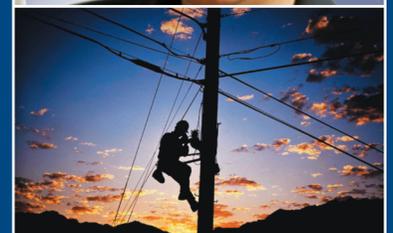


# STAFFING LEVELS

## *A Key to Managing Risk in 24/7 Operations*

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One of the most important, but frequently overlooked, root causes of employee fatigue and human error is an imbalance between workload and staffing levels. Extensive academic research and industrial attention has been paid to the relative merits and risks of shift scheduling alternatives such as 12 hour shifts versus 8 hour shifts, fixed shifts versus rotating shifts, clockwise rotations versus anti-clockwise rotations, fast rotating versus slow rotating schedules, etc., *without* recognizing the underlying impact of staffing levels in the outcome metrics that are used. Even some much cited fatigue risk management schemes (e.g. Dawson & McCulloch 2005) start with duty-rest or shift scheduling as the initial risk level (Sleep Opportunity) without recognizing the underlying risks of fatigue associated with staffing levels.

Because the number of positions to be filled on each shift is essentially fixed in most 24/7 operations, it is the staffing levels, not shift schedules, that play the largest role in determining:

1. The actual amount of overtime per employee
2. The actual time off between shifts
3. The actual time off between consecutive blocks of shifts
4. The actual length of shifts
5. The actual work hours per week
6. The actual number of consecutive days worked
7. The overall discrepancy between the published shift schedule and the actual shift schedule worked
8. The negative impact that all of the above has on sleep opportunity, quantity, and quality in terms of fatigue related to health, safety, and performance

### Consequences of Understaffing

If the staffing level is lower than optimal then the employees in that operation have to work additional hours or extra shifts to keep the positions filled. These hours may be added on by:

1. Holding employees over for additional hours at the end of their shift (i.e. effectively increasing the actual shift length and reducing off-duty rest hours between shifts).
2. Calling employees in early for additional hours at the beginning of their shift (i.e. increasing the actual shift length and reducing off-duty rest hours before the shift).
3. Scheduling employees to work on their days off to cover open shifts (thereby increasing the number of consecutive workdays and/or reducing the number of consecutive days off).

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4. Short notice call-in to cover vacant positions (creating the potential to miss or compromise a planned sleep period and thus start the shift unrested and/or less fit for duty).
5. Having employees work double or even triple shifts (increasing actual shift length and reducing off-duty rest hours after the shift).

As a result, the amount of overtime worked by employees will be significantly increased, and the additional hours and days worked will make the published shift schedule a work of fiction. Up to a point, overtime is often welcomed, if not desired by many employees, as an understandable way to increase their paychecks. Some employees will volunteer for all of the overtime they can get, which buffers those who don't want the extra hours. This also makes life easier for their supervisors. However, from every scientific and operational perspective, any significant understaffing, especially when there is uneven distribution of overtime, will affect both acute and chronic fatigue levels, and can represent a high-risk occupational health and safety exposure.

This white paper does not advocate a goal of zero overtime. After all, when distributed and managed efficiently, overtime provides a measure of operational flexibility and it gives people a chance to earn additional pay. Instead the objective of the white paper is to educate managers at 24-hour operations on the causes and consequences of understaffing, and to help them address staffing and scheduling imbalances so that they can run safer and more productive operations.

### Scheduled Overtime

The mathematics of staffing a 24/7 operation can appear deceptively simple if you overlook the operational realities of running the business. To start with, the simplest example of a 24/7 operation is one that is staffed at a fixed crewing level with an equal number of positions to fill on every shift. The usual approach is to take the 168 hours per week and distribute the work across 4 crews, each scheduled to work 42 hours a week on average. Under US Federal Law, this creates a weekly built in overtime of 2 hours per person on each of the 4 crews (i.e. 8 hours of premium time per week) to achieve the necessary coverage. **This should be looked at as the cost of capacity...not overtime cost per se.** Otherwise, trying to maintain a 40-hour work week and eliminate this built-in overtime, will create an open, 8-hour shift each week that somebody will have to cover at premium time...thus, no cost savings, only the added headache of having to schedule coverage every week. There are really only 2 options if continuous coverage is to be maintained...someone will have to work an overtime shift at 1.5 times pay, or "shiftbreakers"/ relief personnel will have to be provided at pay plus benefit costs. Again, this provides no cost savings. Thus, **there is no additional cost to operating with an average 42-hour work week,** and it is far more operationally efficient. For purposes of fatigue risk in continuous operations,

then, **we define “overtime” as “extra hours worked over and above the regularly scheduled 42 hours”**...not over 40 hours. Yes, the extra 2 hours is subject to premium pay, but that is the unavoidable cost of 24/7 capacity.

