Steidle Building Renewal Project

Technical Report II

Jeffrey E. Duclos

Construction Option

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Executive Summary

For this report, the production of installing HVAC ductwork was studied and analyzed to improve the process and will save time and money without compromising safety and quality. Primarily, the ductwork itself will be analyzed and not the major mechanical equipment (since items like the AHU's and exhaust fans do not lend themselves well to production analysis). However, items essential to the ductwork system, like fan coil units (FCU's), variable air volume units (VAV's), and supply duct insulation will be included.

The first section of this report looks at the existing production plan for the ductwork. This involves developing a detailed production schedule, a detailed cost estimate, and a multi-phase site logistics plan. The purpose of this section is to delve into the current installation practices for the ducts, as well as its impacts on the schedule, budget and site logistics. From there, this section will identify areas that work well for the project and areas that could use improvement.

The second section of this report is an analysis of the production of the ductwork through the developed plan elements stated above. The analysis focuses on crew efficiency, cost breakdowns, and logistics. Based on the analysis, three conclusions were made about the HVAC ductwork system. First, the crews are used fairly efficiently throughout the whole process. The worker utilization chart shows a fairly constant slope, which is indicative of very little downtime or idle crews. Second, the costs associated with installing the ducts are lower than the square foot estimate developed in Technical Report I because that area is being renovated with no new equipment. The total cost of installing the duct in the existing building is $386,821, while the square foot estimate's total HVAC amount for the existing building is $1,823,979. The third conclusion is that while there are many alternative options to improving the productivity of installing the ductwork, they are not feasible given the constraints of the project like the limited entry through the south façade or the tight workspaces for each trade.

An interview focusing on ductwork production was also conducted as part of this report. The interview took place on October 12th at the Mascaro Construction site trailer. It was originally planned to be with the Site Superintendent, but the HVAC Foreman was also available and was willing to participate as well. Subjects addressed during the interview were general details about installing the ductwork, the constructability of the system, and methods for improving production to accelerate the schedule. Their input was taken into consideration when performing the production analysis. Further details may be found in the summary transcript in the appendices.

Production Plan

The process for installing ductwork has not changed very much over the years, however this project presents some interesting challenges. For starters, the ductwork is being installed in both an existing building and a new building. This means that different techniques need to be utilized, which can cause some issues when the work is flowing from one area to another and back again. Another issue is the limited amount of space inside the building for the duct sheetmetal journeymen to work in. The space itself is fairly open per the design intent, but when multiple trades are trying to work in the same area then space becomes quite limited. The last major issue is the restrictions of the site outside of the building. Since Penn State's campus is open year-round, a majority of the walkways and roadways need to be kept open so as to not interfere with the students. This means that space for material storage and lay-down needs to be well managed to prevent clutter and interference between the trades. In order to mediate these issues as much as possible, a well-developed production plan becomes a necessity. That plan will be developed in this report by looking at the site logistics, the installation means and methods, the activity schedule, and the detailed cost breakdown.

Site Logistics Plan

The start of any good production plan is understanding how the activity will work logistically. While a subcontractor is excellent at managing and performing their own work, they're not as concerned with how their activity affects or is affected by the other trades. That is why developing a site logistics plan is crucial to a project's success. For the installation of the ductwork at the Steidle Building, the plan starts when the delivery truck drives up in front of the south entrance (see Figure 1 below). From there, the pallets containing the duct pieces are unloaded by the mobile crane on site and placed in the material lay-down area. This is where the pallets are inspected for transportation damages, inventoried and designated with the location they're headed to.

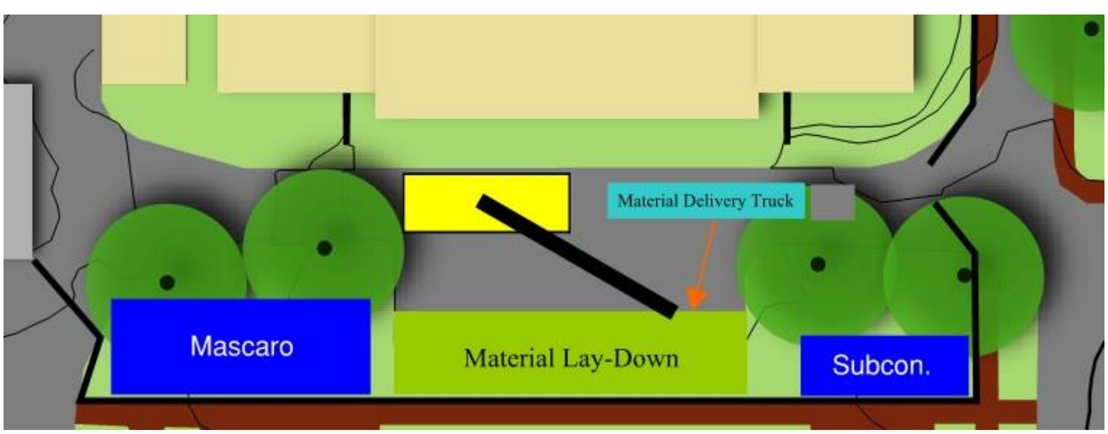


Figure 1 – Detail of the logistics plan for unloading the delivery of the ductwork from the truck to the lay-down area.

It should be noted that the crane is supplied by the contractor performing the bulk of the crane-dependent work at the time. During structural work, that would be Leonard S. Fiore. During the interiors phase, it can vary from Crystal Steel to Farfield to Penn Intallations.

Once the duct pallets have been inspected, inventoried and labeled, they are then hoisted up to their respective floors' material transferal areas, as shown in Figure 2 below. This is where all the materials for each floor are temporarily placed as they await distribution.

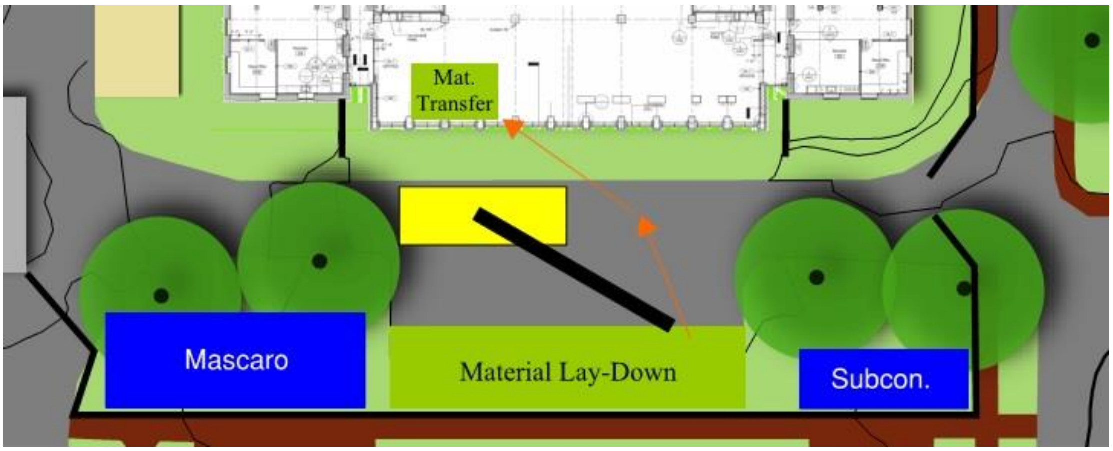


Figure 2 – Detail of the logistics plan for the movement of the ductwork from the exterior lay-down area to the floor-specific transferal area.

Finally, the duct pallets are then loaded onto a floor-wheel cart and sent out to the general area where they are to be installed (shown in Figure 3 below). It is at these small storage areas in the building that the duct pieces will then wait the longest until it is time to install them. Full site logistics plans for the ductwork may be found in Appendix B.

