Ideas + buildings
that honor the broader
goals of society

‘Trans’ Materials –
Modeling and
Specifying a Next
Generation

David Mead, Sustainable Building Advisor
Why are translucent materials important for building sustainable buildings?
Reasons to use translucent materials:

Roof Monitor & Clerestory glazing:
- Avoid expensive initial & long term maintenance options like operable shades & electrochromic glazing
- Avoid options that allow direct sunlight to reach working surfaces through the year like fixed shades and screens
Reasons to use translucent materials:

Skylight glazing:
- Doesn’t require complex geometry to handle direct sunlight
- Translucent materials better at diffusing light for better spread throughout a space
Reasons to use translucent materials:

Daylight glazing:
• Can be located above vision glazing replacing the need for lightshelves and operable devices to control direct sunlight
• Translucent materials create diffuse light for a more even distribution of light throughout a space while also limiting views to the parts of the sky that cause relative visual discomfort
Reasons to be cautious when using translucent materials:

- Good chance there could be relative visual discomfort

- If the project has to use performance based specifications there is no standard performance data to reference so you could get translucent materials that vary from what was modeled
Reasons to be cautious when using translucent materials:

- Due to relative visual comfort issues the VLT of the products may be quite low requiring more area to reach equivalent light levels than with glass.
Traditionally translucent materials are used with artificial light sources rather than the sun.
Building envelopes create more challenging design problems as the potential for visual discomfort is very high due to the sun being a far more variable source of light.
Currently manufacturers typically only publish visible light transmission and surface reflectance.
Knowing this risk there is a great need for metrics to be able to use when modeling translucent materials for projects.

Currently the building industry does not use standardized metrics for explaining how translucent materials behave visually.
Transparent Glass has evolved to include standardized measurements that can be obtained from LBNL’s Optics programs. Translucent materials are still part of the wild west of modeling.
This is the case for all translucent materials, there is no common standard for how to measure the Diffuse Reflectance, Reflected Specularity, Surface Roughness, Diffuse Transmission, or Specular Transmission.

These can be modeled in Radiance but how does one go about measuring them?
Need special measuring devices to work through this – gonio-photometers which are currently not in common use in the industry
This creates risk for designers and engineers as the actual performance is unknown and therefore is hard to specify.

For public projects that have performance based specifications for contractors designers cannot reference any applicable standards.
Fritted Glass Performance

Optics 6 – “Preliminary work has been done to set the stage for a major project to be performed using our new Gonio-spectrophotometer.”

Will be able to measure the BTDF/BRDF

(Bidirectional reflectance distribution function)

(Bi-Directional-Reflectance-Transmission-Function)
Fritted Glass Performance
Translucent Plastics

“ISO 9050, EN 410, ASTM E903, NFRC 300, are standards for measuring and calculating the properties of specular materials using spectrophotometers. Some of them make vague statements regarding the ability to measure nonspecular materials such as fritted glass, painted slats, etc, but this claim is debatable.”
Performance of nonspecular materials needs to be quantified & verified for architects & engineers to be able to optimize envelopes for daylighting. This in practice could save significant amounts of energy.

![Pie chart showing energy consumption](chart.png)

- HVAC: 65%
- Lights: 21%
- Equipment: 9%
- Miscellaneous: 5%
Modeling Radiance ‘trans’ materials as to represent translucent materials that can be specified.
1st rule of ‘trans’ materials
According to page 325 of the *Rendering with Radiance*2 book the *trans* material is:

“...one of the most confusing material entities in the Radiance repertoire. However, it is the simplest material that will trace direct source rays through a semispecular surface in order to determine diffuse and specular transmitted components...”.
Trans

(definition from The RADIANCE 3.5 Synthetic Imaging System Manual)

Trans is a translucent material, similar to plastic. The *diffuse transmittance* is the fraction of penetrating light that travels all the way through the material.

The transmitted specular component is the fraction of transmitted light that is not diffusely scattered. Transmitted and diffusely reflected light is modified by the material color. Translucent objects are infinitely thin.

```plaintext
mod trans id
0
0
7 red green blue spec rough trans tspec
```
IESNA definitions:
Transmissivity = (transmittance per unit distance)
Transmittance: Ratio of the transmitted flux to the incident flux
Function of:
  • Geometry
    • of the incident flux
    • of collection for the transmitted flux
  • Spectral Distribution
    • characteristic of the incident flux
    • weighting function for the collected flux
  • Polarization (*Ignored by Radiance*)
    • of the incident flux
    • component defined for the collected flux
Cr,Cg,Cb are the diffuse reflectance in R,G,B channels

Diffuse Transmission (Td) - (fraction transmitted diffusely in a scattering fashion)

Specular Transmission (Ts) - (fraction transmitted as a beam, like through clear glass, not scattered)

Diffuse Reflection (Rd)

Specular Reflectance (Rs)

Absorption

Sr is surface roughness (similar to plastic)
Diffuse Reflectance (Cr)  Color (black = min 0, white = max 1)
Diffuse Reflectance (Cg)  Color (black = min 0, white = max 1)
Diffuse Reflectance (Cb)  Color (black = min 0, white = max 1)
Reflected Specularity (Rs)  Matte = min 0, Satin = suggested max 0.07
Surface Roughness (Sr)  Polished = 0, Low gloss = suggested max 0.02
Diffuse Transmission (Td)  Opaque = 0, Transparent = 1
Specular Transmission (Ts)  Diffuse = 0, Clear = 1

