COMPASS
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2019

International Hi-Tech / Pharmaceutical / Manufacturing / Cleanroom Facilities Estimating Yearbook

15TH EDITION

2019 International Hi-Tech / Pharmaceutical / Manufacturing / Cleanroom Facilities Estimating Yearbook

15TH ANNUAL EDITION

- Square Foot / M2 Estimating Data for (70 +) Hi-Tech / Pharmaceutical / Industrial / Commercial Facilities:
- Benchmarking Data / Cost Estimating of Classified ISO 3 - 8 / Clean Rooms Facilities / BSL 1 – thru BSL 4:
- Manufacturing Equipment Costs (45 + equipment items)
- Historical Percentage Hi-Tech Facility Factors and Methods:
- North American (280 + Cities) and International Location Factors (30 + Countries / Additional Cities):
- 1,000 + Labor and Material Unit Prices cost line items:
- Labor Rates Union and Open Shop:
- Engineering, Architectural, Validation and CM Fee's:
- Value Engineering / COM / Estimating Checklist:
- Required Engineering / Design Deliverables:
- Glossary of Terms / Cost Data Sources:

Compass International Consultants Inc.

Morrisville, Pennsylvania, USA

COMPASS INTERNATIONAL INC.

ABOUT THE FIRM

Compass International Consultants Inc. was founded in 1992 (C.I.C.I) and is a provider of estimating services, international construction cost data, location factors, training seminars, value engineering, estimating support and conceptual construction economic cost data. Compass International is backed by an excellent staff of experienced Cost Engineers, Cost Estimators, Civil / Mechanical / Chemical Engineers and Economists.

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Acknowledgements: This data source is the result of more than twenty years research and data collection. The information contained in this data source was collected from more than 30 + completed CAPEX projects (Hi -Tech Facilities, Pharmaceutical and Manufacturing Facilities) located in North America, the UK, Ireland, Sweden, Denmark, Norway, France, Germany, China, Singapore, India, and a number of countries located in Africa and South America valued between $0.25 million to over $3 billion. The data is based on Compass International's two decades old construction cost library, augmented with latest cost and labor data from International Development Banks and Agencies, European Union Commission Reports, various Country National Libraries and Bibliotheques from around the world, numerous Government Information Agencies, Global Quasi-Governance Organizations, assorted Government Trade Promotion Departments / Labor Departments, numerous trade magazines, hourly and annual salary rates from US / Overseas labor unions, professional society articles, an assortment of newspaper / magazine articles, various international almanacs, directories, reference books and tables, together with an assortment of international A/E & CM submissions, contractor proposals and bids, internet data and various construction related publications. The cost models and tables have also been enhanced by a number of personal estimating libraries (that in some cases are more than twenty years old), this information has been audited, expanded upon, reorganize, modified and calibrated and refined to today's construction methods and installation applications. We would like to express our sincere thanks to the many architects, engineers, contractors, construction managers, vendors and other individuals (friends and colleagues) too many to mention who have given freely of their advice, input, time and knowledge so that this data source could be produced for the benefit of individuals that have an interest in this subject matter. We welcome any comments or data that could be used in future updates to make this database more complete and accurate.

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Square Foot / Square Meter Estimating Background, Data & Forecasting Methods

"The path forward to the future success of a new pharmaceutical / hi-tech manufacturing facility is effective Engineering, Procurement, Construction and possibly Validation activities (EPC&V). The successful meshing together of these activities, should result in a positive outcome. The secret of success in producing accurate cost estimates - is front-end planning and the development of the project scope that the end-user requires to produce the "future" product, a scope of work (that spells out the intent of the project and the work that is to be accomplished) that the end-user can afford (one of the main reasons for this publication) and produces the required product quality, together with a completion date that meets the business goals of the end-user".

A great number of challenges and hurdles remain in place for Hi - Tech / Manufacturing / Pharmaceutical companies (and their decisions to build new / revamped facilities). As we look into the future as of late 2018 the issues to be faced in 2019 and beyond, include a myriad of topics (that have construction cost consequences), that will need to be considered and planned for. The High-Tech manufacturing / production industry as the engineering / construction professionals know it in 2019 will have changed dramatically in the next twenty years. Emerging economies such as China, India, Brazil and South Korea, to name but a few, will continue to forge ahead in developing their R & D and manufacturing bases. There is an increasing anxiety in some of the more developed nations as to how this will all play out and what impact this manufacturing / economic "sea change" will have on the future employment, costs and engineering / construction activities in Western Europe, North America and around the world. Hopefully this publication, and its future updates, will assist the reader in navigating and understanding the dynamics and the associated construction related costs, specific to Hi-Tech, Pharmaceutical facilities.

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THE GENERAL FORECAST FOR 2019 AND BEYOND:

(Specific to the Hi -Tech Industry and to the construction of these facilities).

