A Rational Methodology for Conducting Operations Staffing Assessments

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Have you been compelled to consider if your plant is staffed at an appropriate level and that your operating positions are well balanced in terms of operating complexity and scope of responsibility? As always, the highly competitive business climate in the petrochemical and refining sector compels companies to deliver solid returns on increasingly expensive investments. As always, executives must focus on both the top and bottom lines, while the short horizons of the investment community compel these executives to provide a return on capital employed in ever shorter time frames. As always, our industry’s standard metrics compel plant managers in this year’s bottom quartile to focus on reducing fixed and variable costs, without compromising safety, environmental integrity, or equipment reliability. With some irony, this makes headcount an attractive target for operating cost reductions, particularly when combined with investments in control systems and technology that profess to improve operator and plant performance, allegedly making it possible for fewer operators to do more. However, as recent incidents have shown, even the best technology cannot compensate for human error, nor can it add hours to the day to enable those fewer operators to do more then their physical capabilities will allow. We have come to the point where plant management teams are being asked, from both the business and safety perspectives, to define the methods used to determine how a unit should be staffed.

A Rational Staffing Assessment Methodology

A review of our client’s current practice in the area of staffing level assessments revealed that most had applied methodologies, such as control loop counts or task analytic time and motion studies, with limited, if any, success. The use of control loop counts is particularly illustrative. As pointed out by Nimmo and Moscatelli (2005), it has been widely accepted that a typical console operator can manage between 200 and 280 control loops. However, our own review of available literature was unable to identify the origins or basis for these numbers in any published, empirical research. Rather, this number, which has been widely acknowledged and applied to determine console loading seems to have no empirical basis whatsoever.
Human Centered Solutions (HCS) has been engaged in research on staffing requirements for safe plant operation, as well as applying the knowledge gained from that research into a structured methodology for conducting staffing assessments. This methodology has both matured and advanced over its frequent application in actual plants throughout the world. At HCS, our objective has been to provide an analytic methodology to support intelligent operator staffing decisions that goes beyond current industry practices of looking at control loop counts and snapshot observation studies of operator workload. Our goal has been to provide a rational basis for operations staffing (both console and field), that is both replicable and data driven to enable the identification of justifiable opportunities to reduce or balance operator positions and/or workload.

HCS’s staffing assessment methodology has three major components that can be applied individually or in total to address a number of staffing assessment issues. The first component is an Operator Performance Support Assessment; a principled comparison of individual and organizational practices that impact operator performance. When performed in conjunction with the next two assessment areas we are able to determine if current support practices are sufficient to enable effective operations at the observed console and field operator workload levels. The second component is a Console Operations Complexity Analysis, which we use to assess and compare the relative operational complexity across console operator positions. The third component is a Field Operations Utilization Analysis that applies the aforementioned task analysis and time and motion methodologies to assess and compare the relative workload of "routine" field activities associated with operator positions. In addition, HCS also offers the more traditional Staffing Risk Assessment (derived from requirements published by the Health and Safety Executive in the UK); a physical check to ensure safe staffing during abnormal plant operations, which will not be discussed in the present paper but is a part of our overall methodology.

**Operations Performance Support Assessment**

HCS’s operator performance support assessment is a principled comparison of individual and organizational practices that impact operator performance. The assessment examines operational practices in five specific areas: (1) **Situation Awareness** – there is a work environment where operators are able to gauge accurately and reliably within the available time the condition and behavior of the plant in normal and in abnormal conditions, without reliance on support. (2) **Alertness and Fatigue**
Countermeasures – there is a limit on the amount of overtime operators can work and individual operator’s overtime is monitored to ensure the limit is not exceeded.  

(3) **Operator Selection and Training** – there is a well structured, competency-based system of training in place to ensure operators have the knowledge, skills, and attributes required to successfully accomplish their roles and responsibilities.  

(4) **Operating Procedures** – there is a procedure management system in place that ensures that current procedures are accessed close to point of use and are presented in a clear, concise manner with checklists and other job aids for critical operations.  

(5) **Safety Management** – there is a culture of safety and continuous learning, and investigations from incidents and/or abnormal events are used in the review of training needs and operating procedures. There is a site safety committee that investigates issues, assigns actions and then tracks completion of those actions.

