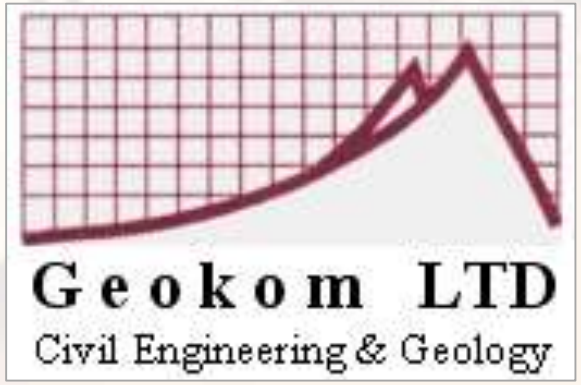
# A Model for Predicting the Deterioration of the Pavement Condition Index and the Road Roughness Index

Research Summary Presentation

## Pavement Evaluation 2019
## Roanoke, Virginia



# PREFACE

The Deterioration Models Development Research project was funded by "**Netivey Israel**" (NTIC) The Israeli National company for Transport Infrastructure.

NTIC Leading team:

- **Mr. Shimon Nessichi** – Chief Scientist
- **Ms. Elinor Mor** – Manager of the R&D department
- **Mr. Vladimir Titov** – The department rep.
- **Mr. Alex Stein** – Manager of the PMS department.

The Research Crew members:

- Prof. Arieh Sidess – Chief research – Civil Engineering, Technion
- Mr. Amnon Ravina - Project manager – Geokom LTD
- Mr. Eyal Oged - Data Processing, editing & programming - Geokom LTD

# INTRODUCTION

- Netivey Israel Company (NTIC) owns and maintains a network of roads and highways in a total length of 8,300 Km (16,000 Km/Lane aprox).
- Since 2007, the company operates a PMS to manage the roads network.
- The PMS includes mapping & subdivision of the network and analysis of the data which is collected in periodical surveys.

**SURVEYS INCLUDE:**

Roughness (IRI) & Geometry
Visual Pavement Distress (PCI)
Rutting (status & follow-up)
Pavement structural capacity (FWD measurements)
Pavement thickness evaluation (GPR - 1 in 5 years)
Friction & Texture Depth (MPD)

# INTRODUCTION

- Netivey Israel Company (NTIC) owns and maintains a network of roads and highways in a total length of 8,300 Km (16,000 Km/Lane aprox).
- Since 2007, the company operates a PMS to manage the roads network.
- The PMS includes mapping & subdivision of the network and analysis of the data which is collected in periodical surveys.
- The collected data is being processed to produce a perennial maintenance work plan for the network.
- The prediction of the future pavement performance parameters is calculated using empirical deterioration coefficients of PCI & IRI.
- These parameters relied on the local experience.

# THE IMPORTANCE OF THE **DETERIORATION PREDICTING MODEL**

- The reliability of the prediction model is significant, as the outcome directly affects the work plan over the years.
- A reliable and a correct model would be the "**GOLDEN FLEECE**" for the PMS, as it will allow efficient resources allocation and optimal budget usage for the network maintenance, in the correct time & place.

# THE STAGES OF THE RESEARCH WORK

1. Literature survey & methodology consolidation.
2. Data mining & preparation of the database for the research.
3. Determination of the subdivision of the network (based on climatic diversity).
4. Model development & calibration.
5. Formulation and implementation of the computerized model into the databases & the PMS.

# THE RESEARCH METHODOLOGY BASICS

- The approach for developing the deterioration models was based on the combination of the empirical-mechanistic approach and the regressive empirical approach.

**MODEL DEVELOPMENT STAGES:**

- Calculation of the deterioration curves of the IRI & PCI based on the models presented by Uzan et al. (2014) and Uzan (2018).
- **Analysis** of the actual IRI & PCI deterioration curves by regressive equations.
- Development of the **model's coefficients**, depending on the various factors related to the pavement structure, subgrade and climate zone.
- **Calculation** of the IRI & PCI deterioration curves based on models & comparison of the calculated results to the measured data.
- **Calibration** of the models, when necessary.

# THE RESEARCH METHODOLOGY BASICS

- The approach for developing the deterioration models was based on the combination of the empirical-mechanistic approach and the regressive empirical approach.
- Subdivision of the Network into 3 climate zones, based on analysis of the impact of the climatic parameters on the deterioration rate.

**THE IMPACT OF THE ENVIRONMENT:**

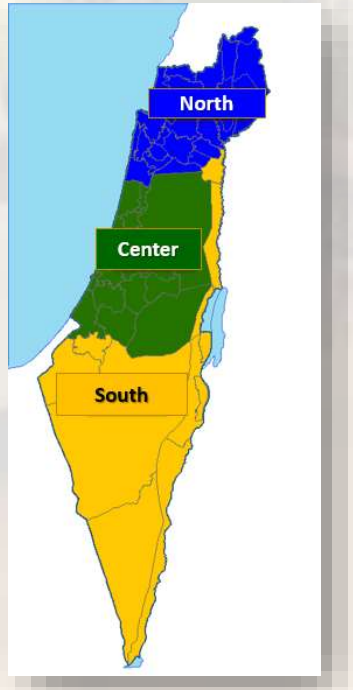
- The analysis was based on the data collected in the **PRS project** *(Uzan, J., (2012), Uzan, J., (2015))*
- The PRS project introduced the calculation of the development of the fatigue & the rutting distresses in the pavements, in various climate zones.
- The analysis of the impact from the geographically varied stations led to the conclusion that the data can be divided into **three main sections**.

# THE RESEARCH METHODOLOGY BASICS

- The approach for developing the deterioration models was based on the combination of the empirical-mechanistic approach and the regressive empirical approach.
- Subdivision of the Network into 3 climate zones, based on analysis of the impact of the environmental parameters on the deterioration rate.

**NETWORK CLIMATE ZONES:**

- ❖ North
- ❖ Center
- ❖ South (including the Rift Valley)



# THE DETERIORATION MODEL FOR **PCI**

- The following equation, expresses the deterioration model which was adopted for the PCI :

$$PCI(t) = PCI_0 - (PCI_0 - PCI_f) \bullet \left( \frac{W_t}{\rho} \right)^{\beta}$$

**Where**:

**PCI(t)** – PCI at time - t (years, months, etc.).

**$PCI_0$** – initial PCI after construction or rehabilitation.

**$PCI_f$** – PCI at failure.

**$W_t$** – cumulative number of 130 kN ESAL applied until time t.

**β, ρ** – regression coefficients dependent on the pavement parameters and environmental variables.

# THE DETERIORATION MODEL FOR **PCI**

- The deterioration model which was adopted for the PCI is expressed in the equation:

$$PCI(t) = PCI_0 - (PCI_0 - PCI_f) \bullet \left( \frac{W_t}{\rho} \right)^{\beta}$$

- As $PCI_0 = 100$ and $PCI_f = 25$, the equation is expressed as follows:

$$PCI(t) = 100 - 75 \bullet \left( \frac{W_t}{\rho} \right)^{\beta}$$

**Where**:

**PCI(t)** – PCI at time

**$PCI_0$** – initial PCI

**$PCI_f$** – PCI at failure.

**$W_t$** – cumulative 130 kN ESAL

**β, ρ** – regression coefficients

# CALIBRATING THE MODEL FOR **PCI**

$$PCI(t) = PCI_0 - (PCI_0 - PCI_f) \bullet \left(\frac{W_t}{\rho}\right)^{\beta} \qquad PCI(t) = 100 - 75 \bullet \left(\frac{W_t}{\rho}\right)^{\beta}$$

- The coefficients β and ρ may be calculated by the optimization of the PCI deterioration curves dependent on the parameters that characterize the pavement and environmental variables as follows:

