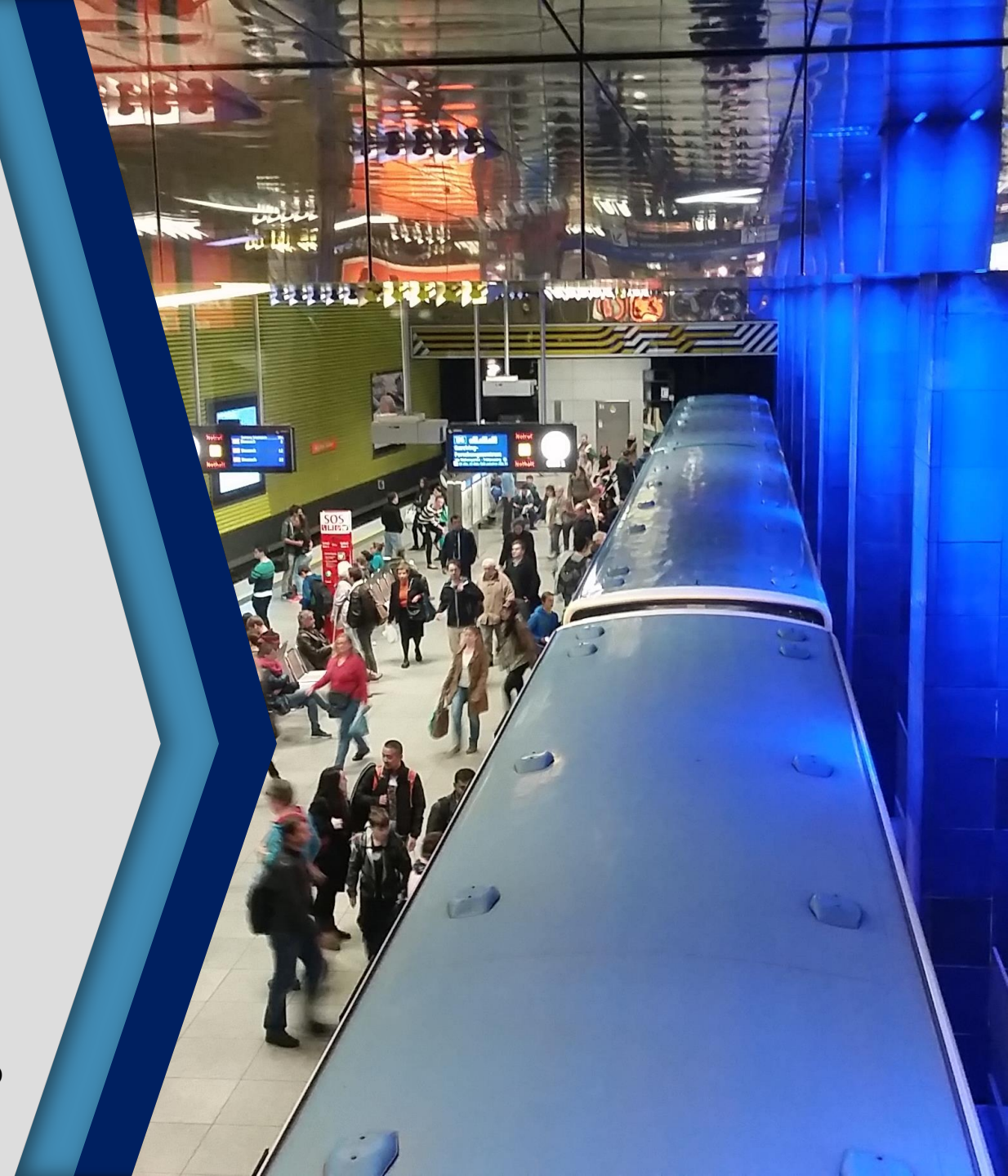
PTR-5925 - Sistemas de Transporte Coletivo Urbano de Passageiros: Oferta e Avaliação Econômica

Qualidade e Capacidade

Prof. Dr. Gabriel Feriancic



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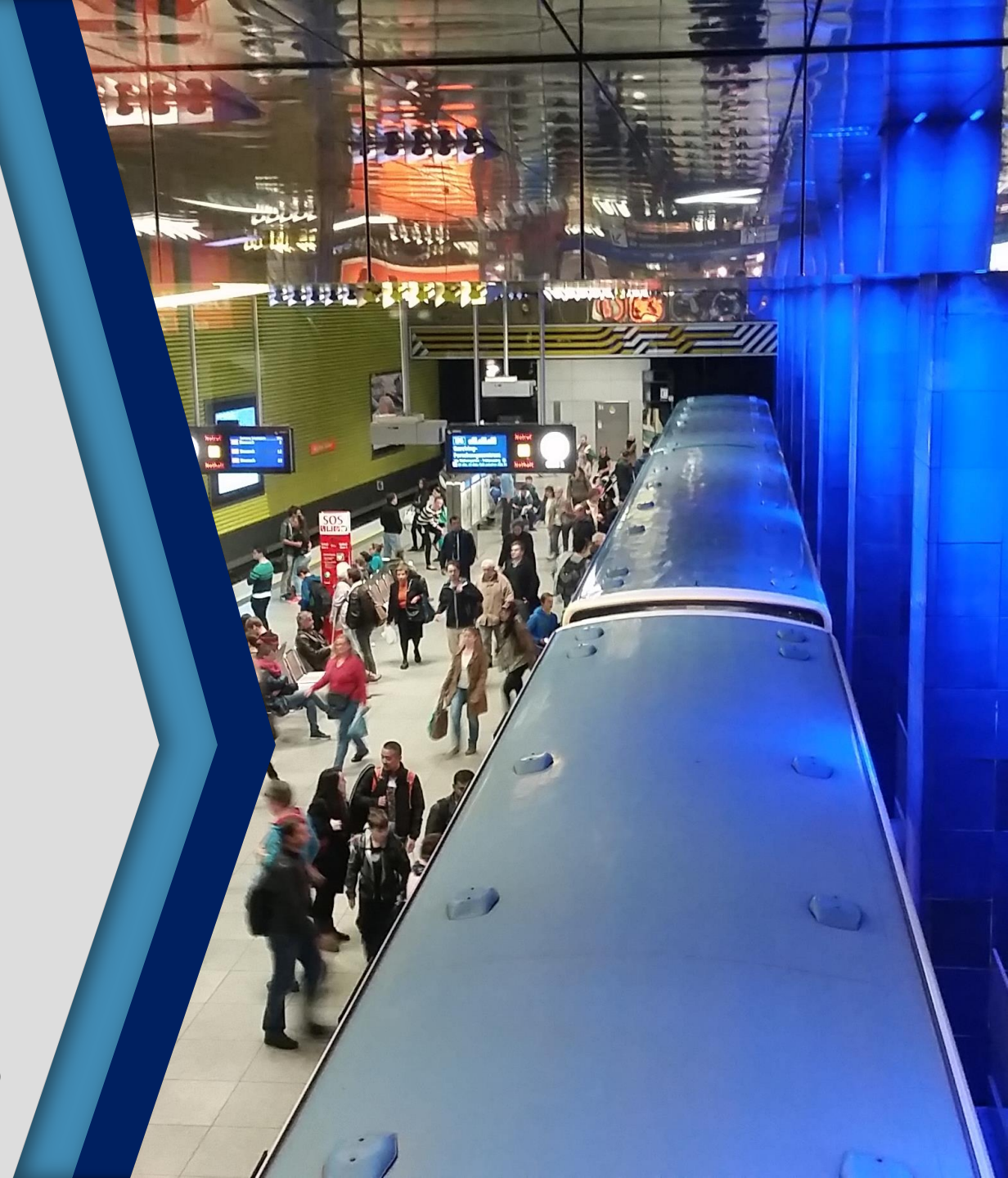
Departamento de Engenharia de Transportes
PTR-5925 – 2º Sem/2017

Tópicos da Aula

- Aulas 04 – Usuários, Qualidade e Capacidade
  - Conceito de Qualidade
  - Conceito de Capacidade
  - Capacidade Rodoviária
  - Capacidade Ferroviária

PTR3431 - Planejamento e Operação de Sistemas de Transporte

Conceito de Qualidade



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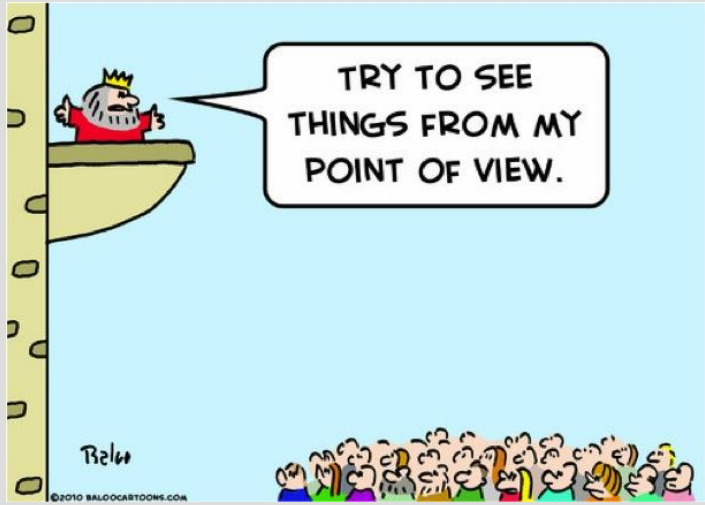
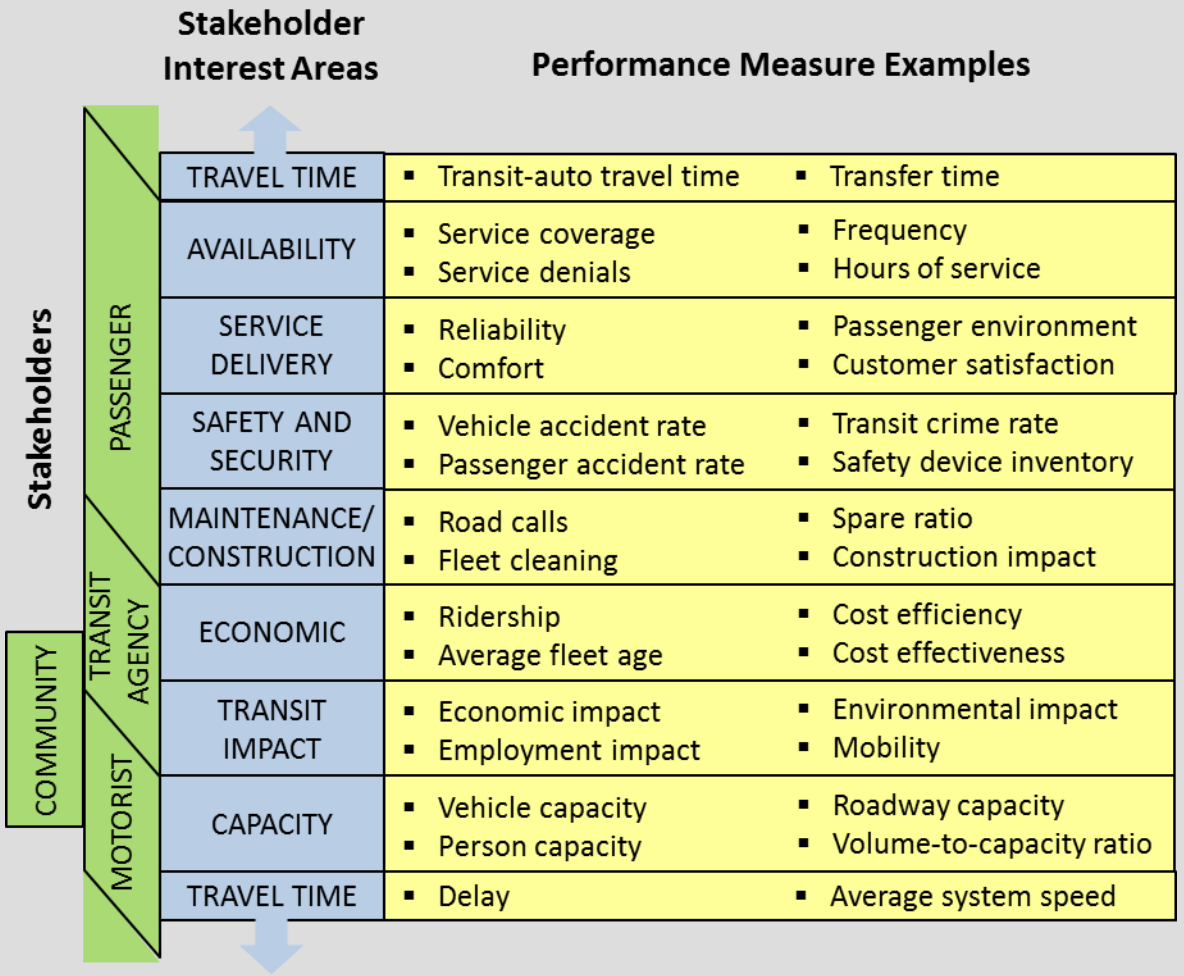
Avaliação de Projetos – Ponto de Vista?