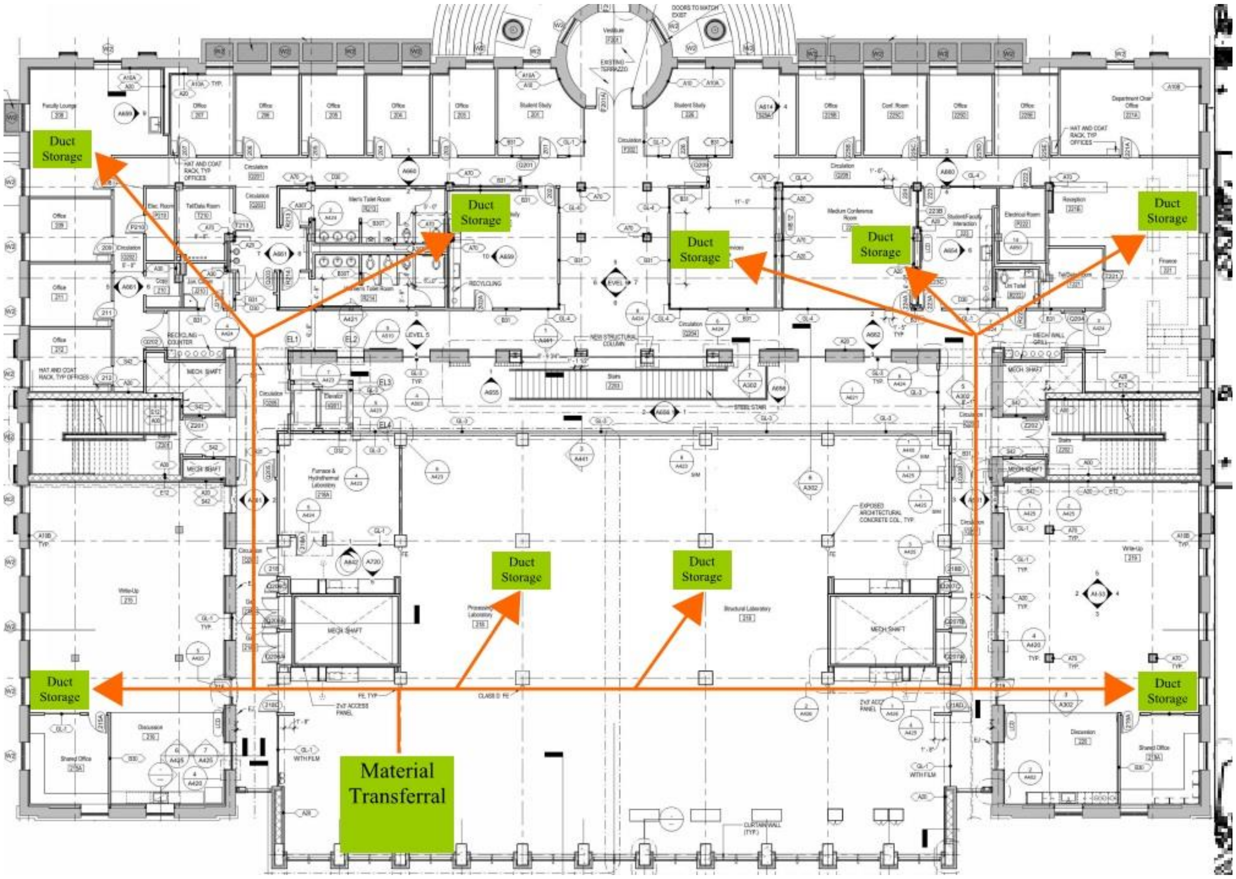


Figure 3 – Detail of the logistics plan showing the distribution of the ductwork to general locations of their installation

One key aspect of this logistics plan is coordination with the trades. Trades that also make use of the crane in addition to the trade supplying thee crane need to be aware of when the crane will not be available to them so that non-crane-critical work can be properly planned ahead to not coincide with the unloading of the duct pallets. Coordination also includes delivery management. The best case scenario is that the next delivery occurs as soon as the crane becomes available for the use of the HVAC subcontractor. Otherwise, the ductwork will be sitting idle, costing time and money as the other trade(s) try to finish their work with the crane.

Means and Methods

The process for installing the ductwork sheetmetal usually starts with determining the locations where the duct hangers need to be installed. This is done using a Total Station to lay out where the hangers, and by extension the ductwork, need to go. The process then diverges between whether the hangers are being installed in an existing structure or a new structure. For an existing structure, the holes for the hangers are simply drilled into the slab and the hangers are then installed. For a new structure, the hangers are laid out on the formwork for the bottom of the slab. Then, a wood-knocker embedded anchor is inserted into the slab at all the hanger locations. This creates a pre-formed hole for the anchors to be installed in as soon as the slab has cure and the formwork is removed.

Once the hangers are installed, the ductwork is then taken from storage to be installed on the hangers. Sometimes, before the ductwork is installed, pieces will be pre-connected to form a larger section. This saves time for the crew as they don't need to hang as many sections as originally planned. Duct connections are usually made by connecting them with gasket tape and then bolting the flanges together. Afterwards, the duct section is propped up into place with a duct jack. The crew will attach the section to the hangers and any other duct sections already in place. If insulation is required, the crew will usually wrap the required ducts once everything is in place.

After the ductwork is put in place, the HVAC equipment is then installed. This includes the FCU's, VAV's and RHC's. Also at this time, the AHU's are being installed in the penthouse. Once those large equipment pieces are in place, the penthouse ducts and the vertical duct shafts can be installed.

The final pieces of the ductwork system to be installed are the grilles, returns, and diffusers, or GRD's. The GRD's rely on the ceiling grid being installed to provide support, so those usually get installed later in the project. After that, testing, adjusting and balancing is conducted. If the duct system passes all the required tests, then it is complete.

Production Schedule

The system's production schedule for this report focuses primarily on the installation of the ductwork in the existing building. This was done because the ductwork in the existing building is very repetitive. The four floors are very close to each other in terms of air conditioning usage. In fact, the east half of each floor is almost a mirror image of the west half. This makes the existing building ductwork ideal to study the productivity of the crews working in that area as each floor half can be readily compared against the others.

The duct installation started on February 19th, 2015 on the second floor of the building. The sequence of the ductwork follows the sequence of the demolition of the existing building interior – start on the first floor and work up to the fourth floor. However, the first floor would still have work being done on the slabs-on-grade, and what area was left would be used for demolition storage. So, the sequence of the ductwork instead started on the second floor, proceeded to the third floor, went back down to the first floor, and finally ended on the fourth floor. As for the ductwork in the new central wing, that followed the original sequence of first floor to fourth floor as it followed behind the removal of the formwork from the slab.

Installation of the ductwork was usually going on in several locations at one time, so it was important for the HVAC foreman to divide his workforce to cover as much ground as possible. The plan was to utilize four crews of two sheet metal journeymen to work throughout the building. If work became stagnated in one area, then the crew could proceed to another area to perform work until the original area became clear again for work. This resulted in a fairly constant flow of work, as shown in the labor curve (Figure 4 below). Although this only shows the work being performed in the existing building, it is indicative of the flow of work throughout the whole project. Even for specialized areas like the lab spaces or the penthouse, the crews have the versatility and flexibility to be productive even if work is slowed or stopped in one specific area. For the full schedule and activity data, please refer to Appendix C.

