

1 **Rightsizing the Conductor Roster at Metro-North Railroad: Model Development and Application**

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1 **ABSTRACT**

2
3 MTA Metro-North Railroad (Metro-North), like many US commuter railroads, collects fares manually on-board or verifies that a valid time-based ticket is held by the customer using on-board visual inspection
4 methods. If insufficient personnel are available to perform these functions, there is potential for lost
5 revenue. Daily personnel availability is typically a result of fluctuating absence levels and unscheduled
6 work such as flagging for capital projects. Each day after all available FTEs (full time equivalents) and
7 FTEs available to work overtime have been assigned to assignments, if any assignments still remain open
8 they will not be filled. When an assignment is not filled it is referred to as a “blanked” assignment at
9 Metro-North. The cost of blanking an engineer or conductor assignment is very high as this would result
10 in annulling a train; thus engineers and conductors are always staffed to a level where this will rarely if
11 ever occur. However, the cost of having insufficient ticket collectors, a task fulfilled by assistant
12 conductors at Metro-North, will depend on the revenue exposure if one or more ticket collector
13 assignments are not filled (and therefore fares are not collected / verified). There are many factors that
14 influence revenue exposure and these will vary by system depending on fare policy and operating
15 characteristics. Revenue exposure becomes a key factor in determining the optimal assistant conductor
16 staffing level, which is the staffing level that produces the overall minimum cost. Increasing staffing is
17 one way to reduce both overtime and blanked assignments, but this comes at a cost of training new
18 hires and paying additional wages and benefits.
19

20
21 Previously the Operations Services and Operations Planning Departments at Metro-North determined
22 the engineer, conductor and assistant conductor staffing needs based on data analysis (customer
23 counts, schedules, usage patterns) experience and rules of thumb. However, this process was difficult
24 to explain and it lacked transparency. Furthermore, over the past few years Metro-North has found it
25 increasingly difficult to cover all of its assistant conductor assignments each day. This is largely a result
26 of Metro-North policies aimed at reducing overtime, combined with a recently instated longer training
27 program for assistant conductors necessitating additional lead time in work force planning. Expected to
28 further exacerbate this issue is an anticipated high level of retirements in 2013 and reduced overtime
29 potential due to the Federal Railway Administration’s Passenger Hours of Service Regulation. Assessing
30 the impacts of all of these factors required a new method of evaluating staffing needs.
31

32 Metro-North chose to take a detailed and analytical approach to address this issue by building a
33 sophisticated and complex model in-house to determine the optimal number of engineers, conductors,
34 and especially assistant conductors. The model was designed to be used by the Operations Services
35 department to right-size the assistant conductor roster and was successfully used to justify the staffing
36 levels and actions to senior management. The model balances and weights all of the varying
37 requirements including the cost of training a new FTE as well as the potential for revenue loss as a result
38 of blanking an assignment, and determines the most cost effective solution
39

40 This paper documents the development, design, and applications of this model along with the issues
41 encountered during its development and how this model can be used as an example for the
42 development of similar models at other agencies.

1. INTRODUCTION

A problem encountered by commuter rail systems that have onboard fare collection is the potential for lost revenue when not enough conductors/ticket collectors are available to collect tickets onboard trains. Having insufficient personnel to perform this function on any given day is typically a result of fluctuating absence levels and unscheduled work such as flagging for capital projects. The revenue exposure experienced when an assignment is not filled depends on many factors including fare policy and the operating characteristics of its service. Increasing staffing is one way to address this problem, but this comes at a cost of training new hires and paying additional wages and benefits.

1.1. Problem and Concept Description

Typically, assignments are filled first by the FTEs (full time equivalent) who are scheduled to work each assignment, then by the extra list which is comprised of FTEs not assigned to a specific assignment but available to work an open assignment, and finally through overtime as each of these resource types are exhausted. Since overtime availability is limited, once overtime has been exhausted any assignments that remain open will not be filled. At Metro-North these are referred to as “blanked” assignments. The cost of not filling an engineer assignment is very high as this results in annulling a train, thus engineers are always staffed to a level where this will rarely if ever occur. Similarly, a minimum of one conductor is required by regulation per train, therefore conductors are staffed similarly to engineers. However, the cost of having insufficient assistant conductors performing ticket collection, will depend on the revenue exposure if one or more of these assignments is not filled.

In general, Train and Engine staff are expected to work a five day assignment at MNR. Extra List employees are used to cover both planned (vacation) and unplanned absences (sick). These Extra List employees have a payroll guarantee of five work days a week. When they are not used, they receive a “guarantee” payment for the day. Because the number of assignments and the number of available FTEs fluctuates daily, there will be days where there are not enough available FTEs, resulting in overtime and possibly blanked assignments, and other days where there are too many FTEs, resulting in some FTEs being paid guarantee. Increasing staffing levels typically reduces overtime and reduces or eliminates the problem of blanked assignments; however it also has the potential to increase paid guarantee and fringe benefit costs. With respect to engineers, the primary trade off in determining the optimal staffing level is between overtime, guarantee and fringe benefits, since it is unacceptable to blank an engineer assignment. With respect to assistant conductors blanking an assignment, while not preferable, is acceptable, but it carries a potential revenue loss. Therefore, in addition to overtime, guarantee, and fringe benefits the revenue exposure becomes a key factor in determining the optimal assistant conductor staffing level.

Over the past few years Metro-North has found it increasingly difficult to cover all of its assistant conductor assignments each day. There are many factors which contribute to this difficulty, including; Metro-North policies aimed at reducing overtime; a modified conductor training program that previously took 6 weeks to produce an assistant conductor but now takes 8 months to produce a fully qualified conductor, as Metro-North only trains qualified conductors by policy; and changing employee behavior patterns relative to time-off. Conductors can work both conductor and assistant conductor assignments, resulting in a larger number of FTEs able to fill conductor positions, but much longer lead times to train new FTEs able to cover assistant conductor assignments. Expected to exacerbate this problem is an anticipated decrease in the availability of conductors to work overtime on their regular

day off (relief day work) as a result of the Federal Railroad Administration (FRA) new Passenger Hours of Service Regulation, and the unusually high number of retirements expected in 2013.

Assessing the impacts of all of these factors required a new method of evaluating staffing needs. Previously the Operations Services and Operations Planning departments would analyze data and based on experience and rules of thumb would determine optimal staffing needs. However, while relatively accurate with staffing predictions, not only was this process difficult to explain but it lacked transparency, and most importantly it did not provide dollar estimates of the tradeoff between lower and higher staffing levels or the balance between increased staffing and potential revenue loss. Metro-North chose to take a detailed and analytical approach to address this issue by building a sophisticated and complex model in-house to determine the optimal number of assistant conductors. The model is also capable of determining the optimal number of engineers (Engine/E) and both conductors and assistant conductors (Train/T) and can also be used to validate attrition projections, and is thus referred to as the T&E (Train and Engine) rightsizing model. No specific research was conducted to create this model; rather it was based mostly on the authors' previous experience with similar problems and models.

