The Palestra Building
London, England

Architectural Renderings compliments of Alsop Architects

Thesis Research Proposal

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Mechanical Option
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I. Executive Summary

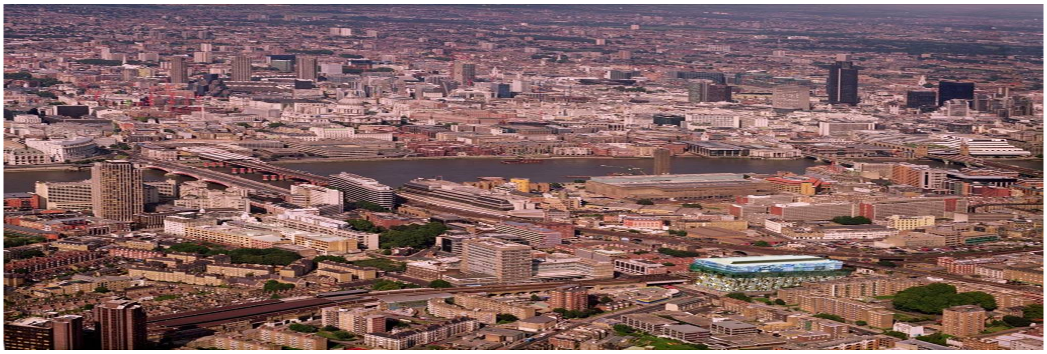
The Palestra Building is a 37,000 square meter office building under construction in the heart of London, England. It is one of the few buildings in London that has full mechanical ventilation due to the poor air quality and high noise pollution caused by its close proximity to an Underground station with connections to lines both above and below grade. This provided many challenges to the design team, in addition to the striking façade created to make this an iconic building. Cooling is provided through a chiller plant located on the roof and consisting of seven 537 kW packaged air-cooled chiller units, six of which run at full load daily, while the seventh serves as a backup unit. Heating is provided through a natural gas-fired central boiler system. The boiler room is located in the basement, and runs on four 800 kW boilers, three of which run at 100% to meet the daily demands while the fourth is a backup during times of maintenance or it can be used as a 'booster boiler' to generate the morning warm-up. The air-side ventilation system in the Palestra Building consists of a constant volume system served by seven different air handling units. Four of the AHUs are located on the roof, two are located in the basement plant room, and one is located in the level 1 mechanical space.

The purpose of this report is to propose redesigns of the building's systems in order to lower the life cycle costs of the building, reduce energy consumption, increase the BREEAM rating, and achieve Approved Document L (2006) compliance several system redesigns have been proposed. BREEAM is the UK's version of the American LEED rating, and is scored on a percentage scale. Approved Document L (Part L) is published by the Office of the Deputy Prime Minister in England regarding energy regulations for buildings, and is the equivalent of ASHRAE Standard 90.1.

Each redesign is thoroughly explained and justified in the report, and a tentative schedule for the completion of a full analysis was set. It is important to note that the proposed topics/breadths as well as the time line are subject to change.

II. Building Background/Existing Conditions

The Palestra Building is the result of a business collaboration between Insignia Richard Ellis Development and Blackfriars Investment. The team wanted to create an iconic landmark office building in southern London as an effort to spur regeneration in the area. In addition to an exciting and contemporary design, great efforts were made to develop the most efficient building from an engineering standpoint as well. With the complex structural systems incorporated throughout the building with the 'dancing columns' and 9 meter cantilever, careful integration of the building services distribution systems was imperative. Due to the 'glass box' nature of the design, a detailed solar shading study was completed to ensure system efficiency with minimal impact on the views from the office space.



However there were several challenges to Palestra's design due to its function and location. The Palestra Building is located 500 meters from the Southwark Underground station that provides connections to both above ground and below ground transportation. The close proximity of these lines demanded extra attention to the depth and location of the infrastructure of the building as well as the maximum allowable concentrated loads during the construction process. In order to avoid additional supervision and costs from National Rail all cranes and loads could not exceed 8.5 tonnes. An additional restriction was the indoor air quality and noise pollution due to the urban location. Most buildings of similar size and scope in

London, England are naturally ventilated, taking advantage of the mild climate. However, in order to maximize thermal comfort for the occupants in the Palestra building a mechanical ventilation system was installed to better control the noise and air quality issues.

