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CITY CENTER PHASE 3A &3B

CONSTRUCTION MANUAL FOR MEP

AL HABTOOR-SPECON

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Document Control

What problem are we trying to solve ?

If you ever lost a document you will agree that there is always a need to keep control of important documents. The document control system has been designed to aid in the filing of documents and provide an easy way of retrieving this information. Some documents we keep because is required by law to keep them. Others we need them in order to control the flow of money in a Company. To summarize the system described in this chapter will help you file your documents better and enable you to retrieve these documents easier.

FIGURE 1: Clay plans of a six-room building, a sanctuary or a private house. From Telloh, ancient Girsu circa 2125, from http://en.wikipedia.org/wiki/Gudea_cylinders

What is document control ?

Document control means that the right persons have the current version of the documents they need, while unauthorized persons are prevented access to them.

We all handle many documents every day. These documents include forms that we fill out, instructions that we follow, invoices that we enter into the computer system, holiday schedules that we check for the next day off, rate sheet that we use to bill out customers, and many more.

An error on any of these documents could lead to problems. Using an outdated version could lead to problems. Not knowing if we have the latest version or not could lead to problems. And so on.

The Document control system affects our entire company, and all business related documents must be controlled. Only documents that don't have an impact on our products, services or company don't need to be controlled – all others need to be controlled. This means, basically, that any business related documents must be controlled.

Whose responsibility ?

FIGURE 2: Diorite statue od the earliest known document Controller. Mesopotamia circa 2150 BC.

Document control is the responsibility of all employees. It is important that all employees understand the purpose of document control and the tools (requirements) that help us control our documents.

Please be aware that if you copy a document or print one out and then distribute it, you are responsible for controlling the distribution ! The original author won't know that you distributed more of his documents, so the original author can't control that distribution. That

is why on critical job sites all copies, faxing and distribution is via our DCC (Document Control Center)

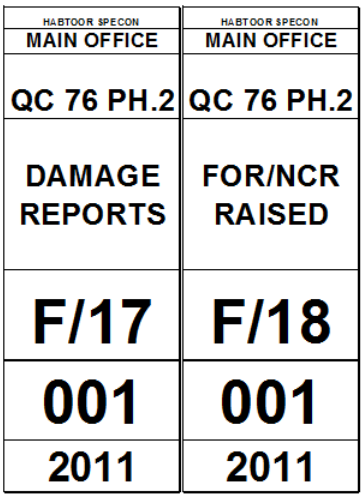


FIGURE 3: Calorifier plant-room in Merweb.

Project Filing

Project filing, follows closely to the system set up at Head Office. You can think of Document Control a bit like the post office where communication is always between one office to another. In many respects filing on sites is more difficult and challenging due to its temporary nature and the changing number of employees as the Project moves through the different phases.

Files are labeled with letters and numbers :

> FILE REF. NO. A/1
> Outgoing Correspondence.

When files overflow we number them consequentially as follows :

> FILE REF. NO. A/1-001
> Outgoing Correspondence.
> FILE REF. NO. A/1-002
> Outgoing Correspondence.

The file references are initially chosen to represent a comprehensive Master File list. An extract from such a Master List is in Table1.

TABLE 1: Extract from filing list

File	Category	Control Copy location	Person resp.	Copy 1	Person resp.	Copy 2 resp.	Person resp.	Copy 3	Person resp.
A/1	Corresp (in).	H.O. Sec.	H.O. Secr.	Site	PM				
A/2	Corresp.(out)	H.O. Sec.	H.O. Secr.	Site	PM				
A/3	memos (in)	H.O. Sec.	H.O. Secr.	Site	PM				
A/4	memos (out)	H.O. Sec.	H.O. Secr.	Site	PM				

What is important to notice in the Table above, that in many cases the filing system allows for up to three copies to be kept, but there is always a two tier system where there is a *control copy*, normally kept at head office and one or two copies kept at other locations. If the site is far from head office or for cases where there is no need to keep copies at Head Office the Document Control Department always keeps the master copy.

It is also important to note that documents have *owners*. In the extract shown in Table1. The owner is the responsible person to make sure that the documents have been filed properly. In most cases this person in the Project Document Controller, but for example for orders the Materials Control Manager is the ultimate responsible person to ensure that MCD documents are filed properly.

Document Order

In general document are filed by *date order*. Numbered documents such as submittals, Quality Assurance Documents and the

like bear that bear *reference numbers* are filed *sequentially*. Accounting documents such as creditors invoices are filed by *date* in the master file and a second copy by *Creditors name*. By choosing carefully the method of filing and normally by having two different methods enables retrieval of the document easier. In general if the system is computerized retrieval becomes easier.

Setting up the system

The filing system should be set at the begining of a new Project. Although this sounds simple and intuitive most Projects start without adequate space, building shelving as we go and continuously buying files. On a well designed system *all* file categories are set up when the Project starts, they are labelled uniformly. As a rule of thumb the minimum space is that of a 20 foot container - and this assuming that files with multiple volumes are archived at certain points. If you do not give it attention at the beginning of the Project you will literally drawn in paper work nobody will be able to find anything and everyone will build their own system as they will not have any *faith* in yours!

The equation below, can be used to estimate the number of files that will be required for a project :

$$N = \frac{p^{0.8}(t+d)}{d}$$

where,
N = number of files
p = mean personnel on project
t = duration of project (months)
d = number of departments

When to file

Generally if people responsible for filing do not clear their intrays daily it leads to problems with retrieval. What happens as they have a continuous backlog the bottom of the tray never gets cleared and after a week or two documents cannot be found (so we get another copy from whoever sent it to us) which leads to another problem that eventually when we find the document we now have two identical copies in the file and stamped with two different incoming date stamps.

Getting the right equipment

During the two critical *crunch periods* of the Project, which are normally the start and end of the Project you will find that documents and document copying and processing is at its peak. During this time of the project unless the Site and its partner Companies have a decent photocopier the flow of documents will slow down

tremendously. It is not unknown for documents to take 11 days to be delivered from the Consultant's desk (via their own document control) to that of the Main contractors's and then to us. For comparison in 1890 a letter would travel at the cost of 1 penny with the Imperial Penny Post from London to Cape Town by steam ship in less than 20 days and taht was door to door delivery. In general a decent photocopier should be purchased based on expected volumes of copying which should never be less than 20000 copies per month (to keep up with peaks). This should be able to interface with a computer and the network and if you are going to charge subcontractors departments or Clients it should have a keypad for logging usage. When the latter is not used, it is also not unknown for people to introduce manual systems of approval and logging of copies usage introducing another cost to the Company and further contributing to bureacratic bloat, inefficiency and delays.

Key performance indicators

Document Control should be able to produce all necessary log forms weekly by close of business every Thursday or at a date agreed with the Project Director. Normally these are :

Material Submittal logs
RFI logs
WIR logs

TABLE 2: Weekly logs produced by Document Control

Document Control should be able to retrieve a document within a maximum of 30 minutes and deliver a copy (right ? you don't want the original copies to leave Document Control - so you do need a good and fast photocopier). The best performance indicator is for the Document Control Department is to keep it *customers* happy.

Dating documents

Require us to show on every document when it was created or last updated. Many of us thought about using the automatic date field for this but.... Should we use the automatic date field on documents ?

Generally not, if you enter the automatic date field into a document, the field will automatically be updated to always show the current date, no matter when you actually created or updated the document.

Another example :

Another example is entering the automatic date field in the footer of a document that you frequently change and then print. You may have used the automatic date field as an easy way to see on your printouts when they were printed ; the idea here was that the document with the latest date is the most current printout. However, you may make one printout today and another tomorrow without hav-

ing made any changes to the document. Though both printouts are identical, they now show different dates. This will inevitably lead to confusion.

Document control requires us to show on any document when it was created or last updated. The automatic date field is not suitable for this. Therefore, as a general rule, don't use the automatic date field to identify version status.

Forms

Yes, a form must be controlled as long as the form has an impact on our services or our company.

Blank forms are similar to instructions as they guide the user to provide certain information. If the form is outdated or incomplete, the user will not be prompted to supply all the necessary information. It is, therefore, important to control blank forms like any other document.

Once a form is filled out, however, it has become a record. At this point, we need to be concerned with filing, storage, archiving, and eventually destruction. All forms and documents are specified in the Company ISO Manual.

Policies and procedures

While most procedure affect only managers, all employee must be familiar with the *Quality Policy* and with the *Document Control Procedure*.

Document Control Organization

The Document control department is actually a Main Department and sattelites. Sattelite sections will exist in other Departments. In general it should be organized as follows :

```
- Document Control (Central Department)
-- Administration /HR (visa related, personnel passports, drivers, petrol control)
-- Correspondence (secretary)
-- QA/QC
-- QS
-- Procurement
-- Design (very limited)
-- CAD Office
-- Accounts
-- Stores (own copies of delivery notes, returns issues etc).
-- Safety department
```

The particular contributions of these departments are laid out in their respective Business process sections. The Document Control department is normally staffed with 3-4 people. The Document

Controller, one or two assistants and a person dedicated to photocopying.

Computerized Systems

Computerized systems do not eliminate the need for paper filing but can reduce it. They can also assist in retrieval and distribution. Unless your manual system is working well, computerization is next to impossible.

Archiving and disposal of documents

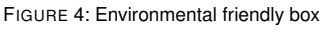


FIGURE 4: Environmental friendly box

At the end of the Project most of the items will require to be disposed or archived. Having now contributed considerably to the destruction of the environment by using all this paper and possibly finished a monstrosity on a pristine location, this can be done by buying environmentally friendly boxes made for the purpose. Documents to be disposed should be shredded if possible. If the system has been followed and monitored, this should be a simple operation as all the filing will already be in boxes and what it means is that only the last files will be boxed. Label the boxes accordingly and state the date that the contents can be disposed off.

