

An Engineering Approach to Increase Chances of Data Capture-ability and Data Analyzability in Work Measurement Practices

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Abstract

The work measurement standard of a given work is determined from the standard operating procedure of the work at hand, as well as from a work study program that captures the time taken to carry out all related activities. The activities must be both 'capture-able' and 'analyzable' in order to set the standard time, where specific values are assigned to defined time elements. Conventional assembly production works are routine, repeatable, have discrete cycle times, and have predictable patterns of execution as per the operating specifications. For this type of work, time studies (also known as 'pre-determined time methods') are able to capture and analyze time elements efficiently. However, factory works have become increasingly sophisticated and non-conventional. Many portions of the work now possess opposite characteristics of the aforementioned, to the extent that conventional work measurement techniques are no longer efficient in the development of the appropriate work measurement standards. In this paper, case studies are used to describe six characteristic attributes of time elements and the pertinent mapping of work measurement techniques in a 'data capture-able versus data analyzable' quadrant, which can be used in the development of work measurement standards of non-conventional factory works. The purpose of the paper is to provide an insight of the capture-ability and analyzability of work data. This may prove useful in future workforce models, which are becoming more integrated in terms of 'digital and human' patterns rather than the routine human-only operations.

Keywords

Industrial Engineering, non-conventional work measurement, non-routine work, time study, indirect labor

1. Introduction

The importance of labor resource as cost factors in the manufacturing sector started during the Industrial Revolution centuries ago. Today the labor cost is in rising trend everywhere globally, so driving labor productivity breakthrough is no longer an option but inevitable. The industries acknowledge the trend and today Industry 4.0 marches towards smart automation, makes the process leaner and explores cost saving methods to save resource. To save labor resource means the work must be measured and controlled, and work measurement techniques have been used to set standards for labor productivity and resource hiring.

Meanwhile, smart automation and the Internet of Thing (IOT) have gradually shifted the traditional direct labor from doing the manual assemblies works to the non-ordinary types of factory production work, which in the past was handled by the indirect labor. The rapid expansion in the smart automation manufacturing has changed the factory work scopes ratio between labor intensive work and non-labor intensive work in favor of the latter. Hence, setting the work standard for this type of works or workforce group (non-production-direct-labor, NPDL as termed in this paper) is needed, which was then, neglected. To add, due to the work nature of the NPDL, in which the occurrence frequencies are not consistent, the cycle time of each occurrence varies, work scope coverage expectation can be vague, time elements are not discrete because the work is carried out in group versus individually, there is no proper existing labor work study and standards determination techniques can be used by IE to determine the NPDL workforce.

The paper focuses on dissecting the factors of difficulties in determining the standard time for NPDL works. A work study quadrant, which is called 'The Data Capture-ability & Data Analyzability Quadrant' is created. The quadrant refines the analogical steps to comprehend the NPDL work contents characteristics attributes and thereafter to analyze and determine the standard time using one or a combination of work measurement techniques. So, despite the NPDL work nature is unchangeable, the quadrant outlines the techniques to modify the work measuring steps, and therefore to enhance the chances of setting standard time accordingly.

1.1 Definitions of Direct Labor (DL), Indirect Labor (IDL) and Non Production Direct Labor (NPDL)

The categorization of direct labor (DL) and indirect labor (IDL) is derived from business accounting balance sheets, prepared in order to have clear tracing of an operation expense and accountability. Direct labors are those directly associated to converting raw materials to finished products or services, which are assigned to a specific product type, cost center or order by a specific customer. Indirect labors are considered as shared resources.

There are reports in the literature that say that the categorization of DL supports the core of the business, whilst the opposite is considered as IDL. The logic of the difference between the categories is based on costing purposes for billable time (Lewis, 2017). Over the years, computer-integrated manufacturing (CIM) processes have greatly reduced traditional DL content of a company's products (Kaplan, 1984). Equally significant, investments in sophisticated new machineries have changed the IDL work profile.