The Palestra Building consists of 12 levels of open plan office space, totaling 37,098 m^2. In order maintain maximum flexibility in the layout of the office spaces the mechanical systems were distributed in such a way to allow up to four tenants per floor (i.e. four zones per level). A detailed breakdown of the areas can be found in Table 2.1.

Table 2.1 Space and Occupancy Design Loads

Space	Area, m^2	Occupancy
Office Space	31606	2202
Water Closets	1125	0
Reception	772	129
Sprinkler Plant	406	1
Boiler Rooms	273	1
Corridors	608	0
TOTAL	**34790**	**2333**

The building's heating, ventilation, and air conditioning are supplied through a Central Chiller Plant located on the roof, a Central Boiler Plant located in the Basement, as well as seven air handling units located throughout the building. The majority of the Palestra's proposed redesign will focus on these mechanical systems.

Air-Side Systems

The air-side ventilation system in the Palestra Building consists of a constant volume system served by seven different air handling units. Four of the AHUs are located on the roof, two are located in the basement plant room, and one is located in the level 1 mechanical space.

Air Handling Units 1 and 2 are located on the roof and supply air to $16107m^2$ of open plan office space disbursed evenly throughout the twelve levels at a rate of 38,139.84 cfm. Each AHU maintains a negative pressure of 500 Pa, and includes a heat exchanger in the form of a heat wheel, a cooling coil, a heating coil, a panel filter of grade G4, and a variable frequency drive supply and extract fan.

Air Handling Units 3 and 4 service the building's water closets and are also located in the roof ventilation plant. Unit 3 supplies air to 498m2 of toilets on the west side of the building, and Unit 4 supplies ventilation to 627m2 of toilet space on the east side. Each unit is sized to supply 6,420.21cfm to their respective areas. These are constant volume systems, and each includes a frost coil, cooling coil, heating coil, as well as supply and extract fans.

Air Handling Units 5 and 6 are located in the basement plant room. Units 5 and 6 are design to serve as extract systems for the toilets as well as the sprinkler plant and boiler rooms. Each unit includes a panel filter of grade G4, a cooling coil, and a heating coil. Units 5 and 6 were designed to provide adequate smoke clearance to these vital mechanical spaces with a flow of 6,356.64 cfm. Approved Document F requires a minimum of 12 m/s face velocity for ventilation extract in the case of fire.

Air Handling Unit 7 is located in the Ground Floor mechanical room and solely supplies air to the reception area, 772m2, at a constant volume flow rate of 7,627.97 cfm. This unit contains a heating coil, cooling coil, a panel filter of grade G4, as well as, supply and extract fans.

Water-Side Systems

The Palestra Building's water-side systems consist of a centralized boiler and chiller plant. Cooling is provided through a chiller plant located on the roof and consisting of seven 537 kW packaged air-cooled chiller units, six of which run at full load daily, while the seventh serves as a backup unit. The total estimated cooling load for the building is 3,291 kW. Chilled water is provided to the building at 7ºC and returned to the plant at 12ºC. These units run the building's chilled water system fed to the fan coil units and cooling coils in the air handling plant. The primary and secondary constant temperature pumps and circuits are located on the room next to the chiller units.

Heating is provided through a natural gas-fired central boiler system. The boiler room is located in the basement, and runs on four 800 kW boilers, three of which run at 100% to meet the daily demands while the fourth is a backup during times of maintenance or it can be used as a 'booster boiler' to generate the morning warm-up. The estimated heating load for the building is 2,135 kW. These boilers serve a low temperature hot water system fed to AHU ventilation systems, fan coil units, and heater batteries and operate with an 11ºC differential.

In addition to these systems there are 314 fan coil units placed on a grid system throughout the building to maximize thermal comfort. The grid layout reiterates the design goal to create office spaces that will meet the needs of current and future tenants. Depending on the desired office layout of the tenant more FCUs can be added for increase climate control for the employees. This is based on a four-pipe fan coil system used on each office level, including water-side controls for responsible operation, room temperature sensors, and variable speed heating and chilled water pumps to conserve energy.

III. Proposal Objectives

There are several primary objectives for this research and redesign of the systems currently in the Palestra Building: to lower the life cycle costs of the building, reduce energy consumption, increase the BREEAM rating, and achieve Part L (2006) compliance.

Lowering life cycle costs without compromising the integrity of the systems has many benefits, most importantly a faster return on investment for the building owner/developer. These savings may also be passed along to the tenants through rental rates, creating more desirable spaces. Life cycle costs take into account many financial issues including first costs, operating costs, and maintenance costs. Ensuring that the proposed design is the best choice with respect to function, longevity, and cost is also an important component of the value engineering provided to the client.

