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Railroad Shiftwork and Safety: Calibration of Models of Accident Risk Due to Shiftwork and Fatigue in Railroad Operation*

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Summary

Shiftwork has been defined as an individual working outside of the hours of 7am to 6pm (Chung, Wolf, Shapiro, 2009). In a global society where labor demands exist around the clock, there is an increasing need for more individuals to work at night, on rotating shifts, and extended night hours. The most common problems reported by shift workers are disturbed sleep and wake time sleepiness (Dean, Fletcher, Hursch, Klerman, 2007). Fatigue is one of the most critical safety issues the railway industry faces today. According to Chung et. al., (2009), sleepiness and fatigue negatively affect individual functioning often resulting in increased errors and workplace accidents. It is clear that fatigue has a detrimental impact on human performance and safety. Fatigue within the transportation industry is particularly challenging due to the fact that the industry operates on a twenty-four hour, seven day a week demand; accidents on the job can have detrimental and fatal effects. In 2002, the Transportation Research Board released a report that found 20 percent of responding transit agencies to a survey conducted by the American Public Transportation Association identified fatigue due to shift work as a contributing factor to job-related accidents (TCRP, Report 81).

There has been an increased interest in the use of bio-mathematical models to understand and predict the impact of extended work hours, exceptional duty rosters, and other work related demands. A review of literature relating the mathematical models to human factor related accidents revealed that there is a higher risk of accidents for groups of railroad personnel when they operate below the recommended cutoff. However, transportation companies must choose between competing models when evaluating their work schedules.

The present study sought to address the question of how to successfully utilize either model by analyzing a representative sample of work schedules typical of the everyday operations of the commuter rail or intercity passenger rail industry and examining the relationship between the two. A representative sample of employee work schedules was obtained from 101 persons employed by a large regional transportation company. The sample consisted of 61% morning starts, 36% in the afternoon, and 3% midnights starts. Schedules were then analyzed using the FAST (Hursh, 2009) and FAID software to produce scores for every 30 minute interval that the employee was working. The results indicate the presence of a highly statistically significant relationship between the two models that supports the assumption that the two models are measuring similar phenomena. Therefore we can assume that the FAID model is also validated and that cutoff scores on the FAID model can also be equated to cutoffs on the previously validated FAST model. The exact score conversion between FAST and FAID is presented using the linear conversion model.

Introduction

In 2008, the Sleep Research Unit at the Institute for Work and Health in Toronto defined "shift work" as an individual working outside of the hours of 7am to 6pm (Chung, Wolf, Shapiro, 2009). Shift work schedules can look very different across occupations. A single shift is normally between 8 to 12 hours in length and can include evening hours, overnight hours, and split shifts. Areas such as transportation, military, restaurant staff, law enforcement, hospitals, and health and safety are just a few examples of the professions that require shift work of some sort. Depending on the work force an individual finds themselves working in, assigned shift work may be permanent or rotate over a given work period, therefore periodically changing the hours worked. Variance can exists between the number of days separating assigned shifts, the time off between shifts, and the mixture of types of shifts assigned (Popkin, Howarth, & Tepes, 2006). Although there is a need for further inquiry, well documented research exists that indicates shift work has negative physiological and social effects on shift workers. Women in the workforce performing shift work deserve special attention and further research within the topic.

As of 2004, 15% of the American workforce, or roughly 8.5 million Americans, were engaged in some sort of shift work (Chung, Wolf, Shapiro, 2009). The reasoning for the majority of men and women working these shifts was not a result of choice, but rather a requirement for the type of job at which they were employed at. Many individuals may find themselves in a position of having to take shift work for promotion, for others it may be strongly influenced by financial need. There are benefits of working shifts work in some instances. Individuals may choose to work shift work to allot more time for things like child and elder care (Shapiro, Helslegrave, Beyers, Picard, 1997). In a society where labor demands exist around the clock, there is an increasing need for more individuals to work at night, on rotating shifts, and extended night hours (Dean, Fletcher, Hursch, Klerman, 2007).

