Work Measurement in Skilled Labor Environments

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Executive Summary

From manufacturing to consumer retail, construction to health care, more and more employers are hiring people for custom, high-skill* jobs. These positions require a well-trained employee to perform a complicated process. Accurate time measurements are vital for proper management of custom jobs. Without them, an organization cannot assign precise costs to an original labor task or predict the savings of an improved one.

Modern United States industry realizes the demand for accurate time estimations of custom work but fails as it attempts to fulfill it. The traditional time study*, or the process of measuring labor with a stopwatch and clipboard, is confronted by major social and technical barriers as it tries to estimate the duration of custom jobs. Yet the time study is often the first method today's industry employs. This report presents modern estimation methods that overcome the difficulties of measuring custom, high-skill jobs with a traditional time study.

Specific social barriers prevent the archaic time study from producing worthwhile estimates in custom, high-skill labor environments. Quickly producing accurate time estimates in any labor environment is challenging, but the nature of a custom-work environment makes this process especially difficult. Custom, high-skill employees often have significant experience and responsibility at the organization where they work. Because of this, they often find it demeaning and even threatening when another employee scrutinizes them with a stopwatch. This unproductive working relationship leads to a limited work time sample size and inaccurate estimates.

These social obstacles are complemented by the technical obsolescence of the traditional time study. Collecting written data with an old-fashion mechanical timer is much more tedious and inaccurate than today's technology should allow (Tolo 34). In addition, mastering custom, high-skill work often takes years of vocational education (Bureau of Labor Statistics 1, 2). An observer who has never done the work may be unable to separate the job into specific elements, or recognize when an employee is doing a job differently than the rest. These unknowns diminish the validity of results.

Despite these barriers, modern methods have been developed which make rapid, precise time estimation possible. Mobile computer software can eliminate the need to collect and analyze time data by hand. Work Sampling and broad Predetermined Motion Times Systems such as MTM-3 reduce the required observation time yet maintain the usefulness of the estimates. Even quicker results can be achieved by training and allowing skilled employees to measure their own work. Along with the technology discussed previously, high-skill workers can use tools ranging from written "tagging sheets" to credit card-like swipe cards to meet the customization needs of their work measurement program.

In conclusion, using a traditional time study in a custom, high-skill labor environment is a practice industry should usually avoid. Fortunately, effective modern methods have made its obsolescence insignificant.

* Term defined further in Glossary on page 22

Introduction

As U.S. industries procure more high-skill labor to meet the need for custom goods and services, reducing the cost and labor-time of such employees becomes absolutely essential for an industry's success. The high-skill labor needed to do custom work costs more than minimum wage. Therefore, any reduction in labor-time spent turns into a significant cost savings for the employer, a quicker response to the customer, and a greater capacity for work.

Any improvement plan to reduce the labor-time spent on a job must be checked to quantify the actual reduction. This check step must quickly and accurately compare the previously required labor-time to the reduced required labor-time. Such a rapid and precise comparison demands a rapid and precise work measurement* tool.

The problem surfaces when an organization tries to find such a tool. The search often starts and stops with a traditional time study*, more commonly known as the stopwatch and clipboard method. Ever since the early 20^{th} century, organizations have used this tool to time a manual labor process. For example, a traditional time study was used effectively on old-fashion assembly lines, where the work was very repetitive and usually completed in the same fashion regardless of the individual doing the work (Department of Labor 9). But when the same tool is applied to today's custom, high-skill job, the complexity of the work often causes it to fail miserably.

This report will discuss ways to decrease the chance of this failure so that the need for custom work measurement can still be met. First, the report will specify barriers a traditional time study faces in today's custom, high-skill labor environment. After defining these barriers, the best work measurement methods for addressing them will be discussed. The report will then conclude with an easily referenced summary of these methods, so that a organization who wishes to start a work measurement program can quickly choose the method that is best for their situation.

Barriers Prohibiting Traditional Work Measurement

According to the Industrial Engineering Publication *IE Terminology*, work measurement is "a generic term used to refer to the setting of a time standard by a recognized industrial engineering technique." While this definition may depict a simplistic image of work measurement, the process of determining a time standard in a complex labor setting is far from easy. Each custom, high-skill labor environment has inherent barriers that often prevent the traditional time study from quickly obtaining accurate data. These barriers can be divided into two categories, Social and Technical. The specific topics related to each type of barrier are depicted in Figure 1 below. This figure is followed by a description of each of the barrier topics. These eight descriptions (while they are by no means all-encompassing or completely independent) discuss the difficulties work measurement must bypass to be successful in a custom, high-skill labor environment.