The primary purpose of the model is to determine the optimal number of FTEs based on a set of inputs. The model was designed to be used by the Operations Services department to forecast the optimal number of assistant conductors and to be able to justify this number to senior management. This will help ensure that training is scheduled and planned appropriately in order to maintain the conductor/assistant conductor roster at the necessary level

1.2. Definitions and Terminology

The model has numerous inputs, which can be grouped into the categories: supply, availability, demand, wages and fringe rates, blanked assignments, and revenue loss. This section describes the terminology and concepts used throughout this paper.

Supply: the number of engineers/conductors on the roster

- Conductors and Assistant Conductors: All conductors at Metro-North receive conductor and assistant conductor training so any conductor can act in either capacity. There are no assistant conductor *positions* but there are assistant conductor assignments and these can be filled by any conductor.
- Roster: All fully trained FTEs
- Attrition: estimated future retirement, non-retirement (promotions, resignations, terminations)
- New Hire Training: number, length, size, and timing of planned training classes
- Extra List: like most transit agencies Metro-North assigns a percentage of the engineer and conductor rosters to an extra list, meaning that these engineers/conductors are not assigned to a particular assignment but rather their purpose is to fill an assignment if an engineer/conductor is unavailable to work their scheduled assignment. They are assigned to days and times but not to a particular assignment and they must report to work on their assigned days/times
- Crew Bases: Metro-North has ten crew bases throughout its territory and some of these crew bases may share FTEs with each other, specifically FTEs on the extra list or available for overtime.

- 1 ➤ Calling Order: The procedure for sharing resources between crew bases is referred
2 to as the calling order and is an input to the model.
3

4 **Availability**: the number of engineers/conductors who are available to work each day.

- 5 ➤ Planned and Unplanned absence: planned absence includes categories like
6 vacation, jury duty, and training, while unplanned absence includes categories like
7 sick leave and bereavement. Planned absence percentages used in the model are
8 based on actual planned absence and unplanned absence percentages are
9 estimated absence rates based on historical behavior.
10 ➤ Relief Day: the regular days off/ rest days for each FTE.
11 ➤ Relief Day Overtime: when an FTE works on his/her day off this is referred to as
12 Relief Day Overtime.
13 ➤ Daily Roster: The total roster less the number of FTEs who have a relief day each
14 day.
15 ➤ Overtime Availability: This is the percentage of the daily roster that is available for
16 overtime each day based on historical availability. The model assumes a maximum
17 percentage of daily available overtime.
18

19 **Demand**: work assignments

- 20 ➤ Crew book assignments: the crew book is the planned schedule for engineers,
21 conductors and assistant conductors by crew base. These fluctuate somewhat by
22 month. Metro-North has a roster system rather than a cafeteria style system.
23 Assignments are created by the schedule department in one week blocks such that
24 an employee chooses an assignment that covers a 5 day work week.
25 ➤ Yard assignments: these are engineer, conductor, and assistant conductor
26 assignments which support switching operations, needed to move equipment in the
27 rail yards as needed in order to operate service.
28 ➤ Capital assignments and monthly variation: capital assignments include flagging and
29 other work necessary for capital projects that must be performed by an engineer
30 and/or a conductor.
31 ➤ Service Plan Changes: the change in the number of assignments based on changes
32 to the service plan for future years. This is an addition to the crew book
33 assignments.
34

35 **Wages and Fringe Rates**: by work assignment and FTE type

- 36 ➤ Weekly Assignment Pay: The three main types of work for engineers and
37 conductors are crew book assignments, yard assignments, and capital assignments.
38 The average weekly rate per crew book and yard assignment is an average of the
39 scheduled assignment rates, while capital assignment pay is based on prior year
40 averages.
41 ➤ Daily Overtime Pay: When there are not enough FTEs to cover all assignments, crew
42 book, yard, or capital assignments may be covered at overtime by an FTE on his/her
43 relief day. The daily overtime rates for each type of work are based on prior year
44 actual average daily overtime pay per assignment.
45 ➤ Guarantee Pay: an FTE on the extra list must report to work on his/her assigned
46 days and times. If there is no assignment for them to work on a day that they are
47 assigned to report then they must stay for eight hours and are paid for an eight hour

day. This is referred to as “guarantee pay” because they are guaranteed pay for a full day even if there is no work for them to do.

- Weekly Student Pay: Engineer training lasts approximately twelve months, while conductor training takes approximately eight months. During this training period students are paid at a somewhat lower rate than fully trained engineers and conductors and also receive benefits. However, during most of the training period they cannot work assignments.

Blanked Assignments and Revenue Loss: An assignment may be blanked when there are not enough engineers / conductors / assistant conductors available to work a particular assignment. In practice only assistant conductor assignments are blanked, as leaving an engineer or conductor assignment blank means that a train must be annulled, resulting in significant missed revenue, negative customer reactions, and potentially negative reactions from elected officials. Likewise, yard assignments are critical for operation and are not blanked. Capital assignments are typically more costly to blank (Section 1.3) than assistant conductor assignments so they are assumed in the model to be must-fill. The model assumes that all engineer, conductor, yard, and capital assignments must be filled so the only assignments that can be left blank are assistant conductors. Assistant conductor assignments are necessary for revenue collection but not train operation (except in a few isolated instances because of platform configuration and these can be handled individually), therefore if one of these assignments is left blank there is a potential loss of revenue but the train will still operate.

1.3. Sensitivity of Key Variables

The model has several key variables such that slight changes in these variables can substantially alter the optimal number of FTEs. These are Lost Revenue per Blanked Assignment (affects only Train), Daily and Monthly Fluctuation of Capital Assignments (affects only Train), and the Impact of the New FRA Hours of Service Policy (affects Engine and Train).

Lost Revenue per Blanked Assignment

The model assigns a cost in terms of estimated lost revenue to assignments that are not filled. Since assignments cannot be blanked for Engineers and Conductors this cost is set very high so that the model will never consider it cost effective to blank an engine assignment.

