

Setting time standards for last mile delivery

Data capture technology helps set the bar for continuous improvement By H. Donald Ratliff, Kenneth Mericle and Louis Martin-Vega

Digital transformation, the process of using new digital technologies to significantly improve business processes, is creating opportunities for a new era of work measurement applications for complex longcycle work, such as last mile delivery. These new work measurement applications not only provide far more accurate metrics for staffing and scheduling work, but also for directing productivity and customer service improvements.

With an injection of new devices to capture data, wireless networks and big data management systems, the old dog learns new tricks.

Last mile delivery refers to the final step or "last mile" of delivery in the journey of a product or package from a warehouse to the doorstep of a customer. The term "last mile" was adopted from the telecommunications industry, which faced difficulty connecting individual homes to the main telecommunications network. Similarly, in supply chain management "last mile" describes the difficulty in transporting people and packages from hubs to final destinations.

In a May 2018 article in *Business Insider*, Shelagh Dolan noted that in addition to being key to customer satisfaction, last mile delivery has become the most expensive and time-consuming part of the shipping process. He also notes that its costs and inefficiencies have been further compounded by the continuous rise of e-commerce in U.S. retail sales, which has dramatically increased the number of parcels delivered each day and has raised customer expectations to include not just fast but also free delivery.

Last mile delivery consists of four complex and variable processes: 1. Pre-delivery or organizing and preparing product and vehicle for delivery; 2. Driving the route from stop to stop; 3. Delivery or securing the vehicle and delivering the product; and 4. Post-delivery or end-of-shift activities. Maximizing the number of deliveries that a driver can accomplish each day is the major determinant of overall last mile delivery productivity. However, assigning too many deliveries to a driver results in costly delivery failures, unhappy customers, and frustrated drivers. Furthermore, driving and delivery occur at decentralized remote locations and are inherently difficult to supervise.

In this environment, engineered standards are an essential tool for effective management, and Work Measurement 4.0 (WM 4.0) is a powerful new way to establish standards for last mile delivery and similar long-cycle variable-content work.

Work measurement 4.0

For more than a century, engineered standards have focused primarily on highly standardized, short-cycle, repetitive tasks consisting of one or a few operations. Work measurement covers the design of standardized tasks, materials and workplace; the establishment of engineered standards; and the calculation of standard time allowed for a fixed volume of tasks. or the expected task volume for a fixed amount of time.

A work measurement system includes a standard (minutes per occurrence), the ability to count the number of occurrences and a procedure for calculating standard time based on the standard and count. For most of its history, the problems of counting and computation were trivial and work measurement focused on development of the standard. Innovations, such as pre-determined motion-time systems (PMTS), computer-applied PMTS, digital timing devices, software for methods improvement and standards calculation have been concentrated almost exclusively on time measurement.

As work evolved in advanced industrial countries, higher levels of machine control, automation, innovations in manufacturing theory (continuous flow, just-in-time, cell-based production) and export of repetitive short-cycle work to low-wage countries all contributed to the decline of work measurement within industrial engineering as traditional target tasks disappeared.

The future of work measurement depends on finding new applications. Work Measurement 4.0 is a comprehensive strategy that emphasizes digital transformation – the automated capture of count data and storage/access to large data bases – new approaches to standard setting and computerized systems for calculating standard time. The target is long-cycle work (e.g., a shift) consisting of a standardized array of activities performed in different mixes and volumes such that each work cycle is unique.

In his review of the evolution of standards in the food distribution industry in the October 2017 issue of *ISE* (*link.iise.org*/

Work measurement, supply chains highlight Annual offerings

Numerous presentations at this year's virtual IISE Annual Conference & Expo 2020 addressed topics related to time management, supply chain efficiency and last mile delivery. Videos of presentations are accessible to conference attendees at *iise.org/Annual*.

Among the topics included on the Work Systems & Services and Logistics & Supply Chain tracks are:

- It's All About Time-Work Measurement at Frito Lay (see article in the August issue of ISE, *link.iise.org/ iseaug2020*).
- Characterizing the Workday of Ambulance Crew Members
- Determining Optimal Fuel Strategies
- A Two-Echelon Distribution System Model with Committed Home-Delivery-Time-Dependent Demand
- Classification of Winners/Losers of Shippers' Weekly Transportation Capacity Procurement
- An Inventory Aware Model for Fleet Management in Service Networks
- Analyzing the Manufacturing Supply Chain Performance for an Essential item during COVID-19 Outbreaks
- Dynamic Management of Demand Disruption in Vast Parcel Delivery Network
- Evaluation on Current Traffic Congestion Measures
- Impact of Autonomous Vehicle Technology on Long Distance Travel Behavior
- Predictive Demand Modeling for New Services in Parcel-Delivery Logistic Systems
- The Future of Autonomous Trucks in the Supply Chain Industry
- Utility Rating System for Last-Mile Delivery Drivers

iseot2017_bishop), George Bishop described several generations of warehouse standards systems, the latest of which share many of the characteristics of Work Measurement 4.0. Our main contribution lies in developing and incorporating digital transformation and automated data capture that enables WM 4.0 to be applied to highly complex long-cycle work.