$$\rho, \beta = f(E_s, SN, T_A, R)$$

**Where**:

**$E_S$** – Subgrade modulus

**SN** – Structural number of the pavement

**$T_A$** – Asphalt layer thickness

**R** – A coefficient depending on environmental variables

# MODEL FOR **PCI** - DEVELOPMENT & VALIDATION

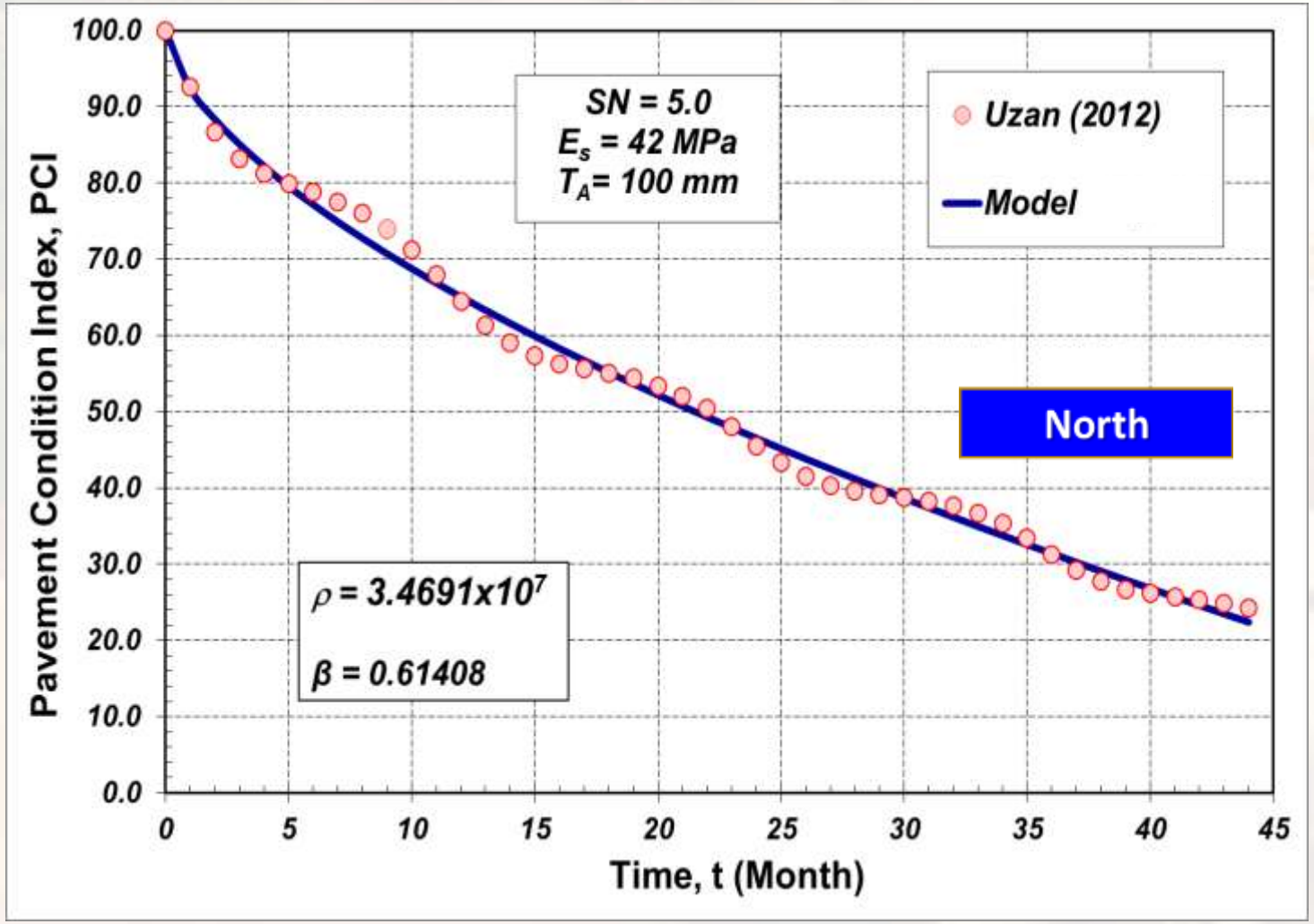
To apply the model into the NTIC network & to implement it on all the roads, further model's developments were performed, including:

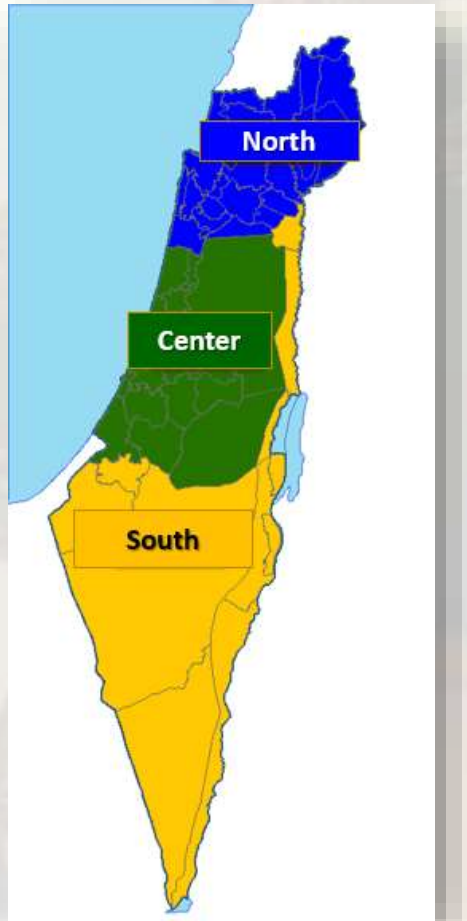
- Development of an algorithm to adjust for the traffic load History.
- Calculation of secondary deterioration coefficients for each geographical zone.

## Validation

The predicted results were compared with actual survey data of more than 200 road sections, with varied pavement characteristics & in different climatic zones

# An example of the PCI deterioration curve & Model calibration



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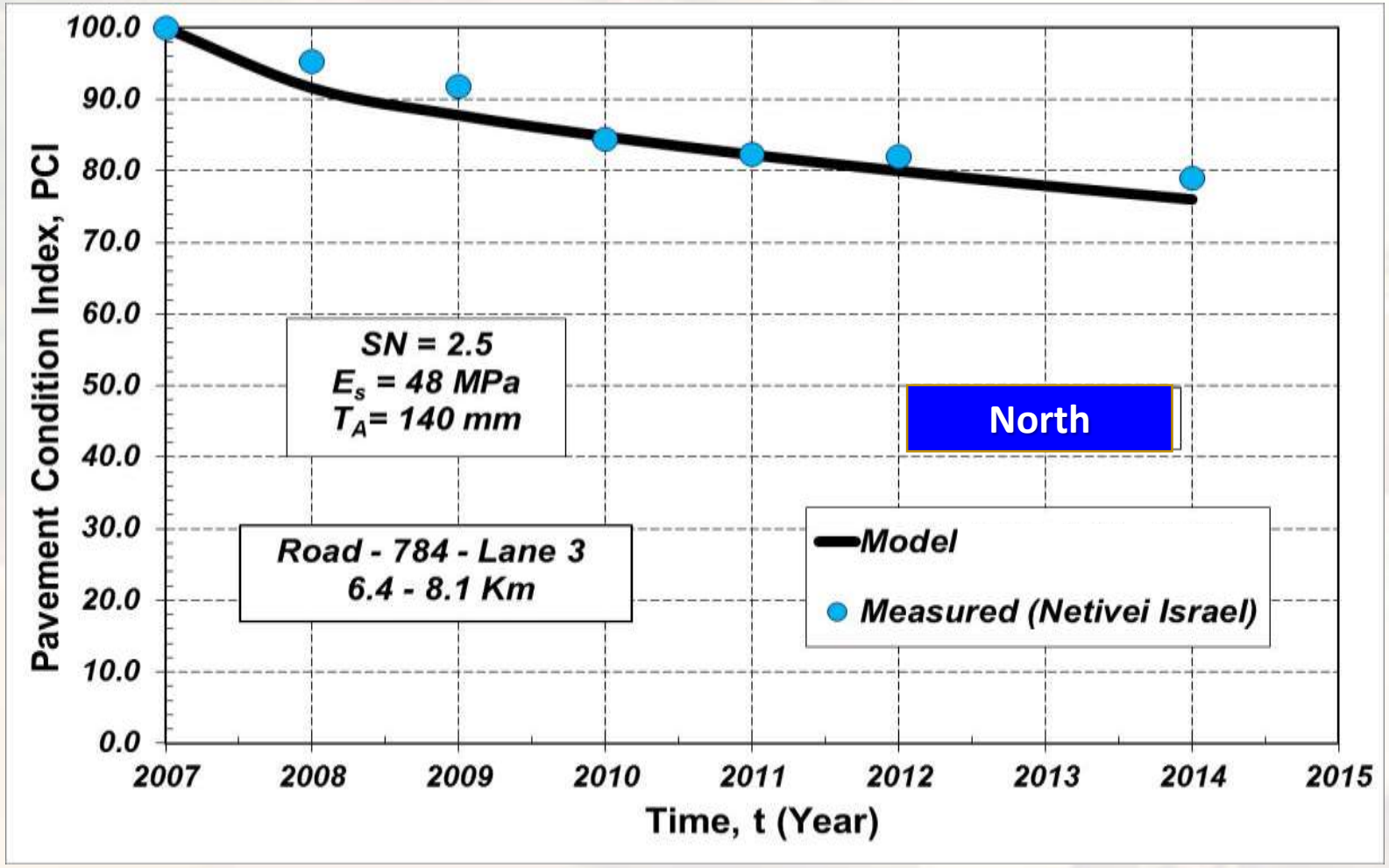
# Comparing PCI calculated curve to measured points – New pavement







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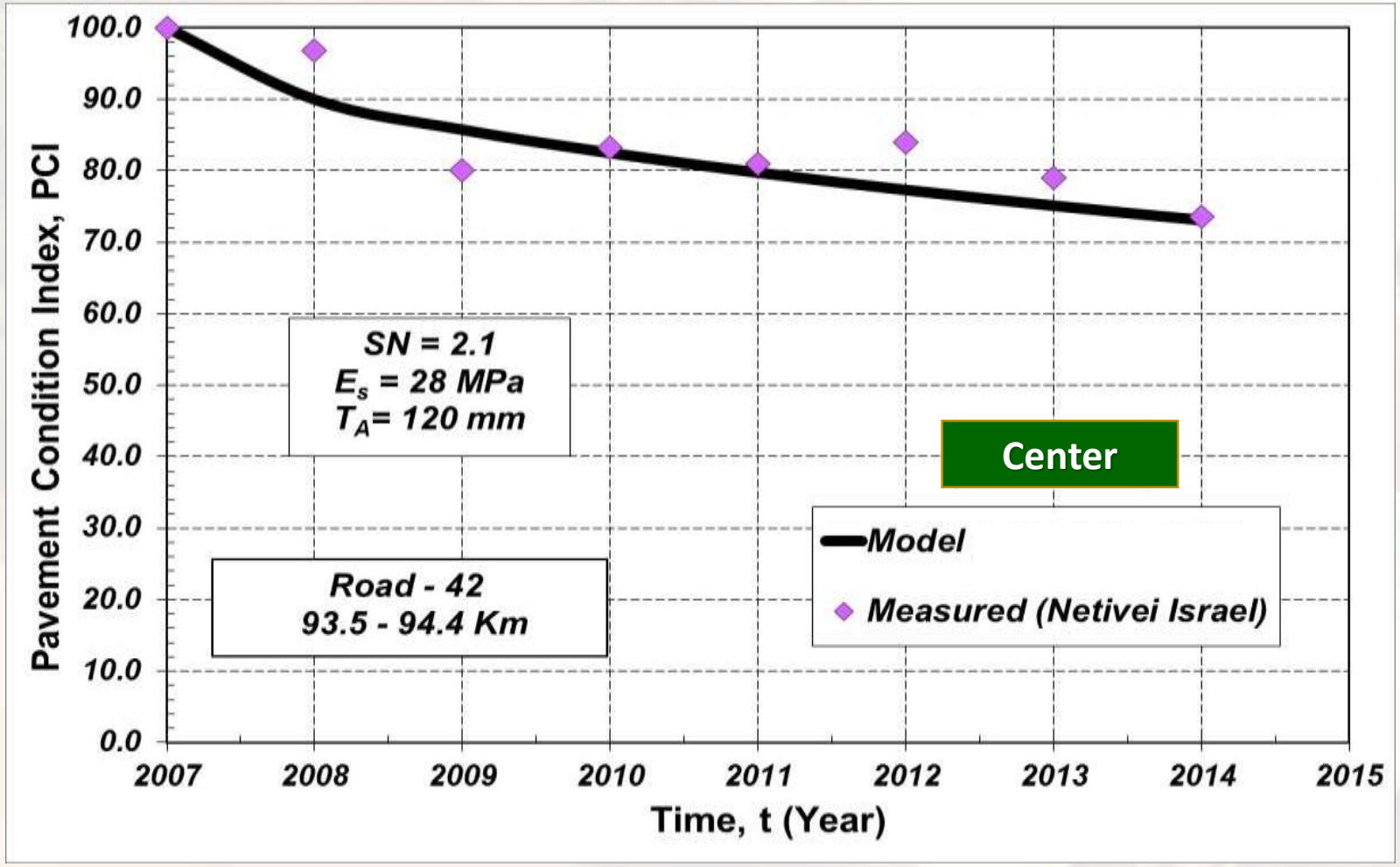