There has been an expansive amount of research conducted on the ill-effects of shift work and night work when the body would typically be sleeping (Barton, 1994). Research literature has had a tendency to fall into three main areas of study: the disturbances in our sleep/wake or circadian cycles (eg., Akerstedt, 1990; DeKonick, 1997; Reinberg, A & Ashkenazi, I, 2008), the physical ill-health effects on our bodies (eg. Barton, L. 1994; Costa, 2003; Amelsvoort, Shouten, E., & Kok, F, 1999; Lin, Y, Hsiao, T, & Chen, P, 2009), and the social and family disturbances that can be a result of working shift work (eg., Culpepper, 2010).

The most common problems reported by shift workers are disturbed sleep and wake time sleepiness (Dean, Fletcher, Hursch, Klerman, 2007). According to Dean et al. (2007), this information comes as no surprise as shift work and working at night forces the natural physiology of the body to be more active when it typically is in a more limited state of activity. Demanding the body to work when it feels it should be asleep, and trying to make the body sleep when it feels it should naturally be awake, can have long-term health consequences. If the cycle continues of depriving the body of sleep, then forcing it to sleep when it feels it should not, sleepiness and fatigue can accumulate to dangerous levels (Dean et al.). Flo, et al. (2012 reported that the prevalence of shift-related insomnia varied in accordance with work schedules with higher frequencies for three-shift rotations and night shifts. However, sleep problems were present in all shifts and schedules suggesting that both shifts and work schedules should be considered in the study of shift work-related sleep and health problems.

The reason for this reported sleepiness and fatigue has been attributed to the nature of the circadian rhythm of our bodies. This rhythm is a 24-hour process that regulates cycles within our bodies such as body temperature, sleep/wake cycle, and hormone secretion (Stevens, 2009). According to Sherry (2005) at the University of Denver, the sleep pattern is related to our circadian rhythm. Consequently, when we disturb our sleep cycle we also disturb our circadian rhythm and vice versa. Shift work, especially at night, can lead to a disruption of both cycles and therefore lead to increased fatigue levels. Sleep deprivation is additive, meaning that a lack of appropriate sleep accumulates overtime and can eventually add to sleep debt. Sherry has found that on average, shift workers slept 2 hours less per night when compared to non-shift workers, making shift workers more prone to developing sleep debt (Sherry, 2005). According to the Department of Family Medicine at Boston University Medical Center, when sleep debt accumulates past a certain level, an individual can actually be diagnosed with Shift-Work Disorder (SWD). SWD is diagnosed by the presence of excessive sleepiness (ES) and/or insomnia lasting a month or longer during which the individual is performing shift work (Culpepper, 2010).

Effects of fatigue can be seen be seen in many forms. Loss of alertness, impaired judgment, slower reaction time, increased errors, increased risk-taking, and reduced motivation are a few examples. Fatigue may also lead to mood changes in the form of irritability and negativity (Sherry, 2005). According to Chung et. al., (2009), “sleepiness, fatigue, and sleep deprivation negatively affect functioning, resulting in decreased productivity, increased errors and workplace accidents, traffic collisions, and deterioration of relationships, and may trigger a general decline in health and well-being”. Fatigue within the transportation industry is particularly challenging due to the fact that the industry operates on a twenty-four hour, seven day a week demand. Accidents on the job within the transportation industry can have detrimental and fatal effects. The issue of fatigue in transportation workers has been a top priority of the National Transportation Safety’s Board (NTSB) for the past 2 decades (Sherry, Belenky, Folkard, 2006). In 2002, the Transportation Research Board released a report that found 20 percent of responding transit agencies to a survey conducted by the American Public Transportation Association identified fatigue as a contributing factor to job-related accidents (TCRP, Report 81).

Additional issues as a result of accumulated disturbance in sleep may be seen in the form of physical and psychological health conditions. Although further research is needed, increased risk for cardiovascular complications (eg. Ellingsen, Bener, Gehani, 2007), higher instances of obesity and gastrointestinal disturbances (eg. Van Amerlsvoot, Schouten, & Kok, 1999), and social interferences (eg. Culpepper, 2010) have been documented. Gender specific risks for females that will be further discussed have additionally included potential changes in menstruation cycles (eg. Costa, 2003), fertility disturbances (eg., Barzilai-Pesach, Sheiner, Potashnik, Shoham-Vardi, 2006), and a possible increased risk for developing breast cancer (eg. Medgal, Kroenke, Laden, Pukkala, & Schernhammer, 2005).

