Productivity Enhancements Using Ergonomics Methodology: A Case Study of Train Drivers

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1. Introduction

Crew scheduling is extremely important for the efficient functioning of many companies. In a large organization, formulating an ideal crew schedule is a difficult task. Breaks, allowances, as well as shift durations are important constraints when designing a crew scheduling system. Due to these constraints and the characteristics of the work to be realized, crew scheduling algorithms applied to real working environments normally result in duties that include idle time and allocated time not required for "on-the-job" tasks. In urban transportation systems, achieving optimality in the scheduling of drivers' shifts is further hampered by labor legislation, company rules, fluctuations in service demand through the day, etc. The "idle time" included in duties tend to have two adverse effects: it lowers productivity and it also lowers employee morale, motivation, thereby reducing productivity further. The result is a vicious cycle.

This paper reports one aspect of a train driver task with the objective of improving overall productivity. Using physiological and subjective measures, worker stress has been quantified. These measures formed the basis for changes in scheduling parameters to improve the driver working conditions. Their implications on productivity have also been evaluated.

2. Methodology

Subjects

A total of 255 drivers (mean age =33.8 years and mean working hours per week = 50.6) were surveyed using a pre-designed questionnaire to obtain subjective perceptions related to their job. In addition, 23 (mean age = 36) out of the 255 subjects consented to the measurement of their heart rates throughout a complete shift.

Equipment

POLAR telemetric heart rate monitors were used. The questionnaire was designed in collaboration with the train company to ensure its appropriateness and validity. The aims of the questionnaire were to determine the sources of stress at work and possible remedies to reduce the work stress.

Procedure

The heart rate sensor was positioned on the chest and tightened in place to obtain a reliable reading. The monitor was programmed to record heart rate every 15 seconds.

3. Results and Analysis

Physiological and Questionnaire

The questionnaire analysis revealed that 75% of the drivers indicated that the stipulated meal allowance of 40 minutes (30 minutes for meals and 10 minutes walk to and from meal facilities) was inadequate. Further analysis showed that 35% of the drivers preferred a 60 minute meal break while 53% did not indicate any preferred level. The inadequacy is also seen in the heart rate reserve measure. Percent Heart Rate Reserve (% HRR) was calculated for each driver using driver age and resting heart rate (Eastman Kodak Company, 1986) as follows:

$$\text{Percent Heart Rate Reserve (\% HRR)} = \frac{\text{(Working Heart Rate-Resting Heart Rate)*100}}{\text{(Maximum Heart Rate-Resting Heart Rate)}}$$

where Maximum Heart Rate = (220-age)

To evaluate the driver job demand during each shift, the shift was broken into three segments:
1. Working time before break
2. Break (meal time, that is lunch or dinner depending on time of shift)
3. Working time after break

An Analysis of Variance (ANOVA) performed on these % HRR values indicated a significant effect at the $p < 0.05$ level. The post-hoc Student Newman Keuls analysis showed that the % HRR values during break time was significantly higher. Even though the % HRR during meal break time was lower than the allowable of 33% for a 8-hour period (Eastman Kodak Company, 1986), it poses an important question: "Should ergonomist be concerned only with work related tasks?" The results of this study point towards an answer of "No" since the stress seems to be "elevated" during break times. The questionnaire results also showed that forty-three percent of the suggestions to reduce stress levels were related to time allowances.

Productivity analysis

A driver's "work" time is composed of the following four elements:
a) Driving time
b) Other work related time (sign-on and off time, train preparation)
c) Work regulations related time (meal allowances, regulation leave, other allowances)
d) Schedule introduced time (change of route allowances, spare time)

Based on the above four, a set of productivity indices was developed. Each index considers *productive* time as either driving time (item *a* above), working time (*a* and *b* above), or working time including regulation related time (*a*, *b* and *c* above). Table 1 shows the definitions of these productivity indices, when the "work" time is the total duty time, that is, the total time the drivers spend in the company. Different indices have different uses for management. For example, a *Driving Productivity* index may be used to measure and control the amount of extra time that is associated with each driving hour; a *Regulated Work* index would be used to evaluate the efficiency of the crew scheduling procedure, that is, the amount of idle time introduced by the procedure.

The questionnaire and physiological analyses seem to indicate an inadequacy of the meal allowance. Meal break time is part of the work regulation time and a parameter used in developing the crew schedule.

Table 1. Definition of Productivity Indices

Index	Definition
Driving	$\frac{\textit{total driving time}}{\textit{total duty time}}$
Work	$\frac{\textit{total driving time + work related time}}{\textit{total duty time}}$
Regulated Work	$\frac{\textit{total driving time + work related time + work regulations related time}}{\textit{total duty time}}$

The questionnaire and interviews indicated that the meal allowance known to drivers is the stipulated time of 40 minutes. However, the crew schedule plan indicated that over 95% of the duties (the type of duty assigned to each driver is generally different from day to day) had an actual meal break of 50 minutes or more, as the meal time generally coincides with lower demand periods. Around 10% of the duties had over 70 minutes of meal break. It seems that those duties with the published duration of the meal allowance of 40 minutes strongly influences the drivers' perception of their work conditions.

For a given number of duty hours, the allowance for meal breaks affects the *Regulated Work* index while the other indices remain unchanged. The R*egulated Work* index prior to the study was 87%. It seemed possible to increase the meal allowance without changing the number of drivers, that is, without changing the total duty time. This possibility was promoted by three factors: the existence of 13% idle time introduced by the scheduling procedure; the low participation of meal allowances in the total duty time (around 5%); and the fact that most meal breaks are scheduled during low demand periods.

Two scenarios were studied. Scenario 1 considered a total meal break allowance time of 50 minutes, while scenario 2 looked at a total meal break allowance time of 60 minutes. In scenario 1, the *Regulated Work* index becomes 90%. In scenario 2 this index becomes 92%. We may conclude that it is possible to increase the meal allowance time, while increasing the *Regulated Work* productivity index. This results from the conversion of idle time introduced by the scheduling procedure to an *official* meal allowance. Since the total duty time and working hours remain unchanged, the other productivity indices do not vary thereby reflecting a better deployment of the non-working duty time of the drivers.

4. Conclusions

Employee opinion coupled with physiological assessments can result in higher productivity and improved employee morale. In addition, the company image may also be improved by having a high *Regulated Work* productivity index published in staff newsletters and annual reports. The values derived for each of the indices are theoretical. Changes in employee morale and attitude may result in higher actual indices. The recommendations are currently being implemented, and the *actual* changes in productivity are to be evaluated.

5. References:

Eastman Kodak Company (1986). Ergonomic Design for People at Work. New York: Van Nostrand Reinhold.