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

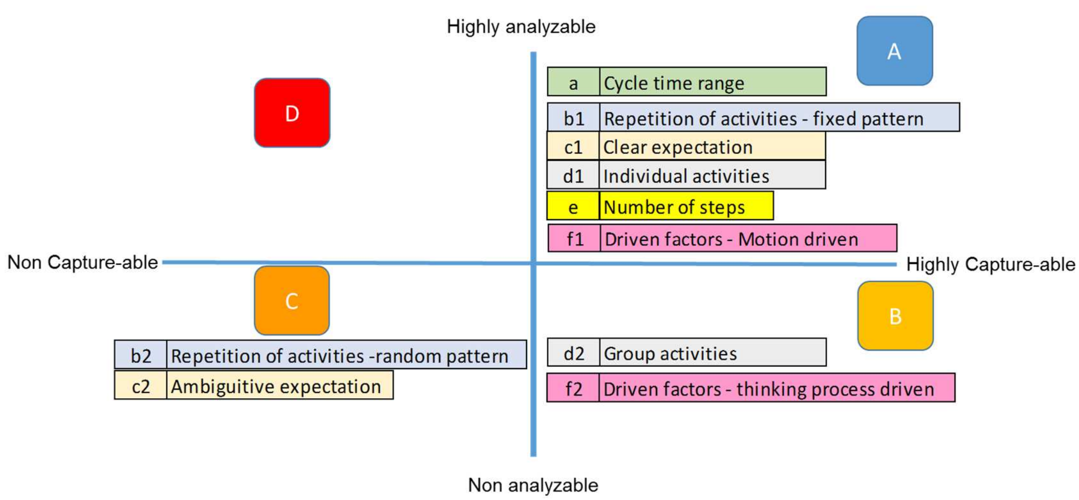
The understanding of the characteristic attributes and its impact to the work study is further developed into the Data Capture-ability versus Data Analyzability Quadrant. The quadrant shall aid the organization to select the best technique to set the standard time for of NPDL work. The quadrant illustrates 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 metal activity practically does not involve body moment 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'



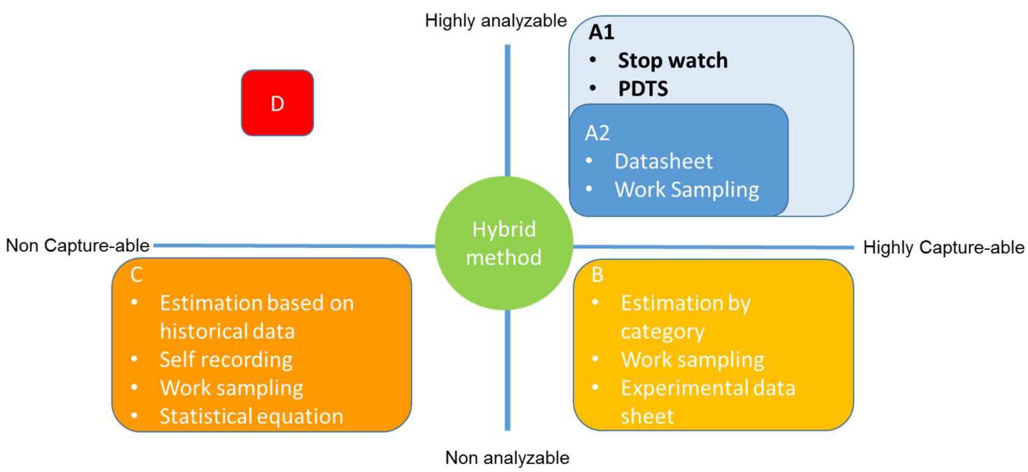
4.2 Work Measurement Techniques in the Quadrant

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'