## Unscheduled Overtime

Often overlooked are the real drivers of overtime in 24/7 operations. In any given week, employees may not be available to fill their scheduled shifts because of multiple reasons including:

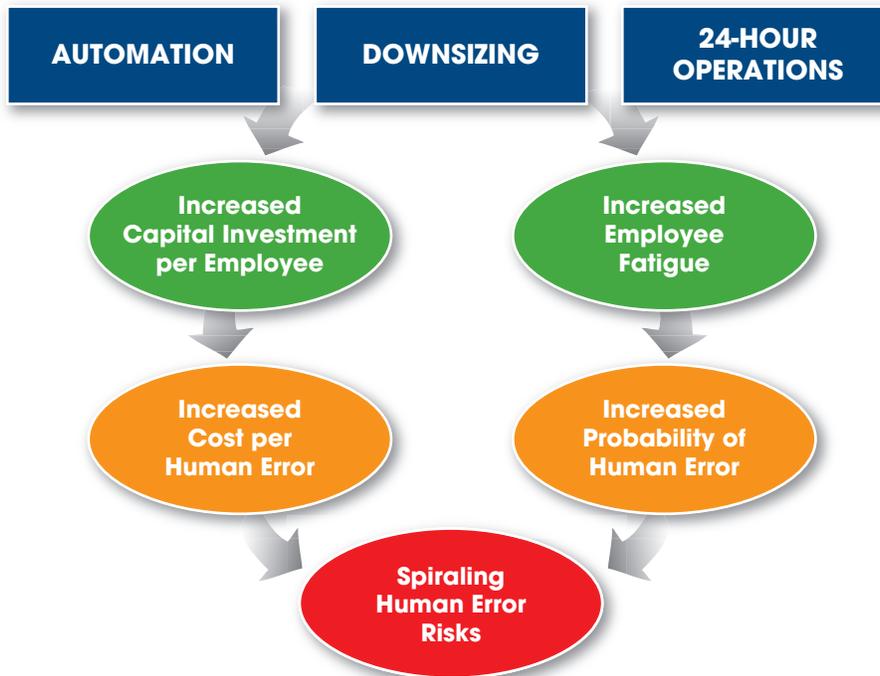
1. Vacation days
2. Floating holidays
3. Sickness related absenteeism
4. Non-sickness related absenteeism/personal days
5. Injury related absenteeism
6. Training
7. Special work assignments (committees, team building, projects, etc.)
8. Jury duty, bereavement, FMLA, etc.
9. Turnover/delays in filling position with adequately trained employees

Many 24/7 operations do not realistically estimate or measure the full impact of these factors and hence run their shifts with fewer staff than needed, effectively increasing the relief coverage requirement (i.e. overtime) and impacting the time on duty and off duty of their personnel. Furthermore, many companies do not monitor and analyze their historical payroll and human resources data so that they are unable to make even simple forecasts about scheduled and unscheduled absenteeism. Thus, absent this data, they are unable to accurately define seasonal, weekly and daily fluctuations in coverage demand. Moreover, many companies rarely recognize the annual increases in vacation time that their employees accrue, creating additional overtime coverage requirements every year, rather than staffing up to cover those absences at straight time.

## Root Cause of Staffing Imbalance

Over the last 30 years there has been a conscious effort to re-engineer business processes to achieve “total quality”, to achieve Kaizen, to become “lean and mean” and to take greater advantage of automation to improve productivity, loosely defined as product output (or revenue generated) per employee. Thus by reducing headcount, the productivity metric automatically increases and Wall Street’s perception of stock value goes up. As a result, the productivity measure of business performance has significantly increased statistically as the headcount has been reduced (Hammer and Champy, 1993). On the other hand, capital expenditures for equipment doesn’t show up in operating budgets, and the price of raw materials is relatively fixed, so the budget cutters/productivity experts see headcount reduction as the “low-hanging fruit” in meeting their targets. Under such pressure, operating managers must respond to corporate mandates to do more with less. By reducing staffing to the minimum level required to cover the base hours, they meet their targets and earn their bonuses without fully understanding the risks and collateral costs of employee fatigue that are created by the resulting increase in overtime (Figure 1).