Shift workers have a moderately higher incidence of cardiovascular disease when compared to non-shift workers (Shapiro et. al, 1997). It is still unclear why this is so but has been equated to the natural circadian rhythm of our body and how it controls our heart rate and blood pressure rates throughout the day (Culpepper, 2010). It is also possible that the stress and strain placed on shift workers bodies and personal lives makes them more susceptible to cardiovascular disease. Even when these factors are taken into account though, an increase rate of heart disease still exists among shift workers. The dangers of heart trouble seem to increase with the duration of years of working shift work (Shapiro et al, 1997). In 2008, a study was released by the Department of Internal Medicine at the Taiwan National University Hospital that monitored shift workers for 48 hours. The study monitored individuals after working a 12 hour night shift, followed by a 36 hour recovery period. The electrocardiogram that was used reported elevated blood pressure, decreased heart rate variability, and incomplete blood pressure recovery within the 36 hour recovery time period (Su, Lin, Baker, Schnall, Chen, Hwuang, Wang, 2008). They reasoned that persistent activity during the night reduces, or eliminates entirely, normal decreases in blood pressure that would naturally happen in the body overnight. They also concluded that heart rate variability is a cycle that is controlled by circadian rhythms during sleep cycles. The study concluded that individuals that do not experience natural circadian controlled fluctuations in blood pressure and heart rate are possibly more likely to develop cardiovascular complications (Culperpper, 2010). An increased risk for cardiovascular disease is being associated with shift-work, reported as high as 40% compared to non-shift workers (Boggild & Knutsson, 1999).

The relationship between sleep disturbance and obesity is well documented but poorly understood, in part because of the complexity of the correlation (Culpepper, 2010). It has been found that there is evidence to suggest that shift workers have lower fitness levels than day workers. It has also been suggested in research that being fit appears to increase tolerance to shift work (Popkin, Howarth, & Tepas, 2006) In 1999, the International Journal of Obesity and the Division of Human Nutrition and Epidemiology at Wageningen Agricultural University in the Netherlands published a study to understand the relationship between duration of shift work and the physical factors that can lead to obesity. Body mass index (BMI) and waist to hip ratio

(WHR) were measured among 377 shift workers and non-shift working controls. They understood that an elevated risk for obesity in shift workers had increasingly been reported in research, but that the mechanisms for this increased risk were still unclear. They wanted to investigate the relationship between BMI as a possible explanation for changed eating habits and altering metabolic involvement as duration of shift work increased (Van Amelsvoort, Schouten, & Kok, 1999).

Compared with their day-time counterparts, shift and night workers have been reported to have an increased risk for gastrointestinal problems such as constipation and diarrhea, as well as longer term gastro-intestinal disorders and peptic ulcer diseases (Shapiro et al, 1997). Research is again linked to disturbances in our sleep patterns in that gastric secretions in the middle of the night caused by eating will interfere in the natural enzymatic activity of our bodies and digestive systems (Culpepper, 2010). Our bodies will additionally release certain enzymes and stomach acids when it feels it should be eating and is not. If work schedules or sleeping patterns do not allow you to eat when your body feels it should, the released acids can cause heartburn and more serious gastrointestinal problems down the road (Shapiro et. al, 1997). It is important to think about the possibility that shift work at night may lead an individual to eating meals at abnormal times and/or eating more than one normally would throughout a 24 hour period. There may be limited types of available meals one can choose from while working at night, especially healthy options. If time did not permit a prepared meal, fast food is likely an easy reach. There is also the possibility that a shift worker battling sleep debt will increase their intake of tobacco, alcohol, and especially caffeine to try to cope with wake-time sleepiness and fatigue on the job. The increase of using these substances may be contributing factors to all health related issues.

