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Review Paper

Workload-Based Manpower Requirements Determination via Generic (Naïve) Modeling

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ABSTRACT: *In this article, via a closed-form generic (naïve) modeling, we device a workload-based manpower equation to determine the number of full-time equivalent (#FTE) manning required to perform major tasks of a mission function in an organization. For illustration, we employ our model to an example case.*

KEYWORDS: *Manpower modeling, manpower requirements determination, full-time equivalent, FTE, workload-based method.*

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I. INTRODUCTION

Various researchers attempted to calculate manpower requirements using various methods presented in the literatures. Schoo, et. al. (2008) summarized the existing methods such as ratio-based method, procedure-based method, categories of care-based method, diagnosis-based method, or combinations of the aforementioned methods [1]. Lee, et. al. (2024) proposed a survey-based method for their hospital manpower calculation [2]. Popoola (2023) discussed the importance of manpower forecasting but only offered some concepts with no formula provided [3]. Kurniawan et. al. (2022) presented a ratio-based manpower approximation method [4]. Doulati et. al. (2013) proposed hourly-availability based manpower estimation method [5]. Rani et. al. (2023) presented a time-and-motion study type of manpower approximation method in a hospital setting [6]. Sharma et. al (2014) pointed out the methodological issues in estimating and forecasting health manpower requirement since they only presented a regression method while not every scenario can suitably (unbiasedly) be estimated by a regression method [7]. Noviandani et. al. (2019) approximated manpower in ship reparation scenario using a subjective method, NASA-TLX method, to reach an optimal number of crew in ship reparation, using the ratio of old days to new days and multiply by number of old crew [8]. Wahyuni et. al (2019) presented a case study on machine maintenance company to approximate the required number of FTE based on the numbers of hours worked [9]. However, none of the contains in these articles devised workload-based methodologies, despite what were claimed in the verbiage on some of the articles.

To date, no (workload-based) methods for calculating required manpower have been published in the journal-articles literature since all the existing ones have all been non-workload-based methods. Consequently, our proposed generic (naïve) manpower modeling (equation) is aimed to close the gap. The manuscript is organized into sections as follows. In Section 2, we develop a workload-based manpower generic model (i.e., a closed-form formula) to calculate the required manning. In Section 3, we describe the data. In Section 4, we provide an example case for illustration. Finally in Section 5, we discuss the conclusion of this work.

II. METHODS

In this section our goal is to formulate a generic (naïve) closed-form mathematical model (equation) to calculate a workload-based #FTE manpower requirement. Specifically, we intend to determine a point estimation for the required (REQD) #FTE manning. Note that the output (i.e., the calculated/estimated manning requirements from our proposed model) represent the required (REQD) #FTE which is different than the authorized (AUTH) number of personnel and is also different than the onboard (ONBD) number of personnel. The REQD is the required #FTE manning to accomplish the essential mission function (EMF) being studied; the

AUTH is the funded (afforded) billets; and the ONBD is the filled-in positions. So, these numbers (REQD, AUTH, and ONBD) can be different.

Prior to unpacking the generic (naïve) mathematical modeling (equation), the following are some definitions and terminologies regarding manpower methodology, manpower model, work study, and workload, which will be useful to any organization who need to determine their required manning.

A manpower methodology in an organization is an overall framework utilized by an organization to identify manpower and document manpower requirements. The methodology is an approach to create a mission ready organization with skilled employees and leaders.

A manpower model in an organization is a part of manpower methodology to produce a defensible and repeatable method to provide decision support to an organizational leadership in determining required manpower based on situational awareness and workload requirements.

To assess manpower request from the fields (or branches) of any lead organization, the lead organization should conduct a work study. Several past research provided the definition of work study as follows. British Standard Institution (2016) defines work study as a generic term for those techniques particularly 'Method Study' and 'Work Measurement' which are used in the examination of work in all its contexts and which leads systematically to the investigation of all the factors which affect the operational efficiency of a specific activity/task and economy of the situation being reviewed in order to incorporate improvements at various levels [10].

In short, among several past research (Management and Study Guide, 2015 [11]; Engineering Economics, 2017 [12]) summarized the definition of work study as an assessment / investigation / examination by means of a consistent system of the work done in an organization in order to achieve the best possible utilization of resources i.e., funding, manpower, machines and materials available.

In a nutshell, work study is mainly concerned with the examination of human work, i.e., manpower study or analysis. While the former term is generic (broader) and the later ones are more specific (manpower only), however these terminologies are often implicitly mixed-up, in the literature. Hence, in general, work study implies manpower study or analysis.

