Workload analysis using Modified Full Time Equivalent (M-FTE) and NASA-TLX methods to optimize engineer headcount in the engineering services department

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Abstract. With the increasing number of project initiatives, requests for engineering technical assistance are also increased. This raises a problem in the Engineering Services department which is uneven project workloads assigned among engineers, while there are no standard tools yet used to calculate accurate workload. To achieve maximum engineering productivity and performance, this study conducted to calculate engineer’s physical and mental workload. To calculate physical workload, the modified Full Time Equivalent (M-FTE) method is used, where engineer’s performance rating and allowance factors are also used to combine with the basic FTE calculation method. Estimate hours divided according to project’s level of complexity are converted into an index of FTE categories, i.e. underload, normal, and overloaded. The NASA-TLX method is used to get mental workload subjectively based on the average weight rating of six indicators. FTE index result shows adequate number of electrical engineers where half of them can still be assign to new project, while most of the instrument engineers already overload. Engineer’s mental workload from NASA-TLX result shows an average WWL (Weighted Workload) up to 81.72, which categorized as ‘Very High’ and corresponds to the nature of projects that always expected to be on schedule with high quality result.

1. Introduction
Every profit-oriented organization or company will always try to improve efficiency and reduce operational costs, while still being required to maintain high standards by providing quality results. As is known that human resources are the main assets of the company in improving the quality of products or services. Effective workforce optimization can make a significant difference to the success of a company. For an organization to operate efficiently and effectively, it must know what its workload is. While there is no one exact definition of workload, it is commonly thought to be the amount of work assigned to, or expected to be completed by a worker in a specified time period. Workload that is set too high or too low can negatively affect overall performance. The main objectives of assessing and predicting workload are to achieve an evenly distributed, manageable workload and to accurately determine the resource levels needed to carry out the work.

In supporting the operations of a company, the main task of the Engineering Services department is to provide technical support and manage resources to be able to help the entire area of the company's operations. Technical support provided includes engineering assessment, technical advice and design, cost calculation, and also root cause failure analysis.

In general, the Engineering Services department works on two types of projects:
1. Operating project; costs less than or equal to USD 40,000 taken from the operating expenses of the owner of the area, and not categorized as company asset.

2. Capital project; costs above USD 40,000 funded by capital expenditure and categorized as company asset to be capitalized.

The main key performance indicators (KPI’s) in the Engineering Services department are:

1. Develop Engineering Work Package (EWP) which can consist of detailed designs, cost estimates, material specifications, reports and technical recommendations, as well as construction drawings. This EWP is created and targeted to be completed according to the schedule set by each project manager. This KPI is called EWP Compliance.

2. Ensuring that the result is in accordance with the goals, scope and technical design of the project so that it can be handed over to the project sponsor/owner as well as the maintenance team. This KPI is called Design Conformity.

These two KPI’s must always exist in each project assign to every engineers. Some projects may have one or more of each KPI’s.

With the increasing number of project initiatives in the company that are related to business continuity, improvement ideas, occupational safety and health, or research and development, the number of requests for engineering support are also increased. So that in the Engineering Services department itself several issues and challenges arise, including:

1. Increasing workload, both in operating and capital projects, which are required to deliver results on time with the best quality.

2. Related to human resource management, the unequal workload between one engineer and another.

3. There are no quantitative tools that can provide strong justification for making decisions on the addition of manpower, also to determine whether an engineer can still take an assignment of a new project or not.

2. Research Methods

Effective workload planning by optimizing the capacity of workers must be done to increase productivity [1]. Methods that are widely used to calculate or analyse workload objectively include the Full Time Equivalent (FTE) method. This method is used to determine the optimal amount of labour for a particular task from the workload it receives [2]. The FTE method can calculate the number of hours worked by one full-time employee over a fixed period of time which is considered as one month or one year [3].

The NASA-TLX method is a fairly popular technique used to measure mental workload subjectively. This method was chosen to complement the results of this study because of previous studies found that mental burden also greatly affects employee performance, both excessive and less mental burden. The use of six subscales in the NASA-TLX method to calculate overall workload scores has been found to reduce variability among subjects, relative to unidimensional workload ratings, and also provide diagnostic information about the source of the workload [4].

