Understanding and Controlling Rail Freight Service Reliability: The role of PMAKE Analysis

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Abstract

Advances in IT and the use of scheduling systems have been much more helpful in reducing costs than in improving service reliability.

Perhaps the basic structure of car scheduling systems is to blame:

- Train connections are not highly reliable =>
    - Trip plans are not at all reliable =>
        - Trip plans should not be used as service standards

PMAKE analysis can use past experience for train and yard performance to:

- Predict train connection reliability and therefore …
    - Predict the expected distribution of trip times and therefore …
        - Create realistic service standards for both trip time and reliability

Contents

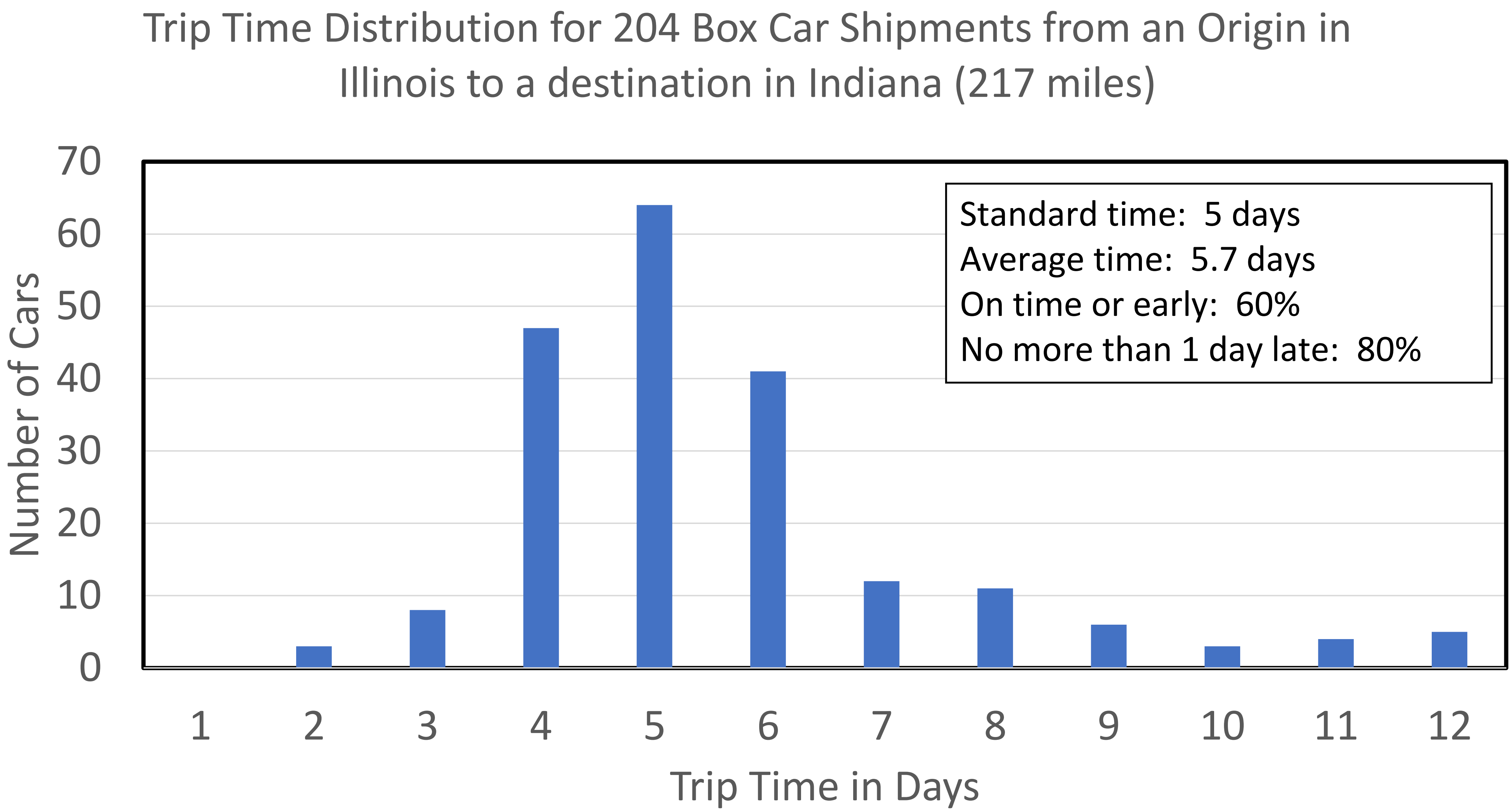
- O-D Service levels –
  - Measures and standards
  - Typical performance
- Evolution of FCS
  - Terminal management systems (SP and SOU)
  - FRA/MP development of FCS
- PMAKE Functions
- PMAKE Analysis Provides a Way to Predict Average Trip Times **AND** Reliability

O-D Service Levels

In the mid-1970s, General Mills Monitored Rail Freight Service Relative to Standards

- General Mills provided trip time distributions and standard trip times for their highest volume box-car movements for 24 O-D pairs.
- The average trip time was 6.0 days, slightly higher than the average standard of 5.3 days.
- O-D Reliability
    - On time or early: 61%
    - No more than 1 day late: 78%

Source: Industry Task Force on Reliability Studies, **Freight Car Utilization and Railroad Reliability: Case Studies**, FCUP, 1977


Trip Time Distribution for 204 Box Car Shipments from an Origin in Illinois to a destination in Indiana (217 miles)
Standard time: 5 days
Average time: 5.7 days
On time or early: 60%
No more than 1 day late: 80%
Number of Cars
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
11
12
Trip Time in Days

Freight Service in Mid-1970s

EXHIBIT 3-16
Typical O-D Performance
(Mid 1970s)

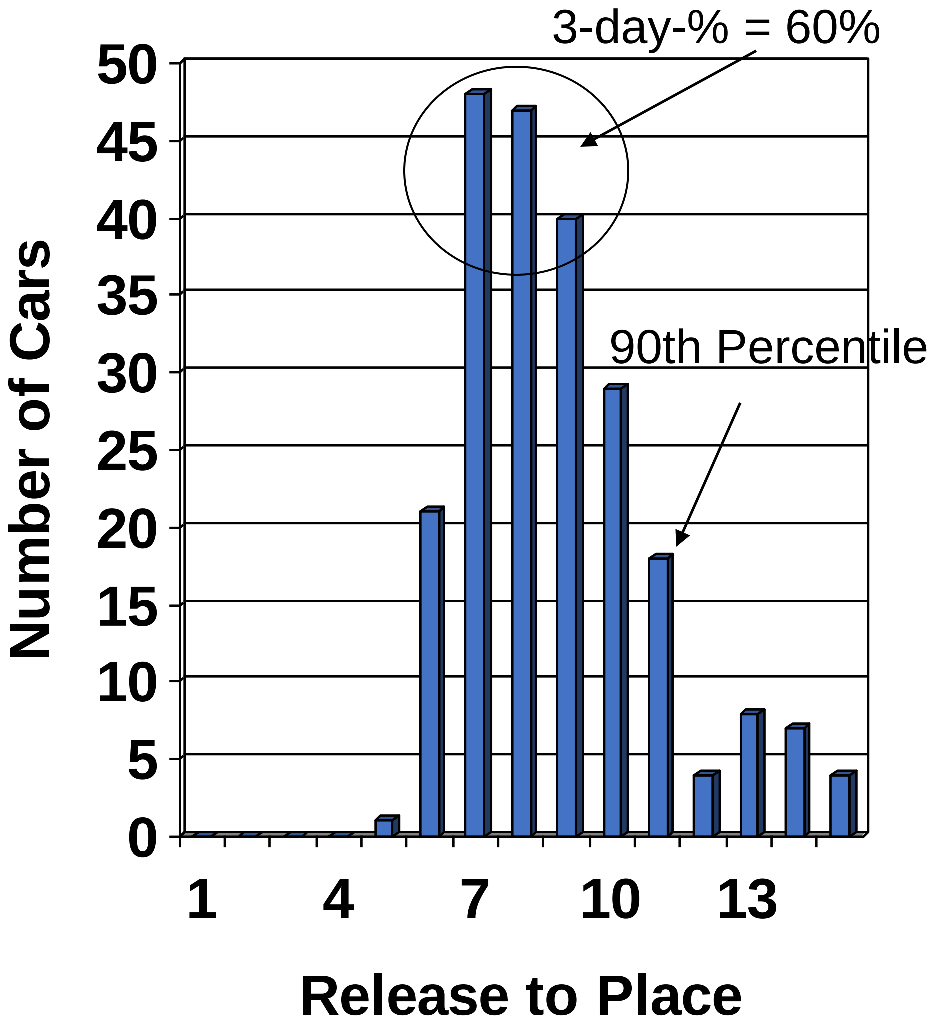
Company	O-D Pairs	Moves	Average	2-day-%
Allied Chemical	13	850	7.8	45%
DuPont	24	1879	6.8	63%
General Mills	24	4920	6.2	59%
Total	61	7649	6.8	57%

Some commodities received better service. In the same Case Studies report, Southern Railway showed that the average trip time was 4.3 days with an average 2-day-% of 77% for 5 distinct movements of auto parts into the Atlanta area.

