Energy Analysis: The Impacts of the Curtain Wall System

Executive Summary of Analysis

Minor components of a building can have major impacts on the buildings costs to the owner. While initial costs can be a significant burden to an owner, the life cycle costs can add up to double, or even triple the initial cost of a component in just a few years.

With this in mind, the curtain wall system for this project will be analyzed and changes suggested according to the efficiency of the curtain wall and glazing. Changes to components include the glazing material, the number of layers of glass, the framing materials, and the coatings applied to the glass.

The effects of each of these changes are quantified and evaluated to give the owner the information necessary to make the best decision based on their interests. Since this is a public owner, funded with taxpayer’s money, the life cycle costs have a large impact on decisions made surrounding the design of the building.
Overview

The exterior façade of Connector B is made up primarily of a glazed curtain wall, 30 feet in height by 40 feet in width on the North side of the building alone. Another 30 feet in height by 10 feet in width is on both the East and West sides of the building. The following set of images depicts a wire frame model of the building, and the curtain wall in question, respectively.

Due to a façade composed primarily of glazing, an efficient façade is critical if the building is to be energy efficient. Before changing the glazing, one important constraint must be addressed – the owner has stipulated that the glazing must appear similar to the surrounding buildings. However the glazing components can be changed while keeping the appearance
similar. The existing design consists of a double glazed system with ½” air gap. A 2 ½”
aluminum frame with a thermal break is used for support and as an architectural feature.

Through the specifications, the curtain wall system is required to have a thermal conductance with an average U-value of 0.66 BTU/(hr-ft²-˚F). Since the curtain wall is the only separation of passengers from the taxiway, the system is required to have average sound transmission losses of not less than 34 dB. Air infiltration can not exceed 0.06 CFM/SF of wall area.

The current glazing has a coating applied to give the window a darker tint and a shaded appearance. The glazing also has a low-e coating, which will provide increased resistance to solar heat gain.

The current design of the glazing has a unique feature. While it is only considered a double glazed window, there are in fact three layers of glass. From the exterior, there is a ¼” piece of glass, a ½” air space, a 1/8” piece of glass, and a polyvinyl inner layer sandwiched by another 1/8” piece of glass. While this design gives the building added sound protection and security, it costs over twice as much as a design without the polyvinyl inner layer.

This analysis will serve to evaluate the effectiveness of the curtain wall as designed for this project, and compare the current design to available alternatives.

**Modeling of the Current System**

**Overview**

An energy modeling program, Energy10, was used to develop a model of the space enclosed by the glazed curtain wall. In this area of Connector B, the floor is open to all four stories to allow for the escalators to transport the passengers from the tunnel level to the concourse level, as shown. When looking up from the tunnel level (the lowest level) the roof can be seen.

![3D view from the Southwest depicting open floor spaces in cyan](image-url)
The open floor space is a key architectural feature of the building and will need to be incorporated into the model. Restraints in Energy10 required the model to be limited to only the above grade portion of the building, therefore the model will incorporate only the apron level and the concourse level, resembling the following.

Analyzing the space in further detail, no floor exists in the area to separate the two stories, therefore one story was used with a 30’ ceiling height, as opposed to two stories each with a 15’ ceiling height. This assumption is valid due to no separation of the apron and concourse levels.

Since the only change being made is to the glazing, the building was simplified to one space. The space designed is a box, 40 feet wide on the North and South sides, 45 feet long on the East and West sides, and 30 feet in height, as shown above.

The building was first modeled to resemble the function of the glazed curtain wall as if no coatings were used on the surfaces of the glass. Many aspects of the design have been changed from the actual design in order to simplify the model, and concentrate on the glazed curtain wall.

**Building Enclosure**

A major assumption made in the modeling process was no changes would be made to any systems except for the glazing. Since this is the case, the actual design of the walls, floors, and roof is insignificant, but efforts were made to resemble the actual design as closely as possible. The construction of the exterior walls was modeled as a typical 8” CMU block wall with an R-value of 2.2, a built-up roof with an R-value of 19, and a floor composed of a slab over a basement to simulate the levels below.

**Windows**

The modeling of windows was done with great care so as to ensure reliable results. The original design consisted of double-glazing with \( \frac{1}{2} \)” airspace and a 2-\( \frac{1}{2} \)” aluminum frame with a thermal break.