Summary

This short document described some of the issues relating to the control of Company documents. As a last word do some kaizen. [1]

o

1. http://en.wikipedia.org/wiki/Kaizen.

Materials Control Department

The Materials Control Department on a Project is the responsible department that ensures that materials are purchased at the *least possible price, they meet the Project quality standards and that they are delivered on time*.

Materials Planning

This is the most difficult phase of teh procurement cycle and if not planned properly the MCD department will be in *panic mode* until the end of the Project. At the beginning of the Project a Materials Control Sheet is created listing all the material requirements of the Project by categories. Categories are normally split in such a way that a category is materials purchased from a single vendor.

At the beginning of the Project at the discretion of the Area Manager and the Project Director, the Engineering Office as well as all the Engineers and perhaps the CAD Office will contribute to material take-offs. The Engineering Office will also handle enquiries and discussions with Suppliers for items where a strong technical input is required. Here is a short list, however what is important is to generate such lists comprehensively at the beginning of the Project. It is the responsibility of the MCD Manager to monitor progress and to produce weekly reports.

It is noteworthy, that all the equipment listed above need to have static calculations in order for orders to be finalized. This is not always possible to be carried out at the beginning of the Project and is best to agree with the Supplier cut-off dates for the supply of this information. In general if you adhere to the following process things are easier[2] :

1. Send out enquiries early based on Tender documents.
2. Narrow down the price with one Supplier.
3. Work with the Supplier to obtain selections and submittals.

Although it is important not to lose time and long-lead items need to be ordered as early as possible it is also very important to act quickly and get approvals and orders out for first fix materials.

Table 7 if handled properly and quickly they enable operations to start on Site. There is no benefit in focusing first on pipes and fittings, if the above will not have an approval and there is no stock on site

2. With software these calculations are not difficult to produce, if the Tender drawings are reasonably well co-ordinated.

TABLE 3: Mechanical long lead items

Item	Responsibility	Technical submittal	Remarks	
1	AHUs	Engineering Office	Engineering Office	take-offs by Section Engineers
2	fcus	Engineering Office	Engineering Office	take-offs by Section Engineers
3	Chillers	Engineering Office	Engineering Office	take-offs by Section Engineers
4	Pumps	Engineering Office	Engineering Office	take-offs by Section Engineers
5	Package Units	Engineering Office	Engineering Office	take-offs by Section Engineers
6	Fans	Engineering Office	Engineering Office	take-offs by Section Engineers
7	ECUs	Engineering Office	Engineering Office	take-offs by Section Engineers

TABLE 4: Mechanical first fix items

Item	Responsibility	Technical submittal	Remarks	
8	anchors	Engineering Office	Engineering Office	take-offs by Section Engineers
9	threaded rods	Engineering Office	Engineering Office	take-offs by Section Engineers
10	supports	Engineering Office	Engineering Office	take-offs by Section Engineers
11	unistrut	Engineering Office	Engineering Office	take-offs by Section Engineers
12	insulation inserts	Engineering Office	Engineering Office	take-offs by Section Engineers
13	conduit systems	Engineering Office	Engineering Office	take-offs by Section Engineers

to start the works. These materials should be closed in the first 3-4 weeks of the Project.

TABLE 5: Mechanical first fix items (second tier)

Item	Responsibility	Technical submittal	Remarks	
14	drainage pipes	Engineering Office	Engineering Office	take-offs by Section Engineers
15	chilled water pipes	Engineering Office	Engineering Office	take-offs by Section Engineers
16	fire protection pipes	Engineering Office	Engineering Office	take-offs by Section Engineers
17	H&C water piping	MCD	MCD/EO	BOQ Section Engineers
18	Cable trays	MCD	MCD/EO	BOQ Section Engineers
19	Cable ladders	MCD	MCD/EO	BOQ Section Engineers
20	ductwork	MCD	MCD/EO	BOQ Section Engineers

Second and Third Fix Materials

Depending on the Project and its requirements second and third fix materials are tackled next. The list below is not comprehensive, but should mre or less be prioritized as shown. Keep in mind what you need to complete the installation and what is affecting follow-up trades such as the Main Contractor cosing walls or ceilings.

TABLE 6: Drainage materials

Item	Responsibility	Technical submittal	Remarks	
21	drainage specialties	Engineering Office	Engineering Office	take-offs by Section Engineers
22	interceptors	Engineering Office	Engineering Office	take-offs by Section Engineers
23	manhole covers	Engineering Office	Engineering Office	take-offs by Section Engineers
24	paddle-flanges	Engineering Office	Engineering Office	take-offs by Section Engineers
25	special sleeves	Engineering Office	Engineering Office	take-offs by Section Engineers

As for the drainage materials, focus is being maintained as to what is needed next. For HVAC is making sure that what is required in terms of ductwork and piping.

TABLE 7: HVAC material lists

Item	Responsibility	Technical submittal	Remarks	
	Ducted systems			
26	Fire Dampers	Engineering Office	Engineering Office	take-offs by Section Engineers
27	Volume Dampers	Engineering Office	Engineering Office	take-offs by Section Engineers
28	Motorized Dampers	Engineering Office	Engineering Office	take-offs by Section Engineers
29	Access Doors	Engineering Office	Engineering Office	take-offs by Section Engineers
30	Sound attenuators	Engineering Office	Engineering Office	take-offs by Section Engineers
31	Flexible ducts	Engineering Office	Engineering Office	take-offs by Section Engineers
32	Flexible connectors	Engineering Office	Engineering Office	take-offs by Section Engineers
33	Grilles & Diffusers	Engineering Office	Engineering Office	take-offs by Section Engineers
34	Louvres	Engineering Office	Engineering Office	take-offs by Section Engineers
35	Sand-trap louvres	Engineering Office	Engineering Office	take-offs by Section Engineers
	Piping Systems			
36	Valves	EO	EO	EO/CAD
37	Flanges			
38	Gaskets			
39	Bolts			
40	Insulation			
41	Insulation accessories			
42	Chemical treatment			
43	Pressurization units			
44	Expansion vessels			
45	De-aerators			
	BMS & Controls			
46	BMS General			
47	BMS Graphics			
48	BMS Cables			

If everything has been co-ordinated properly, orders are placed on agreed staged deliveries or to draw as per Site requirements. When you place orders full at the beginning of the Project you save considerable trouble, you manage less documents, less submittals etc. In general on most jobs, there will be about 150-160 categories of materials. On a target to close between 2-3 categories daily in the first 90 days of the project you will need 3-4 people to process, plus of course the full site Team should be contributing to this. It is the responsibility of the Project Manager to arrange a meeting where *names* are put next to each material to ensure action and responsibilities are clear cut and the materials are processed as fast as possible.

Stock control for consumables

Two bin systems are common on assembly and moving manufacturing lines where components are added to the product or item being built. The two bin system is just like its name suggests, it is composed of two bins which are full of components or materials to start. As production commences one bin is drawn down of materials and the other bin, which is still full, acts as the buffer or safety stock.

When the first bin is completely depleted the worker or assembly line worker switches to the other bin, similar to a FIFO system. The switch of bins can be interpreted as a kanban signal for the supply process of that particular component to manufacture or supply the component just in time before the second bin runs out of material. The kanban signal can also be generated half way throughout the first bin, depending on lead times for the component to be supplied.

This system in a way is similar to the EOQ inventory model with safety stock. It is a very common system used in vehicle manufacturing plants. The size or number of components in each bin is usually determined using the EOQ inventory model or a time period model.

Planning

Planning the works needs no introduction, but the reality is that most Engineers do very little planning of their works whereas many others understand that planning is something done at the beginning of a Project using Primavera and the rest is just following the direction of the Project as it goes.

There are many elements of planning and before we get onto that we will analyse them in details. In many respects planning is like waterpainting, you start sketiching to see what you want to achieve and then you detail it as you go along.

FIGURE 5: Roman soldiers building a fortress, Trajan's Column 113 AD

Planning is both the organizational process of creating and maintaining a *plan*; and the psychological process of thinking about the activities required to create a desired goal.

Determining the right sequence of works

Before any plan is drawn some understanding of the sequence of works is necessary. Activities can be divided into sequential or parallel. A sequential activity is one that you cannot start unless a previous activity has been completed. If the activity of having procured the materials is not completed, then the works cannot be started.

How do I start

The first thing you need to do before you start is to identify the *goal*. In many cases this is not that difficult, but you will find out that the goal as stated is too theoretical and you need to cut it down to smaller objectives.

We will discuss techniques by means of focusing on examples which are smaller. In my opinion this is where most people fail to plan properly and let events overtake them. We will assume that shop drawings are available and that materials are also available and that we will use a Team of Duct erectors.

Measure your target

Unless you measure something, you cannot control it. If you know that you have to install 600 m^2 of ductwork, you may be in a better

position to estimate the time it takes to install it (provided that you have some background information).

When you first start with the plan, a visual representation of the areas and work you will be working on can be invaluable. For example a layout of the area with some coloring can help you identify better to visualize the problem. At this point if the area is available, you should visit the area and get a feeling of the problems that you may encounter. Once you have a good idea of what you want to achieve, you need to translate it into something more definable. For ductwork we would normally divide the work as shown in 9. For most MEP activities is almost a rule that unless you put a Team to start by installing supports, it is almost certain that manhours will be lost later on. By starting supports early you ensure that the chargehand who is marking the support locations is scouting the area and ensuring that there are no impediments. In very rare occassions that this is not necessary, such as ductwork in plantrooms.

The Tower can be represented by a series of squares, which denote an activity. Green is done and white is not done. There is no need to use intermediate colors. they just detract from the visual information.