Source: **Case Studies**, 1977

A Typical Trip Time Distribution c. 2006

- Railroad-owned gondolas
- 227 Moves
- No constructive placement
- Two intermediate class yards plus interchange
- 8.5 day average
- Reliability
    - Std. Dev. = 2.7 days
    - 2-day-% = 42%
    - 3-day-% = 60%
    - 90th Percentile = 11 days



Source: C.D. Martland, Presentation to ASLRRA, October 24, 2006

Also presented to RASIG Roundtable, Pittsburgh, 11/5/2006

Service for 39 Movements with Origin or Destination on a Short Line (June 2006)

Trip Segment	Average Time	Average Standard Deviation
Transit Time (Release to placement or constructive placement)	7.3 days	2.8 days
Class I to final yard on the Short Line (Depart last yard on Class I through interchange until arrival at the destination location on the short Line)	2.6 days	1.9 days
Destination Time (Arrive at final destination until actual placement)	1.6 days	2.1 days
Constructively Placed (CP until actual placement)	2.8 days	3.3 days

Conclusion as of 2006 –
No Lasting Improvements Since The 1970s

- *The typical average trip time in early 2006 was seven to eight days with a standard deviation of one to three days.*
- *This is actually similar to service levels documented in prior studies – studies that were undertaken at various times during the past 30 years …*
- *In other words, service has been a problem for railroads for a long time, and it is a problem today.*

Martland and Alpert, *Origin-to-Destination Performance for General Merchandise Traffic Moving to or from Short Line Railroads*, JTRF, 2007

Evolution of Freight Car Scheduling

SP’s Terminal Management Information System (TIMS)

- Installed in 1968
- Standards for train connection performance based upon cutoffs (generally 12-hours)
- Daily, weekly, monthly reports various levels of detail showing:
    - Average time
    - Consistency (% making proper connection)
    - Cost (based upon switch Engine Minutes/car)

SP had FCS Capabilities in the Early 1970s …

"Programs were developed that anticipated the departure time of each car from the yard based on its tag number and pre-established processing standards. The terminal and over-the-road segments were then linked to produce an origin-to-destination car schedule that was stored in a car schedule file. No change was contemplated in the operational instructions issued to the yard forces. Rather, exception reports were planned which would identify the cars that did not or probably would not move as scheduled."

G.S. Sines, R.C. Shamberger, and A.D. Dingle, **Missouri Pacific's Computerized Freight Car Scheduling System: State of the Art Survey**, April 1976, p.45

… But SP Did Not Implement FCS in 1970s

"Many operating officers were beginning to question the validity of car scheduling. They felt that it is not enough to tell terminal personnel what cars should be on a train, but that the system must also indicate the operational sequence necessary to maintain these car schedules, particularly during shortages of power and crews and during overloads on the switching operation. There was great concern over how publishing schedules of cars, no matter how detailed, was really going to improve the movement of cars."

G.S. Sines, R.C. Shamberger, and A.D. Dingle, **Missouri Pacific's Computerized Freight Car Scheduling System: State of the Art Survey**, April 1976, p.45

MoPac and FRA Championed FCS

- Guerdon Sines of MoPac was the leading railroad advocate for FCS
- Dick Shamberger was the leading FRA advocate for FCS
- FRA provided a grant to MoPac to develop FCS that would be available for transfer to other railroads at minimal cost.
- FRA/MoPac efforts produced two key reports:
  - G.S. Sines, R.C. Shamberger, and A.D. Dingle, **Missouri Pacific's Computerized Freight Car Scheduling System: State of the Art Survey**, April 1976
  - **Missouri Pacific's Computerized Freight Car Scheduling System: Functional Requirements**, July 1977

The Vision for Freight Car Scheduling (1977)

"Car scheduling systems implemented across the nation have the potential to bring assembly line efficiency to America's railroads, enabling then to improve their service while increasing the profitability of doing business."

Missouri Pacific's Computerized Freight Car Scheduling System: Functional Requirements, July 1977 (p.1 – 2)

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The FRA/MoPac report describes or presents examples of the types of reports that FCS can produce:

- Train performance: % on time or early, standard deviation of arrival times
  - The example showed a train that had a S.D. of 9 minutes (p. 4-61)
- Train connection performance: % making proper connection
  - The example showed 91% proper connections for 10/2/76 at Fort Worth (p. 4-71)
- Trip plan compliance report: historical comparison of trip plans to actual car movements, including the % of trips that followed the original trip plan.
  - No example; report to be developed. (p.4-78)

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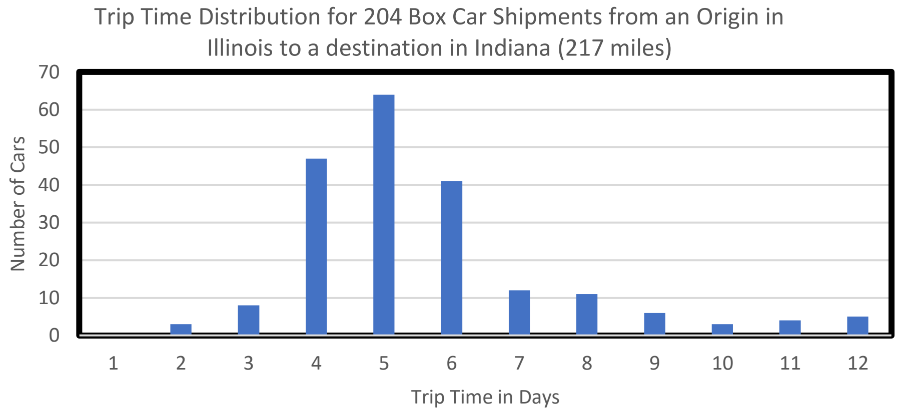
FRA/MoPac State of the Art Survey(1977): Comments from Wilbur Smith, VP General Mills

"Shipper management, the top people in a company like General Mills, are going to have to be objectively persuaded that the railroads have the performance ability for car scheduling. … [Senior management] will probably say 'prove it to me, because I have been around the company for many, many years, and I know that we have seldom seen a railroad performance capability to support scheduled dock-to-dock transportation." (p. E-8)



FRA/MoPac State of the Art Survey(1977): Don Dingle Had to Answer the Crucial Question

"*You pointed out that even with 90% reliability in making moves at any given terminals, that by the time the car completes an entire schedule through numerous terminals and/or several roads, the level of reliability could be very low.*

As a consequence, it would seem to me that … the transportation system has to have an extremely high level of reliability in each of the terminals in order to reach the service objectives that Mr. Smith pointed out.

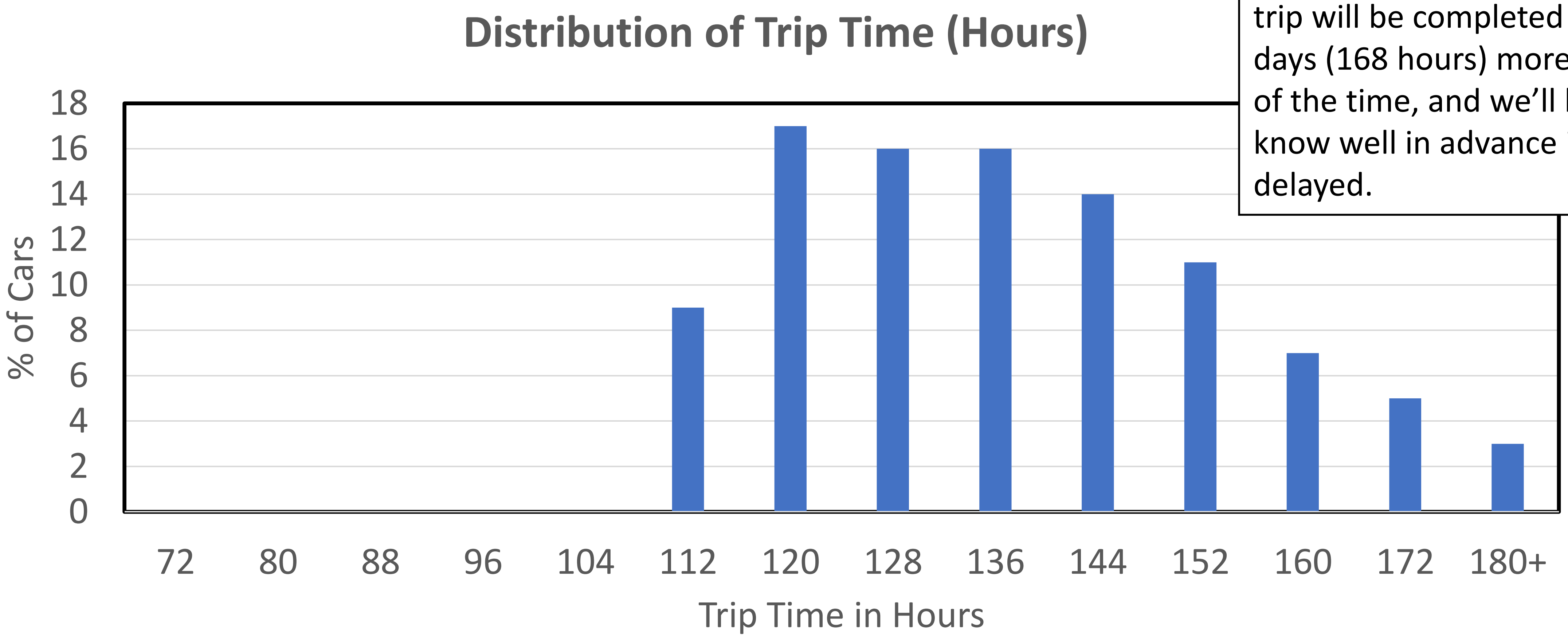
With such a transportation system, the service objectives we are looking for have been obtained and car scheduling is not necessary."

FRA/MoPac State of the Art Survey(1977): Don Dingle Didn't Have an Answer

- Dingle responded with a rather general discussion about how "good service requires good operational plans" and how car scheduling will help find corrective measures when service problems emerge.
- Neither the questioner nor Dingle recognized that they both accepted an unnecessary assumption by assuming that the trip plan generated by FCS will be the standard.