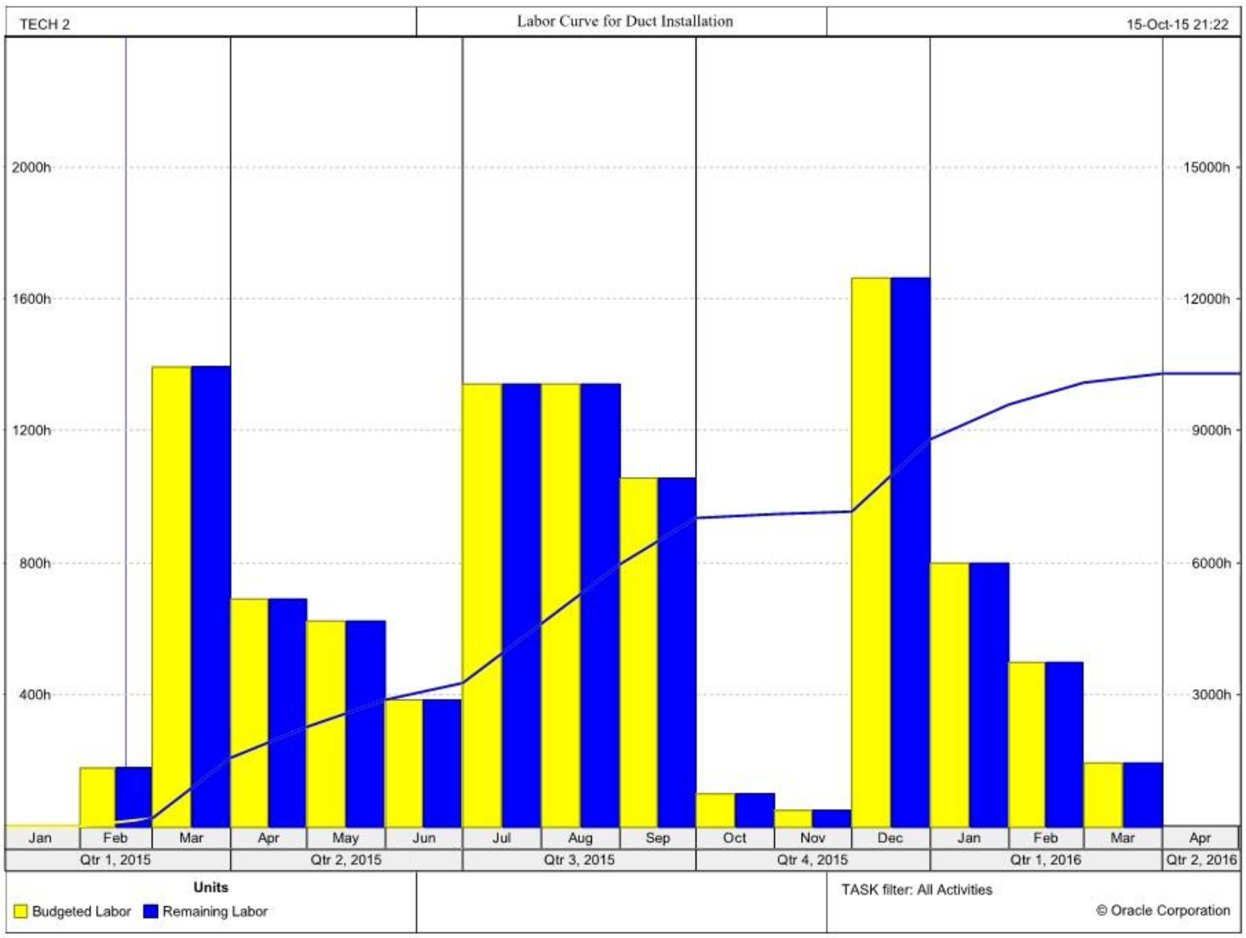


Figure 4 – Labor Curve showing the productivity of the ductwork crews while performing work in the existing building.

Detailed Cost Breakdown

In order to develop a detailed cost breakdown for the existing building's ductwork system, a specific floor was chosen to be considered typical for the rest of the existing building. The third floor best matched what was in the other floors, so it was chosen to be the subject of the estimate. More specifically, the west half of the third floor was chosen, as it is a near mirror image of the east half of the third floor. The takeoff quantities themselves were derived from the shop drawings submitted by the subcontractor. Once the quantities were acquired, they were inputted into the cost estimating software Timberline. The costs for the ductwork installation in the existing building were calculated using information from the HVAC database in Timberline. One assumption worth noting is that that equipment costs for the crane and the duct jacks are not included. This is because it was assumed that the crane was not a part of the HVAC subcontractor's contract and therefore shouldn't be included as part of the production analysis that this estimate is being used. As for the duct jacks, it is assumed that the cost of using those is built into the pay rates for the laborers. In total, the cost of the existing building's ductwork system is $386,821. A full breakdown of the system costs, as well as the drawings used to take off the duct quantities, may be found in Appendix D.

Production Analysis

The productivity of the crews installing the ductwork in the existing building is fairly efficient. By utilizing multiple small crews to work in many various areas of the building, the HVAC contractor was able to maintain a constant rate of work with limited downtime, as shown in the labor productivity curve mention before. As observed on the project, each crew had sufficient resources to be independent, and therefore was capable of working wherever was needed. Even with the space constraints of working around the other crews, the duct journeymen were able to maintain work flow throughout the installation process. However, due to the slower progression of some of the other trades, the installation of the ductwork was not as high as it could have been. That said, in order to obtain that higher productivity rate, the other trades would have to essentially vacate the work area to allow the duct crews sufficient space to work. On an intricate project like this one, that's simply not a possibility. The duct journeymen did the best they could, and that in of itself is commendable.

When comparing the costs of the ductwork in the existing building to the numbers of the square foot estimate in Technical Report I, it can be seen that the numbers are actually lower than previously determined. The square foot estimate determined that the total HVAC cost for the existing building would be $1,823,979. However, the detailed estimate only came in at just under $400,000. This is interesting because ductwork costs are usually supposed to be approximately 60%, not 21%. What's even more interesting is that the square foot estimate came in at almost half what the building actually costs to build. The most likely cause of this is that there is no new equipment being installed in the existing building. All the new HVAC equipment is going into the penthouse in the central wing. It is hypothesized that upon analysis of the penthouse and central wing lab spaces, the costs will not only make up for the lower costs in the existing building, but also far surpass the square foot estimate's original numbers.

Finally, the logistics of the building and the site do not allow for much leeway in terms of alternative methods for installing the ductwork. As it is, utilizing small, distributed storage areas for the duct pieces seems to be the least impactful to the other trades. The HVAC subcontractor has done a good job of utilizing the space they have available as efficiently as possible. However, there are several alternative options for installing the ductwork that could help speed up production. One such option is to prefabricate larger duct sections to shorten the on-site installation time. It would also ensure higher quality standards for the ductwork, resulting in a much lower failure. This could save a lot of time and money that would otherwise be spend on fixing or replacing duct elements that failed during testing. However, prefabricating large duct sections presents a new set of challenges, mostly centered around trying to get the sections to the site and into the building. Larger sections are more susceptible to damage during transportation, so extra time would need to be spent on inspection upon arrival. Also, due to the small distance between the south façade's columns, there is no viable way to get the prefabricated sections into the building short of redesigning the façade. The other option would be to have accelerated the construction of the new stair towers to provide a better working platform for vertical shaft work. This would have been safer and quicker for installing the vertical duct risers, not to mention also saving money on the temporary stairs that wouldn't need to be on site as long as they were. However, it would have meant putting more resources, time and money into fabricating the stair towers that the project team did not have. Had these options been brought up during pre-construction and coordination meetings, then they could've potentially saved the project team time and money.

Appendix A: Superintendent and Foreman Interview

The following is a summary of the main points discussed in the interview with the Site Superintendent and the HVAC Foreman. The interview took place on Monday, October 12th, 2015. The system selected for a discussion on production and productivity was the HVAC ductwork. The people interviewed about this system were the Site Superintendent from Mascaro, Mike Schoeneman, and the HVAC Foreman from Farfield, Myron Hughes.

First of all, thank you for taking the time to conduct this interview. I would like to begin with the some of the general aspects of the HVAC ductwork installation process. To start, how were the schedule and the sequence of activities for the ductwork developed?

It primarily depends on the coordination process for all of the MEPF systems. In this case, the biggest piece of the MEPF work was the ductwork, so that naturally became the first to be installed. This became especially critical in the Mechanical Rooms, where the MEPF work had to be centered around the Heating and Cooling equipment. Farfield wasn't involved in planning the schedule and accepted what we had developed. That is until they actually started installation, which is when they started noticing conflicts and started bringing it to our attention.

For the actual sequence itself, it was primarily based on how demolition progressed inside the building. Demolition started on the first floor and moved up through to the fourth floor. However, at the time of the start of MEPF installation, the first floor was undergoing extensive under-slab work. It was also being used for general material storage due to the ease of access. Therefore, installation of the MEPF systems had to start on the second floor, move up to the third floor, move back down to the first floor, and finally finish up on the fourth floor and penthouse.

I noticed from observing the site that the duct pieces were set up in small, isolated piles rather than in one location? Why this choice for logistics?