- Usuários
- Operadores
- Moradores
- Trabalhadores
- Atividades Produtivas
- Uso do Solo
- Proprietários
- Contribuintes

De qual **ponto de vista** os projetos devem ser avaliados?



Stakeholders Viewpoints



Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Conceito de Qualidade - Empreendimento

- Qualidade de projeto;
- Garantia de fornecimento;
- Eficiência nos investimentos;
- Eficiência nos serviços;
- Qualidade dos bens;
- Qualidade dos serviços;
- Oferta de serviços;
- Qualidade ambiental;
- Segurança;

Fonte: Tese de Doutorado, Gabriel Feriancic (2011)

Conceito de Qualidade - Empreendimento

- Manutenção;
- Atualidade;
- Modicidade tarifária;
- Equilíbrio econômico-financeiro;
- Qualidade na reversão dos bens;
- Igualdade;
- Continuidade;
- Universalidade.

Fonte: Tese de Doutorado, Gabriel Feriancic (2011)

Conceito de Qualidade - Serviço

- Quality of service (QOS) is the overall measured or perceived performance of transit service from the passenger's point of view.

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Conceito de Qualidade - Serviço

- Quality of service has two main components
  - Transit availability determines whether transit is even an option for a trip
  - If transit is an option, comfort and convenience factors weigh into a person's decision to choose transit for a given trip

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Conceito de Qualidade - Serviço

- Disponibilidade...

Availability

Spatial Availability (Origin)

Spatial Availability (Destination)

Temporal Availability

Information Availability

Capacity Availability

Fonte: Transit Capacity and Quality of Service Manual, 3nd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Frequency
  - Service Span
  - Service Coverage
  - Passenger Loads
  - Reliability
  - Travel Time
  - etc

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Frequency

>5–10 min	• Frequent service, no need for passengers to consult schedules • Bus bunching possible, which can result in longer-than-planned waits for a bus and more variable loads	• Feasible on high-density corridors with bus or rail service, and where routes converge to serve a major activity center • Short headways needed for circulator routes to be able to compete with walking and bicycling (*2*) • Exclusive right-of-way desirable to reduce external impacts on transit operations and to keep operating speeds high (minimizing operating costs) • Traffic congestion, dwell time variability, and differences in bus operator driving styles may result in bus bunching • Increasing frequency to add capacity usually feasible (budget permitting) when exclusive right-of-way provided in congested areas

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Service Span

Hours of Service	Passenger Perspective	Operator Perspective
>18 h	• A full range of trip purposes can be served • Allows bus travel to replace potentially riskier travel (e.g., crime, drunk driving, poor visibility) by other modes late at night	• Often branded as “night” or “owl” service • May require added driver pay for late-night work • May require increased security measures on transit vehicles and in transit facilities • May only be offered certain days (e.g., Friday and Saturday nights) • May be operated on a different set of routes than operate the rest of the day (e.g., emphasizing coverage over travel time)

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Service Coverage

Service Level	Passenger Perspective	Operator Perspective
>90% of service area population served	• Transit serves nearly all destinations within a community • On-board travel time may be long, as routes wind and loop through neighborhoods to meet a service coverage standard	• Transit operator has made a policy decision to emphasize coverage over cost-efficiency • Portions of routes covering low-density areas likely to be unproductive
>90% of transit-supportive area served	• Transit serves nearly all higher-density areas within the community • Destinations located in lower-density areas may not be accessible	• May be inefficient to serve isolated portions of the transit-supportive area due to poor street connectivity or geographic barriers • Likely inefficient to serve small pockets of higher density surrounded by large areas of low density
75–90% of transit-supportive area served	• Most destinations within higher-density areas are served, but not all	• Balances coverage and cost-efficiency objectives
50–74% of transit-supportive area served	• A majority of destinations within higher-density areas are served • Walking and bicycling access to transit likely to be longer, as service is provided farther away from many origins and/or destinations	• Potential opportunity to add service, as many areas that could support service have no service
<50% of transit-supportive area served	• Service is typically provided only in the community's highest-density corridors • What service is provided is likely to be relatively direct, resulting in relatively short travel times	• Transit operator has made a policy decision to emphasize cost-efficiency over coverage

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Passenger Loads

Vehicles Designed for Most Passengers Seated

Up to 125% seated load	• Up to 20% of passengers must stand • Standees may need to shift position within the vehicle at each stop as other passengers board or alight • Perceived travel time up to 1.25x actual travel time for seated passengers and up to 2.1x actual travel time for standees	• Very productive service • Often used as a service standard for off-peak bus service • Time to serve boarding and alighting passengers goes up when standees are present, resulting in longer dwell times and potentially slower travel speeds than at lower loading levels

Vehicles Designed for Most Passengers Standing

<2.2 ft^2/p <0.20 m^2/p	• Crush loading conditions	• Moving to and from doorways extremely difficult, increasing dwell time (*13*) • Passengers waiting to board may try to shift to a door in a less-crowded section of the vehicle, increasing dwell time • Passengers waiting to board may choose to wait for the next vehicle, increasing platform crowding

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Reliability

Headway-based Service

c_{vh}	P (abs[h_i-h] > 0.5 h)	Passenger and Operator Perspective
0.00-0.21	≤2%	Service provided like clockwork
0.22-0.30	≤10%	Vehicles slightly off headway
0.31-0.39	≤20%	Vehicles often off headway
0.40-0.52	≤33%	Irregular headways, with some bunching
0.53-0.74	≤50%	Frequent bunching
≥0.75	>50%	Most vehicles bunched

standard deviation of headways divided by the scheduled headway

Schedule-based Service

80–89%	• Passenger making one round trip per weekday with no transfers experiences up to two not-on-time vehicles every week	• Typical range for commuter rail that shares track with freight rail • Typical range for light rail with some street running • Achievable by bus services in small to mid-sized cities

no more than 1 minute early and up to 5 minutes late

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Medidas de Qualidade de Serviço

- QOS Measures
  - Travel time

Transit–Auto Travel Time Ratio	Passenger Perspective	Operator Perspective
≤1	• Faster trip by transit than by auto	• Feasible when transit operates in a separate right-of-way and the roadway network is congested
>1–1.25	• Comparable in-vehicle travel times by transit and auto • For a 40-min commute, transit takes up to 10 min longer	• Feasible with express service • Feasible with limited-stop service in an exclusive lane or right-of-way
>1.25–1.5	• Tolerable for choice riders • For a 40-min commute, transit takes up to 20 min longer	
>1.5–1.75	• Round trip up to 1 h longer by transit for a 40-min one-way trip	
>1.75–2	• A trip takes up to twice as long by transit than by auto	• May be best possible result for mixed traffic operations in congested downtown areas
>2	• Tedious for all riders	• May be best possible result for small city service that emphasizes coverage over direct connections

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

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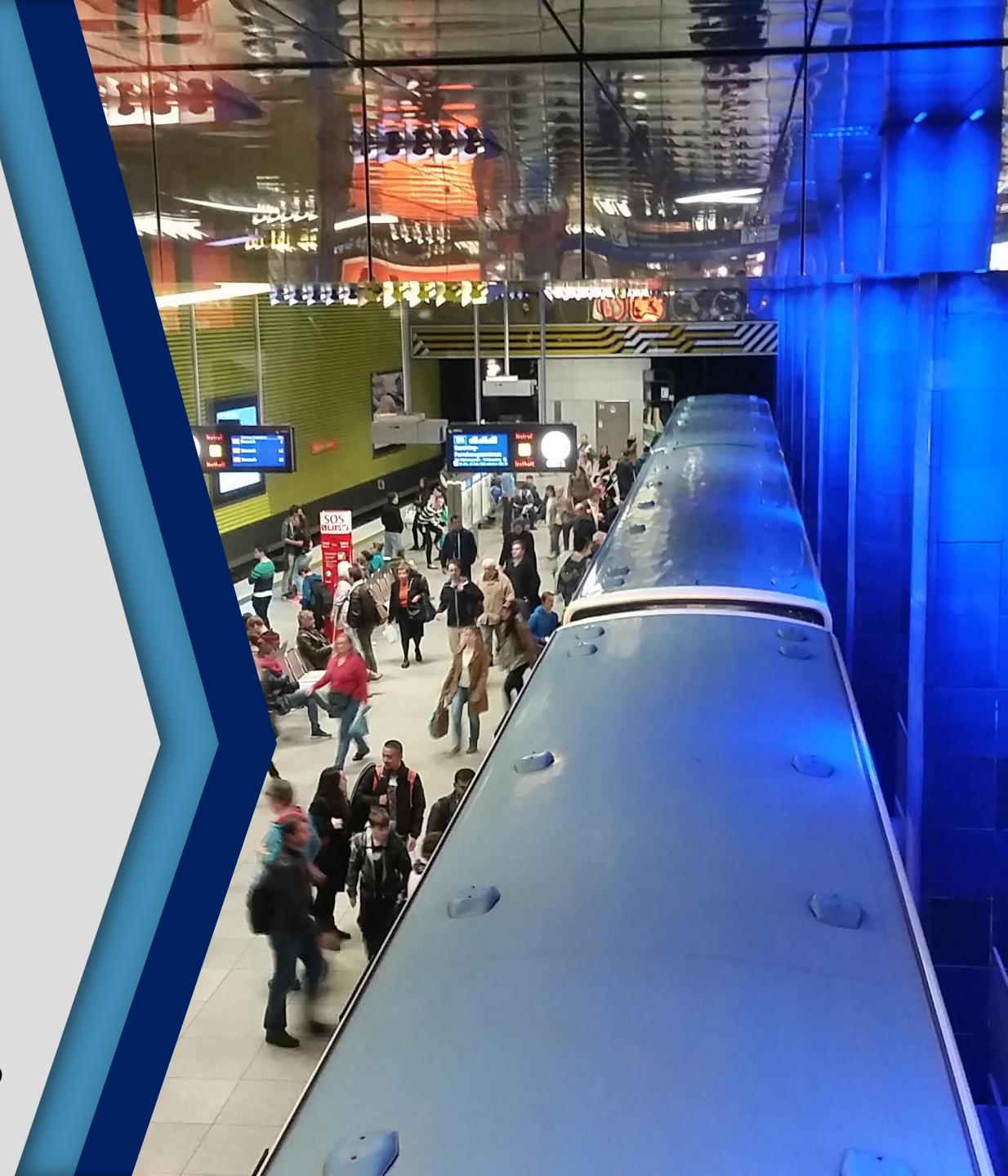
Conceito de Capacidade



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Conceito de Capacidade de Transporte

- O que é capacidade de serviço de transporte?

"O número máximo de passageiros que podem ser transportados em um certo trecho em um certo período sob condições operacionais específicas; sem atrasos, ameaças ou restrições inaceitáveis e com razoável confiabilidade."

