



Load Factor Analysis

The Relationship Between Flight Load
and Passenger Turnaway

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What Is the Significance of Load Factor ?

For every flight over some time period, there is an average load (factor).

- When it is "too high," what are the results?
 - Passengers are turned away—immediate revenue loss.
 - Turned-away passengers difficult to re-attract—potential revenue loss.
- When it is "too low," what are the results?
 - Excess capacity and operating costs.
 - Profitability less than maximum.
- When it is "just right," what are the gains?
 - Passengers are satisfied—they fly when they want.
 - Management is happy—profits are near optimum.

The Most Important Information— Generally Ignored

- There is some variation around the average load factor.
 - Generally ignored.
 - Harder to track as a management tool.
 - Holds the key to solving many problems when carefully analyzed.

What Can Be Done If This Variation Is Known?

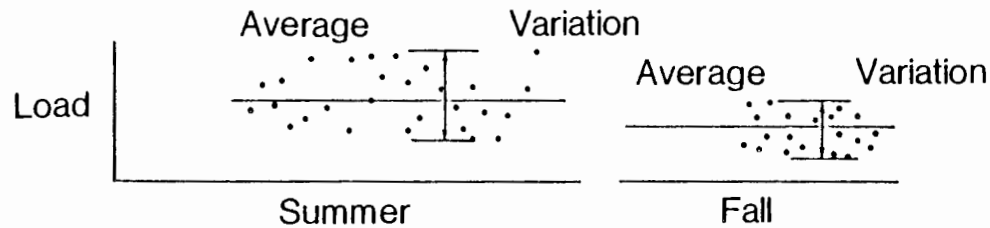
- It is possible to derive the distribution of passenger demand from load data.
- From the demand distribution, it is possible to estimate:
 - The total number of passengers ~~denied boarding~~ ("passenger spill").
 - The total number of flights where at least one passenger was ~~denied boarding~~ ("flight spill").
 - A target (desirable) load factor.
 - The exact number of seats required (airplane capacity) for the target load factor.
 - The profit or loss produced by a change in capacity.
- This information is needed by airlines for efficient operations and for effective competitive marketing.
- Techniques for deriving this information are discussed in the examples that follow.

Sequence of Steps for Load Factor Analysis

1. Start with the right set of data. KNOW YOUR DATA.
2. Derive the demand distribution.
3. Estimate spill for alternative capacities.
4. Calculate cost/revenue/profit for alternative capacities.

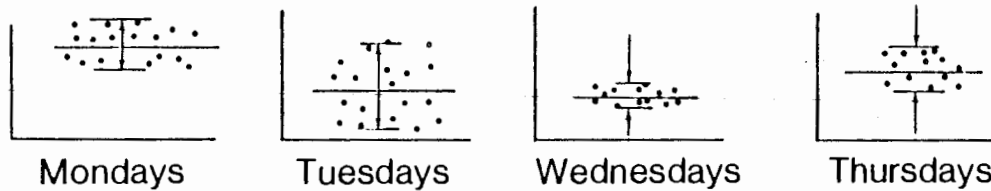
1. Start With the Right Data

- There can be seasonal differences.

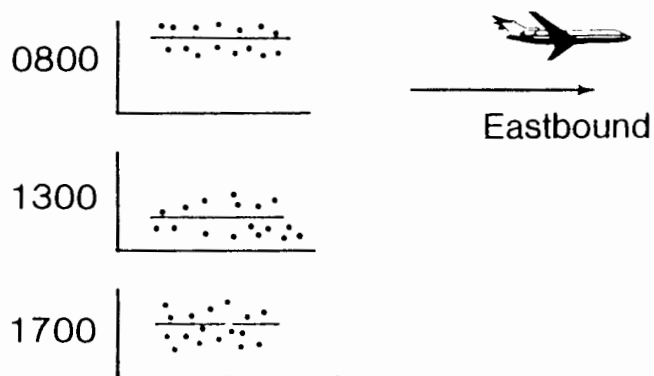


Combining seasons, days, directions, and times can produce errors.

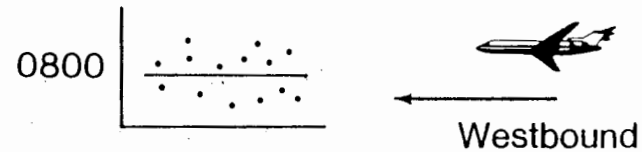
- There can be daily differences.



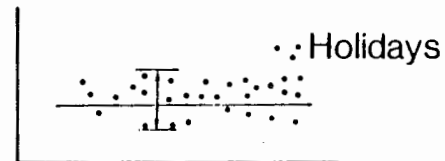
- There can be time-of-day differences.