For Example, Suppose the Trip Plan for a Particular O-D Pair is 140 hours, but Actual Trip Times Are Quite Variable

Don’t promise that the trip will take 140 hours, just say that the trip will be completed within 7 days (168 hours) more than 90% of the time, and we’ll let you know well in advance if the car is delayed.



FRA/MoPac State of the Art Survey(1977): Dingle Could Have Responded Much More Effectively

"Yes, the percentage of cars meeting their original trip plan will certainly be low for a trip involving more than a couple of yards. However, the original trip plan is a goal for operations, not a promise to shippers. Based upon the expected connection performance at each yard, it would be possible to say to the customer that the trip time should be X days or less 90% of the time. If the yards become more reliable or if fewer connections are necessary, then the time required to achieve 90% reliability would be less".

Or, in fewer words: Railroad marketing officials commonly add a buffer to trip plans when describing rail service to potential customer!

FRA/MoPac State of the Art Survey(1977): Comments from Tom Lamphier, VPO, BN

- Focusing on the statistics and computer data bases will fail to do much to improve service and yard performance, because this approach "*passes over one of the culprits in this imbroglio, namely the terminal itself*." (p. D-2)
- *"Terminal control system standards can be established that are far too long for good performance, and cars can be taken out of the terminal count that will artificially improve the terminal's batting average*." (p. D-4)

Unfortunately, Lamphier Was Correct

During the 1980s, railroads adopted slogans such as “Right Car, Right Train” for their highly publicized strategies for improving service through their car scheduling efforts. In order to ensure a respectable “batting average” for connection reliability, cut-offs grew from a reasonable time of eight to ten hours to 15 or even 20 hours.

FRA/MoPac State of the Art Survey(1977): Conclusions

- “The need for computerized car scheduling systems as part of a service reliability and equipment utilization program is widely recognized, but the role scheduling should play is such a program is not well understood nor uniformly recognized. …
- “There is skepticism among many of the operating officers with regard to the way car scheduling is actually going to improve service and utilization. …
- “The acceptance gap between the initial development of a computerized car scheduling system and its universal acceptance could be long. For example, the yard inventory control systems which were first installed in the late 1950’s have not yet been installed at all the major yards of some railroads.”

Does FCS Improve Reliability of Train Connections: Observations from 1981

The final report from the FRA/MoPac FCS effort included charts showing the % of cars departing on their trip plans each month from the implementation of FCS in September 1978 through the end of 1979 at seven MoPac class yards. The conclusion was:

> *"The percentage of cars that departed yards in accordance with their trip plans improved from 1978 to 1979. The greatest improvement occurred at Fort Worth where the compliance increased about 20 percent."*

E.J. Sierleja, George Pipas,, and G.F. List, **Evaluation of the MOPAC's Freight Car Scheduling System**, June1981 (pp. 38-39)

But Were These Improvement Enough?

The same set of charts shows that:

- Only Memphis had connection reliability near 90% in 1979
- Compliance at North Little Rock, a major hump yard, never rose above 75% for any month in 1979
- Most of the other yards had compliance ranging between 60% and 90% during 1979.

E.J. Sierleja, George Pipas,, and G.F. List, **Evaluation of the MOPAC's Freight Car Scheduling System**, June1981 (pp. 38-39)

ISM Task Force (1/4/91): Comments on ETI, ETAs, CTAs, FCS

- "When we created a version of car scheduling on BN, we achieved some improvement in performance vs. specific schedules, but no improvement in consistency over time." (Mark Becker, Integrated Network Planning, BN)
- "When Conrail surveyed customers about six service attributes, their order of importance was: timeliness, equipment, notification of delayus, transit time, tracing, and arranging special services. The largest gap was notification of delays." (Dick Flynn, Customer Service, Conrail)
- "Conrail marketing people quote performance based upon average past performance, including weekend effects."
- "I structure service to provide the level of consistency that the customer wants (60-90%). … I'll set up whatever time is needed for a connection, e.g. I'll put in a 24 hour buffer for a block switch that acts as a buffer for the possibility of losing time anywhere else (such as trains held out of Houston account congestion or missed connections at other yards)." (John Ladd, Transport Services, UP)

ISM Task Force (3/13/91): Comments on ETI, ETAs, CTAs, FCS

- “CN provides an ETA for operation, but the customer sees something different, because Sales tries to put a buffer in there. … We have 3,500 trip plans, and we don’t expect them to be the same tomorrow! Trip plans aren’t linked to the operating plan in any automated way.”
- “Conrail doesn’t reschedule at all, and UP does too much.”
- “We on this Task Force all want ETA/ETI, but we’re not all agreed about the need for trip plans.”
- “The customer wants to know the schedule, but is not concerned with minor variations.”

Unfortunately, the trend continued for decades:

Longer cut-offs, longer yard times:

> *"The average time required to make train connections in a major rail freight classification yard is commonly more than 30 hours, which is more than 50% over the benchmarks achieved at various times and locations in the past three decades…"*

Carl D. Martland, *Factors Affecting Railroad Yard Performance,* Abstract for RASIG Roundtable, Informs Annual Meeting, Pittsburgh, PA, November 4, 2006

Are Train Connections any more Reliable Today? Observations from 2020

“Average yard times are typically 24 hours. Right block, right train, right day as low as 70% ...

“Only Green Cargo has full reservations, and they provide 95% reliable freight car scheduling for both loads and empties …

“Precision Scheduled Railroad: needs to be much better!”

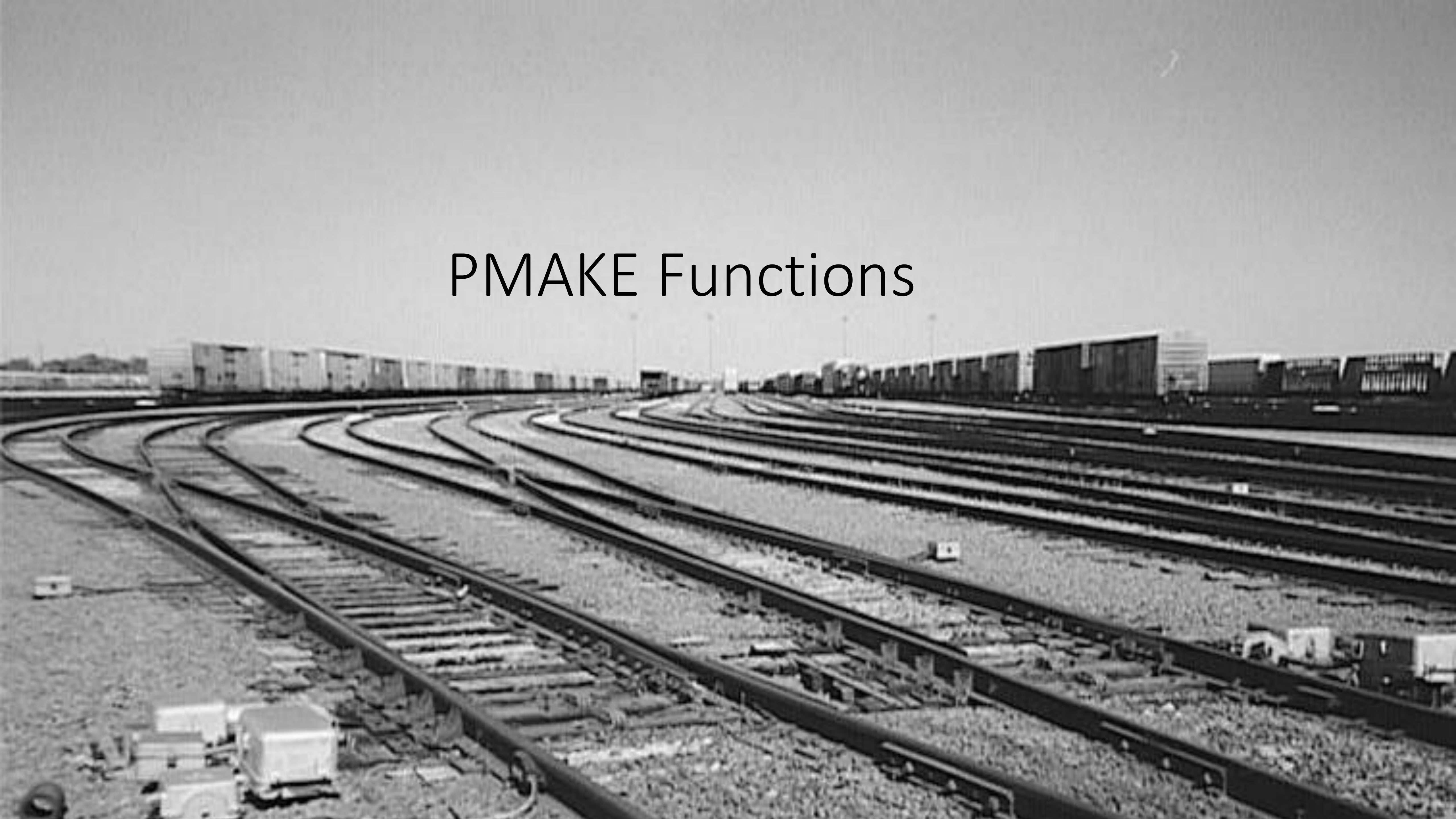
Carl Van Dyke, RAS Presentation, 9/23/20