**FIGURE 1:  
The Challenge of Productivity Initiatives**

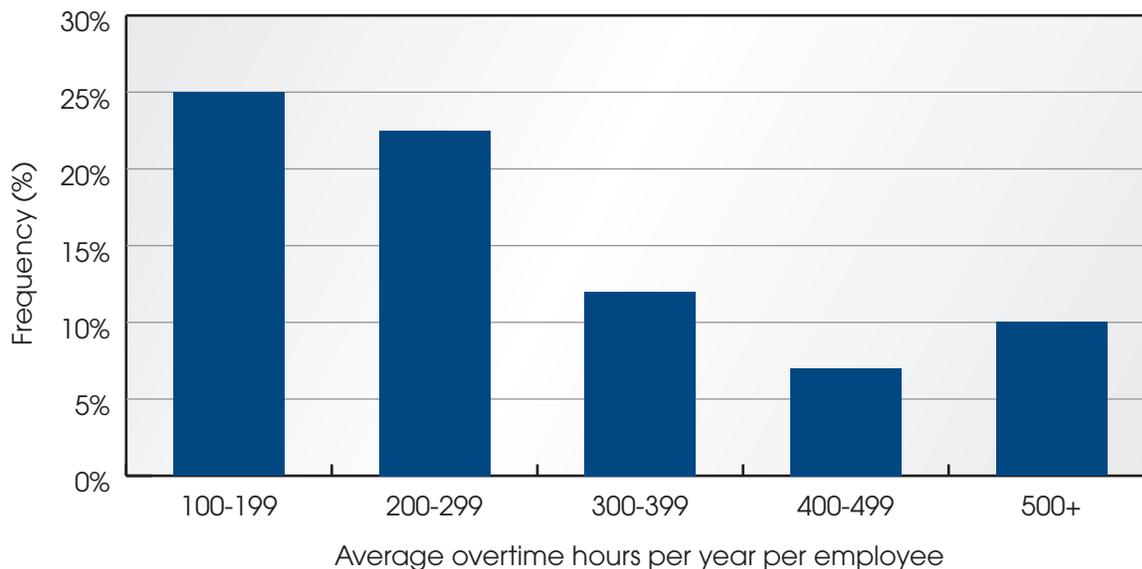


The financial risk (probability x cost) of human error incidents has escalated because technology, automation and expansion of 24/7 operations places more assets at risk per employee, while increasing the fatigue related error-risk per employee if staffing is not adequately managed.

## Overtime Levels in North American 24/7 Operations

Studies of average overtime levels show that overtime is a frequent feature of North American 24/7 shiftwork operations. Figure 2 shows the statistics for the average overtime levels from a survey of 623 North American shift work operations (Kerin 2003).

**FIGURE 2:**  
**Average employee hours of overtime per year in North American shiftwork operations.**



However, these average levels of overtime are not evenly distributed between employees. In many cases, the **majority of the overtime is worked by a minority of employees**, with the result that the overtime levels in these individuals is much higher than the facility average. Thus the 80/20 rule often applies whereby 20% of employees are volunteering for 80% of the available overtime.

If this overtime practice is left unmanaged, it quickly builds a financial **dependency on overtime and a hard-to-break overtime culture that sets your people up to fail due to the resulting fatigue**, thereby creating serious safety, production, and customer satisfaction risks. Given that the company assets at risk per employee today is at unprecedented levels, a simple mental mistake, a moment of inattention, or a 10-second microsleep can be extremely costly, if not catastrophic. With fewer and fewer people working more and more hours and getting more and more tired, **the risk and frequency of fatigue-related human error in the workplace has increased dramatically** (Figure 1). Concurrently, the cost of those errors has increased exponentially. Consequently, the *risk* of serious incidents is spiraling ever upwards, where risk is defined as the probability of an incident multiplied by its costs. Thus, it is critical to monitor and manage both the average levels of overtime and the individual overtime levels for each employee.

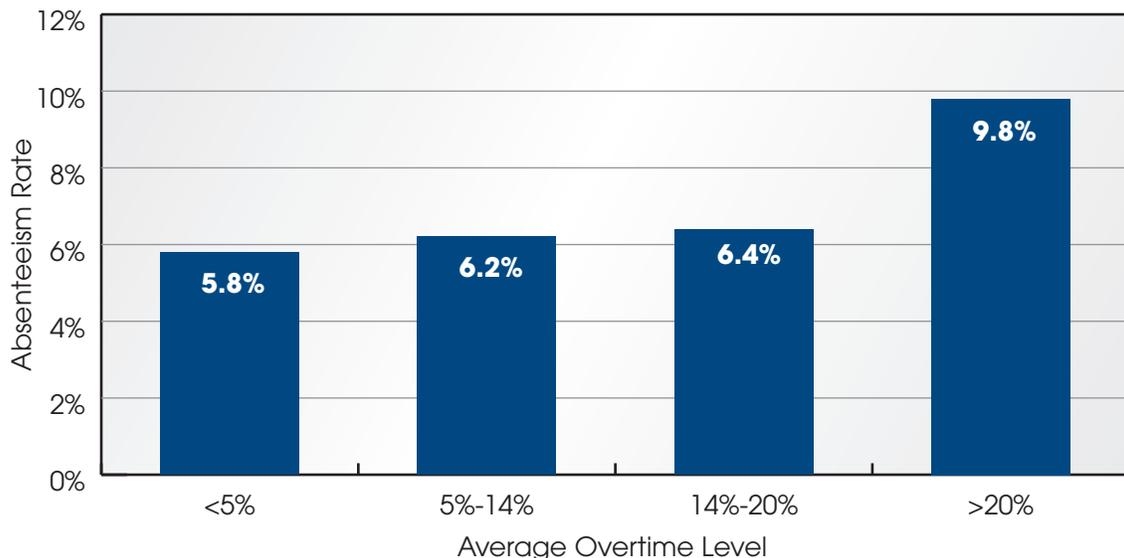
## The actual benefits of lean staffing are not what they seem.

