Predicting Staffing Sizes for Maintaining Computer-Networking Infrastructures

by

Lon D. Gowen, Ph.D.
Lead Systems and Software Engineer
The MITRE Corporation

Abstract

MITRE recently completed a three-month study to assess the "state of the practice" in staffing levels for maintaining a computer-networking infrastructure (CNI). The project determined the state of the practice by looking at technical papers on the subject, conducting organizational and technical-expert surveys, and looking at software models that attempt to predict staffing levels. The research found very few quantitative heuristics available in the literature; however, the data we did find showed that typical CNIs have a 1:42 FTE-to-user ratio; that is, one full-time equivalent of CNI staffing per 42 users using a typical CNI. This number can vary, up or down, by 17% or more depending on the details of the CNI. The DoD, as well as the private sector, can use the results of this study ❶ to predict initial CNI support levels, ❷ to support their current level of staffing, or ❸ to justify an increase or decrease in staffing. Additionally, this paper breaks down CNI support into the four major areas—systems administration (SA), break fix (BF), help desk (HD), and configuration management (CM)—and provides ratios for predicting each of them within a typical CNI.

Keywords

Manpower, Computer, Networking, Infrastructure, Staffing, Estimation, Prediction, Systems Administration, Break Fix, Help Desk, Configuration Management, Systems Engineering, and Labor Research.

Introduction

Having the appropriate amount of manpower for maintaining a given CNI is an important factor to consider since only 26% of a LAN's total cost of ownership (TCO[1]) is hardware while the remaining 74% is labor [1]. The 74% for labor typically breaks down into 43% for end-user operations, 17% for technical support, and 14% for administration [1]. Other common reasons for having an accurate, up-to-date figure involve issues dealing with budgeting, reliability, and quality. If an organization's CNI staffing levels are too high, then it wastes resources. If the staffing levels are too low, then response

times suffer, reliability suffers, end-product quality suffers, overtime is too high, and workers leave for a better working environment (since, at present, the demand is considerably greater than the supply).

Background

Every organization within the DoD has to estimate staffing levels (manpower) for maintaining their CNI. This activity, for most organizations (whether part of the DoD or the private sector), takes place on a regular basis. While not a fascinating or appealing topic of research for many people, manpower-sizing predictions are a critical part of planning. Therefore, MITRE, at the request of its DoD sponsors, conducted a three-month study to try and determine the current "state of the practice" in CNI staffing levels. The focus was primarily on the private sector, since the private sector is presumably more efficient at CNI staffing levels than the government. However, the study also looked at some DoD-based data.

This paper is a sanitized version of the study's full report [2]. Due to the full report's sensitive nature and critical views in certain areas, this paper keeps most of the full report's sources of information (SOIs) anonymous. Such an approach was necessary in order to obtain honest data. Also, due to size limitations, this paper does not contain all of the original report's tables and discussions; however, the author did try to include as much essential information as possible.

For purposes of this study, MITRE determined the "state of the practice" by collecting information from the following sources:

- Information from recent (most within 24 months) technical papers,
- Information from organizations currently supporting CNIs,
- Information from technical experts currently working in the field, and
- Information from current modeling tools.

Issues

Before discussing the research in any detail, the reader should be aware of the issues MITRE encountered that affected the research. Some of these issues, which appear in the sub-sections below, are specific to this particular study, but most of them are generic issues associated with labor studies involving CNI support. Despite these issues, however, the author believes that the resulting data, as a whole, gives a realistic and accurate picture of CNI staffing levels—both generically and specifically—since there is general agreement among the four areas of source data. That is, the technical papers (while having some outliers) are in agreement with the organizational data, the technical experts, and the modeling data from the COTS tool. Another factor supporting this case is that the deviations, after removing the obvious outliers, tighten up significantly. Nevertheless, some caution is appropriate, since there is always a chance that the data "just happens" to agree. Additionally, the data may not reflect "optimal" staffing levels, and there is no oracle to tell us the optimum. Therefore, even if the data accurately portrays the "state of the practice," it may not portray the optimum, since the state of the practice may not be optimal.

Time Contraints

The topic of manpower staffing levels for supporting CNIs is a complex topic and one in which certain companies (such as Gartner, IDC, Sun, IBM, Lucent, and HP) have been working for years. However, many organizations do not have the desire, the time, or the money to study the topic in detail (hence, the reason companies like Gartner and IDC exist). Therefore, there is always a compromise with respect to thoroughness versus timeliness. MITRE took a middle-of-the-road approach by limiting its study to a three-month effort. Within this timeline, there were further tradeoffs dealing with how much time to spend in each area of interest: For example, how much time to spend on technical papers versus organizational surveys versus expert-opinion surveys versus modeling.