Reducing the overall energy consumption of the building is one of the best ways to work towards lowering life cycle costs as well. As the availability of fossil fuels continues to become more critical a stronger emphasis is being placed on energy efficient equipment and alternative methods of energy production. Electrical costs in the UK are currently on the rise as well, and reducing the electrical load specifically would be valuable.

The Palestra Building was created to be an iconic office building with desirable spaces to rent. Part of the initial design concept was to achieve a design that was both eye-catching and sustainable gaining BREEAM certification. BREEAM, The Building Research Environmental Assessment Method, is the UK's version of the American LEED program. BREEAM is specified for commercial buildings.

Currently the Palestra Building is rated as 'Good' according to BREEAM, following the 'Very Good' and 'Excellent' ratings. This objective will be affected by the previous two goals, and if they are achieved they will most likely improve this rating. However, a study of alternative methods to strengthen this rating will also be completed.

The final objective for this redesign is to also find a reasonable method of compliance to the newest energy regulations in the UK published by the Office of the Deputy Prime Minister (ODPM) in the Approved Document L regulation the energy consumption in buildings. The most significant changes to this document include a 28% decrease in carbon emissions as compared to a typical building of similar size and scope. These new regulations do not apply to the Palestra building, however they are expected to have a profound impact on the engineering community in the UK, and the results from this investigation with respect to Palestra could provide valuable data to the stakeholders in the project and supplementing where precedence studies would normally be used.

All of these objectives are acutely related to one another, and thus extreme success in one area will positively impact the other goals. Each proposed design will be judged based on these criteria to determine their success within the Palestra building.

IV. Preliminary Design Considerations

Several schemes for a mechanical redesign of the Palestra Building were contemplated during the research of existing systems. These included a Combined Heat and Power plant, Day lighting Aperture Optimization, and possibly implementing a hybrid chilled water system.

Building Combined Heat and Power (BCHP) is becoming increasingly popular as a means to increase system efficiency and thus decrease emissions by fully burning more of the energy inputted. With the new emission regulations outlined in Approved Document L and the increasing rates for electricity this seemed to be an interesting solution. However BCHP requires a large amount of waste heat and a fairly constant demand load to be most successful. One possibility was to coordinate a system between Palestra and the surrounding residential buildings to balance each buildings' demand peaks, as well as provide the necessary amount of waste heat. The Palestra already shares an electrical substation in its basement with several surrounding buildings, so this would have been a continuation of the current setup. This proposal would require extreme coordination with many stakeholders, and also require a large amount of floor space in the Palestra Building which is at a premium. The commitment on behalf of Palestra's owner would significantly increase, which may not be of interest to them regardless of the long term gains.

Maximizing the benefits of day lighting can have a large impact on the energy efficiency of a building, especially within the Palestra Building's 'glass box' design. By increasing the window efficiency and minimizing the glazing area the overall design could benefit from the increased insulation. However, due to the extensive research already done in this area by the design team, there is little probability that a better design could be achieved without sacrificing the design's architectural integrity. Therefore the efforts of this research would be better served investigating other topics.

A hybrid chilled water plant was also a consideration. This design would include base-loaded electric chillers with gas engine-driven chillers to follow the daily demand curve. Electric motors have their highest performance when running close to full load, while gas engines have much higher part load efficiencies. Therefore in a system like this you are optimizing the performance of all units in the system. There is also an advantage to have a duel-fuel system such as this because major swings in gas and electric costs will not have a dramatic impact on the building's operating costs. In addition, heat recovery systems can be added to the gas engines to increase efficiency further, as well as decrease emissions. While there is a lot of potential with this type of system, the maintenance and first costs are high with a need for larger mechanical spaces as well. The demand curve for the Palestra building dedicated to office space is also not ideal for such a design. From the estimated load profiles a base load would be 120 ton of the 915 ton peak, which is only 13% of the demand. And with predictions for the range between gas and electric prices to only increase in the UK over the next fifty years, an all-gas system could have more advantages.

V. Proposed Mechanical Redesign

Following much consideration to the design objectives of the Palestra Building and the research objectives for this study the following scope was defined have the most potential.

Scope

The main mechanical redesign objectives will be a study optimizing the cooling systems within the building. Research will be completed comparing the existing chiller plant design with two additional alternatives.