- There can be differences in direction.



- There can be special problems.



1. Start With the Right Data

- Typical data segmentation.
 - Data in one direction only.
 - Data for one operational season.
 - Same day of the week, or similar days, combined.
 - Weekend peak days
 - Mid-week days
 - Known holiday peaks removed.
 - Time of day.
 - Head-to-head flights
 - Time-of-day demand
- Next—an example set of segmented load data.

1. Start With the Right Data

Example of segmented load data:

(Capacity= 121)

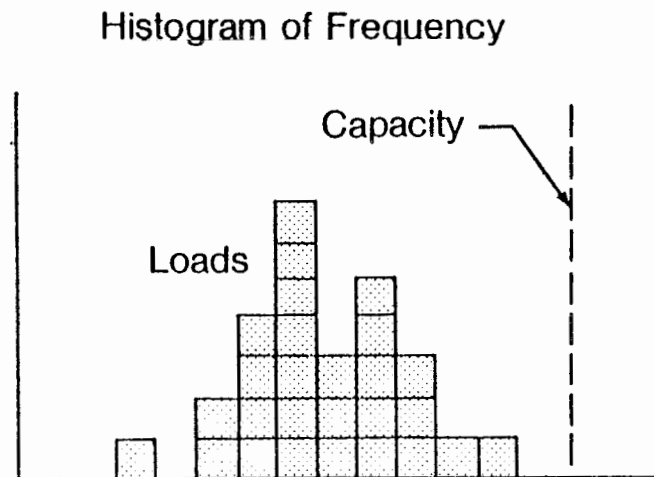
Similar days of the week	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>13</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>17</u>
Tue	68	54	59	68	46	97	76	33	53	82	55	75	62	84	41	112	106
Wed	95	45	60	86	100	77	55	73	93	37	39	100	49	69	37	64	78
Thu	36	48	41	70	56	57	80	82	81	88	78	69	66	82	94	61	85

<u>For each day</u>	<u>Smallest load</u>	<u>Largest load</u>	<u>Average load</u>
Tue	33	112	68.9
Wed	37	100	68.1
Thu	36	94	69.1

- In this example:
 - Average loads are approximately equal.
 - Variation between smallest and largest loads is similar.
 - No passenger demand is turned away.
- Because of these similarities:
 - Data can be treated as a single set of 51 loads instead of as three sets of 17 loads.
 - Increase in sample size gives more confidence in subsequent analysis.

2. Derive the Demand Distribution

- For a flight with low average load factor:
 - All loads are less than capacity.
 - Loads are the same as demand.
 - There is zero spill.
 - Excess capacity and cost may exist.



- Next—use the segmented load data from the previous page to examine a realistic situation with adequate capacity.

2. Derive the Demand Distribution

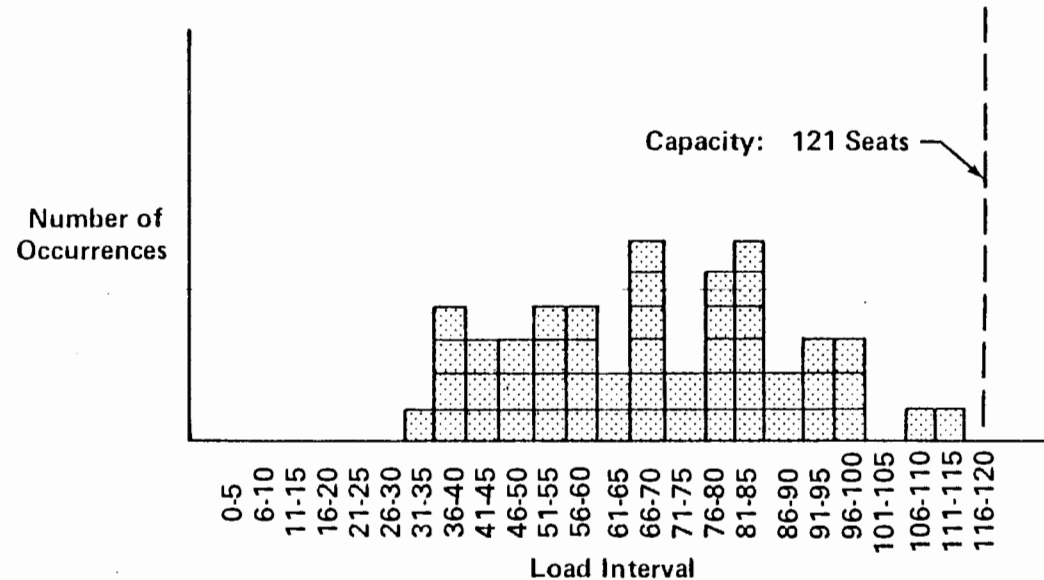
Demand distribution and spill for low-load-factor example:

(Capacity = 121)

Load interval	Recorded load (passengers)
31-35	33
36-40	36, 37, 37, 39
41-45	41, 41, 45
46-50	46, 48, 49
51-55	53, 54, 55, 55
56-60	56, 57, 59, 60
61-65	61, 62, 64
66-70	66, 68, 68, 69, 69, 70
71-75	73, 75
76-80	76, 77, 78, 78, 80
81-85	81, 82, 82, 82, 84, 85
86-90	86, 88
91-95	93, 94, 95
96-100	97, 100, 100
101-105	
106-110	106
111-115	112

Total passengers carried	3,502
Total capacity (121) x (51)	6,171
Load factor (pass. carried/total capacity)	56.7%
Demand factor (3,502/total capacity)	56.7%
Average pass. spilled per flight	0

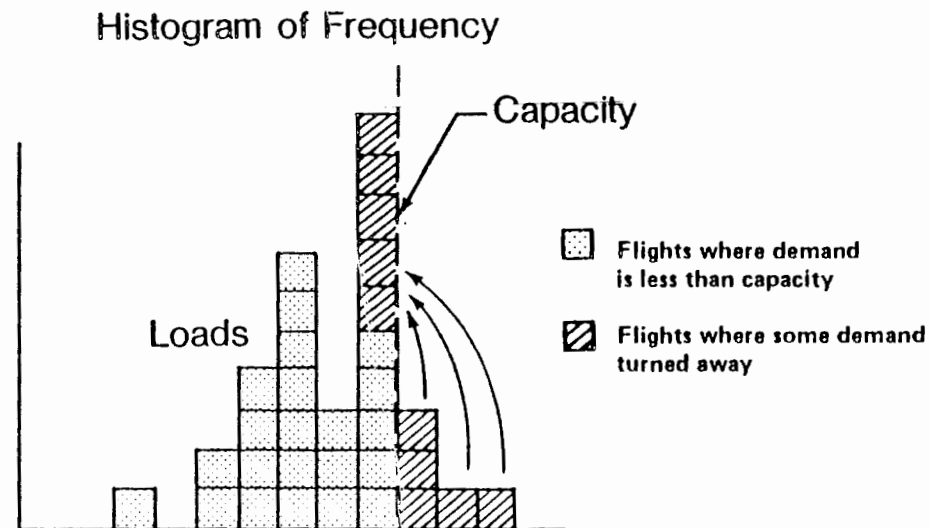
Histogram of Load Data



- There is adequate capacity in this case—no passengers are turned away.
- What would happen if capacity were reduced?

3. Estimate Spill for Alternative Capacities

- If capacity is reduced:
 - Load factors become higher.
 - Some loads will be at capacity.
 - Some loads will be less than demand. → *spill*



- Next—use the same segmented load data but reduce capacity.

3. Estimate Spill for Alternative Capacities

Demand distribution and spill for high-load-factor example:

(Capacity = 90)

