TRB Paper Manuscript #18-01044

Performance Improvement Case Studies in Railroad Construction Projects and Maintenance Processes Through Benchmarking and Utilization Analysis

P. Zhong, R. Patel, M. Youssef, R. Culhane, and A. Lu*
** Corresponding author*

Pallas Zhong
AD-Production Initiatives and Workforce Utilization, Metro-North Railroad
420 Lexington Ave., Floor 10, New York, N.Y. 10170-1099
Tel: (212) 499-4318 Email: *Zhong@mnr.org*

Ridhamkumar Patel
Manager, Special Projects-Connecticut, Metro-North Railroad
920 Union Ave., Bridgeport, Conn. 06607-1137
Tel: (203) 930-3728 Email: *RPatel@mnr.org*

Matthew Youssef
Assistant Chief Engineer—Track, Metro-North Railroad
330 Haarlem Ave., North White Plains, N.Y. 10603-2217
Tel: (914) 686-8455 Email: *Youssef@mnr.org*

Robert Culhane
Director-Operating Budgets & Performance Improvement, Metro-North Railroad
420 Lexington Ave., Floor 10, New York, N.Y. 10170-1099
Tel: (212) 499-4683 Email: *RCulhane@mnr.org*

Alex Lu
ADD-Strategic Operating Initiatives and Field Administration, Metro-North Railroad
525 North Broadway, White Plains, N.Y. 10603-3216
Tel: (212) 340-2684 Email: *Lu@mnr.org*

Submitted for Consideration for Publication in
Transportation Research Records: Journal of the Transportation Research Board

Word Count: 250 (Abstract) + 5,299 (Text) + 5 * 250 (Figures) = 6,799 Words.
Submittal Date: July 31, 2017

Abstract

Two observational studies of common track maintenance processes were conducted at a large Northeastern commuter railroad. First study involved manually laying out crossties while constructing a new controlled siding. On an unsignalized single track branch working under traffic, an eight-person track gang can carry and align 46 tie per hour. Consideration was given to mechanizing the process with tie handler, logging truck, track laying machine, or panel tracks. Using tie handler leads to lower production rates while working between trains, but logging truck should be considered. Second study concerns scrap tie stubs removal from the wayside. Working under electric catenary with off-peak outages using tie handlers, 5.1 stubs are removed per minute, but daily production was limited by scrap cart capacity to 330 stubs. Alternative workplans to utilize larger carts, minimize tie stub handling, and reverse work sequence were considered. Railroad gondola cars, continuous work platforms, or additional flat cart offers higher daily capacity. Interchange service cars, dumpster-on-flatcar, dumpster-on-hi-rail, and rotary dump trucks minimizes handling. Reversing work sequence better utilizes available work time during morning rush hour, when track equipment is forbidden from mainline tracks. For one week's work, 22% reduction in cost per stub removed and 60% increase in weekly production is possible with additional flat cart and reversing work sequence. These studies demonstrate limits of observations; feasibility of new methods under prevailing conditions must be tested with "innovation qualifying" processes. Such process should be developed at the Railroad to enable new initiative implementation without compromising existing production capacity.

INTRODUCTION

This paper describes two case studies in how targeted observational, analytical, and benchmarking methods have been utilized to improve capital track construction and track maintenance processes at a large Northeastern commuter railroad (hereinafter "the Railroad"). The two case studies are: (a) construction of a new siding on a single-track branch line; (b) removal of tie stubs after cyclical track renewal work.

There are several main goals of observational studies. Firstly, observational studies provide channels for highly visible management presence on the jobsites; this encourages two-way communication, builds camaraderie with the workforce, and allows management office personnel who are not necessarily subject matter experts in the task being performed to get a precise understanding of procedures for performing the task and all constraints relating to field conditions. Secondly, by observing the same task being performed on different divisions by different gangs, a set of standard operating procedures (SOPs) can be developed (e.g. (*3*)), and best practices can be shared across divisions. By having a precise understanding of means and methods of carrying out work, it makes it possible to compute theoretical throughputs and expected production rates. This can be used for benchmarking actual work progress against defined internal standards, and also to carry out time-allocation analyses or activity-based costing. This data, some of which is quantitative, also allows alternate work plans to be assessed based on how the expected production rate compares with current methods. Lastly, the detailed knowledge of work processes obtained through observation allows managers to compare work tasks to similar processes on other railroads (e.g. (*4*,*5*)) or in other industries. It allows cross-pollination of ideas and practices, but at the same time provides an understanding of precisely why certain processes that may look similar to the Railroad's work tasks, are in fact not comparable and thus certain practices from other industries may be inapplicable.

METHODOLOGY

The observational studies all follow a general methodology, although analytical detail and sequencing of tasks may vary. Contact is first made with the local Manager to explain that process improvement team would like to study their processes, and they are given an opportunity to provide an overview of projects they are currently working on. Next, the local Manager makes arrangements with the Supervisor in charge of the gang, who then makes arrangements for site visits. During several site visits, the team makes detailed notes on work procedures, manpower allocation, and approximate timing. The team always tries to stay with the gang for the entirety of their workday, both to build relationships and to understand their daily workflow. If analytically necessary, the team returns to perform quantitative timing of each task. If multiple divisions perform similar projects or tasks, each division is observed independently. For industry-standard tasks, a call is put out to industry partners to understand how the task is performed elsewhere and under what conditions; web research is used to fill in gaps where responses are difficult to come by. Finally, through an iterative process of brainstorming with local and outside subject matter experts, ideas for new processes or modifications to existing work procedures is gathered, documented, and by making reasonable consensus estimates (based on experience elsewhere, machine vendor specifications, or testing data), new production rates are forecast. Any potential implementation requirements are also enumerated, and recommendations are determined.

CASE #1: CONSTRUCTION OF NEW PASSING SIDING

The Railroad had been planning to construct two controlled sidings (~2,350 feet long) on behalf of a major client, to accommodate aspirations of increased passenger train service on a branch line. The branch line currently sees 15 trains per day and comprises of a single track with no passing sidings under track warrant control (i.e. each train must be granted permission to occupy each track segment by the Dispatcher via "Form M" or train orders) and end-to-end running time of 45 minutes. With one-train-in-section and minimum turnaround times at the terminus, the best practical directional headway on the branch is 2½ hours. The two passing sidings, situated at 13- and 27-minutes north of the mainline switch, together with signalization of the entire branch, could allow services to operate hourly, dramatically improving line capacity.