The first design replaces the current electrical chillers with gas-fired chillers coupled with thermal storage and the existing gas-fired boilers. The current chiller plant in the Palestra Building utilizes electric chillers and provides 18% additional capacity on the system. While this system functions well in the space, it accumulates large operating costs in order to meet the peak electric loads during the day. Therefore a combination of a gas-engine driven chiller in addition to thermal storage will be considered. An enthalpy wheel will also be added to this design for maximum humidity control in the building. Currently there is no humidity control in the building, and with the mild climate found in the UK humidity is typically only a concern during the winter months when it can drop below 35%.

The second design is the installation of a dedicated outdoor air system (DOAS) supplemented with radiant ceiling panels throughout the building. DOAS not only reduces the ductwork and equipment sizes, but also increases humidity control and reduces energy and first costs. This system meets the latent loads by providing dry outdoor air at low temperatures, while the sensible load is accounted by using the radiant ceiling beams. An additional benefit of this system is the increased indoor air quality. DOAS could prove to solve several of the design challenges that faced the Palestra Building regarding its urban location and lack of humidity controls.

<u>Justification</u>

Both the thermal storage and DOAS systems can significantly reduce the electrical demands especially at peak hours decreasing operating costs, and can help to reduce the building's environmental impact. These were two of the prime objectives for this research. With such an innovative technology as DOAS additional BREEAM credits could be gained, while reducing emissions in compliance with the new regulations in Approved Document L. The addition of thermal storage could increase first costs, but should be offset by the operating costs thus decreasing the overall life cycle costs.

If time permits additional heat recovery technology could be applied to the first proposed redesign to maximize the system efficiency while also decreasing emissions from the fuel combustion by burning it as thoroughly as possible.

<u>Coordination and Integration</u>

The most important coordination of the proposed systems with the existing conditions will be the replacement and/or relocation of equipment. Luckily due to the centralized plant areas renovations to any of the major mechanical systems can be localized to the basement and roof, with minimal disruption to the rest of the building.

There is a significant advantage to the air handling units and chillers being located on the roof due to the lack of space restrictions. The current equipment accounts for only a small percentage of the rooftop area, which is also a space that has low value in the eyes of the developer. However there are space restrictions in the basement with the boiler plant. The addition of thermal storage would require a significant amount of additional space. There is a small allotment of parking spaces in the basement, some of which could be sacrificed for such systems, but it would affect the economic success of such a design.

As noted before the ductwork and equipment sizes for a DOAS system should also decrease, increasing available floor area and thus receiving additional financial benefits. The radiant ceiling panels will also need to be coordinated with the existing lighting grid.

VI. Breadth Areas

The proposed changes to the mechanical systems in the Palestra will have an impact on the other systems in the building and must be accounted for in order to effectively increase the overall efficiency of the building. By adjusting the lighting, electrical and structural systems this also provides an opportunity to align these systems to increase the success of the redesign.

Structural

The structural systems of the building will have to be checked where there is a significant change in the load. In a system such as DOAS this could result in lighter structural elements with first costs savings. However with gas-engine driven chillers there could be a need for additional reinforcement depending on the size and number of the units to be installed.

The maximum load of the basement slab will also need to be addressed if the proposed thermal storage is to be placed in the area currently designated for car parking.

Lighting

With the installation of a radiant ceiling strong coordination with the existing lighting grids will be required. The current design includes recessed fluorescent fixtures throughout the office space. However to maximize the radiant ceilings it is best to suspend them from the ceiling in order to gain the benefits of the convection of air over the top of the unit in addition to the radiant qualities from below. This could hinder the lighting levels at the work level in the office. A lighting study will need to be completed in order to find the most efficient fixture for the space. The results of this selection could affect the structural member the fixtures hang from and the electrical power needed for lighting throughout the building.

Electrical

Both proposed redesigns of the mechanical systems should decrease the overall electrical demand on the building, thereby decreasing the size of equipment needed. It is important to note that there is an electrical substation located in the basement of Palestra that services several surrounding buildings. Therefore there could be limitations on the possible savings.

VII. Project Methods

There will be a variety of project methods used throughout the proposed research for the Palestra Building. Here is a description of the methods that will be used, however depending on the success additional procedures may be added to improve accuracy with respect to this building.

