ENVIRONMENTAL NOISE AND HEALTH: RESEARCH AND POLICY IN CANADA

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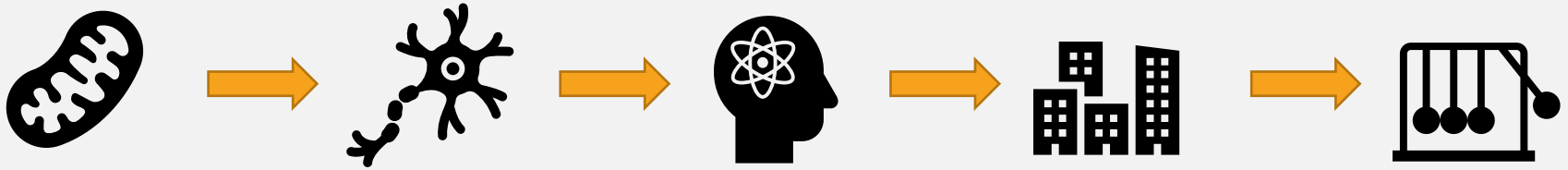
OUTLINE

- Environmental noise overview
- Exposure assessment methods
- Physiological mechanisms and health effects
- Noise research and policy in Canada and Toronto
- Noise assessment and regulation internationally

METHODS AND THEORY IN SOUNDSCAPE AND NOISE RESEARCH

Biomedicine, physiology	Engineering and physics	Psychology	Public health
Geography	Environmental justice	Policy and planning	Urbanism



WHAT IS NOISE?

Everyday sounds vs. noise

- Hedonic; unknown health risk; modulated by source identification

Unwanted and/or harmful sound

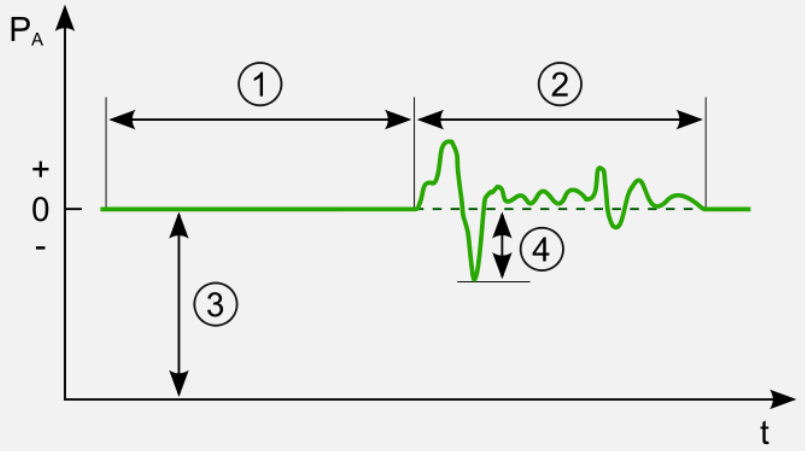
- Subjective and objective (Fink, Proc. Mtgs. Acoust. 39, 050002 (2019))

Environmental noise

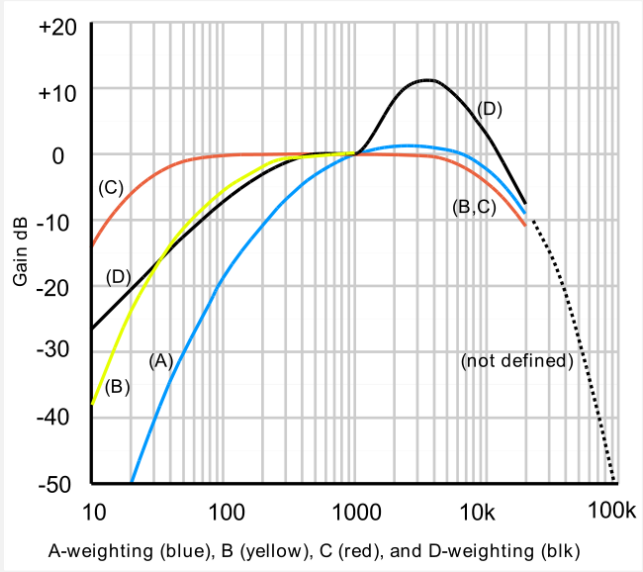
- "Unwanted or harmful outdoor sound created by human activity, such as noise emitted by means of transport, road traffic, rail traffic, air traffic and industrial activity." (Murphy & King, Chapter 4 - Strategic Noise Mapping, Environmental Noise Pollution, Elsevier, 2014)

EXPOSURE ASSESSMENT

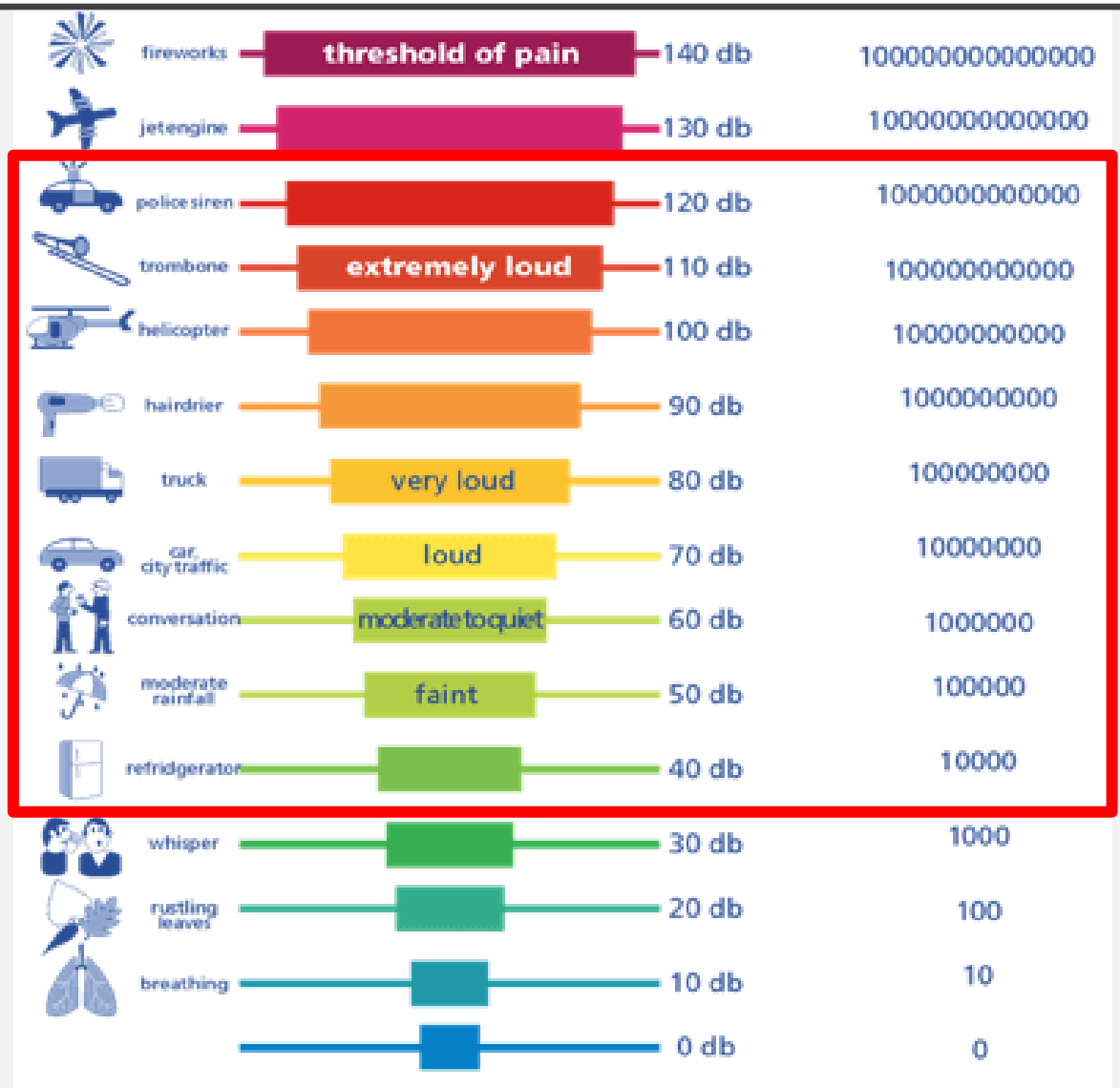
- Sound pressure level (dB): Amplitude of the sound wave
- A-weighted sound pressure level (dBA) adjusted for human perception
- Averaged sound pressure levels used for assessment metrics: day, night, or 24-hour period; $L_{Aeq,8\text{-}24h}$, L_{dn} and L_{den}