Last mile delivery entailing daily variation in products, volumes and customer mix, as well as different mixes of preparation, driving and delivery activities, is a typical Work Measurement 4.0 application. This paper outlines a step-by-step approach for applying WM 4.0 to last mile delivery, including the unique challenges of developing engineered standards in this environment, the development of data capture systems based on newly available technologies and the development of software

Work Measurement 4.0

WM 4.0 is a comprehensive strategy that emphasizes digital transformation, new approaches to standard setting and computerized systems for calculating standard time.



capable of calculating daily standard times that accurately reflect constantly varying conditions (see Figure 1).

Step 1: Create a master plan

By "master plan," we mean a clear statement of project objectives and a description of how they are to be attained. Traditional work measurement involves microanalysis with jobs as independent units of analysis. WM 4.0 involves systems or macroanalysis requiring simultaneous development of complex and interdependent subsystems for counting, standards and computation. There is no point developing a standard for an activity that cannot be counted. The structure of standards will depend on what and how counts can be made. Computational logic will depend on results from the counts and standards subsystems. In this environment, continuous planning is essential for success.

Detailed planning begins by analyzing the workflow and breaking it down into its constituent functions reflecting recognized and integrated components of work. For example, last mile deliveries might consist of these functions: 1) stop and secure vehicle; 2) gather items and equipment for delivery; 3) walk to delivery point and return; 4) deliver item(s); 5) re-enter vehicle and store equipment and returns; and 6) prepare vehicle to begin driving. Each function should be easily understood by all stakeholders. Identifying a complete list of functions ensures comprehensive coverage and provides an overall framework for standards development.

Many functions will have recognizable variations in methods, which have systematic impact on time required. For example, function 4, deliver item(s), may vary because items of high value require a signature, multiple-item deliveries require repetition of item-specific work elements or deliveries involving high volume or weight require use of a conveyance device.

The next step in planning involves identifying countable and measurable activities that capture key variations of functions and serve as building blocks for calculating standard time. Workers and their supervisors understand the work cycle in terms of functions performed. Industrial engineers restate functions in terms of activities so accurate standards can be developed.

Data-capture capabilities will heavily influence the design of activities. For example, if the number of signatures can be recovered from digital device data, it makes sense to create a separate activity for obtaining signatures; otherwise, "obtain signature" would remain as a frequency element in a deliver item activity, with frequency determined from historical data or a frequency study. The same options exist for conveyances.

For variations in the number of items delivered, item counts may be available from the digital device or a delivery manifest database. If the count is recoverable, the deliver item(s) can be divided into a "trip" activity, composed of fixed elements that occur once, irrespective of the number of items delivered, and an "item" activity composed of variable elements that occur for each item delivered.

Specific activities are generally preferable to the frequency approach because they generate standard times that track individual work cycles more closely. However, technical and cost constraints impose practical limits on what can be counted. Frequencies result in standard time that may be tight or loose on a given cycle but should, if carefully estimated, track closely over longer time periods.

The final step in the planning process involves breaking down activities into elements that form a standard method for completing the activity to be used in developing the engineered standard. This step is the same as in traditional work measurement and is widely available in standard textbooks.

This illustrates the planning process in WM 4.0. Describing the workflow in functions (Figure 2) is a necessary step in arriving at a complete set of mutually exclusive activities that can be counted and for which standards will be developed. Data capture will constrain and provide opportunities for structuring activity standards and vice versa. It is impossible to anticipate all

Workflow analysis WM 4.0

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constraints and opportunities at the outset of WM 4.0 design; many will emerge as detailed work on standards and the data capture system progresses. Therefore, the master plan must be treated as a living document that evolves as it guides the project.

Step 2: Digital transformation

Digital transformation is the critical advancement that makes Work Measurement 4.0 possible. The digital transformation of last mile delivery involves digitizing information from maps, documents and human memory; capturing new data, including GPS coordinates and barcode scans using mobile devices; and integration with data from spreadsheets and existing databases. We use several different digital transformation processes to produce accurate activity counts that are an essential input in calculating standard time.