- It is a fact of life that the North American and Western European pharmaceutical / biological manufacturing industry and the engineering and construction sector that supports it is facing uncertain times as we transition into 2019 and beyond. Puerto Rico's pharmaceutical facilities suffered a major blow when Hurricane Maria hit the island in mid September 2017. Some of these facilities were offline for 2 to 4 months. Healthcare cost are increasing, the marketplace is getting more cut throat (historical competitors and new generic drug manufacturers are

Typical Breakout of Cost as an Overall % of Laboratory Facility

COST % BY CONSTRUCTION CATEGORY FOR A NEW LABORATORY / R&D FACILITY

CATEGORY	% RANGE	% AVERAGE
CIVIL / ARCHITECTURAL TRADES		
General Conditions / Preliminaries	4.00 - 6.00	4.90
Excavation / Site Work / Piling / Caissons	1.50 - 3.50	2.90
Concrete Foundations / SOG / Elevated Flatwork	2.00 - 3.50	3.00
Superstructure (Load bearing walls / Structural Steel)	6.50 - 9.50	8.60
Exterior Closure (Curtain walls, Pre-cast Concrete, Facing bricks, Dryvit or a combination of all - note exterior doors are in this value)	5.50 - 8.50	7.80
Roofing system	1.00 - 2.50	1.50
Interior Construction (Drywall, Flooring, Ceilings, Internal Doors, Painting, Carpet, Floor finishes)	8.50 - 13.50	12.30
Elevators	0.50 - 1.50	0.80
Sub Total Civil / Architectural Trades		**41.80**
MECHANICAL / ELECTRICAL TRADES		
Plumbing / any process related piping	7.50 - 12.50	10.50
Fire Protection	1.00 - 2.50	1.90
HVAC (AHU & Ductwork)	17.00 - 25.00	21.40
Electrical Systems	9.50 - 13.50	11.40
Building Automation / Security / CCTV / Card Readers	1.75 - 3.75	2.80
Sub Total Mechanical / Electrical Trades		**48.00**
OTHER COSTS		
Equipment (Minor)	0.50 - 2.00	1.30
Casework / Fume Hoods / Cold Boxes	5.50 - 10.50	8.90
Sub Total Other Costs		**10.20**
TOTAL		**100.00**

Excludes

- Major site works outside the footprint of the building / facility, including roads and parking areas
- Land purchase
- A / E and CM costs including Owner engineering activities etc
- Demolition / asbestos / lead paint removal
- Any major production equipment
- Note: site indirect costs (construction equipment, supervision etc pro-rated into above percentage values).

The following cost models / facility benchmarks are based on completed or substantially completed projects, additional cost models are to be found in Section 2 of this publication.

- see following pages

(A) Typical Cost distribution by major Construction Category specific to R&D– Pilot Plant Facility (designed to ISO Class 7 - 10,000 - 4,400 SF and ISO Class 8 – 100,000 - 76,500 SF)

- 121,500 SF / 11,290 M2 on 2 Floors 2008 Cost of $424 SF / $4,564 M2
- see chart following.

(B) ANIMAL COLONY R&D / TESTING: Typical Cost distribution by major Construction Categories

- 21,830 SF / 2,029 M2 on 2 Floors 2008 Cost of $526 SF / $5,660 M2
- see chart following.

(C) Revamp / Upgrade / Add on to Existing Production Facility:

- Producing various Reagents / Neuro-Chemicals / Peptides / Cell Therapeutics
- RNAi Reagents and related API products
- ISO # 7 (Class 10,000 30%) and ISO # 8 (100,000 60%) unclassified i.e. ISO 9 or less 10%
- 3 Story Building and half basement 2006 Cost Basis

Table I

CONSTRUCTION CATEGORY	%	COMMENTS
General Conditions / Preliminaries	3.25	Typically these percentages can vary by +/- 50%
Underground Foundations	3.51	Typically these percentages can vary by +/- 50%
Sub Structure / Super Structure (Slab on Grade / Structural Steel / Concrete floors – PCC Floor Planks and topping Metal Roof Decking)	9.35	Typically these percentages can vary by +/- 50%
Exterior Wall System (Curtain Wall / Pre-Cast Concrete / Masonry)	8.35	Typically these percentages can vary by +/- 50%
Internal Construction (walls / doors / floors / ceilings / paint)	11.69	Typically these percentages can vary by +/- 50%
Millwork / Casework	4.86	Typically these percentages can vary by +/- 50%
Elevators	0.63	Typically these percentages can vary by +/- 50%
Roofing System	1.42	Typically these percentages can vary by +/- 50%
Plumbing	6.47	Typically these percentages can vary by +/- 50%
Fire Protection	0.81	Typically these percentages can vary by +/- 50%
HVAC	21.02	Typically these percentages can vary by +/- 50%
Manufacturing / Production Equipment	5.25	Typically these percentages can vary by +/- 50%
Electrical	9.78	Typically these percentages can vary by +/- 50%
Building Mgmt Systems	0.35	Typically these percentages can vary by +/- 50%
Architectural / Engineering Services	7.67	Typically these percentages can vary by +/- 50%
Construction Mgmt Services	4.54	Typically these percentages can vary by +/- 50%
Start-Up / Commissioning Activities	1.05	Typically these percentages can vary by +/- 50%
TOTAL	**100.00**	
• *Excludes work outside building footprint* • *Excludes owner engineering costs*		

Table J-1

FACILITY AREAS	SF	M2	# OF STAFF
Manufacturing 112,700 SF	112,700	10,474	50 - 65 operators on 3 shifts
Admin / Cafeteria 24,700 SF	24,700	2,296	50 - 65 staff - 8:00 AM - 5:00 PM
R&D / QA Laboratory 20,500 SF	20,500	1,905	50 - 70 staff - 8:00 AM - 5:00 PM
Warehouse 49,400	49,400	4,591	5 - 7 operators on 3 shifts
Total Facility Footprint	**207,300**	**19,266**	