Using many smaller piles of duct pallets is a lot less impactful on the other trades than one consolidated pile. When, the duct pallets arrive on side, they come in by the south entry where they are unloaded by a crane and "shaken out". Once everything checks out, they are hoisted by a lift and then sent to their respective floors. Once on the floor, they're distributed on a four-wheel cart to the general location of their installation. Both have their drawbacks when trying to work around, but we've found that the impacts are much fewer with smaller stacks.

So once the ducts are in place and ready to be installed, what are the means and methods used?

Even before the ducts can be installed, the hangers have to be put in place. The way Farfield performs this is by using a Total Station to lay out where are the hangers are to be placed on the floor, then translating those positions up to the ceiling. If they are being placed in an existing slab, we'll just hammer-drill the holes and install the hangers from there. However, for new slabs we use what's called a wood-knocker embedded anchor. Those get placed on the plywood forms, basically on the bottom of the concrete slab. Once the slab has cured and the plywood is removed, we've got our pre-made holes to hang the hangers from.

After the hangers are in place, we can start installing the duct. The way it's typically done, and has been done for who knows how long, is to use gasket tape between the pieces and then bolt the flanges together. When possible, we'll do that on the ground to create larger pieces before using the duct jack to get the duct into place. What we really have to be careful of is the insulated ductwork. Externally wrapped duct is usually placed on the supply side of the HVAC system, upstream from the FCU's and the VAV's. After those, you'll find that the duct is internally wrapped, which we have to be careful of when making the connections so as to not do any damage.

After most of the ductwork is in place, the major equipment can go in. This includes the FCU's VAV's, and AHU's. It should be noted that once the AHU's get installed, the large penthouse ducts and the large vertical shafts are installed to complete the major duct lines. Finally, after the ceiling grid goes in, the grilles, returns and diffusers can be installed. The flex duct connecting the GRD's to the main ducts also gets installed at this time. All told, we would have about four crews of two journeymen each working on that ductwork.

I'd like to move on to the constructability of the ductwork. In the beginning, what were some of the unique or challenging issues you guys had with building the system?

One of the big issues even before we started work was coordination and developing the design documents for the renovation. It was tough trying to get everything in while maintaining the architectural integrity of the original building. This was especially tough given that with the existing structure of the building, the space below the existing beams was really tight. Other than that, the only other real challenge was maintaining interrelations between the duct guys and the CM. After all, communication between the CM and all of the trades is important on any job, so keeping those lines open was very important to us.

So what were the solutions that the project developed to overcome these issues?

The biggest part was collaborative teamwork. We couldn't get anything done if we didn't communicate with each other. So that was the first thing that we had to establish. When performing BIM coordination, clash detection was a huge asset. It really helped with coordinating our work, especially with the other trades. And as for working with the existing structure, that was just working hard to find routes that could work on site. One of the key aspects for the duct runs was that they had to mostly be in the corridors for maintenance purposes. The OPP guys need to be able to make fixes without disturbing that other people that are regularly working in the building. Another aspect was basically making the ducts dip below low beams in the existing structure. That's all we needed to do.

Are there any improvements, regarding the means & methods, equipment or resources, that you would've liked to have done for this project?

Performing BIM coordination much earlier in the project would've helped out a little bit, but other than that there isn't much that needs improvement. Using prefab duct sections wasn't feasible due to the size constraints of the building's footprint, like getting them through the south facade columns for example. The means and methods are standard for the industry and have been refined over the years to the point where there is very little room for improvement. This is a straight-forward job, all things considered.

The last major topic I want to cover is improving the construction schedule. What are the biggest risks to the project schedule, especially regarding the completion date, that the ductwork installation process presents?

The ductwork has probably some of the longest lead times when it comes to manufacturing the system. The most critical pieces in terms of lead times are the AHU's and EAHU's. Thankfully, those came in early and were stored out by the stadium until we were ready to install them. Another risk that we've had to deal with is, again, coordination between the MEPF trades. If one crew slows down, then it is almost certain that the others will be affected, so keeping everyone coordinated is key to maintaining the project schedule. Other than those, the only other potential risk relating to the HVAC systems is its integration with the BAS Contols. However, that comes much later, well after the system itself has been installed and tested. While it does present risks to the overall schedule, it probably won't have much of an effect on duct production itself.

In what areas do you see potential to have accelerated the schedule for the duct installation?

Well, again, prefabrication of larger duct sections would have definitely helped speed up the installation process, but that was not feasible due to the constraints of the building footprint and the way the schedule played out. Take the south façade of the building, for example. If the columns had been spaced further apart, then larger prefabricated ductwork sections could have been fit through the façade. Another example would have been restructuring the schedule such that the stair towers were completed before the adjacent duct risers were installed. Had the stairs been done by then, then we would've had the space to support entirely prefabricated duct risers that could have been dropped down into place with a crane instead of being installed piece by piece.

Of course, it also always helps if the duct journeyman had more space with which they could layout and connect together larger duct sections. However, given how many trades are also working in the same space, like the plumbers or the electricians, we could only manage to install the smaller sections. Had the area been vacated by the other trades, then sure the larger sections would have been feasible, but that just wasn't going to happen.

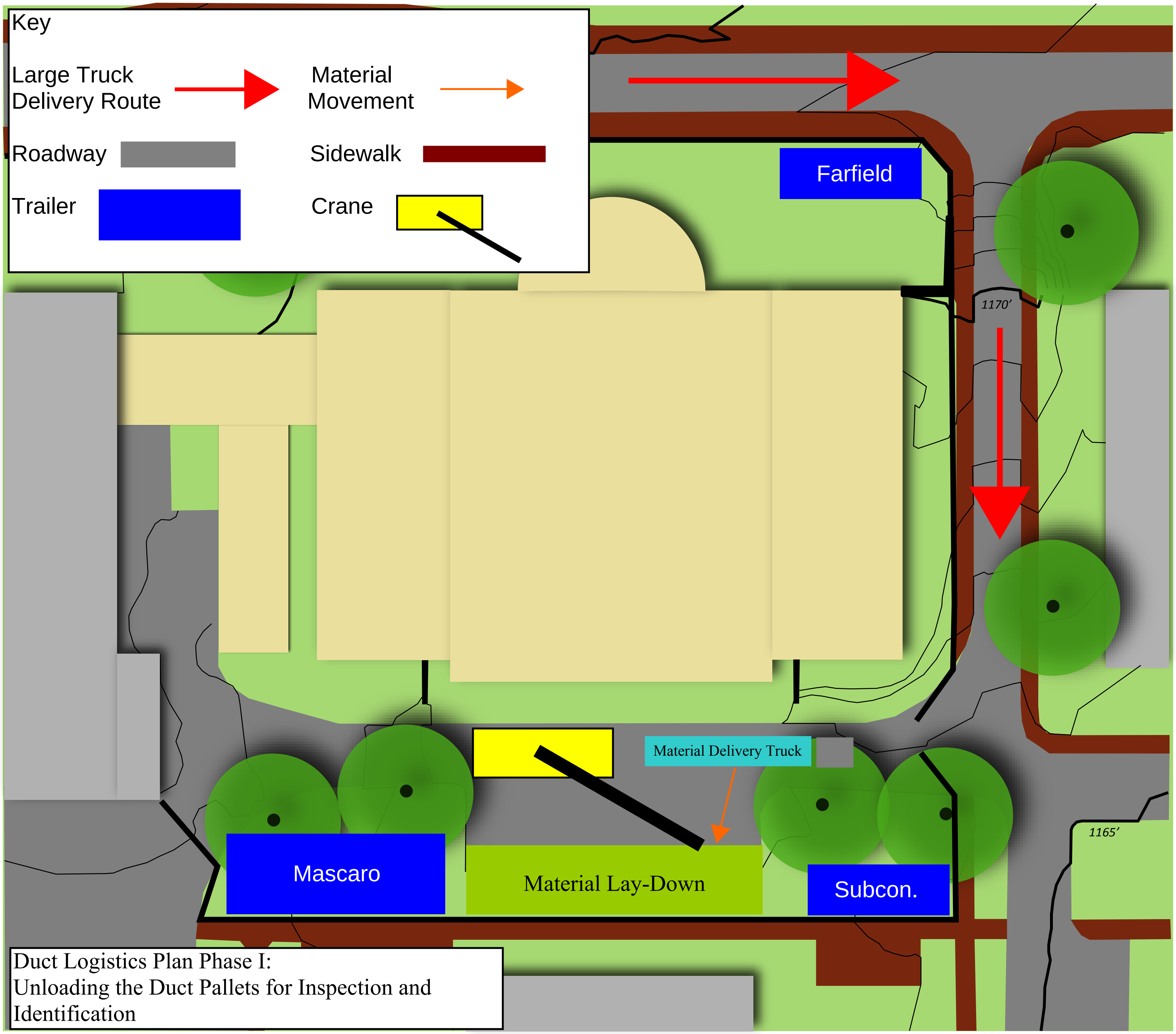
Are there any other requirements, like additional budgeting, resources or other techniques, which would facilitate these improvements?