Let’s consider the often-cited argument that by cutting staffing levels and relying on overtime to fill open shifts a company’s overall benefits and training costs are reduced. Normally these employee benefits average between 30% and 40% of base salary unless there are substantial pension commitments. In other words, with a generous benefit package, including “accounting factors”, each new employee costs a company one and a half times base pay.

On the other hand, running “lean” by short staffing and creating more open shifts that have to be covered with overtime also requires paying at least time and a half and often double time. So what’s the difference? Where’s the savings?

The difference, of course, is the increased risk of fatigue and the human error, the increased absenteeism and presenteeism, reduced productivity, and increased worker’s compensation costs of those employees caused by that fatigue. The difference is also the stress on employees related to shortened and disrupted off-duty family time and increased total weekly workload hours. These stressors cause increased absenteeism (Figure 3), which creates yet more overtime coverage requirements, compounding the fatigue and employee stress problems, and thus creating a vicious cycle of “fabricated” overtime.

**FIGURE 3:  
How Overtime Affects Absenteeism**



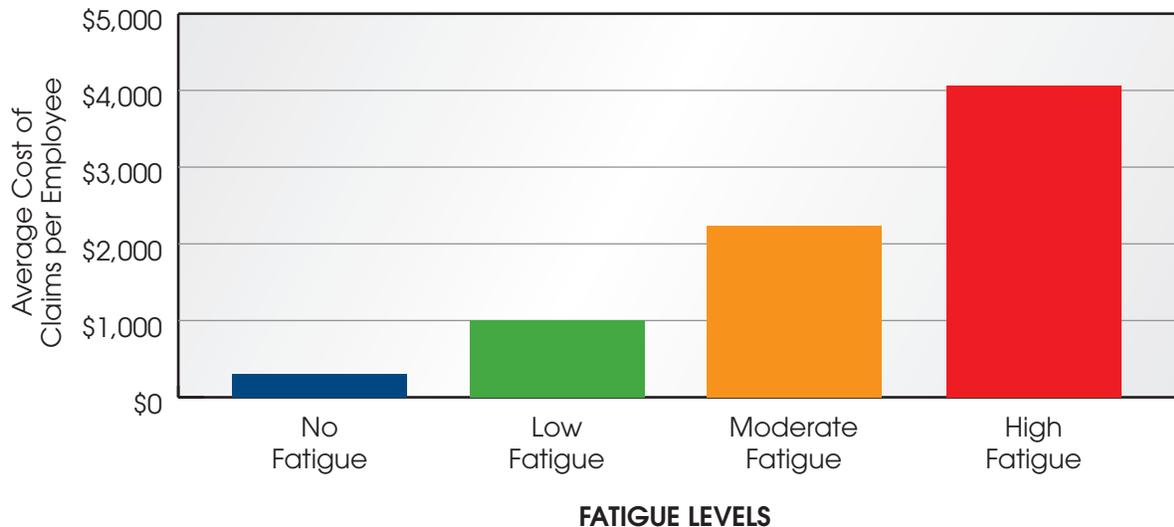
Interrelationship between the absenteeism rate and overtime percentage. (Source: Aguirre & Moore-Ede, “Shiftwork Practices”, 2007).

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Turnover due to normal attrition, relocation, and voluntary/involuntary termination, coupled with hiring delays, today's retention issues, and required training time begets yet more overtime and more employee fatigue, and stress. It has thus become critical for companies to get ahead of the curve through advanced planning and hiring, particularly given the fact that we are currently in the midst of having to replace 40% of the North American skilled workforce as the baby-boomer bubble in employee demographics reaches retirement age!

It is well established that fatigue-related human error is a major contributor to industrial accidents and injuries. The most common root cause of that fatigue is understaffing-driven excessive overtime (e.g. greater than 12% average additional hours worked over and above regularly scheduled time, especially when overtime distributed unevenly across the workforce). As illustrated in Figure 4, it is therefore of no surprise that fatigued shiftworkers exhibit up to 4 times the worker's compensation costs compared to non-fatigued employees. ***Thus, from a purely business perspective, the higher absenteeism, turnover, safety, and medical costs associated with overtime, coupled with reduced performance and productivity, make understaffing a highly questionable practice.***

