

Station-Ahead Car Capacity Display to Reduce Dwell Time

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By measuring the crowding of each subway car in a train assembly before departure from a station, we are able to transmit to the next station on the line the relative loading of riders in each car and display it via overhead platform indicator lights to allow people to queue more efficiently long before the train arrives.

A. Applicant Information

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Application Title: Station-Ahead Car Capacity Display to Reduce Dwell Time
Application ID #:
Applicant Type:

B. Executive Summary

From a macro perspective, minimizing the following components of a subway system increase its efficiency:

1. Dwell Time (how much time is spent at a station waiting for embarking/disembarking)
2. Acceleration/Deceleration Time Profile of the Trains
3. Inter-Train Gap

In order to increase train frequency, which increases line capacity, the above metrics must be minimized. For the sake of this proposal, we will focus on Dwell Time because it is something that is not considered easy to address without radical structural changes such as two-sided embarking/disembarking, station doors, etc.

Our proposal is to measure, by way of multiple, inexpensive, sensor systems the rider density of each subway car in a train assembly as soon as the doors close and before it departs a station and to then immediately transmit that information, detailed on a per-car basis to the next scheduled station where the train will stop.

This information will be converted for display into a series of cylindrical overhead LED lights (to allow 180-degree visibility) above the platform edge of the tracks that display the relative loading of each car for an inbound train that has just departed the prior station. They are positioned such that they will approximately align with the train doors of each car when a motorist has made a proper stop.

This configuration allows riders to queue strategically to avoid overcrowding (and even short-trains) by leveling the pending rider load across the whole train before the train arrives at the station, not while it is dwelling.

Further, next to each queue position indicator light, we can optionally monitor the density of waiting riders and adjust the capacity indicator lights to reflect the potential conditions as well as transmit this data to

inbound trains so that we can display, in the interior of the inbound train, above each door or around each door frame, an LED strip indicating the recommended egress door.

Additionally, we will introduce a reward system, whereby riders who have just entered the station may swipe their Metrocard (or utilize the new contactless payment system), once inside a train car, and if the train doors for that car have closed within the predetermined time-of-day target dwell period, the entirety of the new ridership on that car will be issued a fractional rebate as incentive to be efficient.

Finally, we can enhance the system further by utilizing the queuing data over time to build more accurate statistical models of ridership patterns as they relate to platform position, time of day, station, etc. The techniques to sample and estimate rider density are the following:

1. Passive WiFi MAC counting
2. Infrared depth-sensing arrays
3. Optical face counters
4. Under-floor capacitive measurement

It should be noted that none of these alone can precisely count the dense, often chaotic, ingress and egress that occurs in the subway, however, together they can provide enough data to build a highly accurate model of relative density, and each is very low-cost.

This solution provides key metrics on traffic flow, allows us to establish customary procedures, provides for self-reorganization and allows dynamic programmability to easily support the implementation of rider congestion management such as rear-of-car egress and front-of-car ingress loading patterns. In total, this is a comprehensive solution to meet dwell time objectives. We feel we should win this challenge because this solution addresses a problem that is not easily solved without massive structural changes to both the cars and platforms. This solution is easily retrofitted into all generations of existing rolling stock and all platform layouts. Even achieving a modest realization of a 10% savings on dwell time averages translates to an average increase of 4tph (trains per hour). This is a 15% increase to general system throughput and a very conservative estimate.

C. Technical Overview

Our solution addresses the minimization of dwell time by providing riders with the ability to self-organize ahead of time. It does this in several ways:

1. By providing information to the riders about the car capacity of inbound trains in a simple color indicator format allowing them to relocate themselves on a platform before the train arrives.
2. By providing, in train, information to the riders about the egress area density near a particular door and which side the doors will open on.
3. By encouraging riders to adhere to a common unload/load procedure as indicated by the in-floor LED matrix integrated with the bright-yellow anti-slip strips along the edge of platforms.
4. By financially rewarding riders for meeting reduced dwell time objectives by providing a rebate for riders entering the system when they successfully load a train car and complete a door close event within the target time.
5. By providing support for advanced rider traffic flow control such rear-of-car egress/front-of-car ingress models.
6. By reducing door holding and other non-congestion event-type delays, we reduce the ripple effect that generates crowding downstream.