* Term defined further in Glossary on page 23

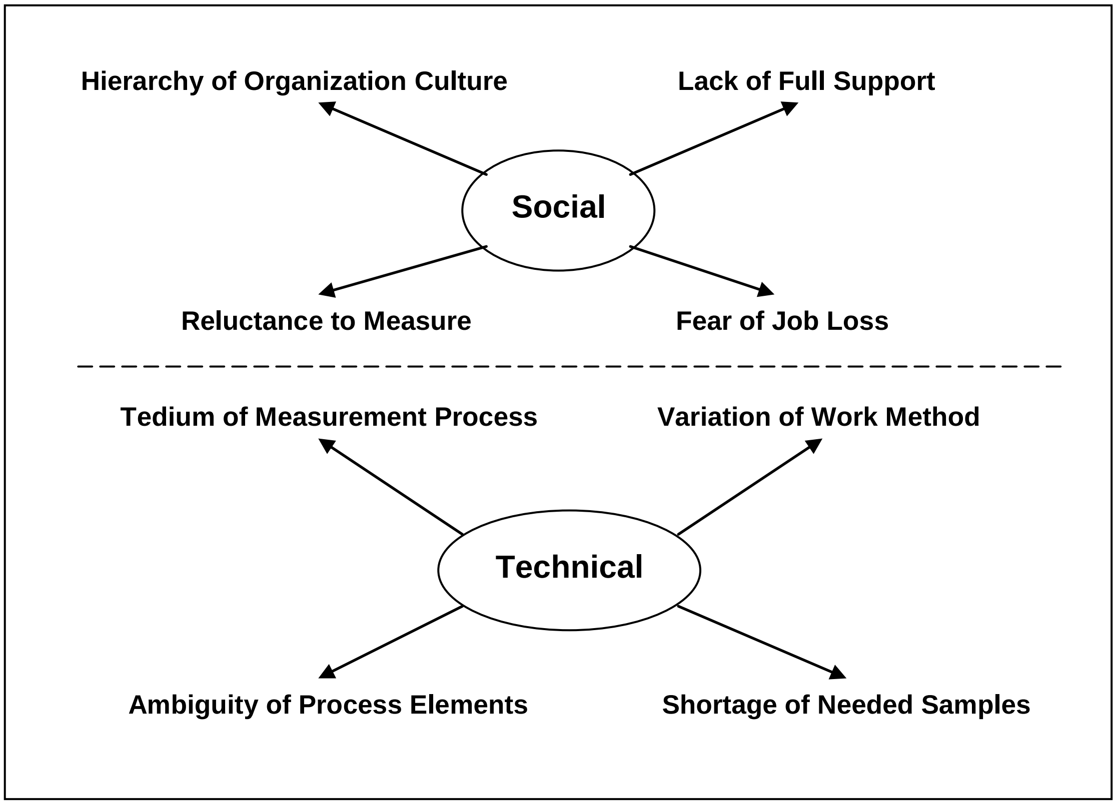

Figure 1: The Two Categories of Work Measurement Barriers and their Sub-Topics

Social Barriers

Hierarchy of Organization Culture

In many health care environments, leadership and hourly staff engage in limited direct communication and joint improvement ventures. An organization's skilled labor often has significant tenure with the organization, yet they still hold an hourly position. Initiatives passed down from leadership to staff without involving them in their development are often questioned or rejected, and give the experienced employees the feeling that their opinions are ignored. "Formal work standards developed by industrial engineers and imposed on workers are alienating" (Adler 98). This alienation is damaging to the success of any work measurement effort.

Lack of Full Support

If a work measurement system is to be implemented and used effectively, it must be supported by everyone involved: the employees doing the work, management, those using the information, and those conducting the study. According to an article by Failing, Janzen, and Blevins, the "major disadvantage of [traditional] time study is its costliness" (Failing, Janzen, and Blevins 106). Any system that is costly leads management to be reluctant to give support. In some cases, senior leadership withholds support because they think their high-skill employees will not buy in to such a project. Therefore, the management team discards the work measurement program in fear that it will create more harm than good.

Reluctance to Measure

While discussing labor time estimation for custom products and services, Doctor Raj Veeramani states that “models should be based on facts and real data [such as…set-up and run times]” (Veeramani 831). Many health care tasks have a current estimated completion time, but these estimates are often based solely on educated guesses, or soft estimation. A strong resistance to changing from soft estimations to data-based estimations is in place because of two concepts: self-efficacy and performance satisfaction.

According to the Federal Highway Administration (FHA), self-efficacy is “an estimate of how well the individual could function in a new environment.” New estimation methods often use basic statistics, and skilled manual employees can feel uncomfortable with this. The FHA defines performance satisfaction as “the individual's estimate of how well things are being done in the current environment.” Many health care employees have been working with a soft-estimation system ever since they started working. In their eyes, the organization has always “gotten by” on this method. Low self-efficacy combined with high performance satisfaction could yield strong resistance to measure.

Fear of Job Loss

When measurements on work are taken, what is the end goal? Ultimately, the measurements should identify those labor tasks which need to be improved. In the mind of the workers being measured, this need for improvement represents a direct threat to their job security. They assume if the measurements show they cannot keep up with an expectation or standard, they will lose their job as management attempts to eliminate inefficiencies. For this reason, employees have some level of fear when they are involved in work measurement, and they will often attempt to hinder the process as a result.

For example, during a time study that I personally conducted, I used a computer to speed up the data collection process. While I was collecting time data, an employee pressed the power button on my computer, causing me to lose an hour’s worth of work. When someone’s work is observed by a superior, the person always has some amount of fear for his or her job security.

This fear is often greater when a stopwatch is involved. Frederick W. Taylor first used the stopwatch for analyzing labor processes in 1910 (Taylor 6). Over the past century, the stopwatch has developed into a symbol of top-down management, a philosophy which is shunned by today’s custom, high-skill employee.

Technical Barriers

Tedium of Measurement Process

From the perspective of someone measuring the work, the technical barriers related to custom, high-skill work measurement are just as daunting as the social barriers. One set of problems related to custom work measurement is the amount of time and effort a traditional time study requires in a custom, high-skill setting. Employees doing this type of work will complete many different steps throughout the day, sometimes with no repetition. An observer completing a traditional time study would have to be available throughout each work day, so that they could be ready to measure each rare step as an operator begins it.

The amount of work escalates even more when a person tries to analyze the data. In order to easily generate a statistical analysis, today's observer will likely transfer the written observations into an electronic document. The longer the observation, the longer the person spends copying the data into a computer.

Variation of Work Methods

A traditional time study in a custom, high-skill industry is not only tedious, but it also lacks accuracy. According to Gerald Nadler, "variations in base time will arise from the method being used for [completing] the job." He then describes how these variations destroy the prediction value of a time study (Nadler 9). Such variations are prevalent in a custom product or service industry, because each high-skill job often employs individuals who complete difficult tasks in a variety of ways.

One example of custom work outside of health care is the time it takes to tack (or fit-up) two sheets of metal. Tacking involves welding a few points along a previously open slit between two metal surfaces. This activity keeps the surfaces from spreading apart during a future process. Tacking becomes more difficult when the two pieces have to be bent and adjusted to fit together. Figure 2 below shows a tacking process taking place.

One Tack

Figure 2: A Welder Tacking Two Pieces of Metal Together This process can be done many different ways depending on the preferred methods of the person doing it.
Image Source: **http://www.tinmantech.com/assets/images/vidst_fender_arch3.jpg**

Wild variation will often be observed in the time taken by each welder who completes this tacking and flushing process. Some welders will take longer than others to complete the operation on the same type of seam. Welding managers often understands this discrepancy completely, because they are aware of the differences between one welder's technique (or even "art") and anothers.

This example elaborates on one of the biggest difficulties with developing accurate time estimates for custom, high-skill work: individuals in the same department often have their own "best way" of finishing a task. Each person's method may be slower or faster than the rest of the department, so a time estimate that was based on the average of the whole department will always be either too short or too long, depending on which operator actually does the job. Inaccurate estimates lead to a different cost for the organization, and an unreliable delivery time for the customer.