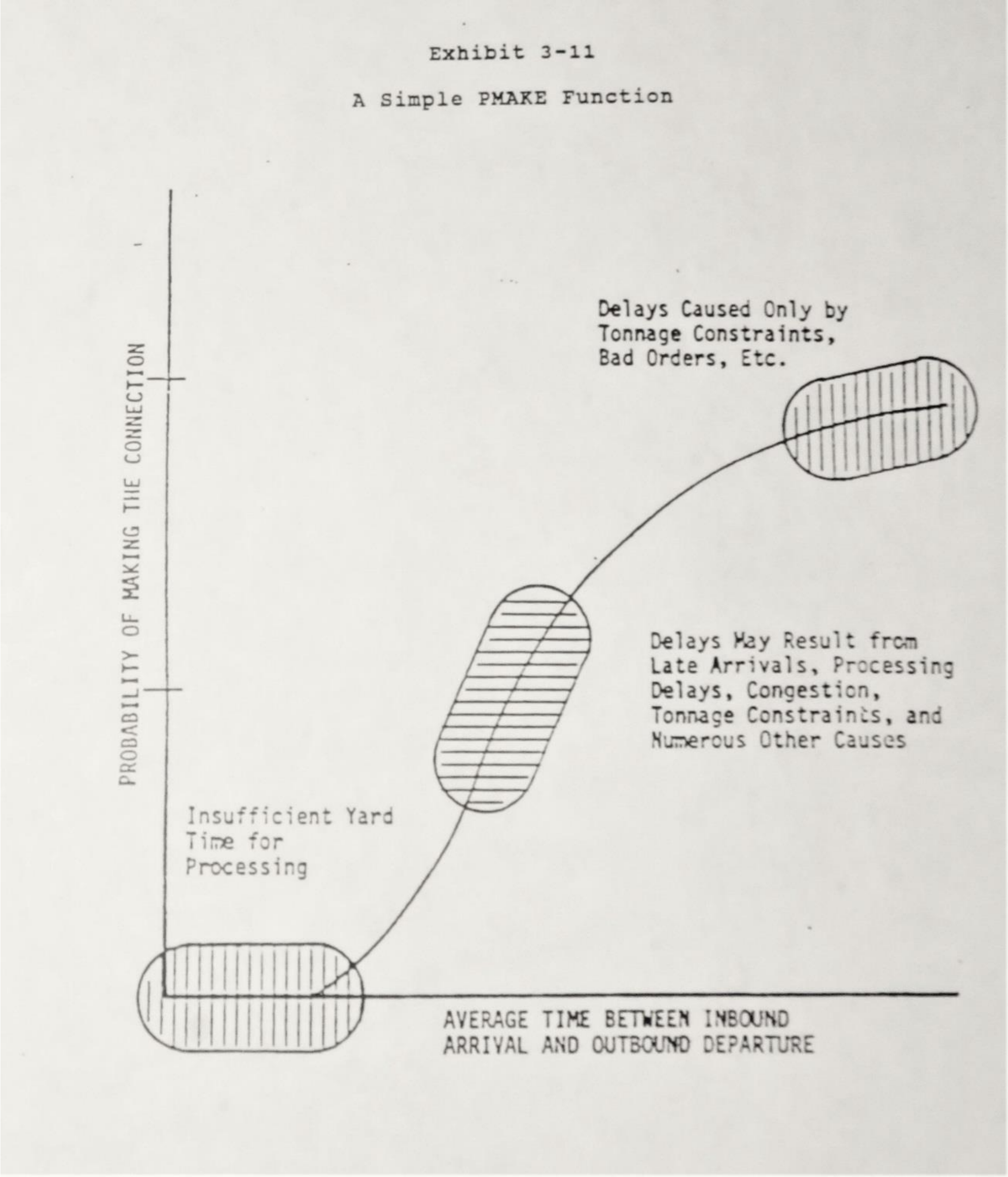
ETAs, CTAs, Trip Plans, and Car Schedules

- Day-to Day Operations Control:
  - Operations: Trip plans and ETAs – do we need to adjust the plan today or expedite certain cars?
  - Customer inquiry: where is my shipment and what is its ETA?
- Service Control
  - Marketing: monitor service relative to "Committed Time of Arrivals (CTA)" promised to some customers
  - Customer: monitor consistency of performance relative to CTAs

FCS is not needed to generate trip plans.
Trip plans need not be communicated to customers who request ETAs.
ETAs are not the same as CTAs.

PMAKE Functions



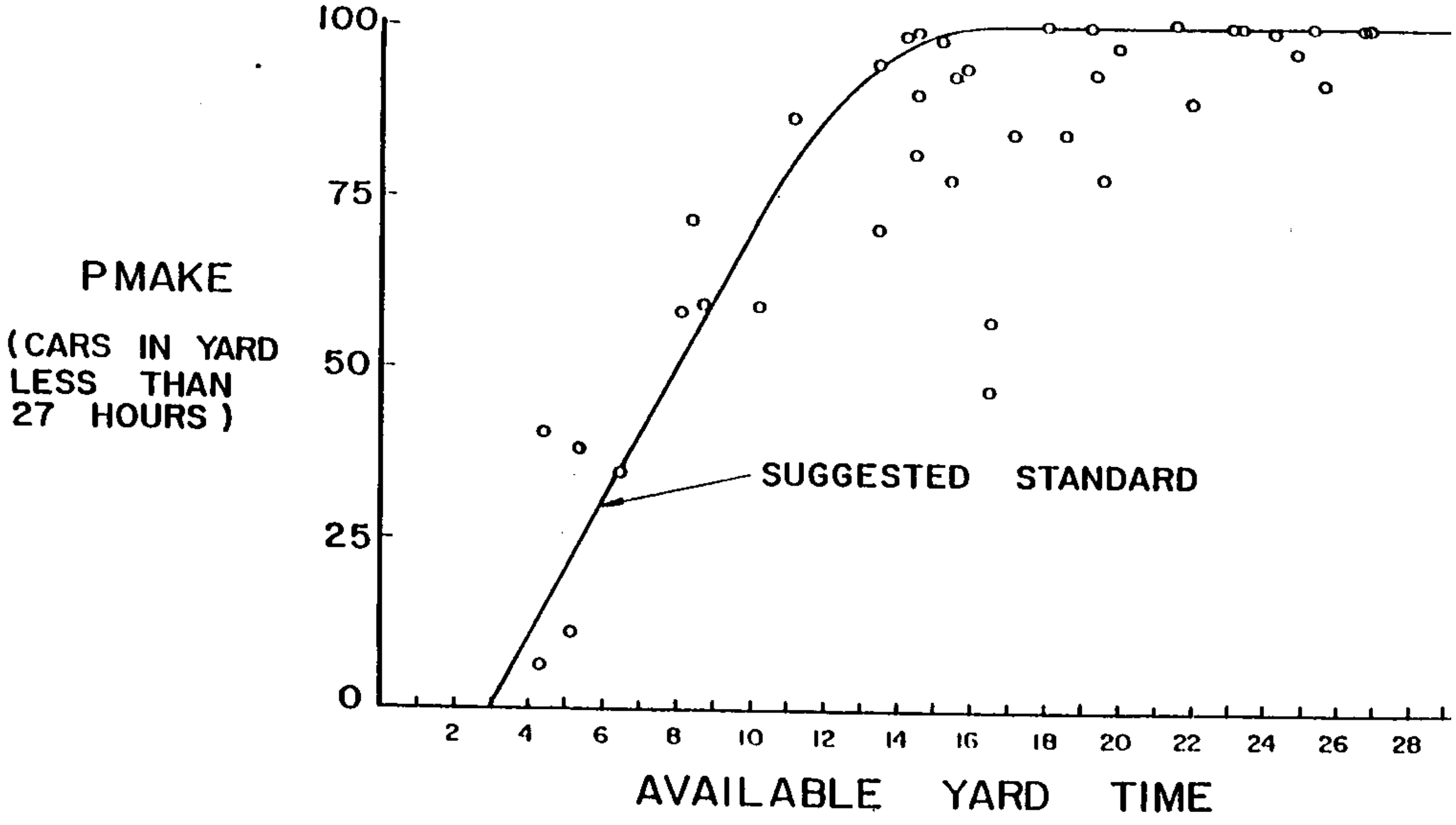


PMAKE Analysis: the basics

- Connection Reliability increases as the time available increases
- The shape of the curve reflects the variability in train arrival and departure times, processing delays, etc.
- Even if sufficient time is available for processing, the connection may be missed because the outbound trains is cancelled or various other reasons