Key Risk Factors

Based on a review of the existing research in this field, a number of risk factors have been identified as likely to increase operator impairment as a result of fatigue. Research related to the Hours of Service legislation (Sherry, Belenky & Folkard 2005) reveal a number of key issues related to fatigue in the railroad industry. More recently, a series of critical factors that should be considered when constructing schedules and evaluating work plans in the transportation industry were recently adopted by Transport Canada. The following list of issues is thought to reflect the key risk factors that are identified as circumstances or conditions that can lead to increased levels of fatigue:

1. The total length of the work shift exceeding 14-16 hours.
2. Continuous hours of wakefulness beyond 19h.
3. Working between the hours of 0000 and 0600.
4. Obtaining less than six hours of continuous sleep in a 24-hour period.
5. Break times that do not permit reasonable recuperative times (<8 hrs).
6. Continuous work beyond 64 hours in a seven day period.
7. Less than two consecutive nights of recuperative sleep.
8. Continuous work for over 5 hours without at least a 30-minute break.

9. Undiagnosed medical conditions (e.g. sleep apnea) that may also affect fatigue
10. Individual differences in ability to sleep (e.g. aging, hardiness)
11. Quality of sleep may affect fatigue.

By identifying these key situations and factors the operating managers can then identify what kinds of schedules will be at a low risk for fatigue and therefore will be “safe” to work. To facilitate the work in this area a worksheet with various points attached has been developed to help evaluate the adequacy or safety of a work shift.

Model Introduction

Another key new development in the rail safety area is an increase interest in the use of bio-mathematical models for attempting to predict the likelihood of situations that might lead to accidents. There has been an increased interest in the use of bio mathematical models to understand and predict the impact of extended work hours, exceptional duty rosters, and other work related demands. Bio mathematical models have been developed in various laboratories around the world with the intention of modeling and predicting the physiological and cognitive responses to a variety of different conditions to which the individual has been exposed.

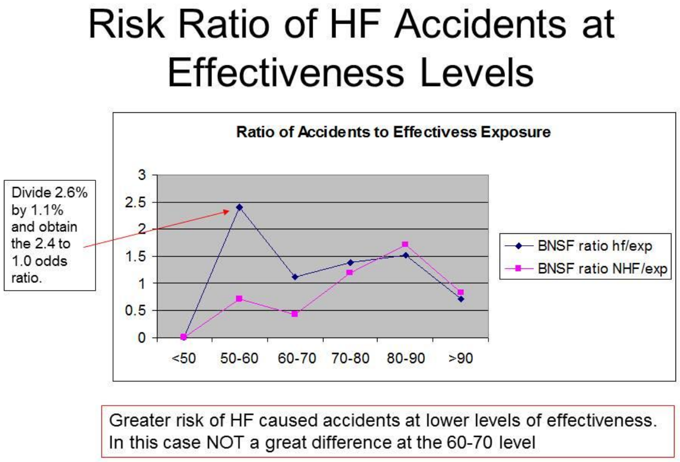
The accuracy of these models for both describing and predicting human behavior was the subject of a conference on fatigue modeling held in Seattle Washington in 2002 and described in a special of issue *Aviation, Space and Environmental Medicine* (Neri, 2004). The most popular and well published models were described and compared using five separate sets of data that were thought to represent common and extreme conditions in the aviation and railroad industry. The conference organizers asked the authors of the models to utilize the prepared data sets and to analyze the data using their models. The models were then compared to determine how well they accounted for the data that they were attempting to model. The results of the conference indicated that none of the models was much better than any of the others in accounting for and predicting human fatigue. In fact the results of the analyses comparing the various models concluded that none of the models was very different from any other. In addition, overall none of the modes was very good at explaining or predicting the restricted sleep scenario conditions, the kind of sleep schedule typically faced by people in the rail industry. Nevertheless, the models offer a somewhat improved ability to describe and understand the trouble with shift work at various times.

