BREATH STUDIES

CONSTRUCTION MANAGEMENT STUDIES

INTRODUCTION

Just because Memorial Sloan-Kettering has been redesigned to support the Outpatient Addition does not imply that this alternative is a logical choice. In order to determine how efficient the structure actually is, it must be analyzed from both a cost and time perspective. Even though MSK has been designed to withstand the gravity and lateral loads acting on its structure, if the building is unreasonably expensive or impractical to erect, then it simply cannot be considered as an option. This construction management study was performed with the goal of determining how expensive the structure of this addition would be compared to if it were built on the north side, as planned. In addition, a structural schedule was created to establish the time it would take to erect the five additional floors. This can be referenced in Appendix C. From these two variables, a much better conclusion was developed to whether or not this alternative design was feasible.

STRUCTURAL COST ANALYSIS

The first step in this study was to analyze Memorial Sloan Kettering's addition from a cost perspective. This task, however, proved to be more complex then initially anticipated. This was due to the fact that when designing the addition's structure system, it was also necessary to redesign the existing four stories beneath it. Those lower stories experienced a large increase in load acting on them and needed to be bulked up in member sizes. Because this action would not be necessary if the addition were placed on the north side of the existing structure, it was decided that this variable should be included in the overall addition price.

Another setback in performing this cost analysis was that there were no prices to compare the findings to. This addition is still in its design phase and because of that, there aren't any figures addressing its overall cost. All of these adaptations and setbacks made it necessary to create assumptions addressing these concerns. The assumptions made for this cost analysis are as follows:

1) The "structural cost" for this analysis will include structural steel and concrete. This includes materials, placement, labor, and formwork. See the following pages and Appendix C for a more detailed summary.

2) The total cost of this Outpatient Addition will include both the structural cost of the five additional stories <u>AND</u> the increased cost created by increasing member sizes on the first four floors.

3) Because the Outpatient Addition is almost identical to the existing structure, it is assumed that if built adjacent to the first four floors, it would cost virtually the same amount as the existing structure did. This allows for a tangible cost comparison rather then a hypothetical one.

COST ANALYSIS RESULTS

To determine the cost of only the Outpatient Addition, it was necessary to find the cost of the entire nine stories and then subtract out the existing values of the first four. That way, the value remaining would include the five additional stories and any extra cost brought about by the increased member sizes. By referencing a Financial Status Report provided by BARR & BARR BUILDERS, cost values were established for the four existing floors of Memorial Sloan Kettering. These values are shown in the chart below:

Phase One Price	
Structural Components	**Price**
Structural Steel	$1,839,199
Concrete on metal decking	$375,000
Total	**$2,214,199**

This chart takes a number of components into consideration for both of those groupings. For instance, the structural steel above includes: gravity columns, gravity beams, frame columns, frame beams, frame braces, shear studs, metal decking. Likewise, the concrete on metal decking includes: concrete slab, welded wire fabric, concrete slab edge formwork. In order to compare costs efficiently, take-offs of all these components were required.

To help accomplish this task, RAM Structural System was used to obtain take-offs for the steel members and shear studs. Metal decking quantities were determined simply by finding the floor area of each floor. The concrete component values were also conceived in a similar way, only with minor alterations. A 7% increase was added to the amount of concrete required due to spillage and shrinkage. Likewise, a 10% increase was calculated into to amount of welded wire fabric needed to account for overlapping. The required formwork for the slab edges was found using the perimeter length for each floor.

Once the take-offs were finished for all of Memorial Sloan Kettering, the only task left to do was find the overall cost. The 2006 R.S. Means was used for this process to calculate all cost values. For each price estimate, the material, labor, and equipment were all taken into account. An overhead and profit adjustment was also added into the price since these values were being compared to contract values. The following page provides a chart summarizing the structural component costs. Also, a full cost breakdown of each component by floor can be referenced in Appendix C.