Ambiguity of Process Elements

Unless the person timing a job is familiar with the work, he or she cannot determine which elements of that work are independent of one another. Independence in this sense means that the variability of one element is unrelated to the variability of the other elements. Without determining independent tasks, and timing them separately, the variability of time estimates will be unexplainable. For example, if a whole job is timed at once, and the times range from very long to very short, the observer cannot determine which portion of the job caused this wide range. One or two independent tasks likely caused the problem, but the observer has no way of knowing because he or she did not separate the tasks originally.

Correctly dividing the job is especially important when developing a time estimate for custom work. An accurate estimate *can* be developed for custom work, but the estimate must compile the correct number and sequence of independent tasks. There are often *many* specific, independent tasks involved, and a traditional time study process requires the observer to measure and understand each one. In-depth knowledge of the work often helps account for each independent task. With custom work, this in-depth knowledge can take months or even years to acquire.

Shortage of Needed Samples

The more task times an observer collects, the more likely it is that the average of those times will be an accurate estimate of how long the task will take. To begin an experiment, most industrial engineers would agree with James Kilgore's general recommendations:

> The [work measurement] developer should get a minimum of 10 readings per variable, per operator. Although not [a] requirement, the number of readings taken on a given variable should be a function of the range and variability of the variables timed (Kilgore 42).

In manufacturing environments of the past, where work measurement was born, there was often a whole department who collected the ten or more times for each task and operator. In today's setting, a traditional work measurement process is often conducted by one person in the organization, as part of a larger improvement plan. When the measurement is done on a custom, high-skill job, the number of independent tasks involved can result in a large overall sample size. The hypothetical scenario in Appendix A results in a total of 549 samples and an estimated 40 hours and 20 minutes[×] of constant observation to record the data. Also, as tasks are separated into two or more independent elements, 99 original times (those in red) could not even be used for the estimation.

[×] Based off a sum of averages

Situations such as this are not uncommon in health care. When faced with this sample size, an observer will often meet the due date for their estimation results by taking fewer samples. This will lead to an estimate which doesn't represent each possible working scenario, which leads to inaccuracy. An inaccurate estimation is a complete waste of effort.

Work Measurement Methods to Address These Barriers

Now that the barriers to using a traditional time study process in a custom, high-skill labor environment have been established, I will present work measurement methods that address these barriers. These improved methods can be broken up into two categories: methods that involve an outside observer measuring the employees who are doing the work and methods that improve the process of high-skill workers measuring themselves. Each of these techniques has strengths and weaknesses when applied to a certain situation. To demonstrate these characteristics, the description of each method explains how the method should be implemented, what specific barriers it addresses, and what technology it puts to use.

External Measurement of High-Skill Workers

Figure 3 below shows the three methods or tools discussed in this section of the report.

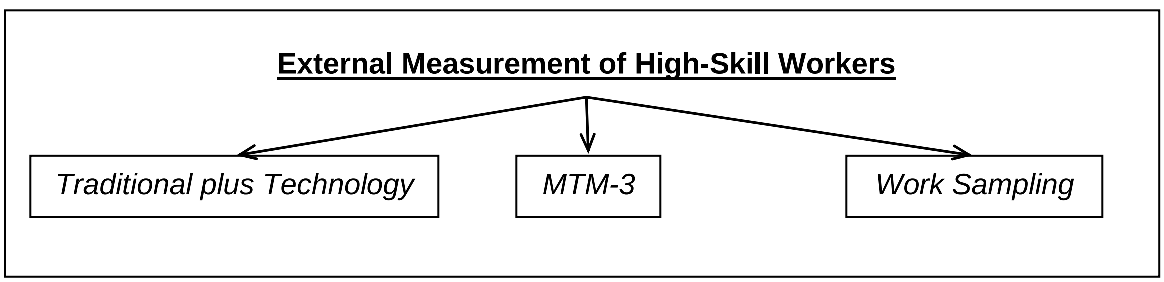

Figure 3: Work Measurement Methods for External Measurement of High-Skill Workers
These three tools are best used when an outside observer is measuring the custom labor process.

Traditional plus Technology

In some labor situations, the most effective way to improve on the traditional time study is not to completely discard it, but to upgrade it. This involves replacing the stopwatch and clipboard with modern technology that is more conducive to quick, accurate data collection. In today's work measurement arena, this technology involves computer-based time study tools and software. The two prominent types of these tools – those based on custom software and those based on Microsoft Excel – are exemplified by the two products shown in Figure 4 below.

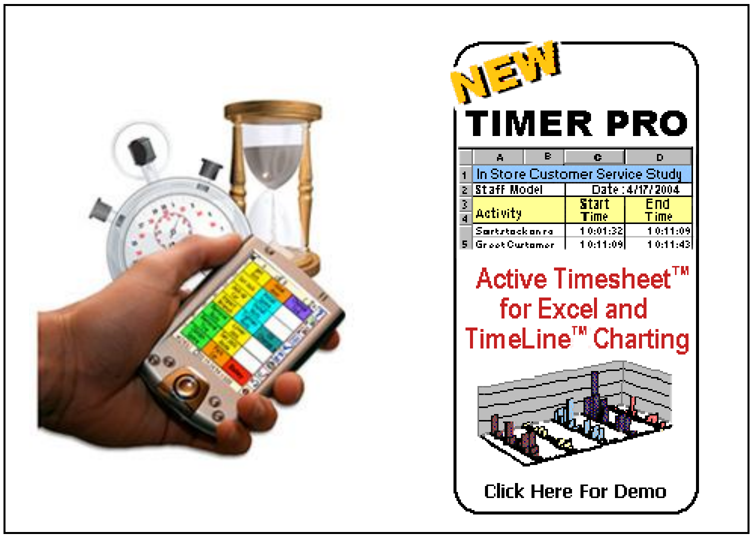

Figure 4: Technology for Time Study
Left: UmtPlus Package (Umt Products) *Right*: Timer Pro™ Software (Ascso)
Photo Sources: umtproducts.com, acsco.com/a/timerpro.htm

Umt Product's UmtPlus Package is one type of software that can be used with a Personal Data Assistant (PDA). Before taking observations, the person controlling the study inputs a list of expected work tasks into the PDA's memory. Each item on the list is then displayed on the PDA screen as an icon or tab. During the time study, if an employee starts doing one of the tasks, the observer simply clicks on the text box (tab) that represents it. As the employee finishes, the observer records completion by clicking on the original tab or on the tab of the next operation. The tool saves the elapsed amount of time in its database.