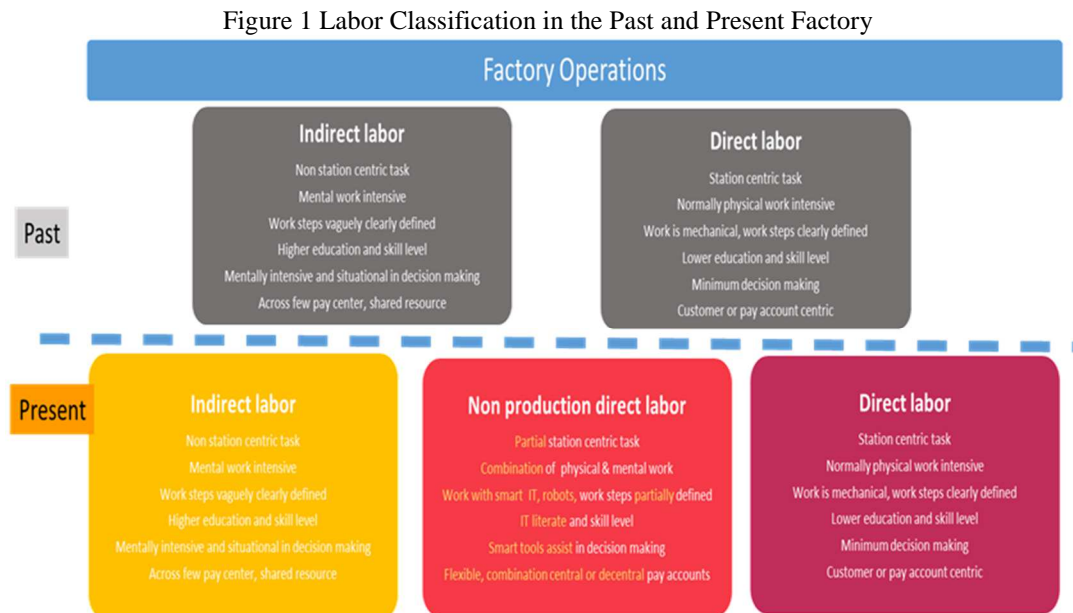
Till recent years, many companies have attempted to implement activities-based costing as a means of turning cost items from indirect cost to direct cost (Schmidt, 2016). The introduction of CIM has replaced manual operation work carried out by DL. Likewise, sophisticated machines are capable of 'thinking' and 'making decisions' and thus carry out tasks that IDL used to do in the past. The effect is that, with less analytical and decision making tasks in the IDL work, DL will be able to handle some of IDL's tasks, with the aid of machines.

DL's work is not confined within the assembly line only. For instance, production line leaders, materials handling staff, and quality control staff who used to be IDL are turned into DL. Their tasks have been modified due to technological and sociological changes. Here are the examples: material handling staff whose tasks comprised placing orders, checking documents and maneuvering carts are replaced with smart supply chain management system with auto triggering, auto-computation and reconciliation of stock level, whilst handling of carts can now be mobilized by automated guided vehicles (AGV). Quality control staff used to be considered as IDL who did quality check activities for multiple products in the past. This type of activity is gradually shifted to inline quality check throughout the production processes. Likewise, production operators are now able to perform self-check work with advanced fool-proof and user-friendly technological systems.

Additionally, the production operators' literacy level has improved overall time and together with the add on advantage of advanced tool in work place, the direct workforce is likely trainable to work across different customers' product line. This phenomenon is getting common in the industry, of which the clear line that used to separate IDL and DL

becoming fuzzier every day. With the trend of reshuffling labor activities based on the aforementioned factors, many IDL tasks fall into DL category.

In this paper, this group of labor is termed as NPDL. With the gradually increasing proportion of traditional DL contents replaced by indirect work, finding the solutions to measure the relevant NPDL work content will enable a better labor staffing profile in the manufacturing operation (Wu and Wu, 1991). Figure 1 summarizes the changes in the structure of factory labor classification.