Source: **Case Studies**, 1977

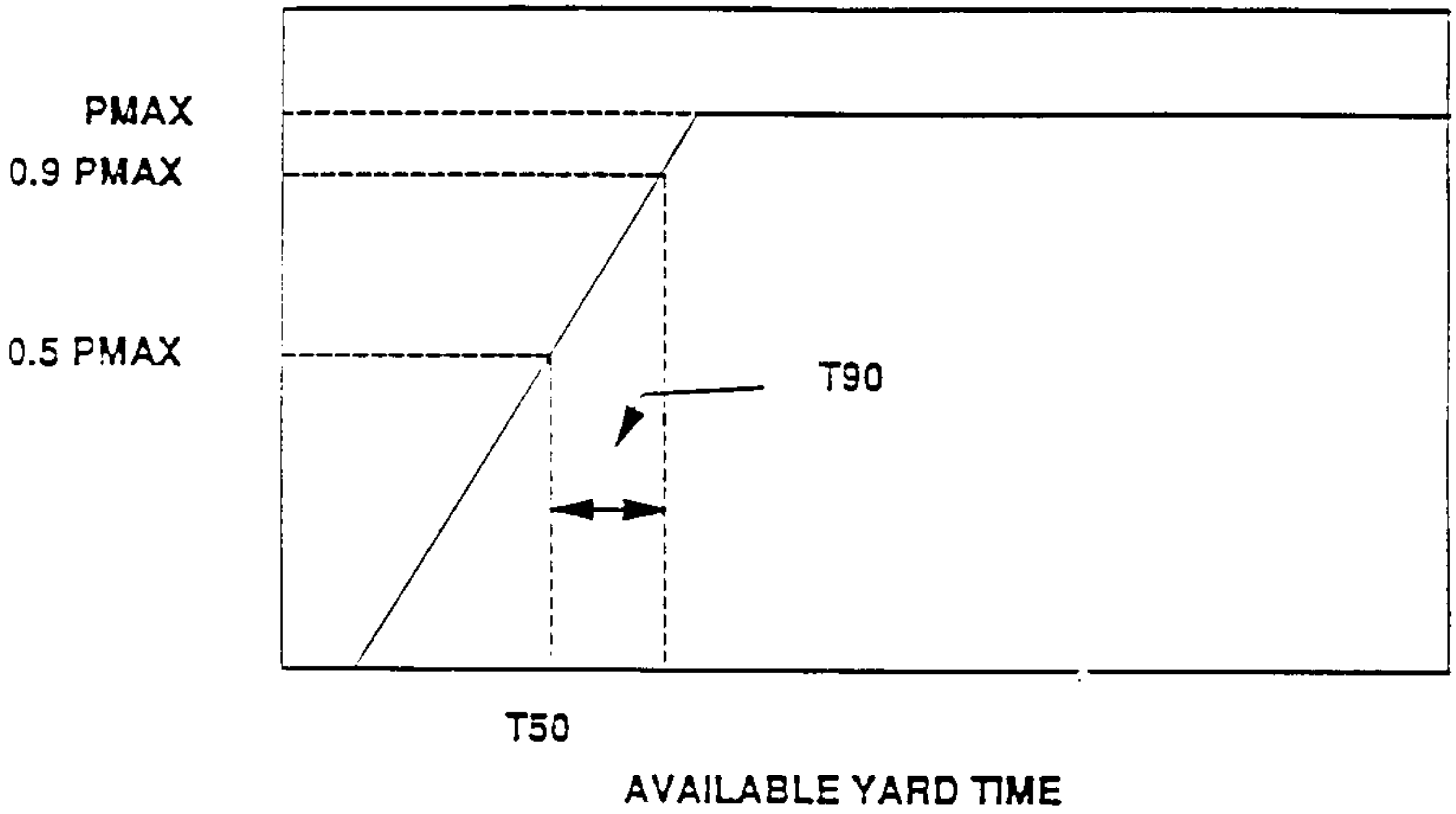
Given data for train connections, you can calibrate a PMAKE or simply suggest a standard for connection reliability



This slide and the typical trip time distribution are from Industry Task Force on Reliability Studies, "Freight Car Utilization and Railroad Reliability: Case Studies," Freight Car Utilization Program, 1977.

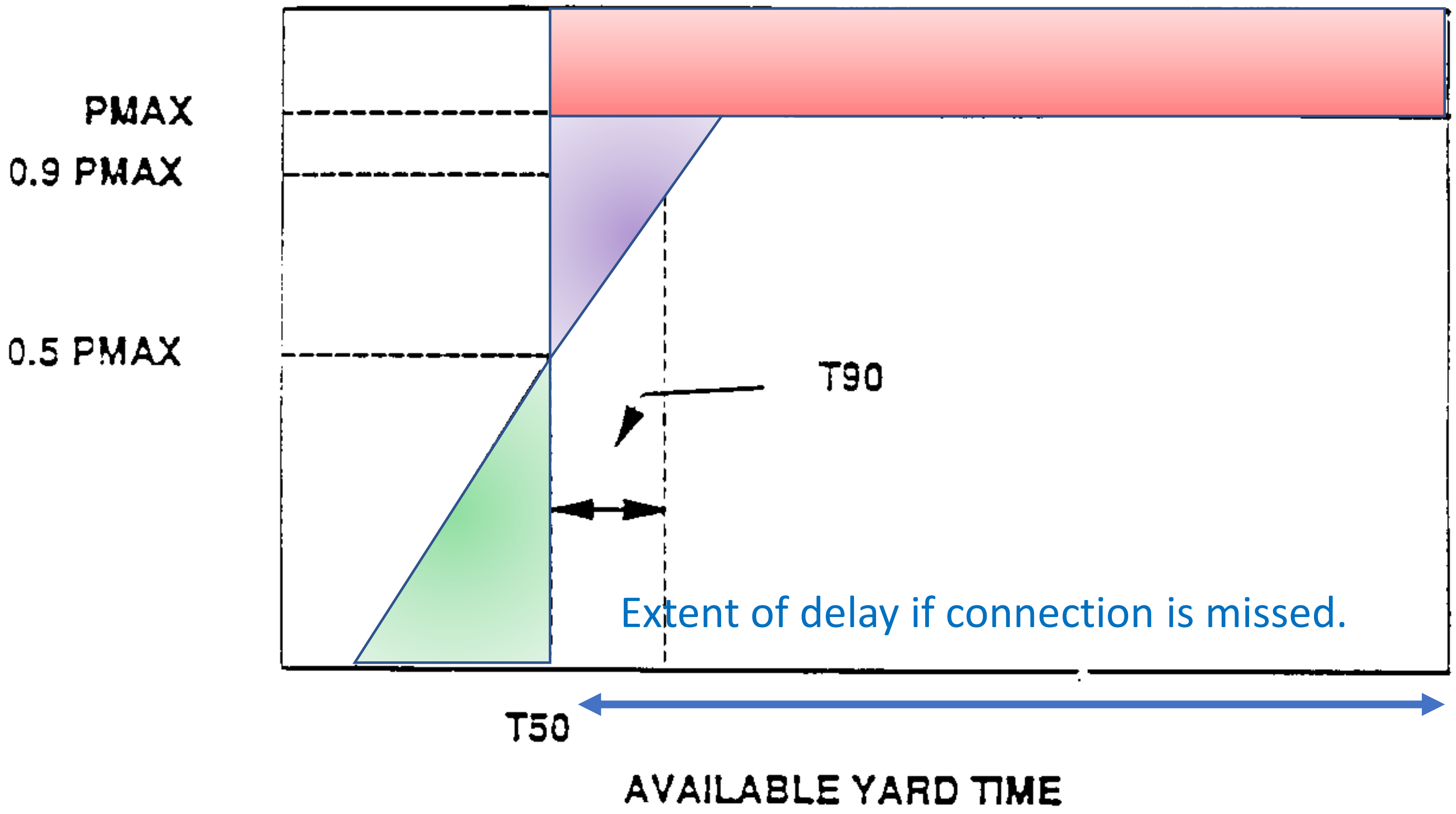
A Piece-Wise Linear PMAKE Function:

Easier to understand than a logit model (and much easier to explain to a yard master!)



PMAX: the best it gets
T50: average processing time
T90: the variability in processing time

If the cut-off is set equal to T50, then the % of cars departing early will be about equal to the % of cars missing connections because of processing delays.