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

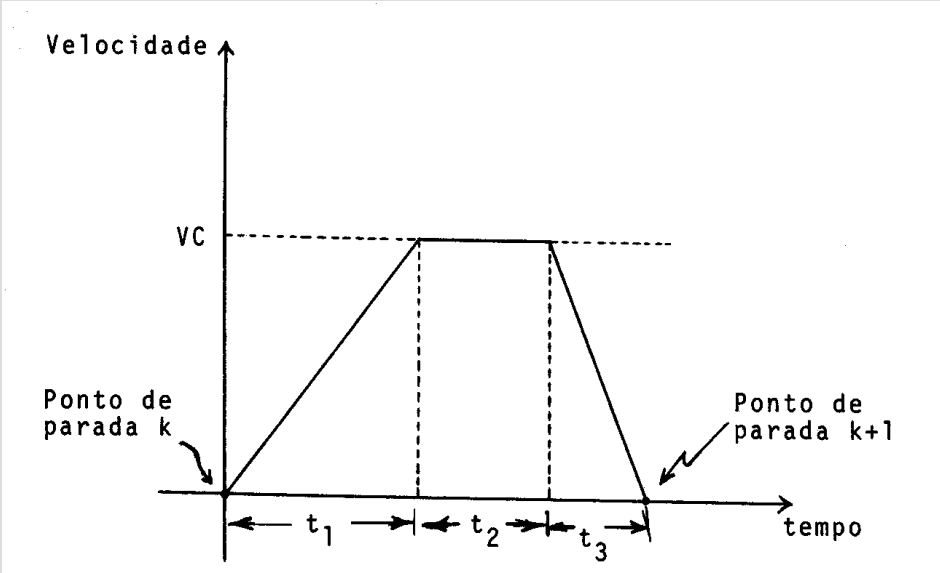
Conceito de Capacidade de Transporte

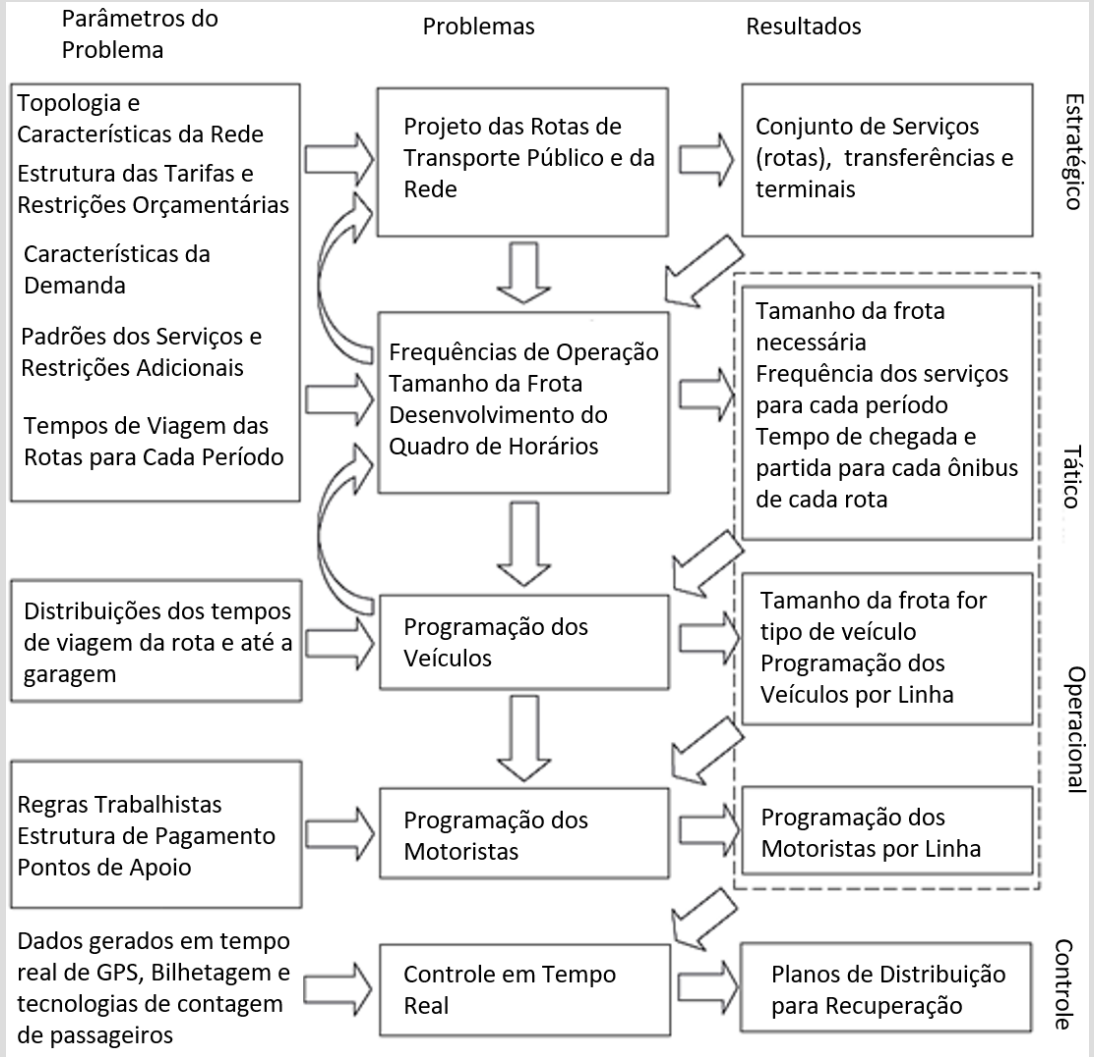
- Capacity reflects the maximum number of transit vehicles, persons, or both, that can travel past a particular location in a given period of time under specified conditions
  - Maximum (theoretical) capacity reflects the greatest number of persons or transit vehicles that can be served under any circumstance
    - Not normally used for planning and design
    - Operating to maximum capacity results in unstable operations
  - Design (achievable, practical) capacity reflects the number of persons or transit vehicles that can be served at a design quality of service
    - What TCQSM procedures calculate, unless specifically stated otherwise
  - Vehicle (bus/line/vessel) capacity is measured in vehicles per hour and expresses how many transit vehicles can pass a point in an hour
  - Passenger capacity is measured in persons per vehicle and expresses how many passengers a transit vehicle can carry at a design loading level
  - Person capacity is the product of vehicle and passenger capacity, is measured in persons per hour, and expresses how many persons can pass a point in an hour

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Capacidade de Transporte

- Conforme visto anteriormente...





Fonte: Ibarra-Rojas et al. (2015), adaptado de Ceder e Wilson (1986).

Capacidade de Transporte

Capacidade de transporte — Passageiros por hora

- **Capacidade do veículo** — Passageiros por veículos
- **Frequência** — Veículos por hora

$CapT = capV \times Freq$

Frequência — Veículos por hora

- Desempenho da via
- Desempenho do veículo
- Tamanho da frota
- Tempos e locais de parada

Headway / **Intervalo** — Tempo entre veículos

$Freq = 1 / hw$

Capacidade de Transporte

Headway

Intervalo

Tempo entre veículos

Tempo de ciclo

Tempo da viagem completa

Frota operacional

Veículos

Hw = TC / frota operacional

Tempo de ciclo

Tempo da viagem completa

- Tempo de deslocamento
- Tempos de paradas
- tempos de embarque e desembarque
- Simulação de marcha

Transporte Público Coletivo

- Diferentes sistemas...

... apresentam diferentes desempenhos e capacidades.

Transporte Público Coletivo

- Diferentes sistemas...

Bonde – "Santa Teresa"
(Rio de Janeiro)

Transporte Público Coletivo

- Diferentes sistemas...

Ônibus em Tráfego Misto
(Rio de Janeiro)

Transporte Público Coletivo

- Diferentes sistemas...

Ônibus em Faixa Preferencial
(Maceió)

Transporte Público Coletivo

- Diferentes sistemas...

Ônibus em Corredor Exclusivo (Curitiba)

Transporte Público Coletivo

- Diferentes sistemas...

People Mover - "Aeromóvel"
(Porto Alegre)

Transporte Público Coletivo

- Diferentes sistemas...

Veículo Leve sobre Trilhos
(Rio de Janeiro)

Transporte Público Coletivo

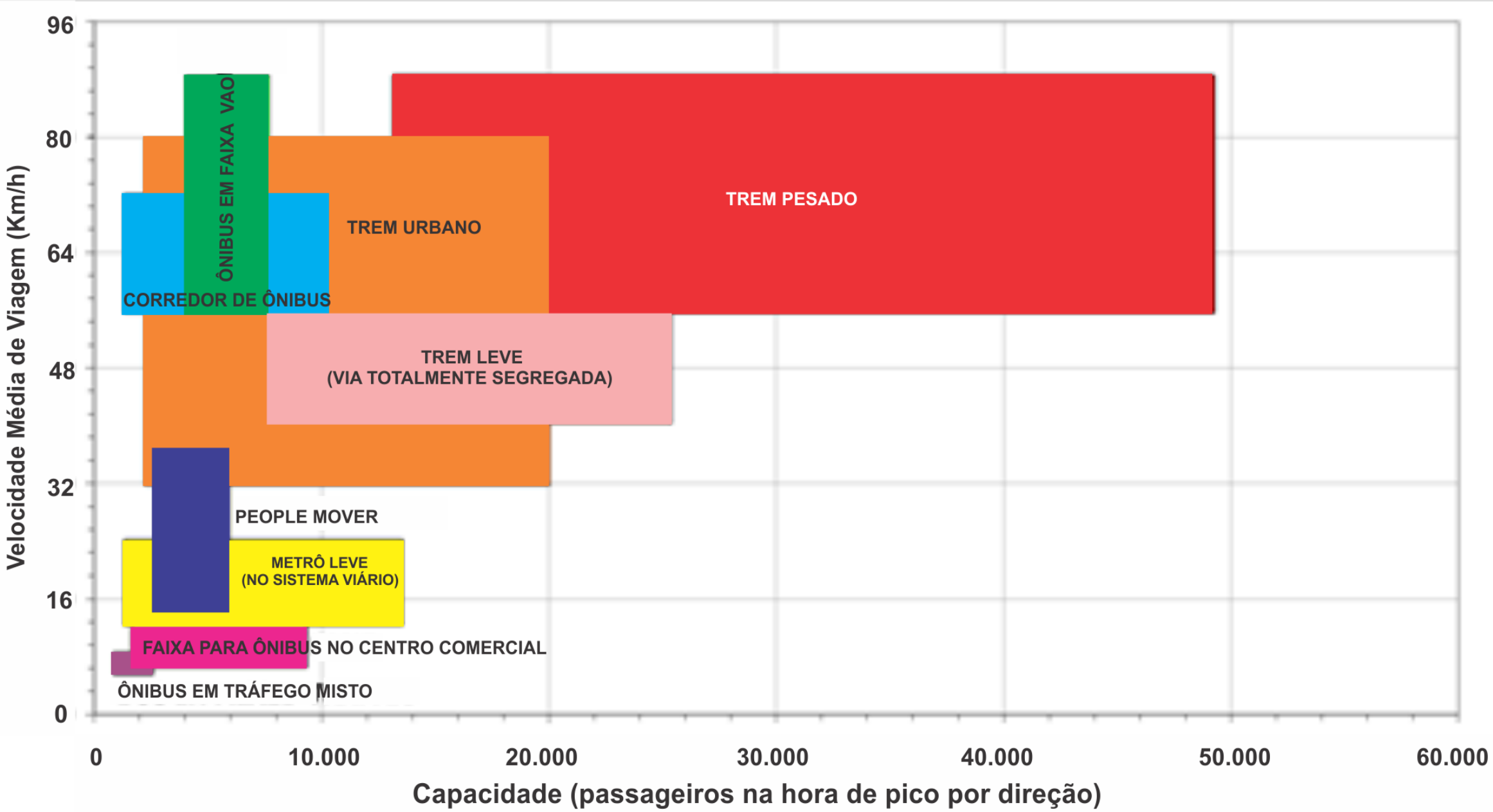
- Diferentes sistemas...

Metrô
(Rio de Janeiro)

Transporte Público Coletivo

- Diferentes sistemas...

Trem Urbano
(São Paulo)



Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

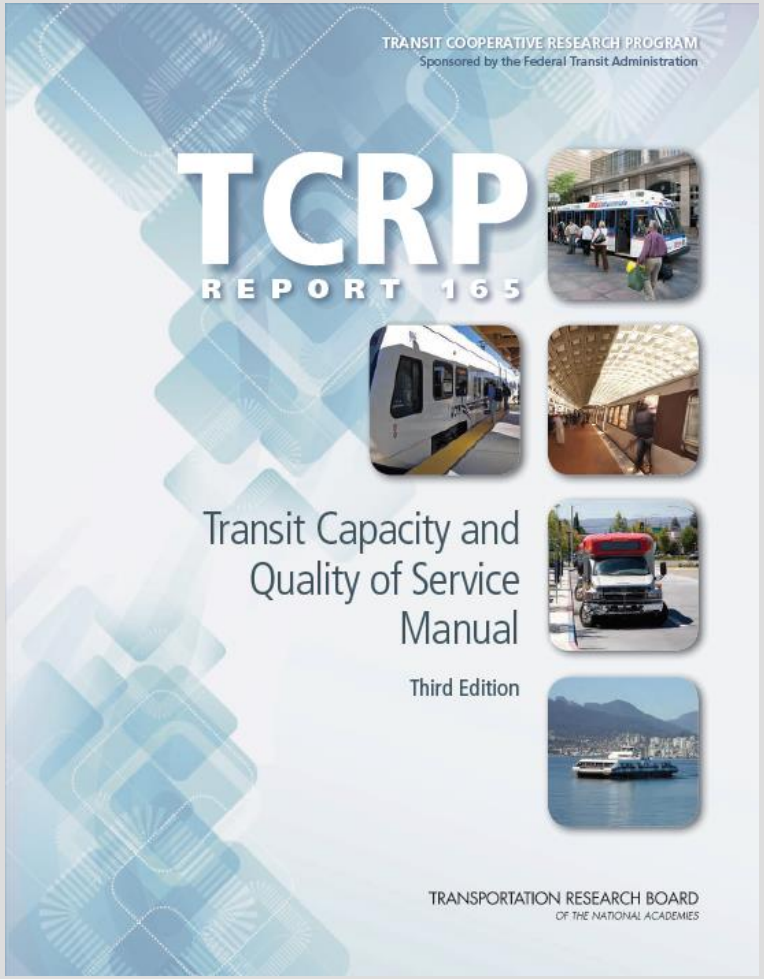
Notas: VAO - Veículos de Alta Ocupação
Intervalo de velocidade reflete principalmente hipóteses diferentes com relação à distância entre paradas e tempo de espera.
Intervalos da capacidade refletem principalmente hipótesesque envolvem diferentes tempo de espera e números de carros por trem.