Fig. 1. Rendering of Capacity Indicator Lights in an older design station.

Capacity Indication is conveyed to the next station on a route by transmitting a sample of a continuously estimated capacity level of each train car in a train-assembly at the moment that the accelerometer detects forward motion after a recently triggered train door close event. This burst is initially transmitted via WiFi, through the in-station WiFi provided by Transit Wireless, to a server, running in a cloud provider's infrastructure (or alternatively in-house), where it is forwarded to the next scheduled station on the line for display. Upon reception of this capacity burst message, the receiving station's Capacity Indicator Lights adjust color to indicate to waiting passengers where more capacity is available (green), capacity is limited (yellow/orange) or no capacity is available (red) because of crowding or a short-train assembly.

Before the door-close trigger event, while the doors are open and the train is in the station, the capacity levels are being continuously sampled and transmitted to the current station so that riders just arriving to a platform are able to see currently available capacity as it changes. In this state, the Capacity Indicator lights on the platform will blink during state changes and simulate a countdown by way of blink frequency to visually alert riders who may be rushing towards the platform. Additionally, upon leaving the station, and continually while in motion, the system transmits updated capacity bursts directly to the next station via LPWAN technology (e.g. LoRa, Sigfox, etc.) to account for the potentially large in-motion rider redistribution effects of open gangway trains.

Once the destination station has received the capacity burst information (approximately 50ms from the

time of departure from the prior station), and so long as there is no train currently in that station, the system will immediately display the estimated capacity levels while it attempts to continuously refine the estimates based on historical patterns of rider load exchange. In other words, we immediately display a rough-estimate at the next station within 50 milliseconds of the door close trigger at the current station and then refine it periodically as new information arrives from the LPWAN bursts and statistical models are run against the bursts and historical data.



Fig. 2. Rendering of Capacity Indicator Lights and IR depth cameras in an older design station. Please note that the IR grid is not visible to the human eye, it is purely for illustration.

Likewise, on the interior of the train, above each door, is a colored visual indicator of the egress density at the destination station. This is updated periodically as the train is in transit. While in its most simplistic form, this suggests to riders which door to exit from in order to have the most efficient egress, however, a more significant value is to use these for an even/odd, ingress/egress model or a front-of-car ingress, rear-of-car egress rider flow control arrangement whereby riders are directed to egress only at green lit doors and queuing riders on the platform are directed (via the Capacity Indicators and In-Floor LED Matrix) to ingress only at specified locations.

The In-Floor LED Matrix, as illustrated in figure 1, will attempt to establish a customary process, by way of visual indicators that indicate timing, to encourage orderly boarding and disembarking. The LED matrix is very sparse, and thus low-cost, and designed to display several patterns that encourage the dedicated flow

of egress traffic (similar to Step Aside markings, but with visual indication of timing) for a programmable period of time before switching patterns to indicate that ingress flow is now acceptable. While we are not able to enforce such a custom (the way two-sided loading can), we can attempt to encourage and socially program an orderly custom in riders. The LED matrix draws its patterns aligned with the door locations of a train brought to a proper stop by the motorist. This allows queuing passengers to have an explicit suggestion on how to arrange themselves to leave clearance for disembarking passengers. The LED matrix also reflects cases of a short-train or out of service car clearly indicating with an X'd rectangular box that there is no train car at this position.