1. Silence
2. Audible sound
3. Atmospheric pressure
4. Sound pressure



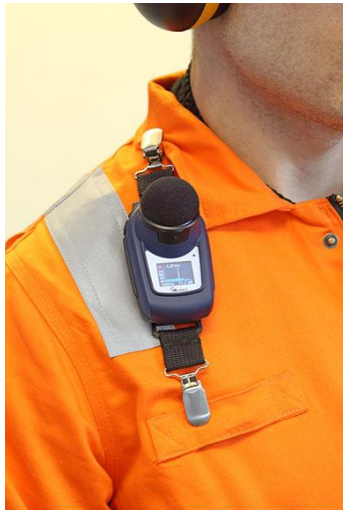
WE MEASURE QUANTITY, NOT QUALITY…



https://www.commodious.co.uk/knowledge-bank/noise/measuring-levels

EXPOSURE ASSESSMENT

Individual monitoring

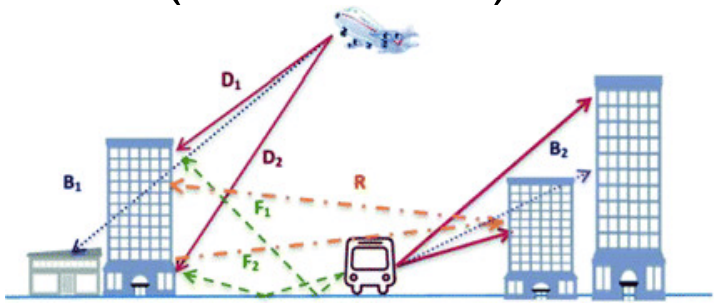


https://www.casellasolutions.com/in/en/products/dbadge2-pro.html

Neighbourhood monitoring

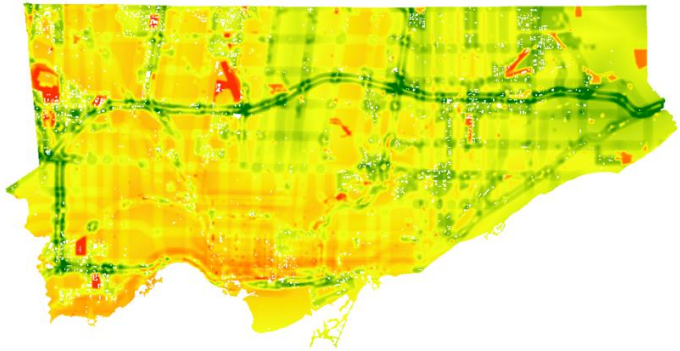
https://www.bksv.com/media/doc/bp2098.pdf

Source-specific modelling (deterministic)



Lu et al., 2017)

Statistical approaches (deterministic/probabilistic)

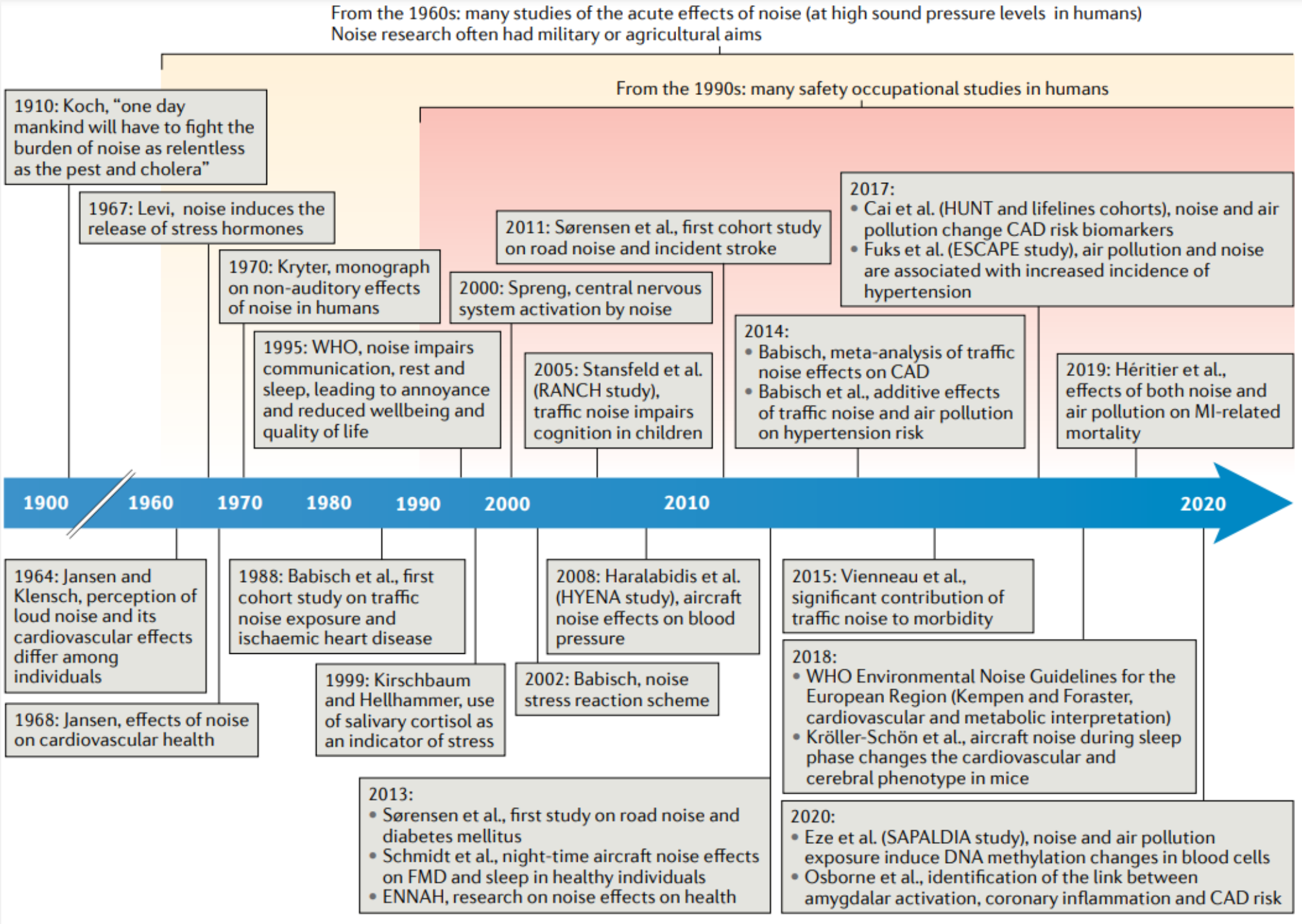


STANDARDIZED MODELLING METHODS

- National and regional standards for road/rail/air traffic and industry
- `Equal Energy Principle´
- Residential estimates based on time of day and most exposed façade
- 2002 EU Environmental Noise Directive and strategic noise mapping
- Common Noise Assessment Methods in Europe (CNOSSOS)

HEALTH EFFECT PATHWAYS AND OUTCOMES

Münzel, T., Sørensen, M. & Daiber, A. Transportation noise pollution and cardiovascular disease. *Nat Rev Cardiol* **18**, 619–636 (2021). https://doi.org/10.1038/s41569-021-00532-5