The redesign of the mechanical systems affecting the ventilation and chiller plants can be simulated through the use of Carrier's Hourly Analysis Program (HAP). Calculations for thermal storage and enthalpy wheels will be done using Microsoft Excel and Engineering Equation Solver (EES). References to the building's specifications as well as British Standards, Approved Documents, and CIBSE's guides of good practice will be utilized to ensure all inputs are accurate. Manufacturers' data will be collected regarding the proposed equipment for each redesign.

The electrical and lighting calculations will be completed using Microsoft Excel, and again utilizing the appropriate manufacturers' data for the selected equipment. Additional lighting simulations may be done using 3D Viz, using equipment specifications.

A structural analysis will be completed in areas where there is a dramatic load shift to ensure the stability of the members and to appropriately decrease the members that will carry less load. This analysis will be completed using both STAAD and Microsoft Excel.

VIII. Preliminary Research

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Appendix A:

Tentative Schedule of Research

January 2006

January 2006

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February 2006

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5	6	7	8	9	10	11
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26	27	28				

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
					January 1, 2006
2	3	4	5	6	7 8
9 DOAS Simulation with Radiant Ceiling Panels First Day of Classes	10 DOAS Simulation with Radiant Ceiling Panels	11 DOAS Simulation with Radiant Ceiling Panels	12 DOAS Simulation with Radiant Ceiling Panels	13 DOAS Simulation with Radiant Ceiling Panels	14 DOAS Simulation with Radiant Ceiling Panels Possible Office Visit 15 DOAS Simulation with Radiant Cei Possible Office Visit
16 DOAS Simulation with Radiant Ceiling Panels	17 DOAS Simulation with Radiant Ceiling Panels	18 ASHRAE Winter Conference (Chicago, IL)	19 ASHRAE Winter Conference (Chicago, IL)	20 ASHRAE Winter Conference (Chicago, IL)	21 ASHRAE Winter Conference (Chicago, IL) 22 ASHRAE Winter Conference (Chica
23 Chiller Plant Optimization (All Gas system)	24 Chiller Plant Optimization (All Gas system)	25 Chiller Plant Optimization (All Gas system)	26 Chiller Plant Optimization (All Gas system)	27 Chiller Plant Optimization (All Gas system)	28 Greek Christian Leadership Confer 29 Greek Christian Leadership Confer
30 Chiller Plant Optimization (All Gas + Heat Recovery)	31 Chiller Plant Optimization (All Gas + Heat Recovery)				

February 2006

February 2006						
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March 2006						
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Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
		February 1	2	3	4
		Chiller Plant Optimization (All Gas + Heat Recovery)			Possible Office Visit
					5 Chiller Plant Optimization (All Gas; Possible Office Visit
6	7	8	9	10	11
Chiller Plant Optimization (All Gas + Heat Recovery)					
					12 Chiller Plant Optimization (All Gas
13	14	15	16	17	18 Penn State Dance Marathon
Chiller Plant Optimization (All Gas + Heat Recovery)					19 Penn State Dance Marathon
20	21	22	23	24	25
Chiller Plant Optimization (All Gas + Thermal Storage)					
Lighting/Electrical Breadth Studies (Fixture Layout, Equipment Sizing)					26 Chiller Plant Optimization (All Gas
27	28				
Chiller Plant Optimization (All Gas + Thermal Storage)					
Structural Breadth Study (Checking Structural Members)					

March 2006

March 2006						
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April 2006						
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30						

Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
		March 1	2	3	4
		Chiller Plant Optimization (All Gas + Thermal Storage)			Spring Break - Thesis Research On
		Structural Breadth Study (Checking Structural Members)			5
					Spring Break - Thesis Research On
6	7	8	9	10	11
Spring Break - Thesis Research On-Site (London, England)					
					12
					Spring Break - Thesis Research On
13	14	15	16	17	18
Finalizing Conclusions of Research, Coordinating results from Site Visit					
					19
					Finalizing Conclusions of Research
20	21	22	23	24	25
Finalizing Conclusions of Research, Coordinating results from Site Visit					
			My 23rd Birthday		26
					Finalizing Conclusions of Research
27	28	29	30	31	
Formatting Final Paper					

April 2006

April 2006						
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May 2006						
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Monday	Tuesday	Wednesday	Thursday	Friday	Sat/Sun
					April 1 Formatting Final Paper 2 Formatting Final Paper
3 Formatting Final Paper	4	5 Thesis Paper Due	6	7	8 9
10 Thesis Presentations	11	12	13	14	15 16
17	18	19	20	21	22 23
24	25	26	27	28	29 30