Calculation

The lost revenue per blanked Assistant Conductor assignment was relatively difficult to calculate. As described previously, when insufficient FTEs are available to work assistant conductor assignments and collect tickets, blanked assignments result with the potential for revenue loss. Assistant conductors at Metro-North perform on-board revenue collection assignments such as selling tickets, punching single and ten trip tickets, and checking weekly and monthly passes. Each train has one or more assistant conductors on board; the number varies by the number of cars on the train, the average ridership on the train and how much time there is between stops. The actual revenue loss from blanking assistant conductor assignments varies depending on how many other assistant conductors are on board and how much additional ticket collection they may do if there is one fewer assistant conductor on board. It also depends on how many passengers are on board and whether they plan to transfer to another train where their ticket might then be collected. Finally, the revenue loss is dependent on how many passengers have single trip tickets, ten trip tickets, or plan to purchase a ticket on board. These

1 passengers may be able to reuse or receive a refund for their ticket if it is not collected /
2 punched, or simply get a free ride if there is no assistant conductor to sell them a ticket.
3 Customers with monthly and weekly passes are not a concern in this respect since their ticket is
4 valid for a set amount of time regardless of how often they ride the train; however, if blanking
5 trains becomes frequent and pervasive enough that passengers expect that their ticket will
6 often not be checked it is possible that passengers may stop buying monthly and weekly passes
7 and switch to ten trip tickets. This would result in significant further losses since these
8 passengers will get a free trip each time their ticket is not punched, and it is one of the factors
9 considered when determining the potential revenue loss per assignment.

10
11 Metro-North has limited ridership data beyond ticket counts and terminal boarding / alighting
12 counts. For this reason it is not known with certainty how often customers with single-ride
13 tickets might re-use their ticket or give it to a friend to use if their ticket is not collected, thereby
14 resulting in a free ride and a loss of revenue for Metro-North. Likewise, Metro-North does not
15 know how often customers with ten trip tickets receive an extra trip because their ticket is not
16 punched. It is also not possible to determine with certainty if a customer requesting a refund
17 might have already received a free trip when a conductor did not collect the ticket for which
18 they are seeking the refund. However, based on previous surveys and data collection, Metro-
19 North's Operations Planning department developed estimates for the revenue exposure per
20 assignment per train based on the dollar amount of single-ride tickets collected and on-board
21 tickets sold per train and the number of crew members on each train. Probabilities were then
22 assigned to these dollar amounts based on how frequently each train in an assignment was
23 blanked in the prior year. An assignment on average consists of four trains. Prior to applying the
24 probabilities this analysis resulted in a revenue loss estimate of \$2000 per assignment. After
25 applying the probabilities it appeared that the estimate was closer to \$1000, implying that
26 \$2000 was too high.

27
28 The model is extremely sensitive to this number, since at values closer to the low estimate it
29 becomes more cost effective to blank assignments than to hire additional FTEs, when
30 considering benefits and daily overtime paid to work an assignment.

31
32 The higher the blanking cost per assignment, the more cost effective it is to increase the number
33 of FTEs versus blanking assignments. The lower the blanking cost, the more cost effective it is to
34 have fewer FTEs and blank assignments.

35
36 The range of \$1000 to \$2000 was eventually narrowed to \$1500 based in part on the results of
37 an additional Metro-North revenue study. It was also based on the fact that blanking too many
38 assignments may result in higher revenue losses as customers realize that tickets are frequently
39 not collected. Based on a sensitivity analysis (Figure 1A), when the revenue loss per blanked
40 assignment was appreciably less than \$1500 this caused the model to reduce the roster to a
41 point where it would result in widespread blanking, which would result in a much higher
42 revenue loss per train than \$1500. Thus \$1500 was chosen as the baseline revenue loss per
43 assignment that would maintain the number of assistant conductors at a reasonable level, while
44 still allowing for the model to blank some assistant conductor assignments.

Daily and Monthly Fluctuation in the Number of Capital Assignments

At Metro-North capital flagging work is performed by the conductor's union and Operations Services must account for additional headcount needs for the capital program. Historically, predictions for the number of capital assignments have not been accurate and there are significant daily and monthly fluctuations in capital flagging needs. Operations Services is currently working with the capital project managers to improve these projections as more accurate projections would allow Operations Services to adjust training schedules and the number and the timing of new hires to better match both operating and capital demand.

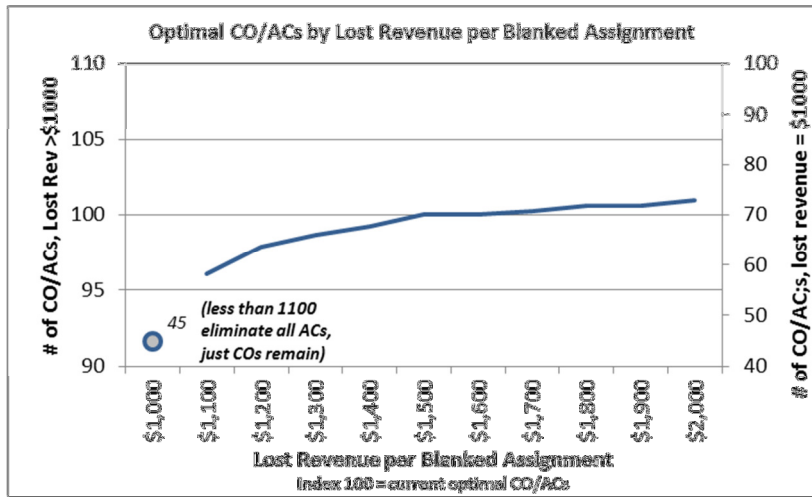
The model assumes an average number of capital assignments per day with a stochastic component to simulate daily variation. An increase of just a few capital assignments will increase the optimal number of FTEs (Figure 1B), and an increase of ten or more would result in a need for more than an entire class of new hires (typically 10-14). Each blanked operating assignment is estimated to result in \$1500 in lost revenue while a blanked capital assignment may result in a project delay cost of \$5,000 to \$10,000 on average but could be as much as \$50,000. Thus, capital assignments receive priority over operating assignments, but there is still a cost associated with a blanked operating assignment. Further complicating the trade-off, these two costs affect different budgets; the capital costs impact the capital budget, while the lost revenue from blanking affects the operating budget.

