Estimating Construction and Demolition Waste in Project Proposals

Columbia University and Lehman College in partnership with the New York City Housing Authority

Special thanks to The Gordian Group

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COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

LEHMAN COLLEGE

NEW YORK CITY HOUSING AUTHORITY

THE GORDIAN GROUP®

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Project Overview

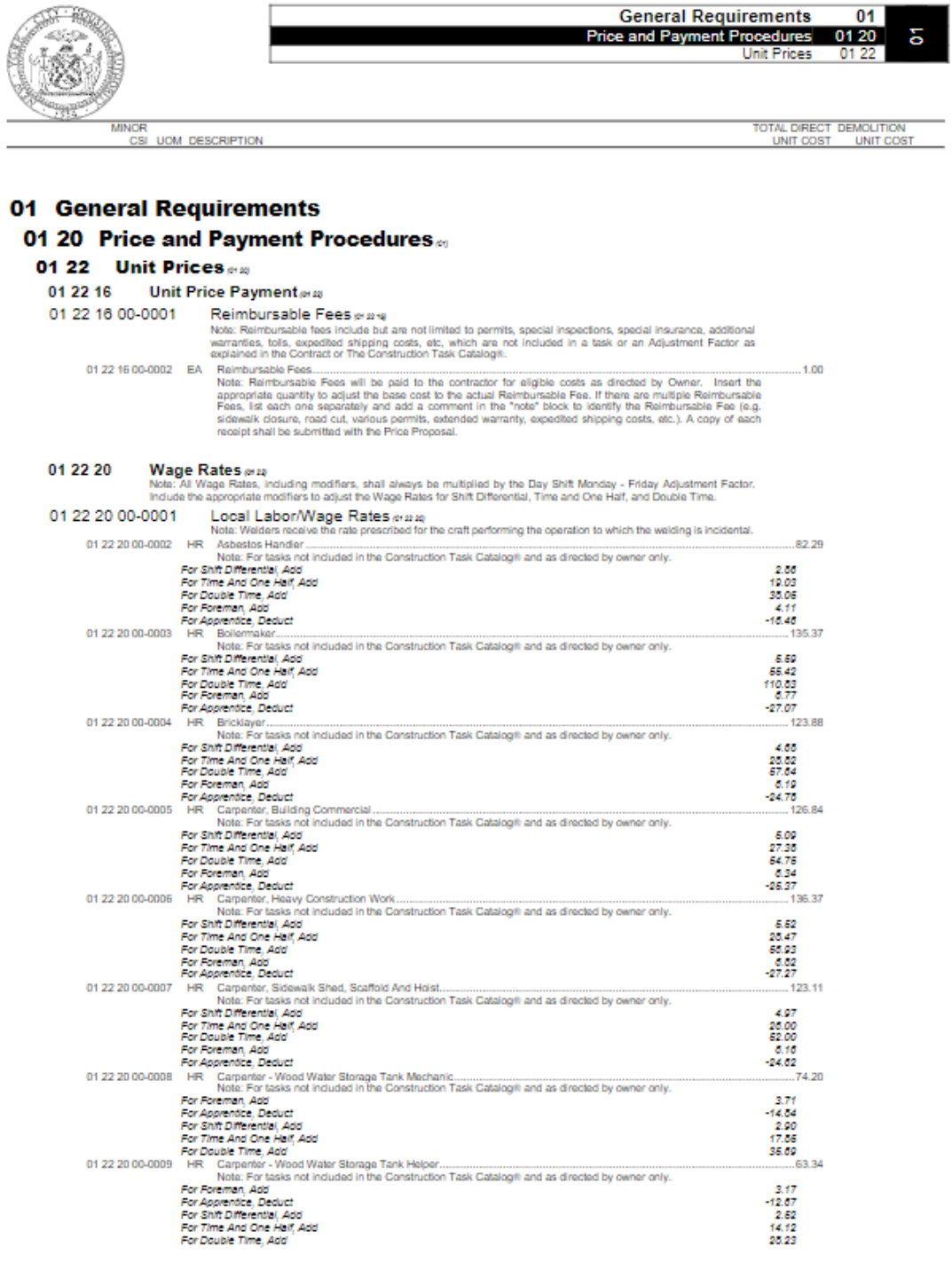
- Given the JOC project proposals, we want to estimate the project's construction and demolition waste.
- In order to achieve this, we need an efficient way of reading project proposal line items and estimating their associated waste.