Recently we oversaw the development of the complex digital transformation system described in the table in Figure 3. The nine-step process was designed to capture last mile delivery drive distances and create statistical drive speed standards, both used in the calculation of standard time for driving on delivery routes. While this example is more complex than most, it illustrates several digital transformation processes, and the central role digital transformation plays in converting raw data into usable formats for calculating standard time in WM 4.0 applications.

Step 3: Data capture systems

The goal of the data capture system is to generate accurate values (counts, distances, locations, times, etc.) of all data elements required to compute standard time for the work cycle. Some data element counts vary with each work cycle; examples include items delivered and stops made. Others are fixed in the short or medium run, such as walk distances in the hub and drive distances on fixed routes, and require convenient systems for updating values when underlying conditions change. Some data elements can be used in their original form; others require digital transformation. Ultimately, all values must be in a digital format so the software can calculate standard time for work cycles.

Dramatic advances in GPS-enabled mobile devices, particularly smartphones and specialized bar-code readers, can capture and transmit delivery data via the internet. These devices provide reasonably accurate GPS coordinates that enable estimates of delivery stop points and drive times. They can also capture data by reading bar codes or in user-friendly, drop-down menus. Bar codes with customer address information can refine geolocations and count delivery activities.

Mapping delivery stops and delivery points is an essential step in establishing times for

drive intervals and walk segments in a route. Technology from commercial providers such as Google can generate geocodes and estimate drive time and distance between adjacent delivery points. These approximations may require manual editing or an automated continual improvement process if the route is in a high density area where drive intervals are short, the delivery point is not on the street address side of the building or the delivery requires walking between the stop and the delivery points.

Drive times provided by commercial providers could be considered statistical standards but there is little information to determine how these estimates were generated. If GPS-enabled mobile devices are deployed with each driver, latitudes and longitudes, drive times and distances between stops can be determined from the GPS data via the process described above and then used as statistical standards for drive times. Traffic may impact time, so the need for a continual improvement/adjustment process for drive times should be employed no matter what method is used to establish standards.

The simplest way to establish time standards for in-route walk segments is to apply a standard walk pace to distances derived from manually positioned stop and delivery points. The accuracy of this standard can be improved by manually specifying the actual walk path. Promising algorithms are being tested for utilizing GPS data to establish these standards, but are unproven.

Several internal databases developed for other business functions are potential sources of count data. These include inventory management systems, production reports from automated sorting equipment, product characteristics and locations, customer orders, product tracking and customer addresses. If they have already been validated, using existing databases can save money and time. Such data capture systems include:

• Human memory

Digital transformation in capturing drive time

The nine-step process designed to capture last mile delivery drive distances and create statistical drive speed standards.

STEP	PROCESS	OUTCOME
1	Collected six weeks of GPS geocodes on routes using digital devices transmitting to the cloud.	Data available for analysis: one breadcrumb per second for 2.5 hours driving per day for 36 days (324,000 data points) per route.
2	Geocodes are processed with an algorithm using data clusters to identify frequent stop locations.	Geocodes of frequent stops available for verification of <u>actual d</u> elivery stop locations.
3	Geocodes of frequent stops are loaded in mapping software and used to predict the route and delivery stop locations.	Tentative route and frequent stop locations are available in visual format with street and buildings for verification by delivery worker
4	Worker verifies route path and delivery stop locations in mapping software and links addresses from a database to delivery stops.	Route path and delivery stop location are digitized based on analysis of geocode data and human memory and are available in digital and visual format; digital data is stored in a route database.
5	Geocode data is collected for a large sample of routes over a long period.	Millions of location-time data pairs are available for analysis of drive times and distances.
6	Geocodes are processed with an algorithm using a stop definition to identify start and end locations and time for drive intervals.	Data is available to calculate drive speeds from interval distances and drive times.
7	A flat file of speeds and distances is sorted into ranges of interval distances and average speeds are calculated for each range.	A matrix of interval ranges and corresponding average speeds is available for development of statistical drive speed standards.
8	Statistical drive speed standards are created by adjusting average drive speeds for allowances.	A matrix of interval distances and standard drive speeds is available as a lookup table for calculating standard time for driving.
9	Software applies speeds from the matrix to distance from the route database to calculate standard drive time of each interval and the route as a whole.	Digitally transformed data is used in a multistep procedure to calculate standard time for driving on each route.

- Documents
- Mapping software
- Mobile digital devices
- Existing databases
- Custom websites

Step 4: Developing standards

The differences between setting standards in a traditional work measurement application versus WM 4.0 are primarily the result of greater task diversity and complexity and lower levels of standardization. In last mile delivery, there may be significant variations in equipment and vehicles used, the product delivered, layout of hub and delivery locations, distances traveled and work methods employed.