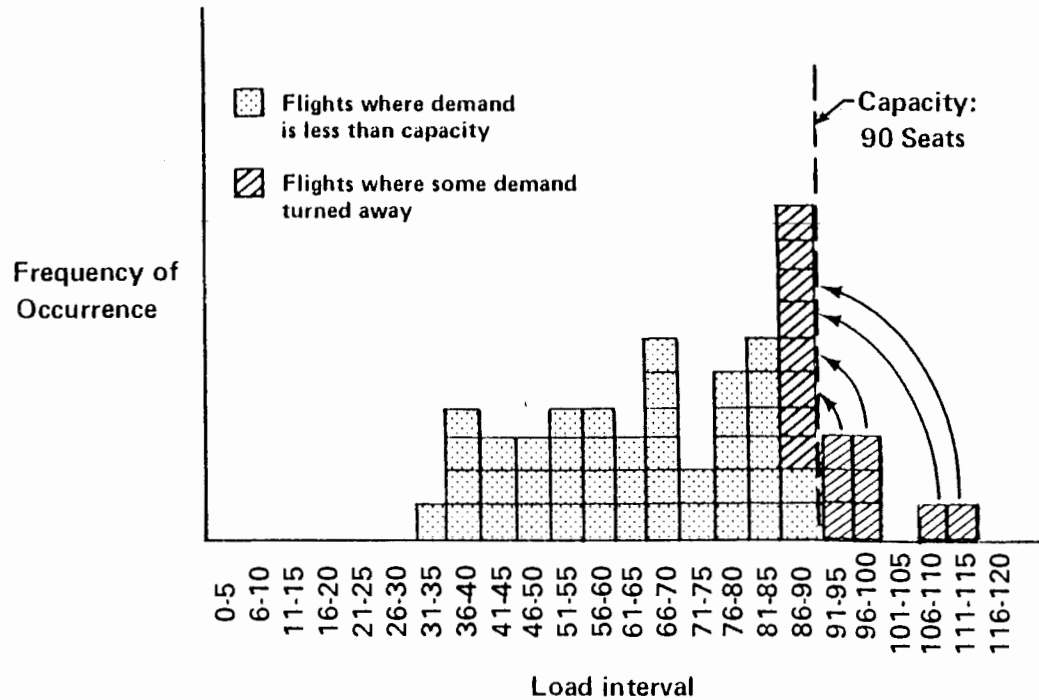
Load interval	Recorded load (passengers)
31-35	33
36-40	36, 37, 37, 39
41-45	41, 41, 45
46-50	46, 48, 49
51-55	53, 54, 55, 55
56-60	56, 57, 59, 60
61-65	61, 62, 64
66-70	66, 68, 68, 69, 69, 70
71-75	73, 75
76-80	76, 77, 78, 78, 80
81-85	81, 82, 82, 82, 84, 85
86-90	86, 88 (and eight loads of 90)

Total pass. carried	3,425
Total capacity (90) x (51)	4,590
Load factor (pass. carried/total capacity)	74.6%
Demand factor (3,502/total capacity)	76.3%
Average pass. spilled per flight:	$\frac{77}{51} = 1.51$

Spill Factor

1.7%

Histogram of Load Data



- There is insufficient capacity in this case.
- 77 passengers are turned away.

3. Estimate Spill for Alternative Capacities

Spill Estimation for Several High-Load-Factor Flights

	Original capacity:	Alternative capacities				
	<u>121 seats</u>	<u>110 seats</u>	<u>100 seats</u>	<u>90 seats</u>	<u>80 seats</u>	<u>70 seats</u>
Total passengers carried	3,502	3,500	3,484	3,425	3,315	3,108
Total capacity	(121)x(51)=6,171	(110)x(51)=5,610	(100)x(51)=5,100	(90)x(51)=4,590	(80)x(51)=4,080	(70)x(51)=3,570
Load factor (%) (Pass. carried/ total capacity)	56.7	62.4	68.3	74.6	81.3	87.1
Demand factor (%) (3,502/total capacity)	56.7	62.4	68.7	76.3	85.8	98.1
Spilled passengers		(3,502)-(3,500)=2	(3,502)-(3,484)=18	(3,502)-(3,425)=77	(3,502)-(3,315)=187	(3,502)-(3,108)=394
Average passengers spilled per flight	0	$\frac{2}{51} = .04$	$\frac{18}{51} = .35$	$\frac{77}{51} = 1.51$	$\frac{187}{51} = 3.67$	$\frac{394}{51} = 7.73$

- From this it is possible to quickly assess the spill for any alternative capacity offered for this flight.
- Such information is valuable whenever it can be developed, because it permits a profit/loss comparison for alternative capacities.

4. Calculate Cost/Revenue/Profit for Alternative Capacities

It is assumed that:

- The revenue loss from one spilled passenger is \$200.
- The operating cost of one added seat is \$50.

Capacity	<u>70</u>	<u>80</u>	<u>90</u>	<u>100</u>	<u>110</u>	<u>121</u>
Cost of capacity (Assume 70 is base)	Base (0)	\$500	\$1,000	\$1,500	\$2,000	\$2,550
Δ Cost		<u>\$500</u>	<u>\$500</u>	<u>\$500</u>	<u>\$500</u>	<u>\$550</u>
Spilled passengers	7.73	3.67	1.51	.35	.04	0
Δ Spill		4.06	2.16	1.16	.31	.04
Δ Revenue gain		<u>\$812</u>	<u>\$432</u>	<u>\$232</u>	<u>\$62</u>	<u>\$8</u>
Revenue gain minus cost		+\$312	-\$68	-\$268	-\$438	-\$542

- An increase in capacity from 70 to 80 (and the corresponding reduction in spill) can produce an increase in profit of $\$812 - \$500 = \$312$.
- Most profitable operation occurs when the last seat that is added still produces a positive increase in profit (between 80 and 90 seats).
- Other levels of capacity are less profitable.