In general, engineer’s tasks, responsibilities and accountability of engineer in the Engineering department are as follows:

- Develop plans, designs, and technical calculations for various elements in electrical and instrumentation projects according to all procedures, standards and policies of Engineering services and HSE departments.

- Prepare engineering construction drawings and ensure the issuance of engineering packages that are comprehensive, understandable, and constructible.

- Ensure project design is completed according to plan and is responsible for safe and reliable results.

- Manage project workflows by providing direct technical support throughout the project and providing reports under the direct supervision of the Electrical / Instrument Supervisor.

- Resolving technical issues during project implementation and completing commissioning after the installation is completed, to ensure the project meets the planned objectives.
• Responsible for quality, technical competence, and professionalism in the engineering efforts undertaken.
• Providing technical assistance to Maintenance and Operations Department when needed.

Table 1 below shows the profile of the engineers who become respondents in this study. The permanent employees consist of 12 (twelve) engineers with three different levels:
• Junior Engineer: 5 (five) people
• Engineer: 6 (six) people
• Senior Engineer: 1 (one) person

Table 1. Engineers profile in the electrical/instrument section.

| No. | Name                  | Position               | Age (years) | Years of experience |
|-----|-----------------------|------------------------|-------------|---------------------|
| 1   | Maharani Hasan        | Jr. Instrument Engineer| 24          | 2                   |
| 2   | Sofyadi W. Sofyan     | Jr. Electrical Engineer| 42          | 2.5                 |
| 3   | Rachmat S. Putra      | Jr. Electrical Engineer| 34          | 2.5                 |
| 4   | Christian Yohanis     | Jr. Electrical Engineer| 38          | 5                   |
| 5   | A. Betteng Gau        | Jr. Electrical Engineer| 40          | 5                   |
| 6   | Busran Mahmud         | Instrument Engineer    | 36          | 8                   |
| 7   | Leo Agung A. Purnomo  | Instrument Engineer    | 35          | 8                   |
| 8   | Zulkifli Hamzah       | Instrument Engineer    | 42          | 16                  |
| 9   | Muhammad Ihsan        | Electrical Engineer    | 36          | 8                   |
| 10  | Zulfikar Ibnu Mas'ud  | Electrical Engineer    | 37          | 8                   |
| 11  | Iwan Ignatius Adam    | Electrical Engineer    | 53          | 22                  |
| 12  | Sofyan                | Sr. Electrical Engineer| 40          | 15                  |

2.1. Modified Full Time Equivalent (M-FTE) calculation
Because the position of the engineer is divided into three levels, namely Junior Engineer, Engineer, and Senior Engineer, each of which also has a different service period, it is necessary to distinguish the weight from the estimated time given to complete the same task in advance by determining a certain multiplier factor (performance rating) for each level and tenure. This weight will be added to the factor in the FTE calculation, so it is called Modified Full Time Equivalent (M-FTE).

The types of projects are also differed from one another. Thus, the estimated work time of each task in a project also needs to be distinguished based on the complexity and cost of the project (capital value) using the matrix used in the conceptual project development stage of FEL (Front-End Loading) method, where the project level is divided into 3 (three) categories, namely: Light, Moderate, and Complex project.

Table 2 shows the total number of tasks for each engineer/respondent from January 2020 until May 2020 taken from the IProM (Integrated Project Management) application, along with the division of project levels for each task that has been determined based on a matrix of complexity and project costs. This data will be processed later in the FTE calculations.
Table 2. Total number of tasks for each E/I engineer as of May 2020