The Applied Computer Services, Inc. (Acsco) Timer Pro™ software facilitates direct electronic data entry by using Microsoft Excel to conduct the time study. To capture a time value, the observer clicks on an empty cell with a computer mouse or PDA pen. This takes a snapshot of the current time from a continuously running clock, and the time value is then presented in the cell. The observer can type a description of the step in the cell adjacent to the time value. As the study finishes, the observer has a saved Excel file which can be later used for data analysis.

These two products were evaluated in a 200 plus page Master's Thesis by Adnane Ben Sedrine of the Université de Montréal in April 2005. A summary table, which takes direct or nearly-direct quotes from an abstract of this thesis, is shown in Table 1 below.

Table 1: UmtPlus and Timer Pro™ Summary These strengths and weaknesses are direct or near-direct quotes from a master's thesis written by Adnane Ben Sedrine in April 2005.

UmtPlus		Timer Pro™	
Strengths	***Weaknesses***	***Strengths***	***Weaknesses***
Efficient when generating results	Expensive to purchase	Inexpensive to purchase	Inadequacy of statistical parameters
User-Friendly during study	Limited hardware is compatible	Practical for simple processes	Impossible to see data during study
Flexible when conducting studies	Initial Training needed for 1st time use		Inefficient deletion of errors
Efficient for simple and complex subjects	Complex User Guide at 1st glance		Easy to invalidate sample size calculations
Final Score : 90/100		**Final Score : 45/100**	

This use of technology to upgrade the traditional time study process alleviates a few of the barriers described previously. One major improvement is the amount of time saved with each data entry. The traditional time study involves pushing the stopwatch button, then writing down the elapsed time and a brief description of the task. The technology condenses data entry into simple clicks of a PDA pen or mouse. This time savings adds up when measuring all the different tasks of a custom, high-skill job. The tools also eliminate the non-value-added* step of copying the data from the clipboard to the computer.

Another barrier addressed is job fear. The anxiety a stopwatch creates as a symbol of hierarchy, scrutiny, and value assessment is reduced by using an ambiguous computer or PDA. Using up-to-date tools also demonstrates to everyone involved that upper management is willing to financially support work measurement with the latest tools available.

As a final note, most of the technology discussed so far can be used effectively with the other methods discussed in this report. The other methods are valuable, but the tools from this section further enhance that value.

Work Sampling

While using the latest technology to improve the time study process decreases the amount of effort it takes to collect data, observers still have to watch the entire process multiple times to develop time estimates. Work Sampling is a common method of work measurement that, when used correctly, can eliminate the need to watch the custom job from start to finish. Work Sampling involves taking instantaneous observations of a job at separate points along its timeline. At each observation, the observer quickly picks which step an employee is doing from a predetermined list of possible tasks. A fictitious situation comparing Work Sampling and the traditional time study is shown in Figure 5 on page 15.

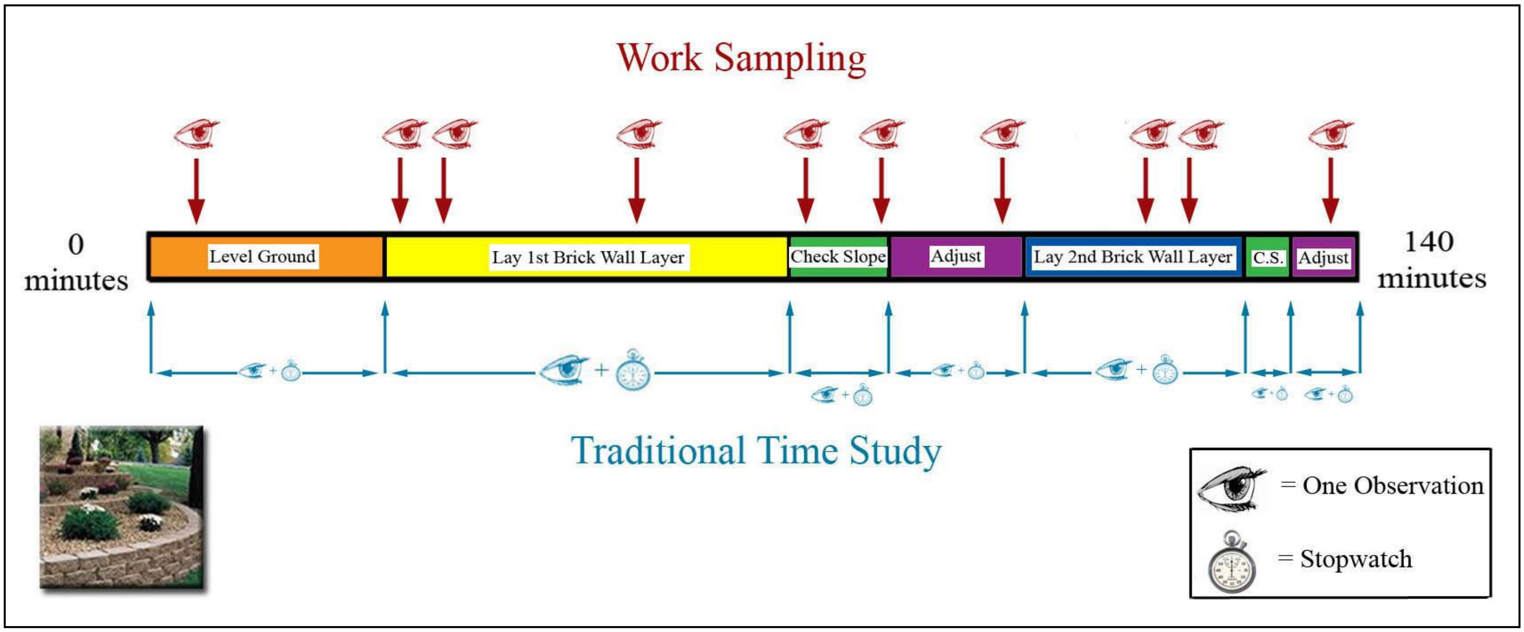

Figure 5: A Comparison of Work Sampling and a Traditional Time Study Each method is measuring 140 minutes of a fictitious brick wall building process. The sequence of the 5 independent tasks observed is as follows: Level Ground, Lay 1st Brick Wall Layer, Check Slope, Adjust, Lay 2nd Brick Wall Layer, Check Slope, and Adjust. While the time study observer is measuring the whole process, the work sampling observer only checks-off which task the specialist is doing at each of the ten observation arrows. Eye Image from www.hasslefreeclipart.com, Stopwatch Image from www.sfist.com, Brick Wall Image from www.seymorebros.com.