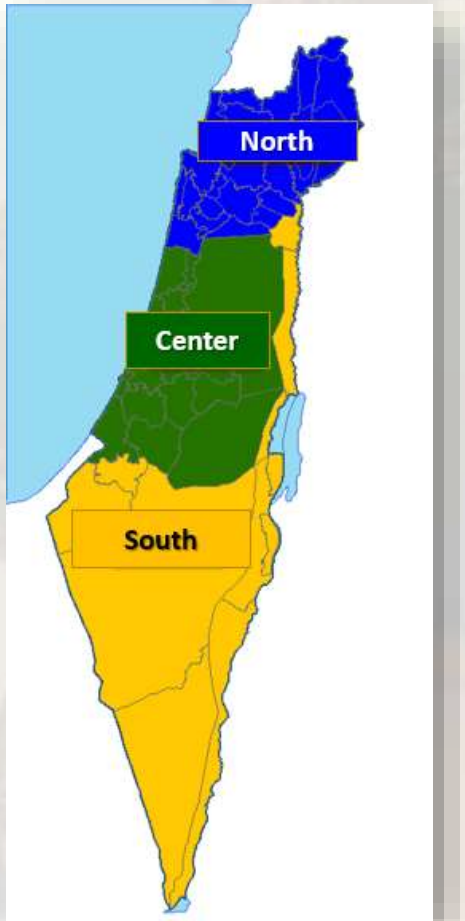




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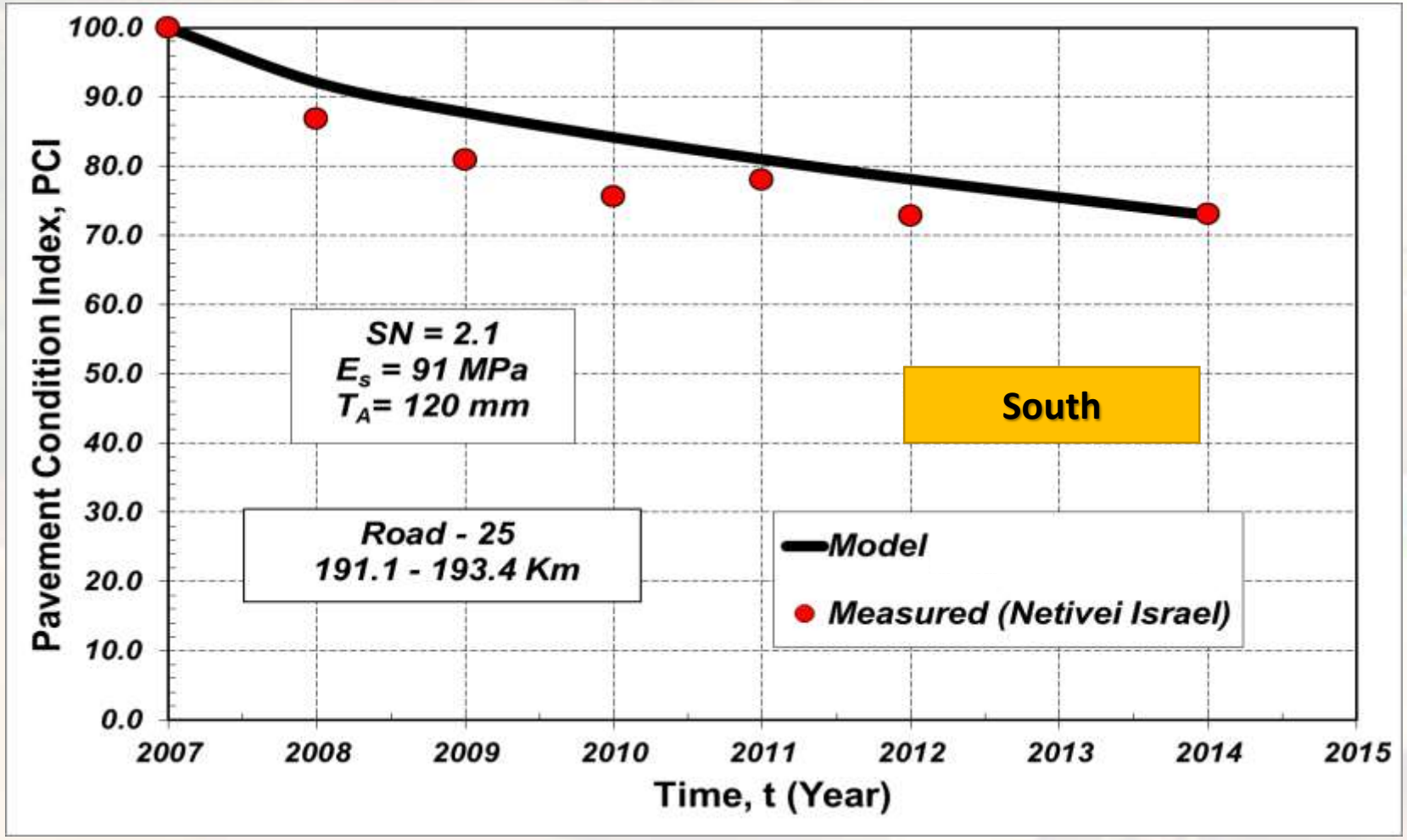
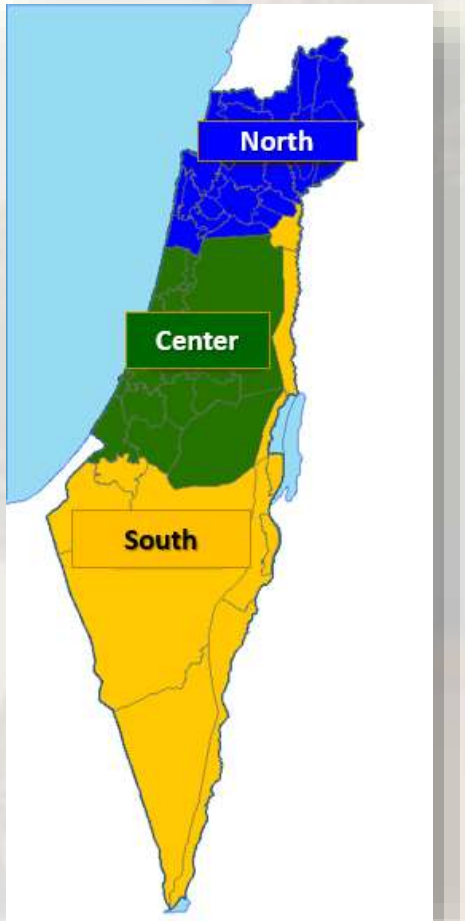
# Comparing PCI calculated curve to measured points – New pavement