Technical Articles

While staffing levels are important organizational concerns, there are, surprisingly, very few technical papers on the subject. Of the technical papers that do exist only a small number (six according to this study) discuss algorithms for determining FTEs with regard to CNI staffing. Another statistic worth noting is that the Gartner Group (GG) has published most of the technical papers in this area (possibly in order to help market their TCO Manager™ modeling tool). Of the six papers that do discuss algorithms, most focus only on a subset of the four major areas of CNI staffing.

Organizational Surveys

Another surprising outcome from this study was that very few companies were willing to share their CNI data. The following are possibilities—gleaned from conversations with organizational representatives—for their sensitivity to sharing data:

1. They are doing a great job at CNI support, thus they do not want anyone else knowing how they do it, since it gives them a competitive advantage;
2. They believe they are doing poorly at CNI support, thus they do not want anyone knowing how poorly they operate their CNI; and
3. They do not have any incentive to spend time sharing information.

Modeling Tools

There are a few companies claiming to have modeling tools for calculating CNI staffing levels. Some of these models are very simplistic (such as a Windows' migration TCO model, which is available as freeware from Microsoft), while others are (at least outwardly) very complex (such as GG's TCO Manager™ tool).

Table 1. List of Companies Claiming to Provide a Modeling Tool for CNI Staffing

Gartner Group
Sun
IBM
Microsoft
Interpose
DMR Consulting
MainControl

Table 1 lists the companies, which MITRE found, who either have a modeling tool or claim to have a modeling tool for determining CNI staffing levels. Companies, such as

Sun and IBM, claim to have such a tool, but they are unwilling to use it for studies. They limit the use of such tools for purposes of marketing and sales (i.e., to show how their CNI solution lowers support costs). They also consider the information in their tools highly proprietary and an important factor that helps them compete with other companies in the same market; therefore, they keep the information proprietary.

The costs for the presumably better COTS modeling tools are quite high; therefore, MITRE used only one of the leading COTS tools in its study. Unfortunately, as the author found out during the research, the company who develops this COTS tool did not independently validate it; therefore, providing no confidence that it computed reasonable or accurate results. Also, some of the model's inputs, which should be essential factors in determining FTEs, are for "informational use only" according to the tool's manufacturer.[2]

Mapping Data

Some of the data from the technical articles and the COTS tool required normalization to ensure that the data were in agreement (i.e., that the research counted apples as apples and oranges as oranges). Everyone seems to have slightly different definitions for the four primary areas of CNI support, which makes studying this area extremely difficult. MITRE learned, early on, that trying to make the areas of study too fine would prevent certain people from wanting to participate and would take too much time; therefore, MITRE kept the granularity at a high level (i.e., simple).

State of the Practice in CNI Staffing Levels

This section lists the data that MITRE collected from the four sources mentioned previously: technical papers, organizational surveys, technical-expert surveys, and modeling tools. After discussing the data from these four areas, there is a section that removes the outliers in order to show how well the data tightens up. There are some people that will have problems with dropping the outliers for statistical reasons; however, the whole purpose of dropping the outliers is not to present any kind of statistical proof. Instead, the purpose is merely to show the effect such changes have on the averages and standard deviations of the remaining data. Such comparisons are very useful to certain organizations.

Table 2. CNI Staffing Data Collected

Type of Data	Source of Data	Number of Users Per FTE of CNI Support			
		Systems Administration	Help Desk	Break Fix	Configuration Management
Technical Papers	1. Lucent INS [3]	155.2	113.8	284.5	853.5
	2. Gartner #1 [4]	106.7	77.6	106.7	
	3. Gartner #2 [5-6]	247.8	60.0		
	4. PC Week [7]		86.0		
	5. IDC [8]		99.0		
Org. Surveys	6. DoD	103.3	110.7	106.9	442.9
	7. Private A	80.0	80.0	80.0	
	8. Private B	71.0		71.0	
Technical Expert Surveys	9. DoD Sector	426.8	81.3	213.4	284.5
	10. Private Sector	227.6	136.6	162.6	227.6
COTS Modeling Tools	11. Run A	92.1	376.0	305.9	388.0
	12. Run B	80.8	199.4	193.1	292.8
Mean (Average)		159.1	129.1	169.3	414.9
Standard Deviation		112.9	90.2	86.6	228.4
Percent Standard Deviation		71.0	69.9	51.1	55.1