Shutting down branch passenger train operations is an expensive proposition requiring shuttle buses to provide alternate service. From a Track & Structures perspective, a siding consists of two turnouts (including switch machine, points, frog, pre-plated long switch timbers), and tracks in between them. To install turnouts it is necessary to close the mainline to all traffic, to be performed during two major weekend outages that also facilitates grade crossing renewals and other work opportunistically. However, workplan calls for building siding tracks during the week and under traffic. The observational study was performed for this portion of work, as construction of new track under traffic is a commonly performed task on the Railroad, and improved production could translate into faster schedules for future construction or rehabilitation projects. Installation of turnouts studied in the future.

Work Procedures

The first proposed siding occupies a location approximately between an existing grade crossing and an existing industrial switch (Figure 1(a)). Discussion with local managers revealed that project scope comprises of discrete construction steps given below. This observational study took place while Step #14 is in progress (Figure 1(c)).

1. Project design with client
2. Site survey to determine property lines
3. Order and pre-assemble two turnouts in a Maintenance of Way (MOW) yard facility
4. Pre-plate ties (fasten Pandrol tie plates to news ties at the correct gauge using screw lags)
5. Clear project area of existing brush with bulldozer
6. Expand and grade new right-of-way (ROW) with front-end loader
7. Fill out new track area with sub-ballast and ballast using rotary dump trucks
8. Compact newly dumped material with roller compactor (Figure 1(b) when complete)
9. Deliver ties to staging area on site
10. Deliver new rail into gauge of existing track
11. Install turnouts (during weekend outage)
12. Measure and mark out location of new track
13. Distribute tie bundles with a logging truck
14. Manually set out and align ties
15. Thread far rail onto new tie plates with rail crane, and verify track center distance
16. Thread near rail into position and bolt all rail joints
17. Dump additional ballast to fill out crib
18. Apply fasteners (Pandrol clips)
19. Tamp, surface, and stabilize track, regulate ballast
20. Thermite weld all rail joints, except heel & toe of the frog
21. Quality check and commissioning

Existing Manpower Assignment

Typically, on the Railroad and elsewhere, the process of laying out ties is performed by a tie handler machine (Figure 2(a)). The trade-off though, is that machines require space to work, and must stop work in the clear periodically to allow revenue trains to pass. During the study period, ties were being laid out by hand by teams of four Trackworkers using tie tongs. Manpower assignments are shown as a stick-figure diagram in Figure 1(d), with roles and responsibilities of employees on site described in Figure 1(e).

Existing Production Rate Estimate

The gang laid out a total of 208 ties between 09:00 hours and 14:30 hours, achieving an average production rate of approximately 38 ties per hour. Removing time for lunch break and three short breaks, productive time is 4½ hours per day, which translates into a continuous production rate of 46 ties per hour or 0.77 tie placed per minute (TPPM). Obviously this figure would vary considerably depending on the distance each tie needed to be carried, and other factors like weather.

Based on this basic rate estimate, and the requirement to lay crossties spaced at 1½ ft for total length of 2,200 ft, or approximately 1,470 ties, we estimate the work to lay out all the ties manually should take eight days, working regular daytime shift under watchman protection.

Alternate Work Methods

As this project takes place on a non-electrified single-track main line, the situation is actually fairly comparable to other U.S. railroads. To generate alternatives, we looked at industry practices through benchmarking research. Several alternate methods mechanizing installation of new track was identified:

1. Utilize a tie handler to lay out ties
2. Utilize a logging truck to lay out ties
3. Utilize a Track Laying Machine (TLM)
4. Pre-fabricate panel tracks in an MOW yard and install on site

Each of these alternatives are analyzed in turn, to understand potential production rates, manning requirements, and feasibility of the method under prevailing constraints.

Mechanize with Tie Handler

Although utilizing a rail-bound tie handler (Figure 2(a)) to lay out ties on the proposed siding track would occupy the main track, and therefore requiring track outage—we decided to explore the possibility of working between trains by taking advantage of the nearby industrial track. Revenue train traffic would be routed on the single main track as normal (Figure 2(b)), however, between trains a warrant would be issued to the Track Foreman allowing the handthrow switch to be unlocked, and the tie handler to occupy main track and perform work. The machine would clear in the spur, handthrow lined and locked, and track occupancy authority given up prior to the following train's scheduled arrival time. Since train frequency was low on the branch, although not preferred, possibility existed that this arrangement could work.

To determine likely productivity utilizing this mechanized method, we estimated the time taken to clear up for each train and re-receive track authority (Figure 2(c)) based on current timetable and typical Dispatcher workload. Although work gang is undoubtedly more productive (and requires less physical exertion by Trackworkers) between trains, due to being able to place 1.5 ties per minute mechanically (compared to 0.8 manually), results shows that due to dramatic reduction in the available work time (Figure 2(d)) because of having to clear up for each train, the expected overall daily productivity is basically identical to the manual method.

The only change in personnel requirement (Figure 2(e,f)) is that the Watchman position would not be required under a mechanized scenario, because the track warrant provides exclusive occupancy of the main track and thus a Watchman is no longer required. Two Trackworkers are required to align ties using lining bars, one Trackworker provides alignment guidance, and one Trackworker assists tie handler Machine Operator as a groundsman. Thus, no Trackworker manpower reduction is possible despite mechanization. Although there are benefits to mechanization with tie handler, like reduction in physical exertion by Trackworkers and decreased risk of accidents, other risks are introduced by having the track gang protected from passing trains solely by movement permits.

Mechanize with Logging Truck

Logging trucks (Figure 2(g)), also known as grapple trucks, are another way to lay out ties when constructing new plain line. The logging truck can work from the wayside without fouling the existing single main track. However, for this specific location it will be necessary to work from South to North (similar to Track Laying Machine alternative, below), and requires tie bundles to not have already been distributed atop the railbed, thereby blocking further access by a logging truck. Working with a logging truck would in effect combine Steps #13 and #14 in the above procedure.

Manpower requirement for this configuration requires two Machine Operators, because the logging truck is operated by two persons (one driver, one operator atop of grapple). This study was unable to determine estimated productivity for the logging truck alternative, as no recent project at the Railroad had utilized the truck in this manner. More typical use case for logging trucks is to deliver and transport materiel (including new bundles of ties but not individual ties), and to remove scrap ties from site. The production rates could be examined in future when opportunities to observe such work arises.

Track Laying Machine

TLMs or variants thereof have been available since the beginning of the 20th Century (*8*). TLM is currently in use at the Long Island Rail Road (LIRR) for concrete tie normal replacement task (*1*), and also for new main track construction on the Farmingdale to Ronkonkoma double track project. Amtrak is currently using a TLM for the New Haven-Hartford-Springfield high speed rail project (*9*). One Western Class I railroad utilizes TLM for new main track construction. TLM can be operated while traffic passes on the adjacent main track with wide track centers (*6*)—or under watchman protection with narrower track centers.