Impact of the New Federal Railroad Administration (FRA) Hours of Service Policy

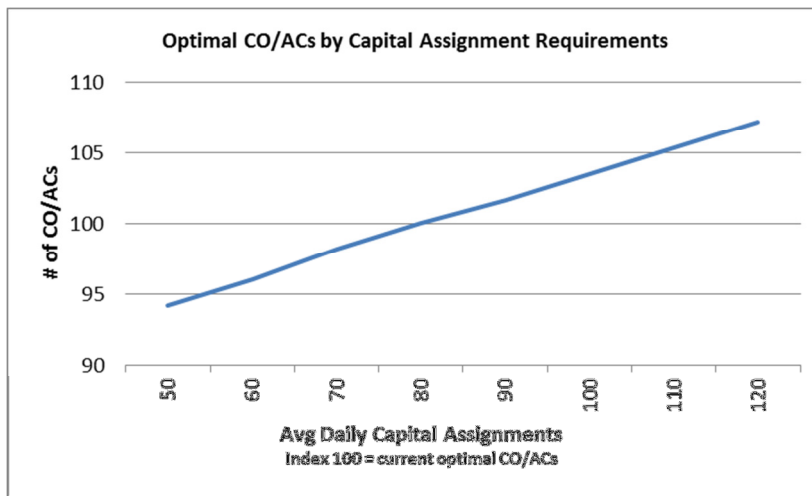
The model assumes a maximum percentage of daily available overtime. This availability was significantly reduced following implementation of the new FRA Hours of Service policy which has complicated rules that require rest days once operators have worked more than a certain number of days and types of assignments in combination. As this new regulation went into effect in April 2012, there is not yet enough data to precisely determine the overtime availability; therefore the model provides an estimate for this impact. Once data is available, this variable will be re-evaluated and adjusted if necessary. Changes to this variable can result in significant changes to the optimal number of FTE's (Figure 1C), because lower overtime availability results in fewer assignments that can be covered at overtime and thus more blanked assignments. Depending on the cost of blanking an assignment this will result in the model either blanking more assignment or increasing the number of FTEs to cover more assignments.

The sensitivity of these variables can be seen in the graphs in Figure 1. The optimal number of conductors (CO) and assistant conductors (AC) is indexed with 100 representing the current optimal number of conductors and assistant conductors. The effects of changes to the three key variables on the optimal number of FTEs are displayed. The optimal number of FTEs is significantly affected when the lost revenue per assignment is less than \$1500, and at less than \$1100 the model will suggest that all assistant conductors be eliminated, while at greater than \$1500 the optimal number increases but at a slower rate vs. the change between \$1000 and \$1500. The relationship between additional average daily capital assignments and the optimal number of FTEs is nearly linear. Finally, the optimal number of FTEs drops as the number of operators available to work overtime increases. In practice, even prior to the new FRA regulations typically the highest percentage available was about 6%, so 10% is not realistic but is shown for the sake of the sensitivity analysis.

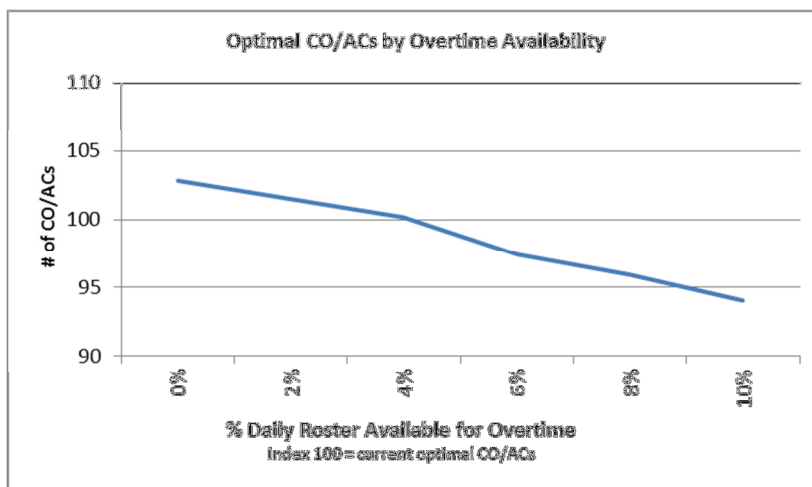
1 Figure 1: Sensitivity Analysis (Lost Revenue per Blanked Assignment, Capital Assignments, Overtime)



A



B



C

2
3

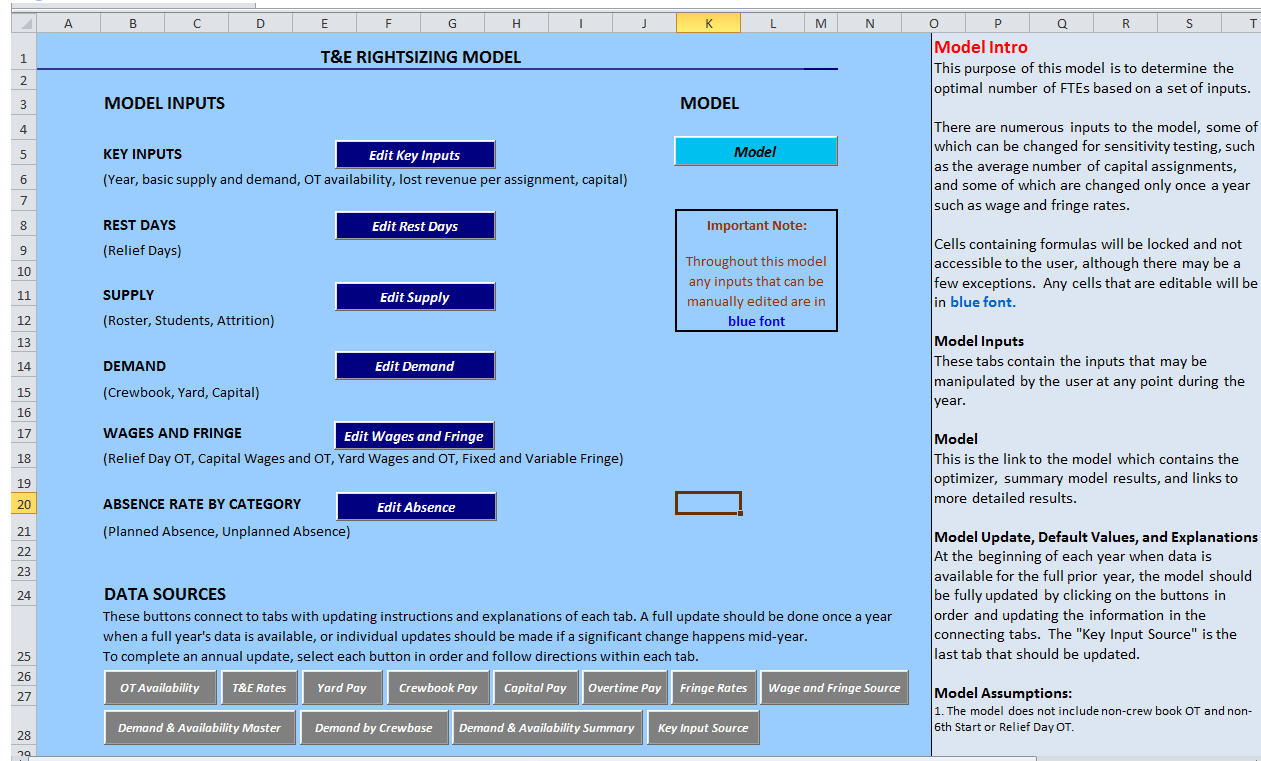
2. T&E MODEL DESIGN AND METHODOLOGY

Metro-North chose to use an MS Excel based model so that it would be run on a platform familiar to the Operations Services department.