Note also, the difference between manpower study versus manpower modeling is as follows. Manpower study is to conduct analysis to determine minimum essential staffing requirements, necessary organizational changes, and required process improvements for unique organizations. Manpower modeling is to develop manpower staffing ratios, equations, allocation rule, templates, etc. for executing specific mission functions, either executed by multiple organizations or by numerous positions within an organization.

Workload is a measure of the amount of work performed by personnel. This measure provides an understanding of the volume of work to be done or overall demand requirement. An expression of the amount of work, identified by the number of work units or volume of a workload factor, that a work center (division/office/organization element) has at hand at any given time or is responsible for performing during a specified period.

Hence, integrating all the literature review, we define in this paper, a work study is an assessment of work/task requirements, based on EMF, in a single location (of a workplace/organization), ideally performed on-site. The purpose of a work study is to assess, report, and develop standards and factors/variables used in converting workload metrics (input variables, data, and relationships) into output past/current workload estimates and forecast future workload projections for manpower requirements determination (MRD). The workload factors for specific organization EMFs, based on quality and reliable data trackable from systems of records (SOR), is one of the necessary inputs to the manpower model (equation) to estimate manpower levels requirements. The work study standardized process employs quantitative, qualitative, and advanced analytics across the workplace/organization to yield consistent informed decisions any involved parties (the fields/branches, stakeholders, funds grantor, auditors, etc.) Typically, MRD is audited to which the workplace/organization must respond consistently by presenting reliable, traceable, and defensible staffing budget based on manpower analytics.

Work studies will identify and capture the necessary actions performed by employees to successfully complete functional requirements to ensure mission accomplishment. The compiling of data through surveys, observations, task mapping, and SOR data will enable consistent estimation of the minimum sufficient manpower required.

Therefore, a work study should be done to collect pertinent (input) data, to determine the #FTE (output) manpower required to perform the major (main) tasks in an organization EMF (typically 5-6 major tasks, in the position description of a job advertisement, posted publicly). Consecutively, the following is the manpower generic (naïve) modeling (equation).

$$\#FTE = (Volume \times Duration) / (Work\ Year \times UR) \tag{1}$$

where,

#FTE = Number of Full Time Equivalent of Manning,
Volume = Quantity of work; the recorded number of a repetitive finished task,
Duration = the average time to complete a routine/repetitive task,
Work Year = a fixed 2080 hours/year (obtained from 52 weeks/year x 40 hours/week),
UR = Utilization Rate; the percentage of a work year remaining (available) after deducting hours used for annual leave, sick leave, holidays, inclement early dismissal, annual trainings, Information Technology and/or Computer Issues, etc.

Although the discussion focus in this paper is on the equation (1), however it is worth noting that, when necessary, the generic (naïve) modeling in equation (1) can practically be further expanded (but not limited) to an additive model such as equation (2), as follows.

$$\#FTE = [(Volume \times Duration) / (Work\ Year \times UR)] + R + D \qquad (2)$$

where,

R = Reserved #FTE due to the non-repetitive nature of their work, which may have un-countable activities of various durations. This may include analytical or supervisory positions;
D = Dedicated #FTE staffing due to specialized expertise needed on hand, independent of the volume of duties.

III. DATA

The materials used here are TS dataset (monthly 'Airline Passengers') [13] and the EXCEL (2021) software. The data as the input components which are required to be collected are on the right-hand side of equation (1) while the output (#FTE) is on the left-hand side of equation (1). Equation (1) shows the relationship between workload and the yearly #FTE manning requirements to accomplish the organizational mission. The Volume dataset are counts of an EMF task. For example, the Volume of 'airline passengers' data as shown in Figure 1 (see the Example Section).

Workload is defined as a measure of the amount of work and how long tasks take to accomplish. Such measure provides an understanding of the volume of work to be done or overall demand requirement. Hence, the numerator in equation (1) is the workload while the denominator is termed as an equivalent unit. Those are the input components data required to be collected.