Total Addition Price (Structural Steel)	
Structural Components	**Price**
Gravity Columns	$338,482
Frame Columns	$206,616
Frame Beams	$96,858
Frame Braces	$171,988
Gravity Beams	$1,905,107
Shear Studs	$46,259
Metal Decking	$1,195,026
Total	$3,960,335
Phase One Cost	$1,839,199
Addition Cost	**$2,121,136**

Total Addition Price (Structural Concrete)	
Stuctural Components	**Price**
Slab Edge Formwork	$112,680.00
Welded Wire Fabric	$58,784.83
Concrete Slab	$302,474.65
Total	**$473,939.47**

Total Addition Price	
Stuctural Components	**Price**
Structural Steel	$2,121,136
Structural Concrete	$473,939
Phase 2 Total	**$2,595,076**
Phase1 Total	**$2,214,199**
Difference	**$380,877**

From the results of this cost analysis, it has been determined that Phase Two would be more expensive to erect vertically above the existing building then if it were being build adjacent to MSK. After a further look at the breakdown of each component, these values make a lot sense. Comparing the structural steel values, Phase 2 would cost approximately $282,000 more by building the addition vertically. This is due to the fact that a vertical addition requires an additional five stories of structural steel compared to the four needed if it were built next to the building. Also, this cost includes the additional material needed by resizing the existing four stories.

When comparing the concrete values, Phase 2 costs approximately $100,000 dollars more by being built vertically. Once again, this has to do with the fact that an additional story would need to be created in order to get the addition's allotted amount of space. In terms of floor by floor cost however, the prices would be almost exact if the Outpatient Addition only required four additional floors.

ADDITION SCHEDULE

The other consideration from a construction management point of view would be the difference in schedule time between the two options. From a financial standpoint, time is money, and the more quickly the addition can be completed and put into use, the more useful it will be. Once again a number of assumptions had to be made to complete this comparison. Only the structural components of each option would be considered, and since Phase 2 is still being designed, the schedule time for Phase 1 would be used for comparison.

To determine the schedule time for Phase 2, both R.S. Means and Microsoft Project were used. R.S. Means provided a daily output value to determine how many units of a certain item could be constructed in a day. The takeoff numbers for each material were divided

by the daily output values which in turn determined the number of days required for construction. Below is a table showing the time breakdown for the erection of the existing structural system.

PHASE ONE	
Concrete	
Slab on Metal Deck (2nd Floor)	8 days
Slab on Metal Deck (3rd Floor)	8 days
Slab on Metal Deck (4th Floor)	8 days
Slab on Metal Deck (Roof)	8 days
	32 days
Structural Steel	
Steel Erection	45 days
Install Metal Deck	15 days
	60 days

Following the procedure explained on the previous page, time schedules were developed for each component of the structural system for Phase Two. In order to create an authentic time frame, labor crews were doubled for concrete installations in order to make working schedules more realistic. Crews erecting the steel structure remained the same. Below is a chart summarizing the time frames required for erecting the Outpatient Addition. An entire schedule breaking down each task can be referenced in Appendix C.

ADDITION	
Concrete	
Placing Slab Reinforcement	
6th Floor	4 days
7th Floor	4 days
8th Floor	4 days
9th Floor	4 days
Roof	4 days
	20 days
Placing Slab Edge	
6th Floor	4 days
7th Floor	4 days
8th Floor	4 days
9th Floor	4 days
Roof	4 days
	20 days
Pouring Slab on Metal Deck	
6th Floor	4 days
7th Floor	4 days
8th Floor	4 days
9th Floor	4 days
Roof	4 days
	20 days
Concrete Total	**60 days**
Structural Steel	

Structural Steel	
Steel Column Erection	
6th - 8th Floor	6 days
9th - Roof	4 days
	10 days
Steel Floor Frame Erection	
6th Floor	4 days
7th Floor	4 days
8th Floor	4 days
9th Floor	4 days
Roof	4 days
	20 days
Install Metal Deck	
6th Floor	5 days
7th Floor	5 days
8th Floor	5 days
9th Floor	5 days
Roof	5 days
	25 days
Install Shear Studs	
6th Floor	3 days
7th Floor	3 days
8th Floor	3 days
9th Floor	3 days
Roof	3 days
	15 days
Structural Steel Total	**70 days**

When the existing schedule and estimated addition schedule were compared, it was once again obvious that the addition took more time to erect. There are a number of reasons to justify the increased length. As noted in the cost analysis section, this addition possesses an additional story that needs to be erected. This explains the increase in schedule time for both the steel and the concrete. Another justification for the increase in time is that there are now more braced frames throughout the building. This difference will require additional labor hours to erect the braces into place. The final justification in the noticeable time difference is that it is more time consuming to place steel and concrete floor elevations increase. All these reasons directly result in an increase in time.