The purpose of this analysis is first to determine the level of performance support practices in actual use at the site in comparison with industry practices. The second purpose of this analysis is to determine if vulnerabilities exist with current workload and operations complexity levels. The structured assessment results also provide the basis for developing an action plan to improve the site’s support practices. The assessment is conducted through interviews and document reviews with plant personnel responsible for plant practices, and whenever possible practices are confirmed during interviews with operators. Figure 1 shows a requirement and a set of examples looked for as part of the Situation Analysis component of the Operations Performance Support Assessment. The examples are specific instantiations of the requirements that would indicate that the organization under study has implemented some aspect of the requirement.
Table 1 below shows the five levels of performance support scoring. Organizations achieve a specific rating level by meeting a certain number of the requirements for the specific performance support category and level as evidenced by the examples (or some variant) observed.

**Table 1: Five levels of performance support scoring**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Pacesetter practice level. Practices at this level typically use the most advanced techniques available to excel in this category.</td>
</tr>
<tr>
<td>B</td>
<td>Best practice level. Practices at this level typically represent a comprehensive approach using proven methods and technologies.</td>
</tr>
<tr>
<td>C</td>
<td>Standard practice level. Practices at this level meet the basic requirements for an effective practice reflective of industry “defacto” standards and government regulatory requirements.</td>
</tr>
<tr>
<td>Y</td>
<td>Below standard practice. Practices at this level show some minimum effort to establish a practice in this area.</td>
</tr>
<tr>
<td>Z</td>
<td>No practice exists. Practices at this level do not show any evidence that any elements have been established.</td>
</tr>
</tbody>
</table>
Table 2 above depicts an example Operations Performance Support Assessment summary for a plant with 12 specific units/control areas. The plant in question had already initiated site wide training and safety management programs before the assessment began as evidenced by the consistency of those scores across the units. However, results revealed to the site management team that although they had implemented a common training platform, there was still room for improvement should they decide to elevate their level of training above the standard practice level.

In addition to the summary, data is also provided for each unit on common effective practices observed across the site, unique good practices observed at each unit, and recommendations for common improvement across the site as well as within specific units/areas.

**Console Operations Complexity Analysis**

HCS's Console Operations Complexity Analysis began with our early work to apply human factors principles to control room operations and design in which we conducted a number of site visits.
and observational studies, and applied numerous task analytic methodologies to understand the job of a console operator. We began to form a picture of the console operator job that went beyond just the number of loops to be controlled. This is not to imply that such knowledge is not valuable, but rather that it provides an incomplete view of the console operator’s job, and does not capture other aspects of the job that add to the workload. HCS identified four areas that eventually evolved into four metrics that provide a more accurate picture of the console operator workload, and the console position job complexity.

The first metric - **Process Equipment Complexity** - measures the amount and types of equipment that are in the operator’s scope of responsibility. Each piece of equipment is given a rating based on its own complexity of operation, its cost, the economic value it returns, and the risk of operation. For example, tanks and exchangers would rank low in equipment complexity, while multi-draw distillation columns would rank very high.

The second metric - **Process Interaction Complexity** - measures the number and complexity of process streams that enter and exit an operator’s scope of responsibility. These upstream and downstream interactions add to the complexity of the console operator’s job, and cannot be measured by a loop count.

The third metric - **Console Collaboration Complexity** - measures the nature, frequency, and method of communication between console operators and field operators, supervisors, and other console operators. In other words, who is the console operator interacting with, how are they being interacted with (i.e., proximity and communication channel), and what is the frequency and impact of those collaborations on the operator’s workload. Another part of the console operator’s job that cannot be measured by a loop count.

The fourth and final console operations complexity metric is the **Control System Behavioral Complexity** which measures the impact of the control system configuration on operator workload in terms of an average utilization rate for both steady-state and upset conditions. In this metric, HCS analyzes control system events in terms of the number of alarms and changes, where changes are measured by intent, not keystrokes. We divide the control system data into two operational periods as established by research by the Abnormal Situation Management Consortium and Engineering Equipment and Materials User Association’s (EEMUA) on how many alarms an operator can handle in a given period of time:
“Base” Periods (steady state), with utilization rates of 20-30%, indicate a quiet console environment where the operator can take on optimization and administration tasks, and “Peak” Periods (non-steady state or upset), represent the human factors established upper limit for cognitive processing.

Each of the four metrics measure particular aspects of cognitive and physical operator activities that contribute to their total perceived workload and, as depicted in Figure 2 below, each metric has been shown to be uncorrelated with the others in data HCS has collected for over 350 consoles.

