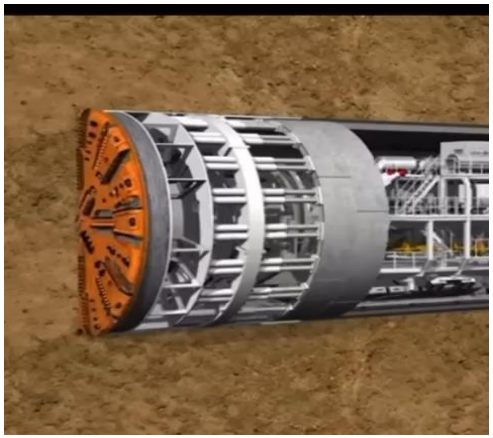
LES PLÉNIÈRES 2025
Sciences et techniques du Génie Civil
JOURNÉES de GÉOTECHNIQUE du RST
en ligne, 5-6/11/2025

In-situ dynamic measurements within the ground during tunnelling in urban areas

I. General Overview



Vibrations generated by tunneling significantly affect the comfort of individuals and activities in nearby structures

Experimental method

Numerical method

II. General Bibliography

Surface Measurements

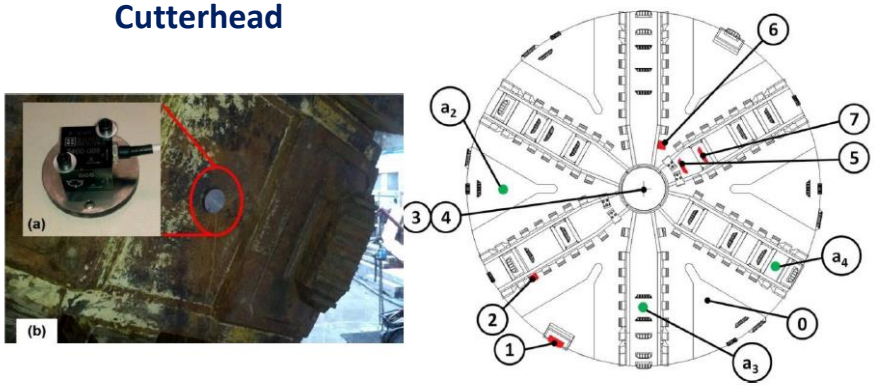
Source	Project	TBM	D (m)	C (m)	Dominant excavated ground
Hanagan,1993	Buffalo subway (USA)	Hard rock TBM	5.6	5–10	Limestones and dolostones
Hiller and Crabb (2000)	London JLE contract 110 (UK)	EPBS	5.1	10.5	London clay
Hiller and Crabb (2000)	London JLE contract 107 (UK)	Slurry Shield	5.1	21.2	Sands and clays
Ferrari et al. (2011)	Lyon subway (France)	Slurry Shield	9.5	15	Granites
Lunardi et al. (2015)	Breschia subway (Italy)	EPBS	8.8	20	Boulders in an alluvial matrix
Bigot and Farotto (2016)	Rennes subway (France)	EPBS	9.5	20	more or less altered shales
Grund et al. (2016)	Karlsruhe subway (Germany)	Slurry Shield	9.3	10	Gravels and sands

Note: D is the tunnel diameter and C is the overburden thickness.

II. General Bibliography

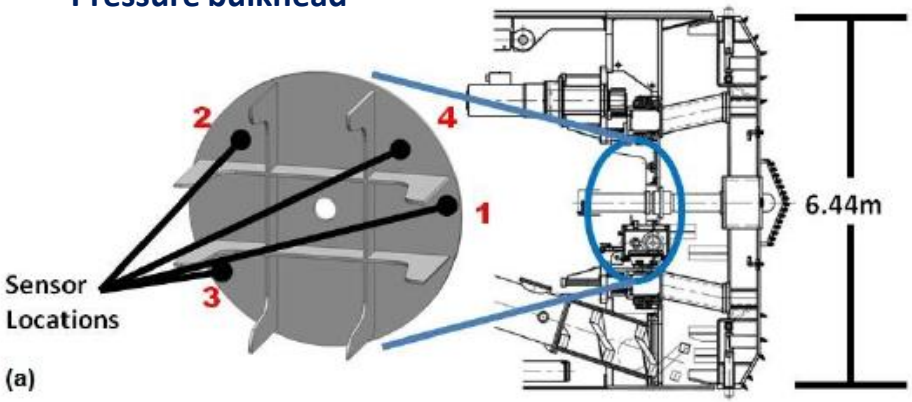
Source Measurements

Cutterhead



. Schematic of Hitachi 6.44 m diameter cutterhead and locations of impacts (0-7) as well as locations of accelerometers (a_2-a_4)

Pressure bulkhead



Influence of driving parameter and geological changes → reduce mechanical failure

Zhang, K.Z., Yu, H.D., Liu, Z.P., Lai, X.M., 2010. Dynamic characteristic analysis of TBM tunnelling in mixed-face conditions. Simulat. Model. Pract. Theor. 18 (7), 1019e 1031. Dr

Huo, J.Z., Zhang, Z.G., Meng, Z.C., Li, J.B., Wu, H.Y., Jia, L.H., 2021. Dynamic analysis and experimental study of a Tunnel boring Machine testbed under multiple conditions. Eng. Fail. Anal. 127, 105557.