2.1. Model Inputs and Data Sources

The model consists of a user interface (Figure 2) which contains links to the main model page and to all of the underlying data worksheets that require user updates. Most of the data is based on the crew book and on prior year data that was collected and provided by the Operations Services Department.

Figure 2: User Interface



The data in the Data Sources tabs is compiled into a reformatted and more user friendly format referred to as the "Model Inputs" in the model. In general, the Data Sources tabs are only updated once a year or if a significant change occurs after the annual update has been completed that might impact one or more of these quantities. The Model Inputs, on the other hand, may be adjusted quarterly or even more frequently; especially Absence and some of the Key Inputs which may be varied for sensitivity testing. The Model Input categories include the following data items, all of which were described in detail in section 1.

Model Inputs

▪ Key Inputs

- Starting year
- Starting roster and students in training
- Overtime availability percentage

- Lost revenue per assignment
- Total (work) assignments
- Planned service plan changes
- Capital assignments and range of daily fluctuation

- **Rest Days (considered part of Supply)**

- FTE regular days off as a percent of the daily roster

- **Supply**

- Roster
- Attrition
- Planned training classes: number, timing, and length
- Roster and Training calculations for additional students can be added manually or through the optimizer (Section 2.4)

- **Demand**

- Crew book assignments
- Yard assignments
- Capital Assignments

- **Wages and Fringe**

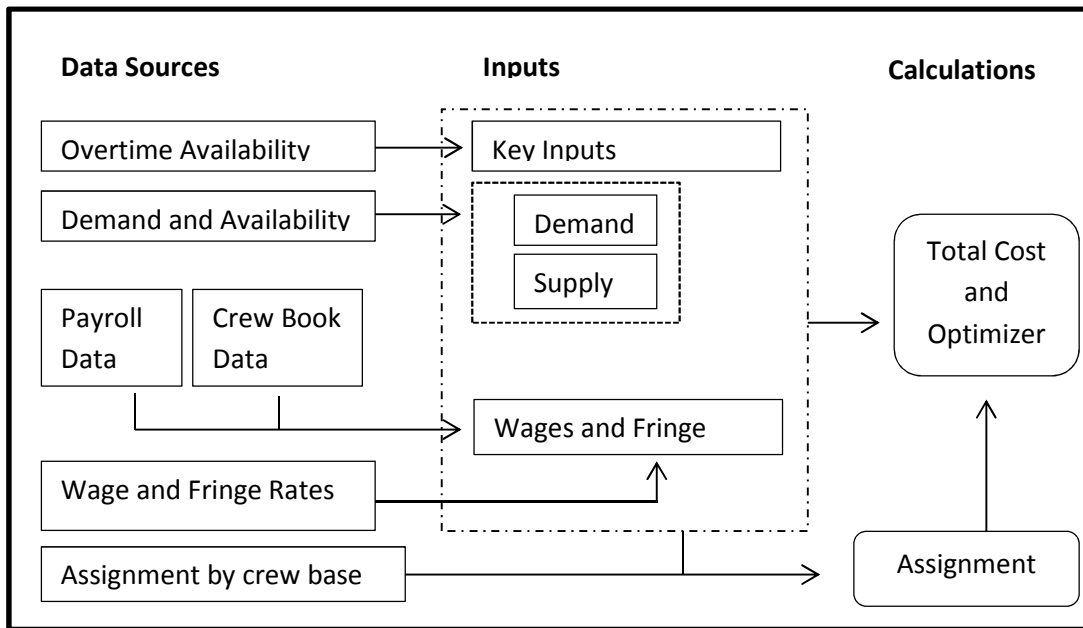
- Daily Overtime Pay: crew book, yard, capital
- Weekly Assignment Pay: crew book, yard, capital
- Weekly Guarantee Pay
- Weekly Student Pay

- **Absence (considered part of Supply)**

- Planned
- Unplanned

The Model Inputs are used by the Assignment process (Section 2.3) and by the Optimizer (Section 2.4) to determine the optimal number of FTEs and the total cost for a particular number of FTEs. Figure 2Error! Reference source not found. below provides a flowchart of the model design.

Figure 1: Model Design Flowchart



2.2. Assignment Process

The assignment process uses the supply and demand inputs to assign FTEs to work assignments. The model calculations are done at the crew base level, but the results are calculated on a monthly basis at a system wide level (Figure 3). The assignment is done on a daily basis at the crew base level. Calculations at the crew base level are important since one crew base may have a surplus while the other has a shortfall, but if they are not close enough to share resources then one crew base may not fill one or more assignments while another may pay guarantee days. For this reason the model may show both guarantee and overtime paid out on the same day. All of the supply, demand, and surplus/shortfall calculations described below are computed first at the crew base level and then summed to determine the aggregate daily results. Crew bases are grouped based on how they share resources and if two crew bases share resources and one has a surplus while the other has a shortfall, then resources will be assigned to the crew base with a shortfall from the crew base with a surplus. These calculations are accomplished in several steps based on the calling order. Once there are no available resources or no open assignments within a group of crew bases the aggregate daily guarantee days and blanked assignments are calculated.

Supply Calculation

The first step in the assignment process is to determine the number of available FTEs on a daily basis (Supply), by determining the Daily Roster and the Available Roster which is calculated as:

$$\text{Average monthly roster} - \text{Rest Days} = \text{Daily Roster}$$

$$\text{Daily Roster} - \text{Planned Absence} - \text{Unplanned Absence} = \text{Available Roster}$$

The assignment will also calculate the Available Overtime which is constrained by the percentage of the daily roster entered in the Model Inputs.

$$\text{Daily Roster} * \% \text{ of Daily Roster Available for Overtime} = \text{FTEs Available for Overtime}$$

Demand Calculation

The next step is to determine the number of total daily assignments (Demand) which is calculated as:

$$\text{Crew Book Assignments} + \text{Yard Assignments} + \text{Capital Assignments} = \text{Total Assignments}$$

There are two stochastic elements of the demand calculation:

- Unplanned Absence
- Capital Assignments

The MS Excel Rand() function is used to generate a random variable which is then used to produce percentages from a uniform distribution. The distribution is constrained by a range which is based on an analysis of historical data for unplanned absence and capital assignments. An analysis of the data found that a uniform distribution was a reasonable approximation of the historical daily distribution, and can be easily programmed into excel without complex macros or program add-ons. A random variable is generated for each day for unplanned absence and capital assignments. Both of these variables have significant daily fluctuation so the use of a stochastic function allows the model to account for this daily variation.