Table 2 is a list of the data MITRE collected. The next few sections reference this data in more detail; however, there are a few things worth mentioning here. First, the deviations, as the table shows, are too loose, and one can tighten them by dropping a few outliers within the four areas of CNI support. The numbers, however, still show useful similarities. For example, the averages between SA, HD, and HM are relatively close to each other but considerably smaller than CM. Second, the statistical means for all four areas seem "reasonable" and in general agreement. Third, the standard deviations (as a percent of the mean) are very high. If one combines the data for the four areas (see Table 4), the percentage drops drastically. While MITRE did not investigate the reason for this drop, two potential reasons are as follows: ❶ an inadequate understanding of one or more of the four areas by some or all of the sources and ❷ a different operational definition of these terms.

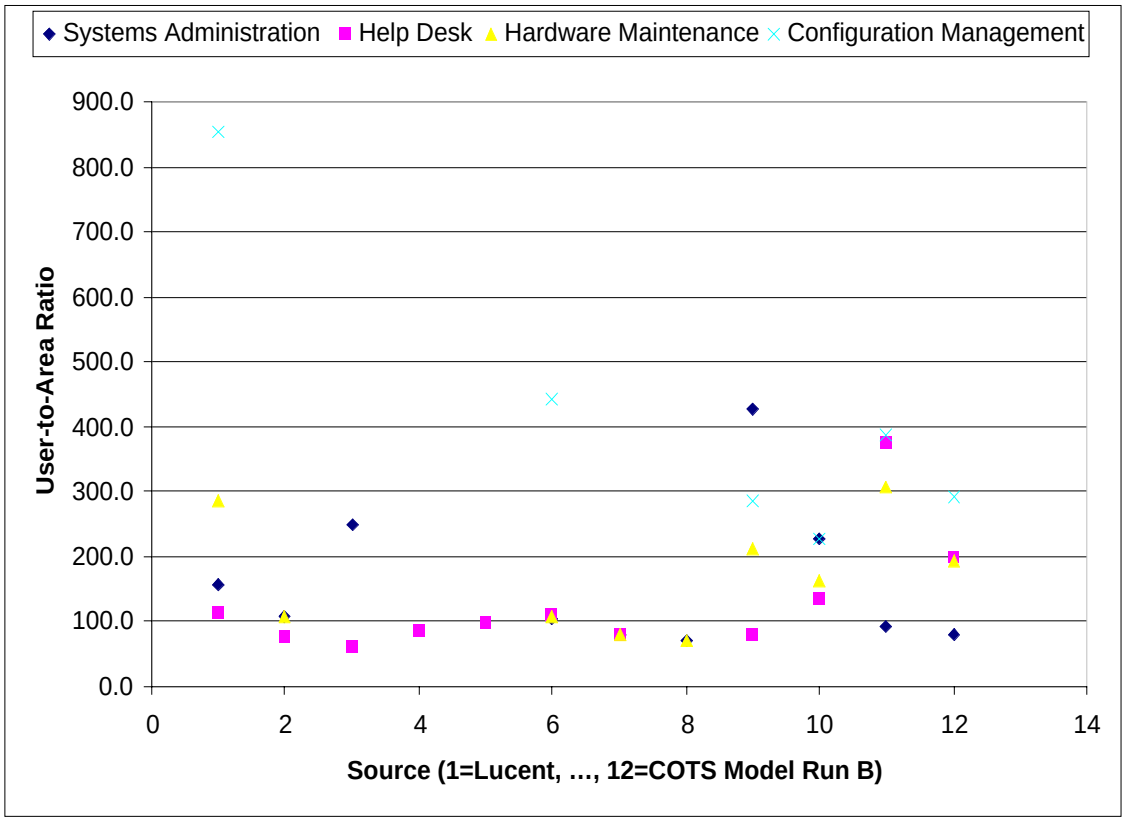

Figure 1. Scatter Graph of the Data Collected

In Figure 1, the numbers on the X-axis correspond to the numbers of the items in Table 2. The figure shows the closeness of the help-desk numbers as well as the obvious outlier. The graph also shows how closely HD and HM track to each other (in several cases, the triangles and squares are close to or on top of each other). Where they are separate, HM is usually smaller (as a ratio) than HD. One can also see that SA and CM have a wider scattering than HD and HM.