II. General Bibliography

Surface Measurements + Close to Cutting Wheel

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Hanagan,1993	Buffalo subway (USA)	Hard rock TBM	5.6	5–10	Limestones and dolostones
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Grund et al. (2016)	Karlsruhe subway (Germany)	Slurry Shield	9.3	10	Gravels and sands
Rallu et al.(2022)	Sorgues (France)	Micro TBM	1.3	10	Gravels and sands
	Lyon subway (France)	Slurry shield	9.8	25	Granites
				20	Gravels and sands
	TULIP (France)	EPBS	9.9	22.5	Clayey sands

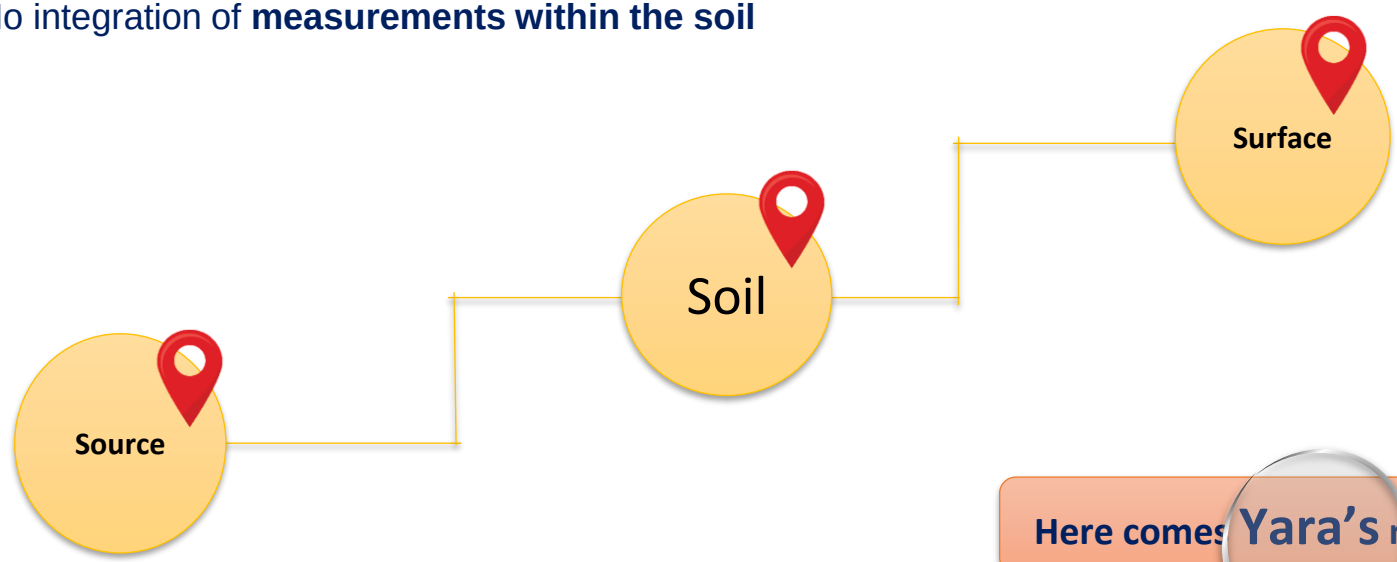
Note: D is the tunnel diameter and C is the overburden thickness.

Influence of travel distance the geological structure and geotechnical characteristics of the ground layers, the groundwater conditions and the operating parameters of the TBM

What's missing in previous studies?