ITEM	DESCRIPTION OF WORK	QUANTITY	D/I	UNIT	UNIT PRICE	Adjustment Factor	Line Total
	01 - General Requirements						
1	Carpenter, Heavy Construction Work	16.00	I	HR	$129.88	1.2316	$2,559.36
2	Carpenter, Heavy Construction Work	16.00	I	HR	$129.88	1.2316	$2,559.36
3	Certified Industrial Hygienist	8.00	I	HR	$125.42	1.2316	$1,235.74
4	Firewatch F01, Fireguard F60	80.00	I	HR	$25.00	1.2316	$2,463.20
5	Principal Architect	40.00	I	HR	$225.00	1.2316	$11,084.40
6	Principal Engineer	40.00	I	HR	$200.00	1.2316	$9,852.80
7	Principal Engineer	52.00	I	HR	$200.00	1.2316	$12,808.64
8	Flagperson For Traffic Control	320.00	I	HR	$76.58	1.2316	$30,181.10
9	80' Engine Powered, Articulating (Up/Over) Boom Man Lift With Platform	4.00	I	MO	$5,772.67	1.2316	$28,438.48
10	2,000 Watt, 115 Volt, 2 Lamp, Portable Light Stand With Tripod	28.00	I	MO	$317.75	1.2316	$10,957.55
11	5 Ton, 20' Lift, 2-Speed, 230/460 Volt, 60 Cycle, Electric Chain Hoist	6.00	I	MO	$575.00	1.2316	$4,249.02
12	Up To 400#, Manual Swing Roof Hoist	4.00	I	MO	$685.32	1.2316	$3,376.16
13	Electrician Minimum Charge	1.00	I	EA	$1,221.76	1.2316	$1,504.72
14	Sheet Metal Worker Minimum Charge	1.00	I	EA	$1,056.79	1.2316	$1,301.54
15	Bacteria Test (Total Coliform Bacteria And E. Coli Bacteria)	20.00	I	EA	$29.49	1.2316	$726.40
16	Temporary 100 Amperes, NEMA 1 Or 3R, Disconnect Switch With Fuses	1.00	I	EA	$1,577.06	1.2316	$1,942.31
17	Temporary 100 Amperes, Panelboard Complete With GFCI Circuit Breakers	1.00	I	EA	$1,567.66	1.2316	$1,930.73
18	Temporary 200 Amperes, Panelboard Complete With GFCI Circuit Breakers	2.00	I	EA	$2,253.85	1.2316	$5,551.68
19	Temporary Branch Circuit Conduit And Wiring For Temporary Disconnect Switches And Temporary	200.00	I	LF	$7.38	1.2316	$1,817.84
20	Temporary High Bay Light	42.00	I	EA	$455.33	1.2316	$23,552.95
21	Temporary Wood Walkway, 3/4" Plywood On 2 x 6 Stringers	50.00	I	SF	$5.80	1.2316	$357.16
22	Temporary Wooden Guardrail, 42" High, Posts, Handrail, And Intermediate Rail	600.00	I	LF	$34.07	1.2316	$25,176.37
23	Scaffolding With Bracing Accessories - Area Based On 5' Wide Sections (CCF / Month)	1,920.00	I	CCF	$21.82	1.2316	$51,597.14
24	Scaffolding With Bracing Accessories - Area Based On 3' Wide Sections (CCF / Month)	6.00	I	CCF	$32.73	1.2316	$241.86
25	For Up To 25, Add	6.00	I	MOD	$13.09	1.2316	$96.73
26	Up To 20' Height Scaffolding Initial Erection And Final Dismantling, Per CCF Of Scaffolding And Accessori	31.50	I	CCF	$59.29	1.2316	$2,300.18
27	>80' Height Scaffolding Initial Erection And Final Dismantling, Per CCF Of Scaffolding And Accessories	640.00	I	CCF	$112.65	1.2316	$88,793.43
28	Netting for Exterior Building Scaffolding	281.25	I	CSF	$32.50	1.2316	$11,257.59
29	10 Mil, Fire Retardant, Reinforced, Plastic Sheeting, Applied To Scaffolding	2,150.00	I	SF	$0.83	1.2316	$2,197.79
30	Temporary Metal Door And Frame	1.00	I	EA	$626.32	1.2316	$771.38
31	Installation of Heavy Duty Steel Post And Beam Sidewalk Bridge Assembly	200.00	I	LF	$189.74	1.2316	$46,736.76
32	For Each Additional Foot Over 8' Wide, Add	1,600.00	I	MOD	$3.00	1.2316	$5,911.68
33	For Each Additional Foot Over 8' High, Add	800.00	I	MOD	$2.00	1.2316	$1,970.56
34	Monthly Rental Of Up To 8' Wide, 8' - 12' High, 2 Post System, Heavy Duty Steel Post And Beam	600.00	I	LF	$9.66	1.2316	$7,138.35
35	Monthly Rental of Netting for Sidewalk Bridge	600.00	I	LF	$1.61	1.2316	$1,189.73
36	Removal of Heavy Duty Steel Post And Beam Sidewalk Bridge Assembly	200.00	I	LF	$39.49	1.2316	$9,727.18
37	For Each Additional Foot Over 8' Wide, Add	1,600.00	I	MOD	$1.25	1.2316	$2,463.20

