=1}^{K_2} G_{2k}$ | ... | $F_3G_{J1}$ | $F_3G_{J2}$ | $F_3G_{J3}$ | $F_3G_{JK_J}$ | $F_3 \sum_{k=1}^{K_J} G_{JK}$ | $F_3 \sum_{j=1}^{J} \sum_{k=1}^{K_j} G_{jk}$ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | | ⋮ | ⋮ | ⋮ | ⋮ | | |
| $F_N$ | $F_NG_{11}$ | $F_NG_{12}$ | $F_NG_{13}$ | $F_NG_{1k_1}$ | $F_N \sum_{k=1}^{K_1} G_{1k}$ | $F_NG_{21}$ | $F_NG_{23}$ | $F_NG_{23}$ | $F_NG_{2K_2}$ | $F_N \sum_{k=1}^{K_3} G$ | | $F_NG_{J1}$ | $F_NG_{J2}$ | $F_NG_{J3}$ | $F_NG_{JK_J}$ | $F_N \sum_{k=1}^{K_J} G_{Jk}$ | $F_N \sum_{j=1}^{J} \sum_{k=1}^{K_j} G_{jk}$ |
| | | | | | $\sum_{i=1}^{N} F_1 \sum_{k=1}^{K_1} F_{1k}$ | | | | | $\sum_{i=1}^{N} F_1 \sum_{k=1}^{K_2} G_{2k}$ | | | | | | $\sum_{i=1}^{N} F_i \sum_{k=1}^{K_J} G_{Jk}$ | $\sum_{i=1}^{N} F_i \sum_{j=1}^{J} \sum_{k=1}^{K_j} G_{jk}$ |

$$U_{F_1} = F_1 \left( \sum_{k=1}^{K_1} G_{1k} + \sum_{k=1}^{K_2} G_{2k} + \sum_{k=1}^{K_3} G_{3k} + ....... + \sum_{k=1}^{K_J} G_{Jk} \right)$$

$$U_{F_2} = F_2 \left( \sum_{k=1}^{K_1} G_{1k} + \sum_{k=1}^{K_2} G_{2k} + \sum_{k=1}^{K_3} G_{3k} + ....... + \sum_{k=1}^{K_J} G_{Jk} \right)$$

$$U_{F3} = F_3 \left( \sum_{k=1}^{K_1} G_{1k} + \sum_{k=1}^{K_2} G_{2k} + \sum_{k=1}^{K_3} G_{3k} + ....... + \sum_{k=1}^{K_J} G_{Jk} \right)$$

$$\vdots$$

$$U_{F_N} = F_N \left( \sum_{k=1}^{K_1} G_{1k} + \sum_{k=1}^{K_2} G_{2k} + \sum_{k=1}^{K_3} G_{3k} + ....... + \sum_{k=1}^{K_J} G_{Jk} \right)$$

$$\text{THFU} = \sum_{i=1}^{N} U_{F_i} = \sum_{i=1}^{N} F_i \sum_{j=1}^{J} \sum_{k=1}^{K_j} G_{jk}$$

Table 2

GOALS $G_j$

| Goal Categories Rating / Features Rating | Productivity Goal ($G_1$) | | | | | Health and Safety Goal ($G_2$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $G_{11}$ | $G_{12}$ | $G_{13}$ | $G_{14}$ | $F_i \sum_{k=1}^{K_1} G_{1k}$ | $G_{21}$ | $G_{22}$ | $G_{23}$ | $F_i \sum_{k=1}^{K_2} G_{2k}$ |
| $F_1$ | $F_1 G_{11}$ | $F_1 G_{12}$ | $F_1 G_{13}$ | $F_1 G_{14}$ | $F_1 \sum_{k=1}^{4} G_{1k}$ | $F_1 G_{21}$ | $F_1 G_{22}$ | $F_1 G_{23}$ | $F_1 \sum_{k=1}^{3} G_{2k}$ |
| $F_2$ | $F_2 G_{11}$ | $F_2 G_{12}$ | $F_2 G_{13}$ | $F_2 G_{14}$ | $F_2 \sum_{k=1}^{4} G_{1k}$ | $F_2 G_{21}$ | $F_2 G_{22}$ | $F_2 G_{23}$ | $F_2 \sum_{k=1}^{3} G_{2k}$ |
| $F_3$ | $F_3 G_{11}$ | $F_3 G_{12}$ | $F_3 G_{13}$ | $F_3 G_{14}$ | $F_3 \sum_{k=1}^{4} G_{1k}$ | $F_3 G_{21}$ | $F_3 G_{22}$ | $F_3 G_{23}$ | $F_3 \sum_{k=1}^{3} G_{2k}$ |
| $F_4$ | $F_4 G_{11}$ | $F_4 G_{12}$ | $F_4 G_{13}$ | $F_4 G_{14}$ | $F_4 \sum_{k=1}^{4} G_{1k}$ | $F_4 G_{21}$ | $F_4 G_{22}$ | $F_4 G_{23}$ | $F_4 \sum_{k=1}^{3} G_{2k}$ |
| | | | | | $\sum_{i=1}^{4} F_i \sum_{k=1}^{4} G_{1k}$ | | | | $\sum_{i=1}^{4} F_i \sum_{k=1}^{3} G_{2k}$ |

$$U_{F_1} = F_1\left(\sum_{k=1}^{4} G_{1k} + \sum_{k=1}^{3} G_{2k}\right) \qquad U_{F_2} = F_2\left(\sum_{k=1}^{4} G_{1k} + \sum_{k=1}^{3} G_{2k}\right)$$

$$U_{F_3} = F_3\left(\sum_{k=1}^{4} G_{1k} + \sum_{k=1}^{3} G_{2k}\right) \qquad U_{F_4} = F_4\left(\sum_{k=1}^{4} G_{1k} + \sum_{k=1}^{3} G_{2k}\right)$$

$$THFU = \sum_{i=1}^{4} U_{F_i} = \sum_{i=1}^{4} F_1 \left(\sum_{k=1}^{4} G_{1k} + \sum_{k=1}^{3} G_{2k}\right)$$

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 ( $U_{F_i}$ ) and also the total human factor utility (THFU). Table 2: gives a more specific decripition based on the four features presented in this peper 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 whith quick and easy interpretation of the analysis results, however, it is very important that the retings be obtained carefully with the involvement of concerned individuals, professionals and departments to mininize 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 marker to make a decision about a given manual in spection workstation with better authority.

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