What Next ?

- So far we have seen that:
 - Load data must be screened to remove variations other than those that are random.
 - These loads can then be used to estimate the demand that generated the loads.
 - The resulting demands can be used to examine the economics of various capacity alternatives.
- To relate demands to loads so that one can be estimated from the other requires generalization of this technique mathematically.
- This process is discussed on the following pages.

Describing the Distribution of Demand Mathematically

- It is assumed that the distribution of demand is a normal distribution.
 - A normal distribution is defined by two parameters:
 - The mean or average, μ , a measure of central tendency.
 - The standard deviation, σ , a measure of dispersion of the distribution about the mean.
 - The ratio, σ/μ , is the coefficient of variation, K, and describes the shape of the demand distribution.
 - Typical values of K for the airline industry range between .20 and .40.
 - Unique properties of the normal distribution:
 - Approximately 68% of all the demand data will fall within one standard deviation of the mean ($\mu \pm \sigma$).
 - Approximately 95% of all the demand data will fall within two standard deviations of the mean ($\mu \pm 2\sigma$).
- Substantial experience with actual airline data confirms that the assumption of a normal distribution is valid and realistic.

Quick But Approximate Estimates of σ , μ , and K

- 95% of the time, the demand values will fall within two standard deviations of the mean.
- For example, if it is thought that 95% of the time the demands would fall between 50 passengers and 150 passengers, the mean would be 100 and the standard deviation would be $\frac{100 - 50}{2} = 25$.
- And the K $\left(= \frac{\sigma}{\mu} \right)$ would be .25.
- A word of caution is necessary when considering this method, because quite often the range of data is estimated to be too small, resulting in a low estimate for K. This will cause a low estimate for spill.
- Precise techniques for estimating μ , σ , and K with low and high load factors are in the Appendix.

Example: Estimate μ , σ , and K for Segmented Load Data Used Previously

- The 51 load values range from 33 to 112.
 - 49 values lie between 36 to 106.
 - The 49 values contain $\frac{49}{51} = 96\%$ of all loads.
- A 95% interval of where the demand values fall could be between 34.5 and 109.
 - Therefore, the mean would be $\frac{34.5 + 109}{2} = 71.8$
 - The standard deviation would be $\frac{71.8 - 34.5}{2} = 18.7$
 - And $K = \frac{18.7}{71.8} = .26$

Mathematical Formulation

The expression for calculating the mean (first moment) of a truncated normal distribution (the case when spill occurs) can be written in terms of load factor (L) and demand factor (D), as follows:

$$L = (D - 1) F_0 \left(\frac{1}{KD} - \frac{1}{K} \right) - KD f_0 \left(\frac{1}{KD} - \frac{1}{K} \right) + 1$$

where: $K = \frac{\sigma}{\mu} = \frac{\text{Demand standard deviation}}{\text{Demand mean}}$

$$f_0(x) = \frac{\exp(-x^2/2)}{\sqrt{2\pi}}$$

$$F_0(x) = \int_{-\infty}^x f_0(t) dt$$

$$L = \frac{\text{Average load}}{\text{Capacity}} = \text{Load factor}$$

$$D = \frac{\text{Average demand}}{\text{Capacity}} = \text{Demand factor}$$

This expression can be evaluated using normal probability tables for various values of K and D.

Spill is calculated by $C(D - L)$, where C is aircraft capacity.

Tables of spill as a function of L and D for various values of K have been calculated from this expression and appear in the Appendix of this document.

Example

Consider the case where:

$$\begin{aligned} \mu &= 72 \\ \sigma &= 19 \\ C &= 80 \end{aligned}$$

Then: $K = 19/72 = .264$

$D = 72/80 = .900$

$KD = (.264)(.900) = .238$

$$\frac{1}{KD} - \frac{1}{K} = .421$$

$$\begin{aligned} L &= (.900 - 1.000) F_0(.421) - .238 f_0(.421) + 1.000 \\ &= (-.100)(.6632) - (.238)(.3651) + 1.000 \\ &= .847 \end{aligned}$$

$$\begin{aligned} \text{Spill} &= C(D - L) = 80 (.900 - .847) \\ &= 4.240 \text{ passengers per flight} \end{aligned}$$

What Did the Mathematical Formulation Accomplish ?

Provided the necessary data base to start detailed analysis:

- Base for finding demand distribution.
 - Demand mean
 - Demand standard deviation
 - K factor
- Base for estimating spilled passengers.
 - Revenue lost because of turned away passengers
 - Revenue gained for alternate choices of increased capacity

Provides first step in estimating carrier's market share.