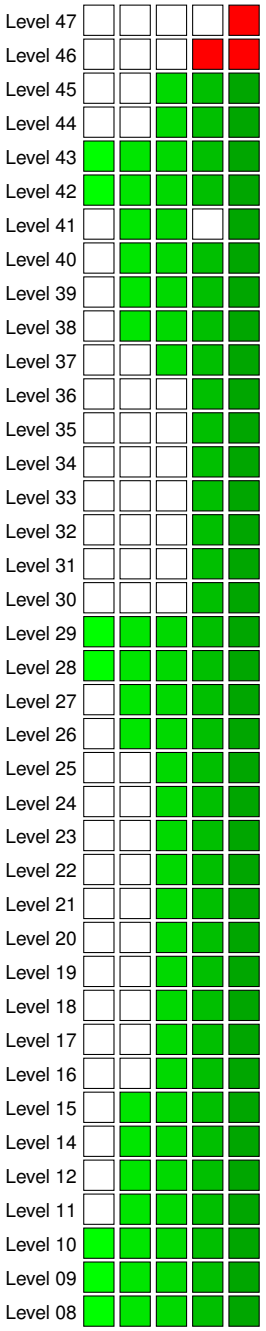
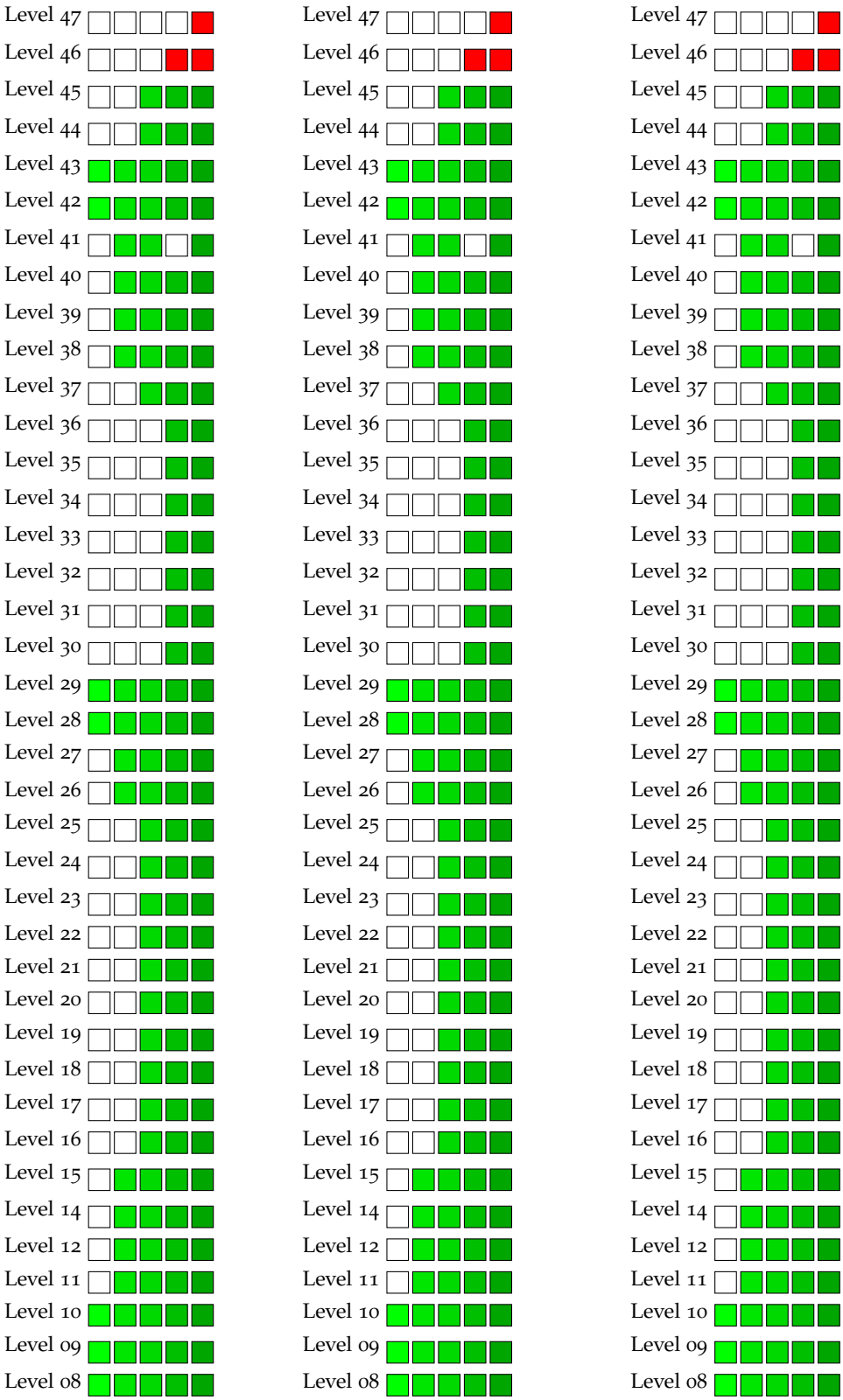


FIGURE 6: Rotana Tower Progress, each square represents one separate activity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Level 08

TABLE 8: Example of 6 week look-ahead program for installation of ductwork.

item	Description	Qty	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
1	supports	400	100	100	100	100			
2	ductwork (insulated)	1200	200	200	200	200	200	200	
3	ductwork (uninsulated)	600							
4	vol. dampers								
5	fire dampers								
6	flexibles								
7	WIR								

TABLE 9: Example of 6 week look-ahead program for installation of ductwork.

item	Description	qty	unit	manhours	f_1	f_2	f_3	f_4	Total
1	supports	400	each						
2	ductwork (insulated)	1200	m^2						
3	ductwork (uninsulated)	600	m^2						
4	vol. dampers	80	each						
5	fire dampers	20	each						
6	flexibles	60	each						
7	WIR	5	each						

The factors f_1, f_2, f_3, f_4 are a series of factors that ca be used to adjust your estimate based on your observations of the rate of the works and the actual conditions that the work is taking place.

f_1 = congestion factor.

f_2 = weather factor.

f_3 = team expertise.

f_4 = overtime work.

Of importance is to note that your budget for overtime works will increase the total manhours that are required to complete the works, as overtime work in general reduces efficiency of personnel.

The above costs are estimated to be on the low side. Published tables are frequently used to quantify loss of productivity for scheduled overtime [18,19,20,21], overmanning [22,23,24], congestion of trades [23], remobilization [22], and weather [25,26,27].

In this Project the Contractor accelerated completion activities in many areas in order to follow the program. Loss of productivity occurred as a result of overtime due to a number of reasons : fatigue ; demotivation ; absenteeism ; reduction of workpace and congestion, see Figure 8 ; The factors most commonly cited in the literature are those prepared by the Construction Users' Anti-Inflation Roundatable [3], shown in Figure 7. These impacts have not be taken into account in the above calculations, as the Contractor was aware that overtime, however, inefficient had to be introduced to complete the works by the agreed date. However, not all these costs belong to the Contractor as the Contractor attempted to coomplete Engineer's Instructions and other changes as quick as possible.

The major cause of schedule disruptions and delays all related to lack of information and change orders. Essentially, all causes beyond the Contractor's control

3. Construction Users' Anti-Inflation Roundtable, ''Overtime in Construction'', AACE Bulletin, Vol. 15, No. 5, October 1973.

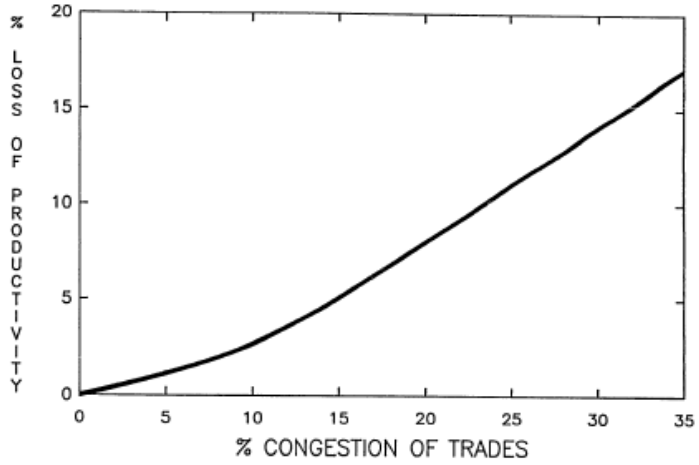


FIGURE 7: Impact of overtime on productivity

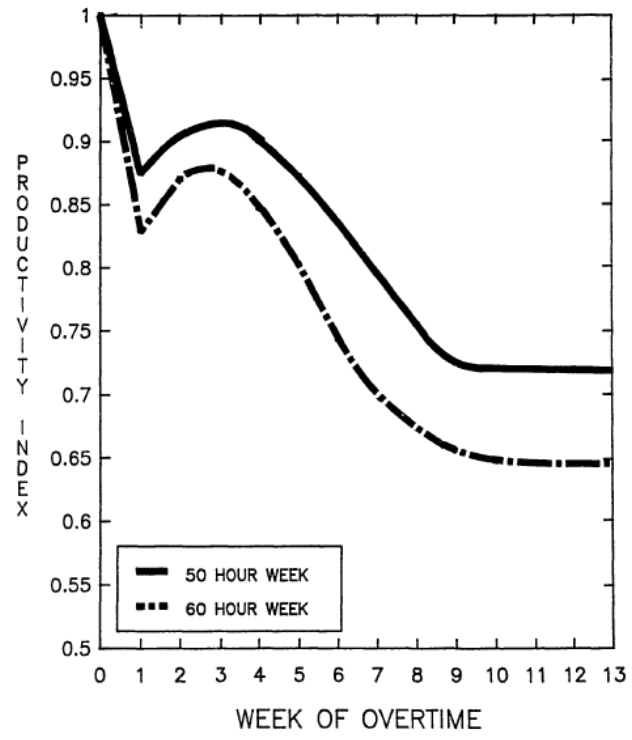


FIGURE 8: Impact of overtime on productivity

0.0.1 Resourcing

The first step that we discussed so far is how to analyze an activity and produce a rough estimate of the man-hours required to complete the works. In the second Table we have added some factors that can assist to determine productivity ; when they are applied they will either increase or decrease the estimate.