Well, most of these improvements do not have any tangible costs – we would just have to focus on them during the coordination and pre-construction phases. In fact, most of these improvements would be identified when reviewing the project or visiting the site. All it takes is an "Ah-Ha Moment" during these phases, when you just think of something that would be better than what has been originally proposed. For example, if we were thinking about utilizing large prefabricated duct risers, then we could have asked for a redesign of the duct riser shafts to allow for this.

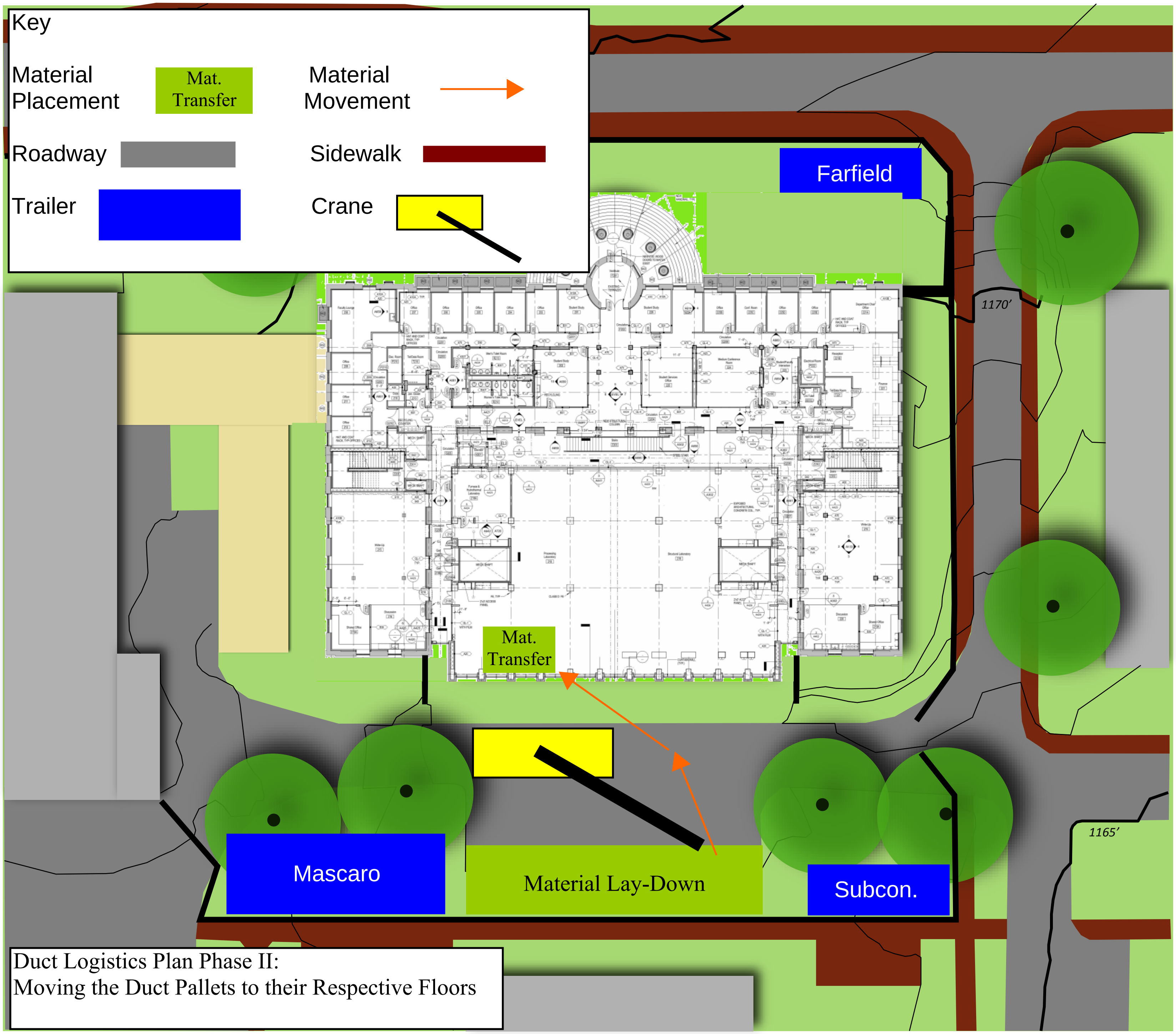
When looking at the schedule, we could have rearranged some of the schedule milestones to accommodate the duct installation. We could have accelerated the demolition in the existing building along with the fabrication and erection of the stair towers to focus on installing the duct risers. But again, we would need to have actually thought of that during preconstruction.

Well, thank you again for allowing me to interview both of you. I look forward to talking with you further about the project, and I wish you all the best of luck.

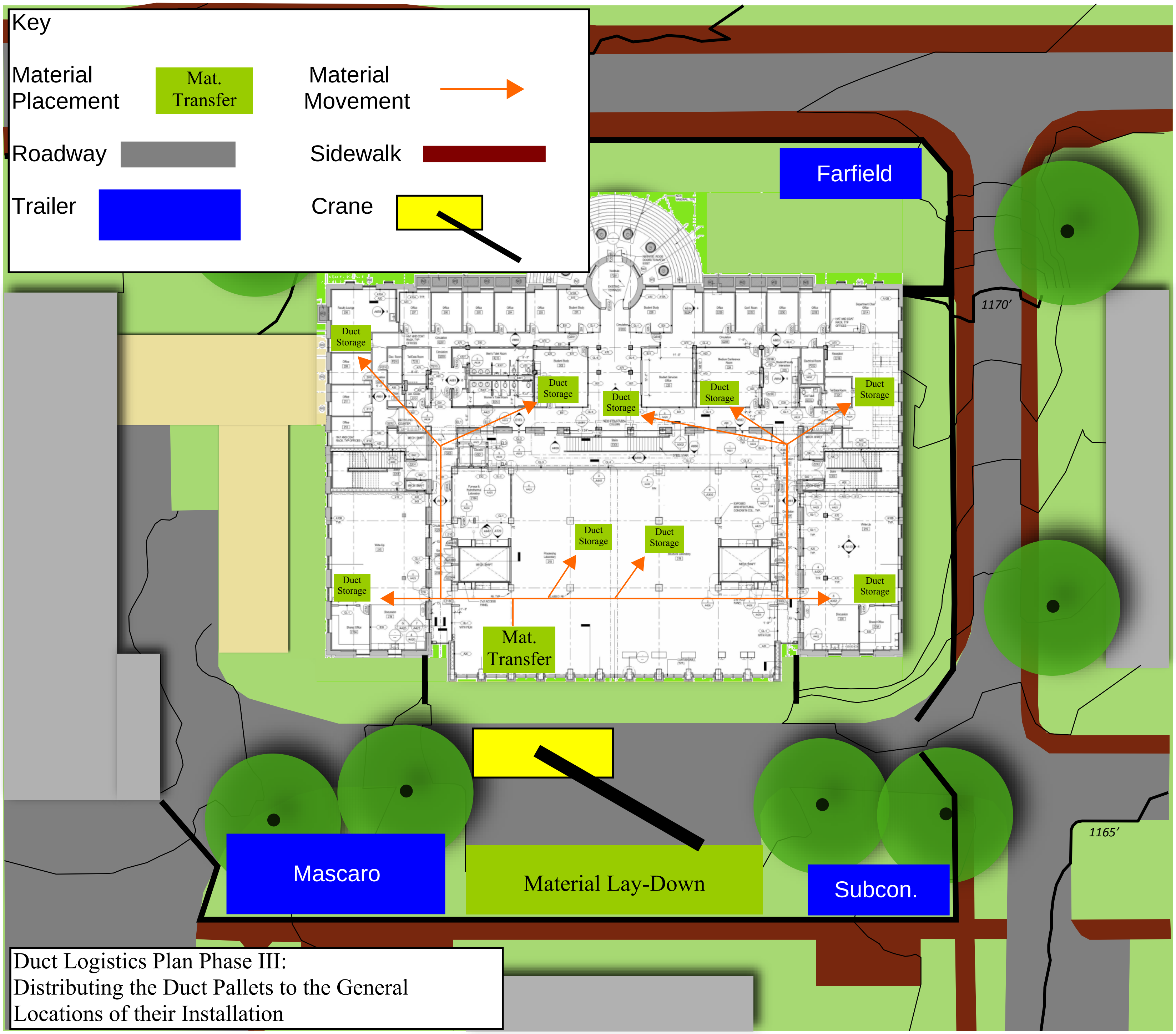
Appendix B: Site Logistic Plans



Duct Logistics Plan Phase I:
Unloading the Duct Pallets for Inspection and Identification