Fatores de Capacidade

- Bibliografia sugerida:

Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

http://www.trb.org/Main/Blurbs/169437.aspx



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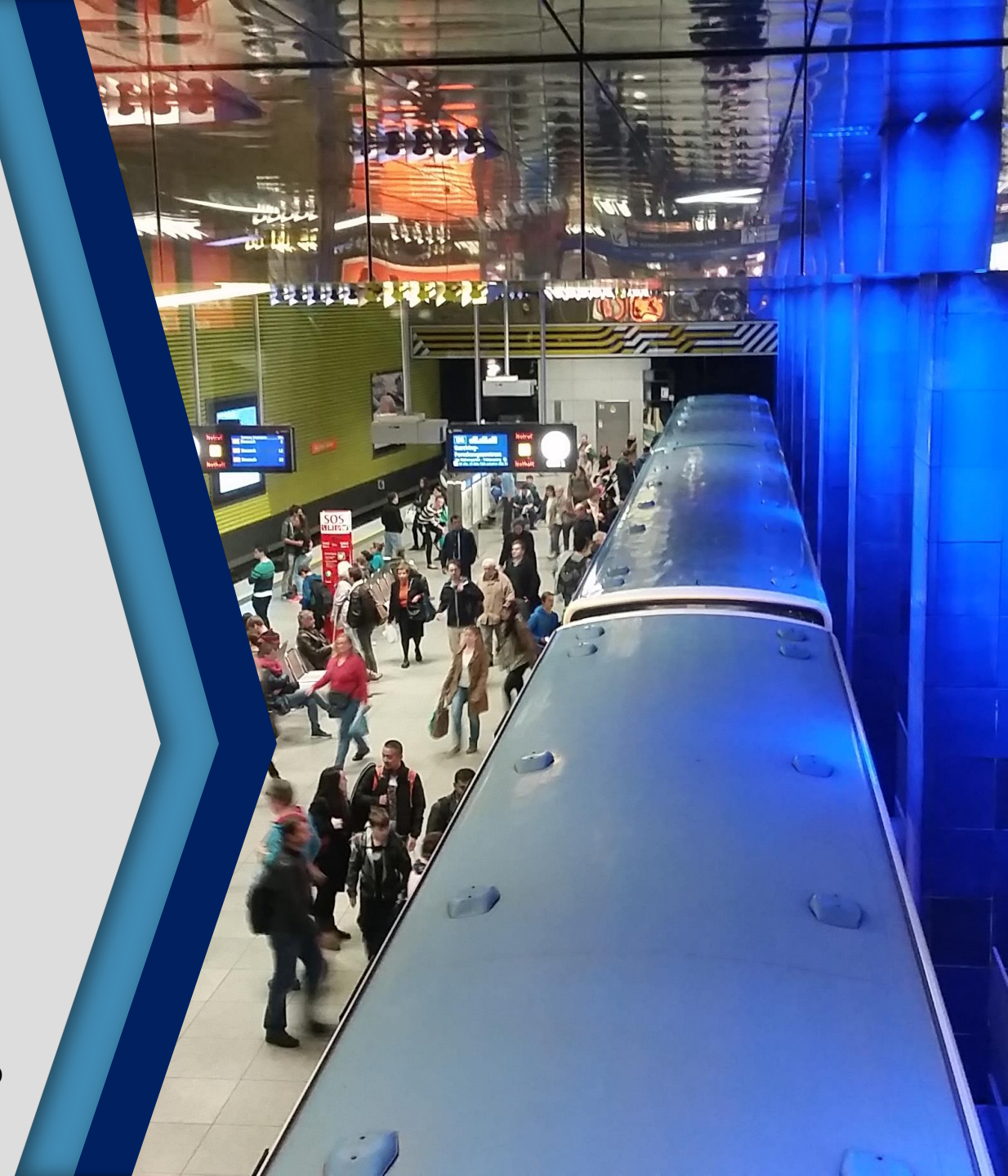
Capacidade - Ônibus



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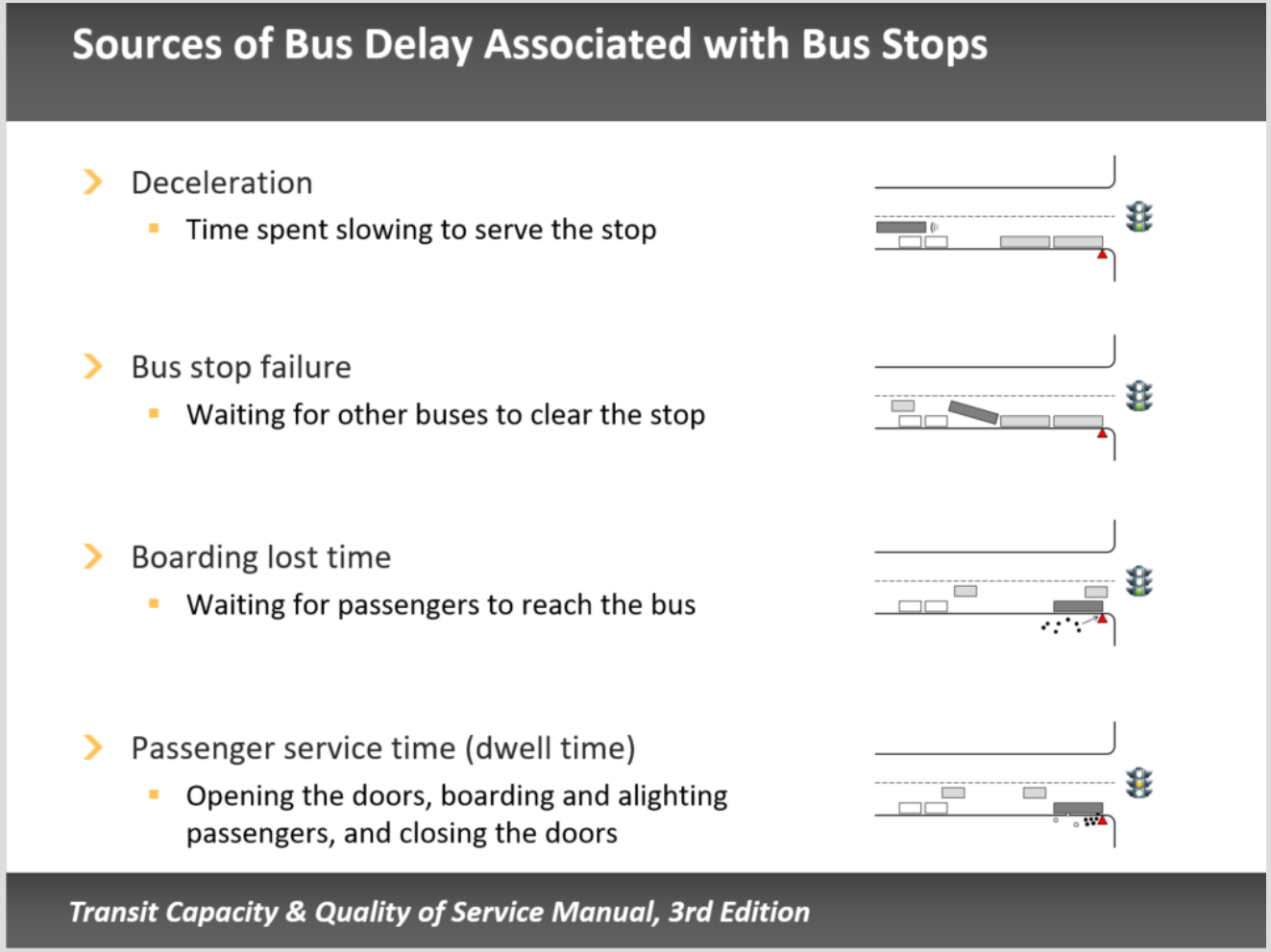
Fatores de Capacidade - Ônibus

Fatores de Capacidade - Ônibus

- Atrasos...



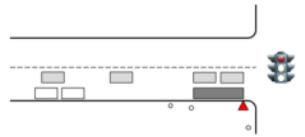
Fonte: Transit Capacity and Quality of Service Manual, 3nrd Edition (2013)

Fatores de Capacidade - Ônibus

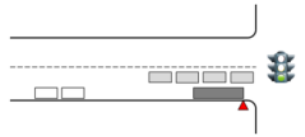
- Atrasos...

Sources of Bus Delay Associated with Bus Stops (cont'd.)

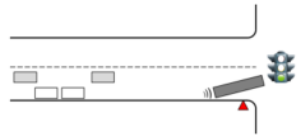
- Traffic signal (traffic control) delay
  - Waiting for the signal to turn green, or other traffic control delay



- Re-entry delay
  - Waiting for a gap in traffic



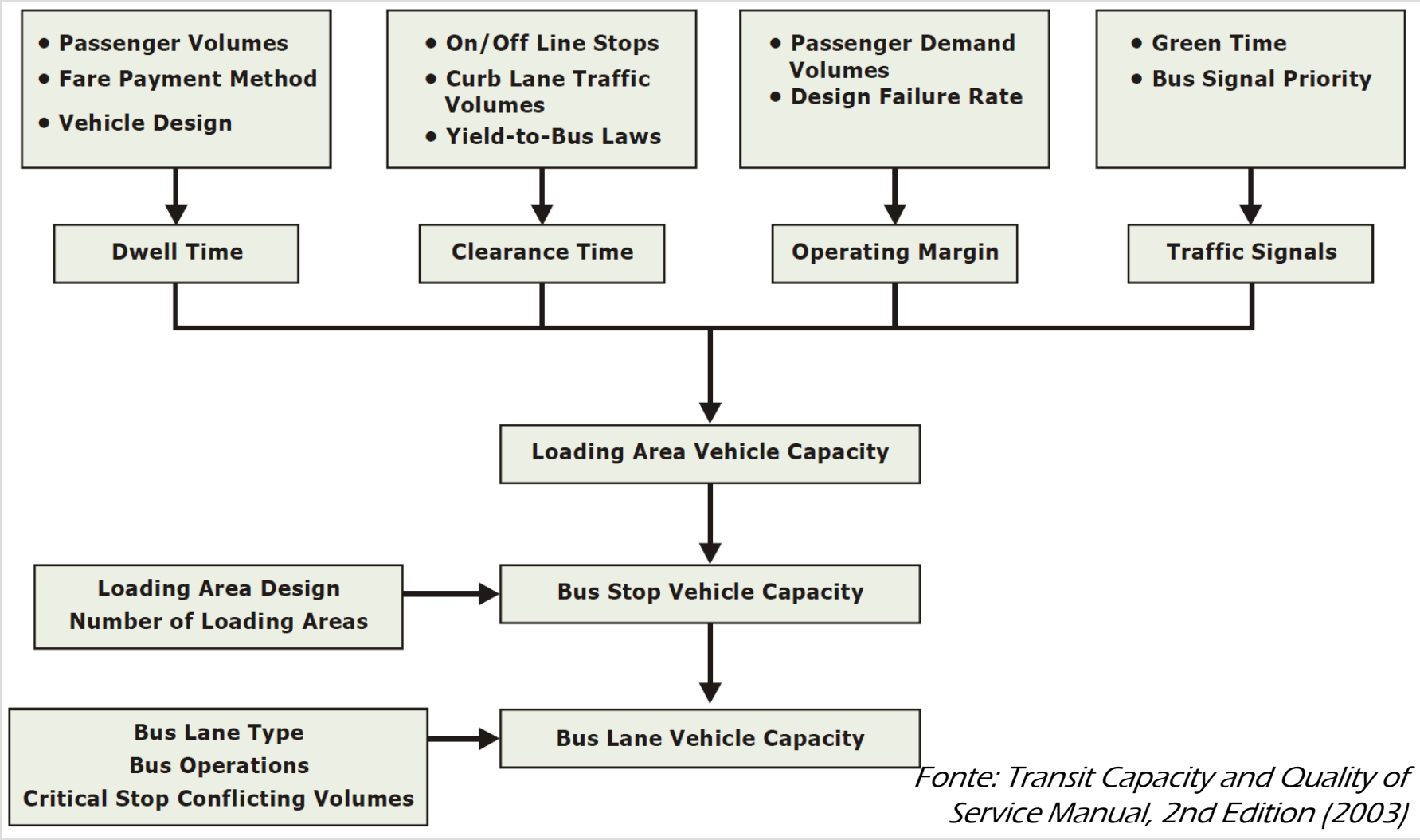
- Acceleration
  - Time spent getting back up to speed