Methods

In order to convert the catalog, we wrote a Python algorithm (now on GitHub) which performs the following steps

1. Does a raw conversion of the PDF into a CSV.
2. Breaks the CSV up by line, then separates line items from unit types and other information.
3. Reads the line item to determine material type and size specifications, then determines weight of associated waste.
4. Prints line item, material, and waste to output file.



General Requirements 01
Price and Payment Procedures 01 20
Unit Prices 01 22
01

MINOR CSI UOM DESCRIPTION — TOTAL DIRECT UNIT COST — DEMOLITION UNIT COST

01 General Requirements

01 20 Price and Payment Procedures

01 22 Unit Prices

01 22 16 Unit Price Payment

01 22 16 00-0001 Reimbursable Fees
Note: Reimbursable fees include but are not limited to permits, special inspections, special insurance, additional warranties, tolls, expedited shipping costs, etc, which are not included in a task or an Adjustment Factor as explained in the Contract or The Construction Task Catalog®.

01 22 16 00-0002 EA Reimbursable Fees 1.00
Note: Reimbursable Fees will be paid to the contractor for eligible costs as directed by Owner. Insert the appropriate quantity to adjust the base cost to the actual Reimbursable Fee. If there are multiple Reimbursable Fees, list each one separately and add a comment in the "note" block to identify the Reimbursable Fee (e.g. sidewalk closure, road cut, various permits, extended warranty, expedited shipping costs, etc.). A copy of each receipt shall be submitted with the Price Proposal.

01 22 20 Wage Rates
Note: All Wage Rates, including modifiers, shall always be multiplied by the Day Shift Monday - Friday Adjustment Factor. Include the appropriate modifiers to adjust the Wage Rates for Shift Differential, Time and One Half, and Double Time.

01 22 20 00-0001 Local Labor/Wage Rates
Note: Welders receive the rate prescribed for the craft performing the operation to which the welding is incidental.

01 22 20 00-0002 HR Asbestos Handler 82.29
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 2.66
For Time And One Half, Add 19.03
For Double Time, Add 35.06
For Foreman, Add 4.11
For Apprentice, Deduct -16.46

01 22 20 00-0003 HR Boilermaker 135.37
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 5.69
For Time And One Half, Add 56.42
For Double Time, Add 110.63
For Foreman, Add 6.77
For Apprentice, Deduct -27.07

01 22 20 00-0004 HR Bricklayer 123.88
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 4.65
For Time And One Half, Add 28.62
For Double Time, Add 57.64
For Foreman, Add 6.19
For Apprentice, Deduct -24.76

01 22 20 00-0005 HR Carpenter, Building Commercial 126.84
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 5.09
For Time And One Half, Add 27.36
For Double Time, Add 54.76
For Foreman, Add 6.34
For Apprentice, Deduct -25.37

01 22 20 00-0006 HR Carpenter, Heavy Construction Work 136.37
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 5.62
For Time And One Half, Add 28.47
For Double Time, Add 56.93
For Foreman, Add 6.82
For Apprentice, Deduct -27.27

01 22 20 00-0007 HR Carpenter, Sidewalk Shed, Scaffold And Hoist 123.11
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Shift Differential, Add 4.97
For Time And One Half, Add 26.00
For Double Time, Add 52.00
For Foreman, Add 6.16
For Apprentice, Deduct -24.62

01 22 20 00-0008 HR Carpenter - Wood Water Storage Tank Mechanic 74.20
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Foreman, Add 3.71
For Apprentice, Deduct -14.84
For Shift Differential, Add 2.90
For Time And One Half, Add 17.66
For Double Time, Add 35.69

01 22 20 00-0009 HR Carpenter - Wood Water Storage Tank Helper 63.34
Note: For tasks not included in the Construction Task Catalog® and as directed by owner only.
For Foreman, Add 3.17
For Apprentice, Deduct -12.67
For Shift Differential, Add 2.62
For Time And One Half, Add 14.12
For Double Time, Add 25.23

Methods

In order to convert the catalog, we wrote a Python algorithm (now on GitHub) which performs the following steps