Surplus/Shortfall Calculation

The next step in the assignment is to assign all available FTEs to work assignments to determine the surplus (too many FTEs) or shortfall (too few FTEs). The calculations are:

$$\text{Available Roster} - \text{Total Assignments} = \text{Surplus(+)/Shortfall (-)}$$

The optimizer will then consider any surplus to be Guarantee Days (when an operator is paid but doesn't work) and/or will assign the Shortfall to the FTEs Available for Overtime. Anything left over after this assignment will be considered a blank (missed) assignment. As discussed previously only assistant conductor assignments can be blanked. The equations are as follows:

$$\text{Surplus(+)} = \text{Guarantee Days}$$

$$\text{Minimum [Shortfall (-)+Available Overtime, 0]} = \text{Number of Blank Assignments}$$

The number of blank assignments is equal to zero if all assignments are covered.

2.3. Cost Calculation

The assignment process in the model produces the daily number of assignments worked at overtime, the number of FTEs paid guarantee days, and the number of assignments left blank. The model then applies the appropriate costs to each to calculate the total cost for a particular number of FTEs (Figure 3).

Engineer training lasts approximately twelve months, while conductor training takes approximately eight months. During the majority of this training period, students are paid and receive benefits but they cannot work assignments; therefore there is a cost incurred during this training period and the benefit is

only achieved after. For this reason the model looks several years ahead to consider the benefits received from training an additional person once they are fully trained.

The model calculates the basic cost of service as the cost for all FTEs being paid for their regular assignment. The reason for this is that all FTE's are paid their weekly assignment rate on any day that they are scheduled to work even if they don't work, except in the rare instance that they take unpaid time off. As an example, if an FTE takes sick leave then that FTE is still paid his/her regular assignment rate as sick leave pay while another FTE may work overtime to fill the sick FTE's assignment. The same is true for all other types of paid leave, thus the model assumes that all FTEs are always paid their standard weekly assignment rate and then calculates any overtime in excess of this figure. This basic cost of service is referred to as the "All other FTE" cost in the model and is calculated as:

$$\text{Average Cost per Scheduled Weekly Assignment} * (\text{Total Roster} - \# \text{ of Students} - \# \text{ of Yard Assignments} - \# \text{ of Capital Assignments} - \# \text{ of Guarantee Assignments}) = \text{All other FTE \$}$$

Students are paid at a lower rate so they are excluded from the "All other FTE" calculation and calculated separately. Similarly Yard, Capital assignments, and Guarantee days are paid at a different rate than Road Assignments and are also removed from the "All other FTE" calculation and are calculated separately.

The annual cost for Yard, Capital, Blank, Operating Overtime, Capital Overtime, Guarantee, and Students are calculated by applying the unit cost to the model estimated units. The units for Yard, Capital, Blank, and Overtime are the average number of assignments, for Guarantee its guarantee days, and finally for students it is the number of students. These units are computed based on the key inputs and by the assignment process in the model.

The Total cost is calculated in a series of equations:

$$\text{Yard \$} + \text{Operating Overtime \$} + \text{Guarantee \$} + \text{Student \$} + \text{All Other FTE \$} = \text{Total Operating FTE Pay}$$

$$\text{Capital \$} + \text{Capital Overtime \$} = \text{Total Capital FTE Pay}$$

$$\text{Total Operating FTE Pay} + \text{Total Capital FTE Pay} = \text{Total FTE Pay}$$

$$\text{Fixed Fringe \$} + \text{Variable Fringe \$} = \text{Total Fringe Cost}$$

$$\text{Total FTE Pay} + \text{Total Blank Lost Revenue} + \text{Total Fringe Cost} = \text{Total Cost}$$

In addition to the total cost the model has the ability to calculate the net financial impact between one set of variables and another set (Figure 4).

Figure 3: Detailed Model Forecast Sample Output
(FTE and \$ are illustrative and not actual Metro-North FTE and \$)