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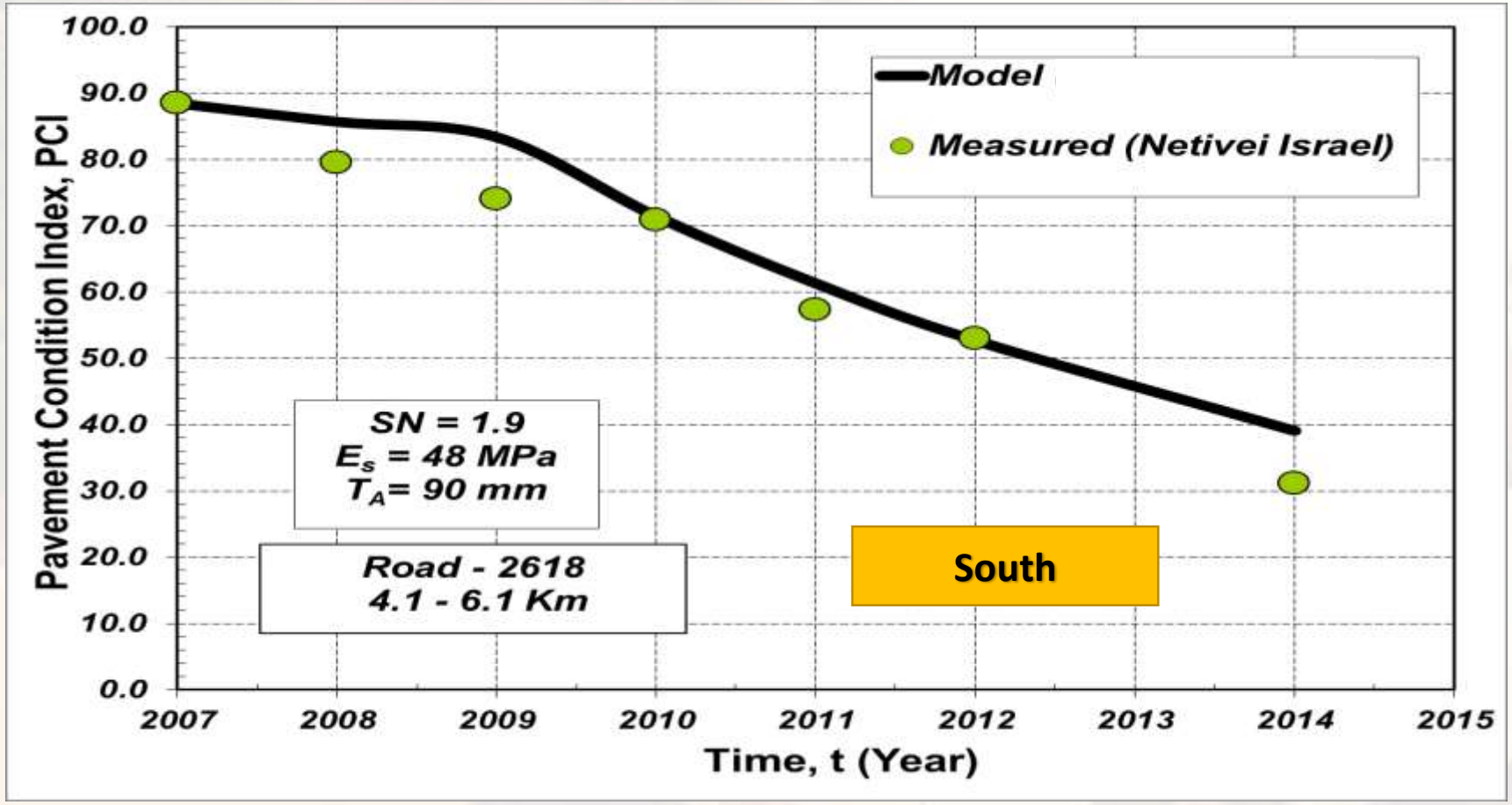
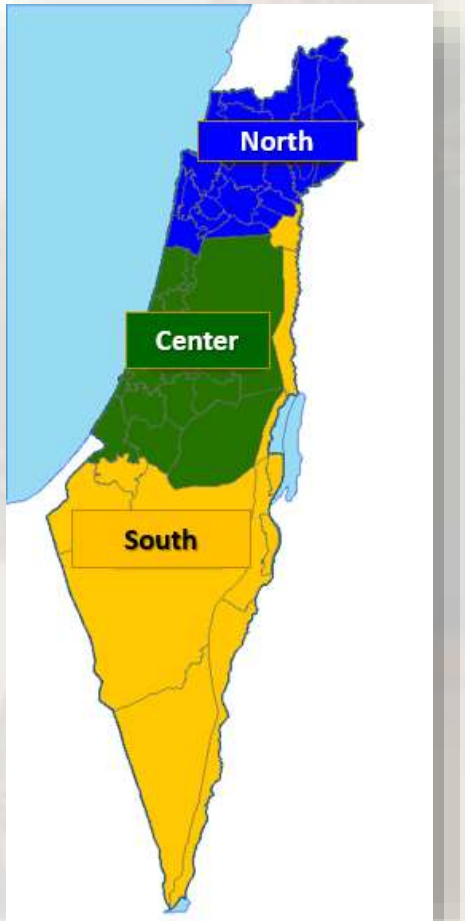
# Comparing PCI calculated curve to measured points – Disturbed pavement



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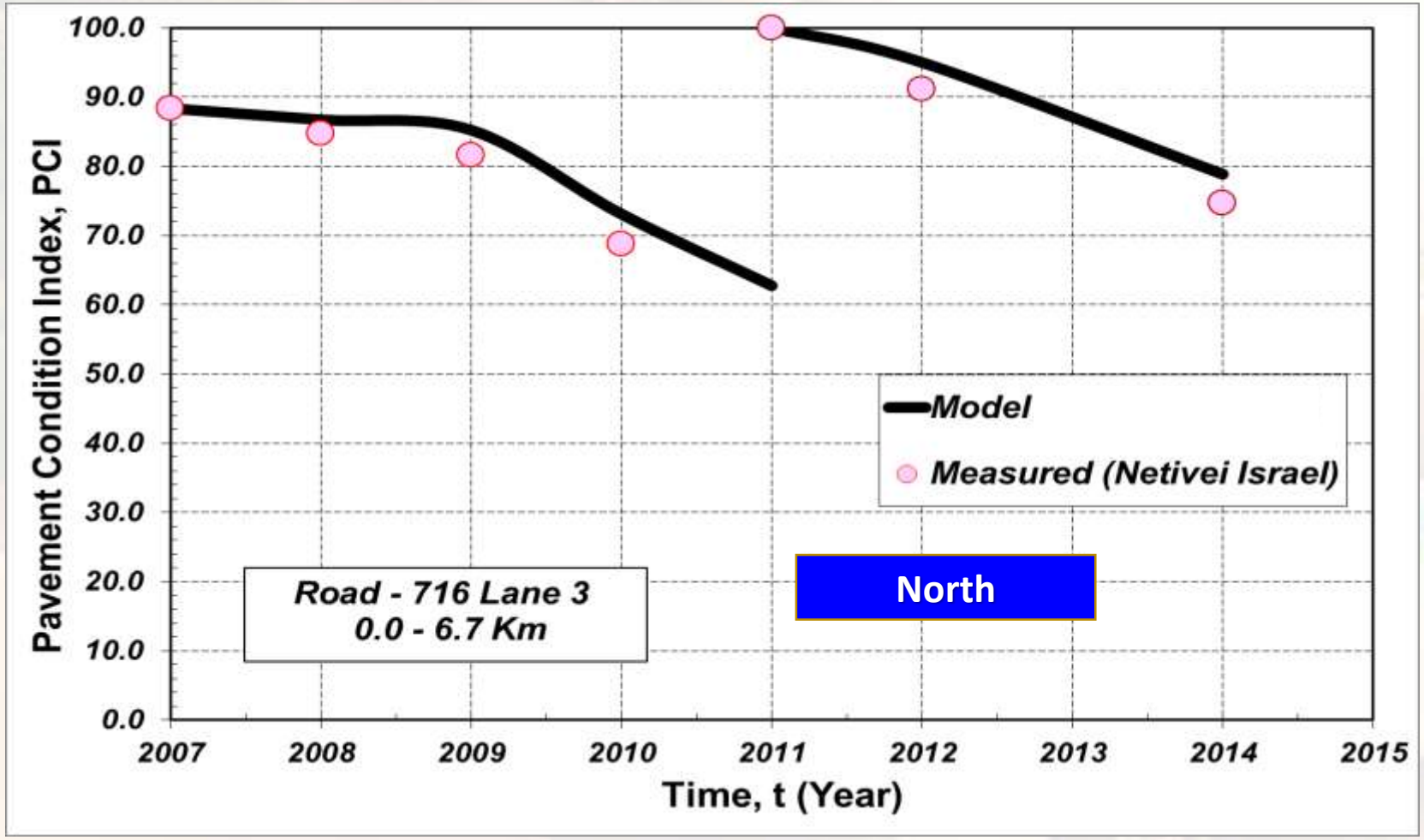
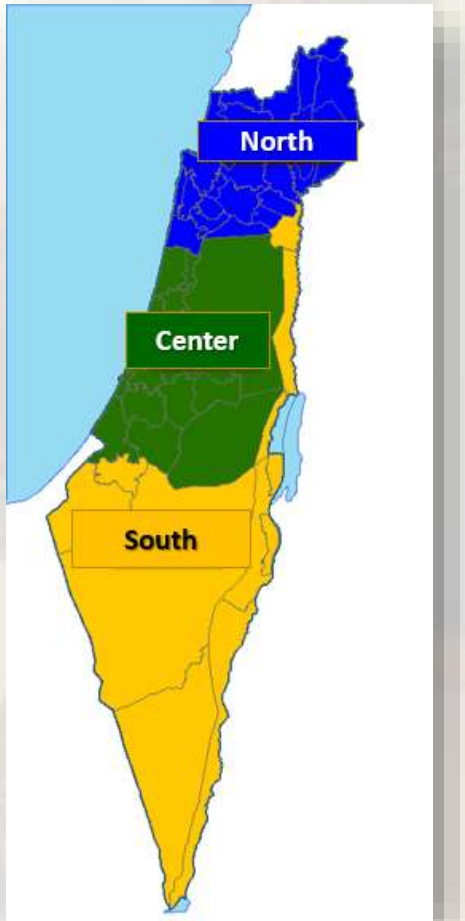
# Comparing PCI calculated curve to measured points – Rehabilitated pavement