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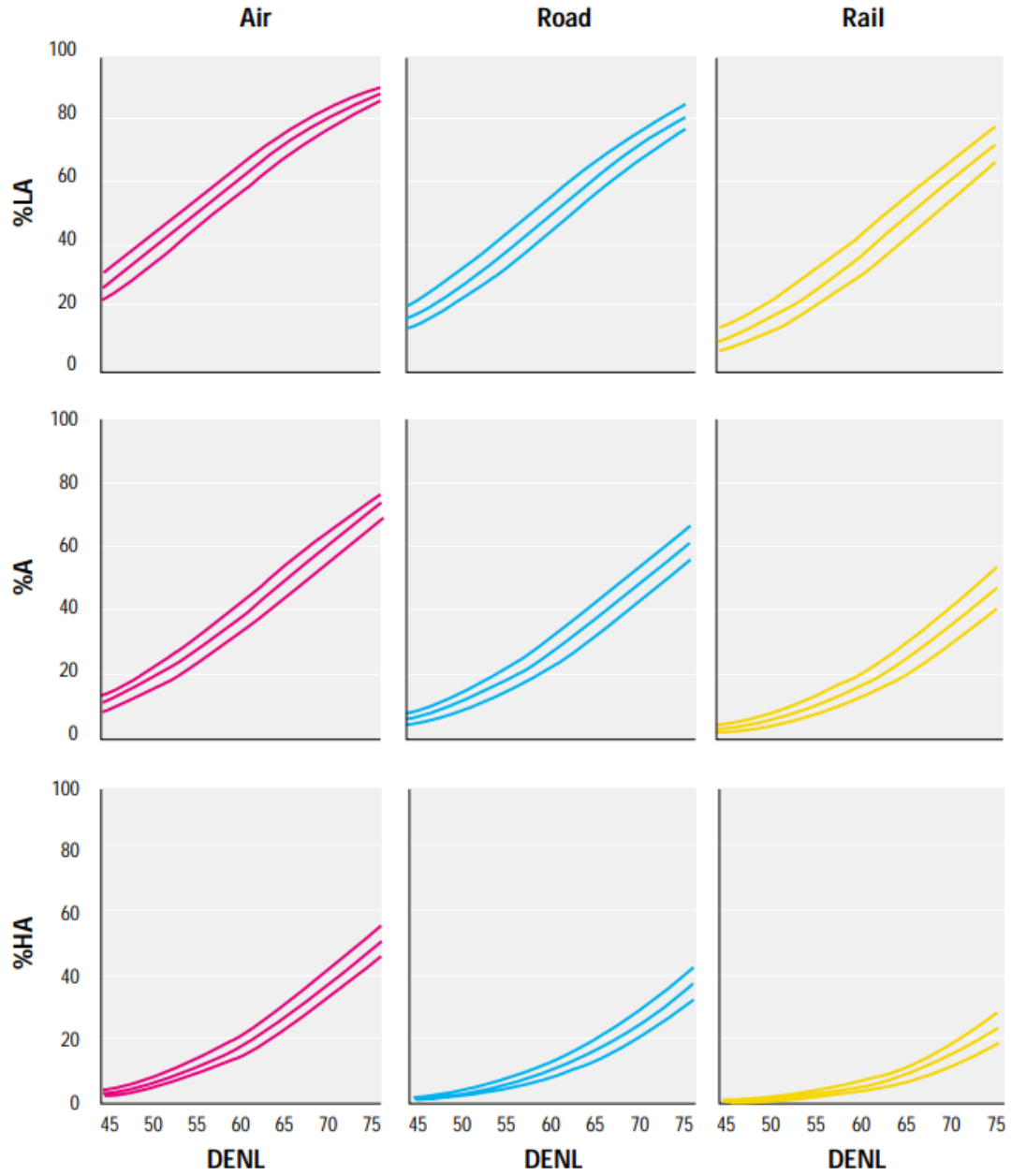

Miedema HM, Oudshoorn CG. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environ Health Perspect. 2001 Apr;109(4):409-16. doi: 10.1289/ehp.01109409. PMID: 11335190; PMCID: PMC1240282.

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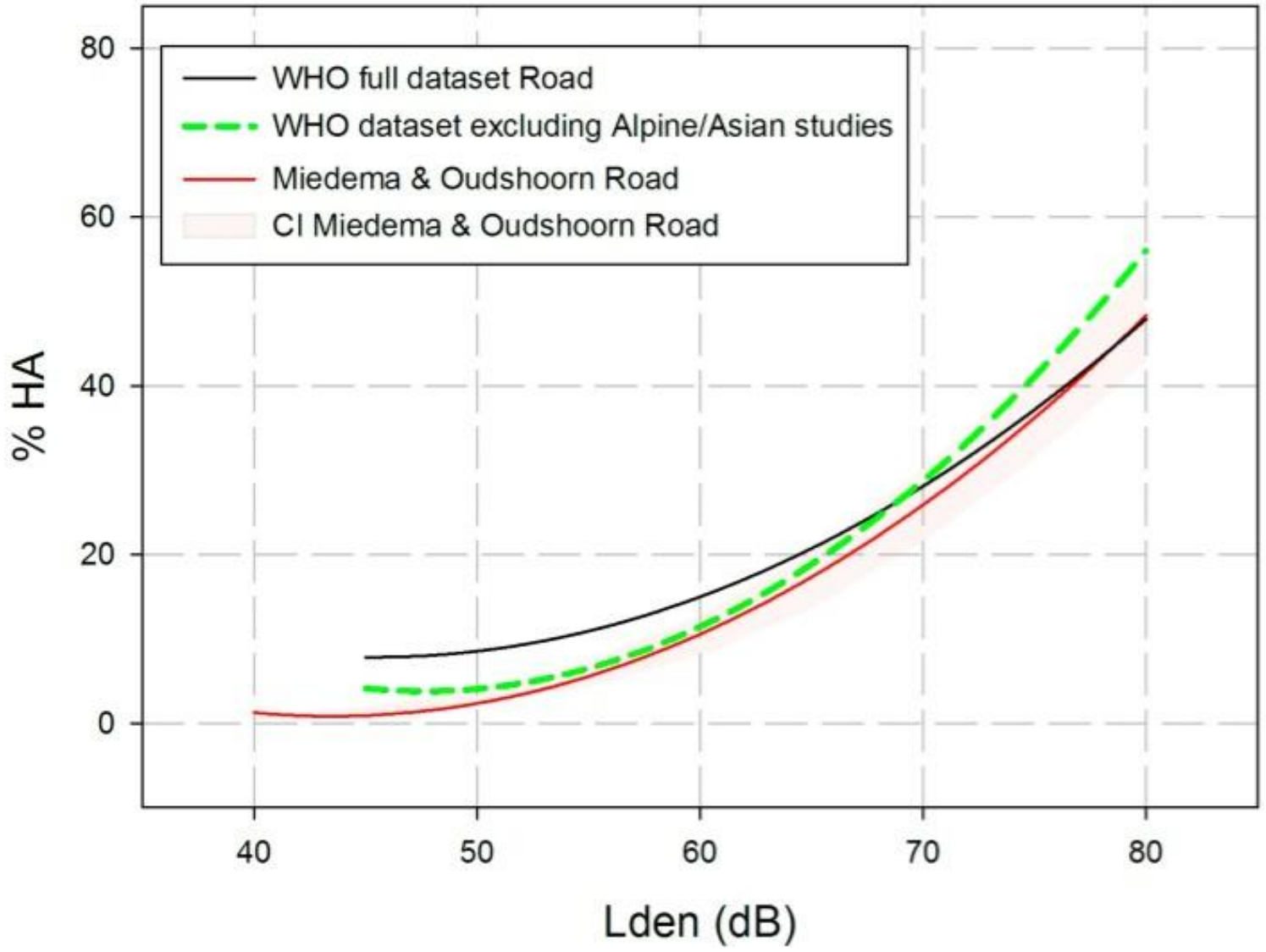

Guski R, Schreckenberg D, Schuemer R. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. Int J Environ Res Public Health. 2017 Dec 8;14(12):1539. doi: 10.3390/ijerph14121539. PMID: 29292769; PMCID: PMC5750957.

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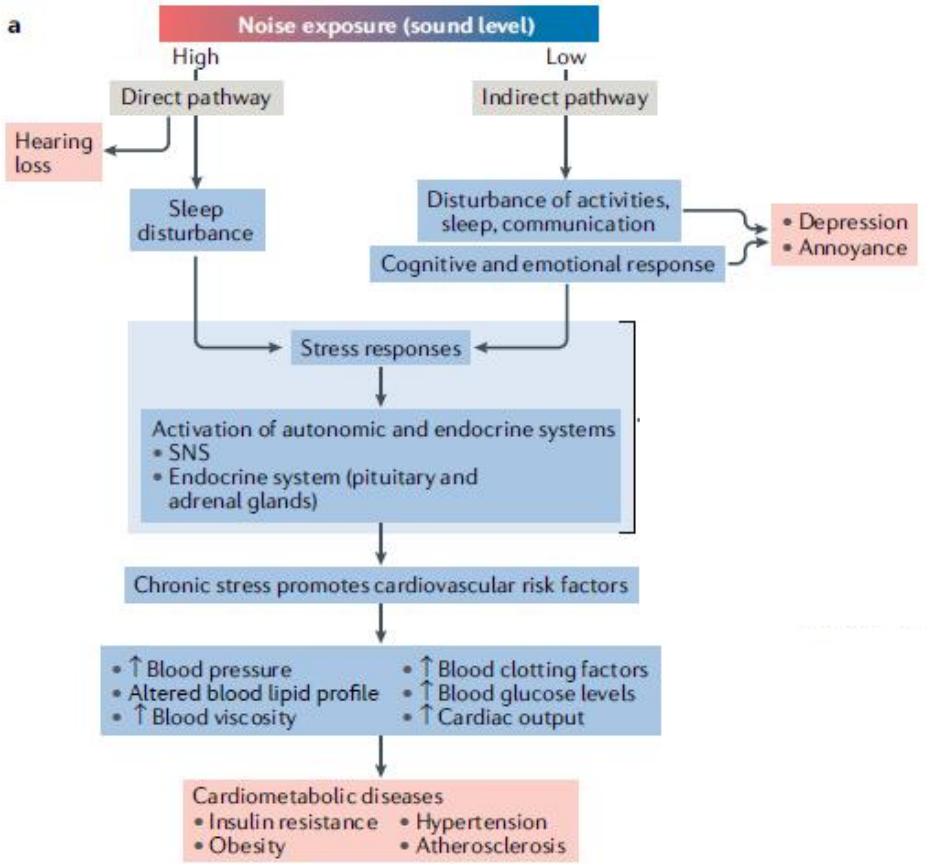