CONSTRUCTION MANAGEMENT CONCLUSION

After performing both a cost analysis and time schedule for the vertical addition, it was determined that this option was not as efficient as the original position from a cost perspective. The analysis concluded that due to an additional floor and increased member sizes, both the steel and concrete prices would increase by building vertically. Overall, erecting the Outpatient Addition on top of the existing structure would cost approximately 17% more then if it were kept where it was originally proposed to be built.

Comparing both schedules on a time perspective also displayed negative aspects for the vertical expansion of this addition. By adding those stories, the scheduled time of erection for the structural system alone increased by over 40%. This does not even consider the amount of downtime Memorial Sloan Kettering would experience from this construction as well.

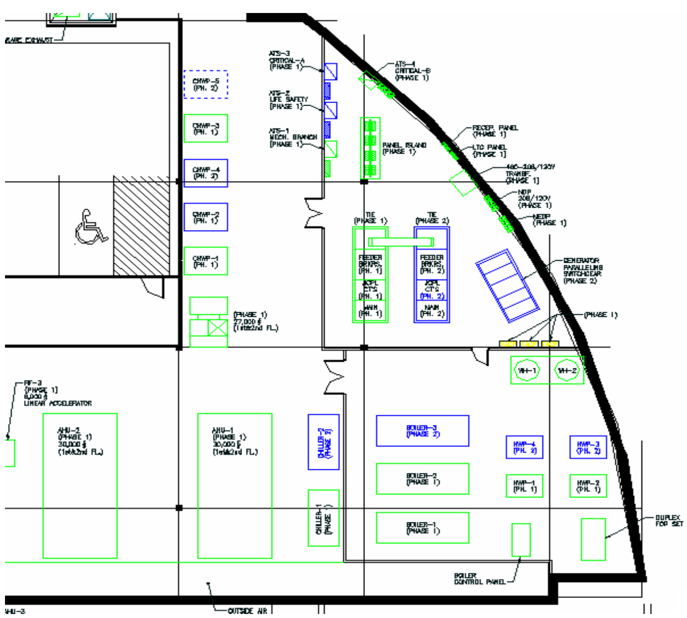
In conclusion, this construction management study proved that changing the site plan for the Outpatient Addition would prove to be an expensive choice, from both a cost and time perspective. An additional $381,000 would have to be spent on the structural system. Furthermore, it would require an extra seven weeks to construct. Memorial Sloan-Kettering would have to close for at least some of this process, creating another negative feature this proposal would create. Simply from the results of this breath study, it would be suggested that Memorial Sloan-Kettering continue with the original design of placing the addition to the north side of the existing structure.

MECHANICAL & ACOUSTIC STUDY

Erecting an addition on top of an existing, operational facility requires more then just a structural redesign. Every system within that building needs to be resized or repositioned in order to support that new area. This study focuses on the MEP system within Memorial Sloan-Kettering and more specifically the Air-Handling Units located on the roof of the existing structure. To avoid disrupting air flow in MSK and having to reposition a large amount of equipment, the 5th floor of the addition will maintain the Air-Handling Units and become a mechanical floor A layout will be formed to position all of the additional required mechanical equipment. Also, an acoustics study will be performed between the mechanical floor and adjacent floors in order to determine whether or not additional soundproofing will be required. In all, this study hopes to prove whether or not this addition is feasible from a mechanical perspective.

MECHANICAL STUDY

Now that the structural design of the Outpatient Addition is complete, its necessary to look at how that space will be provided with the essential mechanical equipment. The current mechanical room for the existing infrastructure is located in the basement. Three additional air-handling units are also located on the roof and provide air circulation for the 3rd and 4th floors. When laying out the mechanical floor plan for the existing structure, additional room was left for MEP equipment supplying Phase 2. This situation worked out perfectly for erecting the addition vertically because now the new equipment was able to be placed in the basement and only the air-handling units needed to be positioned elsewhere in the building. Below is the mechanical layout provided for both Phase 1 and Phase 2 of Memorial Sloan-Kettering. Phase 2 equipment is shown in dark blue.



Mechanical Layout

Instead of moving the three air-handling units to a different location, it proved to be simpler to leave them alone and instead make the 5^{th} floor a mechanical floor. After all, each unit is approximately 27' x 10' in dimension and weighs almost 7 kips. Two of the units provide air to the 4^{th} floor, which acts as a surgical floor, while the other circulates the 3^{rd} floor. In addition to the three existing systems, two more air-handling units were placed on this floor to supply the 6^{th} and 7^{th} floors. The 8^{th} and 9^{th} floors would have air supplied to them by units on the addition's roof.