1. Does a raw conversion of the PDF into a CSV.
2. Breaks the CSV up by line, then separates line items from unit types and other information.
3. Reads the line item to determine material type and size specifications, then determines weight of associated waste.
4. Prints line item, material, and waste to output file.

```
#Break up cell by line
for row in range(len(df.index)):
    curCell=(str.splitlines(str(df.loc[row][0])))
    #For each line, break up substrings by double space
    for line in curCell:
        curSubStrSet=line.split('  ')
        #For each substring, if substring contains '...', do more
        lineIdx=-1
        for curSubStrIdx in range(len(curSubStrSet)):
            if curSubStrSet[curSubStrIdx]!='':
                lineIdx+=1
                if lineIdx==2:
                    #Set Unit
                    unitIdx=curSubStrIdx-1
                    while unit == None:
                        if curSubStrSet[unitIdx]!='':
                            unit=curSubStrSet[unitIdx].strip()
                        else:
                            unitIdx-=1
                    if unit!=False:
                        #Set Line Item
                        lineItem = curSubStrSet[curSubStrIdx].split('...')[0].strip()
                        #Set Material
                        for material in materials_set:
                            if material in lineItem.lower():
                                curMaterial = material
                        #Set Weight
                        weight='WEIGHT'
                        if curMaterial!='MATERIAL':
                            weightRow=None
                            weightColumn=None
                            for row in range(28):
                                if curMaterial==str(weights_df.loc[row][0]):
                                    weightRow=row
                                    for col in range(6):
                                        if unit==str(weights_df.loc[0][col]):
                                            weightColumn=col
                                            if unit in square_set:
                                                depth=0
                                                if '"' in lineItem:
                                                    if '/' in lineItem:
                                                        try:
```

Excel Use

Our final step was to write excel macros to read our waste catalog

J3

```
=INDEX('https://d.docs.live.net/7e1c3008d405868a/PIT-DSC/Edited%20Cost%20Sheets/OneDrive_1_7-28-2022/[05WorkCostBreakdownforOMB (16).xls]Sheet2'!$C$2:$F$2357,MATCH(B3,'https://d.docs.live.net/7e1c3008d405868a/PIT-DSC/Edited%20Cost%20Sheets/OneDrive_1_7-28-2022/[05WorkCostBreakdownforOMB (16).xls]Sheet2'!$C$2:$C$2357,0),2)
```

PROJECT MANAGER: [redacted]
BID COMPARISON DATE:
CONTRACT #: GR1925097
ORACLE #:
BID DATE:
TITLE: Interior & Exterior Restoration @ Fredrick Samuel Houses Building #35
DEVELOPMENT: SAMUEL (MHOP) I