MONTH		Service Demand	Total Roster	Student	Rest Days	Daily Roster	Absence Planned	Simulated Unplanned	Available	Surplus (Shortfall)
Train Service										
1	JAN	170	280	20	50	210	30	20	160	(10.0)
2	FEB	170	290	20	50	220	20	20	180	10.0
3	MAR	170	290	10	50	230	30	20	180	10.0
4	APR	180	280	20	50	210	30	20	160	(20.0)
5	MAY	180	280	10	50	220	30	20	170	(10.0)
6	JUN	180	280	10	50	220	30	20	170	(10.0)
7	JUL	180	280	20	50	210	30	20	160	(20.0)
8	AUG	180	280	10	50	220	30	20	170	(10.0)
9	SEP	180	290	20	50	220	30	20	170	(10.0)
10	OCT	180	280	10	40	230	30	20	180	0.0
11	NOV	180	280	10	50	220	30	20	170	(10.0)
12	DEC	180	280	10	50	220	30	20	170	(10.0)
		178	283	14	49	219	29	20	170	(8)
MONTH		Crewbook +Xtra Road	Yard	Simulated Capital	Blank (Daily Avg)	OT (Daily Avg)	Guarantee (Daily Avg)			
Train Service										
1	JAN	140	10	20	-	1.1	3.2			
2	FEB	140	10	20	-	0.9	3.6			
3	MAR	140	10	20	-	0.7	5.5			
4	APR	140	10	30	0.6	6.6	-			
5	MAY	140	10	30	0.2	4.4	0.6			
6	JUN	140	10	30	0.9	6.7	-			
7	JUL	140	10	30	2.6	8.3	-			
8	AUG	140	10	30	0.5	6.3	0.1			
9	SEP	140	10	30	1.1	6.8	0.1			
10	OCT	140	10	30	1.7	7.7	-			
11	NOV	140	10	30	2.5	8.3	-			
12	DEC	140	10	20	0.4	5.3	0.2			
		140	10	27	1	5	1.1			
MONTH		Yard \$	Capital \$	Blank \$	Operating OT \$	Capital OT \$	Total OT \$	Guarantee \$	Student \$	All Other FTE \$
Train Service										
1	JAN	\$ 79,000	\$ 224,000	\$ -	\$ 10,000	\$ 2,000	\$ 12,000	\$ 19,000	\$ 61,000	\$ 1,830,000
2	FEB	\$ 79,000	\$ 208,000	\$ -	\$ 8,000	\$ 1,000	\$ 9,000	\$ 21,000	\$ 75,000	\$ 1,840,000
3	MAR	\$ 79,000	\$ 234,000	\$ -	\$ 6,000	\$ 1,000	\$ 7,000	\$ 32,000	\$ 49,000	\$ 1,843,000
4	APR	\$ 99,000	\$ 321,000	\$ 23,000	\$ 73,000	\$ 14,000	\$ 87,000	\$ -	\$ 80,000	\$ 2,252,000
5	MAY	\$ 79,000	\$ 258,000	\$ 5,000	\$ 39,000	\$ 7,000	\$ 46,000	\$ 3,000	\$ 47,000	\$ 1,833,000
6	JUN	\$ 79,000	\$ 258,000	\$ 28,000	\$ 59,000	\$ 11,000	\$ 70,000	\$ -	\$ 47,000	\$ 1,821,000
7	JUL	\$ 99,000	\$ 335,000	\$ 96,000	\$ 92,000	\$ 17,000	\$ 109,000	\$ -	\$ 77,000	\$ 2,267,000
8	AUG	\$ 79,000	\$ 259,000	\$ 14,000	\$ 56,000	\$ 11,000	\$ 67,000	\$ 1,000	\$ 44,000	\$ 1,857,000
9	SEP	\$ 99,000	\$ 325,000	\$ 40,000	\$ 76,000	\$ 14,000	\$ 90,000	\$ -	\$ 74,000	\$ 2,301,000
10	OCT	\$ 79,000	\$ 285,000	\$ 52,000	\$ 68,000	\$ 13,000	\$ 81,000	\$ -	\$ 44,000	\$ 1,788,000
11	NOV	\$ 79,000	\$ 289,000	\$ 75,000	\$ 74,000	\$ 14,000	\$ 88,000	\$ -	\$ 44,000	\$ 1,785,000
12	DEC	\$ 99,000	\$ 282,000	\$ 14,000	\$ 59,000	\$ 11,000	\$ 70,000	\$ 2,000	\$ 56,000	\$ 2,319,000
		\$ 1,028,000	\$ 3,278,000	\$ 347,000	\$ 620,000	\$ 116,000	\$ 736,000	\$ 78,000	\$ 698,000	\$ 23,736,000

MONTH		Total Operating FTE Pay	Total Capital FTE Pay	Fixed Fringe \$	Variable Fringe \$	Total FTE Pay	Total Blank Lost Revenue	Total Fringe Cost	Total Cost
Train Service									
1	JAN	\$ 1,999,000	\$ 226,000	\$ 392,000	\$ 754,000	\$ 2,225,000	\$ -	\$ 1,146,000	\$ 3,371,000
2	FEB	\$ 2,023,000	\$ 209,000	\$ 397,000	\$ 757,000	\$ 2,232,000	\$ -	\$ 1,154,000	\$ 3,386,000
3	MAR	\$ 2,009,000	\$ 235,000	\$ 395,000	\$ 762,000	\$ 2,244,000	\$ -	\$ 1,157,000	\$ 3,401,000
4	APR	\$ 2,504,000	\$ 335,000	\$ 486,000	\$ 963,000	\$ 2,839,000	\$ 23,000	\$ 1,449,000	\$ 4,311,000
5	MAY	\$ 2,001,000	\$ 265,000	\$ 389,000	\$ 769,000	\$ 2,266,000	\$ 5,000	\$ 1,158,000	\$ 3,429,000
6	JUN	\$ 2,006,000	\$ 269,000	\$ 386,000	\$ 772,000	\$ 2,275,000	\$ 28,000	\$ 1,158,000	\$ 3,461,000
7	JUL	\$ 2,535,000	\$ 352,000	\$ 489,000	\$ 979,000	\$ 2,887,000	\$ 96,000	\$ 1,468,000	\$ 4,451,000
8	AUG	\$ 2,037,000	\$ 270,000	\$ 391,000	\$ 782,000	\$ 2,307,000	\$ 14,000	\$ 1,173,000	\$ 3,494,000
9	SEP	\$ 2,550,000	\$ 339,000	\$ 493,000	\$ 980,000	\$ 2,889,000	\$ 40,000	\$ 1,473,000	\$ 4,402,000
10	OCT	\$ 1,979,000	\$ 298,000	\$ 383,000	\$ 773,000	\$ 2,277,000	\$ 52,000	\$ 1,156,000	\$ 3,485,000
11	NOV	\$ 1,982,000	\$ 303,000	\$ 383,000	\$ 775,000	\$ 2,285,000	\$ 75,000	\$ 1,158,000	\$ 3,518,000
12	DEC	\$ 2,535,000	\$ 293,000	\$ 483,000	\$ 959,000	\$ 2,828,000	\$ 14,000	\$ 1,442,000	\$ 4,284,000
		\$ 26,160,000	\$ 3,394,000	\$ 5,067,000	\$ 10,025,000	\$ 29,554,000	\$ 347,000	\$ 15,092,000	\$ 44,993,000

Figure 4: Detailed NFI Cost Breakdown

(\$ are illustrative and not actual Metro-North \$, positive number are costs, negative numbers are savings)

	Lost Revenue from blanked assignments	Operating OT	Cost of guarantee	Cost of new hire students	Total Capital FTE Pay	Total Fringe: fixed + variable	All other FTE cost and Yard Costs	
Train								
	Blank	Relief Day OT	Guarantee	Students	Capital	Fringe	All Other	Total
2012	-	-	-	56,000	-	39,000	-	95,000
2013	(228,000)	(62,000)	11,000	17,000	(12,000)	91,000	190,000	7,000
2014	(226,000)	(72,000)	22,000	-	(14,000)	95,000	212,000	18,000
2015	(305,000)	(56,000)	22,000	-	(11,000)	106,000	212,000	(32,000)
2016	(365,000)	(48,000)	15,000	-	(9,000)	114,000	222,000	(70,000)
2017	(365,000)	(48,000)	15,000	-	(9,000)	114,000	222,000	(70,000)
Total	(1,488,000)	(287,000)	84,000	73,000	(53,000)	559,000	1,058,000	(53,000)

2.4. Optimizer

The Optimizer is a series of macros that runs a Monte Carlo simulation testing different numbers of FTEs on a quarterly basis to determine how many new students need to be trained each quarter over the next two years in order to produce the lowest five year cost. The simulation involves ten iterations of the quarterly FTE minimum cost testing; during model testing it was determined that the simulation typically converged in less than 10 iterations.