Once this step has been completed, we need to allocate the necessary resources to the activity, that is alloacte technicians that are going to carry out the installation.

My suggestion : when you need to structure a big project, don't impose a *preferred team* size on people just because it is written in a book. Try to allow self-organization to do its job and let the people (within their real environment) figure out what their optimum is. Do they want to cut a team of seven into two teams of three and four ? Sure, why not ? Are they merging two teams into one big team of fifteen ? Fine, let them see if that works. And be aware that they might want to reconsider things when the environment (or the set of personalities in the team) changes again.

In general though use what it works, but allocate the teams.

A charge-hand can handle up to a 'tent-group' well which should be 5-9 people. We will call these groups, by letters

Ducting Group A
Ducting Group B
Ducting Group C
Ducting Group D
Ducting Group E

The ideal size of a group

The two-pizza principle can be used to determine an ideal group size. Simply stated is that you should be able to feed this group with two-pizzas. [4] For ductwork the suggestion is to use 12 people per charge-hand. The rationale behind this is that this is the maximum size group that a charge-hand can handle well. It divides into 3 smaller groups of four, which makes installation of heavier ductwork easier. During third fix activities, it can be split into six pairs for installation of diffusers.

4. Jeff Bezos, has been quoted at http://www.fastcompany.com/magazine/85/bezos_4.html.

Some rule of thumbs to allow for ductwork installation that is fully inclusive of all grilles, diffusers and the like is that you can get a productivity of approximately 1 m^2 per worker. So if you had a full Team able to install ductwork for 12 months, out of a 24 month Project to install 100,000 m^2 of ductwork you will need.

$$n = \frac{100000}{260 \times 12 \times f_1 \times f_2 \times f_3}$$

If the productivity factors were set to 1 it would require 32 men. Of course the above is ideal, where one assumes that the workers are working the full day in ductwork installation, there are are no delays that reduce the productivity. However, keep this in mind. The

other issue is factors relating to the learning curve and also the fact that work does not always lend it self to a constant production rate. For smaller ductwork productivity really drops to about less than half of the above ideal. This also excludes manufacturing of special pieces tha that necessary, connection of equipment and the like. Those should rather be measured as individual pieces.

Subdividing the work

We briefly touched, while discussing productivity factors on the subject of the *learning curve*. The concept of the learning curve was introduced to the aircraft industry in 1936 when T. P. Wright published an article in the February 1936 Journal of the Aeronautical Science. Wright described a basic theory for obtaining cost estimates based on repetitive production of airplane assemblies. Since then, learning curves (also known as progress functions) have been applied to all types of work from simple tasks to complex jobs like manufacturing a Space Shuttle.

The theory of learning is simple. It is recognized that repetition of the same operation results in less time or effort expended on that operation. For the Wright learning curve, the underlying hypothesis is that the direct labor man-hours necessary to complete a unit of production will decrease by a constant percentage each time the production quantity is doubled. If the rate of improvement is 20% between doubled quantities, then the learning percent would be 80% (100-20=80). While the learning curve emphasizes time, it can be easily extended to cost as well.

This simple and now widely accepted principle should be leveraged in your production planning. For example on high-rise buildings, one should plan the work vertically, for example one group doing the same activity as they are going up the Tower See the 10.

Although, technicians are trained in what they do, the fact that just by moving around in different areas of the building in unfamiliar surroundings keeps on affecting productivity. So the rule is to try and plan the works in such a way that you get the benefit of productivity improvements by using repetitive tasks.

The Gant Chart

So far we have discussed a number of visual tools and tabular methods to help assess and plan the works. These are important tools for day to day work and for work spanning up to six weeks of planning. However, tempting to extend them to longer periods these will tend to fail as the amount of complexity you adding prohibits people from understanding them well. In addition if the plan needs revisions they take took long to modify that one will lose any benefit from such updates.

A Gantt chart is a type of bar chart that illustrates a project schedule. Gantt charts illustrate the start and finish dates of the terminal

TABLE 10: Merweb Ceiling and Wall Closure Plan

Merweb Ceiling and Wall Closure					
Level	Corridor	Pass. lift lobby	Serv. lift lobby	Rooms	Dry walls
Lvl 43					
Lvl 41					
Lvl 40	done	done	done	done	done
Lvl 39	done	done	done	done	done
Lvl 38	done	done	done	done	done
Lvl 37	done	done	done	done	done
Lvl 36	done	done	done	done	done
Lvl 35	done	done	done	done	done
Lvl 34	done	done	done	done	done
Lvl 33	done	done	done	done	done
Lvl 32	done	done	done	done	done
Lvl 31	done	done	done	done	done
Lvl 30	done	done	done	done	done
Lvl 29	done	done	done	done	done
Lvl 28	done	27 Jul	27 Jul	27 Jul	done
Lvl 27	29 Jul	29 Jul	29 Jul	29 Jul	done
Lvl 26	2 Aug	2 Aug	2 Aug	2 Aug	done
Lvl 25	4 Aug	4 Aug	4 Aug	4 Aug	done
Lvl 24	7 Aug	7 Aug	7 Aug	7 Aug	done
Lvl 23	9 Aug	9 Aug	9 Aug	9 Aug	24 Jul
Lvl 22	11 Aug	11 Aug	11 Aug	11 Aug	26 Jul
Lvl 21	14 Aug	14 Aug	14 Aug	14 Aug	28 Jul
Lvl 20	16 Aug	16 Aug	16 Aug	16 Aug	30 Jul
Lvl 19	18 Aug	18 Aug	18 Aug	18 Aug	1 Aug
Lvl 18	21 Aug	21 Aug	21 Aug	21 Aug	3 Aug
Lvl 17	23 Aug	23 Aug	23 Aug	23 Aug	5 Aug
Lvl 16	25 Aug	25 Aug	25 Aug	25 Aug	7 Aug
Lvl 15	27 Aug	27 Aug	27 Aug	27 Aug	9 Aug
Lvl 14	30 Aug	30 Aug	30 Aug	30 Aug	11 Aug
Lvl 13	1 Sep	1 Sep	1 Sep	1 Sep	13 Aug
Lvl 12	4 Sep	4 Sep	4 Sep	4 Sep	15 Aug
Lvl 11	6 Sep	6 Sep	6 Sep	6 Sep	17 Aug
Lvl 10	8 Sep	8 Sep	8 Sep	8 Sep	19 Aug
Lvl 09	10 Sep	10 Sep	11 Sep	11 Sep	21 Aug
Lvl 08	12 Sep	12 Sep	13 Sep	13 Sep	23 Aug
Lvl 07	15 Sep	15 Sep	15 Sep	15 Sep	25 Aug

elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of the project. Some Gantt charts also show the dependency (i.e., precedence network) relationships between activities. Gantt charts can be used to show current schedule status using percent-complete shadings and a vertical "TODAY" line as shown here.

Although now regarded as a common charting technique, Gantt charts were considered revolutionary when they were introduced[citation needed]. In recognition of Henry Gantt's contributions, the Henry Laurence Gantt Medal is awarded for distinguished achievement in management and in community service.

FIGURE 9: Henry Laurence Gantt, A.B., M.E. (1861 - 23 November 1919) was an American mechanical engineer and management consultant who is most famous for developing the Gantt chart in the 1910s. These Gantt charts were employed on major infrastructure projects including the Hoover Dam and Interstate highway system and continue to be an important tool in project management.

These charts who are produced using Primavera by the Planning Department is virtually our only tool that communicates the MEP sequence of works to the rest of the Construction Team. None of the other methods that we have discussed handles this intercommunication. During construction though experienced Construction Managers would normally revert to simpler tabular or visual methods.

A simple gantt chart (more of a bar chart) can be used to define longer period activities, that can establish targets. This does not show interdependencies of activities and for which a more complicated version should be prepared by the Project Planner. It is important also to bear in mind that if the works are delayed for reasons other than owr own (i.e., for example by late information or by changes) unless there is a good document illustrating these delays it is extremely difficult to justify the delays.

Responsibilities

Planning spans across all lines of management. Table indicates the type of plans required and who is responsible to produce them.

item	Description	Prepare	Check	Approve
1	Project Plan	Planner	PMs	Pro. Director
2	6-week look aheads	Section eng.	PM	–
3	Graphical monitoring plans	Section Eng.	PM	–
4	Drawings Planning	CAD Manager	DM	PD
5	Materials Planning	MCD Manager	PM	PD
6	Mobilization/demobilization	Planner	HR	PD
7	Documentation Plan	Planner	DM	PD
8	Claims	Comm.Manager		PD

Delays

Delays and changes to planning are inevitable. As you will recall one of the main purpose for developing plans in the first place is to be able to estimate and predict the impact of events on the end date of the Project. It is the responsibility of the Engineer in charge and the Project Manager to identify these delays and appropriate action be taken to mitigate them, either by requesting more resources

to accelerate the works - once the constraints are removed - or by requesting for an extension of time.

Engineering

In our line of work *design* is both ill-defined as well as generally poorly misunderstood and applied. On mos Projects the Owner would have appointed a Consultant who will produce a design and give it out to tender. In most instances this is incomplete and supplemented with every conceivable type of clause in a specification to limit claims by the Contractor. On other type of Contracts we might have design responsibility for the full works. These are called design-build contracts. In either case a substantial amount of engineering needs to be developed to complete the design, procure the materials, install the works and putting the plant into operation.

The Engineering Department

On Projects that are not design-build an Engineering Department is set-up with an Engineering Manager. He is normally assisted with Design Engineers. In addition he is the ultimate responsible person for overseeing the works of the CAD Office.

0.1 Design Audit

At the start of the Project a quick design audit is undertaken to review the current design by the Engineer and to identify areas of concerns, missing information and opportunities for savings in costs. This should be summarized in a report with full details. The same document can then progressively be modified to record all changes and calculations as works progress.