In order to get outdoor air to the equipment on the mechanical floor, louvers needed to be installed on each exterior wall. To determine a proper dimension for each louver, it was necessary to find the required amount of fresh air needed for each unit. ASHRAE Standard 62.1 outlines proper ventilation for acceptable indoor air quality and proved to be the right place to look. Table E-1, shown below, gives outdoor air requirements for ventilation of healthcare facilities.

TABLE E-1*
Outdoor Air Requirements for Ventilation of Health Care Facilities (Hospitals, Nursing and Convalescent Homes)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/ person	L/s · person	cfm/ft²	L/s · m²	Comments
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms	20			0.50	2.50	Air shall not be recirculated into other spaces.
Physical therapy	20	15	8			

* Table E-1 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.
** Net occupiable space.

From the chart above, the 4^{th} floor fell under "operating rooms" application while the 3^{rd}, 6^{th}, and 7^{th} floors were all "medical procedure" areas. Manipulating those values gave the required amount of cubic feet per minute necessary for the entire floor. From that, it was necessary to find the average wind velocity acting in that area. For this piece of data, a RETScreen Energy Model, shown in Appendix C, was referenced for the New York City area. It was found that an average wind velocity would be somewhere around 4.9 mph, which converts to around 431.2 feet per minute. The calculations on the following page show how a louver size was determined.

Louver Calculations

Air Handling Units on 5th Floor		
Unit	**Handles**	**Dimension**
RAHU-1	3rd Floor	12' x 27'
RAHU-2	Ambulatory Surgery	12' x 27'
RAHU-3	Ambulatory Surgery	12' x 27'
RAHU-4	6th Floor	12' x 27'
RAHU-5	7th Floor	12' x 27'

TABLE E-1

ASHRAE Standard 62.1 (Ventilation for Acceptable Indoor Air Quality)		
Application	**Max Occupancy Density**	**Outdoor Air Requirement**
	#/1000 ft^2	**cmf/person**
Medical Procedure	20	15
Operating Rooms	20	30

Each Floor Area is Approximately **20,000 square feet**
Five Air Handling Units located on the 5th Floor (See Above)
- 3rd, 6th, and 7th Floors - Medical Procedure Floors
- 4th Floor - Operating Room (2 units)

Required CFM Calculations

Medical Procedure Floors

= (20 people/1000 ft^2)(20,000 ft^2) = 400 people
= (400 people)(15 cfm/person) = 6000 cfm
= (6000 cfm per floor)(3 floors) = **18,000 cfm**

Operating Room Floor

= (20 people/1000 ft^2)(20,000 ft^2) = 400 people
= (400 people)(30 cfm/person) = **12000 cfm**

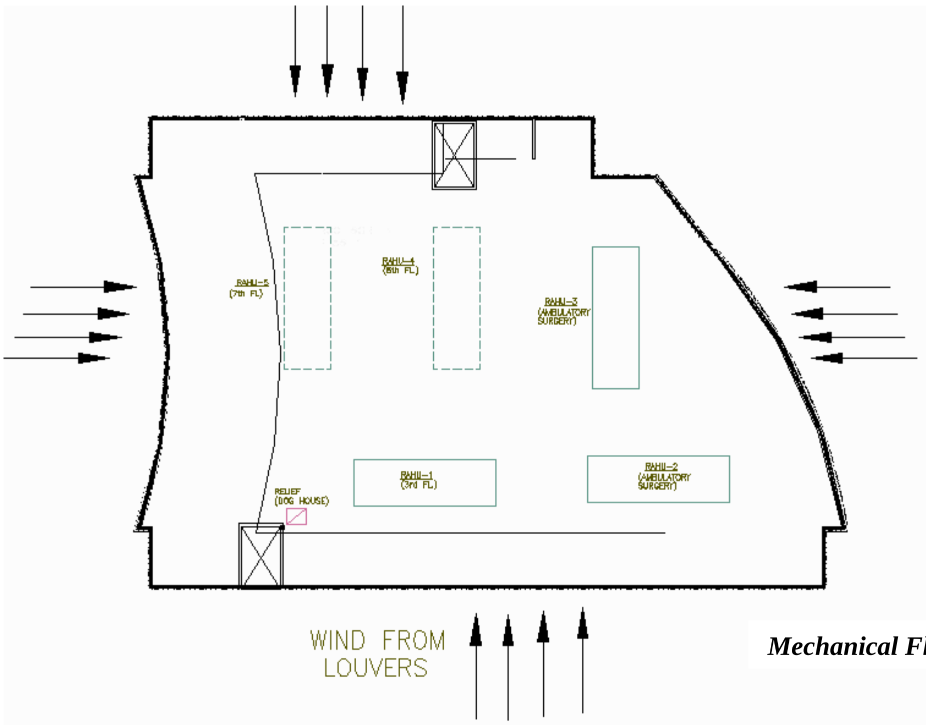
Total Required cfm = 30,000 cfm

Convert Values to Area of Louver needed (ft^2)