Each ratio, in Table 2, represents how many users one (1) FTE of CNI staffing can support for a given area. For example, Lucent's paper recommends one help-desk FTE per 113.8 users. The shorthand for such a ratio, in this paper, is 1:113.8.

Technical Papers

Of the 29 papers reviewed, only six papers (see references 3 through 8) contained sufficient information to be useful for predicting CNI support levels. MITRE collected the six papers into five groups (numbered "1" through "5" in Table 2), since two of the Gartner papers (being disjoint) allowed us to combine them easily. Something worth mentioning from the Gartner papers is that their own data on SA differs between their own papers by a large amount: 1:106.7 versus 1:247.8. Their papers did not explain the reasons for these differences.

As Table 2 shows, the help-desk area receives the most research. Almost every source of data has recommendations for help-desk staffing, and the mathematical mean of their recommendations is 1:87.3 (one help-desk staff for every 87.3 users) with a standard

deviation of 20.5 users. Therefore, depending on the CNI's environment, the typical number of help-desk staff can range from 1:66.8 through 1:107.8.

Systems administration (SA) is the next most heavily discussed area among the sources with three data points. The mathematical mean of the ratios is 1:169.9 with a standard deviation of 71.7 users. One advantage of the technical paper data is that companies often consider it more accurate than other sources of data. Therefore, when other sources of data start to show similarities to the technical papers, they tend to confirm each others validity.

The technical papers ignore, relative to the other areas, both hardware maintenance (to which this paper also refers to as "break fix," "HM," or "BF") and CM. Only two papers contained HM recommendations, while only one paper contained CM recommendations.

Organizational Surveys

The organizational surveys represent data from existing organizations—some from the private sector and one from the DoD sector. MITRE collected this data by contacting various organizations from the DoD sector and from the private sector (the paper intentionally keeps the names of these organizations anonymous) to see which ones would be willing to participate. Unfortunately, none of the private-sector organizations were willing to participate openly, so MITRE submitted the survey anonymously to a different set of private-sector organizations in order to gain some "unofficial" information. MITRE obtained a few responses, but only two of them had enough clients and servers to be useful for this study. In general, the private-sector data has limited application, since MITRE obtained data from small CNIs and obtained only two somewhat useful responses. As for the DoD sector, MITRE ran into the same problem with the exception of one very large DoD organization, which was willing to share their information. Since this study was focusing on private-sector data, one data point here was sufficient.

Table 2 also summarizes the data MITRE collected from its organizational surveys. The mean SA ratio (1:84.8) and the standard deviation (16.7 users) are much larger (i.e., more FTEs) than are those of the technical papers. The data seems to show a large disconnect between the technical papers and actual practice for SA. MITRE did not investigate potential causes of this difference, but one possibility is that the "research centers" are overly optimistic. Another possibility is that this data does not accurately reflect what organizations (in general) are actually doing (i.e., since the sample space is so small, it is not accurately showing the state of the practice). The numbers for HD need no comment, since they are in general agreement. As for HM and CM, the ratios, again, are "larger" than are those of the technical papers. Again, MITRE did not investigate the reasons for this difference, but the same possibilities exist.

From Figure 1, one can see how closely the ratios of SA, HD, and HM are to each other for each of the organizations. The icons within the graph are either on top of each other or almost on top of each other. The reason from the private sector is that they view the three areas as having overlapping talent, and the private-sector data points are such small CNIs that they must overlap their talent. For the DoD data set, the organization has such specialized systems that they require a large number of SAs, thus pushing the SA

ratio close to the other two ratios. Without some compelling need (such as the examples above), an organization would not have as many SA staff as HD staff.

Technical-Expert Surveys

The technical-expert surveys represented "best guesses" at how experts might staff a sample CNI. For this survey, MITRE used a CNI containing approximately 100 servers, 1000 clients, and 1100 users. MITRE had one expert from the private sector and one from the DoD sector answer the survey. Per the agreement on the survey, this paper keeps both respondents anonymous.

Table 2 summaries the data from the two expert-opinion responses. The largest deviation, between the two sets of answers, is in the SA area, where the DoD expert's estimate is almost twice the private-sector expert's estimate. Figure 1 shows some drastic differences between the intra-organizational ratios. For example, the DoD-sector response shows a clear spread between all four areas of CNI support with SA at the top of the graph and HD at the bottom. While the private-sector response is not as drastic, the graph still shows a larger spread than those of the organizational survey.