1.2 The Problems of Work Measurement for Non Production Direct Labor

Direct Labor workers perform tasks in the Production area (Production Direct Labor – PDL) and their tasks are routine, repeatable, have discrete cycle time, and have predictable pattern of execution as per the operating specifications. To compute the number of PDL workers needed, industrial engineers use conventional work measurement techniques. However, NPDL activities are largely opposite to PDL in many aspects. They tend to be non-discrete, non-routine, non-repeatable, in a non-predictable pattern, and the work process steps are loosely defined.

The characteristics of the NPDL works have two key commonalities, which are the motion of the standard works tasks is less describable in terms of frequency of occurrence and the work tasks lack of structured time elements which fit into the conventional work study technique as well. The time value for task elements therefore cannot be assigned accordingly.

2. Methodologies

This paper involved 5 on-site observation case studies and 13 cases from published papers.

2.1 Cases from past technical papers:

A total of 13 cases are examined in terms of their operational scenarios in factories, offices, administrative centers, hospitals, outdoor work plantations, construction, and plumbing works. The work environment and task profiling in terms of workers' motion and effort that fulfil the work requirement is similar to the NPDL. An example is clerical administrative work, whereby the tasks include data entry using desktop or laptop. These are very common routine operational tasks found in manufacturing shop floors, warehouses and Quality Assurance departments. The summary is in the Table 4.

2.2 On Site Observations:

5 case studies are carried out in factories to identify labor work study and standards (in short it is called labor standard time) determination techniques that are most used for non-production supporting crew, the data collection

is based on observations. Four of the factories are electronics assembly and box-build manufacturing factories. One of the factories is located in Eastern Europe and the others are located in two countries in Asia (China and Malaysia). The head count is approximately five hundred workers for two factories respectively, five thousand for another one factory, and the largest is over fifteen thousand for another factory manufacturing cell-phones and mobile – network cards.

In all five locations, there are resident Industrial Engineer whose job is to oversee direct labor planning using work study methods. In carrying out observation work in this research, the researcher shadowed the industrial engineers in order to get a clear portrayal for the planning of work measurement techniques, designing the template for data collection, and analyzing the data. The researcher is also involved in many discussion sessions related to the implementation of the work study measurements. In addition, workers are interviewed in the area where the case studies take place, so as to really understand the issues that they face.

The focus of this portion of the study is on support crews who work in the production line. Office administrative workforce with the same job grade level is excluded. The number of NPDL in this case study range from 15% – 30% of the total direct labor workforce. Their primary job does not take place on the production line, rather, they facilitate production to be more efficient. They comprise security guards and patrolling service crew, incoming part quality control auditors (IPQC), raw material distribution crew, and the workers who carry out maintenance and troubleshooting of equipment, tools, and electronics systems. Included too are workers doing collection and verification of problematic products, finished goods, products transportation, and administrative work. Workers who do facilitating and those who fill up gaps among work stations or working zones are also in this group.

3. Case Studies Findings

The five case studies above are mapped in Table 1. The mapping indicates that although the occurrence frequency is not fixed, the randomness can be handled with track record reference. Data retrieval of hard copy records has been challenging in the past, but this task is now made easier with the availability of electronic systems.

3.1 Task Activities Attributes & Work Measurement Techniques

Another area that deserves close attention is cycle time determination. Cycle time is analyzable only if it is capture-able and breakable into quantifiable pieces. Non-discrete cycle time, inconsistent cycle time length from cycle to cycle, and undefined process steps are the most influential factors to set time standards. Even if these types of cycle time can be captured through recordings, it would be difficult to break them down to absolute time elements performed by an individual or by a process step. In the case studies, the cycle time has been analyzed through work sampling. It provides the estimated time for certain task out of fraction of working hours.