Model Validation & Calibration

In its November 2010 report, “Procedures *for Validation and Calibration of Human Fatigue Models: The Fatigue Audit InterDyne Tool,*” the Federal Railroad Administration (FRA) described a method for validating fatigue models that involved demonstrating a statistically significant relationship with an already or previously validated model. Previously the FAST model (Hursh, et al., 2004) had been related to an increased risk of human factor caused accidents with scores on the FAST model below 70 (Hursh, Raslear, Kaye, and Fanzone, 2006). Essentially, the Hursh et al, 2004, study showed that when the level of fatigue fell below a certain level there was a greater increase in the likelihood or probability of human factors caused accidents. For example, when conducting the study, these data have been presented and subject to various analyses. For example, separate railroads provided information on the extent to which there were human Factors caused accidents and non-HF caused accidents. As can be seen in Figure 1.1 you can see the probability of working at a certain level of effectiveness and also the probability of being involved in a Human Factor caused accident are plotted against each other. The relationship between the two probabilities reveals that there is a greater likelihood of accidents when the effectiveness level falls below 70. The highest risk occurs at the 50-60 effectiveness level. A more recent study by Roma et. al. (2012) found that there was a significant relationship between SAFTE scores and reaction times in flight attendants.

Previous research by Tabac & Raslear (2010) revealed a significant relationship between FAST and FAID was demonstrated and a calibration set as well. Results of this analysis demonstrated that there was a significant linear relationship between the FAST and the FAID scores and that a bio mathematical model was able to be determined. In fact, the published correlation coefficient between FAST and FAID scores was >.90. However, this relationship was based on bin, or ten point interval, means of the FAST scores, comprised of the scores that fell within a ten point range of FAST scores rather than individual pairs of scores. Such an approach reduces the normal variation in the relationship between the independent and dependent variables examined in this analysis. The application of linear regression techniques is typically undertaken with the assumption that the underlying distribution has a moderate amount of variability. By limiting the analyses to bin means the variability is thereby reduced and predictive and explanatory power is reduced considerably. A more robust application of linear regression requires the use of data with more variability.

Figure 1.1



Risk Ratio of HF Accidents at Effectiveness Levels

Divide 2.6% by 1.1% and obtain the 2.4 to 1.0 odds ratio.

Greater risk of HF caused accidents at lower levels of effectiveness. In this case NOT a great difference at the 60-70 level

Results of the Tabac & Raslear (2010) study determined that a FAID cutoff score of 60 corresponded to a FAST score of 70 following the linear transformation of the FAID score using the parameter weights and constants identified in the study. However, the identification of 60 as the corresponding equivalent to the FAST score may also be the result of unique characteristics of the data set used to generate the linear transformation equation. The data set identified consisted of work schedules of employees involved in either human factor or nonhuman factor caused accidents in the freight industry. Inspection of the data provided by Hursh, Raslear, Kaye, and Fanzone (2006) reveals that most of the accident data provided fell 21:00 and 05:00 hours. Thus, this particular data set might have a slight bias towards lower levels of alertness and higher levels of fatigue. While such a data set is useful in showing the relationship between accident data and fatigue models it is not optimal for calibrating one model to another because the mean of the data set is weighted towards the fatigued end. In this there will likely be a preponderance of scores from both the FAST and the FAID model that would be in the range suggesting a higher risk for fatigue. These scores, due to the law of central tendency, would have the effect of skewing the distribution towards the fatigued end.

Since one goal of these studies is to provide a tool that can apply generally to the passenger rail industry, an alternative methodology would be to use a sample of typical work schedules drawn from the passenger rail industry. Moreover, since the goal is to establish a mathematical relationship between the two models a more robust relationship may be demonstrated by choosing a typical sample of work schedules that represent the likely activities of everyday operations. Thus, the present study sought to analyze a more representative sample of work schedules typical of the everyday operations of the commuter rail or intercity passenger rail industry.

Present Study

Based on the proposed alternative methodology for determining the best calibration of FAST and FAID it was proposed that a representative sample of schedules be analyzed according to the percentage of morning afternoon and midnight schedules. The data submitted suggested that some of the largest railroads had the following percentage breakdown of work schedules.

Percentage of Morning, Afternoon and Nighttime Schedules In Passenger Railroad Operations

On Duty		Off Duty		RR1	RR2	RR3	RR4
3:30 AM	10:00 AM	11:30 AM	10:00 PM	65%	60%	62%	57%
10:00 AM	9:00 PM	1:00 PM	3:00 AM	32%	37%	32%	42%
9:30 PM	3:30 AM	7:00 AM	9:30 AM	2%	2%	6%	1%

Given that this percentage breakdown is consistent for four major commuter railroads a representative sample of work schedules was obtained that consisted of 101 work schedules. In this sample 61% were morning starts, 36% were afternoon, and 3% were midnight starts.