ITEM	DESCRIPTION OF WORK	QUANTITY	D/I	UNIT	UNIT PRICE	Adjustment Factor	Line Total	User Note	Material	Weight	Hazardous
	01 - General Requirements								#N/A	#N/A	#N/A
1	Carpenter, Heavy Construction Work	16.00	I	HR	$129.88	1.2316	$2,559.36	Probes to verify type 'A' Partition condition.	#N/A	#N/A	#N/A
2	Carpenter, Heavy Construction Work	16.00	I	HR	$129.88	1.2316	$2,559.36	2 men at 1 day to confirm operation of all windows. report to be issued to client for confirmation	#N/A	#N/A	#N/A
3	Certified Industrial Hygienist	8.00	I	HR	$125.42	1.2316	$1,235.74	Asbestos Abatement Plan	#N/A	#N/A	#N/A
4	Firewatch F01, Fireguard F60	80.00	I	HR	$25.00	1.2316	$2,463.20		#N/A	#N/A	#N/A
5	Principal Architect	40.00	I	HR	$225.00	1.2316	$11,084.40	tpp1	#N/A	#N/A	#N/A
6	Principal Engineer	40.00	I	HR	$200.00	1.2316	$9,852.80	Design for Sidewalk bridge & scaffold	#N/A	#N/A	#N/A
7	Principal Engineer	52.00	I	HR	$200.00	1.2316	$12,808.64	Shoring system & plan for stabilization of wood joist removal & replacement	#N/A	#N/A	#N/A
8	Flagperson For Traffic Control	320.00	I	HR	$76.58	1.2316	$30,181.10	2 men @ 1 month allowance for flagging deliveries, pedestrian protection during work hours	#N/A	#N/A	#N/A
9	80' Engine Powered, Articulating (Up/Over) Boom Man Lift With Platform	4.00	I	MO	$5,772.67	1.2316	$28,438.48		#N/A	#N/A	#N/A
10	2,000 Watt, 115 Volt, 2 Lamp, Portable Light Stand With Tripod	28.00	I	MO	$317.75	1.2316	$10,957.55	2 per floor @ 2 months	#N/A	#N/A	#N/A
11	5 Ton, 20' Lift, 2-Speed, 230/460 Volt, 60 Cycle, Electric Chain Hoist	6.00	I	MO	$575.00	1.2316	$4,249.02		#N/A	#N/A	#N/A
12	Up To 400#, Manual Swing Roof Hoist	4.00	I	MO	$685.32	1.2316	$3,376.16		#N/A	#N/A	#N/A
13	Electrician Minimum Charge	1.00	I	EA	$1,221.76	1.2316	$1,504.72	Confirm operation of existing kitchen exhaust	#N/A	#N/A	#N/A
14	Sheet Metal Worker Minimum Charge	1.00	I	EA	$1,056.79	1.2316	$1,301.54	Confirm operation of existing kitchen exhaust	#N/A	#N/A	#N/A
15	Bacteria Test (Total Coliform Bacteria And E. Coli Bacteria)	20.00	I	EA	$29.49	1.2316	$726.40	10% of the system capacity	#N/A	#N/A	#N/A
16	Temporary 100 Amperes, NEMA 1 Or 3R, Disconnect Switch With Fuses	1.00	I	EA	$1,577.06	1.2316	$1,942.31		#N/A	#N/A	#N/A
17	Temporary 100 Amperes, Panelboard Complete With GFCI Circuit Breakers	1.00	I	EA	$1,567.66	1.2316	$1,930.73		#N/A	#N/A	#N/A
18	Temporary 200 Amperes, Panelboard Complete With GFCI Circuit Breakers	2.00	I	EA	$2,253.85	1.2316	$5,551.68		#N/A	#N/A	#N/A
19	Temporary Branch Circuit Conduit And Wiring For Temporary Disconnect Switches And Temporary	200.00	I	LF	$7.38	1.2316	$1,817.84		#N/A	#N/A	#N/A
20	Temporary High Bay Light	42.00	I	EA	$455.33	1.2316	$23,552.95	6 units per floor x 7 =	#N/A	#N/A	#N/A
21	Temporary Wood Walkway, 3/4" Plywood On 2 x 6 Stringers	50.00	I	SF	$5.80	1.2316	$357.16		wood	2.2344	FALSE
22	Temporary Wooden Guardrail, 42" High, Posts, Handrail, And Intermediate Rail	600.00	I	LF	$34.07	1.2316	$25,176.37	4 locations of 5x5 perimeter x 6 levels of protection	#N/A	#N/A	#N/A
23	Scaffolding With Bracing Accessories - Area Based On 5' Wide Sections (CCF / Month)	1,920.00	I	CCF	$21.82	1.2316	$51,597.14	200lf @ 5x8 = 8000cf x 8 stories = 64,000 x 3 month minimum = 192,000 = 1920ccf	#N/A	#N/A	#N/A
24	Scaffolding With Bracing Accessories - Area Based On 3' Wide Sections (CCF / Month)	6.00	I	CCF	$32.73	1.2316	$241.86	10' x5'x3' = 150cf/100 = 1.5ccf x 4 months during structural replacements = 6ccf	#N/A	#N/A	#N/A
25	For Up To 25, Add	6.00	I	MOD	$13.09	1.2316	$96.73		#N/A	#N/A	#N/A
26	Up To 20' Height Scaffolding Initial Erection And Final Dismantling, Per CCF Of Scaffolding And Accessori	31.50	I	CCF	$59.29	1.2316	$2,300.18	10' x5'x3' = 150cf/100 = 1.5ccf x 7 stories x 3 locations = 31.5ccf	#N/A	#N/A	#N/A
27	>80' Height Scaffolding Initial Erection And Final Dismantling, Per CCF Of Scaffolding And Accessories	640.00	I	CCF	$112.65	1.2316	$88,793.43	200lf @ 5x8 = 8000cf x 8 stories = 64,000= 640ccf	#N/A	#N/A	#N/A
28	Netting for Exterior Building Scaffolding	281.25	I	CSF	$32.50	1.2316	$11,257.59	125' high @ 220 = 28125sf = 281.25	#N/A	#N/A	#N/A
29	10 Mil, Fire Retardant, Reinforced, Plastic Sheeting, Applied To Scaffolding	2,150.00	I	SF	$0.83	1.2316	$2,197.79	50sf/ opening @ 43 total = 2150	plastic	0	FALSE
30	Temporary Metal Door And Frame	1.00	I	EA	$626.32	1.2316	$771.38	for work isolation	#N/A	#N/A	#N/A
31	Installation of Heavy Duty Steel Post And Beam Sidewalk Bridge Assembly	200.00	I	LF	$189.74	1.2316	$46,736.76		#N/A	#N/A	#N/A
32	For Each Additional Foot Over 8' Wide, Add	1,600.00	I	MOD	$3.00	1.2316	$5,911.68	200lf x 8' wide = 1600	#N/A	#N/A	#N/A
33	For Each Additional Foot Over 8' High, Add	800.00	I	MOD	$2.00	1.2316	$1,970.56	200lf x 4' higher =800	#N/A	#N/A	#N/A
34	Monthly Rental Of Up To 8' Wide, 8' - 12' High, 2 Post System, Heavy Duty Steel Post And Beam	600.00	I	LF	$9.66	1.2316	$7,138.35	3 month minimum	#N/A	#N/A	#N/A
35	Monthly Rental of Netting for Sidewalk Bridge	600.00	I	LF	$1.61	1.2316	$1,189.73	3 month minimum	#N/A	#N/A	#N/A
36	Removal of Heavy Duty Steel Post And Beam Sidewalk Bridge Assembly	200.00	I	LF	$39.49	1.2316	$9,727.18		#N/A	#N/A	#N/A
37	For Each Additional Foot Over 8' Wide, Add	1,600.00	I	MOD	$1.25	1.2316	$2,463.20		#N/A	#N/A	#N/A