Based on vendor literature (*2*), the actual TLM is 148 ft in length, and is coupled to ten to fifteen 40 ft flat cars each carrying 220 ties (22 ties per batch, five batches per stack, two stacks on each flat.) The requirement is to lay crossties spaced at 1½ ft for total length of 2,200 ft, or approximately 1,470 ties (seven flatcar loads). Vendor-quoted continuous production rate suggests entire siding could be laid in about 2½ hours under ideal conditions. Accounting for field conditions such as machine issues, our consensus was that one workday should be sufficient to complete almost all ties required for the siding. Adding in time required for setting up, staging, preparation, ancillary work like loading pre-plated wood ties onto TLM, performing manual quality work as required, and packing up after completion of work; we expect main track construction for one siding could be completed during a normal weekend outage.

Manpower requirement for the TLM is as follows: one front-end loader operator, one tie placement operator, one beam operator (threading rail onto ties), one gantry operator (reloading ties), one nipper-clipper operator (fastening rail to ties), several trackworkers or spare operators for quality work, one foreman, and one mechanic.

However, utilizing TLM for this task comes with certain requirements that must be met. First, south switch to siding must have been fully installed. TLM requires at least one end of track be complete to deploy (to host flat cars and other rail-bourne supporting vehicles), and only the north end offers sufficient clearance for front end loader to leave the site. Secondly, a complete possession of the single track would be needed, since initially TLM would be building the siding but occupying the switch while leaving most tie-carrying flat cars on the single main track.

Although the TLM method seemed promising, the consensus at the Railroad is that the TLM is overkill for such a small project involving two sidings each 0.45 miles in length. Lease and labour costs to operate the TLM reputedly ran up to $200,000 per month (based on acquisition cost of $10 million and prevailing labour and overhead rates), and it may be difficult to obtain the TLM from a contractor for use only for a short period. An opportunity would present itself for TLM use should any significant expansion in track miles be planned in future.

Prefabricated Track Panels

Track panels are a quick and easy way to restore short segments of damaged track following a derailment or other damage. Pre-fabricated track panels are generally available in 40-ft, 60-ft, and 80-ft lengths, and can be carried stacked on flatcars of the appropriate length. The track panels are normally offloaded by a rail-mounted Burro crane, a crawler crane on the wayside, or a backhoe once carried to the site using flat cars. Maneuvering track panels using Burro crane on single track can result in some awkward switching moves since the Burro crane will have access only to flatcars immediately adjacent. To use a crawler crane or backhoe on the wayside requires a staging area, thus requires ROW wider than available at this site.

Typical use for panel track in new track construction is for use as temporary track while building high speed rail lines (*7*). Panel track is laid down by crane, joined together with joint bars, and is used only for delivery of permanent continuously-welded rails (CWR). When permanent concrete ties are delivered and installed, temporary panel track is removed. Generally speaking, on passenger main lines, panel track is unsuitable as new track construction method due to large number of rail welds that must be made to join all track panels into one continuous plain line. The 2,200 ft siding would have required 28 track panels and 58 field welds, compared to six field welds utilizing CWR. Each field weld has possibility of introducing defects or uneven track surface. Panel track construction are more suitable for light-density industrial tracks that utilizes jointed rail.

Recommendations in Case #1

We do not recommend mechanizing this process until logging truck production rates could be benchmarked. Existing procedure calls for tie bundles to be dropped on new trackbed, and most effective method to lay them out is to do so by hand. For the second siding project, an existing roadway adjacent to Railroad ROW provides easier access. Laying ties out individually by logging trucks could be considered, which would not interfere with railroad traffic. Additionally, TLM could be considered for future new track construction projects where track-miles required is more than a few miles.

(e)

Tie Tong Persons	Machine Operator	Foremen	Watchman
Four (4) track workers operate two tie tongs to move wood ties. Wood tie weighs approximately 225 lbs, plus about 25 lbs for each tie plate and fastening hardware, making the total finished weight 275 lbs or 68¾ lbs per person, close to the maximum carry weight per person (75 lbs), thus four employees are required to safely carry pre-plated ties. This is heavy work; in hot weather, these employees will require frequent breaks to re-hydrate. Foremen typically authorize one 5-10 minute break every hour. Breaks serve to improve productivity and reduce accidents or issues with overexertion.	One (1) machine operator is typically assigned with track laying gang to operate machinery and also to drive gang bus to and from work site. This machine operator was not being utilized because of insufficient room on right-of-way to safely operate backhoe.	Two (2) foremen are assigned to gang with one acting as the Roadway-Worker-in-Charge (RWIC).	One (1) track worker is assigned to lookout duty. Their only task for the day is to be responsible for the safety of gang. Although gang is working on the right of way at new siding location, and therefore not fouling existing main track, there is a risk that employees may foul main track inadvertently. There are no restrictions for train operations on main track. Lookout uses orange disc and alerts other employees if train is approaching from either direction.

FIGURE 1 Existing means and methods, Derby Siding project: (a) site conditions sketch; (b) site photo after roller compaction; (c) process to manually lay out ties; (d) stick-figure diagram; (e) roles and responsibilities description.

(a)

(b)

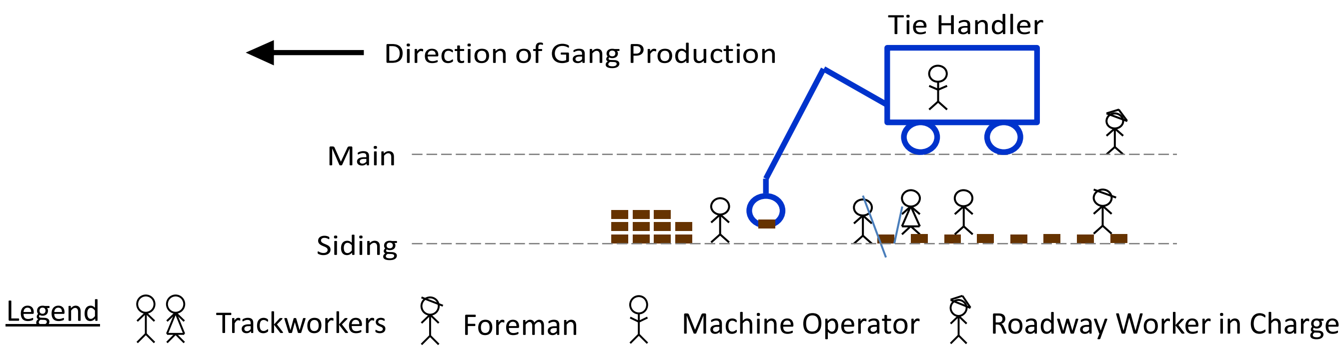
(c)