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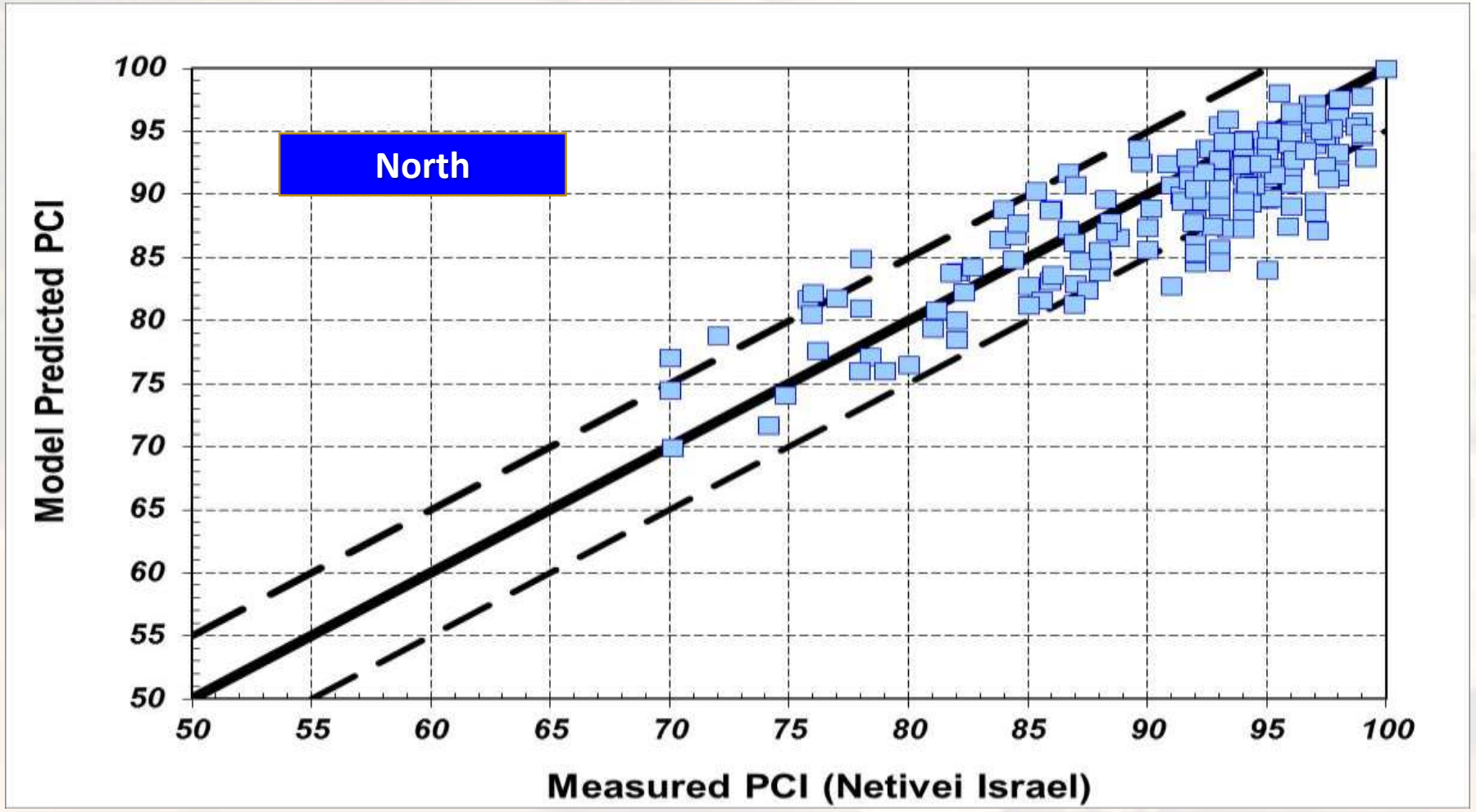
# Measured vs. predicted PCI for various road sections (new pavements)







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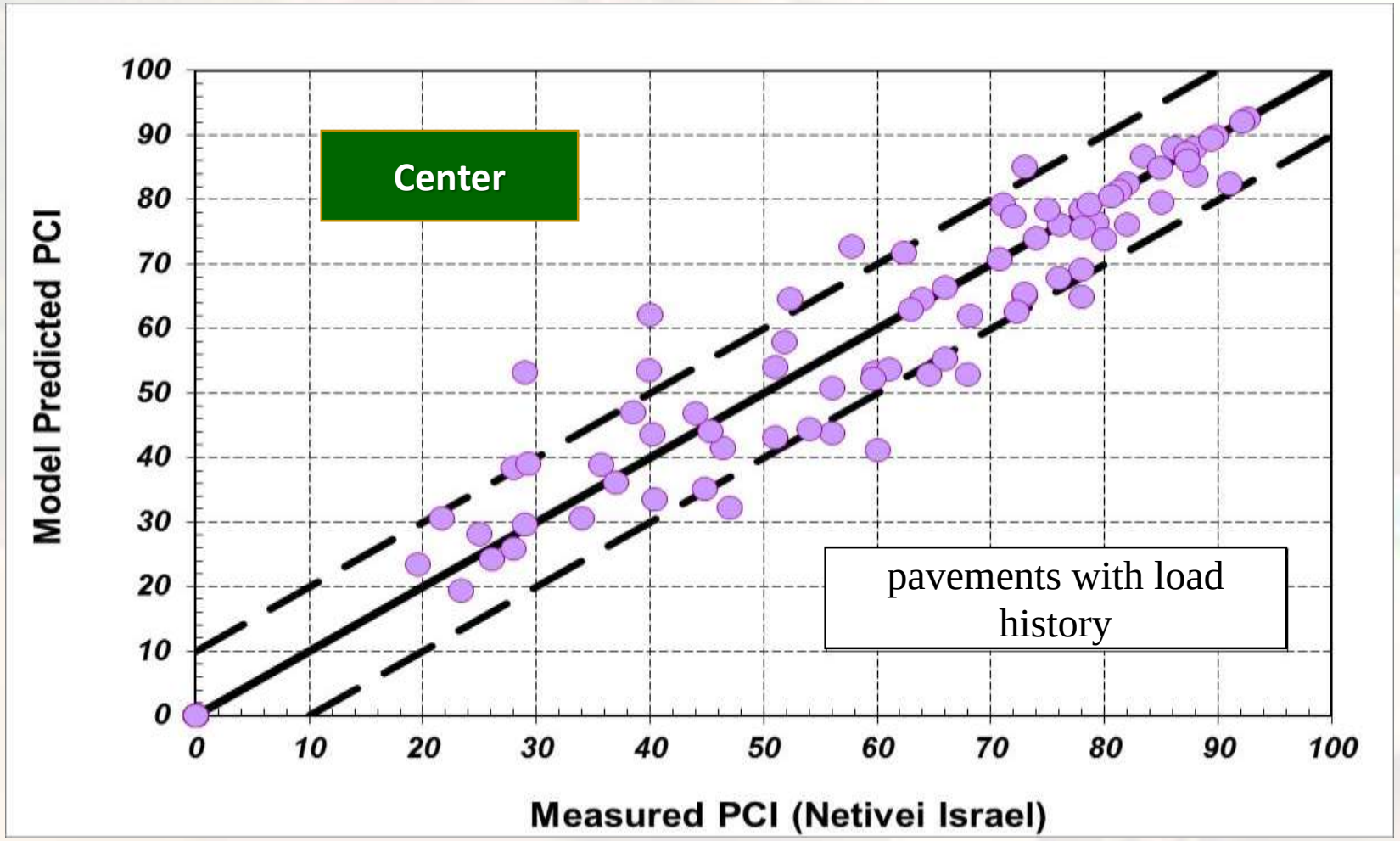
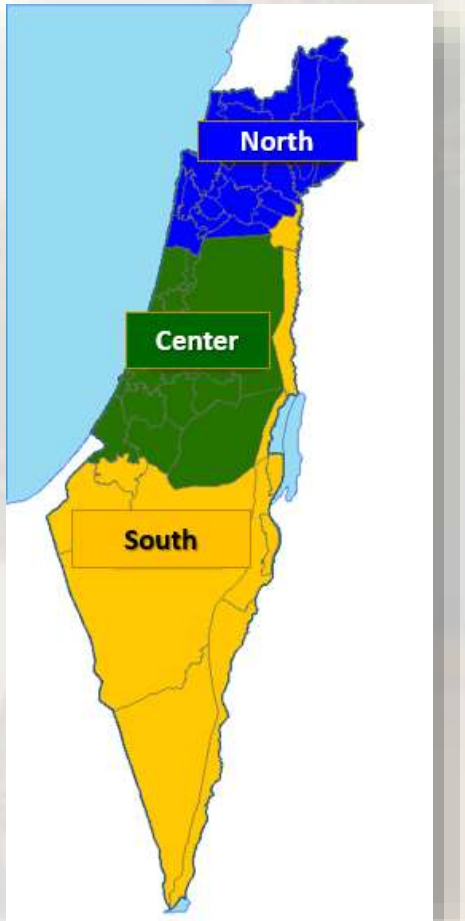
# Measured vs. predicted PCI for various road sections (Load history pavements)



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# DETERIORATION MODEL FOR **IRI**

- The deterioration model which was adopted for the IRI is expressed in the equation :

$$IRI(t) = IRI_0 + K \bullet (W_t)^{\gamma}$$

**Where**:

**IRI(t)** – IRI at time - t (months, years, etc.), m/km.

**$IRI_0$** – initial IRI after construction or rehabilitation, m/km.

**$W_t$** – cumulative number of 130 kN ESAL applied until time t.

**K, γ** – regression coefficients dependent on the pavement parameters and climatic variables.

# DETERIORATION MODEL FOR **IRI**

- The deterioration model which was adopted for the IRI is expressed in the equation:

$$IRI(t) = IRI_0 + K \bullet (W_t)^{\gamma}$$

- The IRI of a pavement after construction or rehabilitation - $IRI_0$ is set to 1.10 m/km (*Uzan et al. 2014*), Thus the equation may be expressed as follows:

$$IRI(t) = 1.10 + K \bullet (W_t)^{\gamma}$$

**Where**:

**IRI(t)** – IRI at time

**$IRI_0$** – initial IRI

**$W_t$** – cumulative 130 kN ESAL

**K, γ** – regression coefficients

# CALIBRATING & VALIDATING THE MODEL FOR **IRI**

$$IRI(t) = IRI_0 + K \bullet (W_t)^{\gamma} \qquad IRI(t) = 1.10 + K \bullet (W_t)^{\gamma}$$