The optimizer will provide adjustments to the planned hiring plan by proposing additional training or reducing training classes. The hiring plan addresses attrition and the service plan, but the optimizer will identify areas of under/ overstaffing with respect to this plan. The results of this optimization are displayed in the Main Calculations Page (Figure 5).

Figure 5: Main Calculation Page

(\$ are illustrative and not actual Metro-North \$, positive number are costs, negative numbers are savings)

Model Results

Total Cost / Net Financial Impact

	ENGINE	TRAIN	TOTAL
2012	\$ 20,367,000	\$ 44,257,000	\$ 64,625,000
2013	\$ 21,004,000	\$ 44,993,000	\$ 65,997,000
2014	\$ 21,349,000	\$ 45,188,000	\$ 66,536,000
2015	\$ 21,744,000	\$ 45,526,000	\$ 67,270,000
2016	\$ 22,244,000	\$ 45,948,000	\$ 68,192,000
2017	\$ 22,244,000	\$ 45,948,000	\$ 68,192,000
Total 6-Year C	\$ 128,952,000	\$ 271,859,000	\$ 400,812,000

Detailed Forecast

NFI of adding FTE's

Set NFI Baseline

Note: This button can only be used for New FTE Classes

	ENGINE	TRAIN	TOTAL
2012	\$ (48,000)	\$ 95,000	\$ 47,000
2013	\$ (62,000)	\$ 7,000	\$ (56,000)
2014	\$ (80,000)	\$ 18,000	\$ (62,000)
2015	\$ (89,000)	\$ (32,000)	\$ (122,000)
2016	\$ (96,000)	\$ (70,000)	\$ (166,000)
2017	\$ (96,000)	\$ (70,000)	\$ (166,000)
Net Financial In	\$ (471,000)	\$ (53,000)	\$ (525,000)

NFI Detailed

Optimizer

Run Optimizer ENGINE

Run Optimizer TRAIN

New FTE Classes

Adjustment to Planned Classes for Attrition

Engine	New FTE Students					
Month	2012	2013	2014	2015	2016	
Jan	-	-	-	-	-	-
Feb	-	-	-	-	-	-
Mar	-	-	-	-	-	-
Apr	-	-	-	-	-	-
May	-	-	-	-	-	-
Jun	(2)	-	-	-	-	-
Jul	-	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-
Dec	-	-	-	-	-	-
Total	(2)	-	-	-	-	-

Train	New FTE Students					
Month	2012	2013	2014	2015	2016	
Jan	-	-	-	-	-	-
Feb	-	-	-	-	-	-
Mar	-	-	-	-	-	-
Apr	-	-	-	-	-	-
May	-	-	-	-	-	-
Jun	-	-	-	-	-	-
Jul	7	-	-	-	-	-
Aug	-	-	-	-	-	-
Sep	-	-	-	-	-	-
Oct	-	-	-	-	-	-
Nov	-	-	-	-	-	-
Dec	-	-	-	-	-	-
Total	7	-	-	-	-	-

Edit Key Inputs

3.1. Data

The model requires a substantial amount of data; determining where to find this data was a time consuming process. The model also requires substantial annual manual data updates.

3.2. Training Facility and Resource Constraints

Conductor training takes about 8 months, while engineer training takes one full year, therefore there is a long lead time between when new engineers and conductors are hired and when they are fully trained and available to work assignments. Furthermore, training resources are limited, including the number of classrooms and the number of instructors, which makes it difficult to quickly increase the number of new hire trainees.

3.3. Attrition (Retirement)

Metro-North is expecting substantial attrition due to retirements across the agency during 2013 and for several years following, due to their reaching milestone dates in age and years of service that directly affect their future pensions. Accurately predicting the number of retirees is critical but difficult; some employees won't retire even when eligible and some will retire even before reaching the number of years necessary for the maximum pension amount, especially once their colleagues and friends retire in significant numbers. Because of the long training time for conductors and engineers, advance hiring is critical to avoid a shortage of FTEs and the resulting increase in blanked assignments.

3.4. Agency Cooperation and Support

Metro-North management was very interested in developing this model so that engineer and conductor costs could be better quantified and to provide a tool that the Operations Services department could use to help with rightsizing the conductor roster. The development of the model was a significant undertaking and involved input from many departments, but the majority of the support and data was provided by the Operations Services department. The Finance/Budget Department developed the model and worked closely with the Operations Services Department every step of the way to ensure that the resulting product would be understandable and useful to the Operations Services department. Without this cooperation, and the support of senior management this project would not have been possible.

3.5. Applications

The primary purpose of the model and the reason for its development was rightsizing the assistant conductor roster, but the model is a powerful and comprehensive tool that can be used for scenario testing, including:

- Evaluating the cost/savings of changes in planned and unplanned absences by manipulating these inputs accordingly and determining the optimal number of FTEs once an input is adjusted. This would be useful if Operations Services wishes to evaluate the effect of a revised training program. The model can be used to evaluate the impact of adjusting the ongoing training program so that there is less training in months with higher service demand and more during months with lower service demand. Another application might be to evaluate the cost of a

1 projected increase in unplanned absence (such as FMLA leave) which is increasing at many
2 transit agencies.

3
4 Determining the estimated annual cost savings if Metro-North did not have assistant
5 conductors: This was most recently calculated for an international benchmarking group of
6 which Metro-North is a member. However, a similar analysis would be useful to determine the
7 estimated annual cost of switching to a proof of payment system. In this type of system
8 assistant conductors would no longer be necessary since their primary responsibility is ticket
9 collection, but these savings would need to be balanced against the cost of having proof-of-
10 payment fare inspectors on the payroll.

11 **4. CONCLUSIONS AND RECOMMENDATIONS**

12 Initial development of the model took several months to produce a working draft. Then several more
13 months were needed to fix any remaining bugs, formatting it for ease of use and aesthetic purposes,
14 and finally to fully document and annotate the model. The next step in the process is to fully train the
15 Operations Services department in how to use and update the model.

16
17 The model is an important tool for determining the optimal size of the roster and for testing scenarios
18 and potential changes to inputs, such as retirement, absence, and capital flagging needs. The model has
19 already been used to test some of these scenarios and it is expected that it will continue to be used and
20 updated to test future scenarios and determine optimal roster size. It is also a useful tool to quantify
21 the costs of various scenarios and for supporting documentation when presenting requests for
22 additional FTEs to senior management.

23
24 Metro-North believes that a similar model would be beneficial to other agencies to be used as a tool by
25 the operations division to determine optimal staffing and for scenario testing. This paper documented
26 and described the model design and development in the hopes that this would be helpful to other
27 agencies in designing their own model.
28
29