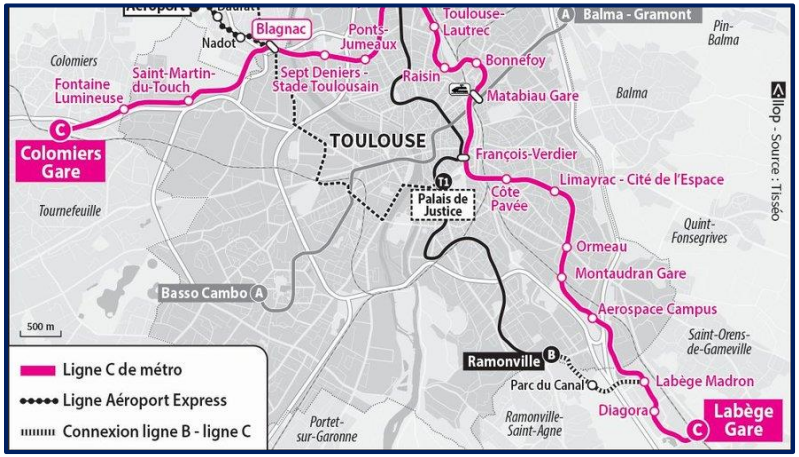


- No full analysis of vibration **propagation from source to surface**
- No integration of **measurements within the soil**





II. Cases of Study



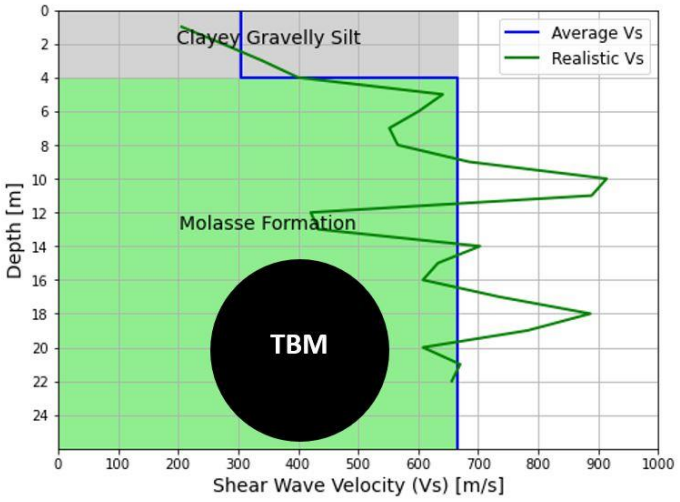


Metro line C - Toulouse

Metro line 18 - Orly

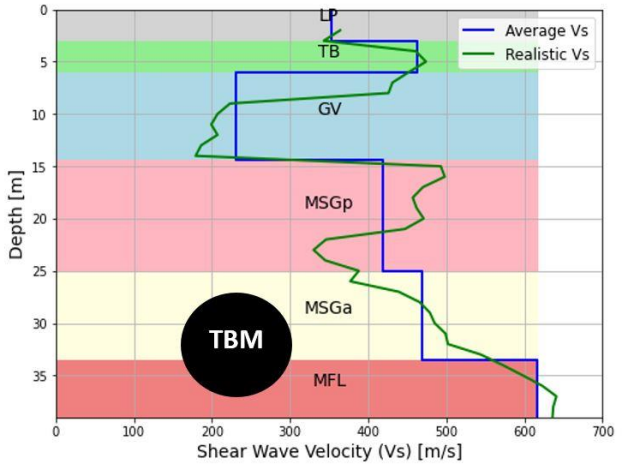
III. Soil Description

Depth interval (m)	Geological Layer	V_s (m/s)	V_p (m/s)
0 – 4	Clayey gravelly silt	305	1019
4 – 25	Molasse Formation	665	2149



Metro line C - Toulouse

Depth interval (m)	Geological Layer	V_s (m/s)	V_p (m/s)
0 – 3	LP: Plateau silt	353	1644
3 – 6	TB: Brie and Sannois limestone	462	1997
6 – 14.42	GV: Green clays	230	1551
14.42 – 25	MSGp: Supragypsous marls of Pantin	418	1532
25 – 33.5	MSGa: Supragypsum marls of Argenteuil	469	1830
33.5 – 39.5	MFL: Masses and marls of gypsum	616	1826



Metro line 18 - Orly

IV. Instrumentation



Tromino(3D)

Surface /Inside TBM



Rosina (1D)