IV. EXAMPLE

As an illustration, we utilize the famous monthly 'Airline Passengers' dataset described in Box and Jenkins (1976) famous book "Time Series Analysis: Forecasting and Control," page 531 [13]. The data consist of Volume (counts) of 144-monthly totals of a US airline passengers, from 1949 to 1960 (see Figure 1). Such dataset is also available online via Google search.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1949	112	118	132	129	121	135	148	148	136	119	104	118
1950	115	126	141	135	125	149	170	170	158	133	114	140
1951	145	150	178	163	172	178	199	199	184	162	146	166
1952	171	180	193	181	183	218	230	242	209	191	172	194
1953	196	196	236	235	229	243	264	272	237	211	180	201
1954	204	188	235	227	234	264	302	293	259	229	203	229
1955	242	233	267	269	270	315	364	347	312	274	237	278
1956	284	277	317	313	318	374	413	405	355	306	271	306
1957	315	301	356	348	355	422	465	467	404	347	305	336
1958	340	318	362	348	363	435	491	505	404	359	310	337
1959	360	342	406	396	420	472	548	559	463	407	362	405
1960	417	391	419	461	472	535	622	606	508	461	390	432

Figure 1: The 'Airline Passengers' dataset.

For an illustration, in this specific example, suppose for a Shuttle-Van company, a major/main task of one of the company's EMF was to transport all the airline passengers in Figure 1 (from each passenger's pick-up point to the drop-off point at the airport). The company's aimed to determine the numbers of FTE drivers required to perform the above EMF.

Ideally, for each EMF, a work study should be done in details, to achieve the balance between the company's aimed timeliness and accuracy level. However, for illustration purpose, the following components were the assumed inputs for the major/main task of 'Transporting Passengers' EMF:

1) Volume (counts) of 144-monthly totals of a US airline passengers, from 1949 to 1960, in Figure 1.
2) Average Duration = 3 hour/passenger.
3) Work Year = 40 hours/week × 52 weeks/year = 2080 hours/year.
4) UR = 0.64 with the following assumptions. Suppose on the average, deducting annual trainings, sick leaves, annual leaves, public holidays, etc., the remaining percentage of working hours is 80%. Assuming another 20% of margins to do unexpected miscellaneous (minor) tasks, the remaining working availability (i.e., utilization rate, UR) for the major tasks was 0.80 × 0.80 = 0.64.

Therefore, with the Total Volume (1960 airline passengers) = 5714, we obtained #FTE = 12.88 drivers (rounded up to 13 drivers) to accomplish one of the EMF of the Shuttle-Van company; in this case, 'Transporting Passengers'.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	VOLUME	#FTE	Ave 3y #FTE)
1949	112	118	132	129	121	135	148	148	136	119	104	118	1520	3	
1950	115	126	141	135	125	149	170	170	158	133	114	140	1676	4	
1951	145	150	178	163	172	178	199	199	184	162	146	166	2042	5	
1952	171	180	193	181	183	218	230	242	209	191	172	194	2364	5	
1953	196	196	236	235	229	243	264	272	237	211	180	201	2700	6	
1954	204	188	235	227	234	264	302	293	259	229	203	229	2867	6	
1955	242	233	267	269	270	315	364	347	312	274	237	278	3408	8	
1956	284	277	317	313	318	374	413	405	355	306	271	306	3939	9	
1957	315	301	356	348	355	422	465	467	404	347	305	336	4421	10	
1958	340	318	362	348	363	435	491	505	404	359	310	337	4572	10	
1959	360	342	406	396	420	472	548	559	463	407	362	405	5140	12	
1960	417	391	419	461	472	535	622	606	508	461	390	432	5714	13	12

Table 1: Annual Estimated REQD #FTE drivers for the Shuttle-Van Company

In the same manner, Table 1 showed the estimated REQD #FTE drivers for each year of Figure 1. As seen on Table 1, the Shuttle-Van company had different annual estimation of #FTE drivers. Suppose, the company update their estimation every 3-year, so in practice, an average of the 'past 3-year' estimator were obtained to represent the most recent year (1960) estimation: (10 + 12 + 13) / 3 = 12 FTE drivers. Similarly, any other alternative way of calculating a data-reduction summary statistic (than applying a '3-year average') can be applied, in general, depending on the standard practice of every organization.

V. CONCLUSION

In this paper, we have prescribed a workload-based method to determine manpower requirements via a generic closed-form mathematical modeling (equation) which was termed as the generic (naïve) modeling. We have provided a walkthrough example case for an illustration. Such prescribed workload-based manpower formula is very practical and helpful to practitioners and researchers in their applied fields such as business, human resources, social sciences, psychology, manufacturing, medicine, industry, health care, etc. to determine the required #FTE manpower to perform an EMF in an organization.

Additionally, for future research, there are more workload-based advanced modeling beyond the generic (naïve) model discussed in this paper. However, such advanced modeling are beyond the scope of this paper.

DISCLAIMER STATEMENT

This research represents the author's own work and opinion. It does not reflect any policy nor represent the official position of the U.S. Department of Defense nor any other federal agency.

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