Transit Capacity & Quality of Service Manual, 3rd Edition

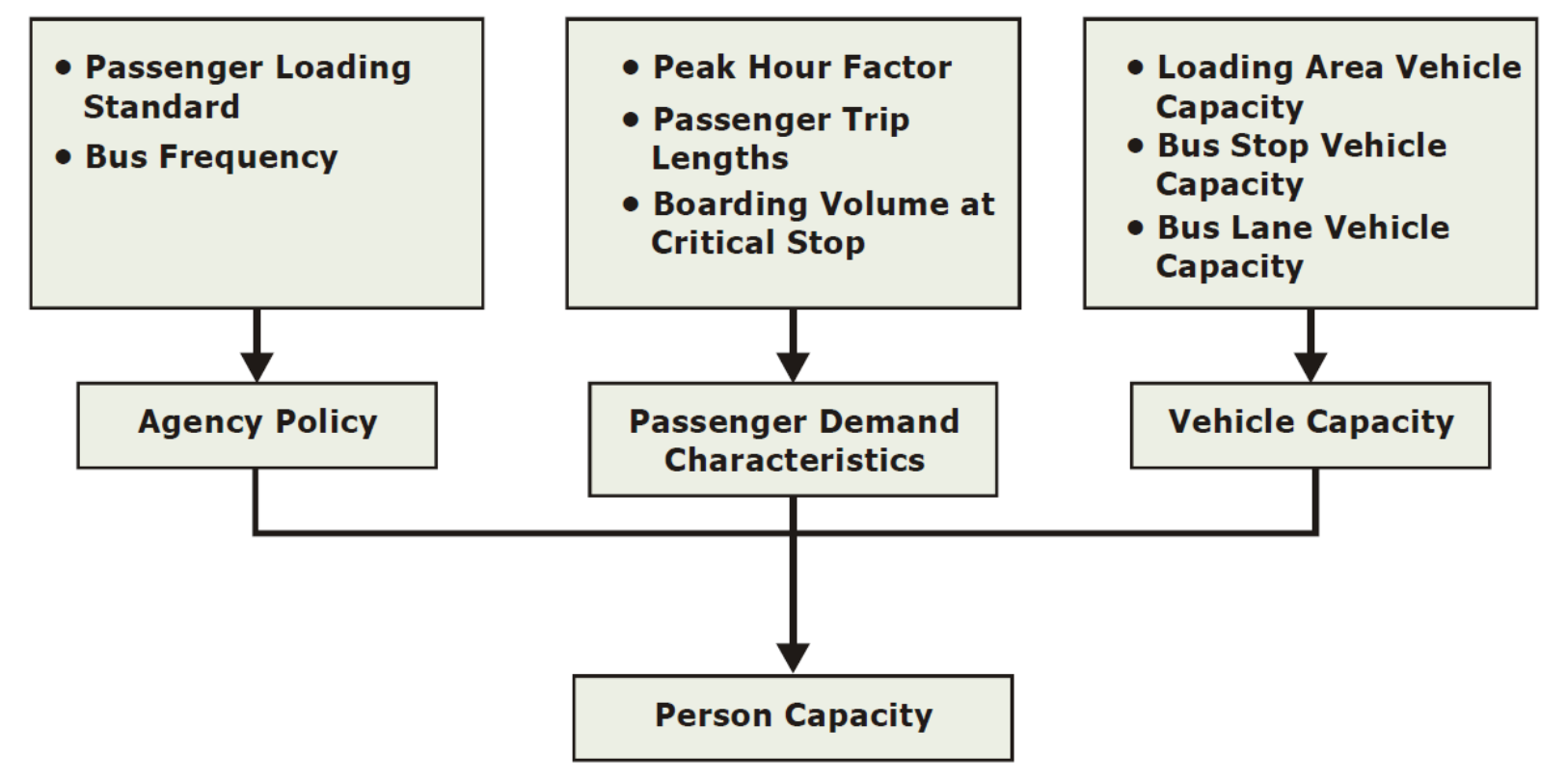
Fonte: Transit Capacity and Quality of Service Manual, 3nrd Edition (2013)

Fatores de Capacidade - Ônibus



Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

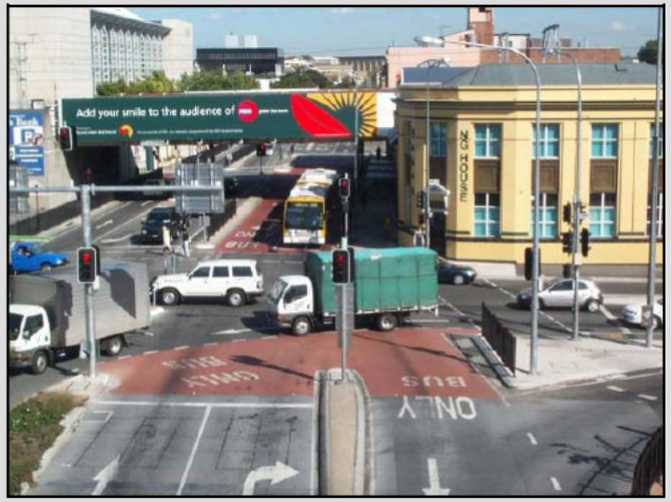


Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial e exclusivo
  - Problemas típicos: Ultrapassagem, Sinalização, Conversão, Conflito em tráfego misto

(a) No Passing Lane Available



(b) Traffic Signals

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Faixa central
  - Faixa lateral com restrição de estacionamento em via pública
  - Lei de espera ao ônibus (“Yield-to-bus”)
  - Faixa para veículos com alta ocupação
  - Priorização semafórica
  - Ilhas de embarque
  - Alargamento de calçada

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Faixa central

(a) Curitiba, Brazil

(b) Montréal

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Faixa lateral com restrição de estacionamento em via pública

(a) Full-time lane (Portland, Oregon)

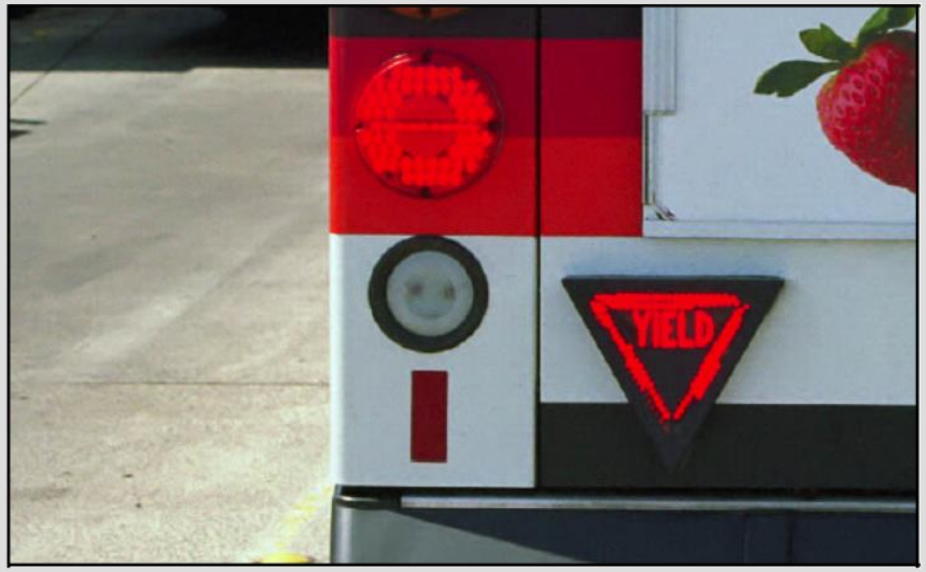
(b) Part-time lane (San Francisco)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Lei de espera ao ônibus ("Yield-to-bus")

(a) Montréal



(b) Portland, Oregon

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Faixa para veículos com alta ocupação

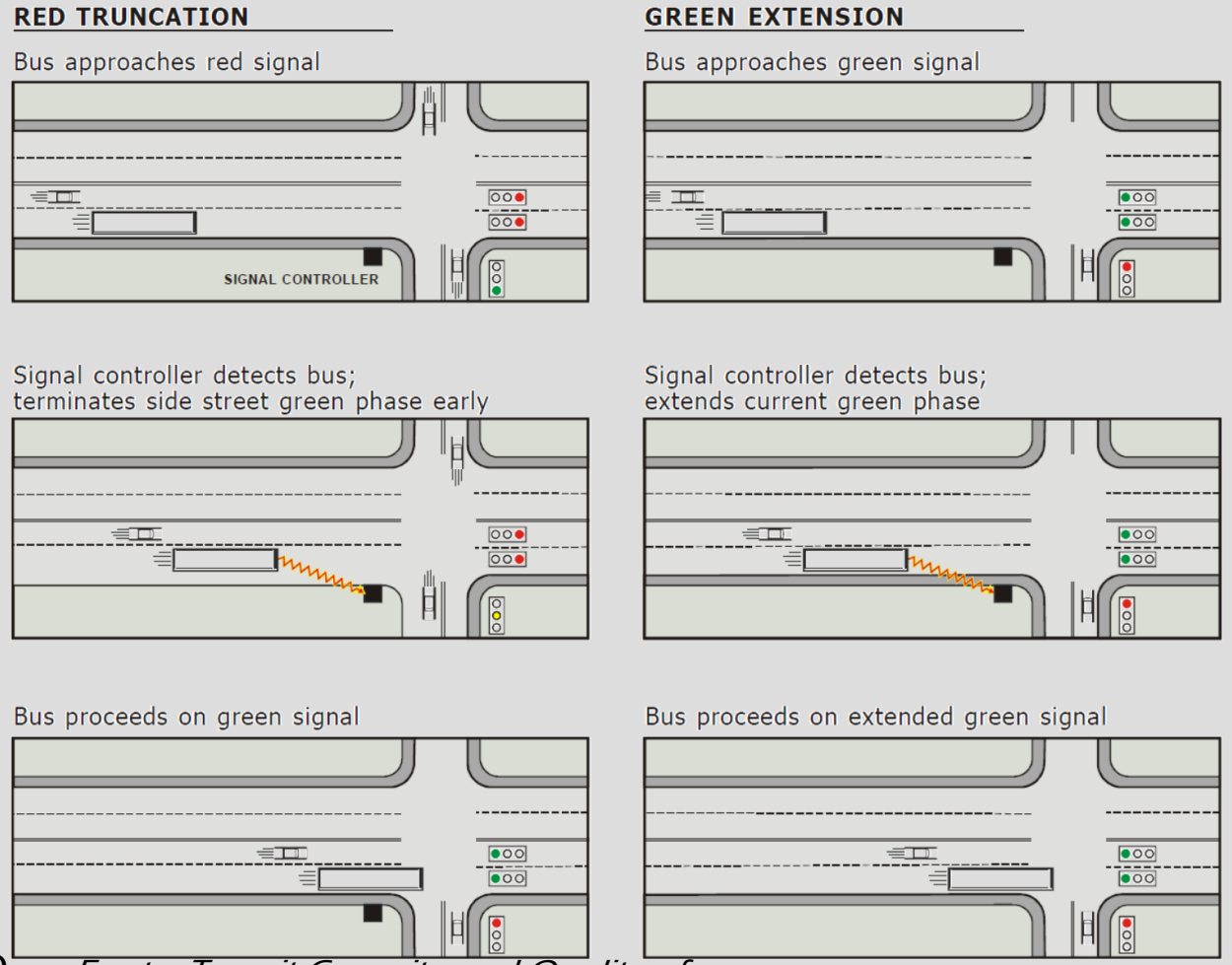
(a) I-10 Katy Freeway

(b) I-45 North Freeway

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

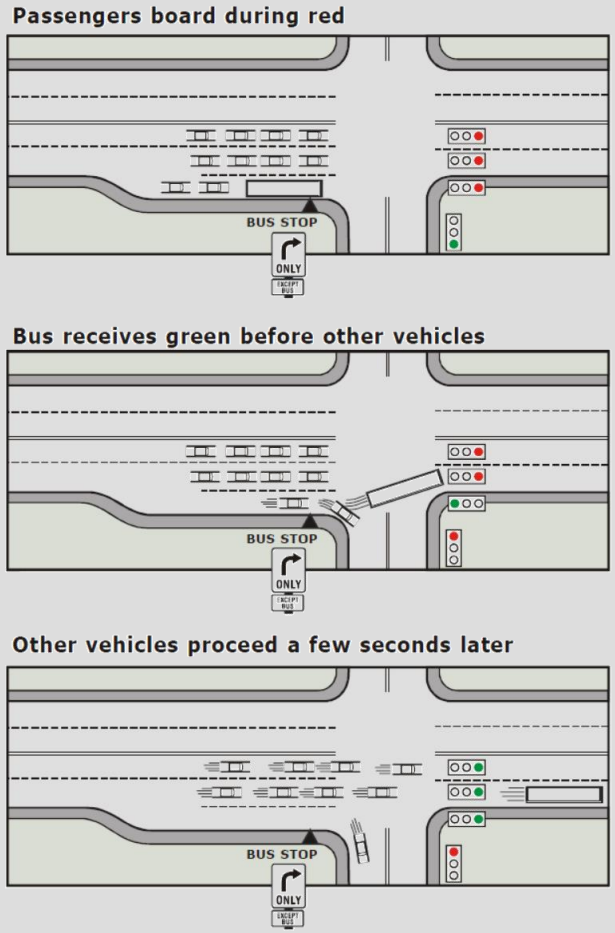
- Tráfego preferencial
  - Priorização semafórica



Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Priorização semafórica



(a) Near-Side Concept

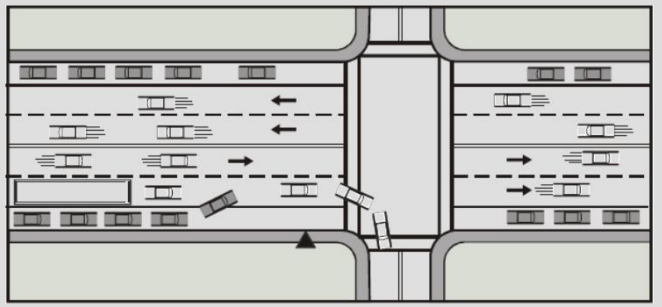
(b) Near-Side Application (Copenhagen)

(c) Far-Side Application (Portland, Oregon)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Ilhas de embarque



(a) Concept

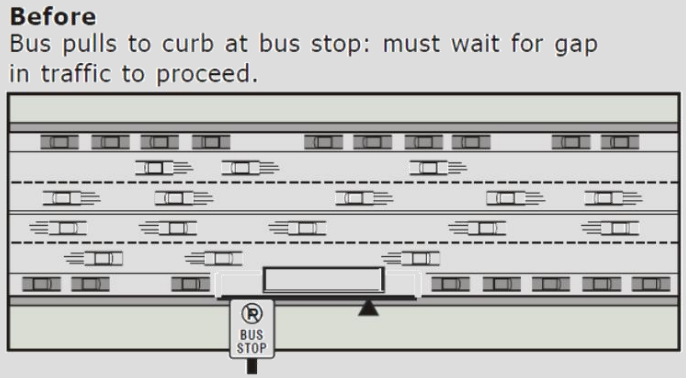
(b) Application (Washington, DC)

(c) Application (San Francisco)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego preferencial
  - Alargamento de calçada



(a) Concept

(b) Application (Vienna, Austria)

(c) Application (Portland, Oregon)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego exclusivo - Soluções típicas

(a) Exclusive, Grade-Separated Facility

(b) Passing Lanes at Stations

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

- Tráfego exclusivo - Soluções típicas

(c) Multiple Loading Areas

(d) Grade-Separated Pedestrian Crossings

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade - Ônibus

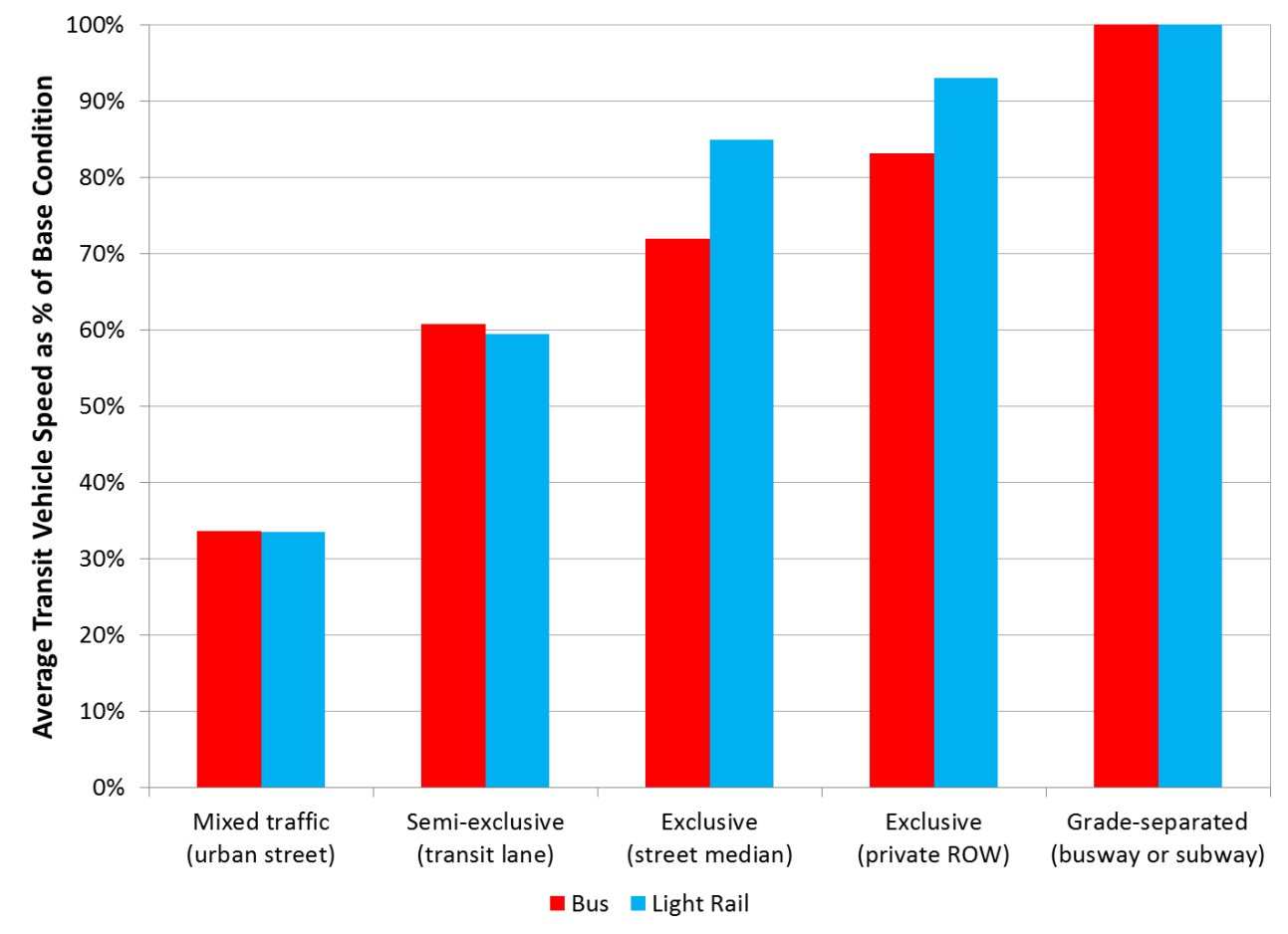
- Tráfego exclusivo - Soluções típicas

(e) Integration with Adjacent Land Uses

(f) Park-and-Ride Lots, Feeder Bus Access

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

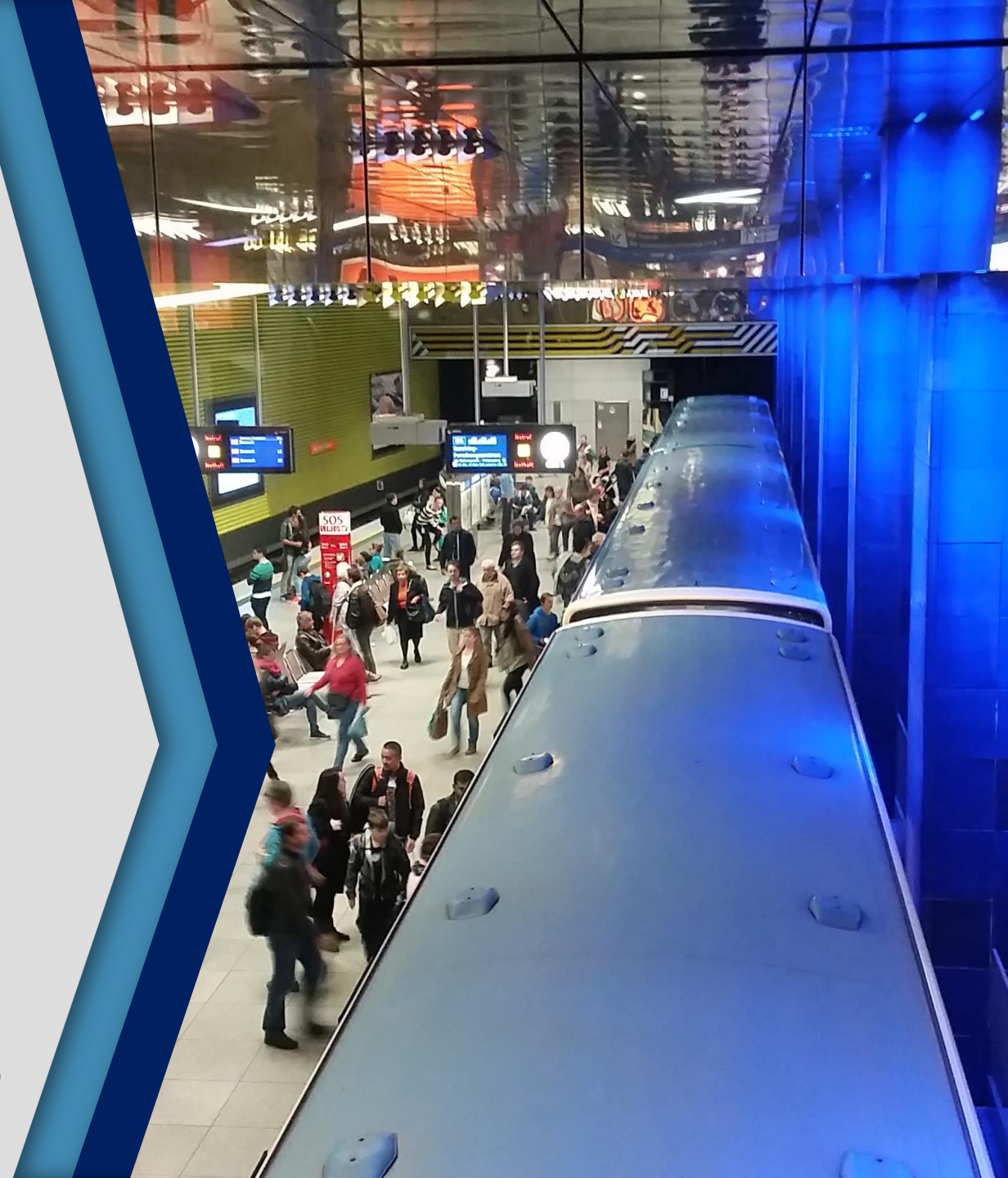
Comparação BRT x LRT



Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

PTR3431 - Planejamento e Operação de Sistemas de Transporte

Capacidade - Ferrovia



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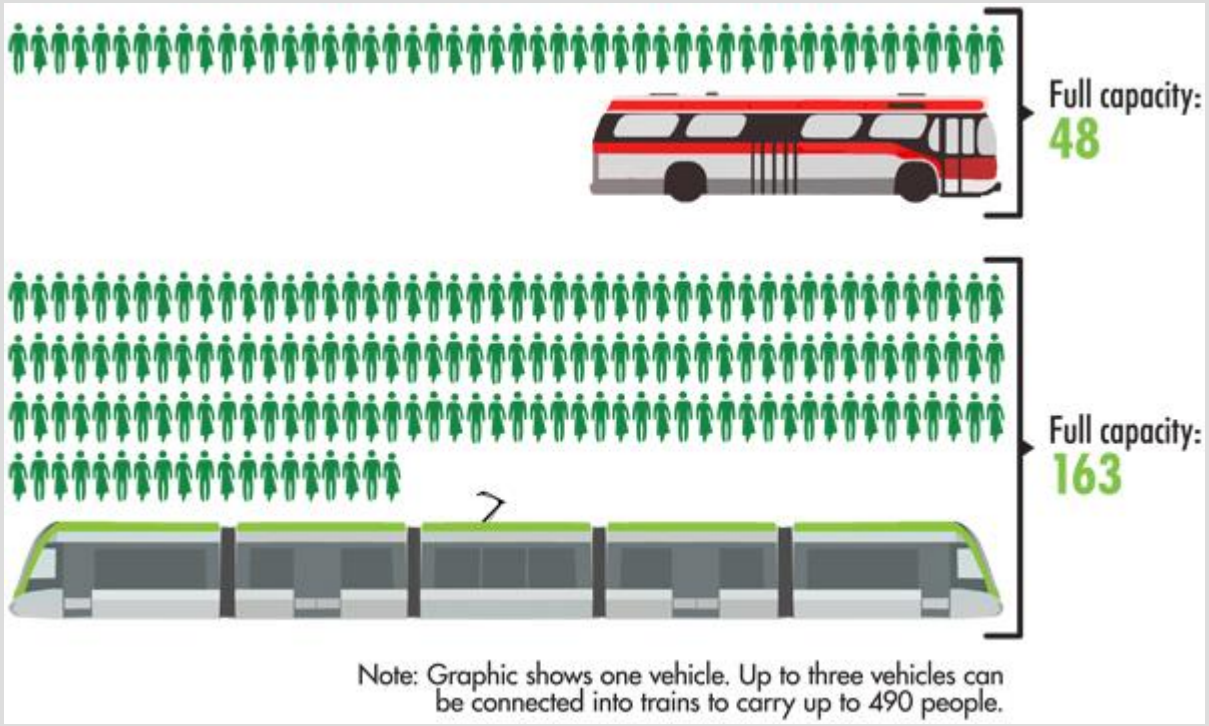
Fatores de Capacidade - Ferrovia