The results of each study from Figure 5 are shown in Table 2 below.

Table 2: The Time Estimates Obtained from the Two Measurement Processes in Figure 5 The traditional time study estimates come from actual stopwatch readings. To acquire the work sampling estimates, the analyst would first add up the number of random observations of each task. These sums are 1 for "Level Ground, 3 for "Lay 1st Brick Wall Layer," 2 for "Check Slope," 2 for "Adjust," and 2 for "Lay 2nd Brick Wall Layer". Next, the percentage of the total observations (10) is multiplied by the total time of the job to determine time estimates for each independent task.

Traditional Time Study	Brick Wall Building Tasks	Work Sampling
27 minutes	*Level Ground*	0.10 x 140 = **14 minutes**
44 minutes	*Lay 1st Brick Wall Layer*	0.30 x 140 = **42 minutes**
15 minutes (9 + 4)	*Check Slope*	0.20 x 140 = **28 minutes**
23 minutes (16 + 7)	*Adjust*	0.20 x 140 = **28 minutes**
31 minutes	*Lay 2nd Brick Wall Layer*	0.20 x 140 = **28 minutes**

The estimates from Table 2 are significantly different, but only because the Work Sampling observation size was small. For example, the Work Sampling time estimate for the "Level Ground" task is only based on one instantaneous observation. As the observation size of each study increases, the estimates from the two studies should begin to converge on the same values.

A work sampler's observation schedule can be established randomly, or the schedule can be determined with a set length of time in between each observation. A random schedule with many observations is usually preferred, because a list of set observation times may skew the findings towards one or two specific tasks. For example, suppose a Work Sampling study with a nurse is scheduled to take an observation once every five minutes. If the nurse administers medicine to a patient every fifteen minutes, then the Work Sampling study will deduce that one third of her time is being spent administering medicine. If, in fact, the nurse spends only one minute administering medicine, the study would be over estimating the amount of time spent with medication.

In addition to eliminating the need for continuous observation, Work Sampling addresses other barriers presented in this report. High-skill workers may be less likely to have job fear reactions to a Work Sampling study, because they are not actually being timed. Also, Work Sampling requires the observer to establish the possible task list with the employee before beginning the study. This discussion helps to reduce the hierarchy inherent to a traditional time study.

Methods Time Measurement - 3 (MTM-3)

Despite numerous advantages, a Work Sampling program is not the best choice in every custom, high-skill labor environment. Even though observers can often do some of their own work while measuring someone else with a Work Sampling study, they still have to be available to collect each of the samples and develop estimates from them, processes that take weeks or even months if the task being measured isn't done often.

Predetermined Motion Times Systems (PMTSs) have been developed throughout the past century to minimize this sampling time. A slew of system names exist in the realm of industry. A few of the more common general systems are Methods Time Measurement (MTM), Maynard Operation Sequence Technique (MOST), Modular Arrangement of Predetermined Time Standards (MODAPTS), Master Standard Data (MS), and WorkFactor (Dossett 22). Every system has been developed by industry for a similar purpose; each is a collection of time estimates for individual human motions in a specific work environment. Examples of these motions often include walking in a straight line, gripping an object with one hand, or bending at the waist to pick up a heavy object.

PMTSs generally fall into two categories: detailed and condensed tables. Detailed systems "provide subdivisions of body-member motions," while condensed tables encompass times for more general combinations of body motions (Hodson 4.70). One of the original detailed PMTSs is MTM-1. To develop a time estimate with MTM-1, the observer would watch an operator, and match each small movement the person makes to one of the body motions defined in MTM-1. Each movement on that list has a specific number of Time Measured Units (TMUs) assigned to it by its developers. Figure 6 below shows the common conversions from TMUs to standard time measurement.

27.78 TMU		1667 TMU		100,000 TMU
=	◄►	=	◄►	=
1 second		1 minute		1 hour

Figure 6: Common Time Measured Unit (TMU) Conversions
Numbers Source: Hodson 4.74

The problem with using detailed PMTSs like MTM-1 in a custom, high-skill setting relates to the specificity of the motions on the MTM-1 list. For example, MTM-1 breaks the process of using a wrench into seven different motions that sum up to 170 TMUs, or approximately 6 seconds (Hodson 4.97). Each of these motions had to be identified by the person who observed the wrench use. The brick wall building measurement in Figure 5 took a total of 140 minutes. The amount of separate motions that an observer would have to identify using the MTM-1 system would be colossal. In fact, developing the whole labor estimate would take roughly *817 hours* using MTM-1 (Karger and Hancock 123)*!* After all that work on the part of the observer, that exact wall may never be built again, making the time estimate difficult to apply to new jobs.

So far, one would think that measuring custom, high-skill work with a PMTS is a wasted effort. On the contrary, all that is needed to make the project more manageable is one of the condensed table methods. The best such method for custom, high-skill work is MTM-3. MTM-3's predetermined time list only has four specific types of motion (Handle-H, Transport-T, Step-S, and Bend/Arise-B), and ten different TMU values that could be assigned to the task being measured (Karger and Hancock 126). Figure 7 below shows the table used for MTM-3 analysis.

MTM-3

RANGE	CODE	HA	HB	TA	TB
Up to 6"	-6	18	34	7	21
Over 6"	-32	34	48	16	29
		SF	18	B	61

Figure 7: MTM-3 Time Motion Unit Table The 10 numbers to the right of the Code column are the TMU values that an observer would assign to different employee motions. The types of motion are Handle without corrections (HA), Handle with corrections (HB), Transport without corrections (TA), Transport with corrections (TB), Step (SF), and Bend/Arise(B). If the movement starts and finishes with no "unintentional stops, hesitations, or changes in direction," it can be considered an HA or TA (Kargers and Hancock 128). This table was developed by the MTM Association in 1971, and was documented in Karger and Hancock on page 126.

Instead of taking 817 hours to develop an estimate for the 140 minute operation, an MTM-3 user could complete the study in less than 60 hours (Karger and Hancock 123).

This is still a great deal of time, but using a condensed table PMTS like MTM-3 addresses some barriers that other work measurement methods do not. Times do not need to be determined by the observer; they are already established by the credible US/Canada MTM Association. Using these times has been proven to result in a very accurate estimation. An MTM-3 estimation for a job like the 140-minute brick wall project gives a result with less than 2% total system variations (Kargers and Hancock 124). Because of this accuracy, hourly employees and top management are more likely to believe an estimate that came from the MTM Association instead of a manufacturing engineer or intern at their own place of work.