47.0 TERMINAL AIRPORT
(Regional airport) 2 Floors, 32 Ft Story Height, 388,000 Square Feet
- See chart below

47.0 Terminal Airport
2 FLOORS, 32 FT STORY HEIGHT, 388,000 SQUARE FEET

EXTERIOR	COST PER SQUARE FOOT - M2
Brick, concrete block back-up steel frame	$226 - $2,432
Pre cast panels, steel frame	$235 - $2,529
Metal and Glass or Stone Curtain wall	$261 - $2,808

Building / Facility Type: Terminal
DATA TABLE

CSI DIVISION	DESCRIPTION	% RANGE OF COST	REMARKS
1	General Requirements	5.50 – 10.50	Gen Conditions / Preliminaries
2	Site Construction	8.50 – 12.50	
3	Concrete	5.00 – 7.50	
4	Masonry	3.50 – 5.50	
5	Metals	3.00 – 6.50	
6	Wood & Plastics	7.50 – 13.50	
7	Thermal & Moisture Protection	5.50 – 7.50	
8	Doors & Windows	4.50 – 6.50	
9	Finishes	7.50 – 10.50	
10	Specialties	1.50 – 2.50	
11	Equipment	0.50 – 1.50	
12	Furnishings	0.50 – 2.50	
13	Special Construction	0.50 – 2.50	
14	Conveying Systems	2.00 – 5.50	
15	Mechanical	10.50 – 16.50	
16	Electrical	8.00 – 11.50	
	Total Percentage	100.00	
	A / E Fees	4.50 – 8.00	Percentage of Construction Cost
	CM Fees	3.00 – 5.50	Percentage of Construction Cost

***EXCLUDES:** New utilities outside building footprint, parking areas, roads, gatehouses, fencing, landscaping, and demolition of existing facilities:*

54.0 WAREHOUSE / (VL) LOGISTICS CENTER / OFFICE
1 Story, 18 Ft Story Height, 427,000 Square Feet
- See chart below

54.0 Warehouse / Logistics Center

1 STORY, 18 FT STORY HEIGHT, 427,000 SQUARE FEET

EXTERIOR	COST PER SQUARE FOOT - M2
Concrete block, steel roof frame	$90 - $968
Insulated metal panel, steel frame	$86 - $925
Tilt-up panels, steel frame	$85 - $915
Pre cast panels, steel frame	$84 - $904
Metal siding on steel frame	$81 - $871

Building / Facility Type: Warehouse / (VL) Logistics Center

DATA TABLE

CSI DIVISION	DESCRIPTION	% RANGE OF COST	REMARKS
1	General Requirements	5.50 – 10.50	Gen Conditions / Preliminaries
2	Site Construction	8.50 – 12.50	
3	Concrete	5.00 – 7.50	
4	Masonry	3.50 – 5.50	
5	Metals	5.00 – 7.50	
6	Wood & Plastics	10.50 – 14.50	
7	Thermal & Moisture Protection	7.50 – 9.50	
8	Doors & Windows	4.50 – 6.50	
9	Finishes	5.50 – 10.50	
10	Specialties	0.50 – 2.00	
11	Equipment	0.50 – 1.50	
12	Furnishings	0.50 – 2.50	
13	Special Construction	0.50 – 2.50	
14	Conveying Systems	0.00 – 0.00	
15	Mechanical	10.50 – 14.50	
16	Electrical	8.00 – 10.50	
	Total Percentage	100.00	
	A / E Fees	4.50 – 6.50	Percentage of Construction Cost
	CM Fees	2.50 – 4.50	Percentage of Construction Cost

***EXCLUDES:** New utilities outside building footprint, parking areas, roads, gatehouses, fencing, landscaping, and demolition of existing facilities:*

- Epoxy / Vinyl Wall / Gypsum / Fiberglass board / Sprayed on coatings:
- Registers / barrel and pyramidal diffusers / penetrations.
- Open-plenum application / flush-grid lay in / ceiling grid (suspension method - T support bar or other grid type / hanger applications).

Doors (Single and Double) and frames: they should be washable, durable (hard) and resistant to dusting / delaminating (i.e. non-porous and resilient to rigorous cleaning regimes and harsh cleaning chemicals). They should be as smooth as possible, with no seams or horizontal surfaces that can attract or harbor dust or dirt. Door furniture / hinges / automatic closures / screws / push plates etc, should be stainless steel. Some of the various materials can include metal with an enamel coated finish or 304 / 316 stainless steel, reinforced plastic (RFP) and glass. Doors should be tight fitting to reduce any air leakage.

Windows (Internal) / Pass-Through's: should be washable, durable (hard) and resistant to dusting / delaminating (i.e. non-porous and resilient to rigorous cleaning regimes and harsh cleaning chemicals), made from tempered or laminated glass products that will be resistant to breakage. The windows should have rounded corners and concealed anti-moisture attributes. They should be as smooth as possible, with no seams or ledges that can attract dust or dirt. Door furniture / hinges / screws / push plates and should be 304 / 316 stainless steel.