Modeling

The modeling results represent data collected by taking the same scenario above (from the technical-expert surveys) and running it through one of the well-known COTS modeling tools. Again, per agreements with the tool vendor, this paper keeps the tool and vendor anonymous.

Table 2 contains the data from two separate runs of the model: Run "A" views the CNI from a better "light" than run "B" (more details on this below). SA is very close between the runs; however, the other areas have a much larger deviation as the table shows. These differences are due to how the two sets of inputs characterized the scenario's CNI with respect to "best practices" and "complexity," which are essential input parameters to the COTS model in question. Run "A" characterized the scenario's CNI as more advanced with respect to best practices than run "B"; run "A" also characterized the scenario's CNI as less complex than run "B." The two runs provide some insight into how these parameters affect the modeling tool and thus affect the staffing levels, which the model predicts.

One point worth mentioning is that the tool's values for HD are significantly different from all other source's of values for HD. With an HD ratio of 1:376, the author believes the tool is modeling more of a customer-service center rather than a true help desk. The same holds true for HM. Since the vendor has no official validation of their tool, this issue may be an error in their software. Although this research strived to eliminate any differences between definitions, there may be a disconnect between the tool's terminology and those that this paper uses. That is, what the tool considers part of the HD support, this paper may consider to be in some other category. These mapping issues are always a source of potential differences. However, these differences go away when combining the data (as Table 4 shows).

Figure 1 shows the intra-set spread and inter-set similarities and differences between the two runs. The tool puts SA and CM on opposite ends of the spectrum with HD and HM somewhere in between. Run "B" is visually tighter (closer in ratios) than

run "A." Another obvious difference is how HD is similar to CM in run "A" but similar to HM in run "B."

The Outliers

As the previous section mentioned and as Figure 1 shows, there appears to be some obvious outliers in the data. This section removes some of those outliers merely to show the effects on the data—both numerically and visually—since some organizations find such information useful.

Table 3. The Data without the Outliers

Type of Data	Source of Data	Number of Users Per FTE of CNI Support			
		Systems Administration	Help Desk	Break Fix	Configuration Management
Technical Papers	1. Gartner #1 [4]	106.7	77.6	106.7	
	2. Gartner #2 [5-6]	247.8	60.0		
	3. PC Week [7]		86.0		
	4. IDC [8]		99.0		
Org. Surveys	6. DoD	103.3	110.7	106.9	442.9
	7. Private A	80.0	80.0	80.0	
	8. Private B	71.0		71.0	
Technical Expert Surveys	10. Private Sector	227.6	136.6	162.6	227.6
COTS Modeling Tools	12. Run B	80.8	199.4	193.1	292.8
Mean (Average)		131.0	106.2	120.0	321.1
Standard Deviation		74.2	44.3	48.0	110.4
Percent Standard Deviation		56.6	41.7	40.0	34.4

Table 3 removes three outliers from the data set. The table drops the data from the Lucent paper due to its very small ratios for HM (1:284.5) and CM (1:853.5). The ratio of one CM person per 853 users is significantly different than all other data points for this area. Next, the table drops the DoD expert's data, since it had a very small SA ratio (1:426.8) relative to all other data points. Lastly, the table drops the values from run "A" of the COTS modeling tool, since it had very low ratios for HD, HM, and CM relative to the other sources.