Duct Logistics Plan Phase II:
Moving the Duct Pallets to their Respective Floors



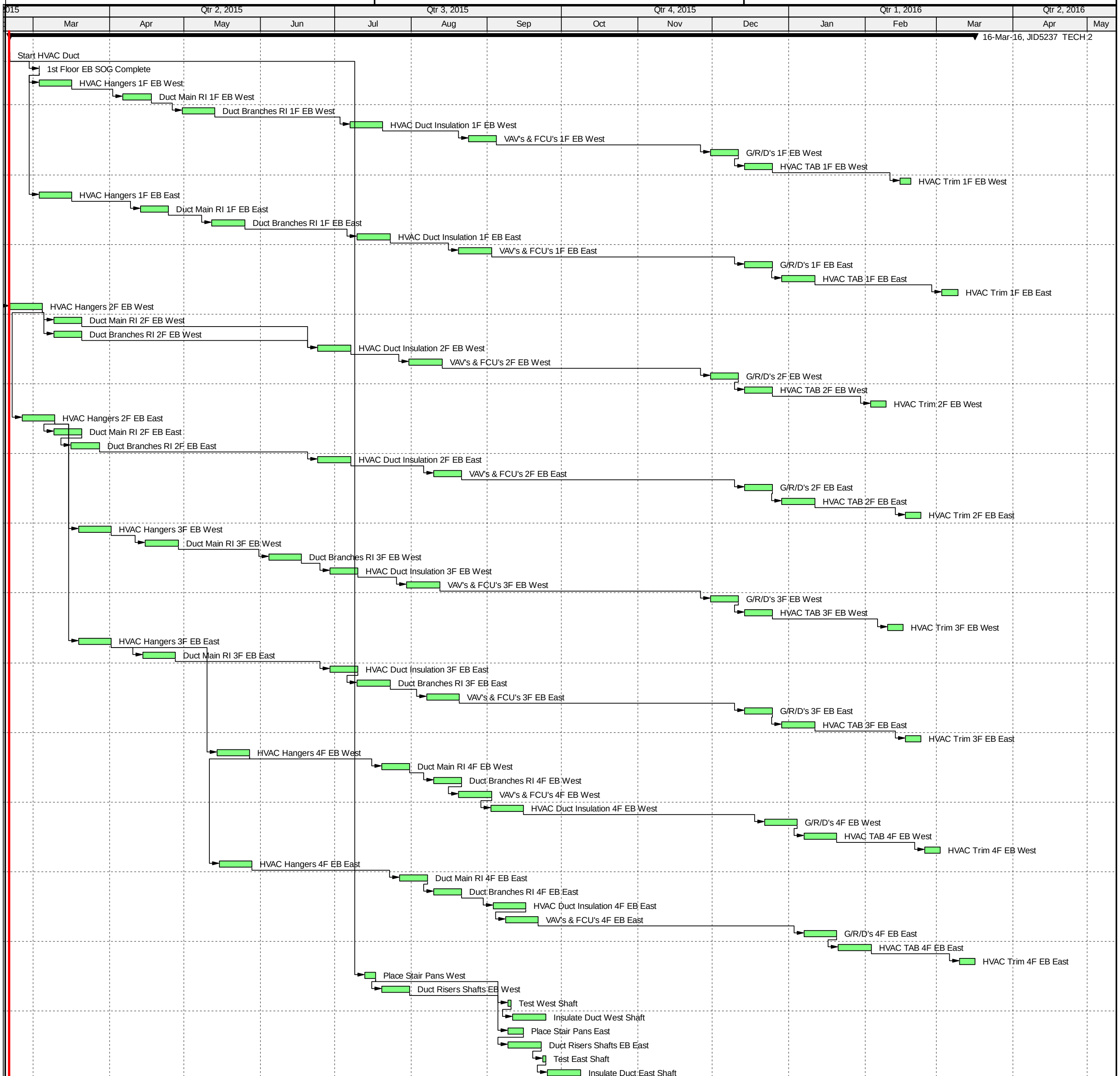
Duct Logistics Plan Phase III:
Distributing the Duct Pallets to the General
Locations of their Installation

Appendix C: Production Schedule for HVAC Duct Installation

TECH 2

Activity Schedule for Duct Installation

15-Oct-15 21:14



Actual Level of Effort
Actual Work
Remaining Work
Critical Remaining Work
Milestone