**FIGURE 4:**  
**Workers' Compensation Costs and Fatigue Levels**



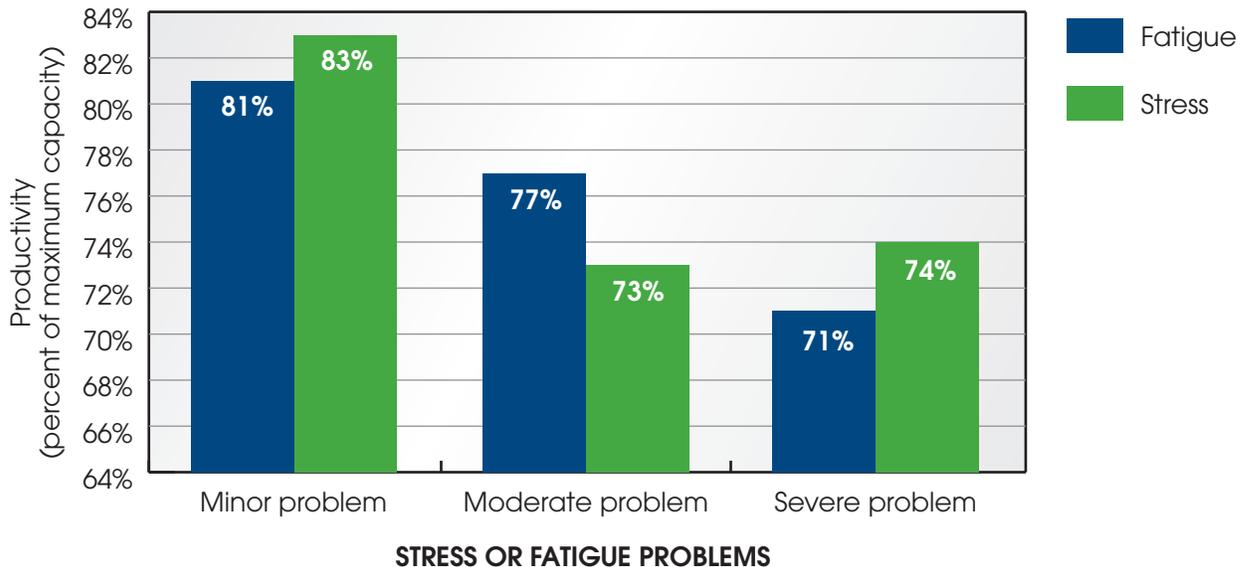
The average rates of worker compensation claims per employee (total employees including claimants and non-claimants) per year paid in 24/7 industrial and transportation operations with levels of employee fatigue ranging from low to high. (Source: Aguirre, A. Shiftwork Practices Survey, 2005).

## Staffing Expanded Hours of Operation

Another common scenario where staffing imbalances and overtime can increase significantly is when production has to be increased to meet greater market demand, to improve the utilization of capital equipment (by expanding traditional 5-day operations to continuous, 24/7 production scheduling), or to consolidate older facilities and equipment into the remaining sites and operating those sites 24/7. With such business decisions, especially if there is uncertainty about how long the increase in business demand will last, managers may be reluctant to hire the additional employees required to support a 24/7 schedule. Rather, they may be more inclined to hedge their bets by maintaining the traditional 24/5 schedule and by covering the weekends with voluntary or mandatory overtime. As a result, employees can be required to work six or seven days per week with only occasional days off, consequently experiencing burn-out from fatigue and stress in exchange for the allure of higher income. Businesses can get by with this model in the short term, but it is clearly not a sustainable way to operate one's business productively in the longer term.

The negative impact of fatigue and stress on productivity is clearly illustrated in Figure 5 which shows the results from an analysis of 400 industrial and transportation operations in North America (Aguirre A, 2005).