Table 1: Comparison of Task Activities Attributes

Category	Criteria # Worker	IPQC	Repair Man	Maintenance	Store hand	Security Guard
Task cycle time and activities related attributes	Cycle time range	short	Highly mixture	Highly mixture	Highly mixture	Highly mixture
	Group or individual activities	individual	individual	1- 2 persons	1- 2 persons	1- 2 persons
	Number of steps / cycle	1-10 steps/cycle 20-50 steps/cycle	>50 steps without clear start and end	>50 steps without clear start and end	20-50 steps/cycle	1-10 steps/cycle 20-50 steps/cycle >50 steps for disaster recovery case which is rare)
	Driven factors - Motion driven	Mostly Physical motion & some thinking	Thinking, judgmental decision making	Thinking, judgmental decision making	Physical motion	Physical Motion, Thinking, judgmental decision making
Frequency & occurrence pattern	Repetition of activities (random or fixed pattern)	Mixture & predictable	Mixture & predictable	Mixture & predictable	Mixture & predictable	Mixture & predictable
	Expectation of the activities	List of work steps available	Partially defined	Partially defined	Partially defined	Partially defined

Four out of five case studies (except case studies #1 IPQC) show that the work task cycle time is non-discrete (terms as Highly Mixture in Table 2), in which the motion is not describable and thus time value is difficult to be assigned accordingly. To overcome a situation such as this, instead of measuring each motion, time value is assigned to a

batch of activities in a high level context. The batch activities are then assigned with a referencing code or equivalent identification.

Table 2: Comparison of Application Techniques

Variables	Methods for setting time standards				
Method Worker type	IPQC	Repair Man	Maintenance	Store hand	Security Guard
Cycle time	Time Study	Electronic System Time Study	Time study for activities which have process steps defined.	Time Study for discrete activities	Time Study for discrete activities
Frequency	Track record Yield trend	Track record Product quality profile		Track record	Track record
Alternate Verification Needs	n/a	n/a	Work sampling	Work sampling	Work sampling

To aid the work measurement, another option is that, time is be measured with engineered, non- engineered or a combination technique for the segments which are describable in ‘motion’ or steps. For any other task activities which are not measurable, the alternate verification method is work sampling. Work sampling may be carried out at macro levels, then gradually into micro levels. Table 2 summarizes the types of work measurement techniques used in the case studies.

4. Development of the Data Capture-ability Versus Data Analyzability Quadrant

Work study is carried out to determine the working standard based on standard operating procedures of given tasks. It is meant to capture and determine the time on agreeable work activities.

From the 5 cases study, it is observed that the activities’ occurrence must be capture-able and ‘analyzable’ to complete the standard time determination, with a value assigned to a defined time element. Table 3 shows the summary of six characteristic attributes (represented by a, b, c, d, e, and f) of the time elements based on the case studies. Characteristic attributes b, c, are frequency-related. Characteristic attributes d, e, and f are activities time elements discreteness related

Table 3: Characteristic Attributes that Impacts Work Study

	Criteria #	Criteria description
	a	Cycle time range
Frequency related	b1	Repetition of activities - fixed pattern
	b2	Repetition of activities -random pattern
	c1	Clear expectation
	c2	Ambiguitive expectation
Time elements discreteness	d1	Individual activities
	d2	Group activities
	e	Number of steps
	f1	Driven factors - Motion driven
	f2	Driven factors - thinking process driven

4.1 Data Capture-ability versus Data Analyzability Quadrant

The understanding of the characteristic attributes and its impact to the work study is further developed into the Data Capture-ability versus Data Analyzability Quadrant. The quadrant shall aid the organization to select the best technique to set the standard time for of NPDL work. The quadrant illustrates the relationships and effects among the six characteristic attributes in the work study program, as shown in Figure 2. The development of this quadrant is

based on the five case studies carried out in this research. There are four zones in this quadrant, namely A, B, C, and D. Zone A is in the level of capture-able and analyzable data, while Zone B is in the level of capture-able data but having difficulties/non-analyzable data. Zone C is in the level of both difficult/ non-capture-able as well as facing difficulties/non-analyzable data. Zone D is where data is non capture-able but analyzable. Theoretically, no task fall in this category.