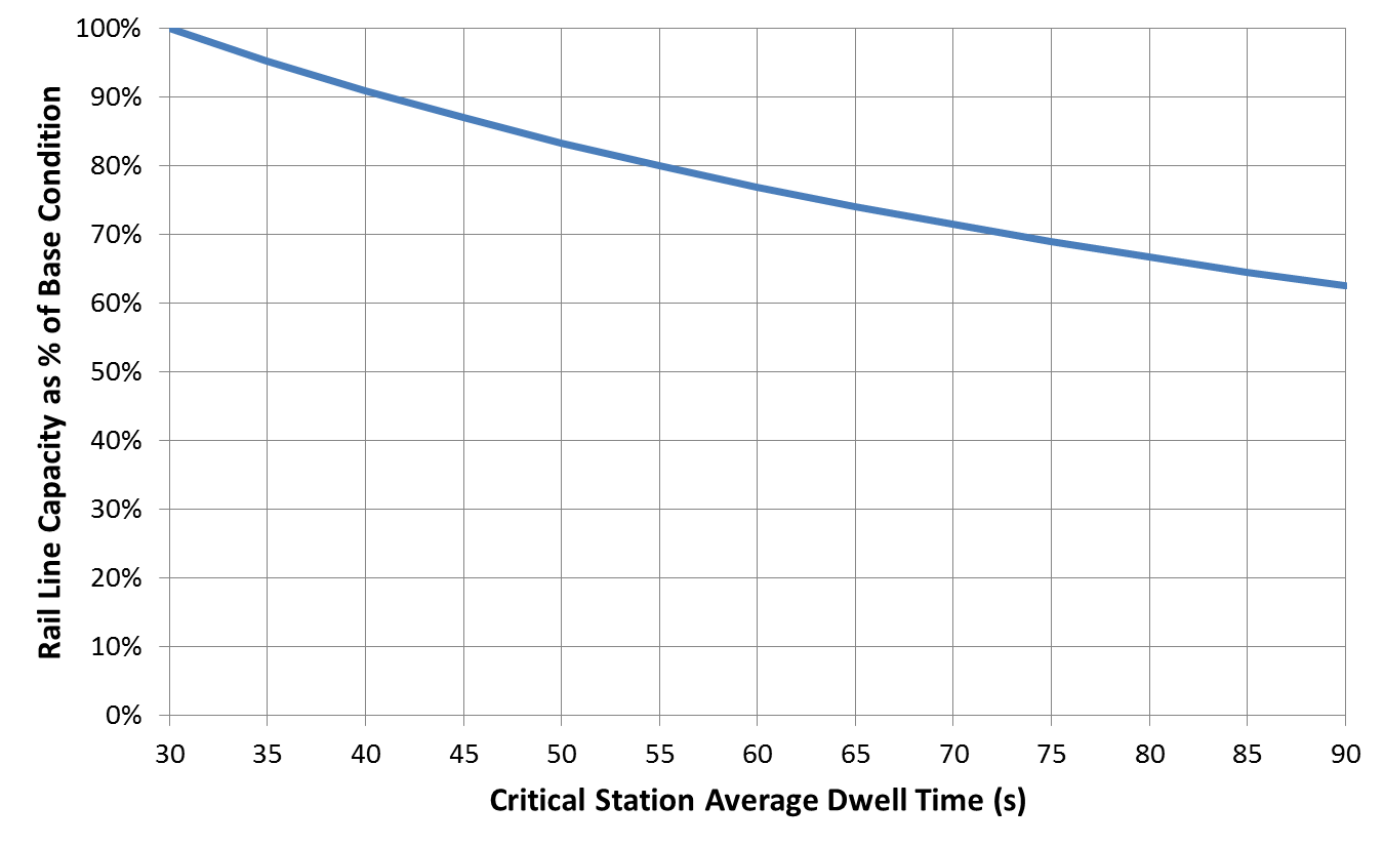
Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Tempo de parada
    - Tempo de abertura e fechamento de portas
    - Tempo de partida após fechamento de portas
    - Tempo do fluxo dos passageiros
    - Tempo que as portas permanecem abertas após término do fluxo

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade – Ferrovia

- Efeito do Tempo de Parada – *Dwell Time*



Base condition assumes 30-second dwell times, 20-second operating margin, 50-second minimum train separation

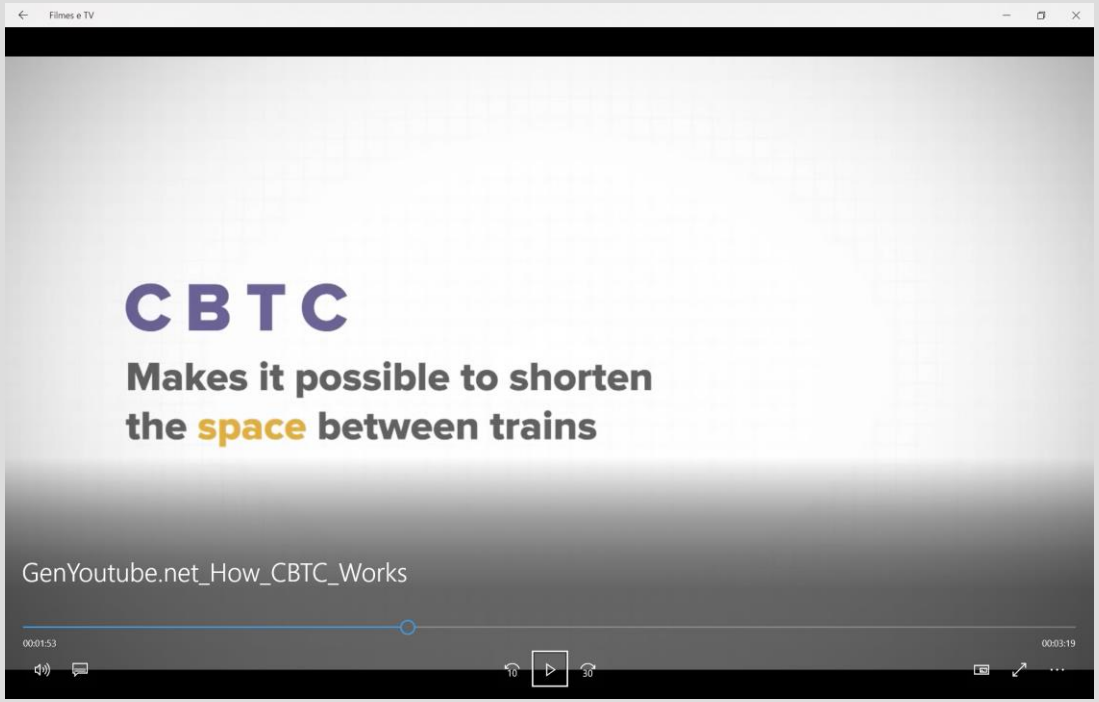
Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Margem operacional
    - Quando a operação está no limite, pequenas variações operacionais podem gerar atrasos
    - O atraso do trem na plataforma impede o avanço do trem seguinte

Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Sistema de Sinalização

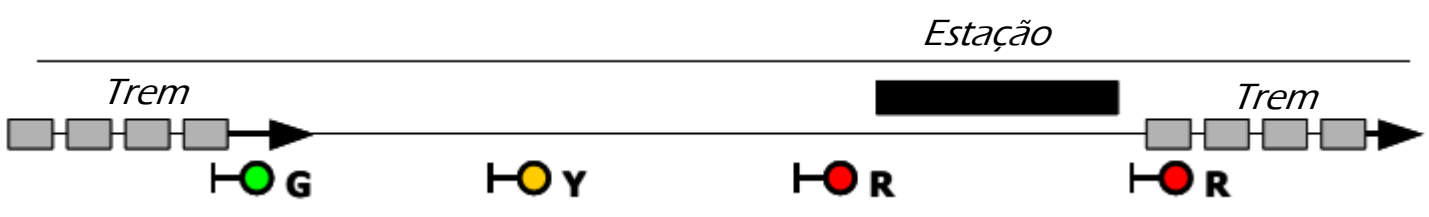


https://www.youtube.com/watch?v=x8Y237PcuzY

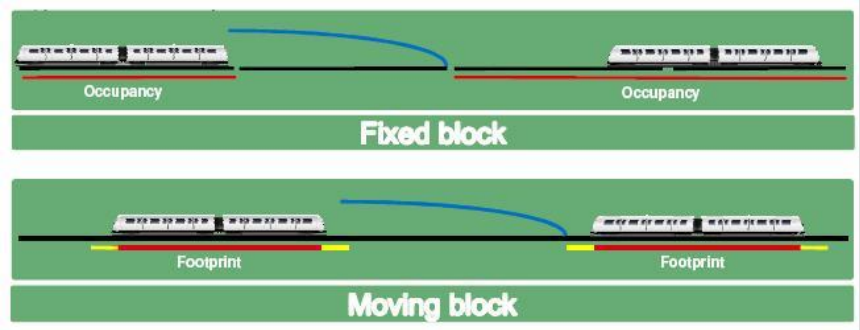
Fonte: RPA New York City, divulgação

Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Sistema de Controle e Sinalização



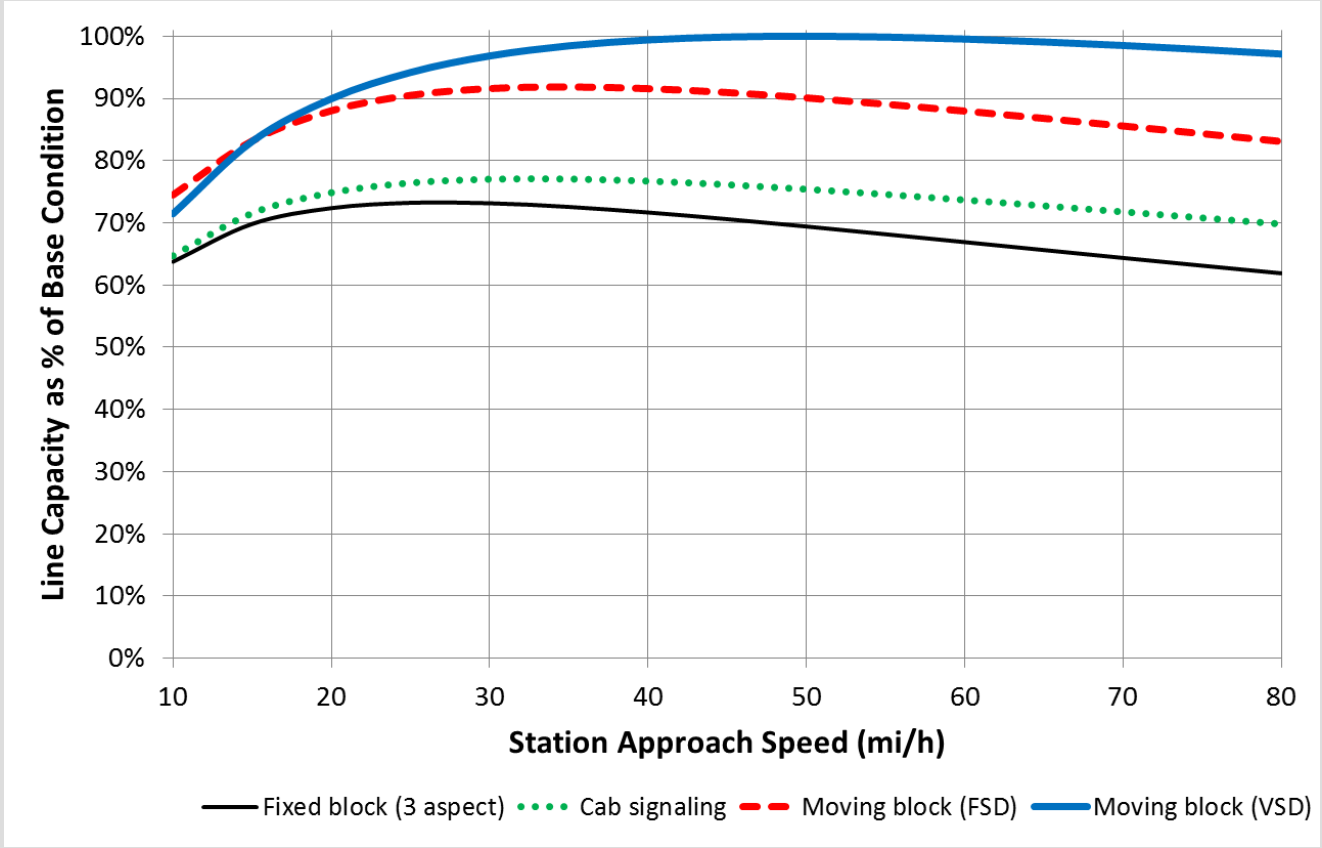
- Tipos:
  - Blocos fixos
  - Blocos móveis



Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade – Ferrovia

- Efeito do Sistema de Sinalização



Base condition assumes moving block signals with variable safety distances, 45-second average dwell time, 20-second operating margin, and no grade entering station. FSD = fixed safety distance, VSD = variable safety distance

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Fatores de Capacidade – Ferrovia

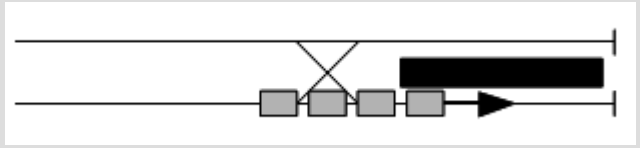
- Fatores que limitam o intervalo entre trens
  - Tempos e operação de retornos operacionais nas ponta de linha

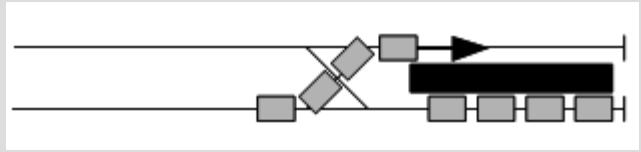
Hatfield Government Center Station, Hillsboro, Oregon

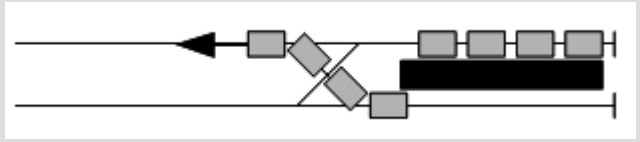
Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

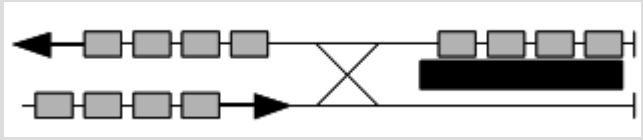
Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Tempos e operação de retornos operacionais nas ponta de linha

1. 