Wind Velocity = 4.9 mph ----> convert to ft/min = **431.2 ft/min**
cfm/(ft/min) = ft^2 -----> gives area
= (30,000 cfm)/(431.2 ft/min) = **69.57 ft^2**
- Multiply Area by 1.43, assume that louver only provides 70% free area
(1.43)*(69.57 ft^2) = **100 ft^2** per wall

- Also take into account louver size needed for maintenance/ repair
- Increase louver size to 15' x 10' , therefore **150 ft^2** per wall

From these calculations, it was determined that the minimum louver size that would provide adequate air flow into the mechanical room would be 100 square feet on each wall. However, in order to make sure that an air-handling unit would be able to be repaired, each louver size was increased to 15’ wide by 10’ high. The reason for putting a louver of each wall is so air would flow into the space no matter which direction it’s blowing. Also, this design would not allow excessive internal pressure to build up on the floor. Below is a layout of the mechanical floor. The arrows represent where wind can enter/exit from the louvers. The dashed air handling units represent those units that will supply floors on the addition.



Mechanical Floor Plan

ACOUSTIC STUDY

Once it was decided that the 5th floor of Memorial Sloan-Kettering was to become a mechanical floor, the question arose to whether or not acoustic issues would arise on the 6th and 4th floors. In terms of acoustics, different rooms have different acceptable noise levels. For a building like a healthcare facility, all floors should remain quiet enough to allow conversation while at the same time upholding privacy. Therefore, these floors should have a relatively low range of noise criteria. Noise criteria (NC) ranges provide acceptable background noise levels in order to achieve satisfactory sound isolation. The goal for this study was to determine whether these NC ranges were upheld even with the additional noise of the air-handling units.

The first task of this study was to determine the sound absorption coefficients provided from the building elements surrounding both the source and receiver areas. This helped determine how much noise would be absorbed and how much continued to the receiver areas. The mechanical room has a concrete floor and ceiling, which provide very little sound absorption. The louvers in this room, however, act as an open space and do not reflect any sound. Similarly, the materials in the office and operating room are all good sound absorbers. Once all these variables were taken into consideration and the source noise level was reduced, it was possible to determine what transmission loss value was necessary for the partition separating the source and the receiver. This transmission loss measures how much sound energy is reduced in transmission through materials. If that partition was adequate in reducing the sound into the required noise range, then no additional acoustical measures would need to be taken. Below are the calculations performed for both the operating room and private offices.

Required Transmition Loss for 4th Floor Operating Rooms

Sound Absorption coeffiecents for source and reciever rooms								
Frequency	Mechanical Room				O.R.			Source
Hz	Walls (α)	Floor (α)	Ceiling (α)	Louver (α)	Walls (α)	Floor (α)	Ceiling (α)	Lw
125	0.36	0.01	0.01	1.00	0.55	0.02	0.76	89
250	0.44	0.01	0.01	1.00	0.14	0.03	0.93	88
500	0.31	0.02	0.02	1.00	0.08	0.03	0.83	89
1000	0.29	0.02	0.02	1.00	0.04	0.03	0.99	86
2000	0.39	0.02	0.02	1.00	0.05	0.03	0.99	82
4000	0.25	0.02	0.02	1.00	0.11	0.02	0.94	77

Frequency											
Hz	α sab (avg)	Sα	RTs	α sab (avg)	Sα	RTr	RC-25 Lp	Source Lp	NR	TL	Adj TL
125	0.0817	362.56	394.81	0.4614	77.52	143.94	40	69.04	29	24.1	29.13
250	0.0954	423.52	468.20	0.3282	55.14	82.08	35	67.30	32	29.8	34.83
500	0.0813	360.70	392.61	0.2738	45.99	63.33	30	69.06	39	37.7	42.72
1000	0.0778	345.46	374.62	0.3002	50.43	72.06	25	66.26	41	39.4	44.36
2000	0.0950	421.66	465.93	0.3046	51.18	73.60	20	61.32	41	39.3	44.32
4000	0.0710	314.98	339.04	0.3148	52.89	77.19	15	57.70	43	40.5	45.50