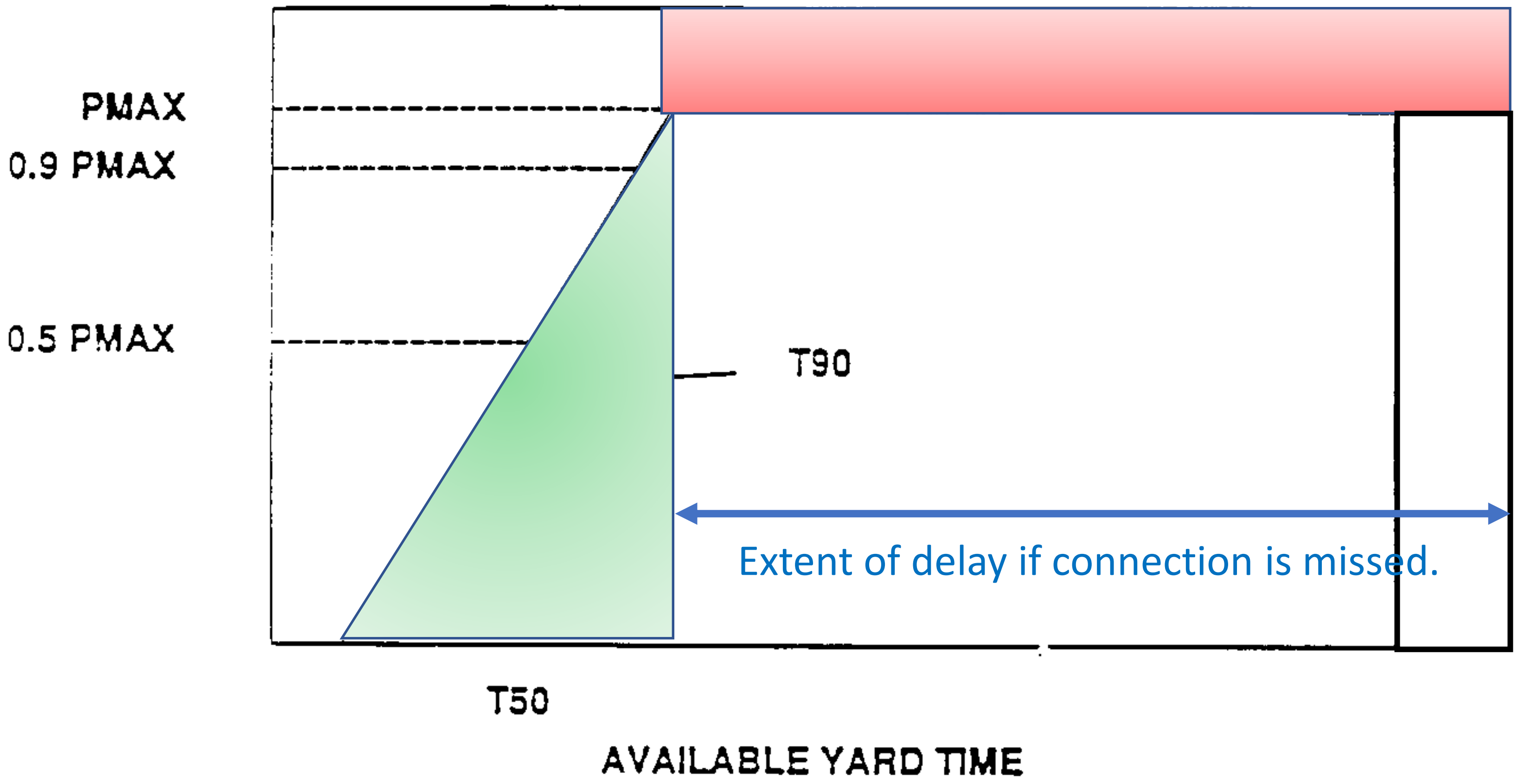


A. Missed connections due to capacity problems

B. Missed connections due to late arrivals and processing delays

C. Early connections due to early arrivals or outbound train delays

If the cut-off is set equal to T50 plus 1.25*T90, then more cars will make early connections and capacity problems will be the main cause of missed connections



A. Missed connections due to capacity problems

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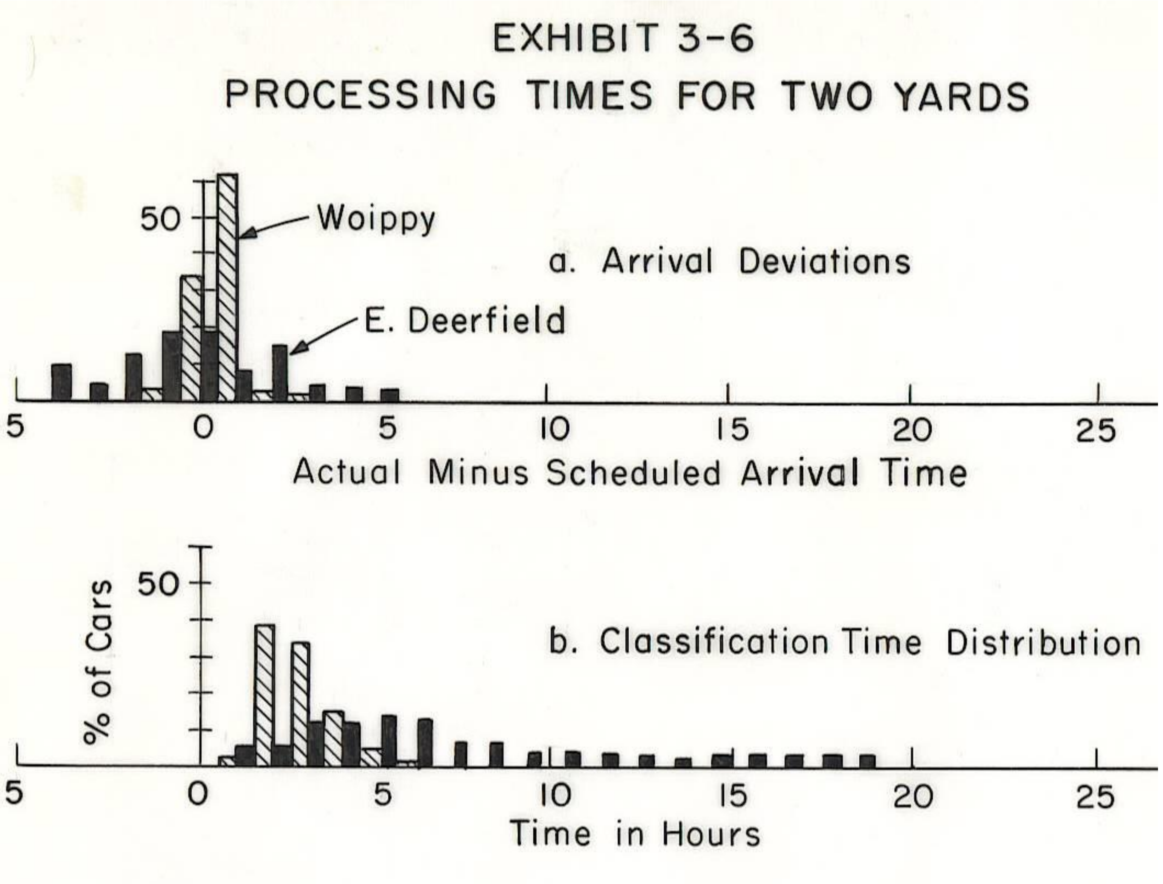
PMAKE Functions Can be Derived from Processing Time Distributions:

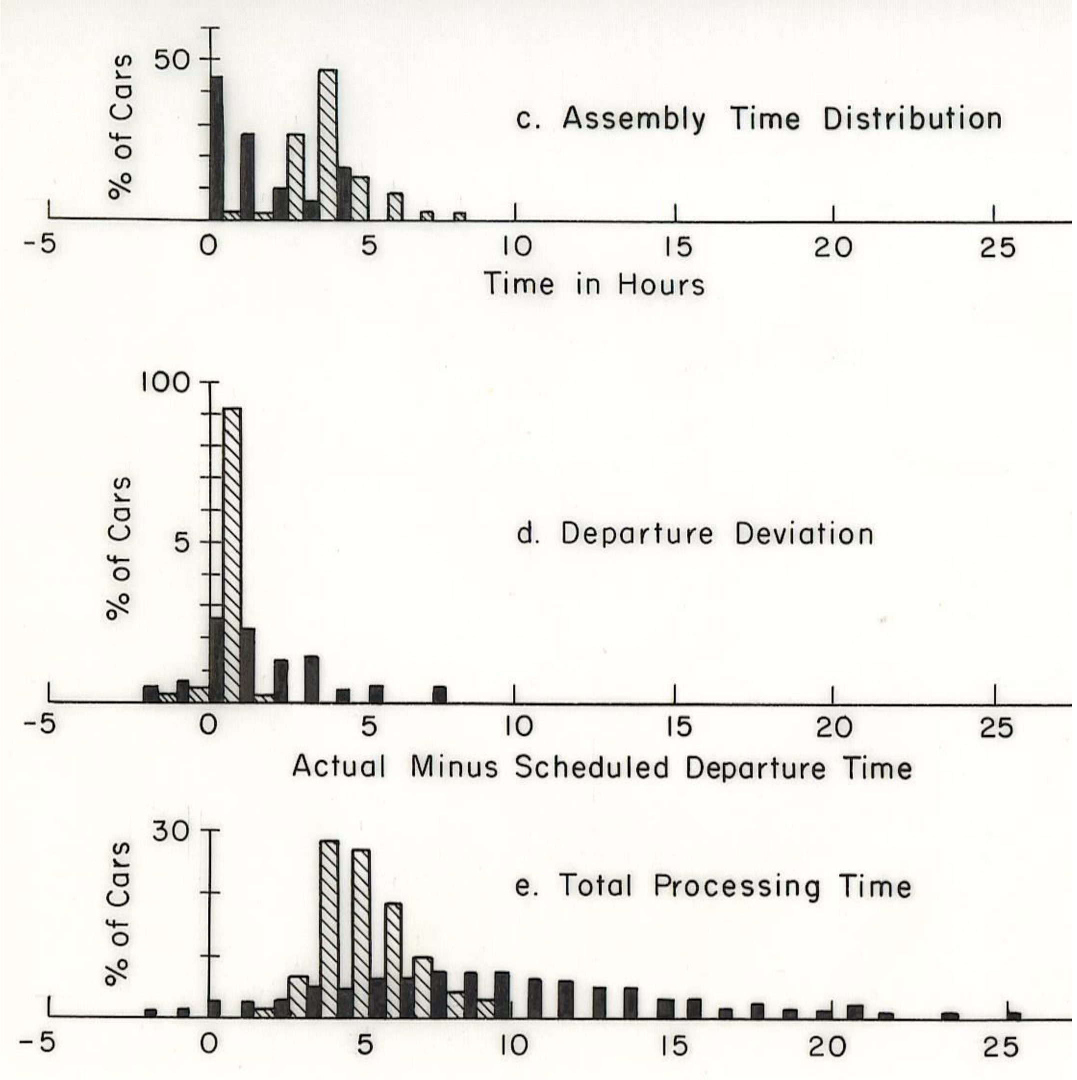
Arrival and Classification Times at East Deerfield (B&M) and Woippy Yard (SNCF)