| No | Name               | Position                        | EWP Compliance | Design Conformity | Total Tasks |
|----|--------------------|--------------------------------|----------------|-------------------|-------------|
|    |                    |                                | Light         | Moderate          | Complex     | Light    | Moderate | Complex | Total |
| 1  | Maharani Hasan     | Jr. Instrument Engineer        | 6             | 5                 | 1           | 3        | 9        | 1       | 25    |
| 2  | Sofyadi W. S.      | Jr. Electrical Engineer        | 1             | 0                 | 2           | 2        | 2        | 1       | 8     |
| 3  | Rachmat S. Putra   | Jr. Electrical Engineer        | 0             | 9                 | 4           | 2        | 2        | 1       | 18    |
| 4  | Yohanis Christian  | Jr. Electrical Engineer        | 3             | 1                 | 1           | 2        | 3        | 1       | 11    |
| 5  | A Betteng Gau      | Jr. Electrical Engineer        | 5             | 1                 | 0           | 7        | 1        | 0       | 14    |
| 6  | Busran Mahmud      | Instrument Engineer            | 4             | 5                 | 1           | 5        | 2        | 0       | 17    |
| 7  | Leo Agung A. P.    | Instrument Engineer            | 0             | 7                 | 0           | 2        | 5        | 0       | 14    |
| 8  | Zulkifli           | Instrument Engineer            | 11            | 2                 | 4           | 1        | 1        | 1       | 20    |
| 9  | Muhammad Ihsan     | Electrical Engineer            | 7             | 3                 | 0           | 14       | 2        | 1       | 27    |
| 10 | Zulfikar I. Masud  | Electrical Engineer            | 10            | 4                 | 1           | 3        | 3        | 0       | 21    |
| 11 | Iwan Adam          | Electrical Engineer            | 3             | 3                 | 0           | 2        | 0        | 0       | 8     |
| 12 | Sofyan             | Sr. Electrical Engineer        | 3             | 2                 | 0           | 2        | 2        | 0       | 9     |

After collecting those data, then it can proceed with the standard stages of the FTE method, which sets the effective work time used to complete a task. FTE calculation derives into two parts, which are FTE of the company and FTE of the employee. FTE of the company is determining how many hours of work that the employees have (the available time), and FTE of the employee is determining how many hours one full-time employee works. The total workload hours are divided by the working hours of one employee.

\[
FTE\ of\ Employee = \frac{Workload\ hours}{FTE\ of\ company}\quad (1)
\]

Workload hour of an activity is determined by how frequent the activity is done in a year (period) and in each period (frequency), how many times the activity is done per unit frequency (quantity or volume), and how long it takes for completing the activity for each unit quantity (process time).

\[
Workload\ hours = period \times frequency \times quantity \times process\ time\quad (2)
\]

The available working hour or FTE of the company is determined by considering working days, off days, standby, and allowances that an employee has in one year working time. The formula is written as Equation 3 as follow.

\[
FTE\ of\ company = (365 - off\ days - standby\ days - allowance) \times number\ of\ working\ hours\ per\ day\quad (3)
\]

The FTE of employee becomes:

\[
FTE\ of\ employee = \frac{period\times frequency \times quantity \times process\ time}{(365 - off\ days - standby\ days - allowance) \times number\ of\ working\ hours\ per\ day}\quad (4)
\]

The result of employee FTE calculation can be categorized into three types which are called as FTE index. These types are Overload, Normal, and Underload. The details of FTE index types are shown in Table 3.
Table 3. FTE index.

| Index         | Definition |
|---------------|------------|
| 0 – 0.99 FTE  | Underload  |
| 1 – 1.28 FTE  | Normal     |
| FTE > 1.28    | Overload   |

The first step to calculate FTE is to define list of task that need to be done by a certain position or subject to be analyse, and then determine how much time needed to complete each task. The duration to complete each task in the KPI is based on estimation data from the Supervisor engineer (expert judgment), by reviewing and analysing historical data for the past three years and also the actual work duration data from the timesheet inputted by each engineer in the existing timesheet online system. From the experience so far, the estimated completion time of a task given by the engineer himself is very vulnerable to bias and cannot be used as an accurate reference.

Table 4 and Table 5 below show list of tasks in each of engineering KPI’s (EWP compliance and Design Conformity). As mention before, all projects assign to engineer must have one or more of this KPI. For example, project A required two EWP tasks and one Design Conformity task. Thus, engineer workload should be calculated based on the number tasks and how many hours required to finish each task.