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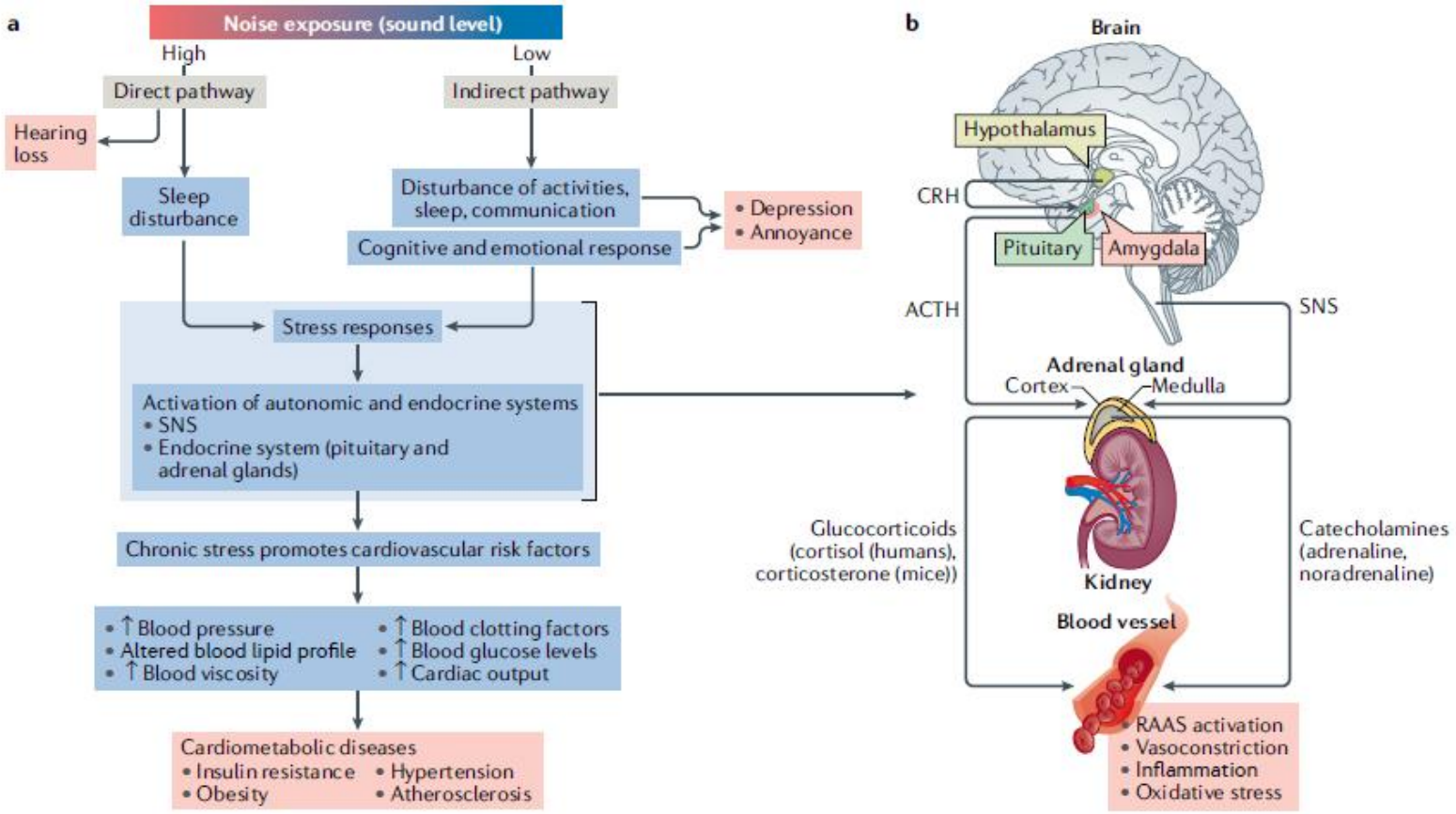


HEALTH EFFECT PATHWAYS AND OUTCOMES

- Sleep disturbance Increase per 10 dB increase from 40 dB (with specific mention of noise in question; Smith et al., 2022)
  - Road – 252%; Aircraft – 218%; Railway – 297%
- Cardiometabolic disease risk per 10 dB increase above 53 dB (Van Kempen et al., 2018)
  - Hypertension from road traffic: 5%
  - IHD from road and rail traffic: 8%
  - Stroke from road traffic: 14%
  - Diabetes from road traffic: 8%
- Cognition (Clark and Paunovic, 2018)

	Environmental Noise Exposure		
Cognitive Domain	**Aircraft Noise: Quality of Evidence & Assessment of Effect**	**Road Traffic Noise: Quality of Evidence & Assessment of Effect**	**Railway Noise: Quality of Evidence & Assessment of Effect**
Reading and oral comprehension	Moderate quality—harmful effect	Very low quality—no effect	n.a.
Standardized assessment tests	Moderate quality—harmful effect	Very low quality—harmful effect	Moderate quality—harmful effect
Long-term and short-term memory	Moderate quality—harmful effect	Very low quality—harmful effect	Very low quality—harmful effect
Attention	Low quality—no effect	Very low quality—no effect	Very low quality—no effect
Executive function	Very low quality—no effect	Low quality—no effect	n.a.

n.a. no studies available to evaluate.

To protect health

WHO/EUROPE NOISE GUIDELINES

recommend reducing noise levels below:

53 dB (45 dB for night)

54 dB (44 dB for night)

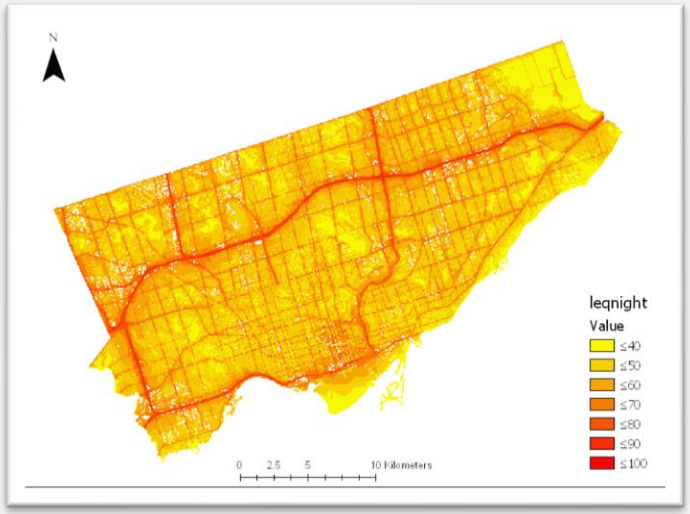
45 dB (40 dB for night)