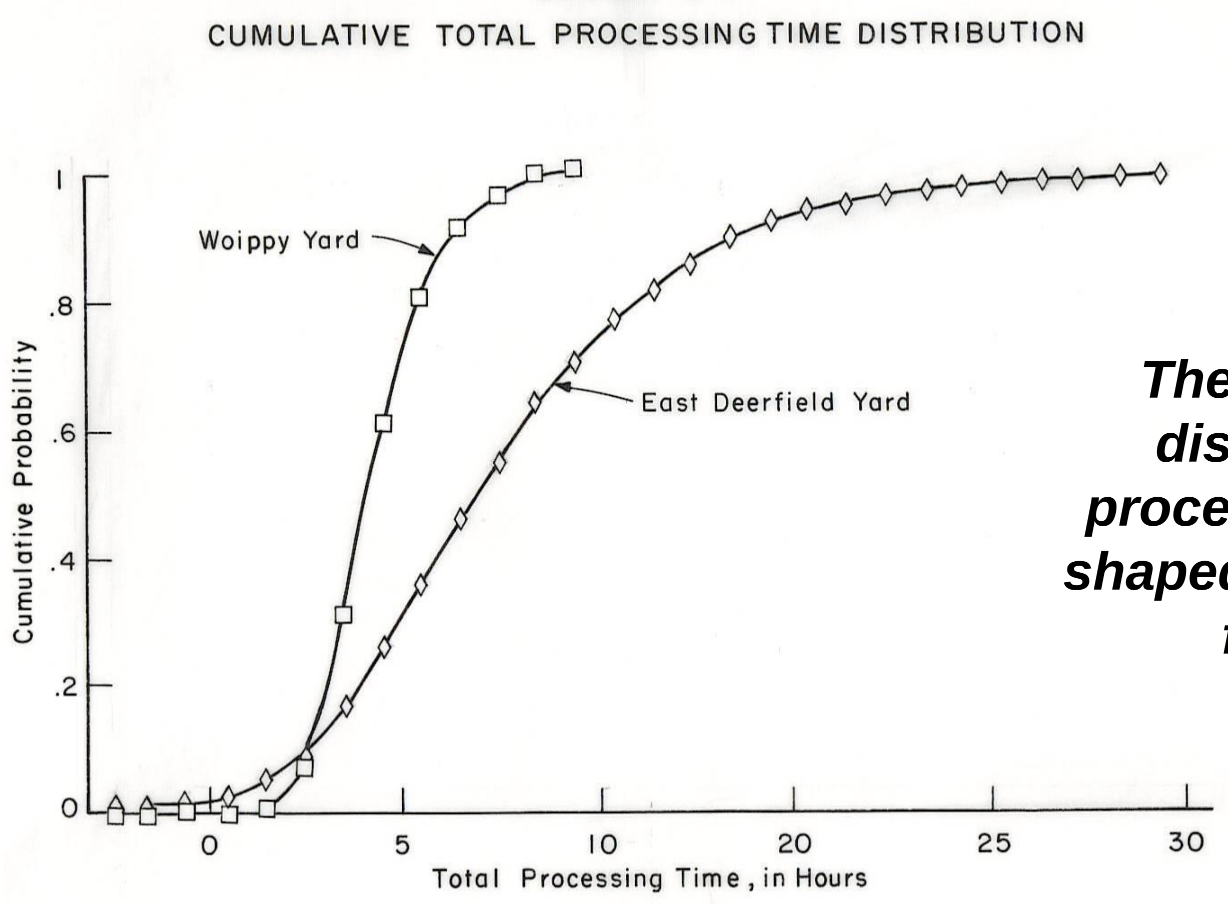
Source: Figure 3-6, p. 36, MIT SROE Vol. 37

Also presented to RASIG Roundtable, Pittsburgh, 11/5/2006

Assembly, Departure and Total Processing Times at East Deerfield and Woippy Yards



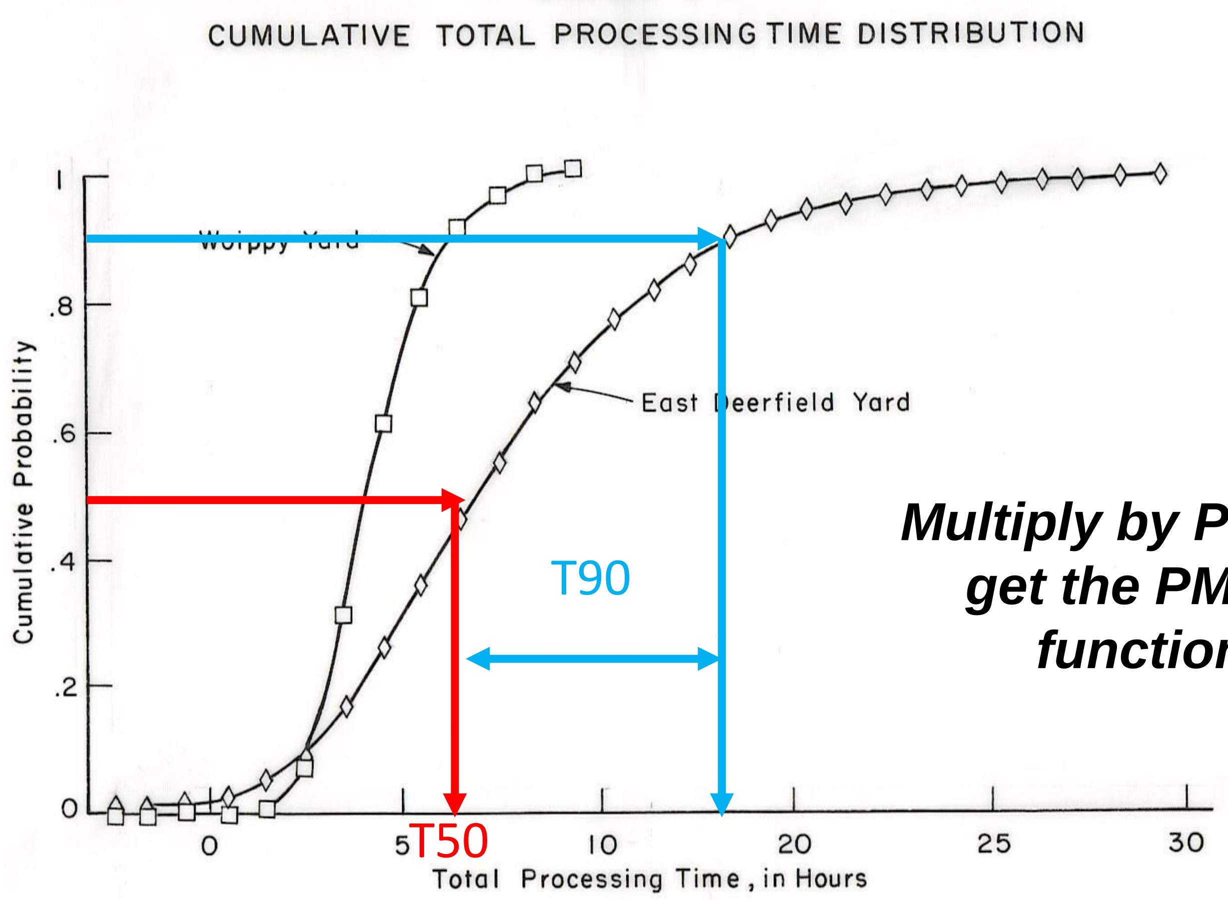
Total Processing Times for East Deerfield (B&M) and Woippy Yards (SNCF)



The cumulative distribution of processing times is shaped like a PMAKE function.

Source: Figure 3-7, p. 37, SROE Vol. 37

Total Processing Times for East Deerfield (B&M) and Woippy Yards (SNCF)



Multiply by PMAX to get the PMAKE functions

Source: Figure 3-7, p. 37, SROE Vol. 37

PMAKE Parameters from Three Studies Conducted for the FCUP During the 1970s

Classification Yard	T50	T90	PMAX
Southern Railway Case Study (1972)			
- Yard A	8	11	92
- Yard C	4	4	77
- Yard D	6	3	84
- Yard E	5	7	98
Boston & Maine Case Study (1978)			
- East Deerfield, MA	7	3	95
- Four large flat yards	5	2.6	95
- Most commonly used for smaller yards	4	2	95
Santa Fe Case Study, various yards	6-12	8-18	70-90

Dick Shamberger and I coordinated the Southern Railway Case Study; L. Stanley Crane was the VPO who supported the study.

Shamberger went on to FRA where he championed the FCUP and Freight Car Scheduling.

Crane became the first chair of the FCUP Executive Committee, then rose to CEO of Southern and then gained fame as the highly successful head of Conrail.

PMAKE Analysis Provides A Way to Predict Average Trip Times <u>AND</u> Trip Time Reliability

Creating a Trip Plan for a Typical General Merchandise Movement

Trip Segment	Available time	Fre-quency	SYT 8-hr cutoff	SYT 12-hr cutoff
Origin Yard	0	24	0	0
Travel to local yard				
Local yard	15	24	15	15
Travel to Class Yard A				
Class Yard A	7	8	15	15
Travel to Class Yard B				
Class Yard B	10	12	10	22
Travel to Class Yard C				
Class Yard C	22	24	22	22
Move to Class Yard D				
Class Yard D	5	8	13	13
Move to Local Yard				
Destination Yard	9	12	9	21
Move to Customer				
Total	**68**		**84**	**108**

With an 8-hour cut-off, the planned yard time will be 84 hours.

With a 12-hour cut-off, the planned yard time will be 108 hours, a day later.

Which is best?