**FIGURE 5:**  
**Reduction in productivity as a function of stress and fatigue as reported by facility management**

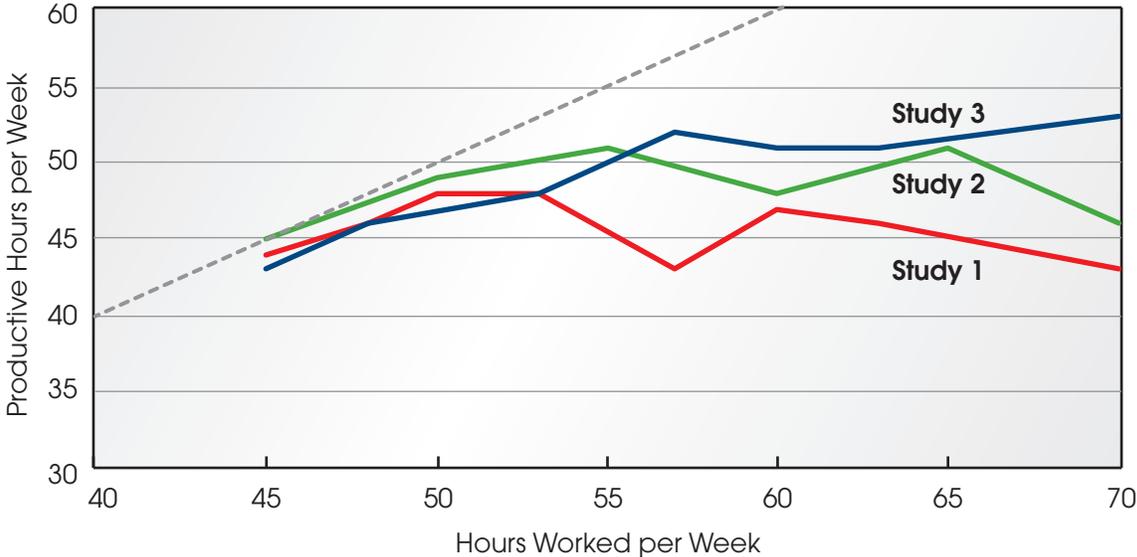


(Source: Aguirre, A. Shiftwork Practices Survey, 2005).

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Moreover, studies in hands-on maintenance and construction work have shown that the amount of productive work performed per week per employee typically levels off at 50-55 hours per week. Thus, working people more than 8-12 hours of overtime per week (or about one extra shift per week) may not yield the projected benefits in terms of productive work output (Figures 4). In the series of studies reported by Nevison, the theoretical 1:1 relationship between work and productive output holds true with four (4) weeks of long hours (Study 1), nor even with one week of long hours (Studies 2 & 3) (Figure 6).

**FIGURE 6:  
Productive work output reaches a plateau when weekly work hours are increased beyond 50-55 hours in hands-on construction and maintenance operations**



Study 1 shows actual productive hours after working 4 weeks of long hours. Study 2 and 3 show the productive hours in single weeks of long hours. In comparison the dotted line shows the linear increase machine productivity (Nevison 1992).

While machines operate linearly; we humans do not. As indicated above, the tipping point is about 10-15 hours of overtime work per week. The more hands-on the work, the more accurate is this statistic. In highly automated operations, some mitigation will obviously occur...depending on the tasks and activities being performed, as well as the work environment. However, **the inescapable conclusion is excessive levels of overtime can make understaffing a losing proposition.**

## Addressing Staffing and Scheduling Imbalances

The workload-staffing imbalance is thus one of the first issues that must be addressed in reducing safety incidents, in improving employee health and in increasing operational efficiency. The key issues to be aware of are:

1. The causal chain of employee fatigue risk starts with workload staffing and scheduling imbalances, as shift schedules and duty-rest rosters cannot be optimized unless the staffing levels are properly determined and unless they are sufficient to support the integrity of the schedule.
2. The predictability of the established work schedules, and thus the consistency of the employee work/rest/sleep cycles, cannot be maintained without proper staffing.
3. Shiftworkers build their lives, their family and social relationships, and their sleep/wake/activity cycles around their shift schedules. Unscheduled overtime due to understaffing severely disrupts this work/life balance.
4. Shiftworkers can become dependent on overtime, creating a “habit” or overtime culture that is difficult to change.

Determining the necessary staffing levels may be less challenging if Hours of Service regulations, Industrial standards such as API/ANSI RP-755, or union agreements exist which set hours of work and hours of rest. However, consistently operating up against the outer boundaries of these rules may actually be counterproductive by contributing to excessive fatigue, since it is difficult to write simple rules to cover all combinations of the complex possibilities, particularly with regard to circadian time of day risks. Indeed, the API-ANSI RP-755 Standard for the petrochemical industry specifically cautions against staffing and scheduling to the outer boundaries of the Standard.

Before hiring additional employees it is always advisable to conduct a detailed analysis of the workload-staffing imbalances and the various options for addressing them. For example, this may include:

1. Re-examining and re-engineering processes designed to reduce the number of positions or the types of jobs that are needed to be filled per each shift.
2. Cross-training and qualifying employees to fill multiple positions, effectively increasing the available staff for relief coverage, for providing scheduling flexibility, and for improving the distribution of overtime across the workforce to minimize the risk of fatigue related human-error due to excessive individual overtime.
3. Increasing use of temporary labor, where appropriate.
4. Where applicable, evaluating the fluctuations in workload to determine predictable patterns, and building a proportional staffing system that better aligns with those fluctuations.

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5. Adjusting staffing levels to maintain a maximum overtime budget of 12%.
6. Initiating your recruiting and training process in advance of the time you will need fully trained personnel at their positions.

To ensure that all these options have been explored, a scheduling factor analysis is needed to periodically assess and confirm that the proper accounting of vacations, training time, and other scheduled and unscheduled absences (which create open positions) have been properly conducted. Once all of these factors have been determined, and the staffing levels optimized accordingly, then the optimal shift schedule can be determined and implemented. This relief factor analysis should be conducted annually to monitor and address any changes that occur in overtime levels.