Train #		**#1916**	**#1961**	**Lunch**	**#1924**	**#1971**	
Time Due		11:04	12:19	—	13:24	13:38	
Clear Up	**Start**	10:44	11:59	11:59	13:04	14:18	
Back to Work	10:00	11:24	—	12:39	13:44	**End**	**Total**
Productive Time	—	**0:44**	**0:35**		**0:25**	**0:34**	**2:19**
Ties Placed	0	65	53	—	37	51	206

(d)

	Work	**Travel**	**Wait**	**Prep. Time & Breaks**
Typical* Job(s)	3:15 (36%)	2:00 (22%)	1:30 (17%)	2:15 (25%)
This Job (Manual)	4:30 (56%)	1:30 (19%)	— (0%)	2:00 (26%)
Using Tie Handler	2:19 (29%)	1:30 (19%)	1:46 (22%)	2:25 (30%)

(e)



(f)

Tie Alignment Persons	**Tie Handler Assistant**	**Machine Operator**	**Foremen**
Three (3) trackworkers are assigned to work with lining bars, one on each side, plus a third providing direction and alignment guidance, to ensure that ties are placed down straight and aligned with surveyed outline. When necessary, third trackworker assists tie handler assistant to unbundle ties and shift ties within bundle.	One (1) trackworker must be assigned to assist tie handler. This trackworker is responsible for unbanding the ties (cutting the metal bands with a shear), shifting ties manually within the bundle where necessary to enable tie handler to grab it, and signal to machine operator where to place ties.	One (1) machine operator is assigned to work the tie handler, to move ties from the bundles to their approximate install locations.	Two (2) foremen are assigned to gang with one acting as Roadway-Worker-in-Charge (RWIC). RWIC is responsible for obtaining track warrants, while the other foreman supervises team of trackworkers in aligning ties.

(g)

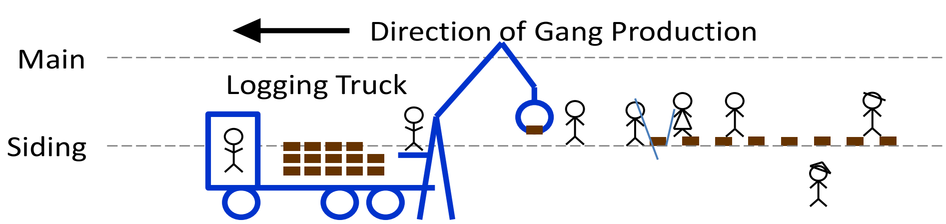


FIGURE 2 Mechanization with Tie Handler: (a) tie handler at work; (b) train occupying single main track; (c) estimated productive time working between trains; (d) time-utilization analysis; (e) stick-figure diagram; (f) roles and responsibilities description; (g) alternate mechanization with Logging Truck.

CASE #2: REMOVAL OF SCRAP TIE STUBS

Wood railroad ties must be removed and replaced periodically as part of normal railroad maintenance activities. Normal rail industry practice is to remove entire ties using Tie Exchanger machine; the scrap tie is then placed beside the ROW for later removal. In confined space situations (such as multiple-track mainlines adjacent to high-level platforms, or too many consecutive ties to be removed), insufficient clearance is available to "submarine" the tie out and to minimize risk of track buckling; in those cases the old tie is cut into three pieces using a Tie Shear, and tie stubs are piled on the wayside. The objective of this observational study is to determine what machines and processes are utilized to remove stubs, and whether this process could be improved to facilitate timely removal.

Work Procedures

Tie stub removal and disposal consists of the following steps:

1. Scrap contractor deposits 40 cubic yd dumpster at MOW access point
2. Tie Handler towing MOW flat cart is operated from MOW yard to site of stub collection
3. Tie Handler is used to pick up each stub, grouping them, and carefully stacked on flat cart
4. Filled flat cart is towed by Tie Handler back to MOW access point
5. Tie Handler picks up each group of stubs (3~5 at one time) and stacks them in the dumpster (Figure 3(a))
6. Dumpster is picked up by scrap contractor for off-site disposal

Existing Manpower Assignment

Each MOW machine is permitted to tow or push up to one flatcar due to power and brake limitations. The Tie Handler requires one Machine Operator and one Trackworker who acts as groundman. Due to how the gang is set up, typically two Tie Handlers (each with attached flat carts) would work as a team under the supervision of one Foreman-in-Charge (Figure 4(c)).

Existing Production Rate Estimate

Short-term continuous work rate was found to be 5.1 Tie Stubs Removed per Minute (TSRPM) with a standard deviation of 1.6 TSRPM. This continuous rate excludes the time taken to reposition the flatcar as necessary, but includes the time taken to travel back and forth by the tie handler the distances of less than 200 feet from where the ties are picked up, to where they must be deposited on the flatcar. The histogram of tie stub recovery work rate is given in Figure 3(b). Most timing periods generate between 5 and 6 TSRPM but there is quite a spread of rates on either side.

Several factors affects TSRPM:

1. Skill of operator (in this case, Supervisors indicated both operators are fully skilled).
2. Distance of travel between where the ties stubs are picked up, and where the flatcars are located.
3. Fragmentation of individual ties stubs, and size of each group.
4. As flatcar fills up with stubs, it becomes progressively more difficult to stack, requiring higher level of care and increased frequency of tamping and aligning action to ensure stability. Figure 3(d) shows that a weak effect with TSRPM decreasing progressively from 5.5 TSRPM for an empty cart, to 4.5 TSRPM for a full cart, but general data scatter shows other factors are at work that significantly affects the TSRPM.

5. Initially we thought as Machine Operators settle into a rhythm, production rate may steadily increase, until such time when pattern is broken by passing train ("Rule 22" Working Limits requiring all work to stop), causing production rate to settle back to low point. However, Figure 3(e) shows opposite is true, with work rate starting at highest level immediately after an interruption at about 6.0 TSRPM, reducing to ~4.0 TSRPM after ~20 minutes post-interruption.

Existing Time Utilization

Figure 3(f) shows distribution of time spent in each category; six passing trains interrupted work due to Working Limit rules. Passing trains together resulted in 18 minutes' in a 91 minute work window (or 19% of time unproductive, see Figure 3(c)). Although this is a disruption and an annoyance to operators, evidence shows significant time remain available between trains to engage in production.

Figure 3(g) shows the daily activity of work gang divided into activity categories. The typical workday is back-loaded (i.e., performs productive work predominantly during the second half of the day.) Due to time required to arrange "piggyback" track outage on this job, and the necessity of waiting for all peak period trains to pass through prior to receiving permission to move equipment from MOW yard to work site, site work generally does not begin until about 10:45~11:45 hours, depending on track usage and distance travelled to job site.

For this task, site work is typically complete by between 13:30 and 14:00 hours; track outage must be relinquished by 16:00, however, typical practice is to begin to return to equipment storage location as soon as flat cart is filled with stubs. Analysis shows that tie stub removal activity is 36% engaged in work activity, while preparation and travel consumes another 47% of total available time.