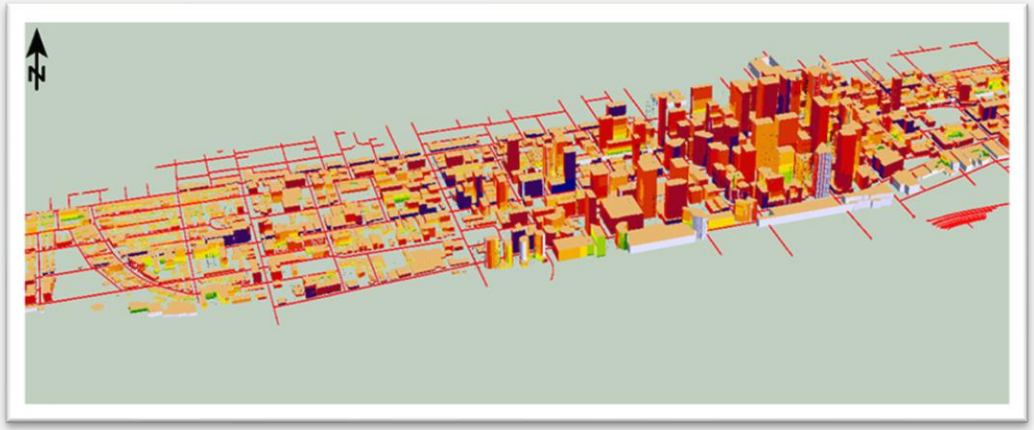
45 dB

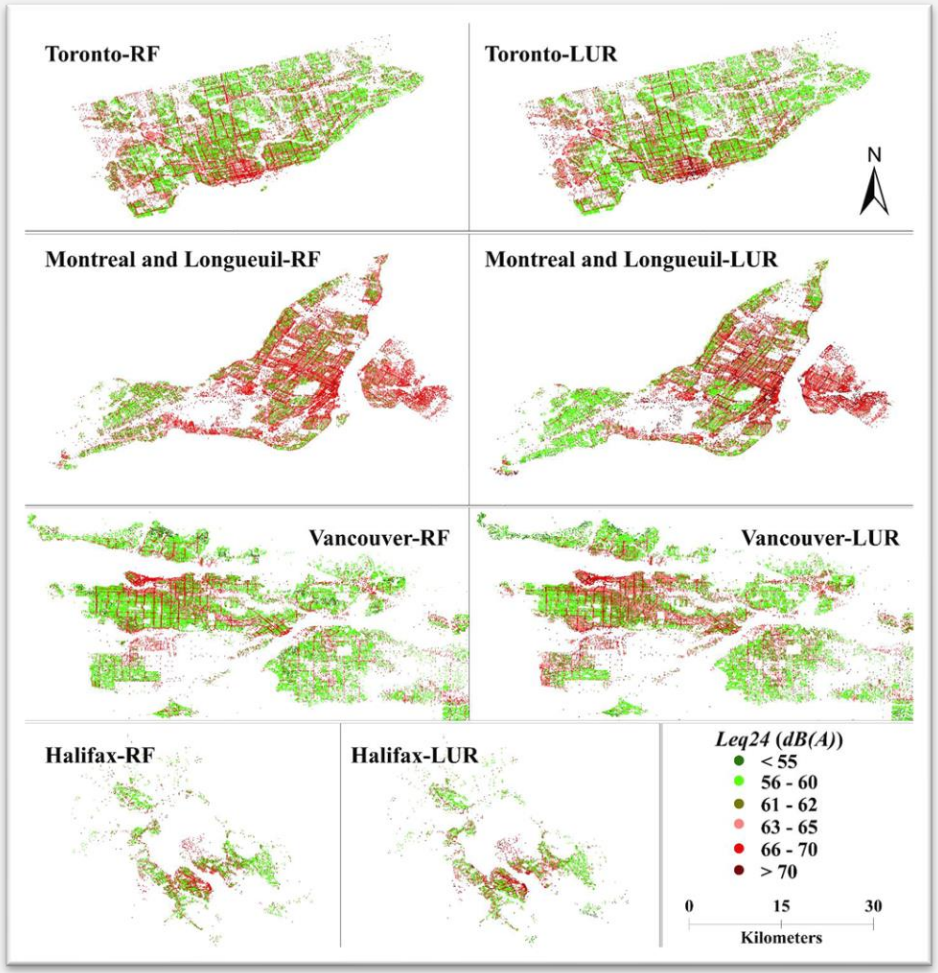
70 dB
(as a yearly average from all leisure noise sources)