Example(s) of Zone C:

Most time elements are capture-able by recording, except under conditions where the items occur very randomly such that they need much resource for recording (Category b2). For example, this type of incident occurs only once or twice quarterly or annually. Given the duration of method study, it is beyond the budgeted resource to wait for data capturing. Category c2 takes place where the task scope is not clearly defined. This type of time element may be excluded. In short, b2 and c2 are non-analyzable because the raw data is not captured.

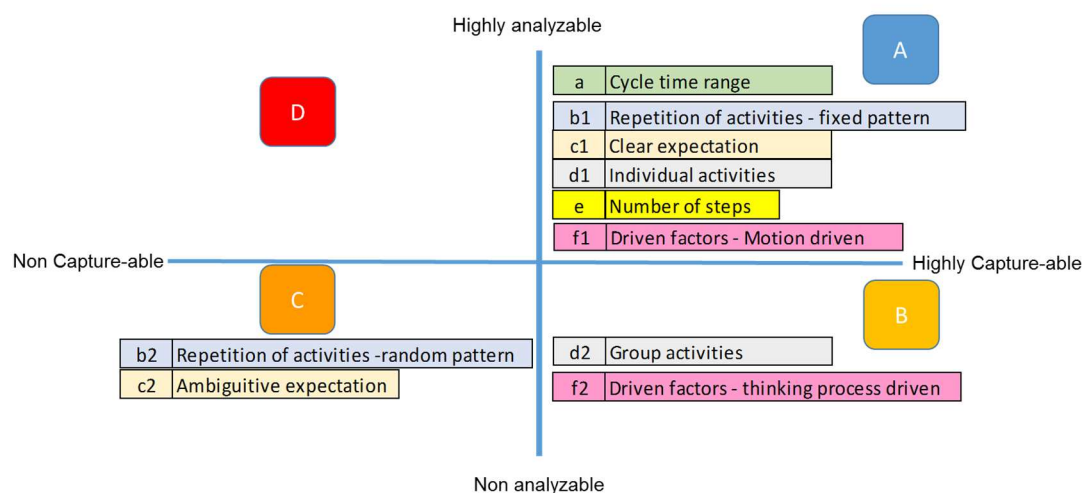
Example(s) of Zone B:

There are two attributes in Zone B, which are d2 (group activities) and time elements for thinking process, which are mostly judgmental activities, f2. The time for a person to think, analyze and decide has a greater variety compared to a person to perform a defined manufacturing task. It is difficult capture the time involved for f2 because this type of mental activity practically does not involve body movement that is physically observable, and the duration depends on unquantifiable factors. Furthermore, the time required by one person can be very different from the time required by another person (International Modapts association, 2009). Similarly, quantifying the time elements to absolute units and by an individual is difficult for d2 because the process has no discrete start or stop points (for f2). In short, elements in this category can be recorded by a recorder, sampling, and other observable means. However, they have no absolute start and stop points that can be used as the basis for single time element or a time element belonging to a single person.

Example(s) of Zone A:

The rest of the attributes in Zone A are activities or motions that are capture-able as per the documented task scope. They are quantifiable through measuring directly or are calculated according to the predicted frequency occurrence and motion steps. The work activities in this zone normally happens in manufacturing and production processing lines, where process steps are systematically defined, documented and strictly followed by workers.

Figure 2 Quadrant of 'Data Capture-able versus Data Analyzable'



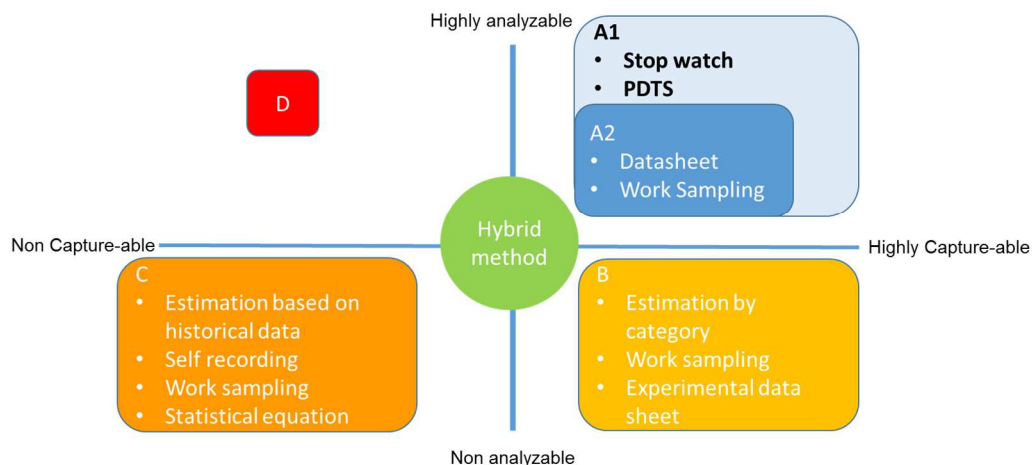
4.2 Work Measurement Techniques in the Quadrant