The Financial Reward component, while an optional feature of the system, is a way to motivate the reduction of dwell time and improve capacity distribution by providing a rebate that is redeemable by swiping your Metrocard (or using the new contactless system) on compact reader/writers located in the statistically least dense areas of a train car. For all newly entered riders, of a car that has successfully closed its doors with the dwell time target, a rebate will be provided. What this achieves is two-fold:

1. It encourages migration towards the Metrocard terminals, which are strategically placed along the interior center of the trains (see figure 3), away from the car doors. This redistributes the riders while the situation is fluid and clears the doorway area.
2. It psychologically incentivizes group collaboration in order to avoid the all to common door-holding.



Fig. 3. Rendering of IR depth cameras and capacitive flooring (not actually visible) in a new generation train car interior. Please note that the IR grid is not visible to the human eye, it is purely for illustration.

Our solution consists of the following components:

1. In-Train (per-car)
    1. 6-12 IR Array Cameras, very compact modules, the same modules being used in smart-phones
    2. Capacitive sub-flooring, installed under existing train flooring
    3. Egress Indicator LED Strip: on the interior, above train doors, or around door window frames, indicating which side the doors will open on and where there is the least density of riders waiting

to board
    4. Passive WiFi MAC address counters integrated into IR camera assembly (this is optional and depends on whether an in-train communications systems is available, in which case this will be omitted)
    5. LPWAN Modules (will be omitted if a reliable in-train communications system becomes available)
    6. Strategically placed Metrocard terminals (see figure 3)
2. In-Station (along each platform edge)
    1. Capacity Indicator Lights: train door spaced, above head-level, capacity indicator lights, either cylindrical or flat array LED depending on station design (see figure 2)
    2. Overhead IR Array Cameras, integrated into Capacity Indicator Lights
    3. Passive WiFi MAC address counters integrated into Capacity Indicator Lights (this is optional and depends on whether Transit Wireless's WiFi system can be augmented to capture the data, in which case this will be omitted)
3. Cloud-based virtual machines and databases to collect, route and model the data streams

D. Implementation Detail

1. Our solution is very specific to the challenges facing the MTA. However, all of the components upon which it is designed are in use to varying degrees in retail and advertising markets as well as in existing consumer electronics.
2. We will require a modest amount of design and engineering effort to realize this solution, but nothing that hasn't already been done in the technology industry at large. IR sensors, capacitive sensors, face counters and the classical statistical and machine learning models to combine such data already exist. LED components for platform light fixtures are readily available.
3. We believe there are no regulatory concerns that would impair this project.
4. The only key project risks that we envision are cost slippage and component availability that would impact timing. This is otherwise a very static project to forecast. We also consider perception risk in the area of face counting. If while working with the MTA, we decide that face counting is perceived as too intrusive, we will simply disable it, but we feel the culture at large is past that.
5. We anticipate the entire project duration to be approximately 1 year. The initial design and engineering of the physical fixtures (Capacity Indicator Lights and sensors) will be the only bottleneck to construction parallelism. We envision requiring only electrician labor, of which we can likely source from the MTA as they would be best suited for the installation. A full breakdown of the project can be found in figure 4.
6. We require the following support from the MTA:
    1. Current 3D CAD drawings of the various train car models in service
    2. Current 3D CAD drawings of the platform areas of the stations
    3. Electrical facility detail is required for both trains and platform areas

E. Cost Detail

1. For all 473 stations, 1,500 platform edges (estimated) and approximately 6,500 cars of rolling stock, for the full feature set, we estimate the total installed cost to be between $60 and $80m. We apologize for the large price differential between this proposal and our original one ($15m); the justification follows: First, we've expanded the type and density of sensors and visual indicators to make this a more complete solution. Additionally, some of the critical components that we plan to use are in

high-demand from the smartphone manufacturers because of technologies such as Apple's Face ID and this is creating upwards price pressure for small orders (for example, we only require ~150k IR camera modules). While we can scale back the vision to reduce the cost, we ask that you please review the total value that this solution brings to the MTA's ridership experience before requesting reversion to a simplified implementation.