Selection of equipment

Equipment selections and submittals fall within the work that the Engineering Department undertakes. As these works might take time to implement the Project Director at the early stages of a Project allocate responsibilities to Senior Engineers to assist. Some equipment might need calculations before they are ordered as for example fans, pumps, cables, electrical boards and similar items.

Drawings

The production of drawings should be done in the *fastest* way possible. This is important for two reasons :

1. As at the beginning of the Project, information might be missing, this is the best time to record delays, before any *concurrent delays* occur. In many instances the Project Managers or Engineer might issue an information schedule, i.e, a time table listing all the missing information and when this will be issued. Unless this is covered with the Clause (14) programme, one should only accept with the reservation that the Contractot has a right to claim for late information. The Commercial Manager for certain would need to respond. Although late information for sanitary fixings might not delay the Project it may delay the drawings and the opening required to accommodate floor mounted units and similar items. If the Engineer has issued a set of IFC drawings no further delays without claims would be acceptable.
2. If works start late on site due to late issue of Shop Drawings or unavailabilty of materials due to late issue of information we would need to add tradesment to accelerate the works and keep up with the programme. It is always easier to add one CAD Operator than to add 100 tradesmen and more cost effective, given the inefficiencies of disruption and crowded work faces.

How big a team

Although, this will depend on the quality of the original design, the number of services involved, the nature of the Project and if the Building has areas where the design is repetitive a good formula to use is the following :

$$n = \sum_{n=1}^{n=k} \frac{f_1}{100} \times C + \frac{f_2}{100} \times C + \cdots + \frac{f_k}{100} \times C_k \qquad (1)$$

The mimimum size Team should never be less than 16 on Projects that are greater than QR 200 million.

Co-ordination

Possibly more than 70% of all issues that cause work to stop or to move inefficiently can be attributed to poor co-ordination. Although the original designers bear responsibility for primary co-ordination, we bear responsibility for co-ordinating the services and for raising the alarm when there are problems with primary co-ordination.

Co-ordination sequence

At the start of a Project co-ordination needs to follow a sequence of works and although one will need to go through a number of it-

erations before the drawings can be finalized the following sequence will work in most typical cases :

1. If the ceiling voids have large beams, consider locating the fire mains within the void provided by the beams to conserve space. Fire mains can easily be sleeved through and is a good solution, especially in car parks.
2. Drainage pipes should be located hard against the nearest beam and sloped as required, consider changing direction if necessary to have drainage pipes run shorter routes.
3. It is normal where there is drainage pipes to have cold and hot water. Following a similar route for these pipes would ease co-ordination.
4. Cable trays should be similarly zoned in parallel with walls. Preferably no other services should run under or over cable trays to enable clearances for pulling cables.
5. Ductwork is a special case and if possible should be run at the lowest level with flexibles on the side of the ducts.

Co-ordination in shafts

1. Shaft co-ordination should start early and if possible the first type of co-ordination to take place. This is important as any crossover of services would seriously reduce ceiling void heights.
2. Always consider providing a platform in shafts. Although this might marginally add to costs, it can speed-up construction tremendously and enable easy hoisting of piping through the shafts.
3. For typical plumbing shafts on high rise buildings and or hotels and apartments consider making an early mock-up - not necessarily in situ - to optimize the installation and work out small details such as expansion.
4. Allow adequate space behind ducts and pipes for access to install insulation. This is a normally overlooked aspect.

Co-ordinators

Each CAD operator has responsibilty to check his work in terms of completeness and co-ordination.

Common pitfalls

1. One service obstructing another, such as a BMS control box installed too near a fan-coil unit, so that it cannot be opened. This is also common with MCC boards being too big and cannot be accomodated in Plantrooms.
2. Condensate drains on mechanical equipment that have been - missed on drainage drawings. This can be avoided by showing condensate drains and fan-coil units on a separate layer and importing this layer on both the VAC drawings as well as the drainage

drawings. Similarly for any equipment requiring power supplies etc.

3. Not allowing an adequate clearance both under or over sectional water tanks. This is also a common error by Consultants.
4. Very low plinths for AHUs with high static pressures. This can also happen when plinths are designed from structural drawings and then waterproofing is about 50 mm high ending up with plinths that are only 50 mm high.
5. Not allowing properly for the curvature of cables when entering switchboards or for panels to be ordered bottom entry but the cables are top entry. This is a result of poor scheduling and detailing.

Professional Drawings

One can pin-point what makes a professional drawing when he sees one, but it is very difficult to lay down the parameters that make such a drawing professional. These are some parameters :

1. All information required to execute the works is shown on the drawings.
2. Standard drawings are specific for the Project and are meaningful.
3. Schedules.
4. Cross referencing.
5. Good choice of pens and styles.
6. The drawing has *dimensions*.
7. The drawings include sections and larger scale details.
8. The drawing is printed at the right scale.

Site Works

> In most people's vocabularies, design means veneer. It's interior decorating. It's the fabric of the curtains and the sofa. But to me, nothing could be further from the meaning of design. Design is the fundamental soul of a man-made creation that ends up expressing itself in successive outer layers of the product or service.
>
> Steve Jobs

Siteworks encompass the actual construction. Everything we do is immaterial unless the works on site can be executed.

Responsibilities

Any works on site fall under the responsibility of the relevant Section Engineers. The Project Manager will manage his section [5] of the works but ultimately the owner of a section of the works is the Project or Site Engineer.

5. A section of the works is not necessarily defined by area, but it can also be defined by service for example drainage works will normally fall onto one or two section Engineers, whereas another one might be responsible for a Tower.

Resource Scheduling

The Section Engineer is responsible to plan, monitor the execution of the works and produce daily and weekly reports as required.

Workflow

All Section Engineers and as a matter of fact everyone working on the Project must be familiar with the standards required of the Project by having read the specification and by having studied the drawings of his section.

On having been allocated a section of the works the Section Engineer needs to complete the following activities :

1. *Review Shop Drawings* One needs to take into consideration that Shop drawings might not contain the full information required to carry out the works. The Section Engineer must review the drawings carefully, assist if necessary with comments that will enable further details to be added and that co-ordination is possible, ceiling heights achievable and shafts workable.
2. Keep a set of drawings for red-marking.

3. Create a Materials Plan.
4. Prepare Material Take-offs.
5. Issue Site Order Releases.
6. Liaise with Main Contractor for Civil works.

In many instances due to Projects peaking at different times, it is quite likely that an Engineer will be allocated to a Project during a period that the works are under pressure. This should not really matter, but then it is still the Section Engineer's responsibility to make sure that the above steps are followed. If he is replacing someone that has left the Project then if there is a handover report one can verify that the information is correct.

Site Diary

All Section Engineer's should keep a Site Diary in which to record the day to day activities of the works. The Site Diary can be invaluable if claims are lodged and eventually there is arbitration. The minimum information that must be logged is :

Area and type of works : start date/end date.

Personnel allocation.

Problems encountered.

Key events related to milestones.

In general keep as much information as possible to enable someone - with your assistance to recreate the events during the construction period.

FIGURE 10: Abandoned and dirty materials, make for a very unprofessional work place.

Workface Housekeeping

There is nothing more wasteful than materials and waste lying all over the place. The section Engineer must set daily procedures and responsibilities to ensure that all workfaces are clean, even if this entails cleaning some of the Main Contractor's rubble that was left behind, when they arrived and made opening that we *forgot* to tell them about. By keeping the area clean you ensure that not only it is safe to work but waste is eliminated and productivity improves. Have an adequate supply of clear plastic bags for the disposal of rubbish (use clear bags to minimize pilferage).

Protecting the works

You should ensure that the works are always protected. All piping and ducting should be wrapped in polyethylene when completed and all open ends closed to minimize the amount of debri and dust that can get in. This ensures that during commissioning less time is spent in cleaning the system.

Damage Reports

However, hard you try at a point you will reach a stage at which some damages would occur. These are reported properly using a Damages Report format, which is issued via the Commercial Department as a claim. Be certain that at the end of the Project you will face the same from other parties. A damaged works log is to be kept by the QA/QC Department, as well as Document Control.

Quality

Although quality assurance and quality control are handled in a dedicated chapter we have to mention it here. The Section Engineer is resposnible for the quality of the works in his area. It takes the same effort to complete the works with the right quality as substandard work. In general the following strategy works well in raising the bar on quality :

1. Never accept substandard work
2. Prepare a prototype for all works that you are starting for the first time. This will ensure that all stake-holders and technicians understand the quality of works required.
3. Offer constructive advise to technicians and supervisors during your Site Walks for work that just does not look right.
4. Snag the works before you offer them for inspection.
5. Attend the inspections (if not all of them) at least the ones that are offered for the first time or that have failed and are offered again for inspection.
6. Do not offer works for inspection unless you have checked and can verify that all materials used are as per approved submittals and the installation is as per approved drawings. Essentially you must make sure that the materials are correct and the installation is as per the contract, which in most cases is as per specification and drawings. Investigate any deviations and take remedial action if necessary.

FIGURE 11: Create an environment of openess and co-operation. Quality and targets are only achieved via a spirit co-operation and Team Work.

Quality perception

Most inspections are *visual* and hence perception psychology plays an important part. A well lit and *clean* area with a Team on standby that looks professional, with you having done your homework so that you can answer any question that the inspector asks will go a long way to a trouble free inspections. With over 30,000 inspections budgeted on larger Projects, if you do not take care of inspections they are bound to cause delays.

Other visual items that you will need to take care of is paintwork, supports, slopes of piping and insulation.

FIGURE 12: Painted and cleaned piping works and ensuring that nearby pipes run at the same level increase the perception of quality and makes work look professional.

Low quality

If you find that quality is consistently below an acceptable level, make sure that you arrange for training for the concerned technicians and or have a prep talk with everyone. Discuss it with your senior Supervisor and decide what to do.