Alternate Work Methods

In non-catenary territory, typical method for removing scrap ties is to use hi-rail logging trucks (or grapple trucks, Figure 4(a)) or continuous work platform (CWP, Figure 4(g)). Relatively low clearance of electric catenary precludes use of hi-rail logging trucks, although standard logging trucks can work from wayside with power grounded. Where platforms, rock cuts, or high retaining walls exist on the wayside, this method is not feasible for tie stub removal.

During observational study, we discussed alternative methods of work with subject matter experts and also performed a review of equipment available in marketplace. Several alternate channels for improving tie stub removal process were identified:

1. Provide larger scrap cart capacity to maximize daily haul from site
2. Minimize tie stub handling by using gondola cars or hi-rail dumpsters
3. Reverse sequence of work to maximize resource utilization

Each of these alternatives are analyzed in turn, to understand equipment and manning requirements, and feasibility under prevailing constraints.

Larger Scrap Cart Capacity

Tie Handler has a 24' maximum reach from track center. MOW flat cart is about 20' long and essentially has tie handler operating at maximum reach at the far end. It is not feasible to simply use a longer cart. Assessment of existing scrap cart (40,000 lbs flat cart, approx. dimensions 8' x 20' stacked 6' high) revealed effective working capacity of 28~36 cu. yds. when stacked full with ~330 tie stubs. Rotary dump trucks have capacities of 12~15 cu. yds, while standard dumpsters hold 10~40 cu. yds—

smaller or within range of what is achievable with flat cart. (40 cu. yds. dumpster is 22' long and 8' high, resulting in 10% inaccessible space at the far end, and potentially catenary interference if loading by crane is attempted with tail gate closed; the hi-rail base is 4' tall resulting overall vehicle height of 12', whereas safe operating limit under catenary is about 14'). Based on this assessment, only three alternatives exist to substantially improve scrap capacity:

1. Railroad gondola cars have capacities of up to 100 cu. yds., or a three-fold increase on the flat cart. However, it would be necessary to take an adjacent track out of service as it is not possible to have the gondola and the tie crane on the same track. Additionally, because the operator could not see through the walls of the gondola car, less efficient stacking is likely to result. Gondolas with 100 cu. yds. capacity are equipped with high walls, with similar potential catenary interference issues. As multiple cars can be strung into one train, gons offer virtually unlimited capacity for scrap removal—and cars may be consigned directly to a waste disposal facility rather than requiring secondary transfer. To provide multiple gondola cars, it is necessary to provide a locomotive and a full crew (Engineer, Conductor, and Brakeman).

2. Continuous Work Platform (CWP, or slot train) can pick up tie stubs with the built-in Komatsu grapple excavator and offers capacity equivalent to about 380 cu. yds. or space for about 4,200 tie stubs. This equipment is capable of working without requiring adjacent track outage.

3. Gang set up is modified as shown in Figure 4(d). Tie handler tows one flat cart as normal, but an additional machine operator would tow another flat cart with a motor cart, with flat cart facing tie handler. Tie handler could then load up twice as many ties (48~72 cu. yds.) prior to leaving the track outage. However, it would also take twice as long to unload the flat car once the machines return to yard, which could require an additional three hours of overtime, if unloading work is performed in the evening.

Minimize Tie Stub Handling

To minimize tie stub handling, stubs should be loaded at site directly into containers that could be consigned to waste disposal facilities. Several alternatives exist:

1. Discussed previously, interchange service railroad cars could travel over general system of railroads to disposal facilities without special handling. However, it would be necessary to locate a facility capable of accepting rail consignments. Additional gondola cars would be required for long cycle times by freight train between Railroad property and out-of-state waste disposal facilities, and dwell time it spends awaiting loading.

2. 40 cu. yds. dumpster that conforms to specific dimensional standard is ordered from contractor. Vendor drops off dumpster at Railroad facility, where it is picked up Railroad-owned hi-rail dumpster carrier (roll-off) truck and operate to work site (Figure 4(e)). Dumpster gate is opened such that stubs can be loaded horizontally from one end. Alternatively, dumpster can be loaded via forklift (where available) onto railroad flat car, then hauled to work site.

3. Rotary dumps (Figure 4(b) can, in theory, dump stubs directly into dumpsters. Stubs may not stack correctly, but this method might minimize scrap tie handling. Current practice with rotary dumps is to dump stubs on ground at MOW yard prior to picking them up with tie handlers for a second time to place in dumpster. Instead, stubs could be trucked to centralized location where facilities (e.g. Figure 4(f), similar to coal loading platform) might allow dump trucks to dump scrap tie directly into railroad cars.

Reverse Sequence of Work

Figure 5(a) shows daily activity chart when sequence of work is reversed. If previous day's stubs are not offloaded until the morning, critical off-peak track outage wouldn't be required until 12:00, and the punch-out time moves to 16:00 instead of 17:00, decreasing required overtime by one (1) hour.

Assuming double capacity of two flat carts per tie handler per day, and with sequence of work reversed, it would be necessary to start the gang at 07:30 to avoid running afoul of track outage window. Outage would be required at 13:00 and would be given up by 16:15. Punch-out does not occur until 18:00, increasing required overtime by 90 minutes. Figure 5(b) shows expected efficiency improvements when two flat carts per tie handler are utilized. However, two additional Machine Operators would be required, to operate the motor carts.

One issue with reversing work sequence is the gang may not perform the same task day after day. Allowing stubs to sit in flat cart overnight (thereby leaving equipment in a non-ready-for-service state at day's end) could cause issues if equipment is needed at night due to unforeseen circumstances. It also causes issues when next day's production plans are altered by unpredictable situations like weather, track outage changes, or overrunning contractor jobs—resulting in personnel and/or equipment not being available to complete dumpster transfer.

The current reality at the Railroad is that track personnel and equipment could be redeployed at a moment's notice to perform tasks different from their regular work plan, in contrast to Class I railroads whose production gangs are more specialized and dedicated to specific projects (and could be travelling many miles from headquarters) thus have greater latitude to leave equipment or work-site in half-completed state, knowing that they would return next morning to continue exactly where they left off.