Source				Receiver			
A (walls)	A (floor)	A (ceiling)	A (louver)	A (walls)	A (floor)	A (ceiling)	A (partition)
762	1812	1812	52	75	46.5	46.5	46.5

Mechanical Room
Floor: Concrete
Ceiling: Concrete
Walls: Coarse Concrete Block

Operating Room
Floor: Linoleum
Ceiling: 3/4" thick acoustical board
Walls: Gypsum board

Transmission Loss from Partition			
(4.5" Reinforced Concrete Slab)			
Frequency	TL (dB)	Rq'd TL	Addition TL needed?
125 Hz	48	29.13	**NO**
250 Hz	42	34.83	**NO**
500 Hz	45	42.72	**NO**
1000 Hz	56	44.36	**NO**
2000 Hz	57	44.32	**NO**
4000 Hz	66	45.50	**NO**

Required Transmition Loss for 6th Floor Private Offices

Sound Absorption coeffiecents for source and reciever rooms								
Frequency	Mechanical Room				Private Offices			Source
Hz	Walls (α)	Floor (α)	Ceiling (α)	Louver (α)	Walls (α)	Floor (α)	Ceiling (α)	Lw
125	0.36	0.01	0.01	1.00	0.55	0.02	0.76	89
250	0.44	0.01	0.01	1.00	0.14	0.06	0.93	88
500	0.31	0.02	0.02	1.00	0.08	0.14	0.83	89
1000	0.29	0.02	0.02	1.00	0.04	0.37	0.99	86
2000	0.39	0.02	0.02	1.00	0.05	0.60	0.99	82
4000	0.25	0.02	0.02	1.00	0.11	0.65	0.94	77

Frequency											
Hz	α sab (avg)	Sα	RTs	α sab (avg)	Sα	RTr	RC-30 Lp	Source Lp	NR	TL	Adj TL
125	0.0817	362.56	394.81	0.4762	57.434	109.66	**45**	69.04	24	18.1	23.08
250	0.0954	423.52	468.20	0.3037	36.622	52.59	**40**	67.30	27	24.5	29.53
500	0.0813	360.70	392.61	0.2667	32.166	43.87	**35**	69.06	34	32.1	37.08
1000	0.0778	345.46	374.62	0.3351	40.408	60.77	**30**	66.26	36	32.9	37.87
2000	0.0950	421.66	465.93	0.3935	47.452	78.23	**25**	61.32	36	31.8	36.82
4000	0.0710	314.98	339.04	0.4258	51.352	89.43	**20**	57.70	38	32.6	37.62

Source				Receiver			
A (walls)	A (floor)	A (ceiling)	A (louver)	A (walls)	A (floor)	A (ceiling)	A (partition)
762	1812	1812	52	65	27.8	27.8	27.8

Mechanical Room
Floor: Concrete
Ceiling: Concrete
Walls: Coarse Concrete Block

Operating Room
Floor: Heavy Carpet
Ceiling: 3/4" thick acoustical board
Walls: Gypsum board

Transmission Loss from Partition			
(4.5" Reinforced Concrete Slab)			
Frequency	TL (dB)	Rq'd TL	Addition TL needed?
125 Hz	48	23.08	**NO**
250 Hz	42	29.53	**NO**
500 Hz	45	37.08	**NO**
1000 Hz	56	37.87	**NO**
2000 Hz	57	36.82	**NO**
4000 Hz	66	37.62	**NO**

From the calculations provided, it was concluded that although the mechanical room would provide additional noise, it was not necessary to provide addition sound absorption in either area. The private office passed acoustic inspection with plenty of decibels to spare under all frequencies. This has to do with the amount of sound absorption throughout the space and the fact that each office only has a small partition area between them and the mechanical room.

The operating room also fell within an adequate noise criteria, however it was a lot closer to being deemed unsatisfactory. This is because a lower noise criteria of 25 was chosen due to need to effectively communicate while in surgery. At a frequency of 500 hertz, the transmission loss was separated by only 2 decibels from its required value. Still, all frequencies passed and as a result, this acoustic study has shown that there was no need to provide additional soundproofing between the mechanical room and adjacent floors.