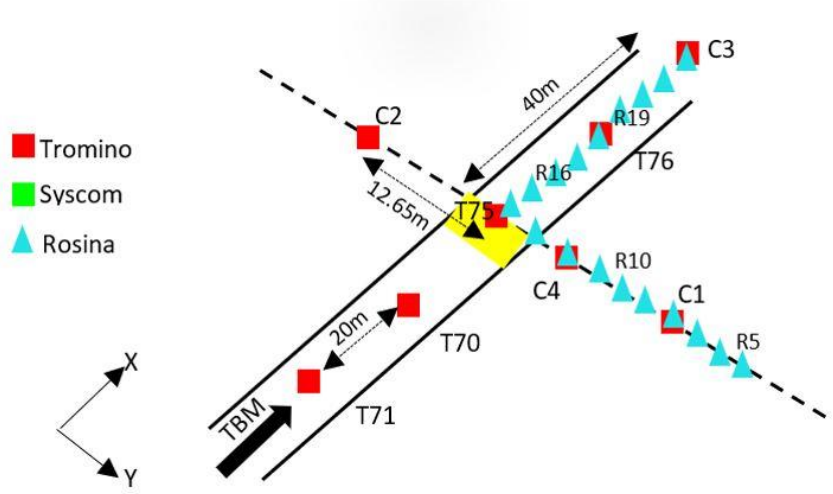
Surface

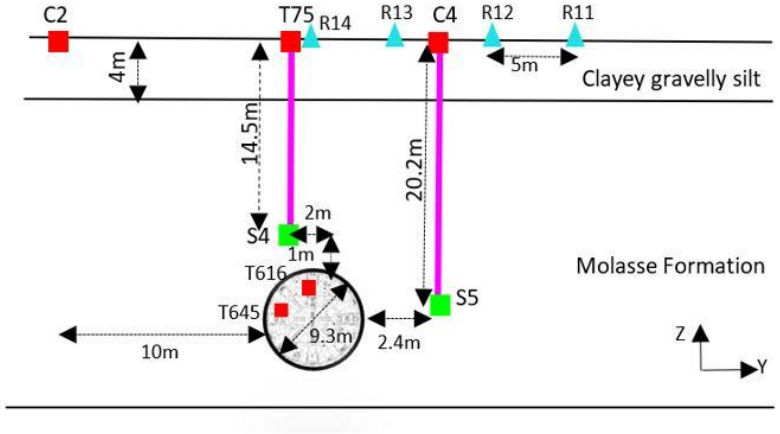


Syscom (3D)