2. The key cost components (for the full solution) are:
    1. Platform Costs: $38m
        - Capacity Indicator Lights
        - IR Camera Assemblies
        - In-Floor LED Matrix
        - Data aggregation and communications
    2. Train Car Costs: $40m
        - IR Camera Assemblies
        - Under-Floor Capacitive Sensors
        - Data aggregation and communications
3. The Budget Summary and Project Plan are included below with key milestones indicated by red diamonds.

Budget Summary

	2018												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Grand Total
SYSTEM DESIGN & ENGINEERING	10%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	
Labor	75	55	55	55	55	55	55	55	55	55	55	55	680
Materials & Equipment	15	15	15	15	15	15	15	15	15	15	15	15	180
System Design & Engineering (Total)	**90**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**860**
LIGHT FIXTURE	0%	0%	0%	0%	0%	0%	0%	23%	23%	23%	23%	5%	
Labor	45	45	45	45	45	45	45	45	45	45	45	700	1,195
Materials & Equipment	25	25	25	25	25	25	25	5,500	5,500	5,500	5,500	500	22,675
Light Fixture (Total)	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**5,545**	**5,545**	**5,545**	**5,545**	**1,200**	**23,870**
SENSOR ASSEMBLY	1%	1%	1%	19%	19%	19%	19%	21%	1%	1%	1%	1%	
Labor	100	100	100	100	100	100	100	600	100	100	100	100	1,700
Materials & Equipment	50	50	50	5,000	5,000	5,000	5,000	5,000	50	50	50	50	25,350
Sensor Assembly (Total)	**150**	**150**	**150**	**5,100**	**5,100**	**5,100**	**5,100**	**5,600**	**150**	**150**	**150**	**150**	**27,050**
SOFTWARE DEVELOPMENT	10%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	
Labor	100	100	100	100	100	100	100	100	100	100	100	100	1,200
Materials & Equipment	45	15	15	15	15	15	15	15	15	15	15	15	210
Software Development (Total)	**145**	**115**	**115**	**115**	**115**	**115**	**115**	**115**	**115**	**115**	**115**	**115**	**1,410**
TRAIN MODIFICATIONS	7%	7%	7%	7%	7%	7%	7%	10%	10%	10%	10%	10%	
Labor	250	250	250	250	250	250	250	250	250	250	250	250	3,000
Materials & Equipment	50	50	50	50	50	50	50	200	200	200	200	200	1,350
Train Modifications (Total)	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**450**	**450**	**450**	**450**	**450**	**4,350**
STATION/PLATFORM MODIFICATIONS	2%	2%	2%	2%	2%	2%	15%	15%	15%	15%	15%	15%	
Labor	250	250	250	250	250	250	250	250	250	250	250	250	3,000
Materials & Equipment	100	100	100	100	100	100	3,000	3,000	3,000	3,000	3,000	3,000	18,600
Station/Platform Modifications (Total)	**350**	**350**	**350**	**350**	**350**	**350**	**3,250**	**3,250**	**3,250**	**3,250**	**3,250**	**3,250**	**21,600**
RESOURCE ONBOARDING	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	
Labor	50	50	50	50	50	50	50	50	50	50	50	50	600
Materials & Equipment	20	20	20	20	20	20	20	20	20	20	20	20	240
Resource Onboarding (Total)	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**840**
QUARTERLY TOTAL (%)	1%	1%	1%	8%	8%	8%	11%	19%	12%	12%	12%	7%	
QUARTERLY TOTAL ($ in 000s)	**1,175**	**1,125**	**1,125**	**6,075**	**6,075**	**6,075**	**8,975**	**15,100**	**9,650**	**9,650**	**9,650**	**5,305**	**79,980**

Fig. 4. Budget Summary by Category and Time.