World Health Organization
REGIONAL OFFICE FOR Europe

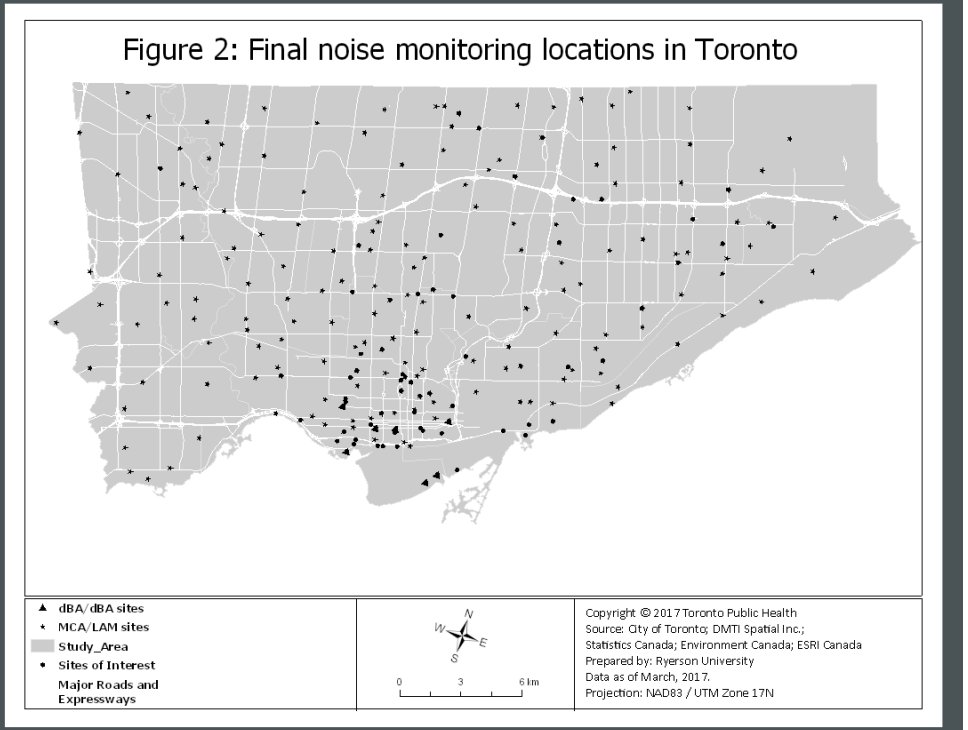
NOISE MAPPING IN CANADA







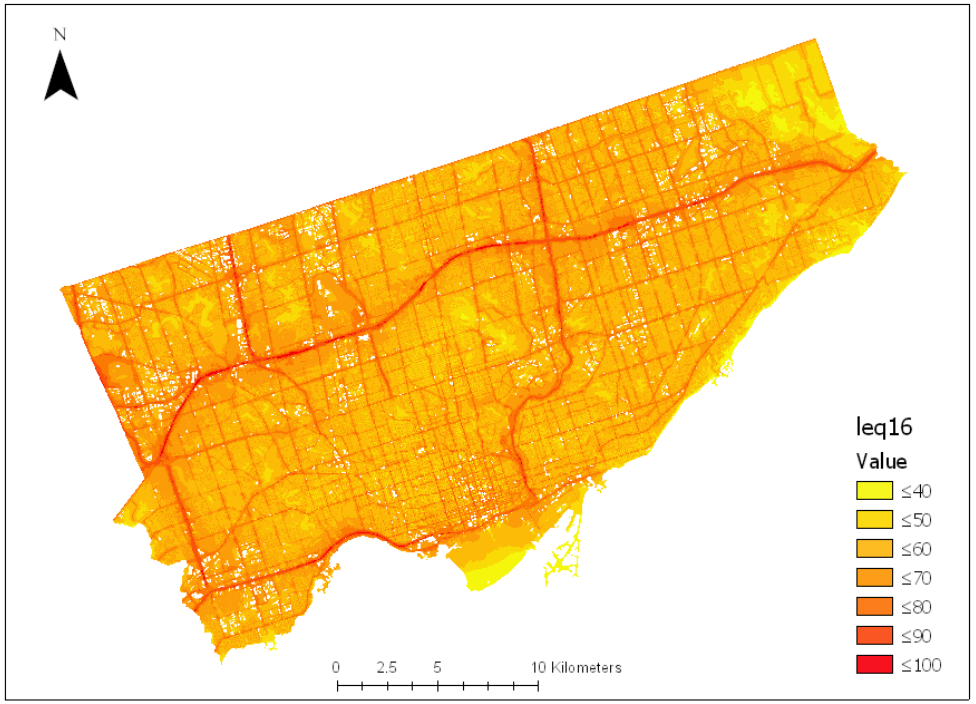
TORONTO NOISE STUDY

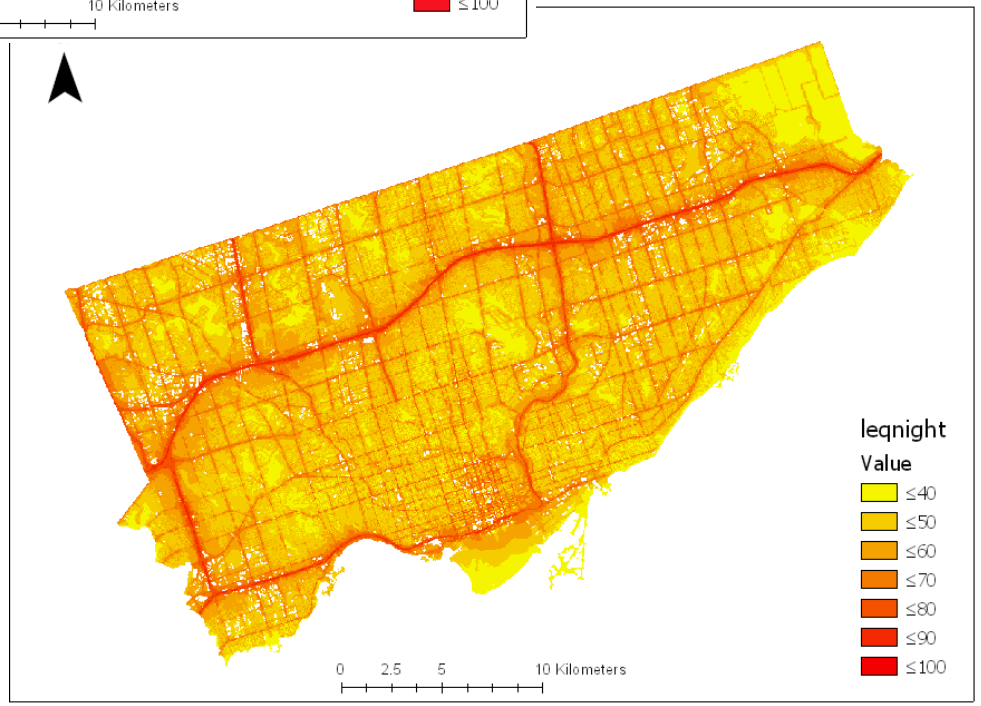


- Propagation model based on known traffic emissions
  - Standardized model (US FHWA)
  - Traffic volumes, speed, composition, topography, 3D building representations, ground cover
- Geo-statistical 'correction model' for other sources

Category	Indicators
Transportation	Length of major roads
	Length of all roads
	Distance to railways
	Length of railways
	Streetcars
	Bus routes
	Nighttime bus routes
	Distance to Pearson Airport
Land use	Commercial
	Government and institutional
	Open area
	Parks and recreation
	Residential
	Resource and industrial
	Waterbody
	Land use entropy
Land cover	Tree canopy
	Grass/Shrub
	Bare earth
	Water
	Buildings
	Roads
	Other paved surfaces
	Agriculture
Vegetation	Normalized Difference Vegetation Index (NDVI)
Demographic	Population density

TORONTO NOISE STUDY





TORONTO NOISE STUDY

Table 2: Arithmetic sound pressure level averages for sites of interest categories													
		Full Week				Weekday				Weekend			
	n	Lden	Leq24h	LeqD	LeqN	Lden	Leq24h	LeqD	LeqN	Lden	Leq24h	LeqD	LeqN
dBA	*220*	66.4	62.9	64.1	57.5	66.7	63.2	64.5	57.6	65.3	61.2	62.4	56.8
dBC	*7*	76.8	71.4	72.0	69.7	76.5	71.5	72.2	69.1	76.6	71.3	71.5	69.1
dBC Control (in dBA)	*7*	69.5	65.1	66.0	61.5	69.3	65.2	66.2	61.2	69.4	61.4	64.7	61.9
Zoning Categories													
Residential	*121*	63.4	60.1	61.4	54.0	63.7	60.6	61.9	54.1	61.9	58.1	59.3	53.2
Open space	*22*	68.0	64.1	65.3	59.3	68.3	64.5	65.7	59.6	66.8	62.6	63.7	58.3
Employment industrial	*15*	71.3	67.7	68.9	62.9	71.7	68.1	69.3	63.4	70.1	66.3	67.5	61.7
Commercial residential	*26*	71.9	67.6	68.7	64.0	72.0	67.9	69.0	63.9	71.6	66.8	67.6	63.9
Road Types													
Local	*98*	62.3	59.0	60.3	52.9	62.6	59.5	60.8	53.0	60.8	57.1	58.3	52.1
Collector	*36*	67.0	63.7	64.9	57.7	67.3	64.2	65.5	57.9	65.5	61.5	62.6	57.0
Major Arterial	*38*	74.7	70.4	71.5	66.8	74.9	70.7	71.7	66.9	74.2	69.6	70.5	66.4
Schools	*10*	68.2	64.4	65.6	59.4	68.6	64.8	66.0	59.7	65.8	61.8	62.9	57.6
Long-term/Hospitals	*9*	68.1	64.4	65.5	59.8	68.2	64.4	65.6	59.9	67.8	63.8	64.9	59.5
Community Housing	*3*	61.9	58.8	60.2	52.7	62.2	59.1	60.4	52.9	61.1	57.9	59.3	52.1
Amplified sound	*16*	70.9	66.7	67.8	62.6	70.8	66.8	67.9	62.5	70.5	66.1	67.0	62.4
Construction	*7*	71.6	67.7	68.8	63.5	71.7	68.3	69.5	63.0	71.2	65.8	66.2	64.0
EMS	*1*	74.4	71.0	72.3	65.9	74.6	71.3	72.6	66.0	73.9	70.1	71.3	65.4
CNE main gates	*1*	74.4	69.0	69.7	67.2	73.7	68.7	69.6	66.0	75.7	69.6	69.8	69.3
BMO Field	*1*	70.4	67.4	68.8	61.2	68.3	61.2	60.6	62.3	73.3	72.0	73.7	55.7
TTC Yards	*2*	76.1	71.8	73.0	68.0	76.2	72.0	73.2	68.1	75.8	71.4	72.5	67.6
Historic or Cultural	*10*	69.9	66.4	67.6	60.9	69.8	66.3	67.5	60.9	69.6	65.8	67.0	60.8
Toronto Island	*2*	64.8	60.7	61.9	56.0	65.2	61.2	62.4	56.3	63.1	58.7	59.8	54.9

TORONTO NOISE STUDY

- ~60% of spatial variability in noise explained by road traffic
- Higher levels in sensitive areas and sites of concern
- 27% of residents exposed to 24-hour Leq 65 dBA or higher
- 93% above WHO nighttime noise guideline (45 dBA)
- Significant differences by socioeconomic status

TORONTO NOISE RESEARCH AND POLICY OUTCOMES

City of Toronto Board of Health adoption of Action Plan

Board recommendations to Province for ambient noise regulation

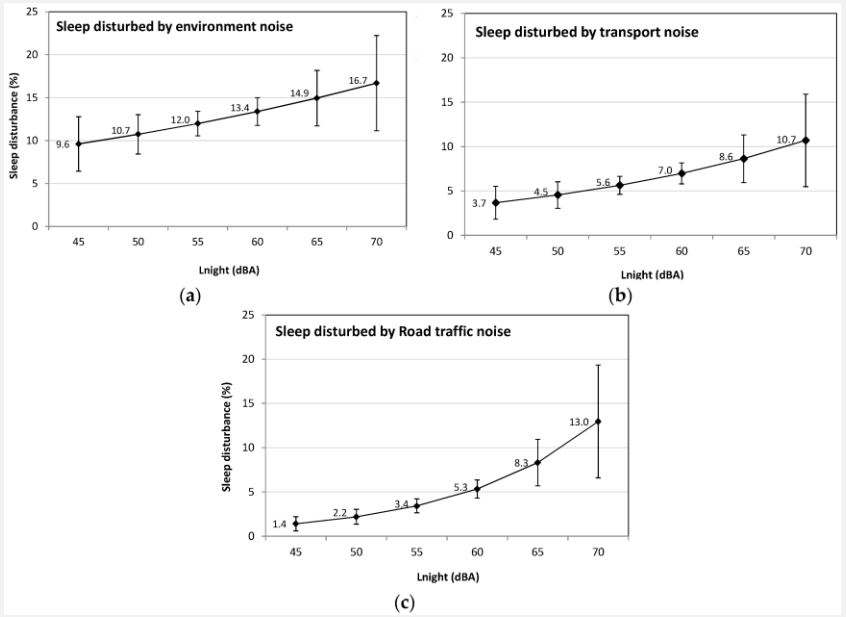
Development of Transportation Equity Opportunity Zones

King Street Transit Priority Corridor

NOISE RESEARCH IN CANADA

- High noise annoyance
  - 20-33% in different areas of Toronto (Oiamo and Stefanova, 2020)
  - 10.5% by traffic noise in urban areas across Canada (Michaud et al., 2022)
- Sleep disturbance
  - Related to environmental noise and specific transportation sources in Montreal (Perron et al., 2016)

Variables		Neighbourhood: Full Sample (n=552)	Trinity Bellwoods (n=98)	Downtown (n=369)	Don Valley (n=85)	Chi-Sq. (*p*-value.)
HA at home (%)	Not Annoyed	67.4	79.6	64.2	67.1	8.32
	Highly Annoyed	32.6	20.4	35.8	32.9	(0.16)
HA in neighbourhood (%)	Not Annoyed	67.8	81.6	65.0	63.5	10.58
	Highly Annoyed	32.2	18.4	35.0	36.5	(0.005)