The glazing component used in Energy10 for an alternate design is **4060 double, alum** meaning double-glazing is used within an aluminum frame. The frame is modeled as **al w/break**, aluminum with a thermal break, with a user specified value of 2.5” wide frame. The PFD width,
which represents the portion of the frame plus a portion of the glazing that is thermally affected by the frame, is 0.75” greater than the frame width, or 3.25”. An overall U-value for this system is 0.509 BTU/(hr-ft²-˚F). The large difference seen in comparing this system to the actual system on the project is due to the addition of a low-e coating. A cost increase of approximately $1-2 per SF of glazing area will be seen to add this coating.

A constant window size of 60” x 72”, or 30 SF, was used throughout the modeling. This was calculated to ensure the same lineal feet of frame is consistent with the actual design, without complicating the model with numerous window sizes. By keeping the model simplified, the model stays flexible for future changes to the systems. A total of 40 windows were used on the North side of the building, resulting in 1200 SF of windows on 1200 SF of façade. The East and West side of the building each have 10 windows, resulting in 300 SF of windows on 1350 SF of façade on each side. The South side of the building has no windows as it connects to the existing Concourse B.

**Interior Systems**

Interior partitions and fixtures were excluded from the model, meaning no thermal mass will be taken into account within the space. This is quite contradictory to the actual layout of the building due to the presence of four, four-story escalators which run through the space, however the additions of this equipment was assumed to have little or no impact on the changes to the amount of energy used correlating to changes in the design of the curtain wall.

Air infiltration was modeled in this process by establishing an Effective Leakage Area, ELA. The ELA was calculated by multiplying the total gross wall area by 0.00090, a constant established as typical construction. This value does not change.

The mechanical system used in the model is DX Cooling with Gas Furnace, the system which most closely resembles the actual mechanical system for the project. An economizer is also used in the model, with a fixed dry bulb temperature of 65°F.

One lighting zone was created to simulate the internal gains created by the light fixtures in the space. Since fixtures in the space have not yet been approved, a default value of 0.82 W/SF was used as the peak value. Internal gains due to occupants and other fixtures such as the 4 story escalators are also included in this section.

**Value Engineering Suggestions**

**Improvements**

Main window components that affect the overall R-value of a window system:
- Type of glazing material
- The numbers of layers of glass
- The size of the air space between the layers of glass
- The thermal resistance or conductance of the frame and spacer materials
- The “tightness” of the installation, factoring into the air infiltration of the system

*This list was found on the Department of Energy’s website, http://www.eere.energy.gov/consumerinfo/factsheets/eewindows.html on 3/26/04.*

**Applications**

Applying these techniques to this project, several options are available, including:
- Increase glazing from double to triple
- Add a coating to the glazing
- Add window shading
- Change the aluminum framing design, to include more efficient thermal breaks, alternate materials

**Evaluation**

In order for a change to the current system to truly be a Value Engineering idea, the change must increase the overall value, either through increasing quality at the same cost, or recovering an additional cost over the life cycle of the building. Changes in regular maintenance also need to be addressed. A less expensive component that needs increased maintenance would not present any value to the owner.

Adding a layer of glass to create a triple-glazed system will certainly increase the thermal resistance of the building, decreasing energy costs. This change would not affect the regular maintenance of the area. However adding a layer of glass will increase the initial cost significantly. In order to evaluate this change, an energy study will need to be done to quantify the amount of energy saved. According to the glazing subcontractor on the project, triple glazing is rarely used except for situations where sound transmission is a major concern. Even though the sound transmission is a concern on the project, it does not represent such a concern as to justify triple glazing all windows.

Adding a low-e coating to the glazing will have the same effect as adding a layer of glass (see US DOE EERE Energy-Efficient Windows, http://www.eere.energy.gov/consumerinfo/factsheets/eewindows.html, 3/26/04), but the increases to cost and weight is significantly less.

Since the design of the system already has a low-e coating, an analysis could be performed to detail the cost increases due to the coating, as well as the life cycle cost savings.

The addition of window shading is another option; however the results may lead to undesirable effects due to the orientation of the building. The glazed curtain wall is on the north side of the building, therefore minimal solar gain will be seen as compared to if it was on the south side of the building.

Changing the thermal breaks to a material with less conductivity would increase the thermal resistance of the system. Upon examination of the current design, there is not another option for materials to be used in the frame of the window.