TASK filter: All Activities

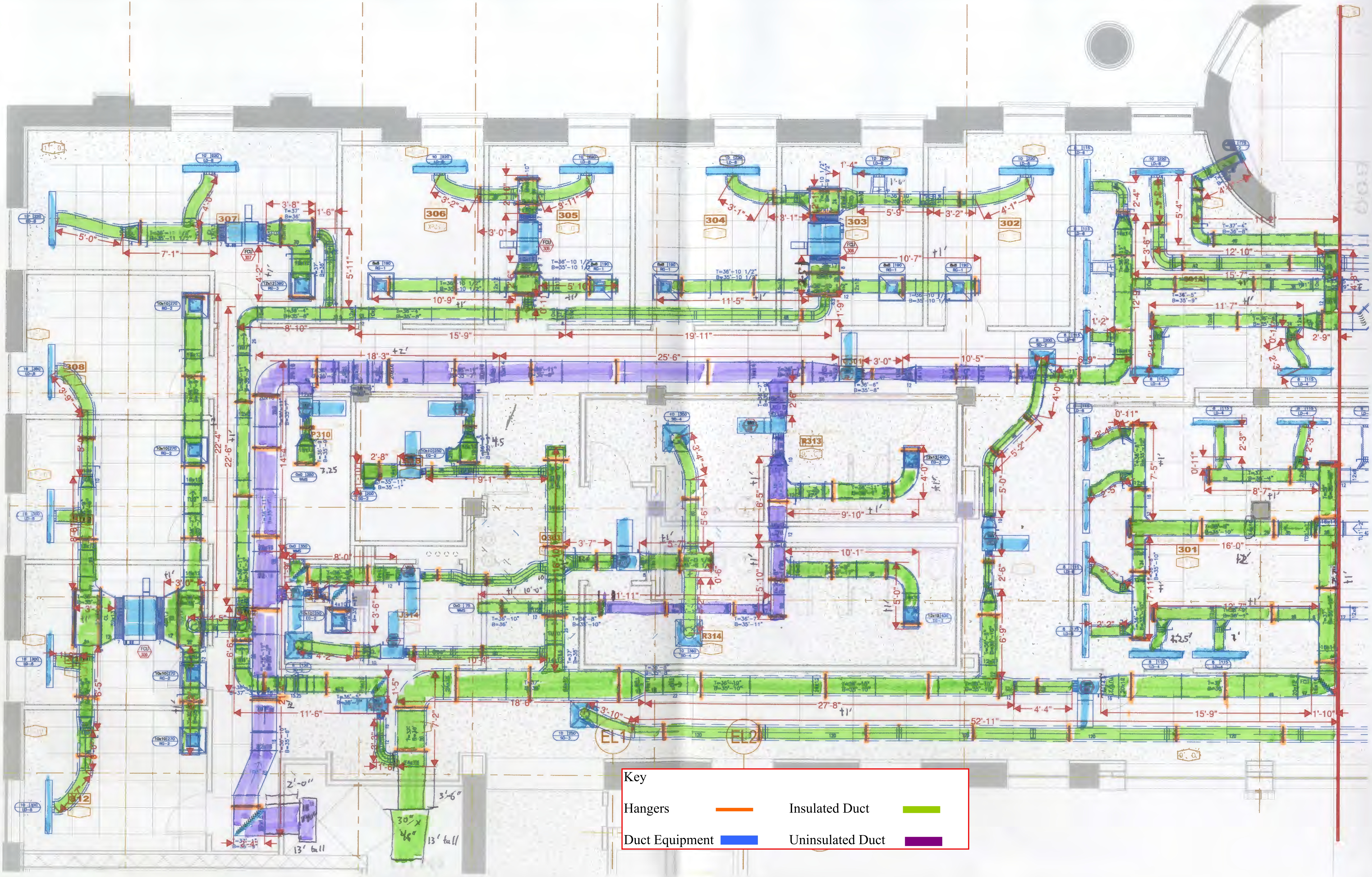
Activity ID	Activity Name	Original Duration	Remaining Duration	Start	Finish	Budgeted Labor Units
JID5237 TECH 2		280	280	19-Feb-15	16-Mar-16	10304
A0010	Start HVAC Duct	0	0	19-Feb-15	19-Feb-15	0
A0040	1st Floor EB SOG Complete	0	0	03-Mar-15	03-Mar-15	0
EB1110	HVAC Hangers 1F EB West	10	10	03-Mar-15	16-Mar-15	160
EB1120	Duct Main RI 1F EB West	10	10	06-Apr-15	17-Apr-15	160
EB1130	Duct Branches RI 1F EB West	10	10	30-Apr-15	13-May-15	160
EB1140	HVAC Duct Insulation 1F EB West	10	10	07-Jul-15	20-Jul-15	160
EB1150	VAV's & FCU's 1F EB West	10	10	24-Aug-15	04-Sep-15	160
EB1160	G/R/D's 1F EB West	10	10	30-Nov-15	11-Dec-15	160
EB1170	HVAC TAB 1F EB West	10	10	14-Dec-15	25-Dec-15	160
EB1180	HVAC Trim 1F EB West	5	5	15-Feb-16	19-Feb-16	80
EB1210	HVAC Hangers 1F EB East	10	10	03-Mar-15	16-Mar-15	160
EB1220	Duct Main RI 1F EB East	10	10	13-Apr-15	24-Apr-15	160
EB1230	Duct Branches RI 1F EB East	10	10	12-May-15	25-May-15	160
EB1240	HVAC Duct Insulation 1F EB East	10	10	10-Jul-15	23-Jul-15	160
EB1250	VAV's & FCU's 1F EB East	10	10	20-Aug-15	02-Sep-15	160
EB1260	G/R/D's 1F EB East	10	10	14-Dec-15	25-Dec-15	160
EB1270	HVAC TAB 1F EB East	10	10	29-Dec-15	11-Jan-16	160
EB1280	HVAC Trim 1F EB East	5	5	03-Mar-16	09-Mar-16	80
EB2110	HVAC Hangers 2F EB West	10	10	19-Feb-15	04-Mar-15	160
EB2120	Duct Main RI 2F EB West	10	10	09-Mar-15	20-Mar-15	160
EB2130	Duct Branches RI 2F EB West	10	10	09-Mar-15	20-Mar-15	160
EB2140	HVAC Duct Insulation 2F EB West	10	10	24-Jun-15	07-Jul-15	160
EB2150	VAV's & FCU's 2F EB West	10	10	31-Jul-15	13-Aug-15	160
EB2160	G/R/D's 2F EB West	10	10	30-Nov-15	11-Dec-15	160
EB2170	HVAC TAB 2F EB West	10	10	14-Dec-15	25-Dec-15	160
EB2180	HVAC Trim 2F EB West	5	5	03-Feb-16	09-Feb-16	80
EB2210	HVAC Hangers 2F EB East	10	10	24-Feb-15	09-Mar-15	160
EB2220	Duct Main RI 2F EB East	10	10	09-Mar-15	20-Mar-15	160
EB2230	Duct Branches RI 2F EB East	10	10	16-Mar-15	27-Mar-15	160
EB2240	HVAC Duct Insulation 2F EB East	10	10	24-Jun-15	07-Jul-15	160
EB2250	VAV's & FCU's 2F EB East	10	10	10-Aug-15	21-Aug-15	160
EB2260	G/R/D's 2F EB East	10	10	14-Dec-15	25-Dec-15	160
EB2270	HVAC TAB 2F EB East	10	10	29-Dec-15	11-Jan-16	160
EB2280	HVAC Trim 2F EB East	5	5	17-Feb-16	23-Feb-16	80
EB3110	HVAC Hangers 3F EB West	10	10	19-Mar-15	01-Apr-15	160
EB3120	Duct Main RI 3F EB West	10	10	15-Apr-15	28-Apr-15	160
EB3130	Duct Branches RI 3F EB West	10	10	04-Jun-15	17-Jun-15	160
EB3140	HVAC Duct Insulation 3F EB West	10	10	29-Jun-15	10-Jul-15	160
EB3150	VAV's & FCU's 3F EB West	10	10	30-Jul-15	12-Aug-15	160
EB3160	G/R/D's 3F EB West	10	10	30-Nov-15	11-Dec-15	160
EB3170	HVAC TAB 3F EB West	10	10	14-Dec-15	25-Dec-15	160
EB3180	HVAC Trim 3F EB West	5	5	10-Feb-16	16-Feb-16	80
EB3210	HVAC Hangers 3F EB East	10	10	19-Mar-15	01-Apr-15	160
EB3220	Duct Main RI 3F EB East	10	10	14-Apr-15	27-Apr-15	160
EB3230	HVAC Duct Insulation 3F EB East	10	10	29-Jun-15	10-Jul-15	160

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Remaining Duration	Start	Finish	Budgeted Labor Units
EB3240	Duct Branches RI 3F EB East	10	10	10-Jul-15	23-Jul-15	160
EB3250	VAV's & FCU's 3F EB East	10	10	07-Aug-15	20-Aug-15	160
EB3260	G/R/D's 3F EB East	10	10	14-Dec-15	25-Dec-15	160
EB3270	HVAC TAB 3F EB East	10	10	29-Dec-15	11-Jan-16	160
EB3280	HVAC Trim 3F EB East	5	5	17-Feb-16	23-Feb-16	80
EB4110	HVAC Hangers 4F EB West	10	10	14-May-15	27-May-15	160
EB4120	Duct Main RI 4F EB West	10	10	20-Jul-15	31-Jul-15	160
EB4130	Duct Branches RI 4F EB West	10	10	10-Aug-15	21-Aug-15	160
EB4135	VAV's & FCU's 4F EB West	10	10	20-Aug-15	02-Sep-15	160
EB4140	HVAC Duct Insulation 4F EB West	10	10	02-Sep-15	15-Sep-15	160
EB4150	G/R/D's 4F EB West	10	10	22-Dec-15	04-Jan-16	160
EB4170	HVAC TAB 4F EB West	10	10	07-Jan-16	20-Jan-16	160
EB4180	HVAC Trim 4F EB West	5	5	25-Feb-16	02-Mar-16	80
EB4210	HVAC Hangers 4F EB East	10	10	15-May-15	28-May-15	160
EB4220	Duct Main RI 4F EB East	10	10	27-Jul-15	07-Aug-15	160
EB4230	Duct Branches RI 4F EB East	10	10	10-Aug-15	21-Aug-15	160
EB4240	HVAC Duct Insulation 4F EB East	10	10	03-Sep-15	16-Sep-15	160
EB4250	VAV's & FCU's 4F EB East	10	10	08-Sep-15	21-Sep-15	160
EB4260	G/R/D's 4F EB East	10	10	07-Jan-16	20-Jan-16	160
EB4270	HVAC TAB 4F EB East	10	10	21-Jan-16	03-Feb-16	160
EB4280	HVAC Trim 4F EB East	5	5	10-Mar-16	16-Mar-16	80
V1005	Place Stair Pans West	5	5	13-Jul-15	17-Jul-15	0
V1015	Duct Risers Shafts EB West	10	10	20-Jul-15	31-Jul-15	160
V1035	Test West Shaft	2	2	09-Sep-15	10-Sep-15	32
V1045	Insulate Duct West Shaft	10	10	11-Sep-15	24-Sep-15	160
V1105	Place Stair Pans East	5	5	09-Sep-15	15-Sep-15	0
V1115	Duct Risers Shafts EB East	10	10	09-Sep-15	22-Sep-15	160
V1135	Test East Shaft	2	2	23-Sep-15	24-Sep-15	32
V1145	Insulate Duct East Shaft	10	10	25-Sep-15	08-Oct-15	160