<table>
<thead>
<tr>
<th></th>
<th>Process Equipment</th>
<th>Process Interaction</th>
<th>Console Collab.</th>
<th>DCS Behavior</th>
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<tbody>
<tr>
<td>Process Equipment</td>
<td></td>
<td>.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Interaction</td>
<td>.39</td>
<td>.06</td>
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<td>- .25</td>
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<td>Console Collab.</td>
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Figure 2: Cross Correlation Analysis of Metric Components

Together these four metrics provide a relative basis for comparing the operational complexity of various operator positions. The four independent metrics are combined into a single overall console complexity score to enable comparison of consoles. The score for each metric is normalized before combining them for an overall console complexity score. The basis for normalization is a “Reference Console” obtained from the broad experiences of HCS analyzing more than 350 consoles. The Reference Console is neither an average console nor is it a target complexity that HCS recommends to our clients. However, we do find the Reference Console a valuable concept for two reasons. First, it establishes a basis that allows for comparison of operational complexity for each metric across a mixture of industries and process types. Second, the Reference Console enables the integration of support practices to be measured at a site, compared with industry practices, and then reflected in the complexity an operator can manage. The reference console is based on expert judgments as representing the approximate workload level where a console operator has a full workload given standard levels of performance support practices. Consequently, given the threshold levels selected for the reference console, an Overall Console Complexity score with a value of 100% should have a relative
interpretation with respect to 100% utilization. In other words, with performance support systems at the best practice or pacesetter level, a console operator could effectively perform at utilizations greater than 100.

HCS’s work in the area of operations staffing assessment has identified an important relationship between the level of console operations complexity sites can sustain and the level of operations performance support practices provided. The better the performance support practices, the greater workload a console operator can manage effectively. Using the results of these two analyses, we compare current staffing levels to other plants; then, taking into account existing staffing practices, training practices, rotation practices, and promotion practices, we make recommendations in these and associated areas. It’s an objective way to evaluate potential changes in staffing.

Exactly what the maximum level is for the Overall Console Complexity metric with the highest quality performance practice levels is not easily identified because it also includes the variability of risk that sites are willing to accept. Other companies who have adopted the HCS methodology for analyzing console complexity and performance support have “raised the bar” for console operators by raising the requirements of their reference console, implying that they are confident their performance support levels warrant an increase in the levels of console complexity their console operators can handle without becoming over-utilized or ineffective.

Figure 3 below depicts the Console Operations Complexity summary for the same site for which the Operations Performance Support data was presented. It is important to note that it is not just the overall console complexity score that is important, but also the pattern of the individual metrics which can be informative in how to manage a unit’s overall complexity level.
For example, in Table 3, Unit 1 had the highest overall console complexity score, despite having the least amount of process equipment complexity (a common measure of span of control, similar to control loop counts). If one were to base the assessment on this factor alone, one might erroneously conclude this unit to be one of the least complex and possibly over staffed. However, anecdotal reports of operators all described an extremely busy area that provided multiple resources for the rest of the site “left them drained” at the end of their shift. Upon review of the individual metrics, it is clear that Unit 1 had the highest level of collaboration at the site, as well as the highest level of DCS utilization under peak conditions. The Collaboration number is reflective of the amount of coordination and communication required by this area because of the centralized role they played at the site, particularly during upsets in those areas. In addition, it confirmed that their DCS (the oldest at the site), was in need of some upgrading, and the application of alarm management practices to reduce the level of peak workload. In general, the data drove to recommendations to reduce the overall complexity of Unit 1 by simplifying the unit’s collaboration and communication infrastructure and requirements, and on improving the unit’s alarm performance.

Another way this data can be looked is demonstrated in Figure 4 below. In Figure 4 each unit’s overall console complexity score is plotted against recommended levels of performance support.
As can be seen by the data presented in Figure 4, at the current levels of overall console complexity observed, most would require performance support at the Pacesetter level to manage the required utilizations. This provided the site with an improvement roadmap, as each unit was given action items to both take steps to reduce their overall console complexity, as well as improve their unit’s level of performance support.