The coefficients K and γ may be calculated by the optimization of the IRI deterioration curves dependent on the parameters that characterize the pavement and environmental variables as follows:

$$K,\ \gamma = f(E_s, SN, T_A, R)$$

**Where**:

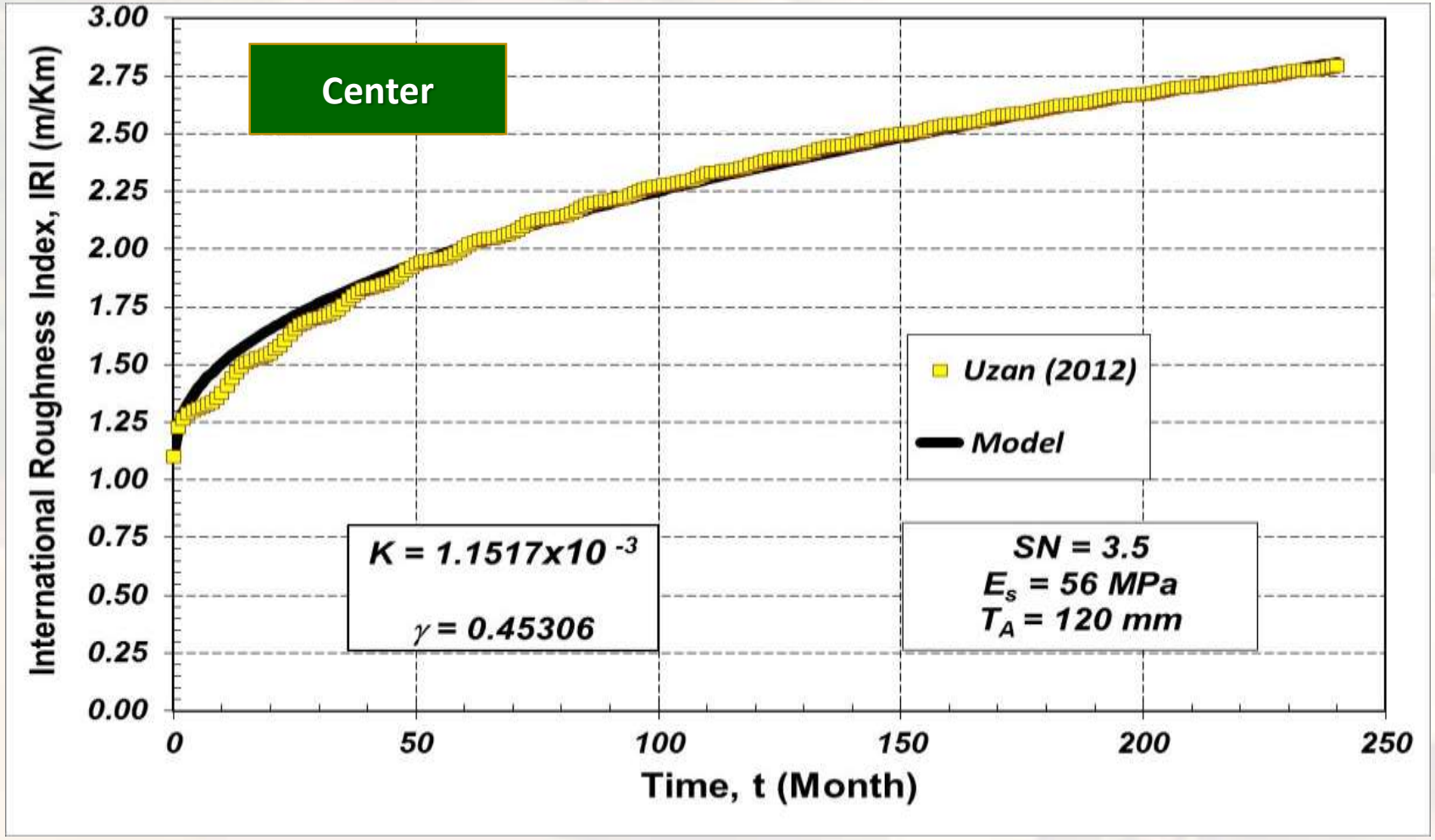
**$E_S$** – Subgrade modulus

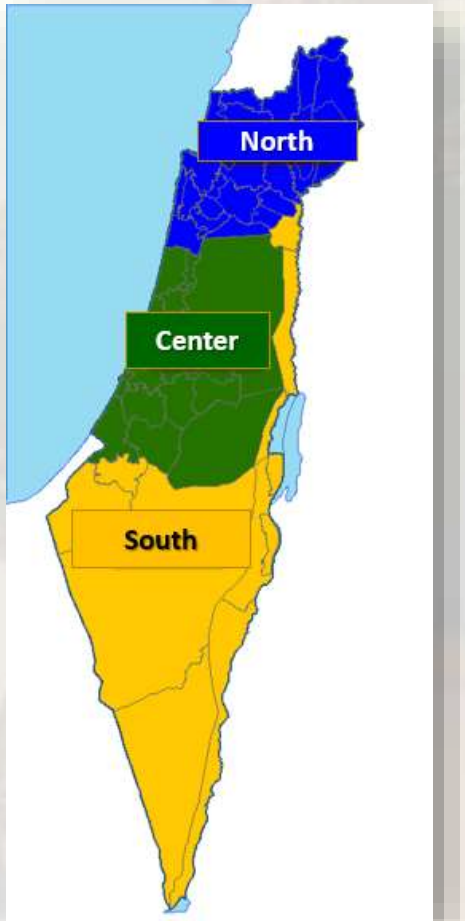
**SN** – Structural number of the pavement

**$T_A$** – Asphalt layer thickness

**R** – A coefficient depending on climatic variables

# An example of the IRI deterioration curve & Model calibration



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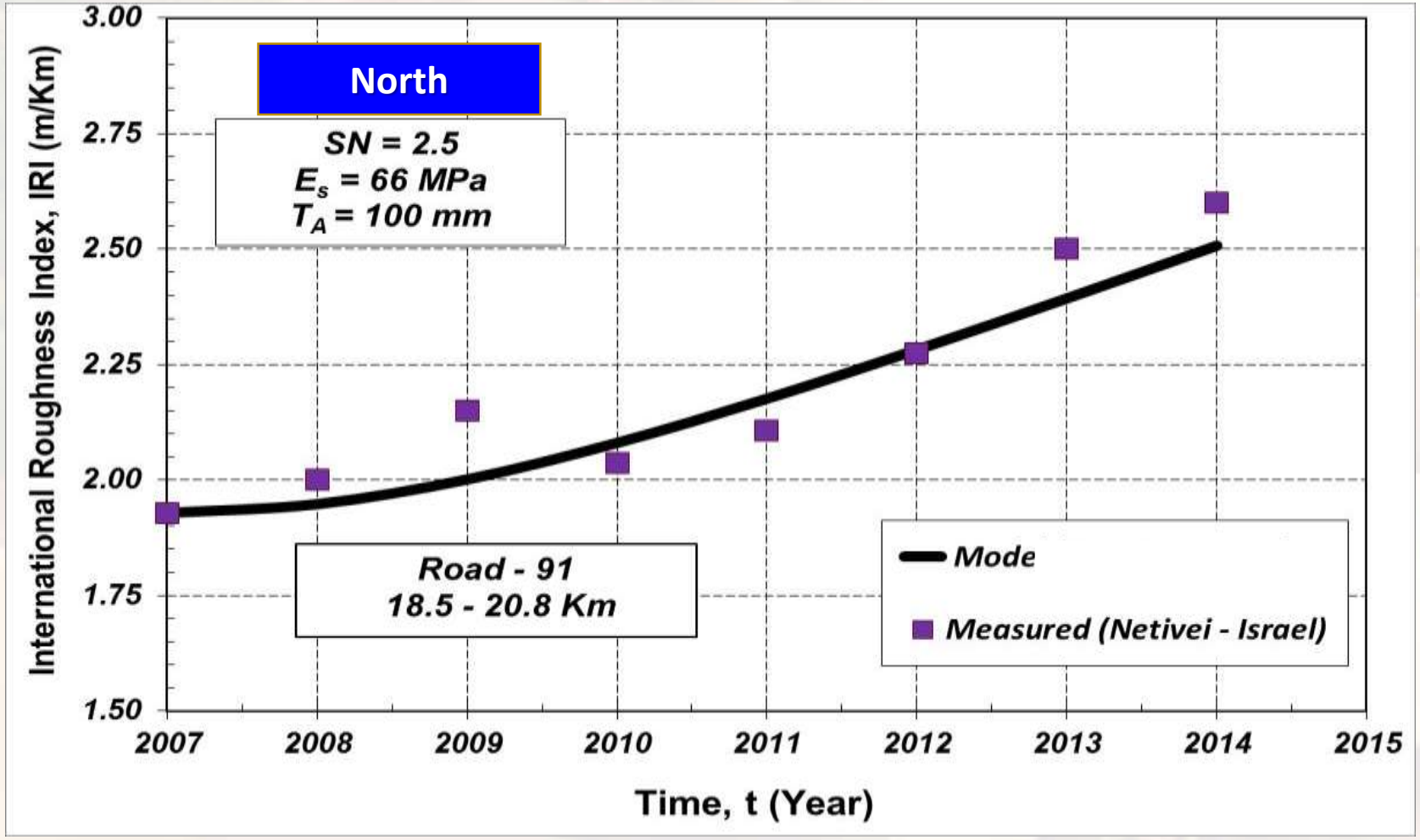
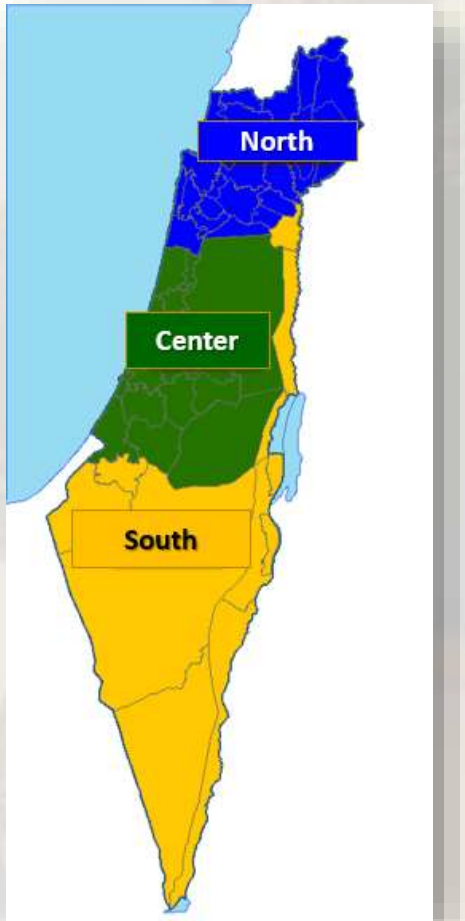
# Comparing IRI calculated curve to measured points – In Service pavement