These schedules were then analyzed to produce FAST scores for every 30 minute interval that the employee was working. Similarly, *InterDynamics* in Australia, publishers of FAID, analyzed the same data set and prepared a similar of set FAID scores during work periods for every 30 minute interval worked. The data for a typical schedule (e.g. schedule #240) was arranged as follows:

Example of FAST FAID Model Scores

Date	Time	FAST	FAID
4/11/2011	14:30	96.26	32
	15:00	96.43	31
	15:30	96.78	31
	16:00	97.26	32
	16:30	97.84	31
	17:00	98.46	29
	17:30	99.06	30
	18:00	99.56	30
	18:30	99.9	30
	19:00	100.01	31
	19:30	99.84	32
	20:00	99.33	34
	20:30	98.45	38
	21:00	97.2	42
	21:30	95.58	44
	22:00	93.63	46
	22:30	91.39	47
	23:00	88.93	48
	23:30	86.32	48
4/12/2011	0:00	83.66	49

The scores for FAST and FAID were arranged in 30 intervals and paired to so that the scores were paired for the same 30 minute interval. These data were then entered into a statistical package and a correlation coefficient was generated. Based on 10,934 FAST-FAID pairs, representing five or six day work schedules, the following statistics were generated.

Descriptive Statistics

	Mean	Std. Deviation	N
FAST	90.63	9.07	10934
FAID	50.07	17.46	10934

There were not an exact number of FAST and FAID scores. The FAID program provides scores at the start, end and for each intervening hour of the work schedule. The FAST program simply calculated the average FAST score for the 30 minute period leading up to the time of day that the work day ended. *InterDynamics* arranged a special run of FAID to produce scores on every half hour of a work schedule and not on the start and end. This enabled half-hourly pairs of FAST and FAID scores to be produced and compared. For the present data, accounting for some missing data, set a total of 10795 FAST-FAID pairs were produced and analyzed.

Correlation Between FAST and FAID

		FAST
FAID	Pearson Correlation	-.729(**)
	Sig. (2-tailed)	.000
	N	10795

** Correlation is significant at the 0.01 level (2-tailed).

The bivariate correlation coefficient that was generated from these paired FAST-FAID scores is shown above. The correlation is statistically significant at beyond the P<.001 level and account for 53% of the explained variance. Note that the correlation is negative as would be expected as the FAST scores are higher for lower levels of fatigue while the FAID scores are lower for lower levels of fatigue. The correlation alone indicates the presence of a highly similar relationship between FAST and FAID. There should be no difficulty whatsoever in describing the statistical relationship between the models.

Prediction of FAST Scores

The FRA published a report (Hursh, Raslear, Kaye, and Fanzone, (2006) showing that there is a greater likelihood of human factors caused accidents among persons whose work schedules produce FAST scores below 70. Accordingly, the FRA has accepted FAST as an acceptable method for determining the risk of fatigue in work schedules. Additionally, FRA demonstrated that there was a significant relationship between FAST and FAID scores in its publication (Tabac & Raslear, 2010). Thus, the FRA study suggests that FAST scores below 70 may be sensitive to detecting human factors caused accidents. Other models, like FAID, if they are highly correlated with FAST, can be assumed to show a similar relationship. The goal of a calibration study is to show that the two models are in fact related mathematically. The two data sets obtained were subjected to further analysis using the SPSS Curve Fitting Procedure (SPSS Release 17.0, 2008). This procedure attempts to fit various mathematical equations to the observed data to estimate the underlying relationship. By understanding the underlying relationship and plotting the data we are able to translate the scores of one model or measuring system to another just as we can convert Fahrenheit to Centigrade on a temperature thermometer. Unfortunately, the two models are not measuring exactly the same thing so we expect that there will not be a perfect translation of the two approaches. Nevertheless, as can be seen, with a correlation of -.73 we have a very high degree of confidence that the models are in fact highly correlated. Nunnaly (1978, p245) describes correlations in the .70 neighborhood as being fairly strong but not describing identical tools.