Figure 5(c) shows sample costing for current workplan assuming one week is devoted to tie stub removal campaign. Forecasting level of improvements obtainable from alternative work strategies can be difficult, particularly because these methods are untested in real world conditions. Making reasonable assumptions, cost impact of two possible strategies outlined, can be assessed:

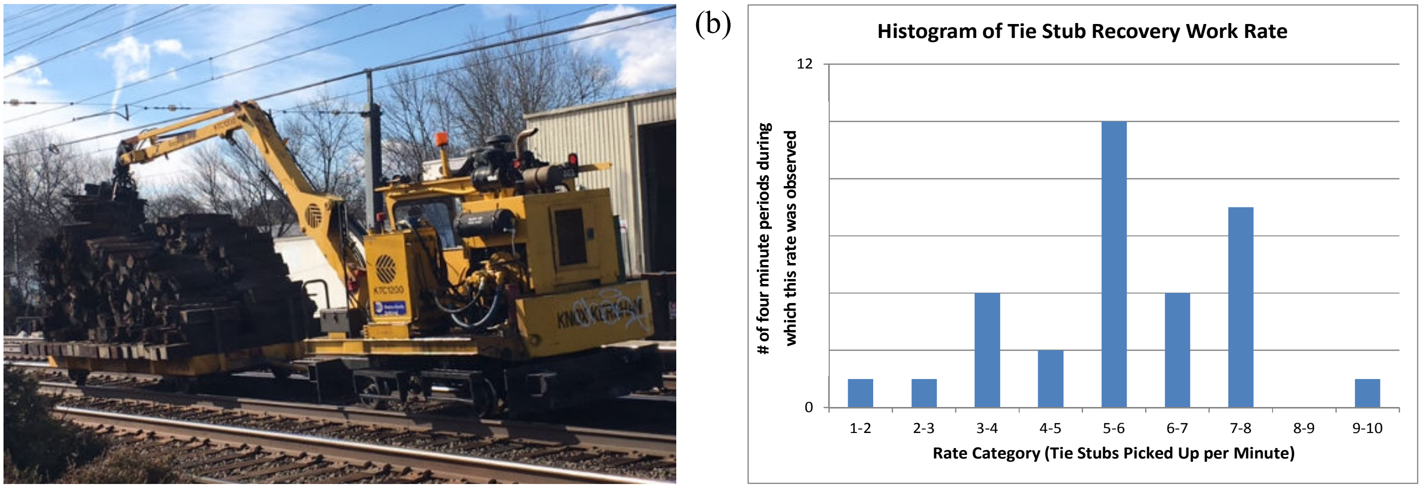
1. Larger Scrap Cart Capacity (two flat carts per tie handler with motor cart)
2. Reverse Sequence of Work

Figure 5(d) shows estimated costs based on similar assumptions for alternative workplan. These preliminary estimate show that a net cost reduction per tie stub removed from $9.83 to $8.07 (or 22% reduction) could be achievable. Adding two Machine Operators could result in production output increase from 3,000 tie stubs removed per week to 4,800 removed (+60%).

Recommendations in Case #2

We recommend that for next ROW cleanup season, an effort is made to test reversing work sequence, to determine whether cost savings can be realized and justifies operational disruptions that may result from effectively dedicating flat carts overnight to tie stub storage. We also recommend that a 40 cu. yd. open-gate dumpster, and hi-rail roll-off truck (or flatbed railcar) be leased to field-test the procedure where tie handlers would deposit scrap ties directly into dumpster, instead of having to transfer it at MOW access points. Where personnel and equipment is available, we recommend doubling daily work capacity of each Tie Handler by providing one additional flat cart for storage, pushed by motor cart.

(a) (b)



(c)

	Work	Move Cart	Rule 22(a)	Total
Tie Handler 1	0:51 (75%)	0:05 (8%)	0:12 (17%)	1:08
Tie Handler 2	1:09 (76%)	0:04 (5%)	0:18 (19%)	1:31
Total	**2:01 (76%)**	**0:09 (6%)**	**0:29 (18%)**	**2:39**

(d) (e) (f) (g)

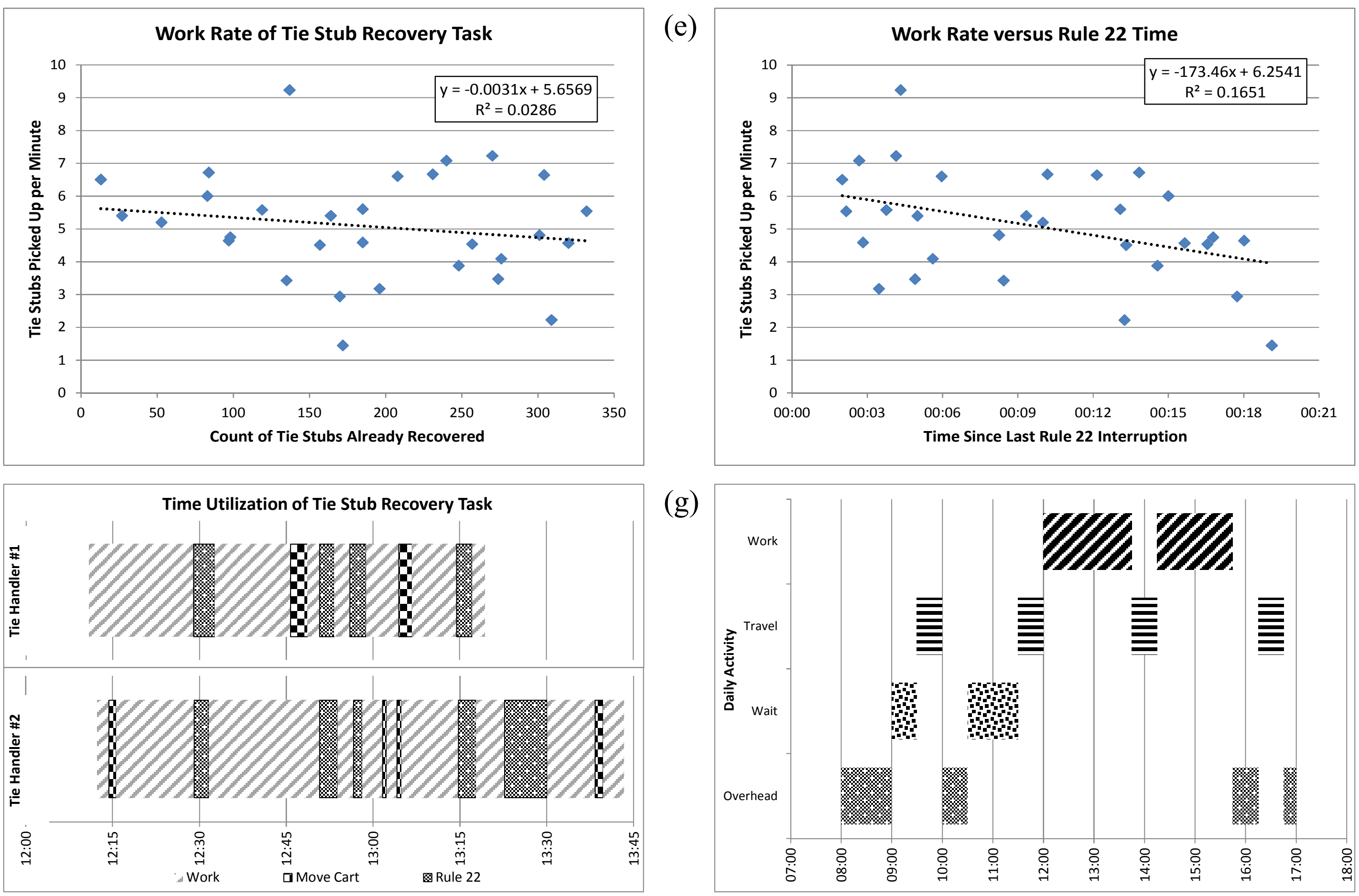


FIGURE 3 Existing conditions, tie stub removal task: (a) tie handler at work; (b) rate variation; (c) train interference; (d) work rate versus progress; (e) work rate versus interruptions; (f) time utilization; (g) daily activity.