### Addressing Workload and Staffing Imbalances

There are different levels of complexity involved in calculating staffing and crewing requirements including the following factors:

1. Small work groups
2. Larger work groups
3. Few job classifications
4. Multiple job classifications
5. Cross training levels
6. Variability of workload/service demand
7. Complexity of benefits and pay practices
8. Budgeted amounts of overtime
9. Attrition rates
10. Collective Bargaining Agreements

Regardless of these scenarios, **every staffing analysis needs to begin by determining the base manpower loading.** For the vast majority of companies, decades of industrial engineering studies and continuous improvement processes have established these parameters by both department and by job classification to a high degree of operational effectiveness. Thus, the base manpower load in terms of hourly and daily positions to be filled by job classification are generally considered a “given” for most operations. Yet further opportunities certainly exist for **determining the minimum number of positions that need to be filled by hour of each day and day of each week,** and these can be routinely addressed over time.

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The next step is to determine the “not at work days” for each individual employee, in terms of **scheduled benefit days** available for that person to be off work. This includes vacation time, floating holidays, training time, special assignments, and other assigned activities that take employees away from their regular jobs, thus creating open shifts.

Next comes an evaluation of the **unscheduled absences** for each individual...sick days, FMLA, bereavement, jury duty, etc. The combination of the scheduled and unscheduled absences, then, represents the amount of relief coverage required to keep all of the positions filled each and every day. Unless a department can run short-staffed when periodically required, somebody (who is qualified) has to fill the vacant position. This can only be done in one of two ways:

1. There are qualified and fit-for-duty relief personnel available to fill those positions.
2. The positions (i.e. open shifts) are filled with overtime.

Based on extensive field experience, a 10-12% overtime budget (based on actual hours worked over and above regularly scheduled) is usually safe, healthy and productive...provided there is a reasonable distribution of those overtime hours across the workforce. At 15% average overtime levels, it is advisable to start hiring additional people, and at 20% it is arguably unsafe to operate because of the significantly increased risk of human error. This is particularly true with night shifts, rotating schedules and/or long, irregular hours.

For small departments of say less than 40 or 50 people and with only 1 or 2 job classifications, and few progressions, staffing levels can be readily calculated with paper and pencil. Simply convert the total hours of scheduled and unscheduled absences into full time equivalents (for each job classification) to determine the total number of relief personnel required. Then subtract 10-12% overtime (again in full time equivalents) to determine the required number of relief coverage personnel. Add this to the base manpower load (i.e. the number of positions to be filled) to identify the optimal staffing levels for a given unit, department and job classification.

However, when the size of the workforce numbers in the hundreds, and/or includes a large number of job classifications with different qualification levels and seniority rules and bidding progressions, etc., the mathematical complexity requires the use of staffing algorithms for achieving efficiency and accuracy. These can be home grown, or outsourced to subject matter experts for objective processing.

## Proportional Staffing

Thus far we only have considered the simplest staffing model for 24/7 operations whereby the workload is consistent and the shifts equally staffed every day of the year. But many shiftwork operations are not like this. **Workload in some businesses inherently fluctuates by the nature of their production or service demands** (think police departments, emergency response teams, overhead linemen, food processors, etc.). Production and/or service demand in such operations can fluctuate by:

1. Hour of day
2. Day of week
3. Seasonally
4. Cyclically
5. Randomly (customer demand, sales promotions, weather, unpredictable events, etc.)

If such operations are staffed at similar levels across all shifts (by establishing an average staffing level), the net result is an oscillation between **being overstaffed (with unproductive increase in cost)** and **being understaffed (with the excessive costs of overtime and increased employee stress and fatigue)**. An example of this is a large city police force which until recently was staffed with a similar number of patrol officers for every shift of the week despite the fact that the number of emergency calls on Friday and Saturday nights was many times higher than those on Tuesday and Wednesday mornings at 3 a.m. Even in less extreme examples, in which efforts are made to try to predict the necessary staffing level hour by hour, day by day or month by month, the mathematical algorithms required are generally too complex to enable efficient alignment of manpower to service demand (Figure 7). This capability simply does not exist internally in most companies, and is best left to subject matter experts.

Proportional staffing determinations require a minimum 3-4 year retro analysis of hourly and daily production or service demand to determine the time of day and day of week algorithms. Staffing levels and schedule relief factors can then be matched to those algorithms (for each and every employee) to achieve the optimal alignment of manpower requirement for servicing the variable demand. This then serves as the basis for calculating the most efficient shift patterns, shift starting times, and manpower utilization rates. In this fashion, both overtime and “undertime” are significantly reduced and employee utilization rates thus increase.