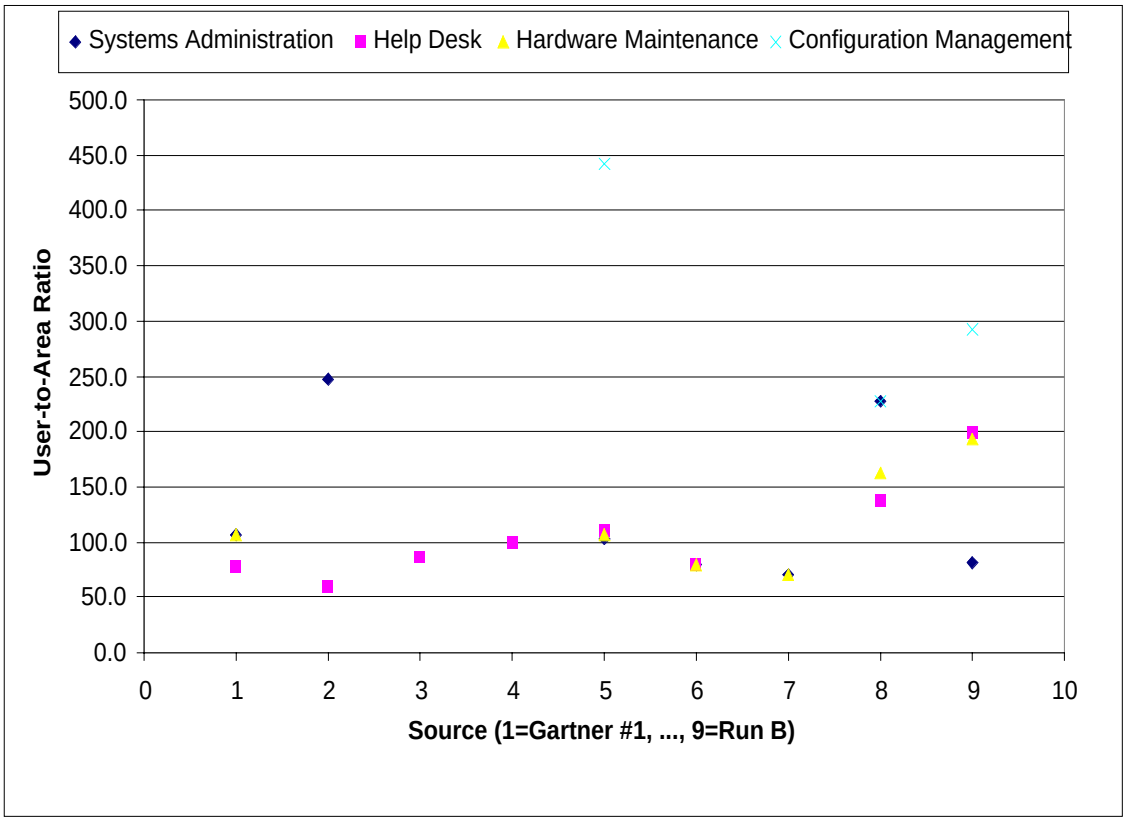

Figure 2. Scatter-Graph of the Data without the Outliers

Figure 2 is a graph of the data from Table 3. One can see (from Table 3) that the deviations drop significantly (as do some of the mathematical means such as CM). These figures are starting to show what is probably the actual "state of the practice" with respect to CNI support. The high standard deviation in CM is due, in the author's opinion, to the fact that there is very little effort expended in CM: from within DoD, the private sector, and technical research. Everyone seems to ignore (largely) the area of CM (similar to quality assurance and testing).

A Composite View of the Data

In order to remove potential differences between how the sources used terms (such as SA, HD, HM, and CM) and in order to provide an easy metric for predicting staffing sizes for CNI support, this section combines the data. That is, this section produces an overall FTE-to-user ratio. The author picked "users" (versus something like servers or clients), because most research in the field uses this same unit of measure (i.e., FTEs per number of users). In some cases, (for example, systems administration) the logic dictates that a different unit of measure (e.g., FTEs per number of servers) is best; however, since the common unit of measure is "users," the composite figures use it. Also, all previous values use this unit of measure as well.

Table 4. Summary of Composite Ratios

	COTS Model Run A	Lucent Paper	Gartner Paper #1	Gartner Paper #2	DoD Org. Survey	DoD Expert Survey	Private Sector Expert Survey	COTS Model Run B	Mean	Std. Dev.
Users per FTE	51.6	50.2	31.6	48.2	33.0	43.8	44.9	38.5	42.1	7.3

Table 4 contains the composite figures, but only for those sources of data that contained heuristics in more than just one of the four areas. For example, the IDC paper as well as the PC Week paper referenced only help-desk staffing, so using these figures in a composite chart are not appropriate or useful. This table also ignores the two private-sector organizational surveys due to their small CNI size. The remaining eight sources of data provide CNI staffing ratios with a mean of 1:42.1 and whose standard deviation is just 7.3—significantly better than the deviations from the non-composite ratios.