The reflected specularity of common uncoated glass is around .06
void trans material
0
0 Roughness
A1 A2 A3 A4 A5 A6 A7
R G B Specular
Reflectance

A1=Cr / ( (1-Rs)*(1-A6) )
A2=Cg / ( (1-Rs)*(1-A6) )
A3=Cb / ( (1-Rs)*(1-A6) )
A4=Rs
A5=Sr
A6=(Td + Ts) / ( Rd + Td + Ts)
A7=Ts / (Td + Ts)

Then the –st setting for rpict or rtrace should be:
St = A6*A7* ( 1 – photopic average (A1,A2,A3) * A4 )
# RADIANCE “trans” model of a translucent panel assuming
# only direct normal hemispherical transmittance is available
# Rd = Cr = C = C = 0.21 = diffuse reflectance g b
# Rs = A =0.08 = specular reflectance 4
# Sr = 0.0 = surface roughness
# Td = 0.24 = direct normal diffuse hemispherical transmittance
# Ts = 0 = transmitted specularity (ideal diffuser)
# A7 = T/(Ts s d+T) = 0
# A6 = (T+T)/(Rd+Td+Ts) = 0.5333 d s
# A5 = Sr = 0
# A1 = A2 =A = R3 s
# S = A*A*(1-A)*A4 = 0
d/((1-R)*(1-A6)) = 0.48913
t 6 7 1
# resulting Radiance material:
void trans PANEL
0
0
7 0.48913 0.48913 0.48913 0.08 0 0.5333 0
# A1   A2   A3   A4   A5   A6   A7

http://software.mcneilorama.com/Gen_TRANS_Widget.html
When a ray (and its radiance) hits a surface, it can be reflected, transmitted, or absorbed

How much is reflected: BRDF (Bidirectional reflectance distribution function)
How much is transmitted: BTDF (Bi-Directional-Reflectance-Transmission-Function)

Most of the time it does the 3 things at the same time, but one component is the most dominant.

(BRDF and BTDF i.e. ratio of the luminance emerging from the sample after either reflection or transmission and incident illuminance on the sample plane)
Examples of Radiance ‘trans’ modeling
<table>
<thead>
<tr>
<th>type</th>
<th>name</th>
<th>Cr, Cg, Cb</th>
<th>Rs</th>
<th>Sr</th>
<th>td</th>
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Cr, Cg, Cb = 0.25
Rs = 0
Sr = 0
Td = 0.15
Ts = 0.35

No Vision Glazing
Trans_01
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<tr>
<td>Rs</td>
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<tr>
<td>Sr</td>
<td>0</td>
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<td>Td</td>
<td>0.15</td>
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<td>Ts</td>
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Vision Glazing
Trans_01
No Vision Glazing

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Vision Glazing
Trans_02

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Work done at Built Ecology (WSP Flack + Kurtz)
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Work done at Built Ecology (WSP Flack + Kurtz)
3-Form Eco Resin Panels – Patent Finish
VLT~70%

There are no published results for:

Direct-hemispherical reflection \( (\rho_{dh}) \)
Direct-hemispherical transmission \( (\tau_{dh}) \)
Diffuse Transmission \( (Td) \)
Specular Transmission \( (Ts) \)
Diffuse Reflectance \( (Cb) \)
Reflected Specularity \( (Rs) \)
Surface Roughness \( (Sr) \)
Work done at Built Ecology (WSP Flack + Kurtz)
Work done at Built Ecology (WSP Flack + Kurtz)
3-Form Eco Resin Panels – Patent Finish  VLT~70%
This is on the transparent side of the translucent material spectrum
Comparing multiple 3-form products made it clear that surface treatments have a huge impact on the performance of panels.
Work done at Built Ecology (WSP Flack + Kurtz)
A light sanded finish can create an extremely diffuse transmission pattern for a material that is almost transparent.
Most Radiance modeling of trans materials assume a surface roughness of 0

This in reality has a large impact on performance as it directly effects *Diffuse Transmission (Td)*, *Specular Transmission (Ts)*, *Diffuse Reflectance (Cb)*, & *Reflected Specularity (Rs)*
Work done at Built Ecology (WSP Flack + Kurtz)
<table>
<thead>
<tr>
<th>3-FORM Product Name</th>
<th>Working surface direct light luminance (cd/m²)</th>
<th>Working surface shadow luminance (cd/m²)</th>
<th>Reflector hot spot (cd/m²)</th>
<th>Reflector Hot Spot close to 90° (cd/m²)</th>
<th>Reflector Edge (cd/m²)</th>
<th>Ceiling by reflector (cd/m²)</th>
<th>working surface illuminance - hot spot (FC)</th>
<th>working surface illuminance - indirect light (FC)</th>
<th>Shroud hot spot (cd/m²)</th>
<th>Reflected Light (cd/m²)</th>
<th>Reflected Light (outside) (cd/m²)</th>
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Direct sunlight into box: 18760
Outside Conditions: 15000

Work done at Built Ecology (WSP Flack + Kurtz)
If there was an ISO/ASTM standard for manufactures to reference it seems the surface roughness could be ignored as long as they can establish the basic guidelines for both diffuse and specular transmission & reflection

How far out is this?

What can the global Radiance community do to encourage this?
Thank You...