Figure 5 depicts the console complexity data after Unit 1 instituted some data gathering tools that reduced the collaboration complexity, as well as a bad actor analysis to remove some nuisance and chattering alarms. As can be seen in Figure 5, Unit 1 managed to reduce their overall console complexity to under 120, now among the lower units at their site and at a level that now requires only Best level rather then Pacesetter level performance support practices.
Field Operations Utilization Analysis

HCS has also developed a methodology for assessing the operational workload of field activities associated with operator positions using traditional task analysis and time and motion methodologies to assess level of routine activity workload in three areas that our experience has shown comprise the bulk of the routine activities a field operator is expected to perform on a daily basis.

The first area, Condition Monitoring Workload, assesses the work activities associated with inspecting equipment and taking process samples. Activities assessed in this area include the time required to catch, analyze and report samples, perform daily inspection rounds and document activities in check sheets, perform tasks associated with each unit's operating routine (e.g., valve adjustments, strainer checks, pump preventative maintenance, etc.), and perform loading and unloading of raw materials, additives, and products. The second area, Maintenance Support Workload, assesses the work associated with issuing maintenance work permits and isolating plant equipment (e.g., preparing equipment for maintenance and returning the equipment to service, issuing permits including job site
inspections and atmospheric testing, and vehicle entry permits and activity). The third area, Operator Maintenance Workload, assesses the work associated with conducting preventive maintenance activities, as well as repair, replacement, installation, and demolition activities. Together these metrics provide a basis for comparing the relative workload of routine field activities associated with operator positions.

Our objective is to baseline the level of routine activities that occur in these three areas to identify the average routine activity workload expected of each field operator position. Our experience has shown us that almost on a daily basis, something unexpected will occur outside of the scope of these routine activities, be it a plant upset or just some unscheduled or unplanned for event that will take time to reconcile and could impact routine activity performance if the expected routine activity workload is too high. Figure 6 shows an example of the summary data generated during this analysis, which when combined with the list of individual items and time estimates, can be used to help manage, balance, and/or reduce field operator workload (i.e., elimination of redundant or unnecessary activities, shifting activities from one field operator to another, combining operator positions, and/or use day positions that employ one operator per position rather then shift positions that employ three).

Figure 6: Example field operator workload plot
These three assessment components can be applied in conjunction to help management make more complicated staffing decisions, such as whether to consolidate or rearrange unit staffing. In another assessment conducted by HCS, one of the site’s existing units consisted of four operators, each of whom performed both console and field activities combined for a single unit position. Management felt that production output was less than optimal or even expected. The feeling was that the operators lacked a clear understanding of the overall process (and of how each position fit within that process), and that the way job responsibilities were broken up (with each person completely “owning” only a portion of that process for both console and field) was keeping them from achieving better production throughput. The challenge was could the current staffing pattern be rearranged to optimize process control without impacting field support?

Figure 7 below depicts the console complexity results mapped against performance support levels for both divided and consolidated staffing configurations. As can be seen in Figure 7, individually, each of the console positions were not very complex, affording them plenty of time to perform field activities in addition to their console duties. When the data was re-analyzed as if controlled by a single, dedicated console operator, the result was a higher overall complexity, but one within the site’s console operator workload expectations level given the level of performance support observed at the site.

Figure 7: Console consolidation example
Further support for the staffing rearrangement can be found in Figure 8 below depicting the effect of field operator workload consolidation. Under the current staffing plan where operators did both board and field duties, field utilization by each of the four operators was a little over 50%, acceptable for an operator with both console and field responsibilities. By adjusting the staffing to one dedicated console position, and three dedicated field positions, the overall field workload per position increased to 70%, but it was within the site’s expectations for dedicated field operator workload. The end result was an improved staffing model that resulted in improved production performance.

![Figure 8: Field operator workload consolidation example](image)

**Summary**

Over the course of several years we have applied and refined our staffing assessment methodology to the point where its results now provide plant management with the data required to make informed decisions about operator staffing, workload, and support, and to do so in a manner that extends across positions, plants, and industries. The types of issues to which this methodology has been successfully applied thus far have included:

- Reducing the operational complexity of individual console positions
- Consolidating the number of operator positions (console, field, or both) required by units
- Balancing the workload across operator positions (console and/or field) across units and sites
- Assessing proposed console loadings and configurations for both new plants not yet under operation and existing plants conducting expansion or consolidation efforts
- Identification of opportunities for alarm management and process automation opportunities within a unit’s DCS implementation
- Identification of opportunities to improve the level of performance support to enable operators to mitigate overall console complexity utilization levels
References