INTEGRATED SYSTEMS AND MODULAR ROOM SYSTEMS (MODULES OR PRE-ASSEMBLIES):

The modular method integrates engineering and construction work with uniform dimensions and sizes that facilitates breaking the finished project into manageable and smaller units that can be later "fitted" together, hopefully saving times and resources. These systems include the total room space / footprint. They include all the floor, wall, and ceiling apparatus / finished out system (many times called modules or pre-assemblies), they include rooms that are typically manufactured in an off-site factory environment and then shipped to the jobsite.

- Walls / ceilings / floors / raised floors / doors / windows
- Architectural finishes
- Electrical services
- Process piping / plumbing systems
- HVAC systems
- Building Management Systems / Control systems
- Air shower / air locks
- Hook-up components – transition pieces
- Pass through's / hatches
- Wall guards / corner guards

These modules or pre-assemblies systems (Pam's) are engineered, procured and constructed (i.e. assembled / manufactured in a factory like environment and are transported to site with all necessary structural supports that are needed to lift and move these module around and to be integrated into it assigned location) – much like Lego blocks. All that is required is the necessary hook-up activities and final commissioning. There are pluses and minus associated with this approach, more on this topic will be covered later on in this section.

Clean Rooms are used in a number of different industries, the main industries that require these facilities are:

- The Biotech / Pharmaceutical industry (To produce a whole array of sterile products):
- The Computer / Electronic Industry (Required in manufacture memory chips / semi-conductors / CD's, TV, Communication Satellites, Telephones and the like):
- The Food and Beverage Industry (Required to produce a whole array of food and drink products):
- The Medical Device Industry (To produce such items as knee and hip replacements, stents and heart pacemakers):
- Healthcare / Hospital needed in operating theaters / operating rooms and some sophisticated testing laboratories.

The following is a comparison of ISO 14644-1 ing and any required x-ray testing or NDT, together with any hydro testing and or pickling of the piping system. This should also include piping related bolts, nuts, gaskets, weldolets, caps, unions, strainers and nipples etc.

- **Pipe Fittings:** All required piping fitting (elbows, caps, reducers, tees)
- **Pipe Flanges / Couplings (150# / 300#):** All required pipe flanges, couplings utilized to join, pipe to pipe, and any required fittings (elbows, reducers, tees) to each other.
- **Pipe Valves:** All necessary valves (gate, globe, check, butterfly etc) utilized in starting, stopping and regulating the flow of fluids throughout the process / manufacturing steps.
- **Pipe hangars:** shoes, guides and any required supports and frames.

Evaluation and points to consider before starting the Scope Review / Take Off / Estimating effort: The estimate / take off effort should recognize its physical location i.e. Inside Battery Limits (ISBL) and OSBL (Outside Battery Limits – Off-sites). Piping material and labor should, where possible be separated out by it's material of construction, codes, (API, ASTM, ASME, and ANSI etc.) specification, diameter, schedule wall thickness (i.e. schedule 40, 80) small bore piping (2"diameter and less, usually joined together with screwed fittings), and large bore piping (2"diameter and greater, typically welded together). Take off the quantity of pipe in LF or Meters; count the number of fittings and their rating (150# or 300# tees, elbows, reducers etc, welded or screwed) and number of valves. Fabrication of process pipe includes the collection of material from lay down yard, preparation, measuring, cutting, beveling, welding, stress relieving and any grinding to manufacture various piping isometrics / spools, for eventual field assembly and installation. Additional factors to take account of include the following:

- Weather protection issues, tarpaulins, sheds, and covered work area.
- Material handing issues, the need for forklifts, trucks, lay down area, bar coding and other warehousing and transportation / logistics issues.
- Control valve installation and the demarcation of pipe fitter & electrician work (consider control wiring and hook-up issues).
- Make sure underground piping is wrapped or coated and is accounted for in the estimate, include thrust blocks.
- Ensure that all required orifices, strainers, blinds; rupture discs, pressure relief valves and any flexible hoses are accounted for.
- Worker protection issues such as weather, noise, fumes and eye protection.
- Size of project issues: i.e. smaller projects have larger mobilization and demobilization activities. These projects typically experience a greater learning curve.
- Shift work / overtime issues such as additional supervision, worker fatigue and shift pay differentials.
- Ensure that pipe sleepers (usually pre-cast concrete) are accounted for.
- Tie in's and shut down issues such as hot taps, hot work permits and equipment standby.
- Limited use of construction equipment / cranes / hoists due to working in existing operating plants.
- Temporary protection of existing production equipment / screens:
- Fire blankets / safety / fire watch personnel.
- Material cost premiums for small quantities / deliveries.
- Small bore diameter pipe (2"diameter and less, usually joined together with screwed fittings). This type of piping is usually fabricated at the site sometimes referred to as field run piping.
- Large bore diameter pipe (2"diameter and greater, typically welded together) is typically fabricated in a pipe fabrication vendor's facility and shipped in spool pieces to the jobsite, the benefits of this is (1) quality control (produced in a factory type environment), (2) schedule enhancement, (3) optimized costs and the need for less welding activities at the job site (i.e. less field manpower requirements).

- The estimate / take off should recognize any vents, drains and waste piping systems (that are usually field run), couplings, expansion joints, thermo welds, weldolets, jumpers and strainers etc that are need and to what level of magnitude.
- Establish scope / and quantity of steam tracing required and estimate accordingly (spiral or straight run tubing).
- Ensure that existing systems are drained and safe prior to new tie-ins to piping systems.
- The estimate / take off should recognize any breaking up of paved areas, excavation, planking & strutting, stone bedding materials, thrust blocks, backfilling and any off site disposal, road crossings and the reinstatement of road or paved areas.