NOISE RESEARCH IN CANADA

- Cardiometabolic effects
  - 6% increased risk of CHD mortality per IQR from traffic noise in Vancouver (Gan et al., 2012)
  - Acute effects of noise on endothelial function and HRV in Toronto (Biel et al., 2020)
  - Traffic noise in Toronto increased risk of diabetes and hypertenstion (Shin et al., 2019), MI and heart failure (bai et al., 2020)

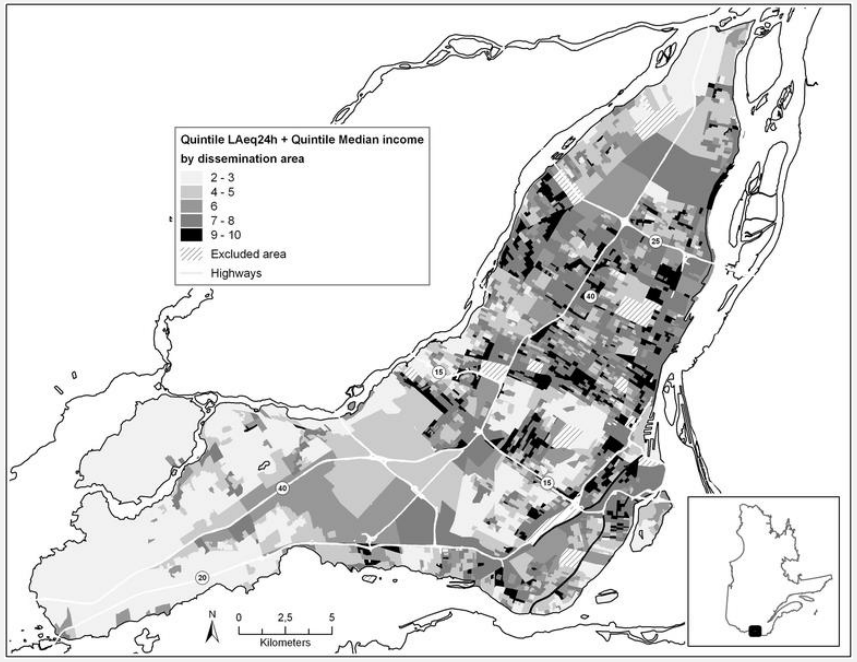
Table 3. Hazard ratios (HRs) and 95% confidence intervals (CIs) for the associations of incidence of acute myocardial infarction (AMI) and congestive heart failure (CHF) with exposure to road traffic noise (LAeq24 and LAeqNight) using interquartile range (IQR) increases and quartiles of exposures.

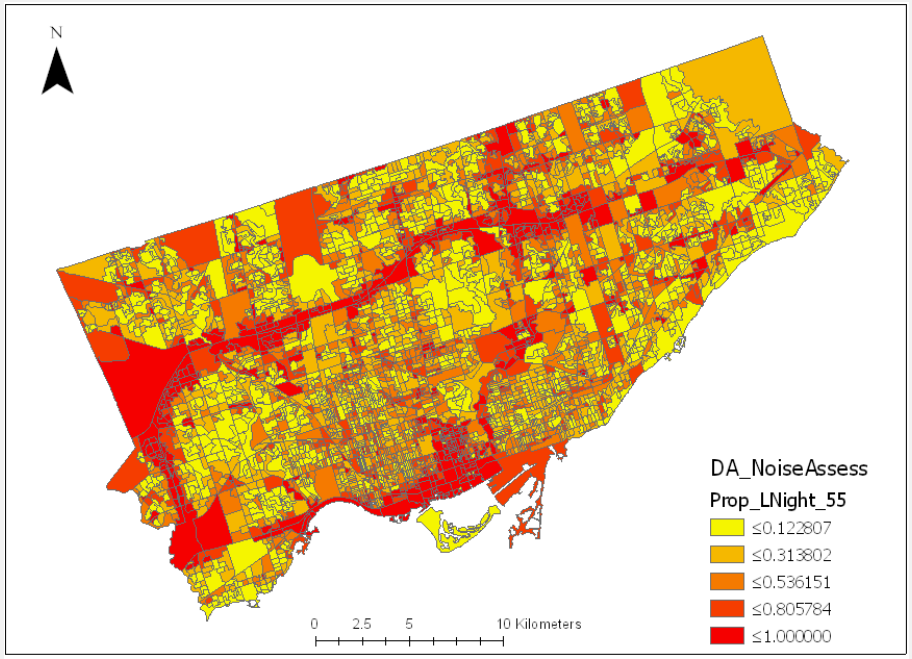
	Incident AMI			Incident CHF		
Model[a]	HR	95% CI		HR	95% CI	
LAeq24 (10.7 dBA per IQR)						
Stratified by age and sex	1.08	1.06	1.09	1.07	1.06	1.08
Further adjusted for census tract–level covariates[b]	1.07	1.06	1.09	1.07	1.06	1.08
LAeq24 (by categories) (dBA)[c]						
≤55	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
56–60	1.07	1.03	1.10	1.07	1.05	1.09
61–65	1.10	1.06	1.13	1.11	1.09	1.04
>65	1.12	1.08	1.15	1.11	1.09	1.13
LAeqNight (10.0 dBA per IQR)						
Stratified by age and sex	1.07	1.06	1.09	1.07	1.06	1.08
Further adjusted for census tract–level covariates[b]	1.07	1.05	1.08	1.06	1.05	1.07
LAeqNight (by categories) (dBA)[c]						
≤45	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
46–50	1.05	1.02	1.08	1.04	1.02	1.06
51–55	1.10	1.06	1.14	1.10	1.08	1.13
>55	1.14	1.11	1.18	1.13	1.11	1.15

Note: dBA, A-weighted decibels; LAeqNight, A-weighted decibels for nighttime (8-h average); LAeq24, A-weighted decibels for 24-h average; Ref., the reference level.
[a]Random-effects Cox proportional hazards models adjusting for neighborhoods ($n = 140$).
[b]Further adjusted for census tract–level recent immigrants, unemployment rate, education, and annual household income.
[c]Hazard ratios by categories were estimated in the models stratified by age and sex and adjusted for census tract–level variables.

NOISE RESEARCH IN CANADA

- Environmental justice: Strong associations between income and noise levels in Montreal (Dale et al., 2015) and Toronto (Oiamo et al., 2018)





NOISE RESEARCH IN CANADA

Burden of disease (DALYs) per 100,000 from traffic noise in Toronto and London, Ontario, 2018 (unpublished findings)

Outcome	Toronto	London
Ischemic heart disease	227	236
High Annoyance	574	563
Sleep Disturbance	388	862
TOTAL	**1188**	**1662**

WHAT'S NEXT?

Improved exposure assessment and access to health data continues to advanced research in Canada

Pathophysiological mechanisms for effects of stress and sleep disturbance

Mitigation in urban environment complex and diverse, but…

Traffic most significant source!!	Building forms and standards	Streetscape design	Regulation	Action plans and performance metrics

NOISE REGULATION: CANADA

Federal	• Air traffic, railroads, new highways • Environmental Assessment Act, Transportation Act 2007, Motor vehicle emissions, occupational safety
Provincial (Ontario)	• Stationary sources and transportation sources • Environmental Protection Act, Envionmental Assessment Act, Planning Act
Municipal	• Construction, residential and other activities • Planning Act (e.g., zoning, Official Plans) and Municipal Act (Bylaws)

NOISE REGULATION: CANADA

- "Guidance for evaluating human health impacts in environmental assessment: noise" (Health Canada)
- Environmental Noise Guideline - Stationary and Transportation Sources - Approval and Planning (NPC-300), Ontario

C3.2.3 Indoor Sound Level Limits

Table C-2 gives the equivalent sound level (L_{eq}) limits and the applicable time periods for the indicated types of indoor spaces. The specified indoor sound level limits are maxima and apply to the indicated indoor spaces with windows and doors closed.