Ensure everything will work

While the daily pressures of work force Engineers to focus on their own section of works, keep an eye and an enquiry mind to make sure everything works. You are the last safety net of both the professional as well as the Contracting Team to pick up and problems that have not been seen earlier. Ask yourself, will it work, what happens when something is switched on, can we drain this section of the works, does it need another valve and so on. You also need to think about being able to access works for maintenance and also for balancing. So if you have an access door on a duct taht you cannot open because there is a sprinkler pipe running across it, you need to take care of it. In general, in this part of the world, it will cost more to add temporary flushing loops and drains, so ensure that these have been marked on drawings or take action to request that they are shown on drawings.

Quality Assurance and Quality Control

Quality cannot be accurately defined, but you know it when you see it. On a Site Quality is the responsibility of everyone and it generally means that you need to give attention to details.

The steps to quality

There are a number of steps that you need to take in order for your work to be considered quality work and they are really simple.

1. Define what you need to do and how to do it. Although the definition part is simple, it needs to meet the specification, in reality in most cases the specification may be vague. You define the product by making a prototype and by ensuring that it is correct from all angles.
2. Add repeatabiliy
3. Cleanliness
4. Presentation

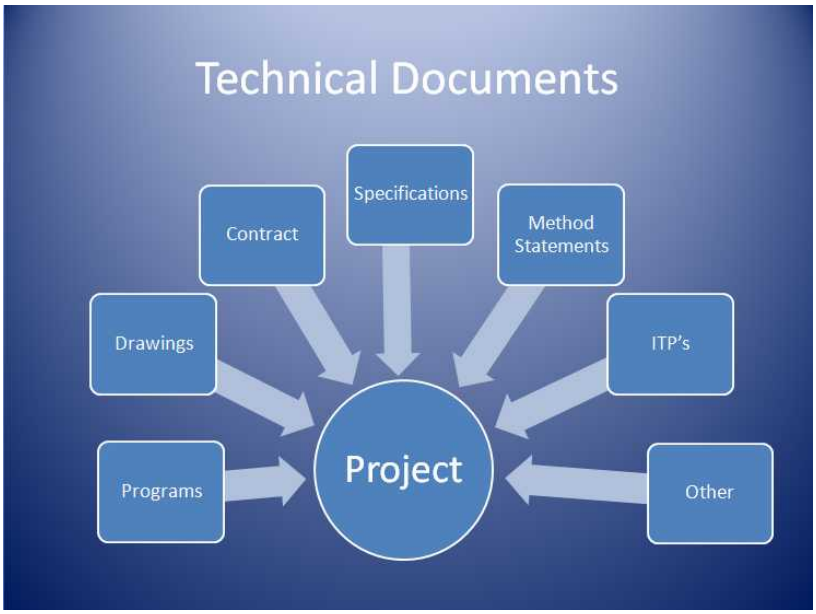
The paperwork

There is a lot of paperwork involved with QA/QC Departments, as a matter of fact perhaps not enough paperwork on a MEP Site as compared to say a manufacturing plant.

Communication

As a rule the medium of communication for Engineers is *drawings*. Engineering is a highly complex field, is information dense and difficult to transmit ideas non-visually. You can have a specification which is six pages long for an example a cooling tower. On a Drawing a simple drawing can describe all that information in a more concise and clear way.

Many other items can be described in traditional documents use in construction :



What materials are we going to Supply ? This is communicated through technical submittals.

How are we going to install them and test them ? This is communicate through ITP's and Method Statements.

When are we going to carry out the work ? This is communicated through a Programme of Works.

Who is doing What ? This is normally through our organization charts ?

Many a better head than this writers have found ways to manage projects along these documents. Although sometimes when misused can cause undue delays, the absence of them can lead to a disastrous Project.

Engineers are not good communicators in general, they work long

hours and under pressure making communication more difficult. Try and put as much information on a drawing as possible. Remember they used to be called plans.

In general we try to commuicate with documents. By utilizing documents rather than verbally communicating requests, actions and the like, documents can flow better. In general use the phone, if you can achieve what you want with the phone-call (such as obtaing the status for something). If the action you request from the person who is next on line will only be completed after a few days commuicate in writing.

Follow-ups

A message flows better between two people rather than a number of persons. In designing our processes we have kept that in mind. As a rule of thumb if you need to follow-up on a particular action, you need to do it with the person you have send the document to. As an example you have send a request for a purchase. It is no good phoning the Area Manager iff he had approved it or the Financial Department if he has issued the check. You need to follow with the Department head to whom you have addressed the documents. (He might have just finished a meeting with the Financial Manager and a direct call to Accounts, in a way will relieve the MCD Department of his responsibility to expedite)!

External communications

Our philosophy is to strive and be professional with our interactions with other Companies. In general we will take a non-confrontational attitude that is pro-active and logical. This does not mean however that we will not stand for our rights.

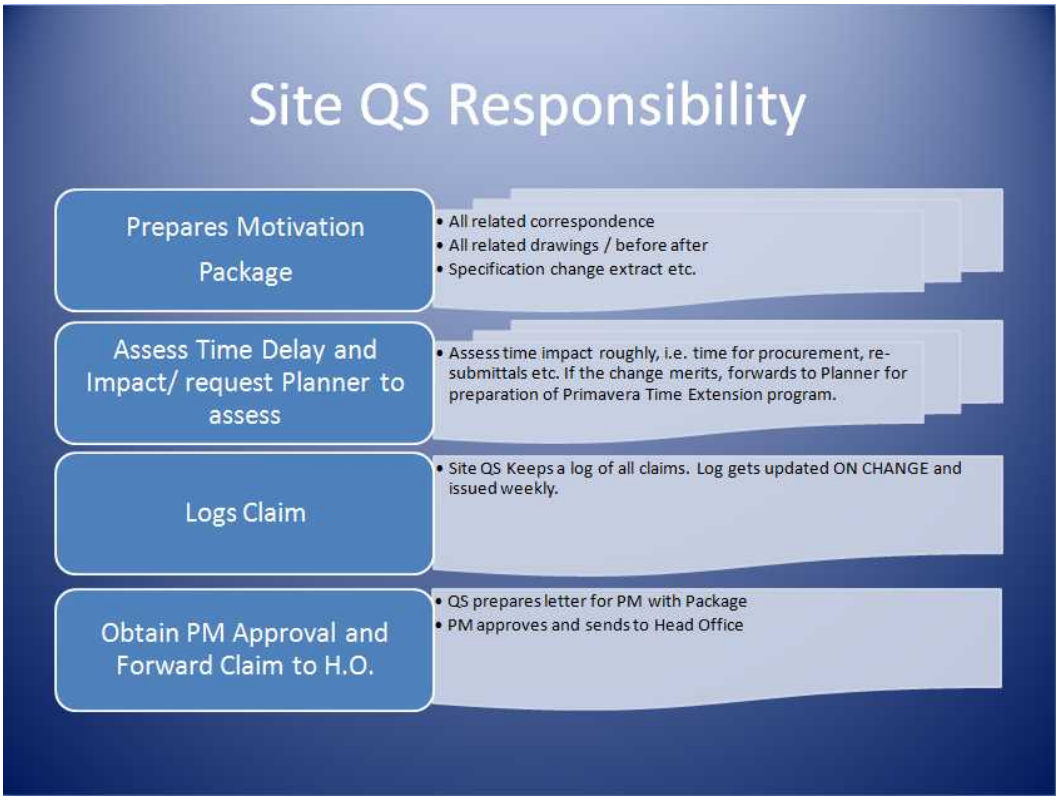
Documentation

All documentation with external Companies should be in writing. Either being our own suppiers and sub-contractors or the Client and other members of the professional team. Special care should be taken in approval of variation orders, invoices and other similar issues to our sub-contractors.

Contractual

It is important that all Engineers are aware of the original scope of works. The original scope of works can be found here.

Responsibility for raising the issue of V.O.'s is as follows :



It is a very rare occassion that the person originating the change will issue an instruction and a variation without us asking for it. However, small this request is, being professional and recording the change will ensure that in the event that all these minor variations add up, a propr claim can be lodged.

Variation Orders

Awareness

Person	Design Changes	Change via EI, RFI or Letter	Program Changes	Verbal Site Instructions
Project Manager	X	X	X	X
Engineering Manager	X			
Senior Engineers	X	X		
Site Engineers				X
Supervisors				X
Planner			X	

Engineers Instructions

In order to be able to submit a variation as per our contrcat with ADCC and following common practice an Engineers Instruction or otherwise needs to be issued to us. The ONUS is on us to request it.

Copies of Engineers Instructions are sent to H.O. Attention : Mr Fiaz who will then monitor and ensure that it is submitted.

Site Responsibility

To issue adequate backgound information for the Variation Order to be submitted. This shold include the 'narrative' as well as any other back-up documents.

Issuing

All documents to flow through document control. All distribution through document control.