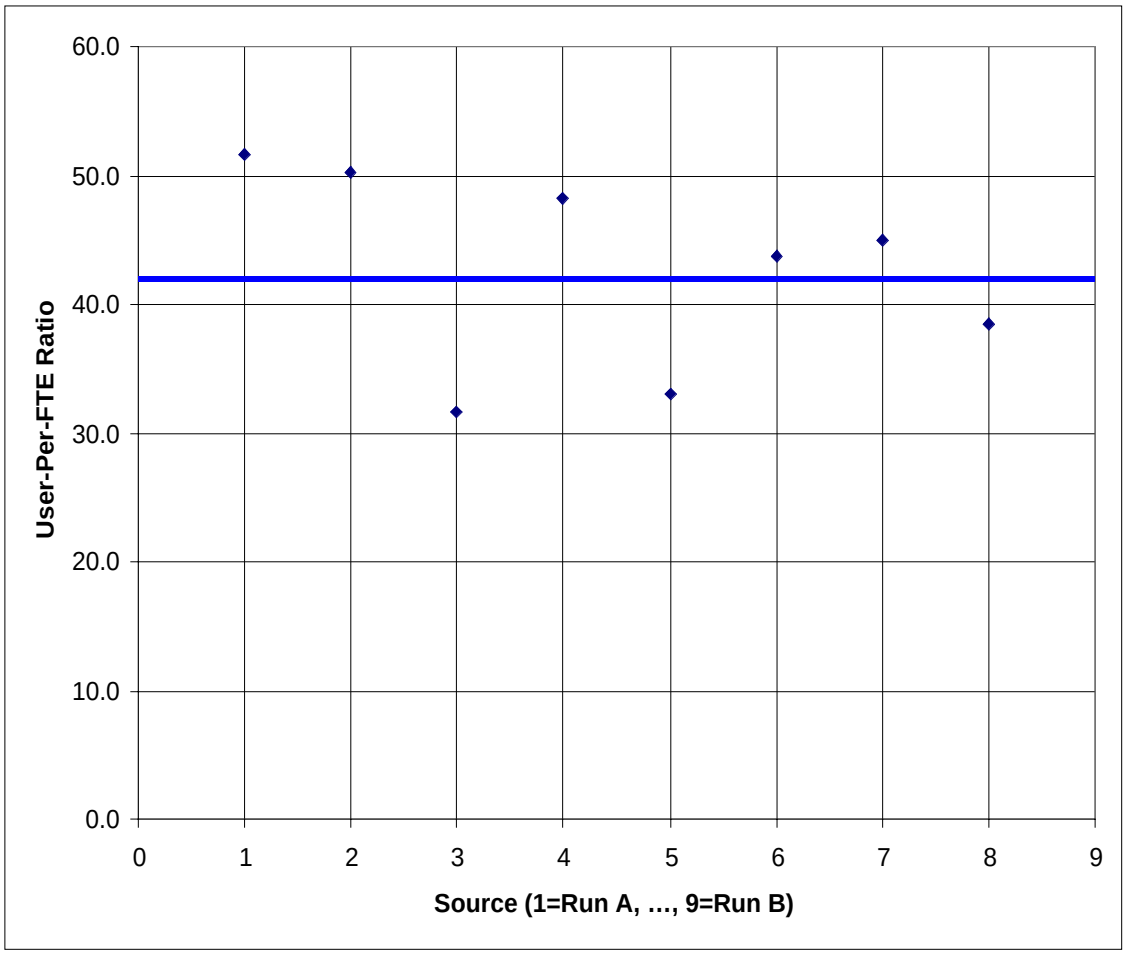

Figure 3. Scatter Graph of Composite Ratios

Figure 3 is a scatter graph of the data in Table 4. As the composite data shows, the standard deviation is relatively small at around 17% of the mathematical mean. The

composition's average ratio, of 1:42.1, represents the state of the practice for typical CNI staffing levels according to all of the research data MITRE was able to collect.

Concluding Remarks

The method for determining support levels for CNIs is still an art, not a science as many would like. There are no excellent technical papers on the subject. Excellence here means those papers that survey one or more areas of CNI support, collect a significant number of data points, build statistical conclusions from the data, and then validate any resulting models or measuring techniques. The papers MITRE identified had, at best, general heuristics. And, many of these papers focused primarily on help-desk activities while ignoring, to a large degree, configuration management. Part of the reason for the lack of public information is undoubtedly due to the proprietary nature of the information for many companies. What data was available from technical papers is present in this paper and part of this research.

MITRE was also unable to isolate any excellent models. Most of the modeling tools were proprietary for internal use only, so MITRE was unable to determine the quality of these tools. MITRE did have access, however, to one of the primary COTS modeling tools and determined that the tool had several shortcomings. For one, it made no use of service-level agreements such as 24x7 or 8x5. It also lacked any kind of validation that an independent third party could use to assess the tool. Without any kind of external validation, these models are no better than any person's best guess. Another weakness is that the tool did not take into account the referent industry and uses very low ratios for the help-desk and break-fix areas. The total FTEs, however, seemed to be reasonable (i.e., in line with other sources).