Predicting FAST from FAID: Model Summary and Parameter Estimates

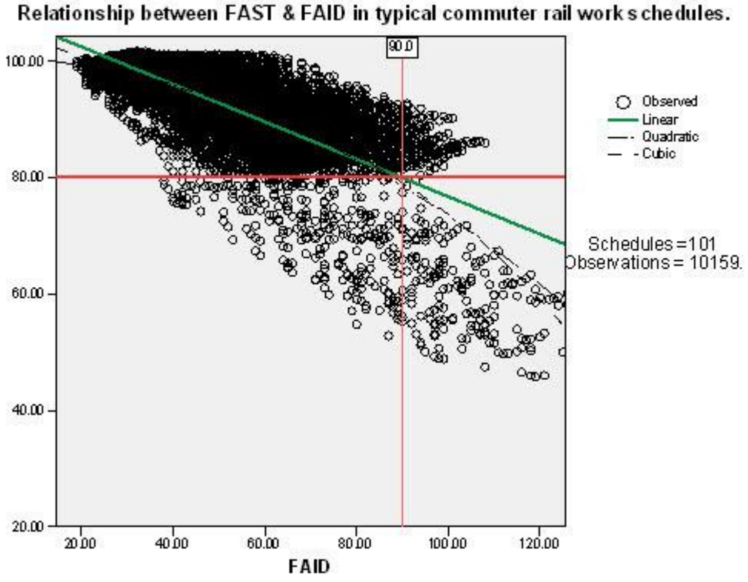
Dependent Variable: FAST

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.531	12239.105	1	10793	.000	108.823	-.321		
Quadratic	.556	6758.315	2	10792	.000	100.461	-.007	-.003	
Cubic	.559	4560.055	3	10791	.000	106.917	-.363	.003	-2.98E-005

The independent variable is FAID.

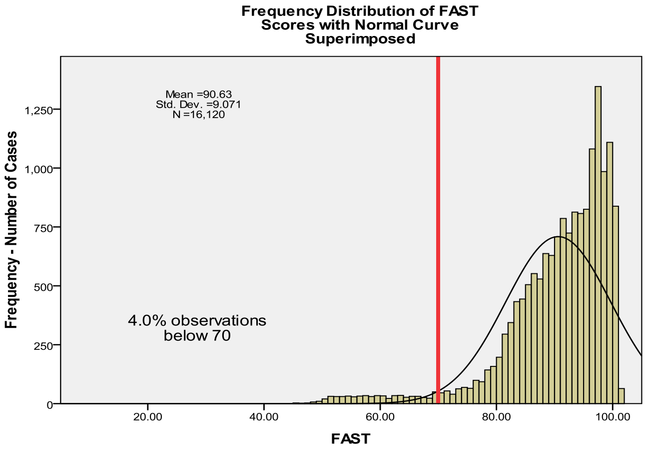
All of the equations are highly statistically significant in terms of explaining the FAST and FAID scores. The models can be compared to each other by examining the amount of variance accounted for, which is represented in the second column of the table under R Square. This statistic shows how well the model or equation accounts for the observed data. The best model in this case is the Cubic model which accounts for .559 or 56% of the variance, as compared to the others. However, they are all in the same neighborhood and we could not really say at this point that one is highly superior. The cubic is 2.7% better at accounting for the variance and so gets the numerical edge. Most likely the underlying relationship between the models is not linear, but curvilinear. This means that instead of a perfectly straight line, the data are likely arranged in more of a curve with the ends or tails sloping up at either end of the distribution.