2. 

3. 

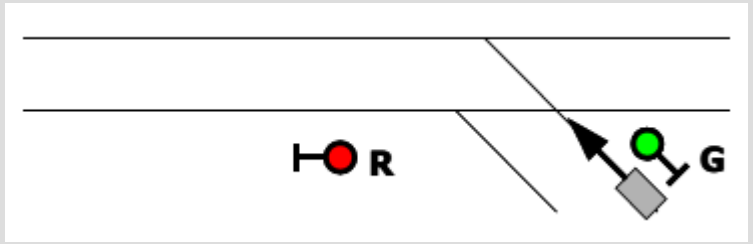
4. 

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Tempos e operação de junções

1.



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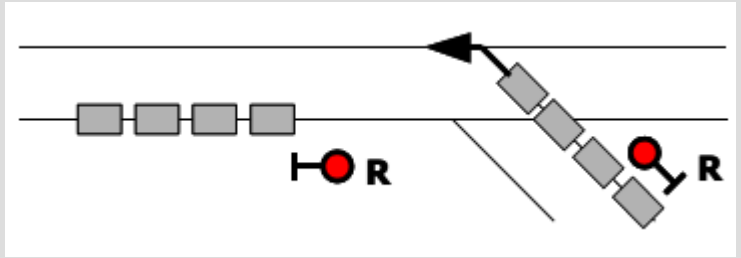

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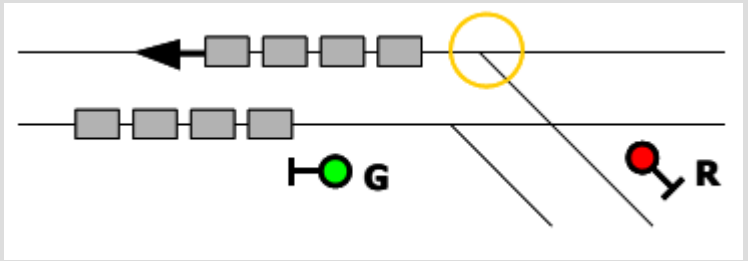

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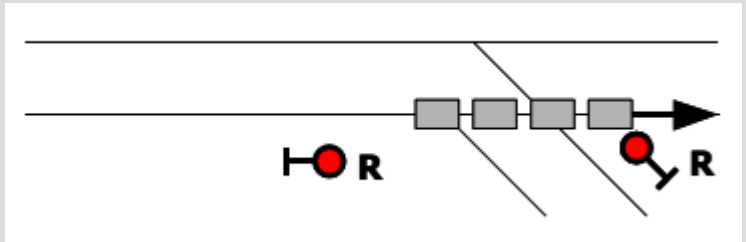
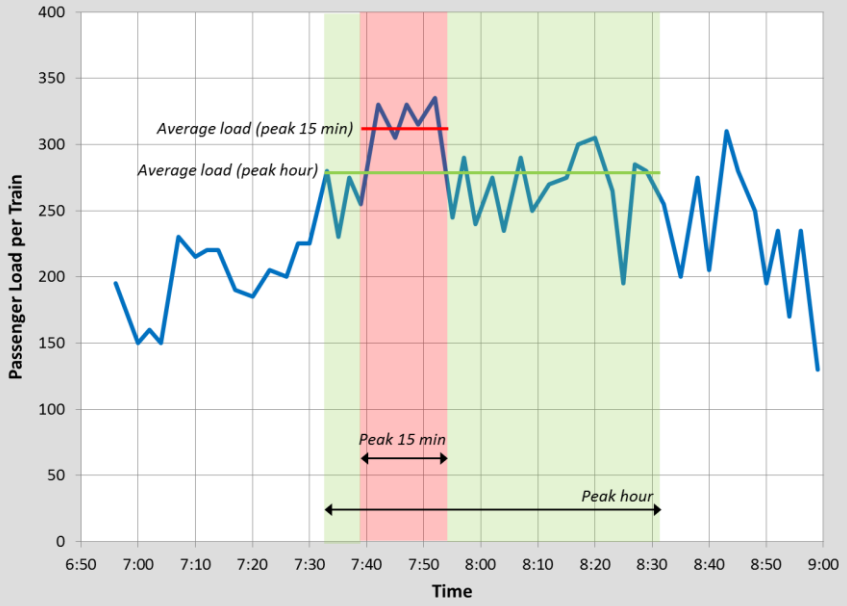


Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

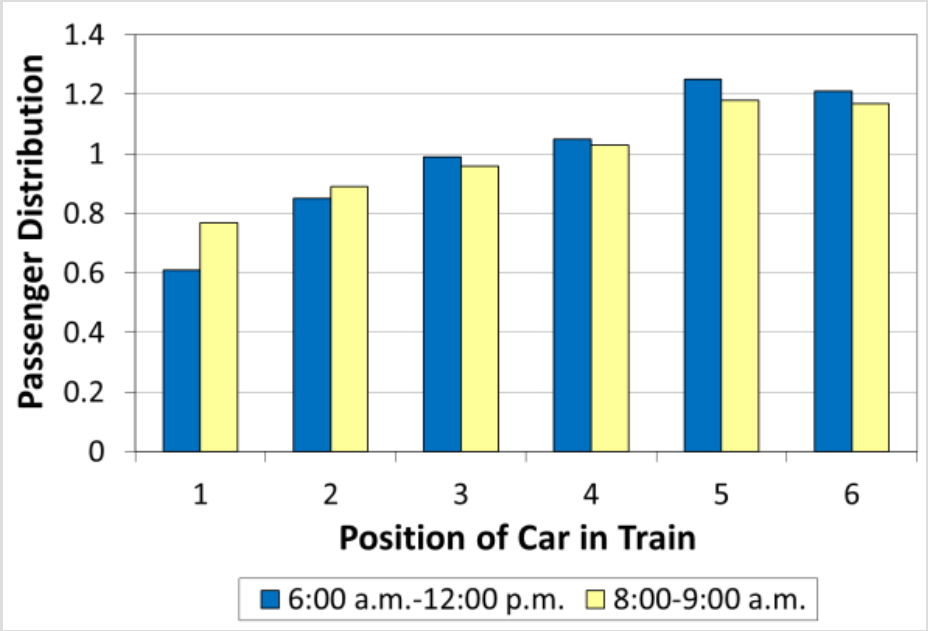
Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Limitações de capacidade de tração
  - Característica da demanda

Derived from TCRP Report 13: Rail Transit Capacity
Vancouver, BC, Broadway Station inbound, 10/27/94



Toronto, Wellesley Station southbound, 1/11/95
The rear two cars are closest to the platform exit at a major transfer station.
Source: TCRP Report 13: Rail Transit Capacity



Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Fatores de Capacidade – Ferrovia

- Fatores que limitam o intervalo entre trens
  - Outros fatores
    - VLT - Veículo Leve sobre Trilhos
      - Operações em via singela
      - Operação em tráfego misto
    - Trens suburbanos
      - Conflitos com passagens de carga

Fonte: Transit Capacity and Quality of Service Manual, 3rd Edition (2013)

Fatores de Capacidade – Ferrovia

- Tipos de Circulação
  - Tráfego misto, Faixa exclusiva, Via exclusiva

(a) Mixed Traffic—Center Lane (Toronto)

(b) Mixed Traffic—Curb Lane (Portland, Oregon)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade – Ferrovia

- Tipos de Circulação
  - Tráfego misto, Faixa exclusiva, Via exclusiva

(c) Exclusive Lane (Salt Lake City)

(d) Exclusive Lane—Contraflow (Denver)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

Fatores de Capacidade – Ferrovia

- Tipos de Circulação
  - Tráfego misto, Faixa exclusiva, Via exclusiva

(a) Private right-of-way (Philadelphia)

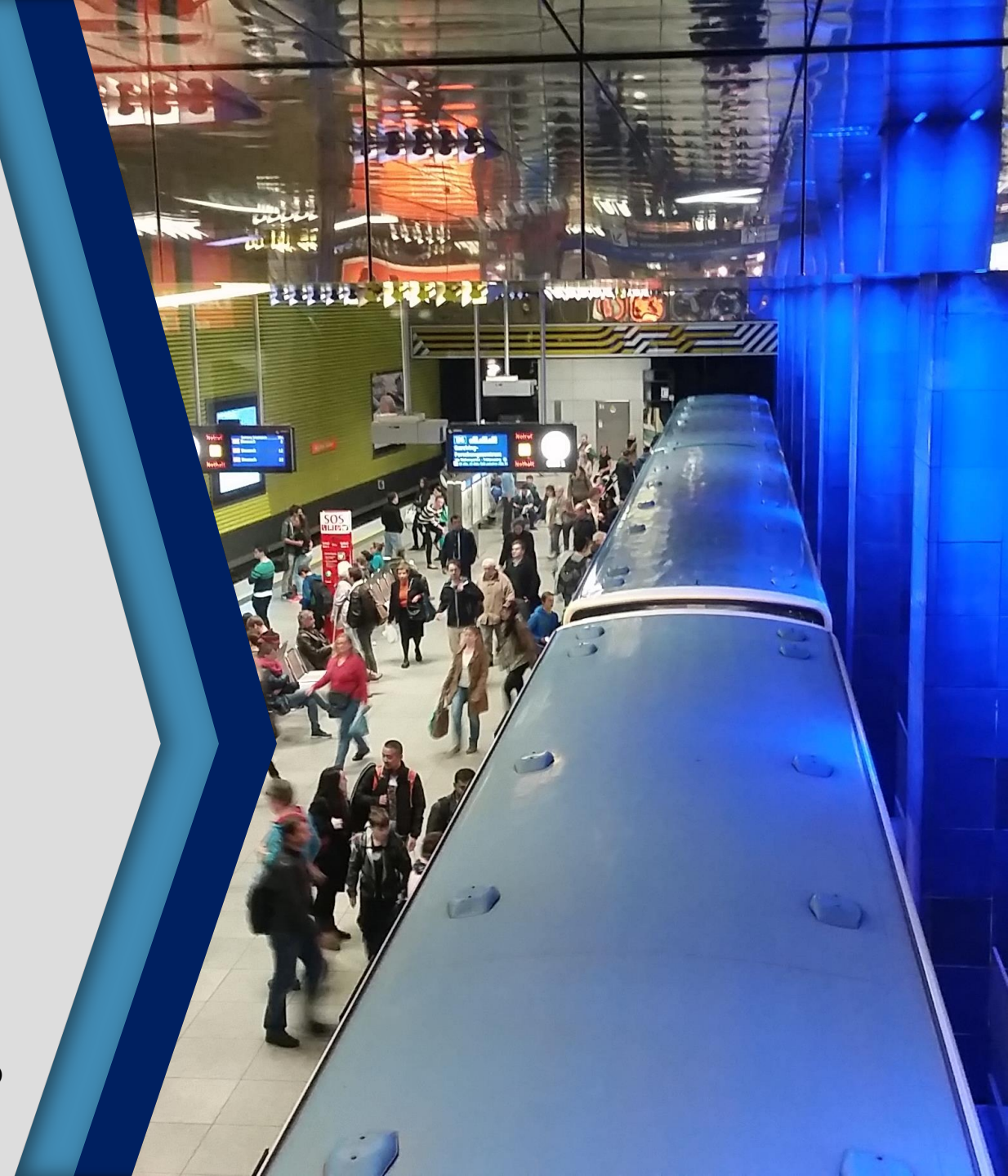
(b) Street median (Los Angeles)

Fonte: Transit Capacity and Quality of Service Manual, 2nd Edition (2003)

PTR-5925 - Sistemas de Transporte Coletivo Urbano de Passageiros: Oferta e Avaliação Econômica

Qualidade e Capacidade

Prof. Dr. Gabriel Feriancic



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