Within Soil

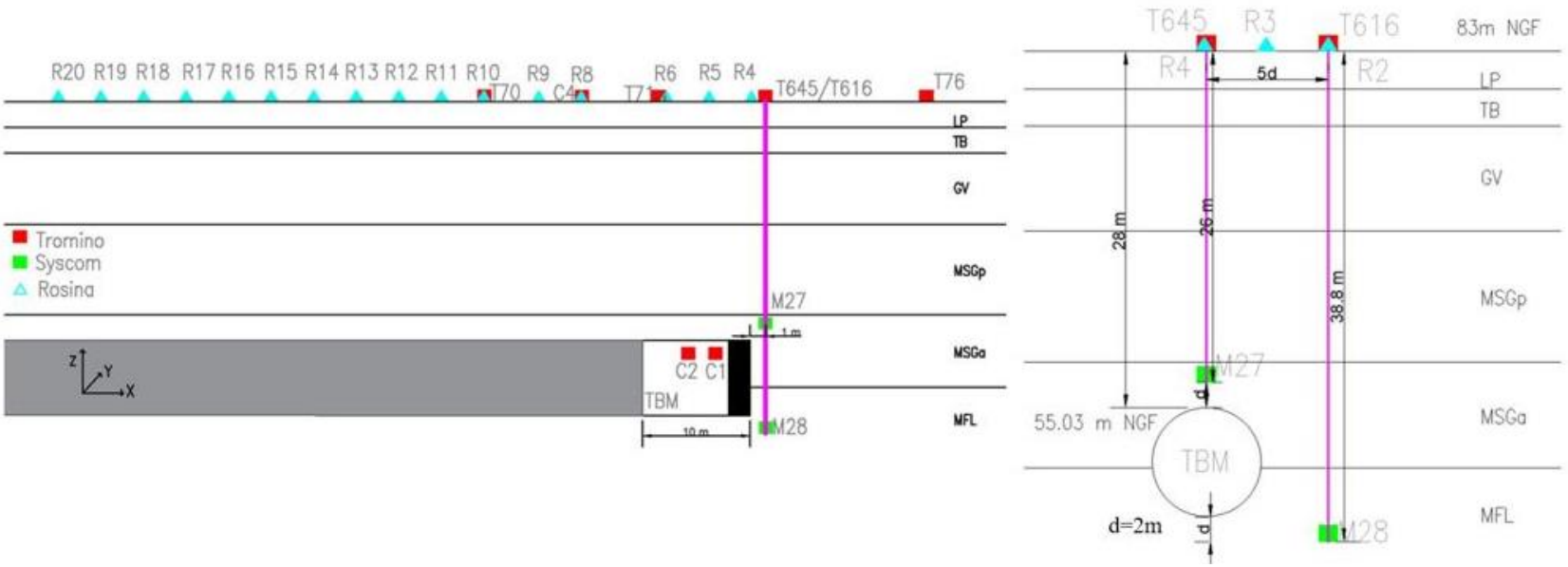
V. Site Installments





Metro line C - Toulouse

V. Site Installments



Metro line 18 - Orly

V. Data Processing Methodology

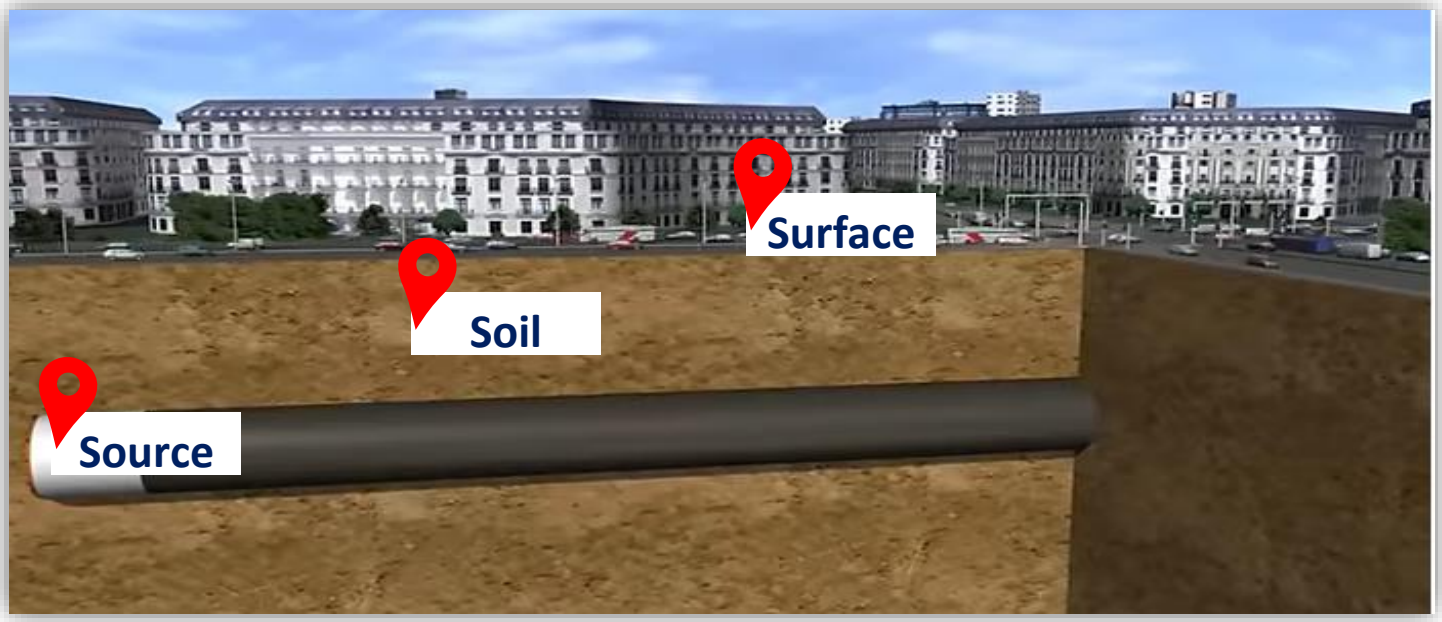
Time Domain Analysis (TDA)

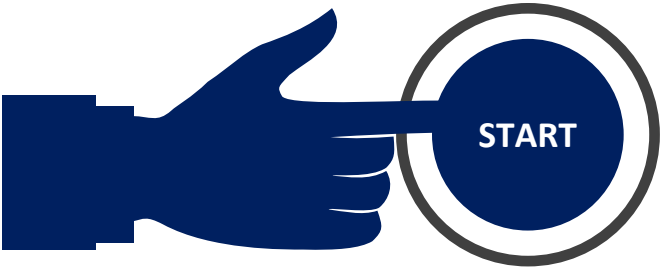
Quantified through the characteristic velocity(v_k) defined as the absolute velocity level that has a 0.5 % probability of being exceeded

Frequency Domain Analysis(FDA)

Transforming the time-domain vibration signals into the frequency domain to examine their spectral content