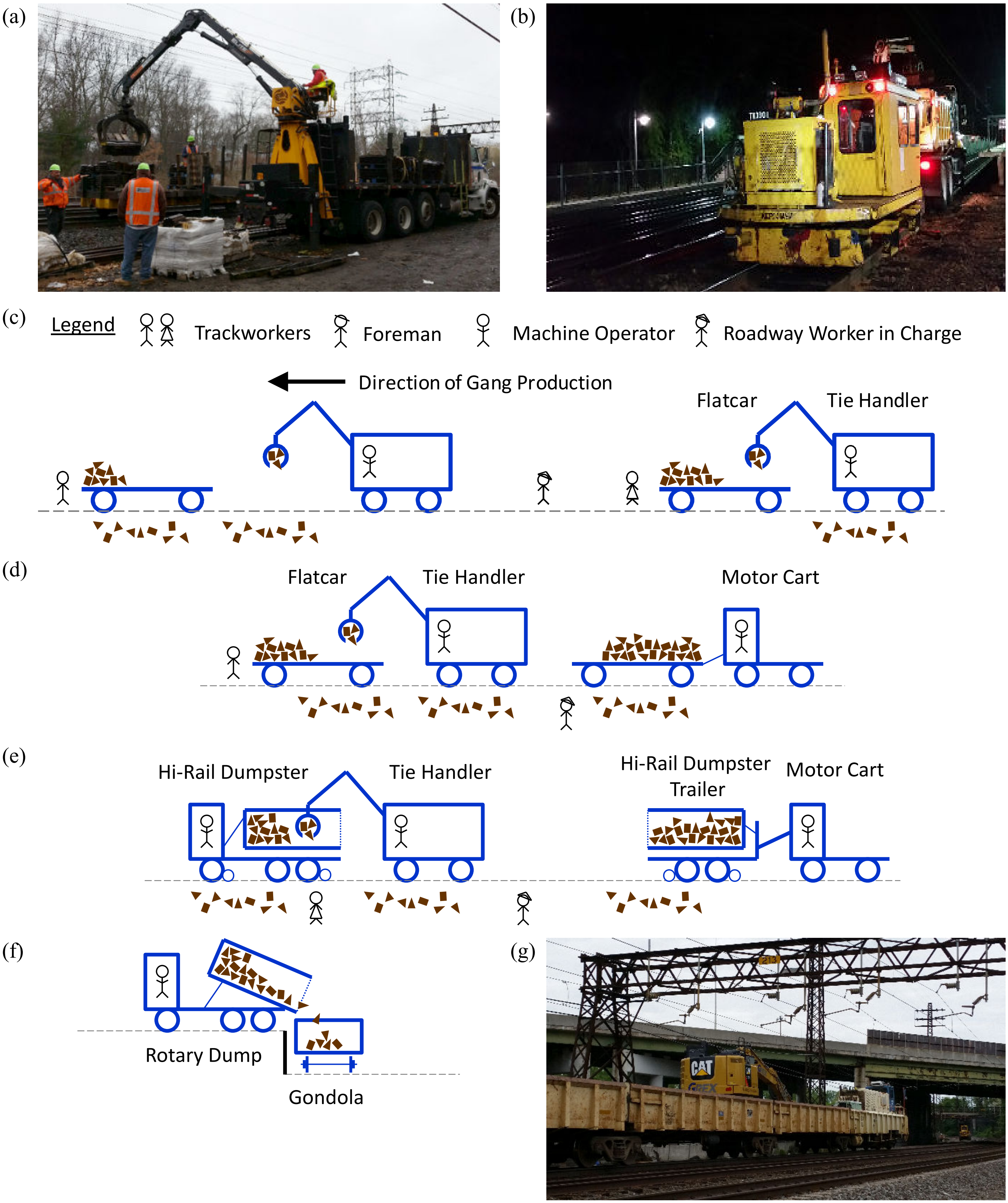
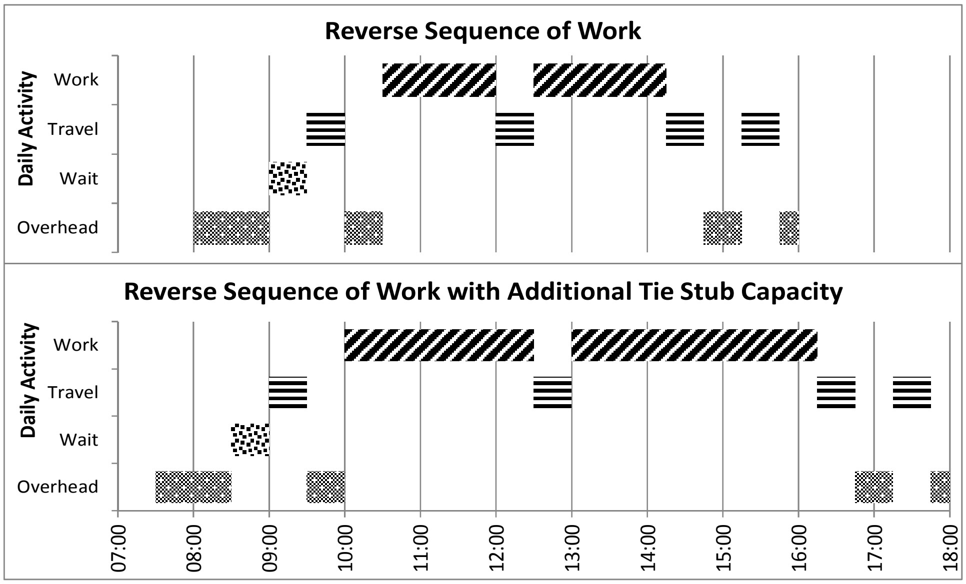


FIGURE 4 Proposed alternative solutions, tie stub removal task: (a) logging truck at work; (b) tie handler with hi-rail rotary dump; (c) stick figure diagram of existing conditions; (d) two flat carts with motor cart; (e) hi-rail dumpsters and dumpster trailers; (f) rotary dump into gondola car via bulk transfer rail loading platform; (g) continuous work platform (CWP) performing concrete tie recovery.