BIOTECH / PHARMACEUTICAL PROCESS FACILITY PIPING:

The piping related to a Biotech / Pharmaceutical Process Facility is typically a big piece of the overall pie. The cost of this work typically runs between 25% - 50% of the total installed cost of the completed facility, so care and attention needs to be taken in scoping out and estimating this element of the project. This topic can be somewhat complex, due to the fact that there are so many systems to consider. The only way to estimate this scope is to break it down into smaller pieces. Some of the systems that will be encountered are listed below:

- Process piping
- HVAC piping
- Service piping for Manufacturing / Process Equipment
- Vacuum systems
- Compressed air systems
- Reverse Osmosis piping (RO)
- Water systems
- Water for injection piping (WFI)
- De-ionized water piping (DI)
- Laboratory gases
- Cryogenic storage systems
- Sanitary treatment
- Drainage system
- Clean in place systems (CIP)
- Steam in place systems (SIP)
- Gases (CO2, nitrogen, argon, natural gas and perhaps more) needed to be quantified.

These and many other systems too numerous to mention need to be "scoped out" and estimated. Biotech / Pharmaceutical process facility type piping must be fabricated and installed to high quality standards. The quality of these piping systems is vital for the future production, safety, quality, and future profitability of any biotech / pharmaceutical company.

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Issues that need to be considered in estimating this type of work includes: materials to be used. There are numerous materials that could be selected that have cost consequences associated with them, some of the most commonly used materials are aluminum, brass, carbon steel, stainless steel, cast iron, copper (some of these are corrosion resistant materials), CPVC, polypropylene pipe, and double wall materials – jacketed piping. Additional items to bear in mind are various cleanouts / clover leaf fittings, gas piping, glass pipe applications, PVC applications, fiberglass reinforced pipe (FRP), various pipe liners, fittings, valves, shock absorbers, hangars and various wrappings. There are two distinct types of piping in Biotech facilities, (1) piping that comes into direct contact with the finished product, many times referred to as "clean piping" more often than not SS 304 and 316, and (2) piping that does not come into direct contact with the finished product, many times referred to as "non clean piping". These piping systems can be copper, carbon steel, plastic and a host of other "less" expensive materials. Pharmaceutical piping systems and manufacturing / production equipment usually makes use of stainless steels applications, stainless steel 304, 304 L, 316, and

(10) Cosmetic Production (Lotions / Creams / Gels and Powders) R& D Laboratory Production Facility 2 Floors:

- Total Installed Cost: $10,280,000
- 34,600 GSF / 3,215 M2
- 2010 Pricing basis $297 / SF $3,196 M2:
- Located in N.E. USA
- 2 Shift Operation 10 - 12 R&D Staff and 30 - 35 Production Workers:
- Excludes Demolition ($0.225 million), Owner Costs ($0.320 million) and road extension ($0.105 million):
- See chart following pages.

Table 1

MAJOR EQUIPMENT RATIO'S / PERCENTAGE UPLIFTS (+/- 25% ACCURACY)

CONSTRUCTION CATEGORY	MATERIAL (M)	LABOR (L)	TOTAL
A DIRECT COSTS			
Major Equipment (M.E.) 39 items	3,767,593	0	
Freight	83,370	0	
M.E. Setting in place	21,657	256,008	
Site Work / Preparation	87,452	72,784	
Civil / Concrete	139,453	223,556	
Facilities / Architectural Finishes / Siding	125,054	109,560	
Structural Steel / Miscellaneous platforms	426,887	169,886	
Piping Systems	1,071,887	1,168,670	
Electrical Systems	467,760	368,763	
Instrument / Controls	901,943	39,076	
Paint / Insulation / Refractory	96,473	109,005	
Fire Protection / Safety	49,550	68,453	
See note (1) below for other items that need to be considered	50,660	42,567	
A TOTAL DIRECT COSTS	**7,289,739**	**2,828,328**	
B IN-DIRECT COSTS			
Trade Supervision / Foreman / Gangers etc.	73,990	313,220	
Consumable supplies / gases / welding mats / grease / rags etc.	103,119	11,545	
Small Tools (items less than $200 per item)	119,655	12,545	
Site Establishment / Trailers / Temp Offices.	262,558	107,556	
Safety / Training	17,744	41,560	
Construction Equipment costs. Rental / Owned.	37,547	187,665	
Construction Equipment Repairs etc. / Fueling.	15,322	42,448	
Material Mgmt / Logistics / Field Support	131,311	53,643	
Ongoing Site Clean Up / Maintenance of roads / barriers / fences etc.	18,080	41,245	
Sales Tax (optional cost item could be excluded)	241,887	N/A	
B TOTAL IN-DIRECT COSTS	**1,021,213**	**811,427**	
TOTAL D & I (A+B)	**8,310,952**	**3,639,755**	**11,950,707**
DETAILED DESIGN & SUPERVISION D.D.& S.			
Home Office EPC Detailed Design 12.19%			1,456,739
Construction Mgmt 3.30%			394,564
Owner Project Eng / CM 1.30%			155,770
Plant C.M. / Eng Support 0.70%			83,450
Front End Project Eng 1.95%			233,000
O/S Review / V.E. Study 0.46%			55,000
Plant Gen Conditions 0.28%			33,006
C Total D.D.& S. Costs			**2,411,529**
TOTAL D & I & D.D. & S (A+B+C)			**14,362,236**

Production Equipment / Unit Prices and Various Miscellaneous Capital Cost Estimating Issues

"Hi-Tech Manufacturing and Pharmaceutical type facilities are complex and expensive facilities to complete - both from a construction and operating point of view. Developing an accurate front-end cost estimate that reflects the intent of the owner – (scope of work) is a critical first step in a projects' life cycle".