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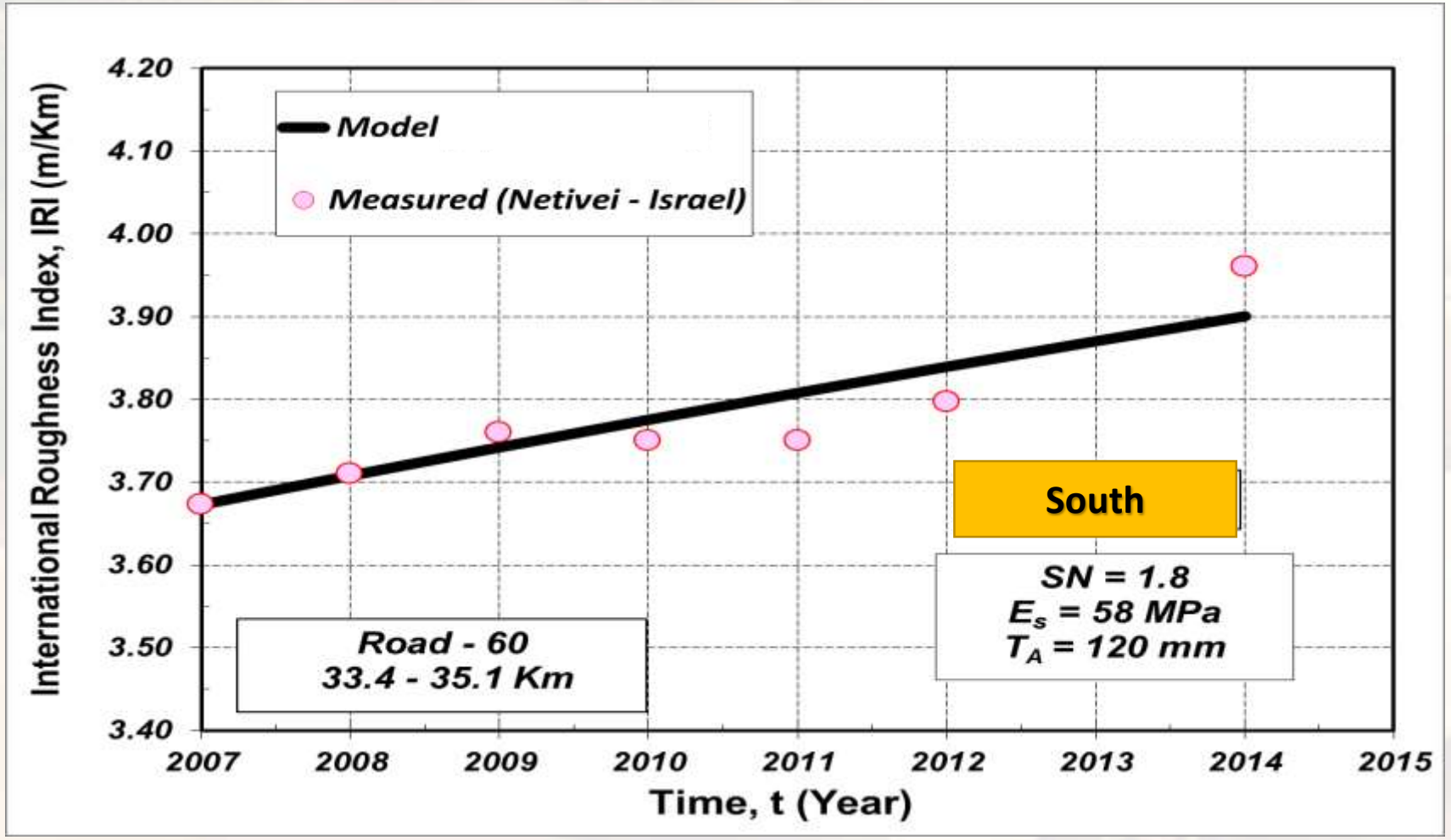
# Comparing IRI calculated curve to measured points – In service pavement







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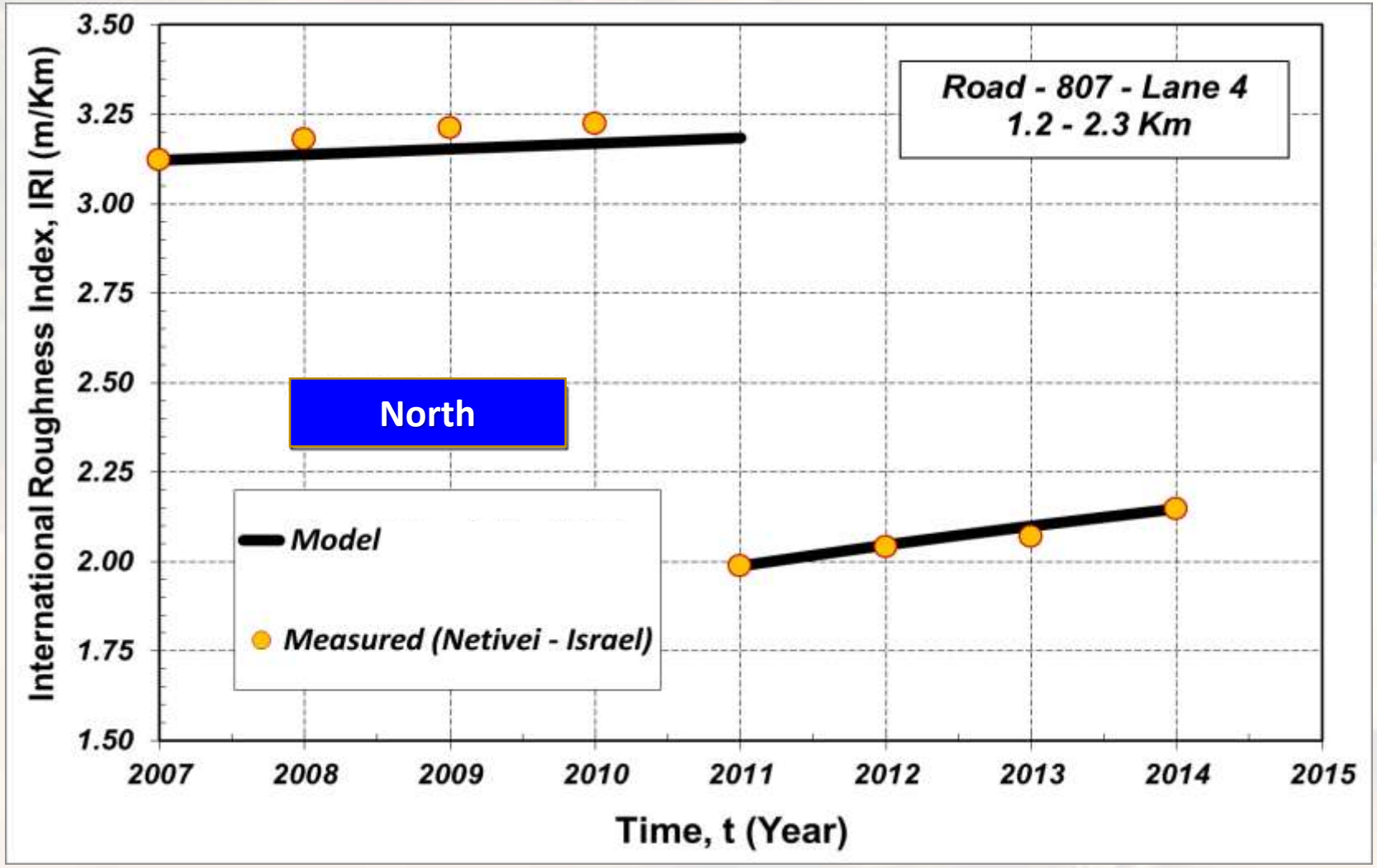
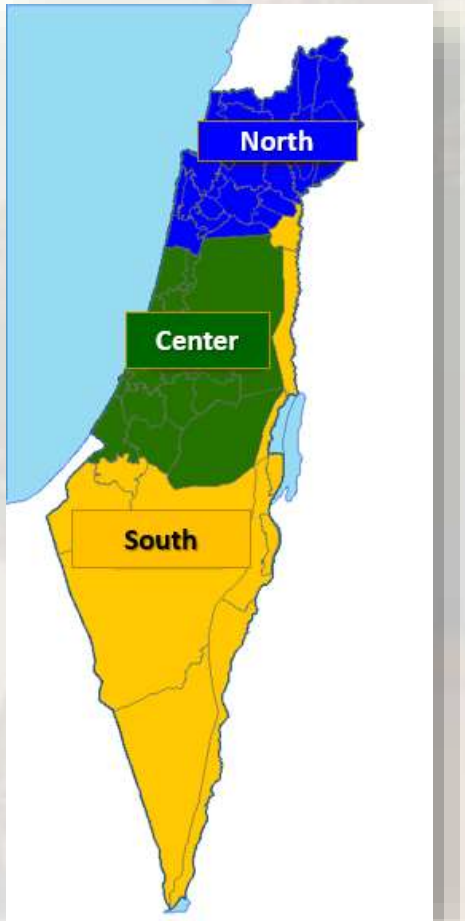
# Comparing IRI calculated curve to measured points – Rehabilitated pavement



