Forest Road Network and Pavement Engineering Revisited

FORMEC ’15
Linz (AUT)

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Network and Pavement Design Origins

Road Network Engineering

1950
1955
1960
1965

1949 UN Conference
Road and Motor Transport
- 2.5m width
- 8 / 14.5 to axle load
- 18 m length (truck-trailer)

Pavement Engineering

AASHO Design Guide
Pavement design

Matthews
Soom
Larsson
Segebaden

Dykstra 1976
Weintraub 1976
Mandt 1974
Road Networks – Built upon 1960 Philosophy?
B-Double Configuration (70to)
90t Configuration SWE (ab 2009)
**Key Questions**

- Take part of network out of service?
- Extend the existing network?
- Upgrade existing roads?
- Adapt pavement structure to traffic and vehicle requirements?
Road Network Geometry – Matthew’s World

\[ RD_r = \frac{l}{l \cdot s_r} = \frac{1}{s_r} \]

\[ AYD_{\text{theor}} = \frac{s_r}{4} = \frac{1}{4 \cdot RD_r} \]
Non-parallel Road Networks – Segebaden’s World

Road Network Efficiency Metrics
- $c_{\text{net}}$ Segebaden
- $e_{\text{net}}$ Backmund

Efficiency Metrics

\[ AYD_{\text{theor}} = \frac{1}{4 \cdot RD_r} = \frac{4 \cdot s_r^2}{4 \cdot 4 \cdot s_r} = \frac{s_r}{4} \]

\[ AYD_{\text{eff}} = \frac{s_r}{3} \]

\[ c_{\text{net}} = \frac{AYD_{\text{eff}}}{AYD_{\text{theor}}} = \frac{s_r \cdot 4}{3 \cdot s_r} = 1 \frac{1}{3} \]

\[ e_{\text{net}} = \frac{AYD_{\text{theor}}}{AYD_{\text{eff}}} = \frac{3}{4} \]
Non-Parallel Road Networks – Poisson World

Network Efficiency

- $c_{net} = 2$
- $e_{net} = 0.5$
**YD - From Mean Values to Distributions**

- **Parallel Network**
- **Grid Network**
- **Poisson Field**

The tail defines effectivity.
YD – Distribution Functions

Cum Density \([F(s_r)]\)

Yarding Distance

- Parallel Network
- Grid Network
- Poisson Field
Road Networks Assessment?
Real-World Example

Cum Density $[F(s)]$

Yarding Distance

Parallel Model

Grid Model

Real-World Net

$e_{net}$
4th-Power Law

Equivalent Standard Axle Load (ESAL)

Axle Load (kN)

Single-Axle

Tamdem-Axle

Tridem-Axle

Standard

Tridem-Gain

1 SAL 80 kN

80 kN

VSS 2011

VSS 2011

Hans R. Heinimann  |  15.12.2015  |  14
40to Truck-Trailer System

1.33 SAL  1.87 SAL  0.20 SAL  0.17 SAL

85 kN  171 kN  53 kN  85 kN
Damage to Pavement Effects of Different Vehicle Configurations

- B-Double road train 70 to: -73%
- Truck + trailer 60 to (SWE): -67%
- Truck + trailer 40+6 to: -50%
- Truck + trailer 40 to
- 3-axle trailer
- 2-axle trailer
- 3-axle truck
- 2-axle truck
AASHTO Pavement Design Approach

- $S_0$: Uncertainties
- $A_T$: Traffic
- $R_P$: Pavement Bearing Resistance
- $R_B$: Soil Bearing Resistance
- $S_0 Z_R$: Error (ESAL + Perf)
- ESAL: Equivalent Standard Axle Load
- SN: Structural Number
- $M_r$: Resilient Modulus
- CBR: California Bearing Ratio
**LVR Pavement Design** [AASHO Guide 1973, simplified]

\[ SN = 12.04 \cdot e^{-0.24 \cdot s_0 \cdot z_R} \cdot ESAL^{0.11} - 2.54 \]

Where:
- **ESAL** = Characteristic value of traffic actions
- **Mr** = Resilient Modulus (kPa)
- **s₀** = standard normal derivative
- **z_R** = Error (ESAL + Performance)
Pavement – Structural Elements

- Bankett Shoulder
- Damm Embankment
- Lockergestein / Fels anstehend In-situ Soil / Bedrock
- Deckschicht Surface Course
- Tragschicht Base Course
- Übergangsschicht Transition Base
- Verbesserter Untergrund Capping Layer

Oberbau Pavement Structure
Unterbau Roadbed
### Pavement Design

**8 cm**
- **SC** Unbound Aggregate UG 0/22
- **BC** Unbound Aggregate UG 0/63
- **TB** Geotextile, if CBR < 3%

\[\text{SN} = 3.3\]

**30 cm**
- **SC-BC AB 16 TDS L**
- **TS** Unbound Aggregate UG 0/63
- **TB** Lime Stabilization

\[\text{SN} = 6.8\]
Conclusions

- **Characterization of Road Networks**
  - **From means to distributions**
  - **The tail of YD distributions** defines network effectivity and efficiency
  - Assessment GIS-based, yielding the CDF

- **4th-power law**
  - Vehicle configurations with **tandem and tridem axles**!
  - **ESAL metric**

- **Pavement design**
  - **AASHTO 1993 Guide**
  - **Standardization of aggregate materials**