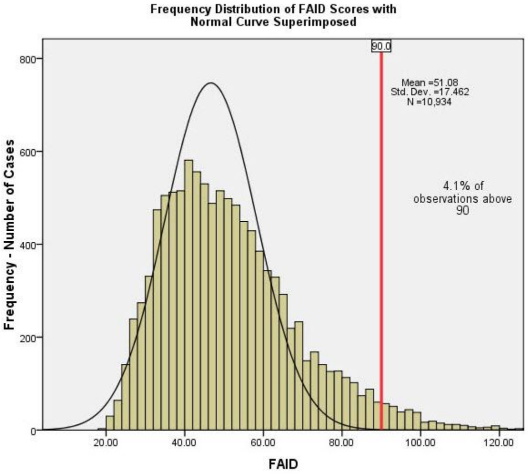
As can be seen from the figure below, the purpose of generating the appropriate model is to be able to predict or convert the scores of one model to another. The diagonal line through the center of the darkened section of the graph shows the plot of the relationship between FAST and FAID. The diagonal line is the linear estimate of the relationship between the two models. The vertical red line in the diagram indicates the position of 90 on the FAID scale (which is the current cutoff recommended by the developers of FAID) intersects with the horizontal line from the point of 80 on the FAST axis. The FAID score of 90 corresponds to a score of 80 on the FAST model. The recommended cutoff for FAST is 70. Thus, the present analysis actually identifies a more restrictive or conservative threshold for fatigue than is currently recommended by the FAID authors and than is currently utilized if we accept that the FAST score of 70 as the validated score below which the risk of human factors caused accidents are likely to occur. In other words, by accepting the FAID cutoff of 90 these data suggest that we would obtain a score of 80 on the FAST.



To summarize, work schedules which are above 90 on the FAID scale that would be considered to be at risk for fatigue would also be considered at risk for fatigue on the FAST model as well.

The following histograms present the number of schedule observations that would be identified as at risk for fatigue with varying cutoff scores. For the FAST model, the number of corresponding cases if the fatigue threshold is set at 70 on the FAST model is also 4%. Using the FAID model if the cutoff were set at 90 (as is recommended) the number of observations falling above the threshold is 4.1%.





The differences between the present study and the Tabac & Raslear (2010) study are likely due to differences between the two samples obtained. In the present study, steps were taken to ensure that a representative sample of work schedules was obtained. The present sample consisted of 61% morning, 36% afternoon and 3% midnight shifts. Thus, the present sample is more reflective of actual work practices as opposed to the more atypical schedules that might have been obtained in the earlier validation study sample (Hursh, Raslear, Kaye, and Fanzone (2006) that was based on human factors and non-human factors caused accidents. Since accidents are so rare in the industry it is clear that theirs was an unusual data set. It should also be noted that the validation sample was obtained entirely from freight operations. The present sample is obtained entirely from commuter rail operations. Examining the means for FAST and FAID reported in the Tabac & Raslear (2010) study on page 16, the mean of FAST and FAID is 69 and 59 respectively. In the present study, FAST and FAID means are 90 and 51 respectively. Thus, the present data is probably more representative of normal working hours and times of day.

Conclusion

The results indicate the presence of a highly statistically significant relationship between the two models. In addition, the underlying relationships between FAST and FAID are robust and permit the calculation of scores from one model to the other. By being able to compute FAST scores from the FAID model we can assume that the two models are both measuring similar phenomena. Therefore we can assume that the FAID model is also validated. Cutoff scores on the FAID model can also be equated to cutoffs on FAST. Thus, the present analyses indicate that the two models are highly correlated and both reflect the degree of fatigue in the work schedule. The exact score conversion between FAST and FAID is listed below using the linear conversion model.

	FAST	FAID
FAST = (-0.32) *FAID + 108.82	70.42	120
	72.02	115
	73.62	110
	75.22	105
	76.82	100
	78.42	95
	80.02	90
	81.62	85
	83.22	80
	84.82	75
	86.42	70
	88.02	65

Based on these results the evidence suggests that have two tools which measure fatigue. Further, the present evidence suggests that there is no reason to set the FAID cutoff lower than 90.

One cautionary note, these scores are estimates of cognitive effectiveness or readiness to perform tasks at a particular point in time given assumptions that the individual has obtained a reasonable amount of sleep prior to doing so. However, these estimates are based on group averages and are not accurate for the estimate of actual individual performance. Variations of work activity, sleeping schedules and opportunities, not to mention individual differences, will all play a significant role in determining actual readiness. The fatigue models are the best estimate of what we might expect in a certain very general situation.

Additional research is needed to improve the accuracy of these models in the workplace. While these models are useful additional real time operational data need to be gathered to specifically demonstrate the operational relevance of such tools.

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