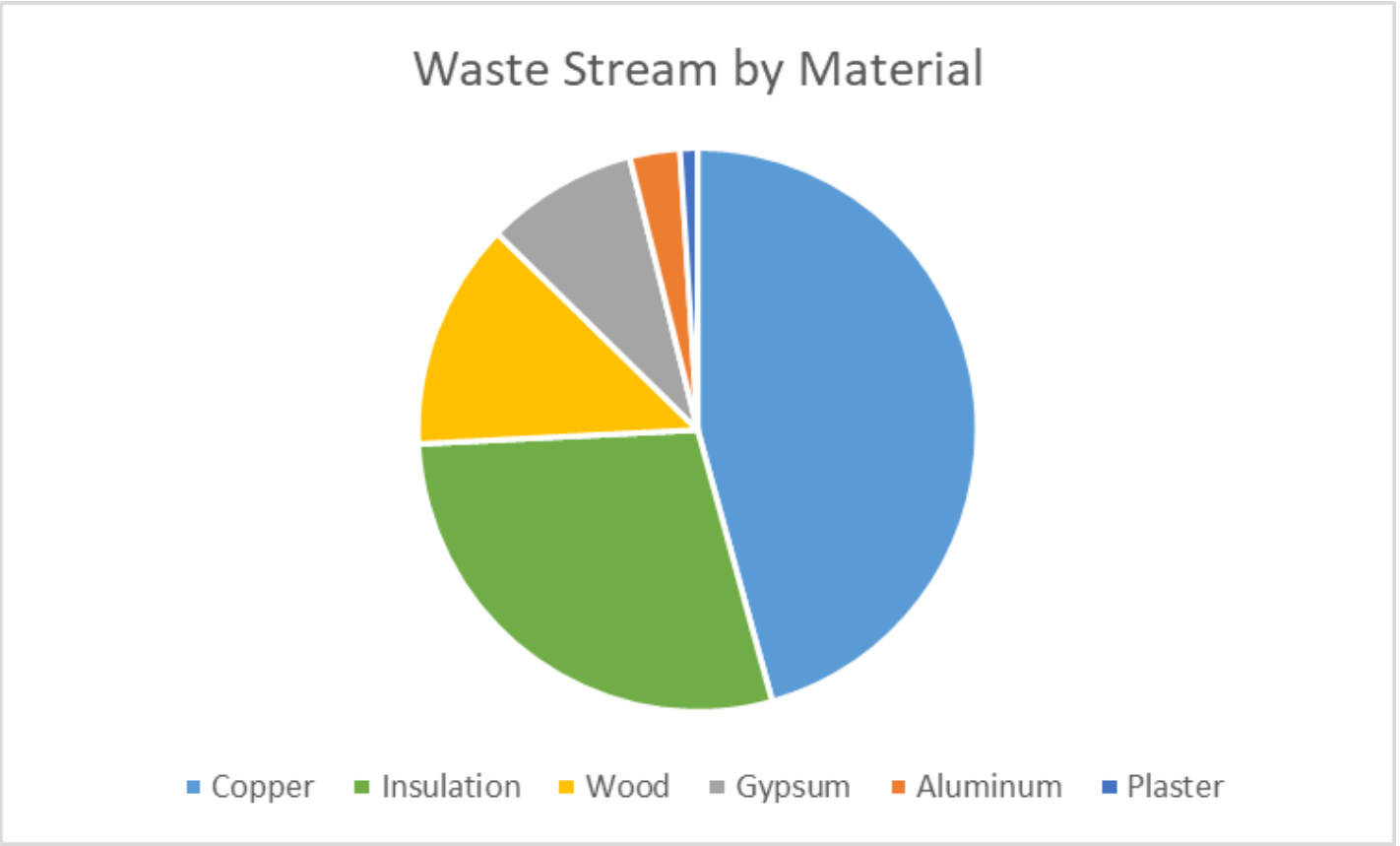
Material	Sum
steel	0
masonr	0
gypsum	5.9167
wood	5.2135
stone	0
insulatic	2.75
plaster	3.3125
linoleum	0
carpet	0
glass	0
plastic	0
vinyl	0
aluminu	15.704
copper	303.75
rubber	0
sand	0
bituminc	0
Total	336.65