Table 4. EWP compliance tasks list.

| List of Task EWP Compliance |
|-----------------------------|
| **Phase: CAR Development / Project Scoping** |
| PSD meeting  |
| Site visit |
| Develop PSD form and submit for approval |
| Develop conceptual design (design brief) |
| Develop Preliminary Design (basic design engineering) |
| Preliminary Hazop meeting |
| Develop WBS and cost estimate |
| Develop project schedule |
| **Phase: Detail Design / Engineering Work Package (EWP)** |
| Site visit |
| Provide detail engineering calculation (Manual and/or Software) |
| Develop engineering sketch (design draft) |
| Provide/review material specification and MR/BoM |
| Review/revise drawings from designer |
| Prepare EWP document and submission |
| Follow up equipment/material procurement - Before PO Issue |
| **PLC / HMI Development (For Instrument discipline only)** |
| Develop/review functional description |
| Develop/review IO list |
| Logic programming |
| HMI programming |
| Logic & HMI test and simulation |
Table 5. Design conformity tasks list.

| List of Task Design Conformity |
|--------------------------------|
| **Phase: Material Procurement** |
| Create MIR (Material Input Request) for new or additional material |
| Follow up equipment/material procurement after PO Issue |
| Factory Acceptance Test (FAT) & Site Acceptance Test (SAT) |
| **Phase: PLC / HMI Development (For Instrument discipline only)** |
| Logic & HMI test and simulation |
| **Phase: Construction & Commissioning** |
| Provide tender document (pricing schedule, etc.) |
| Pre-tender meeting and site visit with contractor |
| Award tender process (clarification and pre-award meeting, kick-off meeting) |
| Construction progress meeting |
| Construction assistance, QA/QC inspection, and problem solving |
| Test and commissioning |
| Safety Observation & Inspection (SOI) |
| **Phase: Close Out** |
| Prepare punch list and follow up to construction team/others |
| Prepare mark-up and as-built drawing |
| Prepare and submit PCC, OCC, CCC and hand over document for approval |
| Coordination meeting, etc. (if any) |

2.2. *NASA-TLX Method*

This stage is done by collecting and summarizing the results of a questionnaire that has been circled in one of two paired indicators given to each engineer as a respondent, which is felt to be more dominant towards the work performed. The questionnaire is a pairwise comparison to calculate the number of tally of each indicator that has the most influence and will be the weight of the mental load indicator [5]. Furthermore, respondents will rank for six indicators of perceived mental workload. Then the rating multiplication will be performed on each indicator with the weight that has been obtained before, and then an addition is made to get the total value of the product and the distribution is done by fifteen (the number of paired comparisons). Then the results obtained are adjusted to a standard range of values. The paired comparison questionnaire to be given to respondents is given in Table 6, while the questionnaire for the weighting of indicators is shown in Table 7.

Table 6. Paired comparison questionnaire.

| No | Indicators       | Code | ✓ | Indicators       | Code |
|----|------------------|------|---|------------------|------|
| 1  | Physical Demand  | PD   |   | Mental Demand    | MD   |
| 2  | Temporal Demand  | TD   |   | Mental Demand    | MD   |
| 3  | Own Performance  | OP   |   | Mental Demand    | MD   |
| 4  | Effort           | EF   |   | Mental Demand    | MD   |
| 5  | Frustration Level| FR   |   | Mental Demand    | MD   |
| 6  | Temporal Demand  | TD   |   | Physical Demand  | PD   |
| 7  | Own Performance  | OP   |   | Physical Demand  | PD   |
| 8  | Effort           | EF   |   | Physical Demand  | PD   |
| 9  | Frustration Level| FR   |   | Physical Demand  | PD   |
| 10 | Own Performance  | OP   |   | Temporal Demand  | TD   |
| 11 | Effort           | EF   |   | Temporal Demand  | TD   |
| 12 | Frustration Level| FR   |   | Temporal Demand  | TD   |
| 13 | Effort           | EF   |   | Own Performance  | OP   |
| 14 | Frustration Level| FR   |   | Own Performance  | OP   |
| 15 | Effort           | EF   |   | Frustration Level| FR   |
Table 7. Indicators weighting.