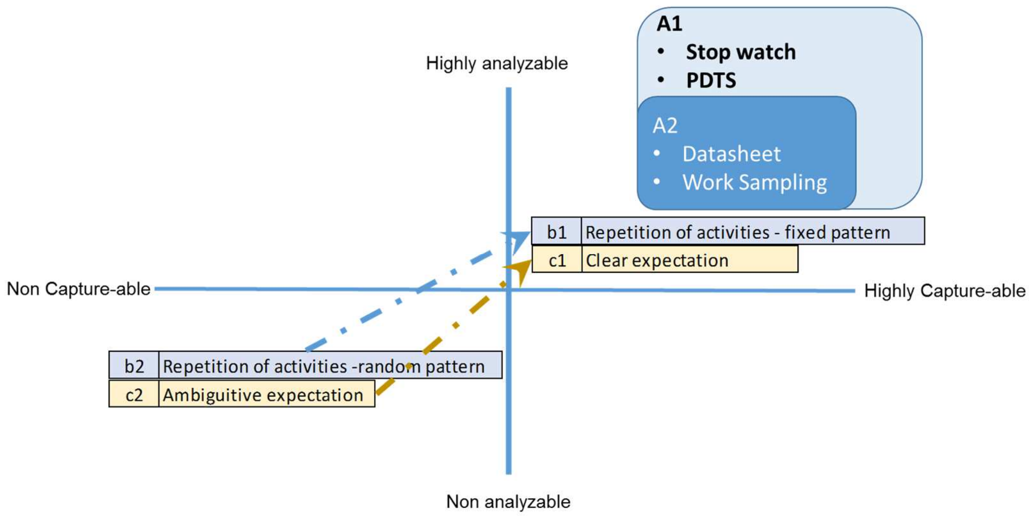


4.3 Increase chances of Data Capture-ability and Data Analyzability

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)	MUA - 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 NPDL 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		
		Medium	A					A					A	A	
		Long					A			A			A	A	
		Mixture		A	A	A					A	A	A		A
b Frequency : Repetition Pattern	b1	Fixed Repetitive/ routine	A				A						A		A
	b2	Random					C						C		
		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		A
	d2	Small group			B		B				B		B		
		Large group			B										
e Discrete-ness : # steps/cycle		1 to 10											A		
		10 to 50	A										A	A	
		>50 with start and stop defined		A	A	A		A		A		A	A	A	A
		> 50 and / or without clear start & end			A		A		A			A	A	A	
f Discrete-ness : observerable-ness	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 NPDL 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 NPDL calculations are accurate, the calculations should be examined regularly.

Traditionally, NPDL 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 NPDL 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 NPDL 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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References

Barrett, D.S.(1997). Standard data in batch production at Rank Xerox. *Work Study*, 46 (1), 9-19

Bechar, A & Eben-Chaime, M (2013). Hand-held computers to increase accuracy and production in agricultural work study. *International Journal of Productivity and Performance Management*, 63 (2), 194-208

Daniels, B. 1991 Choosing a work measurement system. *Work Study MCB University Press*, 44 (1), 18-19

Desai, A & Mital, A (2005). Incorporating Work Factors in Design For Disassembly In Product Design. *Journal of Manufacturing Technology Management*, 16 (7), 712-732

Dossett, R.J. (1995).Work-measured labor standards – The stage pf the art. Industrial Engineering. *ABI/INFORM Global*, 27 (4), 21

Gunesoglu, S & Meric,B. (2007). The analysis of personal and delay allowances using work sampling technique in the sewing room of a clothing manufacturer, *International Journal of Clothing Science and Technology*, 19 (2), 145-150

Jenkins, J.L. & Orth, D.L. (2003). Productivity Improvement through Work Sampling. *AACE International Transactions*

Josephson, P-E & Bjorkman, L. (2013). Why do work sampling studies in construction? The case of plumbing work in Scandinavia, *Engineering Construction and Architectural Management*, 20(6), 589-603

Kaplan, R.S. (1984) Yesterday's Accounting Undermines Production. *Harvard Business Review*. Retrieved March 2016 from https://hbr.org/1984/07/yesterdays-accounting-undermines-production

Lewis, J (2017). Direct Labor vs. Indirect Head Count. *Houston Chronicle*. Retrieved March 2017 from http://smallbusiness.chron.com/direct-labor-vs-indirect-head-count-37186.html.MODAPTS (2009). *Modular Arrangement of Predetermined Time Standards* training material. 1991, 2000 & 2008 International MODAPTS Association, Inc. Southern Shores, North Carolina

Mandel, B.J. (1971). Work sampling in financial management - cost determination in post office department. *Management Science*, 17 (6), 324-338

Myny D., Goubergen, D.V., Limere, V., Gobert, M.,Verhaeghe, S.& Defloor,T. (2009). Determination of standard times of nursing activities based on a nursing minimum dataset. *Journal of Advanced Nursing*

Olm, K.W. (1960). A system for measuring office work performance. *California Management Review*, Winter, 60 (2), 2, 80-89

Paul. R.J (1967). Scientific Determination of performance standards for non-repetitive activities. *Journal of Retailing*. 43 (3), 50-56

Preuschen, G (1967). Standard times for agricultural operations. *The International Journal of Production Research*, 6(1), 57-64

Rei,G., Kohei, A., Hirotsugu, K., Kazuei, O., & Chisato, H (2014). Labor resource use for endoscopic gastric cancer screening in Japanese primary care settings: a work sampling study. *PLoS ONE*, 9 (2), E8813

Richardson, W.J. (1971). Measurement of Indirect work using multiple regression. *International Journal Production Research* 1971,9 (4),481-488

Rickards J (1987). MUA-A Simple Indirect Labor Measurement Technique. *Industrial Management*, Mar/Apr 87, (29) 2, 20-23

Schmidt, M (2014). Direct and Indirect Labor Overhead Costs Explained. *Business Encyclopedia by Solution Matrix Limited*, Retrieved July 2016 from https://www.business-case-analysis.com/direct-labor.html

Sherlock, A.(n.d.). Work Measurement Notes in *Mechanical Engineering with Management* Techniques 4: The University of Edinburgh: Scotland

Wu, J.A. & Wu, N.L. (1991). Productivity Management of Indirect Labour through Variable Work Measurement and Control. *International Journal of Operations & Production Management.* 11 (8), 48-58

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.

Dr Tan Chan Sin was born in 1988 in Kedah, Malaysia. He obtained his PhD from University Malaysia Perlis in 2015 and is currently a Senior Lecturer in the School of Manufacturing Engineering, University Malaysia Perlis. Dr Tan's research areas include Productivity, Quality Modeling and Reliability Analysis. He is also interested in Lean Manufacturing, TQM, and Operations Research. He has published a number of papers in ISI impact journals and international conference proceedings including IEOM conferences.