Sheet1 Sheet2

Sample Cost Estimate

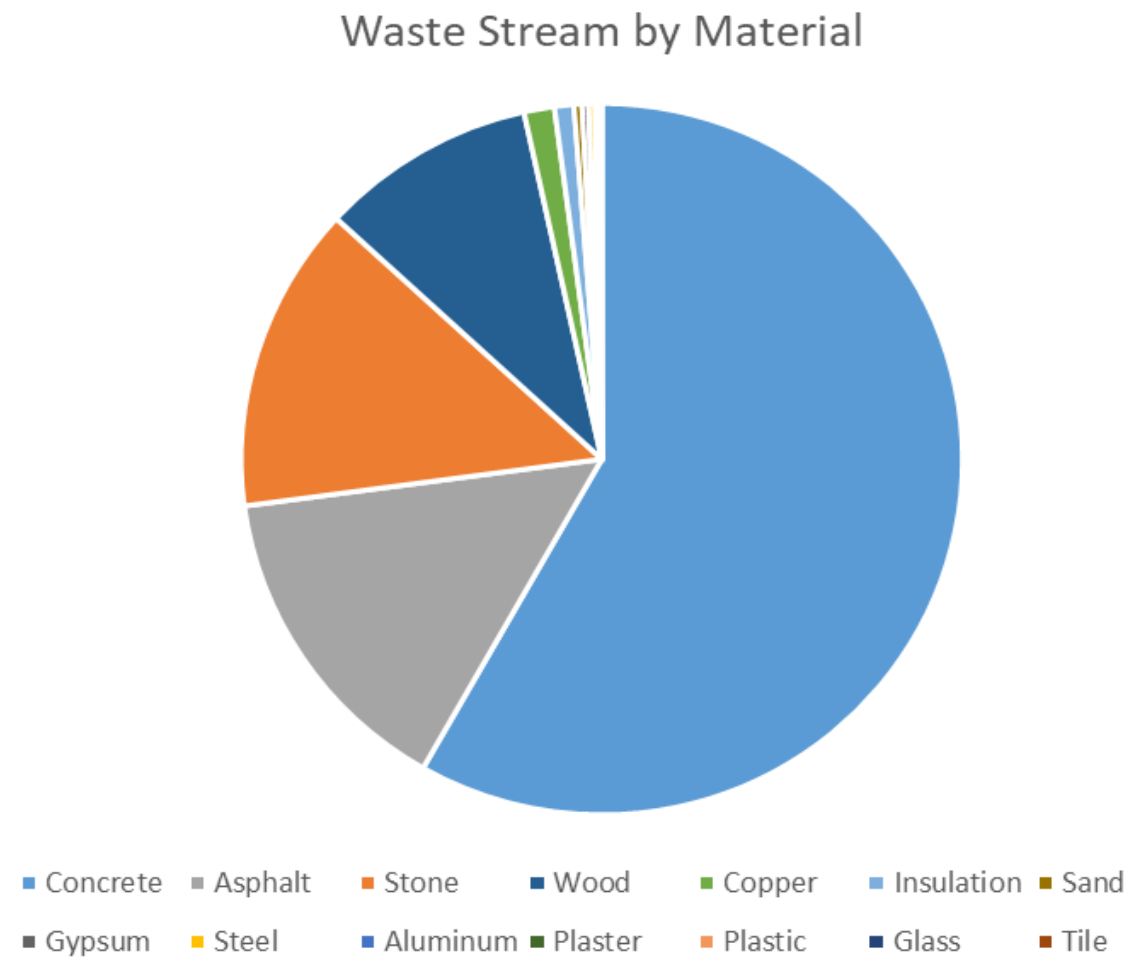
Interior & Exterior Restoration at Fredrick Samuel Houses Building #35