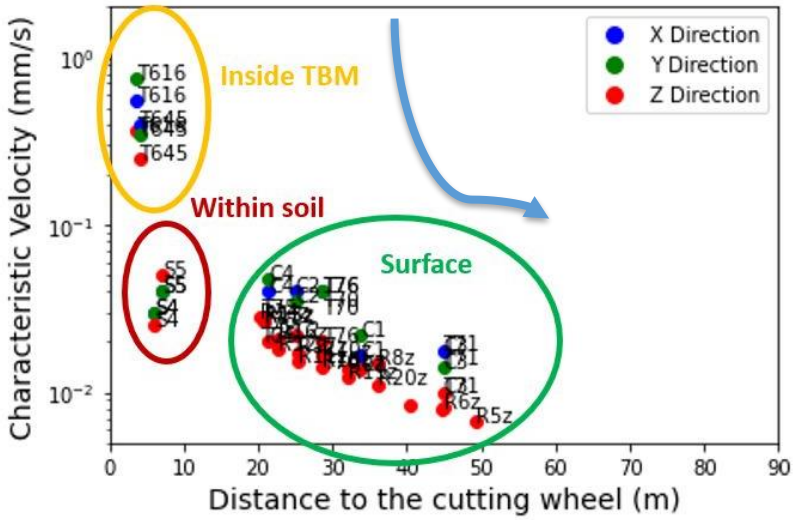
V. Data Processing Methodology



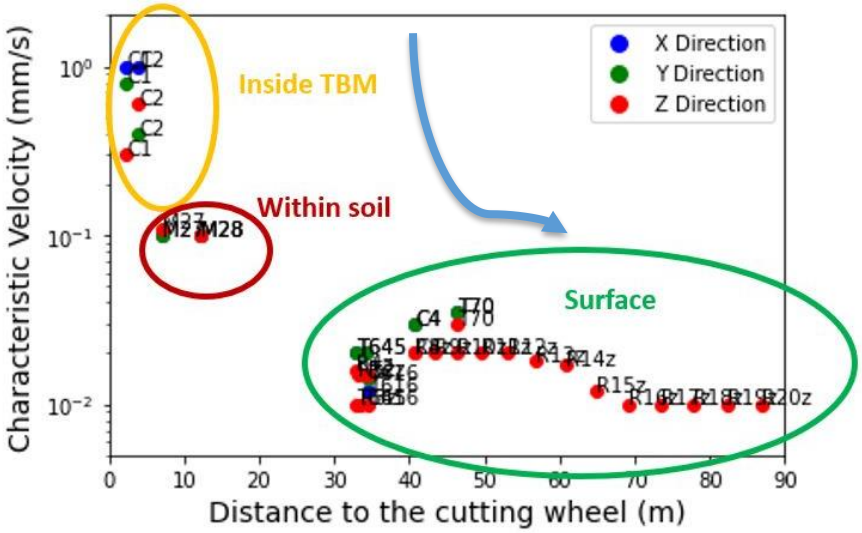


VI. Results

TDA



Metro line C - Toulouse

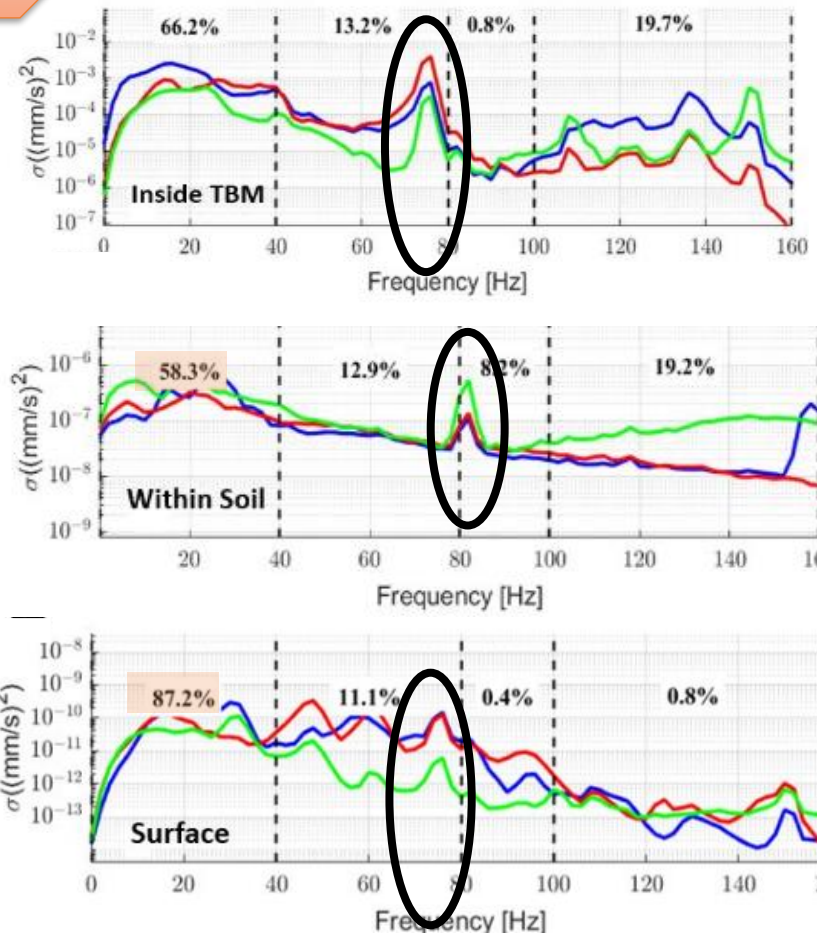


Metro line 18 - Orly

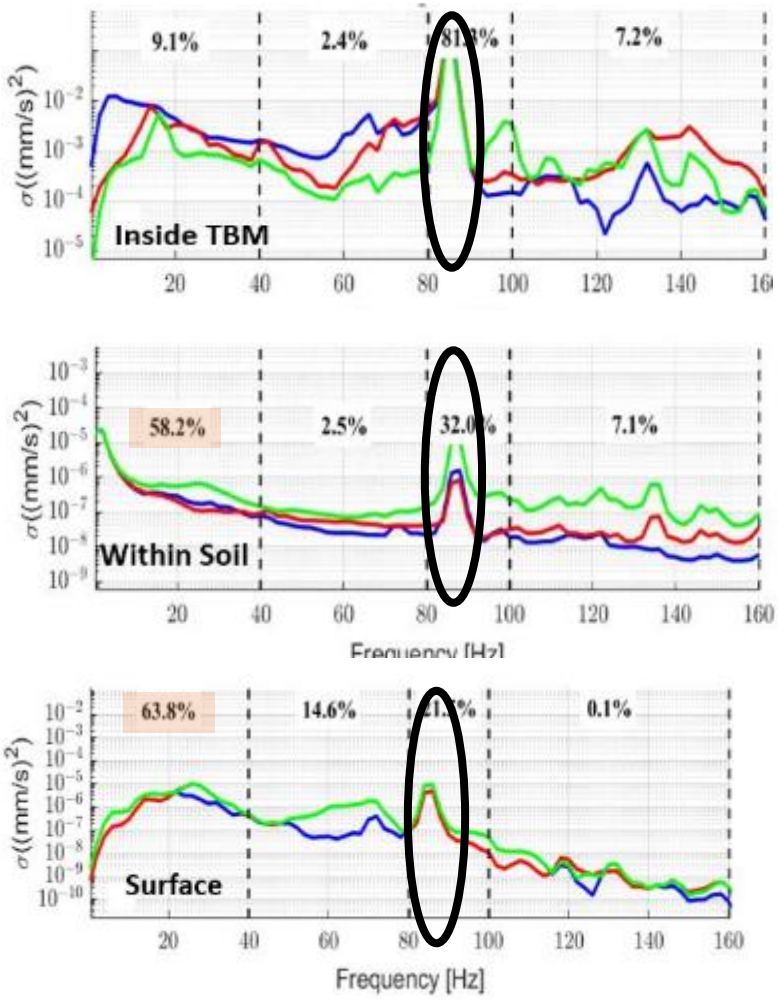
VI. Results

FDA

Metro line C - Toulouse



Metro line 18 - Orly



VII. Comparison with Other Reported TBM-Induced Vibration Studies

Lyon - Line B (Granite)			Lyon - Line B (Alluvium)			Aulnay-sous-Bois - Line 16		
Soil Layer	**Depth (m)**	**V_s (m/s)**	**Soil Layer**	**Depth (m)**	**V_s (m/s)**	**Soil Layer**	**Depth (m)**	**V_s (m/s)**
Sandy-clayey silts	0-5	400	Fill materials	0-3	220	Fill materials	0-5	250
Weathered granite	5-10	800	Sandy-clayey silts	3-10	400	Marly limestones	5-15	500
Massive granite	10-40	2100	Clayey-gravelly sands	10-15	500	Clayey sands	15-25	550
			Pebbles (silty-sandy matrix)	15-35	550	Marly limestones	25-35	800
			Granite bedrock	35-40	2100	Limestones	35-40	1200

Tunnel Location

Site	Type of TBM	Torque on cutterhead (MN·m)	Axial force on face (MN)
Orly - Line 18	EPB	1.5	9.9
Toulouse - Line C	EPB	3.3	17.4
Lyon - Line B (granite)	Variable density	3.0	13.6
Lyon - Line B (alluvium)	Variable density	1.0	15.1
Aulnay-sous-Bois - Line 16	EPB	4.0	13.5