Appendix D: Detailed System Estimate Summary

	Takeoff Quantity	Labor Cost/Unit	Labor Price	Labor Amount	Material Price	Material Amount	Equip Price	Equip Amount	Total Cost/Unit	Total Amount
15080.000 MECHANICAL INSULATION										
15080.305 Duct Insulation Exterior										
	42,368.00 sf	2.80 /sf	55.95 /mh	118,524	0.50 /sf	21,184	-	-	3.30 /sf	139,708
15800.000 AIR DISTRIBUTION										
15810.012 Ductwork - SS 304										
	5,200.00 sf	1.17 /sf	55.95 /mh	6,061	1.22 /lbs	9,579	-	-	3.01 /sf	15,640
	44,432.00 sf	1.12 /sf	55.95 /mh	49,719	1.22 /lbs	65,455	-	-	2.59 /sf	115,174
15811.018 Unistrut Stainless										
	1,536.00 ea	5.60 /ea	55.95 /mh	8,594	/ea		-	-	5.60 /ea	8,594
15820.020 Turning Vanes/Extractors										
	72.00 ea	22.38 /ea	55.95 /mh	1,611	8.40 /ea	605	-	-	30.78 /ea	2,216
15840.006 VAV Boxes by Schedule										
	104.00 ea	279.75 /ea	55.95 /mh	29,094	/ea		-	-	279.75 /ea	29,094
15840.016 Sg Box CVol Fan & Reheat										
	56.00 ea	223.80 /ea	55.95 /mh	12,533	622.00 /ea	34,832	-	-	845.80 /ea	47,365
15850.008 Diffusers Alum Linear										
	248.00 ea	12.92 /ea	55.95 /mh	3,205	30.30 /ea	7,514	-	-	43.22 /ea	10,720
15850.012 Diffusers Rectangle										
	72.00 ea	43.08 /ea	55.95 /mh	3,102	152.00 /ea	10,944	-	-	195.08 /ea	14,046
15850.022 Grilles Supply Rect Alum										
	16.00 ea	10.46 /ea	55.95 /mh	167	7.60 /ea	122	-	-	18.06 /ea	289
15850.028 Grilles Return Rect Alum										
	40.00 ea	13.04 /ea	55.95 /mh	521	8.30 /ea	332	-	-	21.34 /ea	853
	32.00 ea	13.04 /ea	55.95 /mh	417	10.40 /ea	333	-	-	23.44 /ea	750
	16.00 ea	14.27 /ea	55.95 /mh	228	12.50 /ea	200	-	-	26.77 /ea	428
	24.00 ea	19.58 /ea	55.95 /mh	470	25.90 /ea	622	-	-	45.48 /ea	1,092
15850.030 Grilles Eggcrate										
	16.00 ea	13.65 /ea	55.95 /mh	218	12.10 /ea	194	-	-	25.75 /ea	412
	16.00 ea	14.27 /ea	55.95 /mh	228	13.80 /ea	221	-	-	28.07 /ea	449
Grand Total										**$386,821**



307
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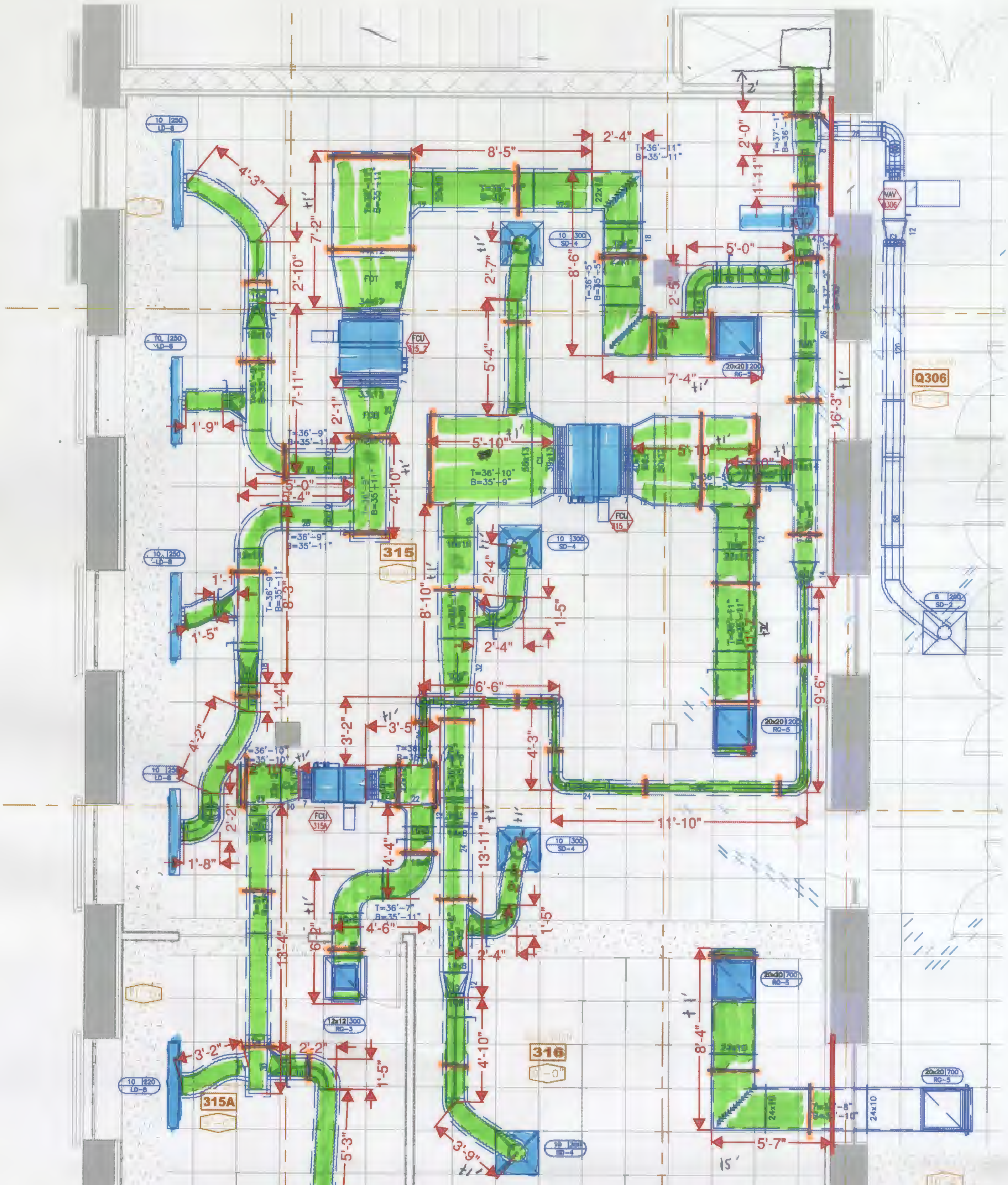
P310
R313
301
R314
EL1
EL2
Key
Hangers
Insulated Duct
Duct Equipment
Uninsulated Duct



Key

Hangers	(orange)	Insulated Duct	(green)
Duct Equipment	(blue)	Uninsulated Duct	(purple)

Appendix E: Source Citations

1. Steidle Building Rendering and Drawings provided by Mascaro Construction Co.
2. "Gauge and Weight Chart for Sheet Steel, Galvanized Steel, Stainless Steel and Aluminum." *Greenheck Fan Corporation.* September 1st, 2004. Online. Retrieved October 15th, 2015