(a)



(b)

	Work	Travel	Wait	Overhead	Daily Total
Base Case	3:15 (36%)	2:00 (22%)	1:30 (17%)	2:15 (25%)	9:00
Reverse Sequence	3:15 (41%)	2:00 (25%)	0:30 (6%)	2:15 (28%)	8:00
with Double Capacity	5:45 (55%)	2:00 (19%)	0:30 (5%)	2:15 (21%)	10:30

(c)

Day	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Totals**
Activities	Fuel Pick Up Dump	Fuel Pick Up Dump	Fuel Pick Up Dump	Fuel Pick Up Dump	Fuel Pick Up Dump	
Duty Time	9:00	9:00	9:00	9:00	9:00	**45:00**
Manpower	6 Trkwrkr 2 Mach. Op. 2 Foreman	6 Trkwrkr 2 Mach. Op. 2 Foreman	6 Trkwrkr 2 Mach. Op. 2 Foreman	6 Trkwrkr 2 Mach. Op. 2 Foreman	6 Trkwrkr 2 Mach. Op. 2 Foreman	**10 Emps.**
Est. Cost	$5,900	$5,900	$5,900	$5,900	$5,900	**$29,500**
Production	600 Tie Stubs	600 Tie Stubs	600 Tie Stubs	600 Tie Stubs	600 Tie Stubs	**3,000**
					Net Cost per Tie Stub Removed	**$9.83**

(d)

Day	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Totals**
Activities	Fuel Pick Up	 Dump Pick Up Fuel	 Dump Pick Up	 Dump Pick Up	Fuel Dump	
Duty Time	8:00	11:00	10:30	10:30	8:00	**47:00**
Manpower	6 Trkwrkr 4 Mach. Op. 2 Foreman	6 Trkwrkr 4 Mach. Op. 2 Foreman	6 Trkwrkr 4 Mach. Op. 2 Foreman	6 Trkwrkr 4 Mach. Op. 2 Foreman	6 Trkwrkr 4 Mach. Op. 2 Foreman	**12 Emps.**
Est. Cost	$6,000	$9,250	$8,750	$8,750	$6,000	**$38,750**
Production	0	1,200 Stubs	1,200 Stubs	1,200 Stubs	1,200 Stubs	**4,800**
					Net Cost per Tie Stub Removed	**$8.07**

FIGURE 5 Impacts, reversing work sequence: (a) daily activity chart; (b) time utilization; (c) weekly workplan and cost estimate with existing method; (d) weekly workplan and cost estimate assuming reversed work sequence.

CONCLUSIONS

Two case studies demonstrate that with careful observation of track construction and maintenance processes at work, great deal of information can be gathered regarding how processes and efficiency might be improved. Value of benchmarking, via physical visits, published literature, or through video sources, is to generate ideas in how else one might approach the task at hand. Observational studies and desktop benchmarking can be thought of as screening tools in process improvement efforts. Several alternatives were dismissed when productivity analyses showed that mechanization would lead to marginal or no improvements. Other alternatives were eliminated when benchmarking (at detailed level) showed that required equipment dimensions or other parameters exceeded constraints on the Railroad, making it infeasible.

However, these case studies also demonstrates limits of observational studies: in all cases, production rates of proposed new methods can be estimated based on existing data, but their feasibility under prevailing conditions could not be fully determined without testing under real-world conditions. We believe an innovation or "labs" process should be developed to allow testing of new equipment and procedures away from production environments, to enable new methods to be tested without compromising existing production capacity. Such a process should be developed by the Railroad to enable implementation of new initiatives in production environments.

Although these two case studies were somewhat basic, we believe underlying methodology can be applied to numerous construction and maintenance processes. We plan to continue observational studies by expanding application of this methodology to other departments on the Railroad, such as traction power, signal, and structures.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge support, assistance, and contribution of the entire Metro-North Special Projects Gang-Connecticut and MOW management. In no specific order we would like to acknowledge contribution of: G.E. Hayden, D. Melillo, M. Albanese, M. Ward, G. Jallow, C. Hart, D. Carmisino, P. Perrotti, C. Cevallos, G. Raguseo, T. Barger, S. Abimbola, and J.E. Kesich. Responsibility for errors or omissions remains with the authors. Opinions expressed or implied herein are solely those of the authors' and do not necessarily reflect official policies or positions of Metro-North Railroad, or any other organizations.

REFERENCES

(1) Pesante, P. *MTA Long Island Rail Road, Hollis Station, Hollis, Queens NY - LIRR Track Replacement—04/13/2013*. Retrieved from https://www.youtube.com/watch?v=s74qH2rqsnQ on July 5, 2017.

(2) Harsco Rail. *New Track Construction*. Retrieved from http://www.harscorail.com/equipment/track-construction-and-renewal/new-track-construction.html on July 5, 2017.

(3) New York City Transit Authority. *Department of Subways Maintenance of Way Departmental Procedure: Type II-IIM Track Brokk Machine Chip Out*, Issued June 14, 2011, New York, N.Y.

(4) Reddy, A.V., A. Lu, and T. Wang. Subway Productivity, Profitability, and Performance: A Tale of Five Cities. In *Transportation Research Record: Journal of the Transportation Research Board 2143*, pp 48-58 (2010).

(5) Lu, Alex and A.N. Marsh. Zen and the Art of Commuter Rail Operations: Taiwan Railways Administration's Design, Operations, and Philosophy. Presented at *Transportation Research Board 90th Annual Meeting* (2011).

(6) Shah, Shaishav. *New Track Construction - NTC Harsco*. Retrieved from https://www.youtube.com/watch?v=d5PHOlyK_rI on July 20, 2017.

(7) Pandrol Track Systems Limited. *Construction of the New LGV-Est High Speed Connecting Central Europe*. Retrieved from http://www.pandrol.com/wp-content/uploads/FC-High-Speed-TGV-case-study.pdf on July 20, 2017.

(8) Talbot, F.A. *The Labour- and Time-Saving Track-Layer and its Work—a Wonderful Machine for Laying Railways along Great Distances*. (1914) Retrieved from http://mikes.railhistory.railfan.net/r122.html on July 25, 2017.

(9) METRO Magazine Blog. *Mammoth-Sized Track Construction Machine Used for Conn. Line Unveiled*, October 12, 2016. Retrieved from http://www.metro-magazine.com/rail/news/716974/mammoth-sized-track-construction-machine-used-for-conn-line-unveiled on July 25, 2017.