Weight and CG estimation

Roskam has weight fraction data in Part V (see reserve copy in library). Jet transport data are in Appendix A, pp. 150 - 159. These weight fractions can be used to estimate weight fractions for different weight groups. We can compare these with a separate estimation procedure from Raymer.¹

Raymer (Table 15.2, pg. 398) gives empirical correlations for estimating "group" weights and the x-location of center of gravity. The correlations quoted here are for jet transports.

<table>
<thead>
<tr>
<th>Group</th>
<th>Raymer Correlation</th>
<th>Roskam data</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{\text{wing}}$ [lb] = 10.0 $S_{\text{exposed planform, wing}}$ [ft²]</td>
<td>40% MAC</td>
<td>15,560 lb</td>
</tr>
<tr>
<td>$W_{\text{h.tail}}$ [lb] = 5.5 $S_{\text{exposed planform,h.tail}}$ [ft²]</td>
<td>40% MAC</td>
<td>3,320 lb</td>
</tr>
<tr>
<td>$W_{\text{v.tail}}$ [lb] = 5.5 $S_{\text{exposed planform,v.tail}}$ [ft²]</td>
<td>40% MAC</td>
<td>16,150 lb</td>
</tr>
<tr>
<td>$W_{\text{fuselage}}$ [lb] = 5.0 $S_{\text{wetted area}}$ [ft²]</td>
<td>40-50% fuselage length</td>
<td>550 nose, 4790 main</td>
</tr>
<tr>
<td>$W_{\text{land. gear}}$ [lb] = 0.043 $W_{\text{TO}}$ [lb]</td>
<td>CG of nose and main gear at points of attachment</td>
<td></td>
</tr>
<tr>
<td>$W_{\text{nose}}$ = 0.15 $W_{\text{land. gear}}$, $W_{\text{main}}$ = 0.85 $W_{\text{land. gear}}$</td>
<td>CG at mid-point of engine</td>
<td></td>
</tr>
<tr>
<td>$W_{\text{installed engine}}$ [lb] = 1.3 $W_{\text{engine}}$ [lb]</td>
<td>(nacelles, auxiliary equipment, etc.)</td>
<td>2290 lb</td>
</tr>
<tr>
<td>$W_{\text{misc}}$ [lb] = 0.17 $W_{\text{TO}}$ [lb]</td>
<td>(fixed equipment: furnishings, electronics, hydraulics, etc.)</td>
<td>40-50% of fuselage length</td>
</tr>
</tbody>
</table>

Example.

MD-80 (Areas estimated from drawings and data taken from Jane's All the World's Aircraft, 1992-93)

$W_{\text{TO}}$ = 140,000 lb

$S_{\text{exposed planform, wing}}$ = 1028 ft²

$S_{\text{exposed planform,h.tail}}$ = $S_{\text{h.tail}}$ = 314 ft² (T-tail)

$S_{\text{exposed planform,v.tail}}$ = $S_{\text{v.tail}}$ = 102.4 ft²

$S_{\text{wetted area,fuselage}}$ = 3660 ft²

Note that for the engines, Jane's quotes about 4500 lb each for JT8D-200 series engines. Raymer's correlation then gives 11,700 lb total for the installed engine. Roskam's data indicates a

lighter engine (4,410 lb each, old data?) and adds 2,120 lb for the nacelle, 1540 lb for the thrust reverser, and 640 lb for the fuel system, to give a total of 13,120 lb quoted above. The biggest discrepancies are in the weight of the wing and empennage - the differences are about 50%. This should probably be investigated further. One could argue that modern airplanes tend to use composites more extensively in the empennage and wing than the MD-80 which is old (early 80's technology). This would make them lighter but I doubt they would be 50% lighter than an all metal wing.

Jane's gives the following operating empty weight of MD-80 series airplanes.

- MD-81  78,440 lb
- MD-82  78,528 lb

Roskam's number is closer because he is using data on the actual airplane rather than making a prediction. For a new airplane, one should use his weight fraction data as a guide and multiply by the estimated gross takeoff weight. Raymer's correlations provide a useful cross-check.