**Modeling of the Redesigned System**

**Impact of the low-e coating**

Limited changes were made to this system for each value engineering suggestion. The first improved model changed only the type of coating on the windows, keeping size and all other construction systems constant. The low-e coating was eliminated from the design, saving approximately $1-2 per square foot of glazing area. With the elimination of this coating, the U-value increases from 0.29 BTU/(hr-ft²-°F) up to 0.49 BTU/(hr-ft²-°F). Initial cost savings at a maximum of $2 per square foot over 1800 square feet of glazing result in a credit back to the owner of approximately $3600. All other enclosure and interior systems remained the same for the alternate system analysis.

Running the analysis of the system with low-e coating compared to the system without low-e coating gave some promising results. The building with low-e coating saved 8% or $235 per year in heating fuel usage, and 14% or $335 per year in electric usage. While the HVAC system for the building does not have an independent system due to the infrastructure in place on
the airport, an energy savings will still be seen. Due to a decreased amount of cooling needed for the space due to the low-e coating, the HVAC systems could also be downsized approximately 10% for additional cost savings.

With the addition of a thin low-e coating, major cost savings were found. The coating serves to reflect heat back towards the source; if the source is inside, heat is reflected back towards the building. When used on the South side of a building, solar heat gain can be greatly reduced with the use of low-e coatings.

Addition of window shading

In this analysis, window shading will be added to the original system with the low-e coating. The shading will be designed in relation to the building’s latitude of approximately 40 degrees. The shading will serve to block excess solar gain in the cooling months, while allowing solar gain during the heating months.

The overall U-value of the system does not change, as the shading is added to the exterior of the building and does not affect the system’s thermal resistance properties.

Running the analysis of window shading compared to no window shading returned unfavorable results for the addition window-shading component. Due to the glazing being primarily on the north side of the building, heating costs actually increased 3% or about $45 per year due to the decrease in solar gain in the heating months. Electricity usage was reduced 10% or approximately $180 per year. This scenario does not lend an additional change to the HVAC system, as the heating system has only slightly changed.

While minor cost savings are seen with the addition of window shading, the additional first cost and maintenance costs must also be taken into account. Aesthetics are another major factor as the owner wishes for this building to blend in with the surrounding architecture. Due to these concerns, window shading should not be considered a value engineering option.

Triple glazing vs. Double glazing

As previously mentioned, the effects of adding another layer of glass will certainly affect the U-value, however increases to initial cost could be a major concern. In order to evaluate the effectiveness of adding another layer of glass, a triple glazed system with a low-e coating will be compared to a double glazed system with a low-e coating.

The overall U-value of the system decreases, becoming more slightly more efficient, changing from 0.29 to 0.23 BTU/(hr-ft²-°F). The impacts of this are seen in energy usage; electricity use decreases 2% and heating costs decrease less than 1%. The additional first cost will range from $7-9 per square foot due to the need for a customized design as triple glazing is rarely used. The increase over 1800 square feet of glazing results in a nearly $15000 change order. Due to the small affects this change had on the energy usage of the building, the major increase in initial cost, and the potential impact on constructability of the system, triple glazing should not be considered as a value engineering option.

Cost Impacts

Analyzing the impacts these various changes to the curtain wall system had on the energy usage of the building, it is important to consider not only the initial costs but the life cycle costs as well.

When considering the initial cost savings from eliminating the low-e coating, investment of a mere $3600 produces a combined energy savings of $570 per year. A calculation of the rate
of return of the investment into the low-e coating results in payback in ($3600/$570 per year = 6.3 years) just over 6 years.

If the owner requires a maximum rate of return period of 10 years for any value engineering change, the maximum cost of the window shading can be calculated. Since the combined energy savings is $135 per year, a maximum initial cost of ($135 per year x 10 years = ) $1350 is required. A budget of $1350 for window shadings would be unreasonable on this project.

A double glazed system with a low-e coating saves roughly 12% in energy costs, or $570 per year. The triple glazed system with a low-e coating saves 1% in energy costs, or about $50 per year. An initial cost of $15000 would result in a rate of return ($15000/$50 per year = 300 years) of about 300 years.

**Conclusions**

Through a careful analytical approach, Value Engineering suggestions can be created, analyzed and reviewed in order to determine the true value to the owner. While initial cost may be a primary concern to the owner, it is extremely important to look at how the changes impact the life cycle costs of the building. Aesthetics are also an issue; even if the owner can save money by making a slight modification to the design, the value of appearance may outweigh the monetary importance.

It is concluded that the current design for the glazing and curtain wall systems of the building may not be the most efficient, but represent the best value to the owner in terms of initial cost and life cycle costs.