Through the understanding of the characteristic attributes, the mapping of the work study methods is aligned to the Quadrant of 'Data Capture-able versus Data Analyzable' as shown in figure 3. In the Zone A, there are clear divisions to two subzones. Zone A1 features the methods that cater for time elements with very sharp and absolute start and end points. The most prominent character is the frequency of occurrence and its repetitiveness. Examples of Zone A1 tasks are machine processing time or loading a device by an operator at a fixed hour. Examples of Zone A2 tasks are similar to Zone A1 in terms of occurrence frequency of device loading but the time required to perform the task may vary by uncertain factors such as by batch size, by quality performance, shift pattern, and other environmental factors. Although the work task and motion are describable, cycle time is non-discrete and thus time value is difficult to be assigned in absolute terms.

To overcome the problem, instead of measuring each motion, time value is assigned to a batch of activities that are describable in 'motion' or in terms of the total process steps in a high level context. The batch activities are then assigned with a referencing code or equivalent identification, which is normally called the data sheet.

Zone B and Zone C are the techniques which are mostly based on estimation or prediction due to task activities are not analyzable.

Figure 3 Work Measurement techniques in Quadrant by 'Data Capture-able versus Data Analyzable'

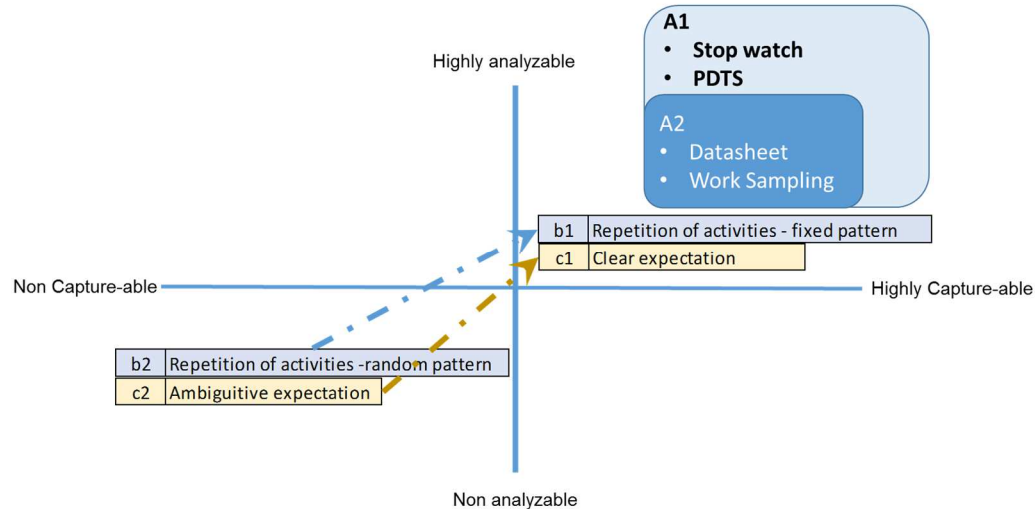


4.3 Increase chances of Data Capture-ability and Data Analyzability

As shown in Figure 2 and Figure 4, if the frequency-related characteristic attributes are enhanced through a more defined procedure, work steps, and structured work instructions, or when the activities occurrence frequency is recorded and retrievable, leveraging the latest smart IT solutions, b2 and c2 elements can shifted to Zone A. This shift will enable a more accurate analytical method. Figure 4 illustrates how the shift improves the chances of capturing the time elements.