Table C-2 Indoor Sound Level Limits Road and Rail

Type of Space	Time Period	L_{eq} (dBA) Road	L_{eq} (dBA) Rail
Living/dining, den areas of residences, hospitals, nursing homes, schools, daycare centres, etc.	07:00 - 23:00	45	40
Living/dining, den areas of residences, hospitals, nursing homes, etc. (except schools or daycare centres)	23:00 - 07:00	45	40
Sleeping quarters	07:00 - 23:00	45	40
Sleeping quarters	23:00 - 07:00	40	35

NOISE REGULATION: NORWAY

- `Neighbour Act´, Public Health Act, Dog Act, Condo Act, Traffic Act, etc. etc….
- Building codes and development/planning regulations

- Pollution Act
  - Can be enforced by local Health Unit
  - All major emitters required to calculate residential exposures every 5 years
  - Detailed modelling required for indoor > 35dBA
  - Mitigation required if indoor > 42 dBA

NOISE REGULATION: NORWAY

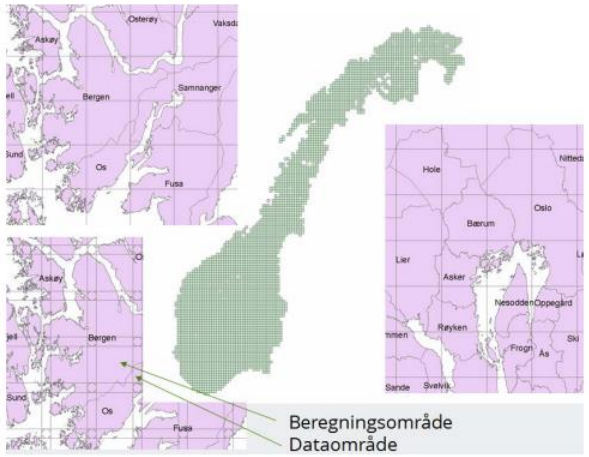
Miljøverndepartemenets retningslinje for behandling av støy i arealplanlegging, T-1442

kapittel 6). Støykilde	Støysone					
	Gul sone			Rød sone		
	Utendørs støynivå	Utendørs støynivå, lørdager og søn-dager/helligdager	Utendørs støy-nivå i nattperiod-en kl. 23 – 07	Utendørs støynivå	Utendørs støynivå , lørdager og søn-dager/helligdager	Utendørs støy-nivå i nattperiod-en kl. 23 – 07
Vei	L_{den} 55 dB		L_{5AF} 70 dB	L_{den} 65 dB		L_{5AF} 85 dB
Bane	L_{den} 58 dB		L_{5AF} 75 dB	L_{den} 68 dB		L_{5AF} 90 dB
Flyplass	L_{den} 52 dB		L_{5AS} 80 dB	L_{den} 62 dB		L_{5AS} 90 dB
Industri med helkontinuerlig drift	Uten impulslyd: L_{den} 55 dB Med impulslyd: L_{den} 50 dB		L_{night} 45 dB L_{AFmax} 60 dB	Uten impulslyd: L_{den} 65 dB Med impulslyd: L_{den} 60 dB		L_{night} 55 dB L_{AFmax} 80 dB
Øvrig industri	Uten impulslyd: L_{den} 55 dB og $L_{evening}$ 50 dB Med impulslyd: L_{den} 50 dB og $L_{evening}$ 45 dB	Uten impulslyd: lørdag: L_{den} 50 dB søndag: L_{den} 45 dB Med impulslyd: lørdag: L_{den} 45 dB søndag: L_{den} 40 dB	L_{night} 45 dB L_{AFmax} 60 dB	Uten impulslyd: L_{den} 65 dB og $L_{evening}$ 60 dB Med impulslyd: L_{den} 60 dB og $L_{evening}$ 55 dB	Uten impulslyd: lørdag: L_{den} 60 dB søndag: L_{den} 55 dB Med impulslyd: lørdag: L_{den} 55 dB søndag: L_{den} 50 dB	L_{night} 55 dB L_{AFmax} 80 dB
Havner og terminaler	Uten impulslyd: L_{den} 55 dB Med impulslyd: L_{den} 50 dB		L_{night} 45 dB L_{AFmax} 60 dB	Uten impulslyd: L_{den} 65 dB Med impulslyd: L_{den} 60 dB		L_{night} 55 dB L_{AFmax} 80 dB
Motorsport	L_{den} 45 dB L_{5AF} 60 dB		Aktivitet bør ikke foregå	L_{den} 55 dB L_{5AF} 70 dB		Aktivitet bør ikke foregå
Skytebaner	L_{den} 30 dB L_{Almax} 60 dB		Aktivitet bør ikke foregå	L_{den} 35 dB L_{Almax} 70 dB		Aktivitet bør ikke foregå

NOISE REGULATION: NORWAY

- National Climate and Environment Goals
  - High noise annoyance reduced by 10% 1999-2020
  - Reduce population with > 38 dBA indoor exposure by 30% (2005-2020)
- National noise model maintaned by Statistical Bureau
  - Emission-propagation model for road, rail and air traffic, industry and motorsport

Figur 7. Inndeling i delområder ved beregning for hele landet

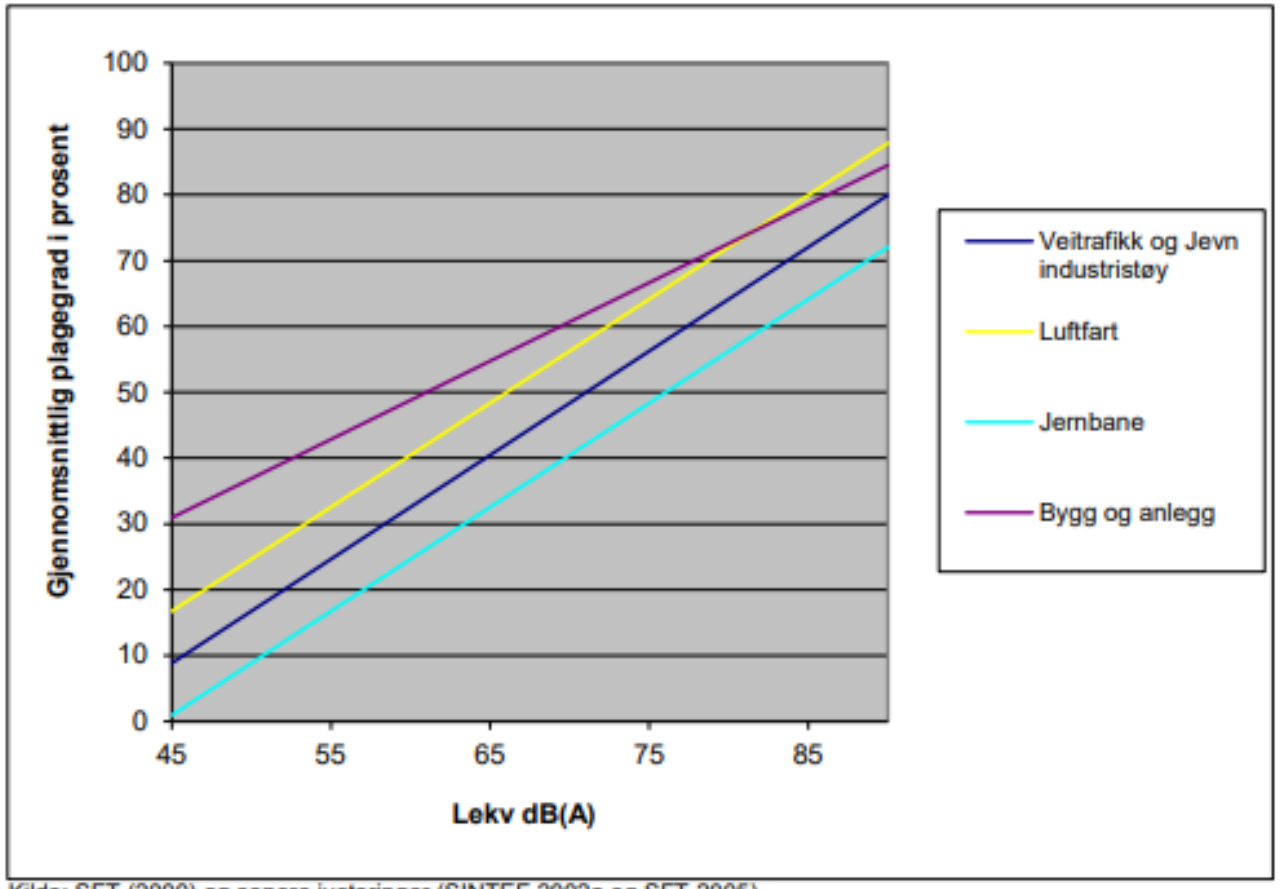


Figur 8. Eksempel på datagrunnlag

Figur 9. Eksempel på modellen som bygges opp i støyberegneren

NOISE REGULATION: NORWAY

Figur 3. Forholdet mellom støynivå og gjennomsnittlig plagegrad (GP)



Kilde: SFT (2000) og senere justeringer (SINTEF 2002a og SFT 2005).

Population levels of annoyance estimated with dose-response functions for individual sources

NOISE REGULATION: NORWAY

Currently…

- Determine source specific dose-response functions from national survey
- Identify appropriate exposure-based indicators for noise annoyance and sleep disturbance
- Set new national goals
- Harmonize with EU Noise Directive for assessment standards and requirements (e.g., CNOSSOS)

KEY DIFFERENCES BETWEEN CANADA AND NORWAY

- Legally binding exposure limits
- National or provincial goals for improvement
- Standardized exposure and health impact assessment
- Integration into legal frameworks across transmission chain (from emission to receptor)
- Public interest?


QUESTIONS OR COMMENTS?