Project Plan

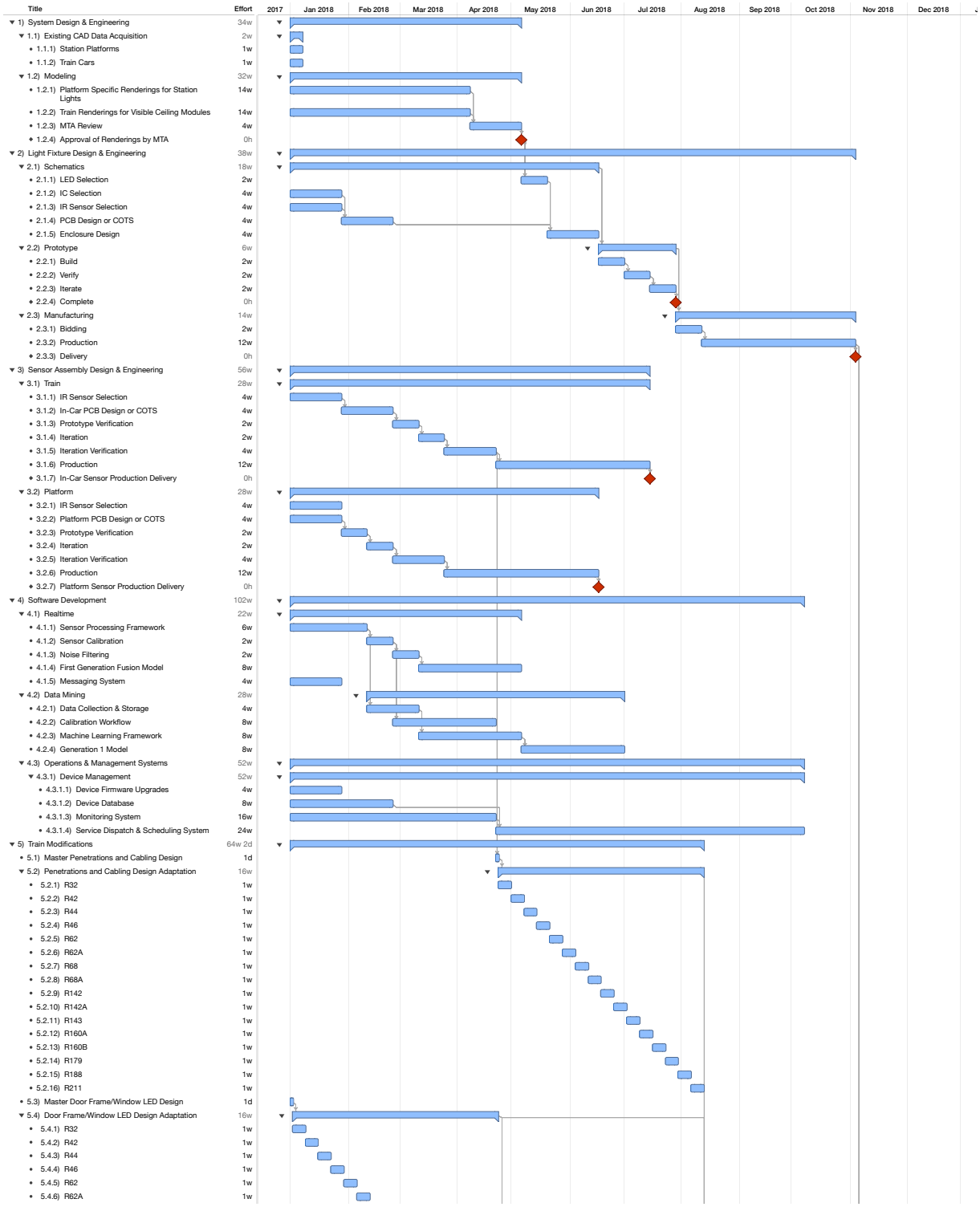


Fig. 5. Project Plan 1/2.