On the other hand, to increase the chances of setting the standard task time for zone B items, which are non-discrete activities, the most possible improvement is to consider grouping the items that require information processing, a.k.a. thinking by levels for time value assignment. If possible, the thinking or judgmental process is made through smart IT solutions instead of human processing, not only for time saving but for consistency in quality, especially when this involves mass production.

Figure 4 Shift of b2 and c2 to the Zone A in the Quadrant by 'Data Capture-able versus Data Analyzable' to improve time capture-ability



5. Validation and Use of Quadrant of Data Capture-ability and Data Analyzability

To ensure the suitability of the 'Data Capture-able versus Data Analyzable' quadrants and work methods in each zone, 13 cases from the literature are examined. The 13 cases are all NPDL scenarios from factories, offices and administrative centers, hospitals, outdoor work plantation, construction, and plumbing works. All the cases are given in Table 4, where the summary of the work measurement methods used in the cases are included. They all match with the Quadrant's prediction. Nine out of 13 cases from Zone B use work sampling, while others are in Zone C.

Table 4: Work Measurement Methods used in the 13 NPDL cases

Case	1	2	3	4	5	6	7	8	9	10	11	12	13
Work Nature	Manufacturing	Disassembly products	Construction work	Nursing	Office work	Office work	Customer service	Cancer screening	Farmer	Plumbing	Sewing	Sales person	Non-continuous IDL
WM Method	Stop Watch												
	Work Sampling												
	PMTS												
	Auto log												
	Estimation												
	Self Recording												
	Experiment												
Others	In house data sheet			Control Survey		Self recording						log book records (transaction)	MJA - Major Unit of Activity
Zone (Actual)	A2	B	B	A2, B, C	B	B & C	B	B	B	B	B	B & C	B
Zone (Quadrant theory)	A1	A2 & C	A, B & C	A, B & C	A, B & C	A, B & C	A, B & C	A, B & C	A & B	A, B & C	A, B & C	A, B & C	A & C

It is noticed that the driving factors are the frequency and time element discreteness- related factors. The characteristic attributes of b2 and c2, which contribute to the difficulty of capturing the time elements, are boxed up in orange color in Table 5. The characteristic attributes d2 and f2 affect the time elements data analysis, which are boxed up in red, as shown. As discussed earlier, loose definitions in work task processing steps and occurrence frequency prediction are among the key factors which are correctable. For the 13 cases, the analysis shows that with the fine-tuning of these shortcomings, the work measurement methods may possibly shift to Zone A in all the cases from Zone C.

Table 5 The Impacts of Work Measurement Methods characteristic attributes of b2, c2, d2 and f2 in the 13 NPD cases

Work Nature		Manufacturing	Disassembly products	Construction work	Nursing	Office work	Office work	Customer service	Cancer screening	Farmer	Plumbing	Sewing	Sales person	Non-continuous IDL
a Discrete-ness : Cycle Time Length	Short	A					A					A		
	Medium	A										A	A	
	Long					A			A			A	A	
	Mixture		A	A	A					A	A	A		A
b1	Fixed Repetitive/routine	A				A						A		A
b Frequency : Repetition Pattern	random					L						L		
	b2 Mixture: random & repetition		C	C	C		C	C	C		C	C		C
	Unpredictable													
c Frequency : Activities Steps Sequencing Expectation	c1 Available	A			A		A	A				A		
	c2 Partially defined			C		C			C		C	C	C	
	Non defined							C				C		C
d Discrete-ness : Activities Grouping	d1 Individual	A	A	A	A		A	A			A	A	A	A
	1-2 persons								A		A			A
	d2 Small group			B		B				B		B		
e Discrete-ness : # steps/cycle	Large group			B										
	1 to 10													
	10 to 50	A										A	A	
	>50 with start and stop defined		A	A	A		A		A		A	A	A	A
f Discrete-ness : observable-ness	> 50 and / or without clear start & end			A		A		A			A	A	A	
	f1 Physical	A	A	A						A	A	A	A	A
	Mind thinking					B	B			B	B	B	B	
f2	Thinking, judgmental, decision making				B	B		B	B			B	B	