Total Yard Time included in the Trip Plan (which also would include 36 hours in trains)

Predicting Trip Times Using PMAKE Analysis

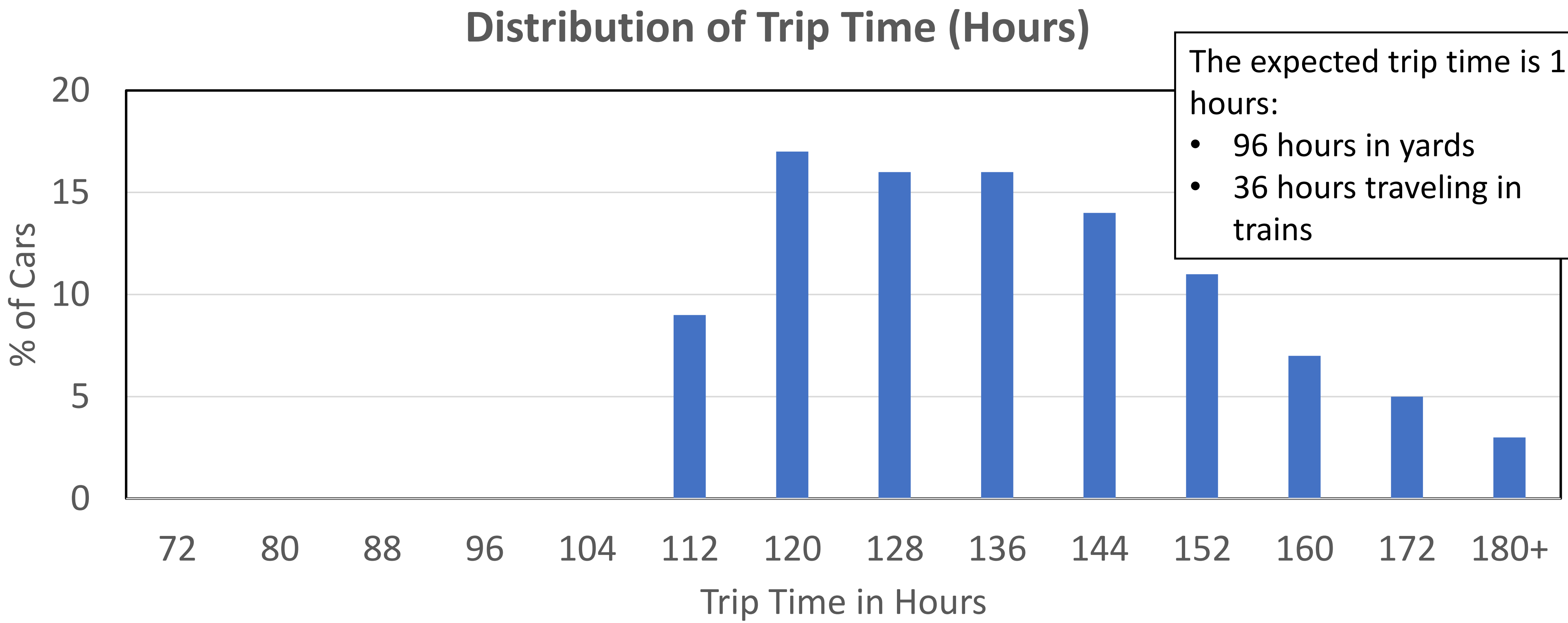
Trip Segment	Available time	Frequency	PMAKE-1	PMAKE-2	PMAKE-3	Average Time
Origin Yard	0	24	0.8	0.2	0	4.8
Local yard	15	24	0.9	0.1	0	17.4
Class Yard A	7	8	0.56	0.3	0.14	11.6
Class Yard B	10	12	0.74	0.22	0.04	13.6
Class Yard C	22	24	0.95	0.05	0	23.2
Class Yard D	5	8	0.5	0.3	0.2	10.6
Destination Yard	9	12	0.65	0.25	0.1	14.4
Total	68					96

PMAKE for each connection can be estimated using prior experience at or standards for each yard.

The expected yard time in this example is 96 hours; expected trip time would be 132 hours.

The Trip Time Distribution for the Typical Trip Plan:

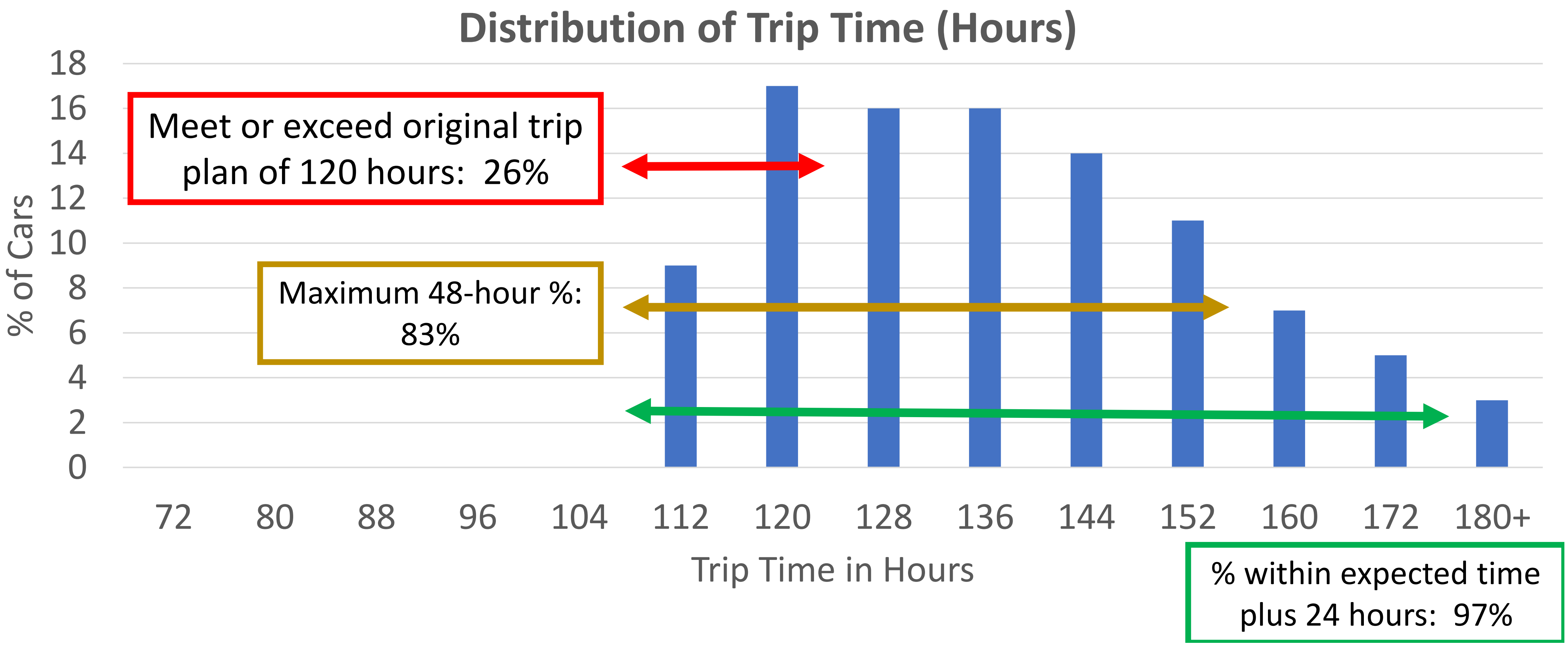
Given connection probabilities at each yard,
it is possible to estimate the trip time distribution



The expected trip time is 132 hours:

- 96 hours in yards
- 36 hours traveling in trains

What is the Reliability of this O-D Movement?



PMAKE Analysis Provides the Basis for Internally Consistent Standards for Processing Times, Yard Times, and O-D Trip Times along with Consistency Standards for These Times

- Relate PMAKE functions to the various activities that determine connection reliability:
  - Variability in train performance
  - Variability in traffic volumes
  - Resources available for yard operations (track, switch engines, crews, inspectors)
  - Resources available for outbound trains (power and crews)
- Estimate the probability that cars will make their scheduled connections using PMAKE functions.
- Use connection probabilities to estimate trip time distributions.
- Use the distribution to determine standards for trip times and reliability.

The MIT Service Planning Model

- Developed by Reilly McCarren as his SM Thesis (!), then transferred to Apple computer (!) by Carl Van Dyke and others with FCUP funding.
- SPM used PMAKE functions to estimate trip time distributions
- Standards for train and yard performance can be used to set standards for PMAKE parameters at each yard.
- Output of the model includes distributions of yard times and O-D trip times.
- Standards for train and yard performance therefore are consistent. To change service, either change the plan or adjust the PMAKE parameters.
- B&M monitored performance relative to standards for yard and trip times, both average times and consistency.
- Most major railroads use the SPM for operations planning during the 1980s

Service Design and FCS Have Advanced Greatly – but without PMAKE analysis

- Algorithmic Blocking
- Automatic Train Scheduling
- Sophisticated Operations planning models

… but they all are based upon cut-offs for train connections and they do not results in internally consistent performance measures for the various elements of operations planning and service design.

Summary - Why Doesn’t Car Scheduling Work?

- FCS assumes that cars will make their scheduled connections at every class yard.
- FCS advocates often assume that it is both possible and necessary for the FCS trip plan to be the service promised to the customer.
- FCS provides no tools to understand or control performance in an environment where demand and processing times can be highly variable.
- RR’s operate 24/7 without a reservation system, and there are predictable weekly and seasonal imbalances in traffic volumes and processing capacity.
- FCS provides excellent capabilities for answering customer queries about car location and ETA, but it does not provide a means for developing reasonable service commitments.

Conclusions from 1970s Remain Valid Today

To deal with unreliability, RR's must measure and manage the processes that affect train connection performance.

PMAKE analysis provides a way to relate line, terminal, O-D and system performance within a comprehensive control system that is geared to the various tasks of and resources available to operations managers.

The concept of an Operating/Service Plan remains useful:

- Schedules, resources, contingency plans and control systems determine the nature of the service that is provided.
- If that level of service is unacceptable, then the plan must be changed.