| Score range | Category |
|-------------|----------|
| 0% - 9%     | Low      |
| 10% - 29%   | Medium   |
| 30% - 49%   | Medium High |
| 50% - 79%   | High     |
| 80% - 100%  | Very High |

3. Result and Discussion

3.1. M-FTE result

Table 8 below shows summary of each employee workload based on M-FTE calculation as mention in section 2.1 above. Number of tasks on each KPI (EWP compliance and Design Conformity) are data from January 2020 until May 2020 as shown on Table 2 previously downloaded from the Integrated Project Management (IProM) software, an online system for controlling and monitoring project used by the project team (Project Manager, Project Controller, Engineer, Material Coordinator) in the company.

Table 8. Engineer’s Workload Summary with M-FTE Calculation.

| No | Name                  | Position            | FTE Index | Category  |
|----|-----------------------|---------------------|-----------|-----------|
| 1  | Sofyan                | Sr. Electrical Engineer | 0.51       | Underload |
| 2  | Iwan Adam             | Electrical Engineer  | 0.42       | Underload |
| 3  | Zulfikar Ibnu Mas’ud  | Electrical Engineer  | 1.26       | Normal    |
| 4  | Muhammad Ihsan        | Electrical Engineer  | 1.27       | Normal    |
| 5  | Sofyadi W. Sofyan     | Jr. Electrical Engineer | 0.74     | Underload |
| 6  | Rachmat S. Putra      | Jr. Electrical Engineer | 1.78     | Overload  |
| 7  | A. Betteng Gau        | Jr. Electrical Engineer | 0.51     | Underload |
| 8  | Christian Yohanis     | Jr. Electrical Engineer | 0.79     | Normal    |
| 9  | Zulkifli Hamzah       | Instrument Engineer  | 1.61       | Overload  |
| 10 | Leo Agung A. Purnomo  | Instrument Engineer  | 1.16       | Normal    |
| 11 | Busran Mahmud         | Instrument Engineer  | 1.10       | Normal    |
| 12 | Maharani Hasan        | Jr. Instrument Engineer  | 1.68     | Overload  |

Based on the workload categories found in the FTE calculation, from total of 8 (eight) electrical engineers, there are 4 (four) or half of them are underload compare to other engineers in the same discipline. While one of them in Junior engineer position is considered overload. Whilst for the total of 4 (four) instrument engineers, half of them already overload and the others are normal.

3.2. NASA-TLX survey result

Using NASA-TLX method, data processing until obtaining the level of mental workload are done as follows:
- Calculate the rank comparison between paired indicators, and later add up the results of the comparison for each selected descriptor.
- Calculate the weighted workload (WWL) for each indicator with the equation:
  \[ \text{WWL} = \sum (\text{rating} \times \text{weight}) \].
- Calculate the average WWL by dividing it with the total weight, that is 15.

Table 9 below shows the recapitulation of total and average weighted workload taken from the NASA-TLX survey form for each respondent with different level and experiences.
Table 9. Recapitulation of total and average WWL.