6. Summary of NPD Work Study Techniques

Rapid changes in product design drive many changes in manufacturing. Product quality performance, type of raw materials needed, and machine/tool conversion need to be taken into consideration at all times. The chain effect will in turn affect the cycle time and frequency of tasks to be carried out. To ensure that NPD calculations are accurate, the calculations should be examined regularly.

Traditionally, NPD resource is justified through the process owners who list out all activities to be carried out. Hence, the justification is looked at without considering standard time and occurrence frequency patterns. There is no verification by industrial engineers in this matter. Therefore, 'buffering' is carried out during resource planning in order to avoid labor constraint.

Now, with the new NPD model, task activities are clearly defined, and usage is transparent. However, management should be aware that each of the methods has its strength and shortcomings in analyzing different types of work activities (Sherlock, n.d.). Details and accuracy are the tradeoffs against speed and cost of application (Daniels, 1991). If the time work task content and steps are loosely defined, choosing methods for standard setting should be based on objective and needs, rather than 'absolute accuracy'. As highlighted by previous research, for example Dossett (1995), 'there is no such thing as an "absolutely accurate" labor standard time. Human workers come in at least a billion specifications and work under varying environmental conditions'.

Similarly, as pointed out in the Quadrant of 'Data Capture-able versus Data Analyzable', the choice of work study can be shifted if certain conditions are met. It must be a conscious effort to set up conditions which are 'scan-able', readable, and capture-able.

Besides the technical perspective, potential resistance from the owner groups may arise. Thus, refusal to accept changes in planning using modeling is not a surprise. Management must ensure that there is continuous support so that documentation of standard work and cooperation among workers continue.

7. Future Work

It has been demonstrated in this thesis that NPD workforce requirement can be derived from a systematic and logical approach through work measurement methods. The computation of time standards and occurrence patterns may not

be similar to the conventional PDL tasks, but they can be overcome with scientific and systematic approaches instead of best estimates, gut feel, past experiences, and PDL: NPDL ratios of the past.

The future workforce model which shifts towards an integrated 'digital and human' patterns or mixture of 'robots and humans' working side by side shall need more flexible methods. This matches with the approach in this research model, which is the 'Data Capture-able versus Data Analyzable' quadrant approach. The quadrants focus not on the type of job alone, but also the scalability of the capture-ability and analyzability data.

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Biography

Thong Sze Yee started off as an Industrial Engineer in Intel and has been with the manufacturing industry practicing Lean and Industrial Engineering for 20 years. Ms.Thong has held various managerial positions in Industrial and Manufacturing Engineering, Operation and Project Teams. She has been a senior manager managing a team of IE, Lean and Six Sigma experts in Flex prior to her current role as a Global Lean Manager facilitating productivity improvement projects and workshops globally. She holds a B.S. degree in Industrial Engineering from Rochester Institute of Technology (RIT), USA. Presently she is a Doctoral Candidate in Manufacturing Engineering with Unimap, Malaysia. Her enthusiasm in IE and LEAN does not stop at workplace, she loves reading IE technical books, writing technical articles & blog posts, and participating in relevant forums at free time. While enjoying her mentorship role at work, her private life is equally enriched with time spent with her three young children and voluntary work in promoting green environment and animal welfare.

Dr Zuraidah Mohd Zain obtained her PhD in 1993 for her work on quality management practices in UK manufacturing industries. Over the years, her research interest spans quality issues in manufacturing and service organizations, particularly in education institutions. Having been involved in both manufacturing as well as services, she has observed first-hand how quality has been adopted, adapted, and executed appropriately, and how the practices have evolved according to the purpose for which they are implemented in the first place. Dr Zuraidah is also interested in green manufacturing.

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