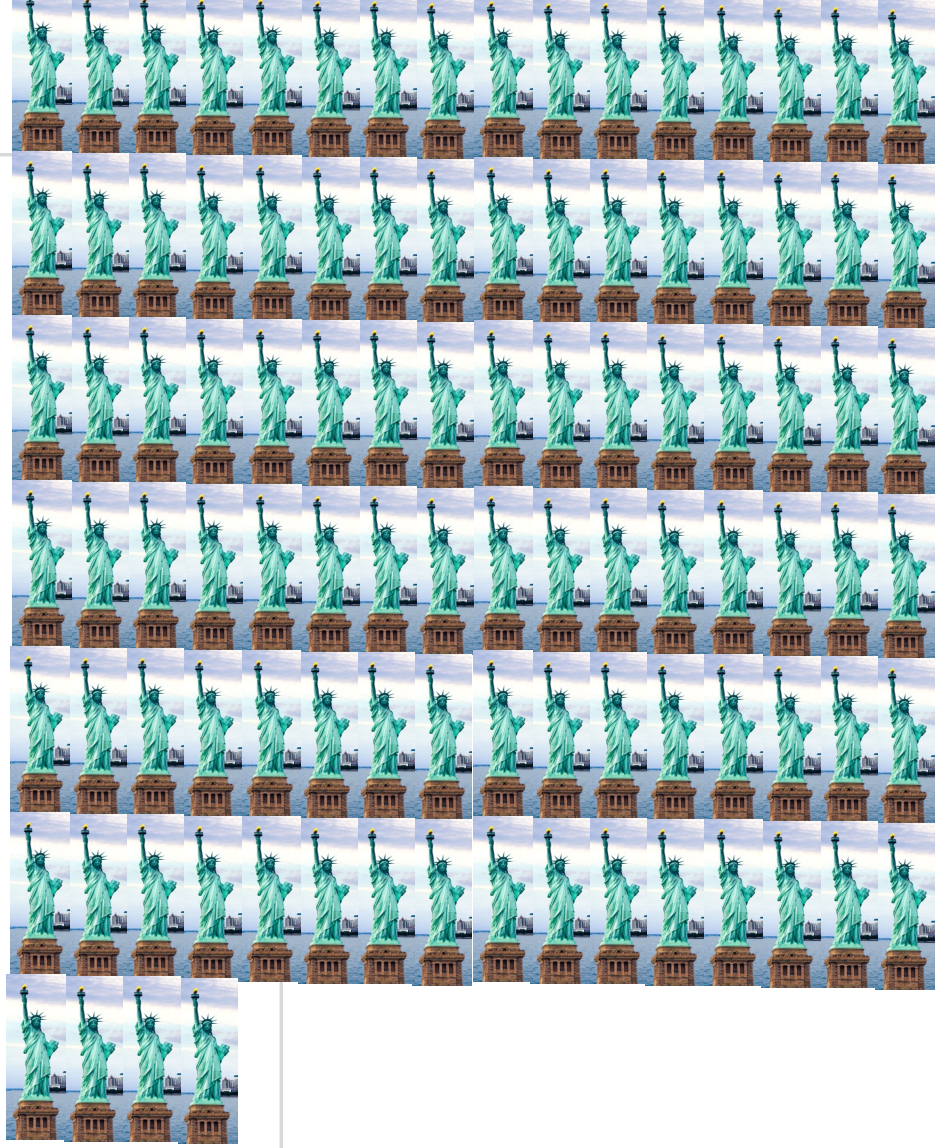
Material	Weight (lb)
Copper	75,330
Insulation	46,970
Wood	21,562
Gypsum	14,496
Aluminum	4,795
Plaster	1,670
Total	164,822



2021 Aggregate Findings

Material	Weight (lb)
Concrete	3,215,484
Asphalt	807,896
Stone	769,184
Wood	535,295
Copper	75,330
Insulation	48,001
Sand	19,750
Gypsum	16,270
Steel	15,831
Aluminum	9,318
Plaster	3,872
Plastic	2,366
Glass	675
Tile	146
Total	6,253,077





In 2021, the construction projects we analyzed produced waste equal to more than 100 Statues of Liberty.

Next Steps & Areas for Improvement

- The excel template is being left with the team, which can be modified to add additional new catalog entries. There does exist outside databases for other materials such as steel.
- The NYCHA team will also have access to our python code for instantiating the catalog and aggregating values.
- Our algorithm only processes units of cubic and square yards/feet. As a result many materials which use other less well defined unit types are typically excluded: EA, LF, etc.
- This may contribute to the underrepresentation of other materials in our waste estimates, as such, we should assume any figures produced by the current iteration of our work are lower estimates.
- Improving upon our work, it would be wise to seek to expand the number of valid line items in order to get a better estimate of true waste output.