VII. Comparison with Other Reported TBM-Induced Vibration Studies

TDA

Inside the TBM

Lyon - Line B (Granite)			Lyon - Line B (Alluvium)			Aulnay-sous-Bois - Line 16		
Soil Layer	**Depth (m)**	**V_s (m/s)**	**Soil Layer**	**Depth (m)**	**V_s (m/s)**	**Soil Layer**	**Depth (m)**	**V_s (m/s)**
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			Pebbles (silty-sandy matrix)	15-35	550	Marly limestones	25-35	800
			Granite bedrock	35-40	2100	Limestones	35-40	1200

Tunnel Location

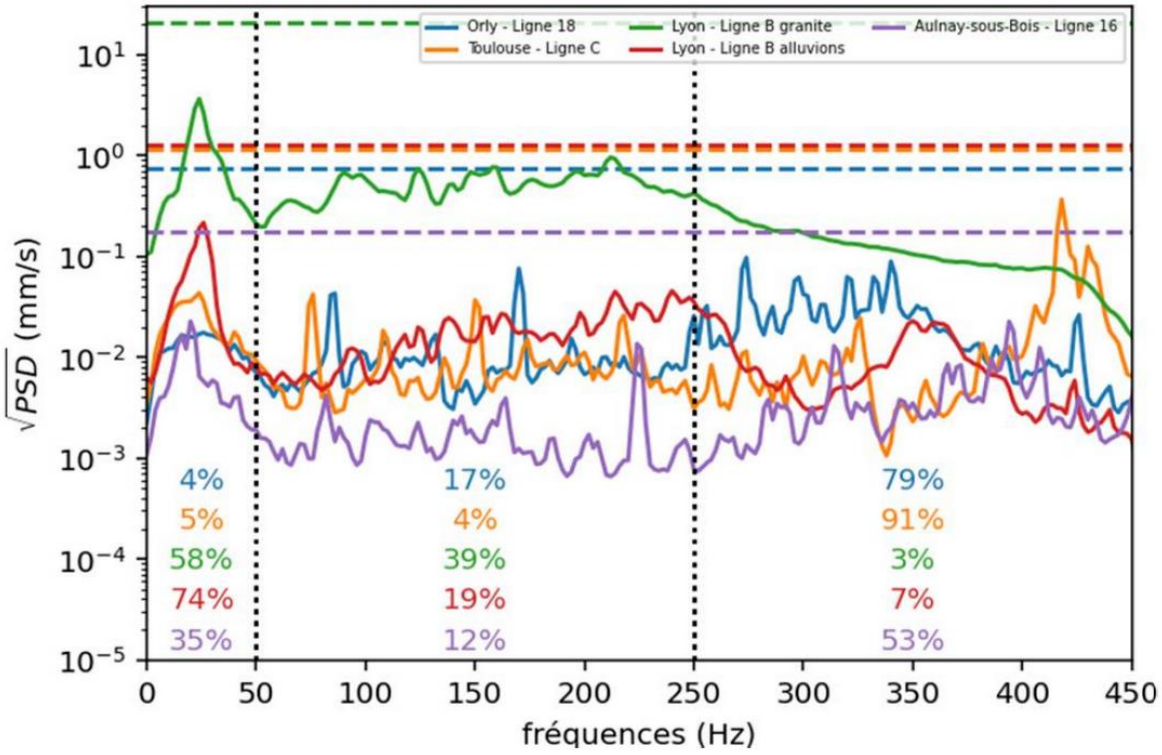
	Orly	Toulouse	Lyon–granite	Lyon–alluvion	Aulnay–sous–Bois
V_s (m/s) of excavated ground	470–660	660	2100	550	550–800
First sensor					
Sensor ID	C1	T6I6	C3	C3	T7G
V_x (mm/s)	1.0	0.7	20.4	1.9	0.14
V_y (mm/s)	0.8	1.0	20.7	1.8	0.16
V_z (mm/s)	1.0	1.5	23.8	1.7	0.17
Second sensor					
Sensor ID	C2	T6I5	C4	C4	—
V_x (mm/s)	1.3	0.6	20.7	1.4	—
V_y (mm/s)	0.6	0.5	21.6	1.1	—
V_z (mm/s)	1.2	0.5	25.2	1.6	—

0.2-2 mm/s

VII. Comparison with Other Reported TBM-Induced Vibration Studies

FDA

Inside the TBM



VII. Conclusion



Two attenuation stages observed: from TBM → soil and soil → surface, with stronger damping at Orly due to stratified layers.

Amplitude range: from **10^{0} mm/s inside the TBM** to **10^{-2}–10^{-3} mm/s at the surface**, depending on the site.

Characteristic frequencies: ~85 Hz (Orly) and ~75 Hz (Toulouse) linked to the TBM cutterhead rotation.

Geological context (stratified vs homogeneous soil) strongly governs vibration attenuation and transmission efficiency.

Thank You for your attention!