The first step in establishing engineered standards involves breaking down work functions into activities that are countable and have enough internal consistency to be measurable. The next step is to standardize each activity as much as possible, bearing in mind that inherent variation is likely to remain much higher than in traditional applications. At this point, the activities are roughly analogous to jobs in traditional work measurement; a standard method can be developed by breaking the activity into work elements that in the aggregate constitute a safe and efficient method, achievable by a worker of normal skill and ability.

The standard method in WM 4.0 is somewhat different than in traditional applications, which employers expect workers to follow exactly, especially if they are having difficulty meeting performance goals. In WM 4.0, the standard method is a typical method that will yield a fair standard time for the work performed, recognizing that the lower specialization of workers due to task diversity and higher inherent variation will mean workers will display greater variation in actual work methods. Nevertheless, the standard meth-

od remains important as the foundation on which the standard is erected and is available to coach workers who do not meet the standard.

Once standard methods have been developed for all work activities, standard development in WM 4.0 looks like any other work measurement application. We believe predetermined motion-time systems (PMTS) work best as a measurement tool in the WM 4.0 environment. Time studies are easiest to do and most accurate in highly standardized environments. Any PMTS has the advantage in less standardized situations of being able to use video images of one or a few workers who are following the standard method, or a close approximation, to set standards.

PMTS is also more efficient in handling composite standards covering two or more variations, occurring with predictable

frequencies, for performing the same activity. The structure of these standards involves specifying separate motion patterns and normal times for each variant and weighting the variants according to frequency performed. From a measurement perspective, we do not have a preference between detailed PMTS like MTM1 versus the simplified (get-put) systems like MSD, MOST or MMMM, although we suspect the economics of standard setting will strongly favor simplified systems, especially those with computer-based application.

Engineered standards are not appropriate in all circumstances. We discussed how statistical standards can be used to establish standard driving times. In a small number of instances where engineered standards are impractical and statistical standards are inappropriate, it may be necessary to use actual time to determine allowed time for an activity. One example is in loading vehicles, where differences in vehicle loading space and characteristics, product mix and volume, and loading locations may mean engineered standards and activity counts are insurmountable. In these circumstances, loading can be treated as off-standard work and based on actual time measured by scans at the beginning and end of the activity.

The main challenge in setting standards in WM 4.0 lies not in measuring individual activities but rather in managing a complex and voluminous process of standard setting under the constraints imposed by the data capture system.

Step 5: Computational system

The last component of a WM 4.0 system is the applications software that draws on the standards and activity counts to compute standard time for all activities and the work cycle. At a conceptual level, the basic model is simple and can be represented by the equation: $\sum_{i=1}^{n} S_i * C_i$, where *i* is the *i*th activity; *Si* is the standard for *i*; *Ci* is the count for *i*; and *n* is the total number of activities. In effect, the software calculates a standard time for each job cycle that reflects the unique product mix and volumes, distances traveled and all other data element values for what actually occurs during that specific cycle.

In many cases, the standard time for an activity is calculated exactly as shown in this equation. However, actual program code is far more complex for some of the activity sequences. For example, the process described earlier for computing daily standard time for driving involves structuring the entire route into sequential, stop-to-stop intervals; computing the length of each interval from stop locations set in mapping software; determining the distance range for each interval; selecting the appropriate drive speed standard by matching interval distance with distance range in a lookup table; computing standard time for each interval by multiplying its actual length by the selected speed standard; and, finally, adding the standard times for all intervals to arrive at the total standard time for the route.

Other complex activity sequences involve conditional logic such as "if" statements, nested "if" statements and lookup tables;

special instructions for rounding up when the time required for a fractional value is the same as an integer value; lengthy formulas containing nested calculations; and combinations of the aforementioned. None of this logic is particularly difficult; however, it must be very carefully constructed and thoroughly validated before being implemented.

This step-by-step approach for applying Work Measurement 4.0 addresses the unique challenges of developing engineered standards in this environment, the development of data capture systems based on newly available technologies and the development of software capable of calculating daily standard times that accurately reflect constantly varying conditions. A major contribution of this approach is that it takes advantage of available data to expand the scope of work measurement to long cycle work by applying data transformation techniques and data capture technologies. It also provides a powerful platform for continuous improvement or ongoing efforts to improve last mile delivery and similar long-cycle work processes. Its usefulness extends to other areas such as pricing, human resource planning, investment decisions, continuous improvement in performance and customer service and related scenarios. It can be applied effectively to any situation characterized by long-cycle, variable content work creating a new demand for work measurement skills that now include "big data" handing techniques and software development. 🛠

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