Impact of change orders

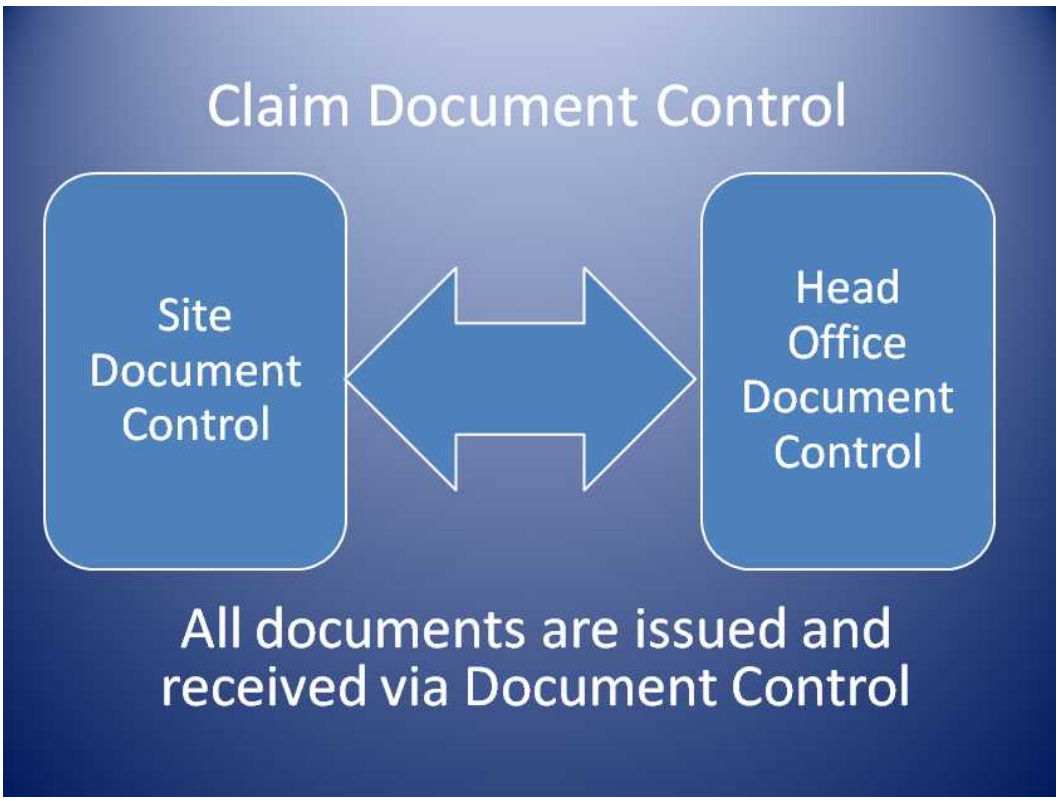
The chart below show the impact of change orders and their distribution.

On Projects where changes are numerous one can produce *measle charts* or as we call the *chicken pox diagrams*. Like a person afflicted with the disease your work will be slowed down and the cumulative impact will be much greater than you think.

Recording the changes

Once a Change Order is initiated a number of steps need to be taken to ensure that contemporaneous records are kept.

The Site QS needs to ensure that a letter is dispatched recording the fact that the change order will have a time and a cost impact.



The Engineering Manager will need to ensure that the Change Order is reflected permanently on drawings. The Shop Drawings need to be revised. Please ensure that revision clouds are included and that the revision text clearly states the reason for the change.

The Project Manager and Section Engineers will need to assess the impact of the EI and inform the Commercial Manager of the impact.

The QS will produce weekly and monthly reports as well as record on the monthly valuations the impact.

TABLE 11: Total number of EIs received since the MOU

	Dec 09	Jan 10	Feb 10	Mar 10	Apr 10	May 10	Jun 10	Jul 10	Aug 10	Sep 10	Oct 10	Nov 10	Dec 10	Jan 11	Feb 11	Total 11
Phase 3a	17	9	10	17	9	21	12	15	16	13	15	15	7	6	6	187
Phase 3b	1	3	0	3	2	5	0	3	3	1	3	11	4	6	nil	46
Phase 2a+3b	18	12	10	20	11	26	12	18	19	14	18	26	11	12	16	233

Charts can assist to better visualize problems with Engineer's Instructions and RFIs.

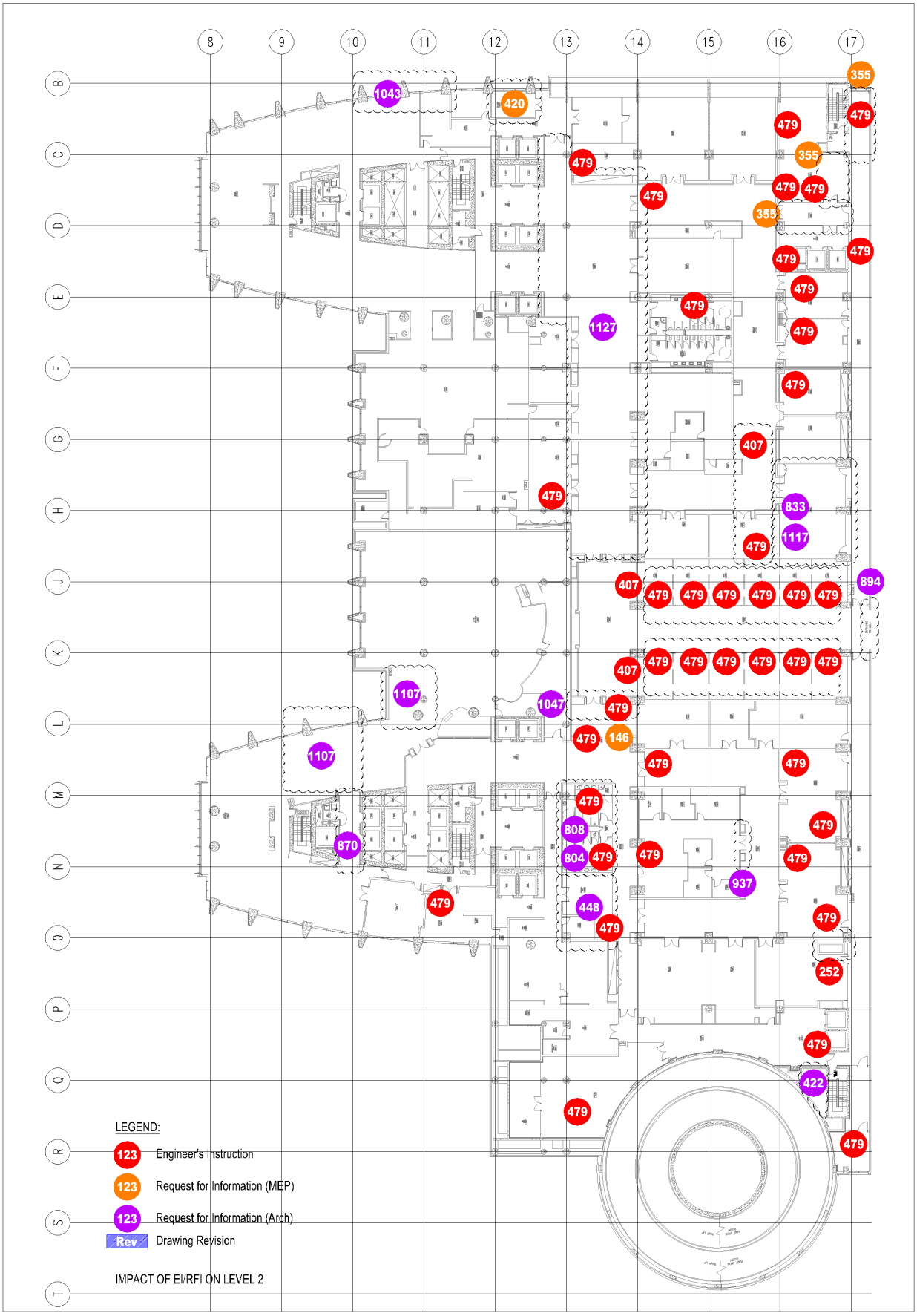


FIGURE 13: Chicken pox diagram showing effect of EIs and major RFIs on Level 2.

TABLE 12: Total number of RFIs issued since the MOU

	Dec 09	Jan 10	Feb 10	Mar 10	Apr 10	May 10	Jun 10	Jul 10	Aug 10	Sep 10	Oct 10	Nov 10	Dec 10	Jan 11	Feb 11	Total 11
Phase 3a	34	38	63	51	56	50	51	79	32	36	32	41	31	38	17	661
Phase 3b	12	19	12	7	28	24	23	21	5	8	12	13	5	6	7	204
Phase 2a+3b	46	57	75	58	84	74	74	100	37	44	44	54	36	44	24	865

Cumulative Impact of other EIs and RFIs

A growing list of Engineer's Instructions and Requests for Information followed-up, the signing of the Memorandum of Agreement. The growth of the EIs is shown graphically in Figure 14. As at the end of May 2011, there were 300 EIs issued and 1054 RFIs. Not only the Engineer failed to complete his design by the 15th of December 2009, as agreed with the Contractor and recorded in the Contractor's approved 6.2 Programme of Works, but the Engineer continued with changes well into a year after the planned Completion Date.