| Name                | Position                  | Age | Years of Experience | WWL  | Average WWL | Category     | (Simanjuntak, 2010) |
|---------------------|---------------------------|-----|---------------------|------|-------------|--------------|---------------------|
| Busran Mahmud       | Instrument Engineer       | 36  | 8                   | 1215 | 81.00       | Very High    |                     |
| Leo Agung A. Purnomo| Instrument Engineer       | 35  | 8                   | 1095 | 73.00       | High         |                     |
| Zulkifli Hamzah     | Instrument Engineer       | 42  | 16                  | 1215 | 81.00       | Very High    |                     |
| Maharani Hasan      | Jr. Instrument Engineer   | 24  | 2                   | 1295 | 86.33       | Very High    |                     |
| Muhammad Ihsan      | Electrical Engineer       | 36  | 8                   | 1405 | 93.67       | Very High    |                     |
| Iwan Ignatius Adam  | Electrical Engineer       | 53  | 22                  | 920  | 61.33       | High         |                     |
| Zulfikar Ibnu Mas’ud| Electrical Engineer       | 37  | 8                   | 1200 | 80.00       | Very High    |                     |
| Sofyadi W. Sofyan   | Jr. Electrical Engineer   | 42  | 2.5                 | 1400 | 93.33       | Very High    |                     |
| Christian Yohanis   | Jr. Electrical Engineer   | 38  | 5                   | 1365 | 91.00       | Very High    |                     |
| Rachmat S. Putra    | Jr. Electrical Engineer   | 34  | 2.5                 | 1240 | 82.67       | Very High    |                     |
| A. Betteng Gau      | Jr. Electrical Engineer   | 40  | 5                   | 1075 | 71.67       | High         |                     |
| Sofyan              | Sr. Electrical Engineer   | 40  | 15                  | 1285 | 85.67       | Very High    |                     |

Figure 1. Average workload for each indicator.

Based on the survey result, the most influential indicator that effect engineers’ workload as shown on Figure 1 is temporal demand by 30%, followed by own performance and mental demand by 27% and 21% respectively. While physical demand is the lowest to 0%.

Comparing the result of M-FTE calculation and NASA-TLX above, especially for electrical engineer position, the physical workload and mental workload are contradictory, where they still have time for new project assignment, but have high, even very high mental demand. One of similar study done by Fernanda, A [6] in department Engineering and Administration of PT PLN Sidoarjo shows similar result, where in certain position they’re doing worker reduction, but the study result shows that position has the highest mental workload.
4. Conclusion
The modified Full Time Equivalent (M-FTE) of each engineer is calculated by determine number of
tasks and estimate hours to complete each task. This calculation also must take in to account the
performance rating number because of the different in level and experience of each engineer. The
method of estimating hours for each task can still be improved perhaps by setting a company standard
to record each hour with combining different method such as using stopwatch study.

The M-FTE method can be used to determine each engineer workload from time to time, so it can be
the basis for the Supervisor/Manager whether or not he/she can give a new project assignment to an
engineer. Because of the nature of the project, it is necessary to differentiate estimate work hours
according to the complexity of the project.

Based on the result from the FTE calculation, current electrical engineer headcount is still sufficient
to handle current workload, where half of the them considered underload and shall have the assignment
for new projects that require electrical discipline to balance the workload among electrical engineers.
But for instrumentation discipline, there are only 4 (four) engineers available where half of them already
have both high physical and mental workload, which indicate the need of additional manpower for new
project requires instrumentation discipline.

Engineer’s mental workload based on the result from NASA-TLX survey shows an average WWL
(Weighted Workload) up to 81.72, which can be categorized as ‘Very High’. The indicator with the
highest value of 30% is the Temporal Demand (TD), which is in accordance with the nature of each task
carried out by the engineer that always has a completion target determined based on the project schedule.
The indicator with the second highest value of 27% is Own Performance (OP), which is also in line with
the demands of the engineer who always expected to deliver quality results in accordance with the
objectives of the project.

Improvements to physical and mental workload can be done in 3 (three) ways, including: elimination,
isolation, and minimization. Elimination is a solution by reducing the activities or jobs that are manual
and then replace it with an automatic machine. Isolation is a solution by preventing a job from being handled by untrained or inexperience workers. Related to this research, the project level assigned to each engineer may also consider their level and experience, since currently, even junior engineers are also assigned to a complex project as well. The mental burden experienced by trained or experienced workers doing certain task shall be smaller than inexperienced workers doing the same task. Minimization can be done by increasing the number of workers, adding time rest, changing work processes to avoid excessive physical or mental exertion [7].

From this result, apart from project assignment balancing, it is unavoidable that the challenge of the engineering supervisor/manager nowadays is that they need to start thinking of new ways of working and communicating to support their human resources and have more of their engagement, also maybe start to invest in stress reliefs program. Further study needs to be done to recommend the best improvement to reduce physical and mental workload for the project-based worker.

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