The Engineering, Procurement and Construction (EPC) of a new or upgraded building, pharmaceutical / chemical plant or manufacturing facility requires a sizeable capital investment expenditure, possibly over a period of three years period prior to any return on investment (ROI) being realized. This section, the following, and previous sections has been written to provide some guidance in producing these essential project deliverables. The construction industry is a "mixture" of assorted sectors that all have a common thread (i.e. see the "players" listed previously in Section 1 and in later sections of this publication). A considerable amount of information and data needs to generated, collected and evaluated in the production of a CAPEX estimate, from any design or reports that have been previously completed, in most cases this information can be found / or is discussed in the following sections of this publication, some of these documents include:

(A) Scope of Work / Mission statement / estimating plan.

(B) Process Flow Diagrams, (PFD's).

(C) Front end / preliminary scope of work statements (execution approach)

(D) Plant / facility location (and location within an existing facility – including any off sites).

(E) Preliminary / early major equipment lists (with budget pricing).

(F) Location of any existing utilities / existing tank farms (if available).

(G) A major milestone schedule (start and completion date)

(H) Applicable sketches / notes / photographs / videos etc.

(I) Preliminary (P&ID's) and or process flow sheets / block diagrams.

The above items together with any other relevant engineering / cost specific data that will aid / support or add accuracy the estimating effort: Again, a lot of the issues related to the basic of CAPEX estimating, CAPEX estimating ground rules are discussed in some detail in Section 1, 2 and 3 of this publication.

Forecasting the cost of a project(s) both accurately and in a timely manner of upcoming new or revamped construction projects is essential to the continued existence of any business, be it a Fortune

#	DESCRIPTION	UNIT	MATERIAL	LABOR	TOTAL
	(9) CSI DIVISION 16 ELECTRICAL				
	CLEAN ROOM ITEMS (CONTINUED)				
116	Air Handler (High Volume) 3300 CFM 1.5 HP	EACH	2,150.37	161.68	2,312.04
117	HDPE 3,000 gallon Polyethylene tank 90" dia x 130" high	EACH	2,219.57	136.73	2,356.30
118	Ditto 5,000 gallon	EACH	4,903.40	136.73	5,040.13
119	Ditto horizontal 2,500 gallon 60" dia	EACH	3,873.33	136.73	4,010.06
120	2 "PVC gate valves with EPDM seat NSF61 150 PSI 120 F	EACH	561.59	136.73	698.32
121	4" ditto	EACH	1,152.82	136.73	1,289.55
122	6" ditto	EACH	2,292.97	136.73	2,429.70
123	1" CPVC pressure valves	EACH	505.16	68.37	573.53
124	2" ditto	EACH	771.86	102.55	874.41
125	1" – 3 way CPVC with threaded socket –true union	EACH	115.72	68.37	184.09
126	2" ditto	EACH	309.02	102.55	411.57
127	4" ditto	EACH	1,313.69	102.55	1,416.24
128	0.50" CPVC solenoid valves with EPDM seals	EACH	735.15	68.37	803.52
129	0.75" ditto	EACH	976.45	68.37	1,044.82
130	0.50" Clear PVC pipe (Material only)	LF	1.94	0.00	1.94
131	0.75" ditto	LF	2.44	0.00	2.44
132	1" ditto	LF	4.82	0.00	4.82
133	1.50" ditto	LF	6.11	0.00	6.11
134	2" ditto	LF	7.73	0.00	7.73
135	4" ditto	LF	24.27	0.00	24.27
136	Multiply above by 1.45 - 1.65 to above for fittings		0.00	0.00	0.00
137	1" CPVC schedule 80 (Material only)	LF	2.99	0.00	2.99
138	2" ditto	LF	9.97	0.00	9.97
139	4" ditto	LF	28.75	0.00	28.75
140	6" ditto	LF	55.55	0.00	55.55
141	Multiply above by 1.45 - 1.65 to above for fittings				
142	304 SS Pass through 40" x 40" with window	EACH	18,153	273	18,427
143	316 SS 12g tank 500 gallon 50" dia x 60" high	EACH	15,842	103	15,944
144	316 SS 12g tank 1,000 gallon 70" dia x 70" high	EACH	26,477	103	26,579
145	316 SS 12g tank 1,500 gallon 80" dia x 70" high	EACH	35,606	137	35,743
146	316 SS Agitator 1 HP TEFC 115 / 230 v single speed 1" dia shaft 32" long	EACH	5,567	137	5,703
147	Ditto 1.5 HP 230 v	EACH	7,267	137	7,404
148	Clean room AC module including ductwork, 220 v and controls 20,000 BTU's	EACH	7,249	273	7,522
149	Ditto 50,000 BTU's	EACH	9,701	273	9,974
150	120 v Solenoid vacuum valve	EACH	272	34	307
151	Ditto 220 v	EACH	294	34	328
152	316 SS Agitator variable speed 1 HP 5/8" x 40' shaft 115 / 220 v TEFC	EACH	6,561	103	6,664
153	Doors – Electronic with photo – activated feature (single size 7' x 3')	EACH	3,879	199	4,079
154	Ditto (double sized 9' x 6')	EACH	4,037	265	4,303
155	Ditto rolling door (7' x 6')	EACH	20,712	332	21,044
156	Seal less Pump PVDF 0.5 HP 115 / 230 V 1 Phase TEFC	EACH	1,232	133	1,365

• Consider modular / pre-assembly construction methods.