In addition, an observer using MTM-3 does not have to be very familiar with the labor process they are measuring. When the person watches an operator, he or she does not need to assign a name to each task, which can be difficult when watching a custom job. The observer only needs to classify each motion under one of the four movement categories. Job fear is also reduced, because no stop watch is present during the observation process. MTM-3, however, takes a significant amount of time, and does not address barriers such as variation of work methods or hierarchy of organization culture. Regardless of these issues, the method can greatly improve the accuracy of an estimate, and reduce overall stress of work measurement.

High-Skill Workers Measuring Themselves

All of the previous methods are more appropriate than a traditional time study for measuring custom, high-skill work, but measurement still takes a great deal of effort. If an organization cannot afford to devote an external observer's time and effort, data collection should be conducted by the people who know the process best: the employees who do the work on a daily basis. With minimal assistance, these people can separate their job into independent tasks, and then measure these tasks by the most fitting method.

One significant case study, done an auto manufacturing plant in Fremont, California, serves as a compelling reason to implement worker-administered work measurement. According to Paul S. Adler, "at [the original plant]…industrial engineers with no direct experience of the work…would shut themselves in a room, ponder various potentials of the human body, time the result, and promulgate a task design" (Adler 103). After the engineers had handed down the new task description, the employee who it affected would simply ignore it until a time study engineer was looking. "The entire charade was part of an ongoing game of coercion and avoidance" (Adler 103). This top-down work measurement philosophy led to a plant closure in 1982.

After an overhaul of top management and a partnership with another member of the industry, the plant re-opened in 1984. Under this new leadership, employees were the ones learning work study tools, conducting the measurement, and designing the tasks. This change in philosophy helped bring about the improvements shown in Table 3 below.

Table 3: Improvements Resulting from New Organizational Philosophies at an Auto Plant
Before 1982, one plant manager summed up the problems by calling it "the worst plant in the world" (Adler 98). By the end of 1991, more than 90% of the plant's employees called themselves "satisfied" or "very satisfied" (Adler 99). All table entries are direct or near-direct quotes from Paul S. Adler's article "Time and Motion Regained," written in 1993.

Auto Plant Conditions	
Before 1982 Closure	**1984 to 1991**
Absenteeism of 20 to 25%	Absenteeism of 3 to 4%
Near the Company-Wide Low for Productivity	Highest Company-Wide Plant Productivity (1986)
Rampant Drug Abuse at Work	Higher Quality than any other Company Plant (1986)
Yearly Union Grievances → 2,000 to 5,000+	Total Union Grievances → 700 in 8 years

The plant's results may have been even more astounding if the plant had software such as UmtPlus and Timer Pro™ at its fingertips. Today's managers have that luxury. Bill Tolo, an industrial engineer working for Marshall Field's Store Support, gave modern work measurement technology to a group of retail associates at his stores. By using these tools to implement a sort of "electronic time log," Tolo was able to effectively measure the custom job of selling shoes and processing new receipts (Tolo 37).

In addition to today's technology, the methods and tools shown in Figure 8 below allow high-skill workers to measure themselves effectively in a custom job environment.

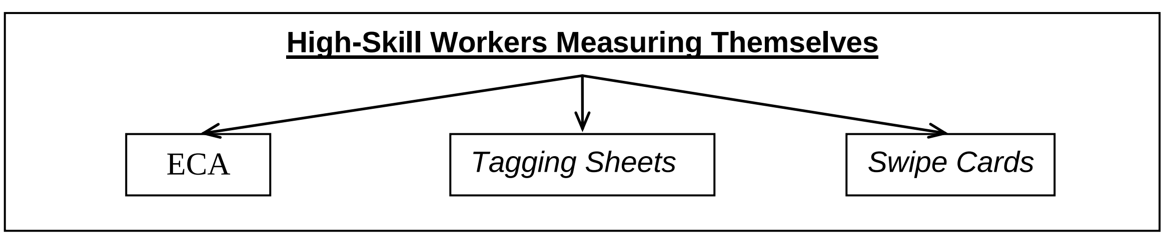

Figure 8: Work Measurement Methods for High-Skill Workers Measuring Themselves
These three tools are best to use when workers are measuring their own custom labor process.

Extended Cycle Analysis (ECA)

This method, mentioned in a technical report by Failing, Janzen, and Blevins in 1988, is similar to Work Sampling. The major difference is that the people doing the custom work are responsible for separating their job into specific tasks, taking instantaneous observations of which task they are doing, and recording the overall job time. Once this data is collected, employees and management can analyze it for production time inefficiencies and the time per task (Failing, Janzen, and Blevins 108).

This method is best used for measuring the longest, most complex jobs. Custom workers who do these jobs should be shown the principles of Work Sampling, so that they know how to take instantaneous observations and then analyze the results. Once they are granted complete control of the data collection and analysis procedure, they must be given full management support. The individuals who develop the work measurement process must be ready to become mediators; they must know how to reduce job fear, organization hierarchy, and resistance to change. Substantial group training and time during the day which is specifically allocated for collecting data will help deal with these social barriers.

Tagging Sheets

If the work measurement program developers wish to minimize the data collection tool's cost, or maximize its flexibility, the Tagging Sheet may be the best choice. An example of this tool is shown in Figure 9 below.

TAGGING SHEET

Name and Job Function	RECEIVED		ACTIVITY LOG		COMMENTS
	Date	Time	Start Time	End Time	
Randy	8/19	9:15 AM	8/19 3:00	3:30	ENTERED INTO PROJECT LOG LOGGED ON SERVER
"			9/5 3:00	3:30	STARTED TOOL ESTIMATE
"			9/8 7:00	8:15	TOOL ESTIMATE PAUSE 15 MIN. + PROJ MGT.
Bob D	9/8	8:20	9/8 10:30	10:40	COMPLETED QUOTE

Figure 9: A Tagging Sheet Example This sheet was used to track four independent tasks of one custom, high-skill job. These tasks took over a week to complete (August 19th to September 8th). Source: Melly, page 8

Two case studies conducted by UW-Madison's Quick Response Manufacturing Center used Tagging Sheets to measure the tasks of custom work that often transferred from person to person before completion. Each person would record the date and time when they began and finished a task, as well as a description of the task itself.