## Other Considerations

As mentioned earlier, one overlooked factor that has recently become an important consideration in staffing analyses is the **increasing rates of employee attrition due to retirements**. It is a statistical fact that businesses in the industrialized world will have to replace 40% of their skilled workforces represented by the aging “baby boom” generation. This bubble exists not only because of the size of the post-war generation, but also because of the large scale reductions in new employee hiring rates over the past twenty years that were made to achieve (through attrition) the headcount reductions needed to meet corporate productivity goals. This means more than just a simple replacement of existing personnel in the workforce. With the sophistication and complexity of today’s high tech equipment, systems and processes has come longer training and orientation time for new hires. For example, control room operators in refineries, chemical plants and power generation stations require upwards of 2 years of training to fully qualify as operators. So, for staffing calculations, this means hiring replacement operators 2 years in advance of a pending retirement to ensure a seamless transition and continuity of safety and operational efficiency. Another frequently overlooked staffing factor is the **annual increase in vacation time** being accrued by each employee. Additional relief coverage needs to be provided just to maintain the status quo, but very few companies are making this adjustment. The net result is annual overtime creep, along with increasing risk of fatigue-related human error.

## Conclusions

There is now an extensive global body of scientific evidence and operational experience confirming that shiftwork and fatigue in the 24/7 workplace represents a high risk occupational health and safety exposure. Fatigue Risk Management Systems (FRMS) have emerged as the internationally accepted standard for managing these inherent costs, risks and liabilities of shiftwork (Moore-Ede, 2010). The enormous assets at risk per employee today have exceeded traditional methods for managing shiftwork-related fatigue, and the high levels of overtime have bred increasing amounts of human error. **The consequences of that human error today are unprecedented, such that a 10 second microsleep is increasingly likely to cause a major incident or production loss...if not a catastrophic failure.**

This white paper has shown that understaffing is a major contributor to not only fatigue and human error, but also to the health, safety, performance, and quality of life of our employees. Just as annual health check ups are important for each individual’s well being, so is a comprehensive, annual examination and re-calculation of staffing levels critical for every business operation. Equally important is that we recognize the cost/benefits of “optimal” staffing vs. understaffing,

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and the impact of high levels of overtime created by that understaffing. When we do the math, short staffing just doesn't add up.

We often hear that it is just not financially possible to make the significant increases in staff needed to reduce overtime to safer levels, that it would be cost prohibitive. In fact, there is plenty of money available! There is an enormous reservoir of cash currently being spent on overtime that could be readily tapped to pay for the extra staff on essentially a cost neutral basis. This conversion could be done gradually over time to help current overtime beneficiaries adjust their personal finances, and to begin to enjoy an increased quality of life and a higher level of performance.

Since overtime levels are the telltale metric for understaffing in 24/7 operations, it's advisable to not only set budgets for overtime, but also to monitor and report overtime levels monthly by department and by individual employee. An additional monthly chart or column should also track the distribution of overtime in hourly buckets (e.g. 0-99 hours/year, 100-199, 200-299, etc.). In the final analysis, it's the distribution of overtime across the workforce and the calendar year that will maintain the integrity, safety and performance of a properly staffed workforce. This may require updating overtime policies and/or Collective Bargaining Agreements, but this effort will produce long term win-win benefits for the company its employees. Moreover, you will now be better positioned to develop a successful Fatigue Risk Management System (FRMS), and to achieve the next major step change in employee health, safety, and quality of life on the one hand, with increased operating efficiency and productivity on the other.

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**DR. MARTIN MOORE-EDE** has been a leading pioneer and expert on managing the risks of human fatigue in transportation and industrial businesses that operate 24/7. After experiencing the challenges of fatigue as a surgeon-in-training required to work 36-hour shifts, Dr. Moore-Ede was one of the first to define the challenges of living, working and sleeping in a 24 hour a day, 7-day a week world. As a professor at Harvard Medical School (1975 – 1998), he led the team that located the biological clock in the human brain that controls the timing of sleep and wake, and pioneered research on how the human body can safely adapt to working around the clock and sustain optimum physical and mental performance.

In 1983 Dr. Moore-Ede founded Circadian Technologies, Inc. As Chairman and CEO, he has guided the growth of the international network of Circadian companies, “CIRCADIAN<sup>®</sup>”, which now advises over half of the Fortune 500 companies on 24/7 work schedules and fatigue risk management.

## ABOUT CIRCADIAN®

CIRCADIAN® is the global leader in providing 24/7 workforce performance and safety solutions for businesses that operate around the clock. Through a unique combination of consulting expertise, research, software tools and informative publications, CIRCADIAN® serves as a subject matter expert to help organizations in the 24-hour economy to optimize employee performance and reduce the inherent costs, risks and liabilities of their extended-hours operations.

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### PUBLISHER'S NOTES:

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Editors: Andrew Moore-Ede, Becca Chacko

Publisher: Circadian Information LP

### FIRST EDITION

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