• Consider generating onsite electricity, i.e. solar, cogeneration or wind power.

• Review backup redundant utility systems and question engineering philosophy.

• Consider different architectural finishes and installation methods.

• Plan and develop lifting schedule / scaffolding requirements to ensure maximum productivity and minimum cost between trades / subcontractors.

• Consider using gravity feed tanks housed in building, V's dedicated tank farm (eliminate pumps / pipe / pipe racks).

• Standardize specifications / design procedures

• Ensure that correct spacing (12" – 15" in height) is allowed between cable trays to allow cost-effective cable pulling activities.

• Increase / Decrease bay sizes, floor to floor heights, optimize support space.

• Use aluminum switchgear if this is feasible.

• Optimize automation methods and endeavor to reduce number of I/O points where possible.

• Use energy efficient equipment that conserves electricity, gas and water.

• Elevate facility building pad, to reduce excavation costs (cut and fill requirements).

• Locate facility / building closer to existing WWT, power and steam production facilities to save on pipe and cable runs.

• Plan flexible workspace for future visitors; provide "hotel" types work space areas.

• Use timers, dimmers and set HVAC thermostats to specific set points to reduce electricity usage and optimize where possible.

• Use natural daylight / windows / skylights in an effort to optimize electrical load.

• Re-visit building insulation designs; consider best / optimum "R" value for walls and roofing systems.

• Re-route new or existing roads / rail spur to save construction costs and schedule, locate new facility close to existing services if possible, to save on piping and electrical runs.

• Can we optimize future long term operating (OPEX) expenditures, by reducing number of operators?

• Discuss with local utility / Power Company on ways to optimize electrical usage to save operating costs.

(COM) practices are intended to enhance the value / worth of a manufacturing / production facility by reducing critical and non-critical scope of work items, by improving reliability and simplifying the manufacturing / production process.

• Use cost effective materials such as PVC, CPVC versus high cost alloys.

• Design facility / building with sufficient employee parking space; be cognizant of local transport needs / bus stops / bike racks / unloading areas / handicap buses / van access and the general location of access roads to the new facility.

• Utilize used equipment / refurbished equipment / use pre-purchased equipment currently in owner's inventory, purchase key spare parts with initial P.O.

• Consider future facility production / campaign increases and decreases to meet market demand and design to needed capacity / demand, can this plant be modified and expanded to increase future production needs.

• Consider the utilization of shop painting and coatings to minimize field painting activities.

• Conduct mini - V.E. sessions during pre-construction reviews / input from construction engineers during the detailed design effort to optimize the EPC effort.

• Plus many more cost saving ideas.

Cost Optimization Methods (COM) and value enhancement approaches: A number of leading "process" -, chemical, manufacturing, oil and gas, pharmaceutical organizations have put into practice the application of a "suite" of Cost Optimization

Methods (COM) and value enhancement approaches to optimize their CAPEX capital project executions programs, this activity relates to front end planning, engineering, procurement, construction and eventual facility operations. This is basically an upgrade to the Value Engineering concept where the total scope of a CAPEX project is re-evaluated to see if additional costs can be "squeezed" out of the current scope of work. Cost Optimization Methods (COM): A front end project practice targeted at optimizing "hard and soft" Engineering, Procurement and Construction project related costs. (COM) practices are intended to enhance the value / worth of a manufacturing / production facility by reducing critical and non-critical scope of work items, by improving reliability and simplifying the manufacturing / production process. Topics that are reviewed and evaluated include in this methodology are: (1) Front End Economic / Business drivers, (2) Early and detailed Engineering / Design activities, (3) Procurement methods and approach to be used in completing the CAPEX project, (4) Construction techniques, (5) Project related "soft" costs, such as Start up costs, Owner Engineering / Construction support, Valida-