In this situation, the whole job was often completed in over a week (Board 11, Melly 8). For such a long job, having a single sheet of paper to track it is much more economical than dedicating one expensive PDA to follow the job through its path. Tagging Sheets also allow employees to write completely ad lib comments and task descriptions. Software such as the UmtPlus Package requires the user to reprogram the PDA each time a new task is added.

For Tagging Sheets to be effective, employees should be completely trained on how to fill them out. The lack of user-friendly software makes errors more likely, so the person who wrote the template should go through one or two specific examples demonstrating how to use it. Notice the 1st column heading in Figure 9 asks for the employee's name and job function. The job function is not written in this blank. One could speculate that this error occurred because the employee was not properly trained to fill out the sheet.

Swipe Cards

This method utilizes the common magnetic strips found in almost every credit and debit card in today's society. Each employee who works on a custom job, or each custom job itself, can be assigned a swipe card. The imprint on the card's magnetic strip can be matched to that employee or job. Each time the card passes through a reader, the time can be recorded.

The best part about the Swipe Card system is that it combines the versatility of Tagging Sheets with electronic data recording. Enough inexpensive cards can be distributed to track all steps in a job, regardless of the people that complete it. Each card can be attached to a person's belt or lanyard. If the tasks' descriptions have already been written, the data collection is as easy as sliding the card through the proper reader. Swipe cards are also extremely helpful because they limit the intrusive nature of employee-directed work study.

The disadvantages of swipe cards relate to the cost of implementing an effective system. Multiple readers, plus the software to receive the data, can be expensive. The cost of any software packages needed to compile the data is unknown.

The system also prevents the proliferation of new task descriptions. A new task may require extra system programming, a new magnetic strip, or even a separate card reader. Custom, high-skill employees should plan out *all* of the possible tasks before the capital investment is made.

Regardless of which data collection method is used when high-skill workers measure themselves, the work measurement administrator must actively participate to ensure that the data obtained will be useful. Other barriers identified in this report may become more pronounced if the data collection process is not coached or encouraged by management. Some employees may exaggerate or shorten their time estimates whenever possible, and this may lead to an inaccurate approximation of the time needed to do their job. An engineer or experienced employee should also help employees identify which tasks must be measured independently, and which can be timed together. If full support is given by the future data user, the high-skill workers will likely surprise management with great results.

Conclusion

Manual labor has evolved into custom, high-skill work, and labor time estimation methods must follow suit. Work measurement methods of the past are too cumbersome and overbearing to keep up with the ever-changing custom labor environment.

The methods and tools shown in Appendix B have been presented during this discussion as those which are best to measure custom, high-skill labor. This table should be used as a reference for members of an organization who are trying to choose which method would fit best in their labor setting.

With quick and accurate time estimation methods for today's custom, high-skill work, an organization *can* schedule sufficient resources to meet society's demand for custom services and products. The methods discussed in this report will effectively meet that goal, yet they can do more; they can successfully identify ways to improve how a task is being done. Today's organization has a variety of highly publicized means of addressing labor process problems at its fingertips, but each of them requires an accurate, dependable baseline to be quickly established. Or, as Richard Elliott of Boeing states, "information from the parts of the problem [must be] accurate enough…for making sound decisions today and in the next generation" (Elliott 45). We as engineers and organization problem-solvers must realize this need, and use the work measurement methods summarized in this report to act upon it.

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http://www.hasslefreeclipart.com Picture of Eye

http://www.seymorebros.com Picture of Brick Wall Landscaping Job

http://www.sfist.com Picture of Stopwatch

http://www.tinmantech.com/assets/images/vidst_fender_arch3.jpg Picture of Welder completing a tacking operation.

http://www.umtproducts.com Picture of UmtPlus Package by Umt Products.

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Glossary

Custom, High-Skill Labor

For the sake of this report, this ambiguous phrase means the following:

A high-skill labor process is any manual labor job that requires substantial amounts of training, vocational education, and/or natural ability to successfully complete. A custom labor process is a job that hardly ever does the same set of tasks in repetition. Subsequent jobs may use the same skills, but each job is noticeably different than the one before it or after it.

Keeping this definition in mind, a short list of professions that usually involve custom, high-skill labor are found in Table i below:

Table i: Jobs **Included** this report's Custom, High-Skill Work Definition

Cashier	*Landscaping Specialist*
Construction Worker	*Mechanic*
Custom Wood Shop Employee	*Plumber*
Electrician	*Shop Welder*
Hospital Nurse	*Taxi Driver*

In this report, the custom, high-skill labor definition only includes employees that complete a specific product or service, and each job they work on has a short specific time frame within which it needs to be finished. The definition does not include work that primarily involves communication or other non-physical tasks during work. Examples of jobs the definition undershoots are found in Table ii below:

Table ii: Jobs **Excluded** from this report's Custom, High-Skill Work Definition

Artist	*Lawyer*
Organization Management	*Police Officer*
Customer Sales Representative	*Purchasing Staff*
Doctor	*Sales Representative*
Engineer	*Teacher*

NOTE: Custom, High-Skill Labor is synonymous with Custom, High-Skill Manual Labor and Custom, High-Skill Work when mentioned during this report.

ECA

Extended Cycle Analysis

Non-Value-Added

This is usually defined as a step in a process that isn't directly leading towards the expected result of the task. These expected results are often defined by the customer of the task. Examples of customers include a buyer of a car, a guest at a restaurant, or the user of work measurement data. Examples of non-value-added steps include copying data from paper into a computer, inspecting a product to make sure it works, moving material around a facility, or performing maintenance on a worn-out tool.