Very few organizations wanted to share their CNI data. MITRE was, at first, very optimistic about collecting such data; however, organizations (for the most part) want to keep this information private. Nevertheless, MITRE was able to collect some data, but the sample sizes were rather small relative to what the author had hoped.

Despite the problems (in each of the areas above) with collecting CNI staffing information, the data set as a whole appears accurate and useful, since there is general agreement among the four sources of data. That is, the technical papers, despite having some outliers, are in agreement with ❶ the organizational data, ❷ the experts' opinions, and ❸ the modeling data from the COTS tool. Another factor supporting this conclusion is that the deviations, after removing the obvious outliers, tighten up significantly, and the composite data is "very tight" for the newness of the industry. Nevertheless, some caution is appropriate, since there is always a chance that the data "just happens" to agree. Additionally, the data may not reflect "optimal" staffing levels, and there is no oracle to tell us the optimum. Therefore, even if the data accurately portrays the "state of the practice," it may not portray the optimum, since the state of the practice may not be optimal.

All of the charts, in this report, focus on user-based ratios for determining support levels (FTEs); however, there are other ratios, for example, those based on the number of servers and clients. When using these ratios, therefore, one must ensure an accurate census before trying to estimate staffing levels. If one uses the user-based ratios, then

that person or group must ensure an accurate accounting of users in the targeted organization beforehand.

Lastly, the findings from this research, while focusing on the private sector, have application to any CNI. The most applicable ratio is the average overall FTE ratio of 1:42; that is, one FTE of CNI support for every 42 users with a standard deviation of 7 users. So, for example, one environment might have a ratio of around 1:35 (i.e., more support staff), while another environment would be 1:49 (fewer support staff). The deviation is about 17.3 percent, plus or minus, of the mean ratio. The HD ratios should also have close applicability to other domains, since the HD area received a lot of attention in the literature and seems to have strong agreement within both the literature and the surveys. Of the remaining three areas of CNI support—HM, SA, and CM—both the HM and SA ratios should provide rough estimates to other domains, while other domains may have trouble using the CM ratio. The state of the practice is very unclear with respect CM, which is why applying the recommended CM ratio may be difficult and inaccurate for other domains. The state of the practice for HM and SA is more thorough but still not as solid as HD. Therefore, when applying HM and SA, other domains may need to allow for a wider variance than they would for HD.

The author hopes this paper will be helpful to many DoD and non-DoD organizations trying to wrestle with this difficult and costly problem. The author also hopes that other organizations, because of the difficulties MITRE encountered, will share information more freely in the future. Lastly, the author encourages colleagues in the DoD and private sector to pass along any CNI staffing data whenever and wherever possible. While MITRE collected all of the technical articles they could find, the author would appreciate hearing about any significant references that our searches may have missed (i.e., anything not listed in the references section)!

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Notes

1. TCO is a term for which there is no "accepted industry standard"; however, the term usually includes just what its name says—all costs associated with owning a piece of hardware to include the support and maintenance.
2. An excellent area for research, therefore, would be ❶ to compare as many of these models against each other as possible and ❷ to determine their accuracy (i.e., attempt some sort of validation). Currently, there are no analyses in the literature (that the author could find) for any of these models.

Author's Biography

Lon D. Gowen is a Lead Staff Engineer for The MITRE Corporation. He currently works on a MITRE Corporation contract at the U.S. Strategic Command, Offutt AFB, Nebraska. Dr. Gowen completed his Ph.D. (1991) and M.S. (1989) from Arizona State University with areas of interest in Software Engineering, Software Languages, and Embedded Systems. He completed his B.S. (1986) with a double major in Computer Science and Applied Mathematics from the University of Nebraska. Dr. Gowen was a Distinguished Visitor for the IEEE Computer Society for three years, and he teaches the Systems and Software Safety classes for the NASA Safety Training Center.

Contact Information

Dr. Lon D. Gowen
The MITRE Corporation
1004 Lincoln Road, PMB 327
Bellevue, NE 68005
Voice: (402) 294-2689, DSN 271-2689
Fax: (402) 294-1264, DSN 271-1264
E-mail: GowenLD@MITRE.org