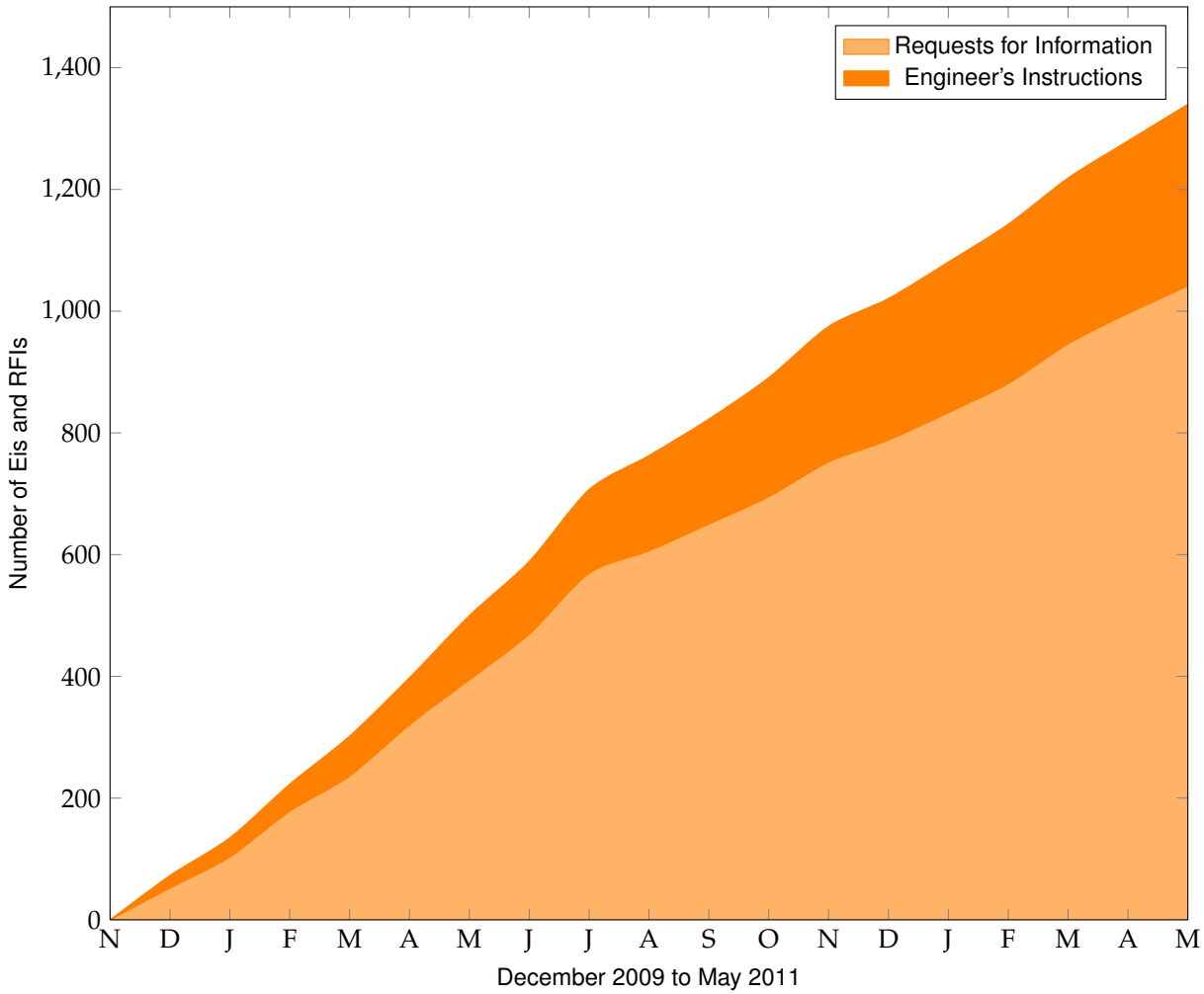


FIGURE 14: Plots showing the growth of Engineer's Instructions and their relationship to Requests for Information, the relationship can be observed clearly. See for example the *bumps* at around April-May 2010.

No Project, where the Design is incomplete can be completed. It is obvious neither the Owner that could instruct the Engineer to add resources to his Team, nor the Engineer considered the Completion Date to be of *essence*.

The Contractor on its part, accelerated works in sections that were critical for the Owners Direct Contractor to have access, providing this access at the end of June 2010.

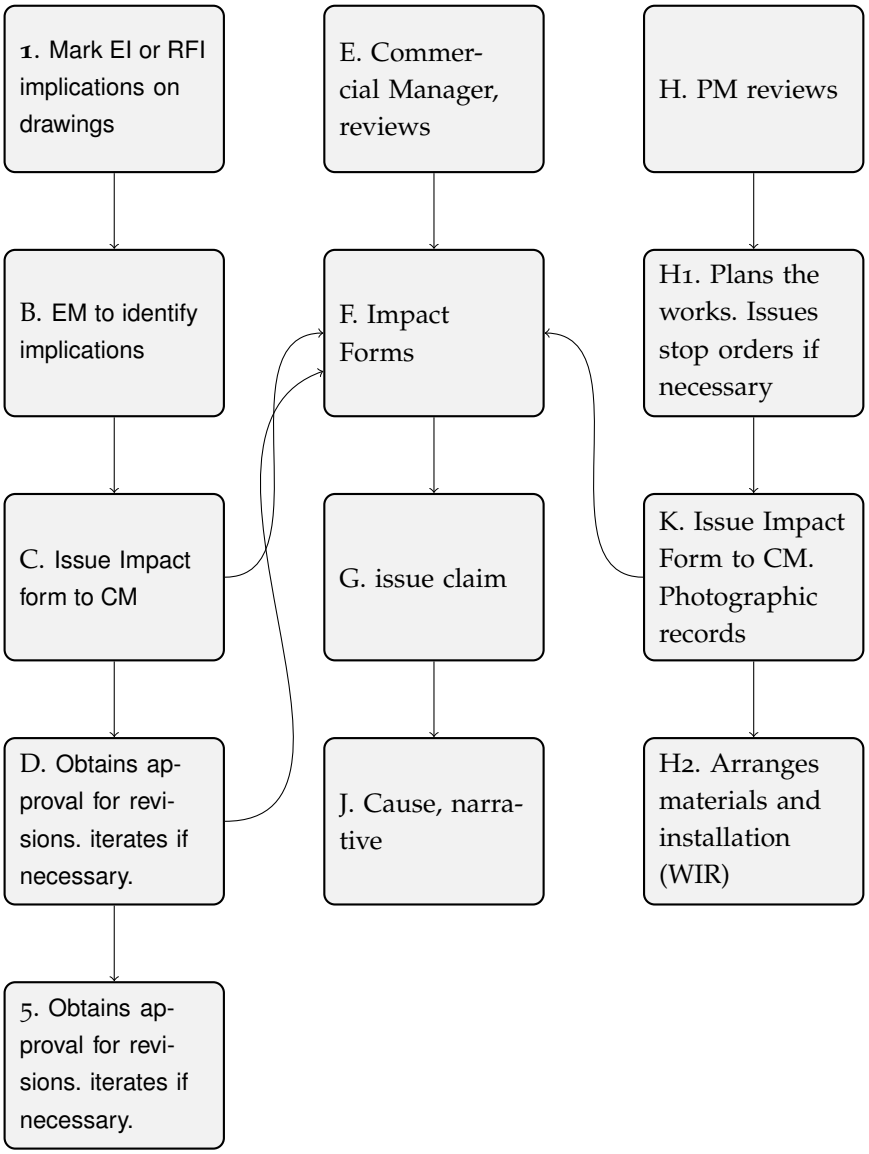
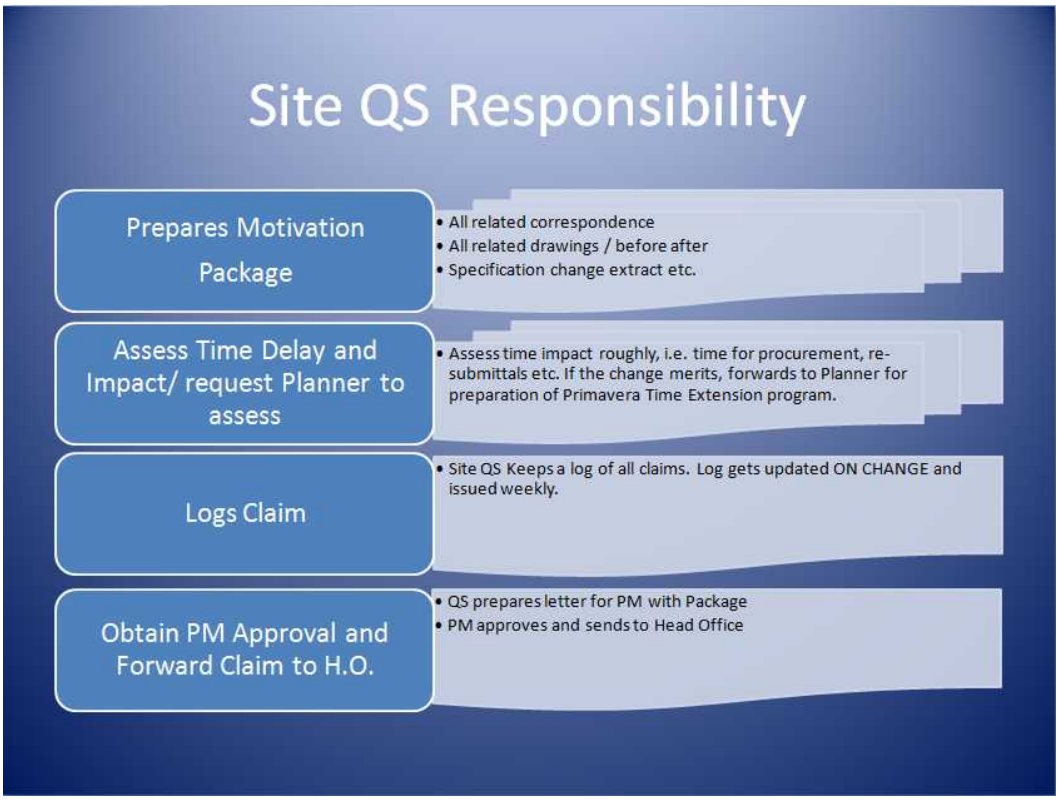


FIGURE 15: Workflow for Engineers Instructions and RFI works. All Departments get involved when there is a Change Order. Evaluate Change Orders as they occur and keep contemporaneous records.

Handover

It is important that all Engineers are aware of the original scope of works. The original scope of works can be found here.

Responsibility for raising the issue of V.O.'s is as follows :



Hand Over Documentation

The aim of collating all documentation at the end of a Project in order to verify that all parties have inspected and accepted the Installation. These documentation will have to be enclosed in the Operations and Maintenance Manuals.

As-Build Drawings

This is the most basic requirements and in an ideal Site they will be produced as an on-going activity, while the Site is operating. Remember that every change on the AS-BUILDS points to lack of good

engineering at the beginning of the Project and to an extent lack of planning. Minor changes are understandable to incorporate Site instructions but any large scale operations to update drawings is as a sad story.

Proof that the Works have been Physically Inspected

A list of all WIR's properly collated should be summarized. Contractor's confirmation that the works have been completed.

Proof of commissioning

The Final Touch

Depending on the specification, the Designers might have even elected to specify the font and the font-sizes for the manual. The OM manuals will impact on our brand long after we have left the project. It is important that they look professional and that they are bound correctly. Drawings and CDs should be copied properly.