PMTS

Predetermined Time Motion System

Common Examples include:
MTM: Methods Time Measurement
MOST: Maynard Operation Sequence Technique
MODAPTS: Modular Arrangement of Predetermined Time Standards
MS: Master Standard Data

TMU

Time Measured Unit, 1 TMU = .036 seconds

Traditional Time Study

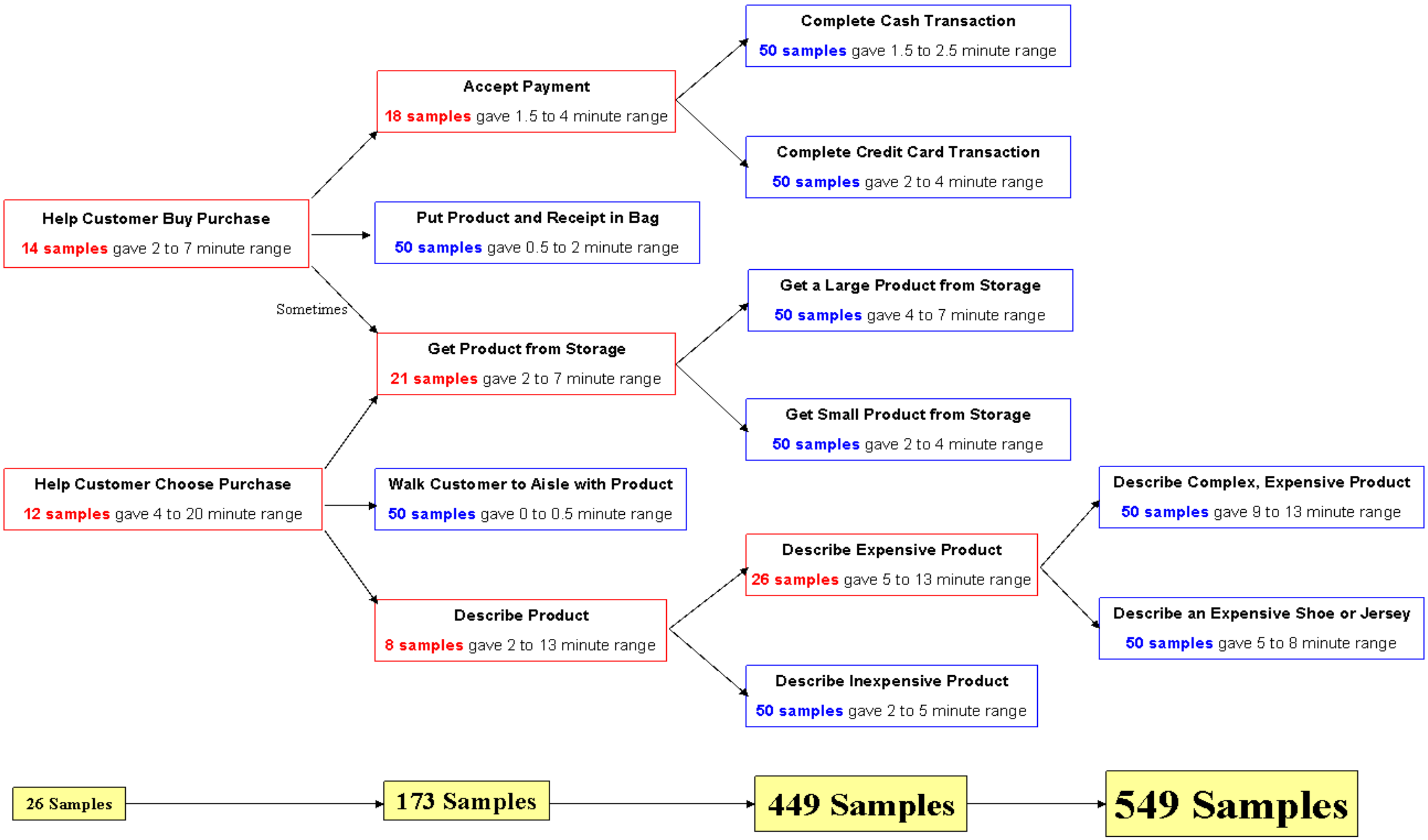
The most well-known method of measuring the time it takes to do a job. The study got its roots in the early 20th century assembly lines, where a time study engineer or technician would set the expected rate for a manual task by timing it with a stop watch, and recording the times on a sheet of paper for further analysis later.

For the sake of my presentation and report, any mention of the traditional time study refers to the process of an outsider observing the work of an employee. The term does not involve any technology beyond a computer for documenting the data after collection, a manual stopwatch or time board, and a notepad.

Work Measurement

IE Terminology defines it as “a generic term used to refer to the setting of a time standard by a recognized industrial engineering technique.” In this report, the term refers to the process of timing a labor situation for any purpose.

Time Study Sample Size for a Helping a Customer



Appendix A: An Example of Sample Size Escalation in Work Measurement The fictitious subject is a Sports Apparel and Equipment Store Attendant helping customers. The person conducting the traditional time study has been told to estimate the amount of time an average organization attendant spends with a potential customer. There are five attendants employed by the store. The person doing the study starts by measuring the time to help a customer choose a purchase, and the time to help the customer buy that purchase. As the study progresses, the observer stops taking samples as she identifies more and more ways she must separate the original two tasks. The samples in **RED** could not be used due to inaccuracy; the **BLUE** were the final study results. Source: Tom Best

Appendix B: A Summary of Custom, High-Skill Work Measurement Tools Each tool is matched up against eight barriers that prohibit effective use of traditional work measurement. A GREEN (G) BOX means that the tool is much better than traditional work measurement at addressing that barrier, a BLUE (B) BOX means that the tool is slightly better than traditional work measurement, and a GRAY (-) BOX means that the two are mostly equal. The methods with black text on a white background are used during External Measurement of High-Skill Worker; those with white text on black background are used when High-Skill Workers Measure Themselves

Work Measurement Tools for Custom, High-Skill Manual Labor									
Method	**Description of Use**	Hierarchy of Organization Culture	Lack of Full Support	Resistance to Continual Change	Fear of Job Loss	Tedium of Measurement Process	Variation of Work Method	Ambiguity of Process Elements	Shortage of Needed Samples
Traditional plus Technology	Modern hardware and software are used by an observer to collect and analyze times.	-	B	-	B	G	-	-	-
Work Sampling	An observer instantaneously assesses what task the subject is doing, and the observations are pooled to calculate task percentages. This is combined with overall completion times to make a time estimate.	-	B	B	B	B	B	-	-
Methods Time Measurement-3 (MTM-3)	An observer notes specific motions conducted during a job. After this one of ten standard time values developed by an outside firm is matched to each motion. The individual times are then added together for the full time estimation.	-	B	-	B	B	-	G	B
Extended Cycle Analysis (ECA)	Similar to a work sampling program that also measures the total job time, but those doing the work make the observations and separate their job into tasks.	G	G	B	G	G	B	G	B
Tagging Sheets	Papers for employees to write their tasks and task times on.	G	G	B	G	B	-	G	-
Swipe Cards	Magnetic strip cards are swiped in a card reader when they start and stop an independent task.	B	B	B	B	G	B	G	G