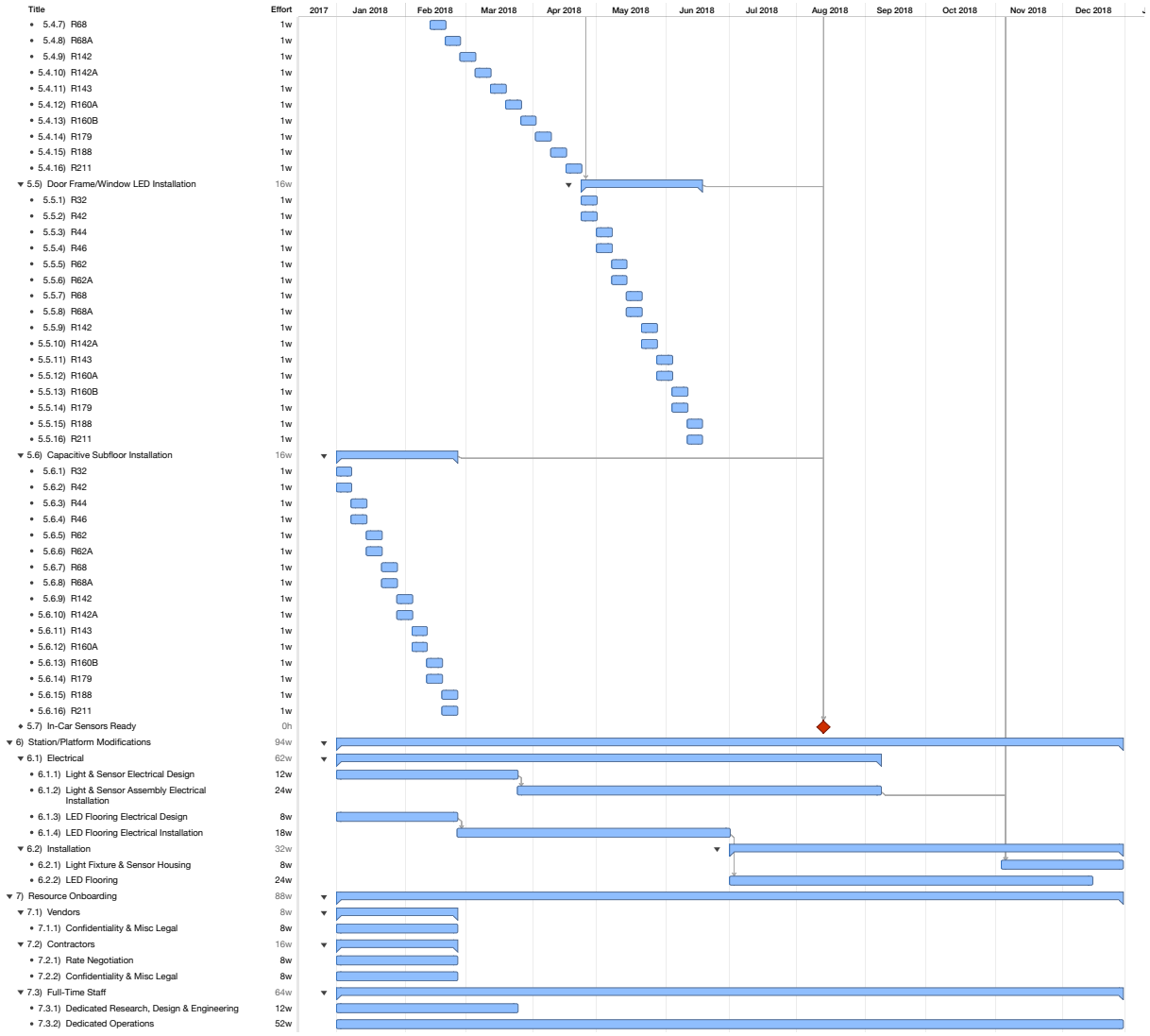


Fig. 6. Project Plan 2/2.