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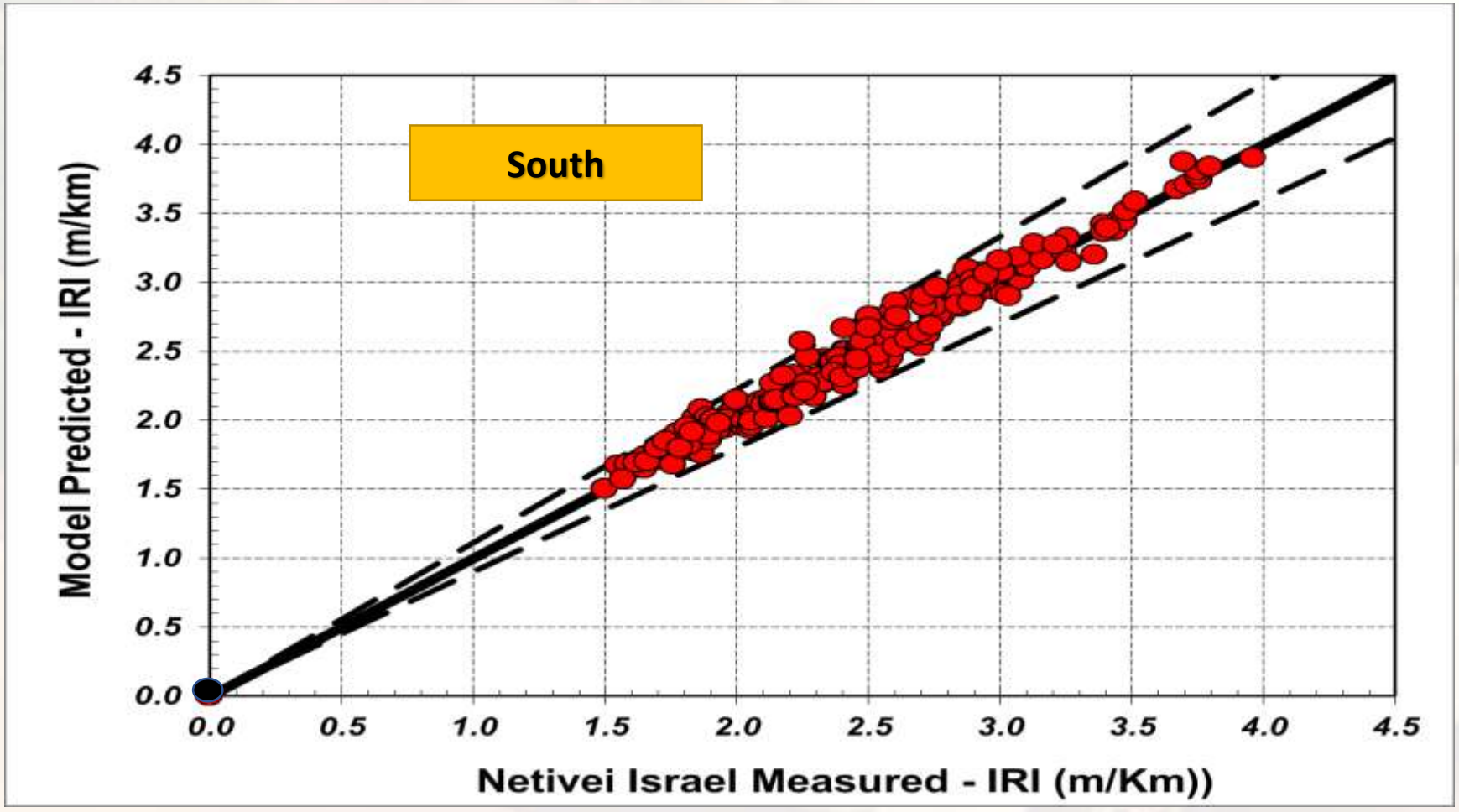
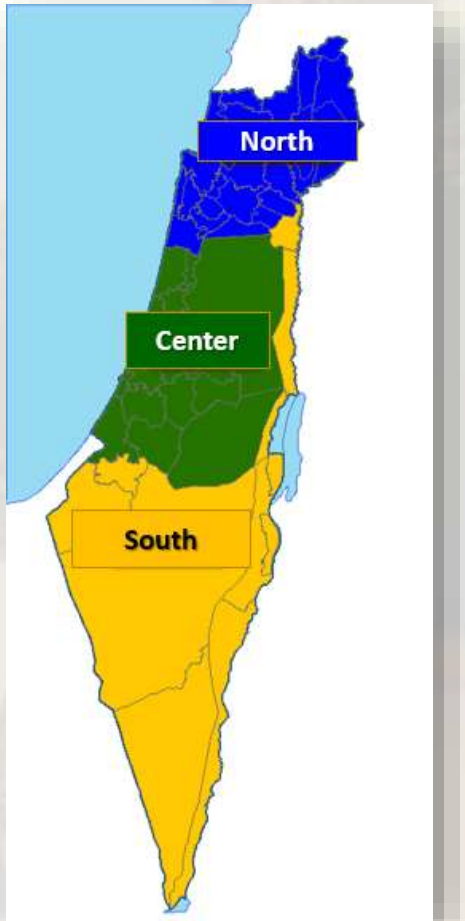
# Measured vs. predicted IRI for various road sections (new pavements)



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# THE FRUITS OF THE RESEARCH

- The model is about to be embedded in the NTIC's PMS
- The new model will improve the prediction of the pavement performance and as a result it will improve maintenance budget planning.
- The utilization of the model can offer a comparison of design alternatives. The authorities in- charge can use varied considerations to strengthen the pavement and to reduce the maintenance budget in return.
- The model may assists enterprisers to evaluate the pavements performance in BOT & PPP Projects.
- The model enables the assessment of the pavement performance at the end of warranty period of new & rehabilitated pavements.

# SUMMARY

- The research presents a methodology for developing a deterioration model of the Roughness index – **IRI** & Pavement Condition Index - **PCI**.
- The methodology is based on the combination of the empirical-mechanistic and regressive empirical approach.
- The model's coefficients can be calculated depending on the pavement parameters environmental variables.
- **Comparison of the predicted and measured results show very good match. Most of the results are within the measurement and interpretation error range.**
- The good match enables the adoption of the methodology in Netivey Israel (NTIC) Pavement Management System (PMS).

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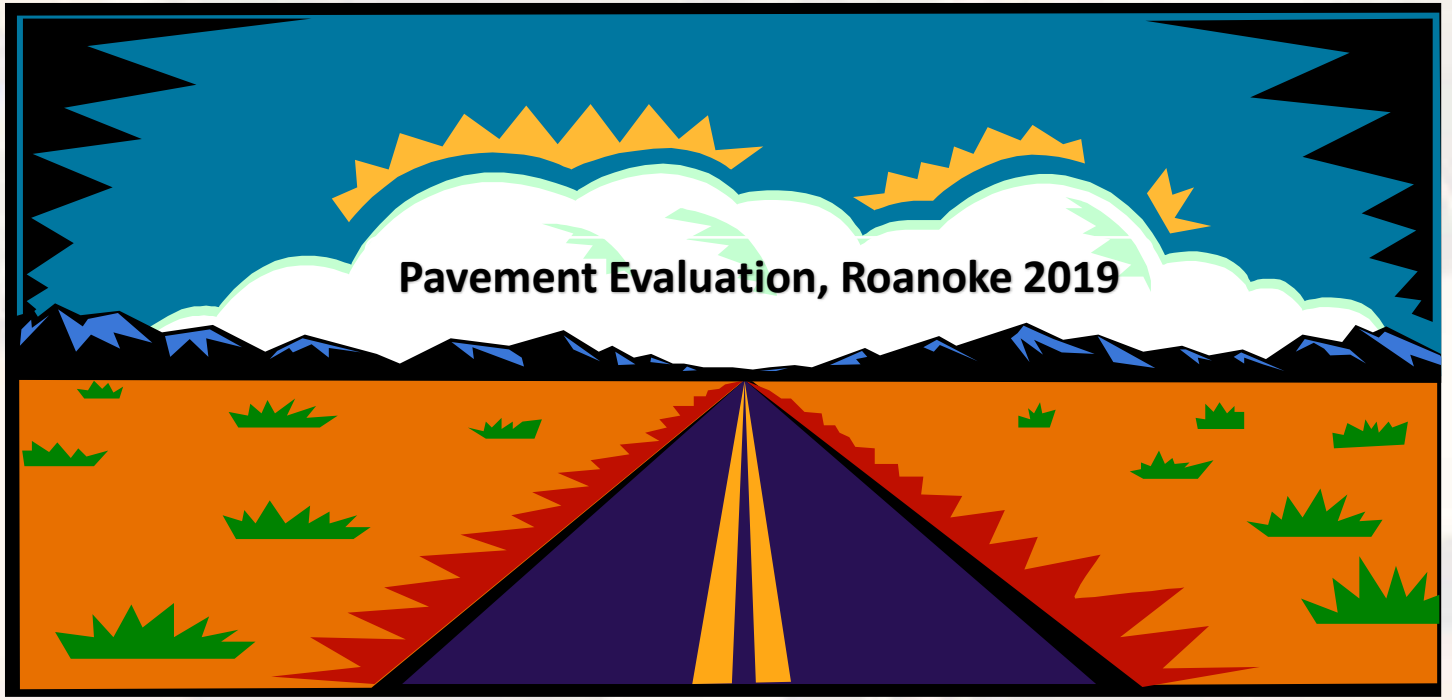
THANK YOU FOR YOUR ATTENTION



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# REFERENCES


- AASHTO, 1993. AASHTO Guide for Design of Pavements Structures, *American Association of State Highway and Transportation Officials, Washington, DC.*

- Uzan, J., Nesichi, S., and Weinstein, N., 2014. A simplified flexible pavement guide with analytical reliability analysis, In: Y. R. Kim, ed. *Proceedings of the 12th Conference of the Int. Soc. For Asphalt Pavements*, 1-5 June 2014 USA. Raleigh, NC: CRC Press, 2, 1851-1860.

- Uzan, J., 2018. Advancing the design and construction quality control of flexible pavements. *International Journal of Pavement Engineering*, 19 (2), 164-173.

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Research Summery Presentation

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