Cost Optimization Methods & Value Enhancement Approaches

#	ESTIMATE TYPE & ACCURACY	DETAILED DESIGN COMPLETION / AVAILABLE ENGINEERING / ESTIMATING / DATA	SUGGESTED COM EFFORT
1	Initial Business Idea Basis - ROM, Blue Sky, OOM, Concept Study, Ratio Estimate type estimates (+/ - 50% accuracy)	1 – 5%, Preliminary SOW statement, partial M.E. list, sketches, known location	Estimator / Project Manager / Project Controls / Project Stakeholders (minimal 2 – 4 hours)
2	Viability / Business Identification - Pre-Detailed Design Estimate Feasibility Estimate, partial AFE / Initial Funding Estimate (+/ - 40% accuracy)	2 – 10% all of the above, M.E. list, preliminary layout known, preliminary OSBL data.	Estimator / Project Manager / Project Controls / Project Stakeholders) (minimal 2 – 4 hours)
3	Funding Estimate Approve for Expenditure (Full or partial CAPEX funding) – Semi-Detailed Estimate, Preliminary Control Estimate, AFE Full Funding Estimate (+/ - 30% accuracy)	10 – 30% all of the above, priced out M.E. list, 40 - 60% CSA / piping / electrical completed, OSBL design 30 - 50% complete, perhaps 20% - 40% quantity take-offs completed.	All the Project Stakeholders (0.5 - 1 day effort)
4	Project Baseline / Project Control Class (used as control tool) Project Control Estimate, GMP Estimate, A Not to Exceed Estimate (+/ - 10% accuracy)	30 – 80% all of the above all of the above, priced out M.E. list, 60 - 80% CSA / piping / electrical completed, OSBL design 50 - 70% complete, perhaps 40% - 70% quantity take-offs completed.	All the Project Stakeholders (1 – 2 day effort)
5	Lump Sum - Hard Money / Lump Sum Proposal Estimate (+/ - 5% accuracy)	50 – 100% all of the above all of the above, priced out M.E. list, 80 - 100% CSA / piping / electrical completed, OSBL design 70 - 100% complete, with perhaps 80% - 100% detailed quantity take-offs completed.	All the Project Stakeholders (1 – 2 day effort)

TERMS & DESCRIPTIONS

CONTINUED

Estimates (Types and Accuracy): To understand the basic differences between an Order of Magnitude Estimate and a Definitive Capital Cost Estimate the following should be understood. An Order of Magnitude Estimate are typically complied by utilizing historical cost data, cost capacity curves, exponents, Wroth, Miller, Cran, Guthrie, Lang, Chilton, Peters / Timmerhaus and Compass type ratio's / factors. Definitive Capital Cost Estimates are compiled from defined engineering deliverables; say 40% - 70% (or in some cases the detailed design is 100% complete), of the detailed engineering is completed. An appraisal / listing / collection of all the future and anticipated expenditures (direct and indirect construction cost elements) and allowances (provisional sums and allowances) of the components of a project or endeavor as described by an established and approved scope of work statement together with any specific drawings and specifications: Some of these estimates are known as:
OOM / Front End / Conceptual etc.
AFE / Funding / Preliminary / Semi-detailed.
And Lump Sum / Hard Money / Tender submission / Turnkey etc.
The above nomenclature are perhaps the most widely used capital cost estimating types used for a manufacturing / process industry facilities, they are described as follows, however there is possibly four to ten additional (hybrids) types that are used throughout the engineering and construction industry on perhaps a less frequent basis some of these are described within this publication:

Front End Estimate / Order of Magnitude Estimate / O.M.M. - an early (in the projects life cycle) estimate made with no complete engineering deliverables or project specific data / or information. Illustrations would be: end product unit method, square foot / square meter unit prices, an estimate from historical percentages, cost capacity curves, an estimate using exponents i.e. 6/10th type factors, or an approximate percentage / ratio type estimate. Lang or Wroth, Peters / Timmerhaus, Cran, Guthrie, Hand, Miller or Chilton type published multipliers. It follows that a capital cost estimate of this kind would be accurate within +40% or -30% range. Typically less than 5% of the detailed design has been completed. AFE Funding Estimate / Budget / Preliminary Estimate / the detailed design in this situation would perhaps be in the 10% to 35% completion range. A budget estimate is prepared with the use of some basic engineering such as preliminary P. F. D. 's / P. & I. D. 's general arrangement drawings, approved / preliminary plot plan, layouts, and preliminary major equipment list together with outline specifications /materials of construction and or pricing, a motor list, a preliminary instrumentation list, a preliminary piping listing. In general it is probable / likely that an estimate of this type would be accurate within +25% or -20% range: Lump Sum Bid Definitive / Hard Money Bid / Tender submission Estimates – this kind of capital cost estimate is an estimate organized from perhaps 70% to 100% complete engineering deliverables. The engineering deliverables include approved / signed off general arrangement drawings, signed off piping and instrument diagrams (P. & I. D' s), electrical area classification map, single line electrical diagrams (home runs), a major equipment list and related data sheets and quotations, motor lists, structural drawings, insulation requirements, soil data and layout of major equipment foundations, building / facility drawings (indicating specification and footprint size), a detailed piping list / specification, instrumentation list and project specifications a listing of offsite O.S.B.L. requirements and a scope of work statement, together with a detailed plan 30 –90 look ahead schedule and a project execution basis - approach, complete with a risk evaluation study and contingency evaluation (perhaps a Monte Carlo simulation). It is anticipated that an estimate of this kind would estimate would fall in the range of accuracy of +10% and -5%, due to the fact that the design deliverables detailed engineering level of effort would be perhaps 70 –100% complete, with perhaps a contingency of 5% - 10%. Most probably some of the construction would be being installed i.e. the foundations and the long lead major equipment items would be on order.

Escalation: The value / stipulation in actual or estimated costs for future increases in the value of major equipment, bulk / engineered materials, labor, engineering etc. due to ongoing increase in prices, i.e. sometimes referred to as inflation.

Escalator Clause: Article included in a contract / agreements / terms and conditions, allowing for future price adjustment based on changes in specific escalation / inflation value.

F.A.R. Federal Government Regulations.

F.A.T. Factory acceptance test.