

ROBUS



Road Barrier
Upgrade
of Standards

Full Scale Tests

GOUBEL Clément
Project and Development Engineer
LIER - France



Laboratoire d'Essais Inrets Equipements de la Route



autostrade // *per l'italia*

cidaut 
Fundación para la Investigación y Desarrollo
en Transporte y Energía



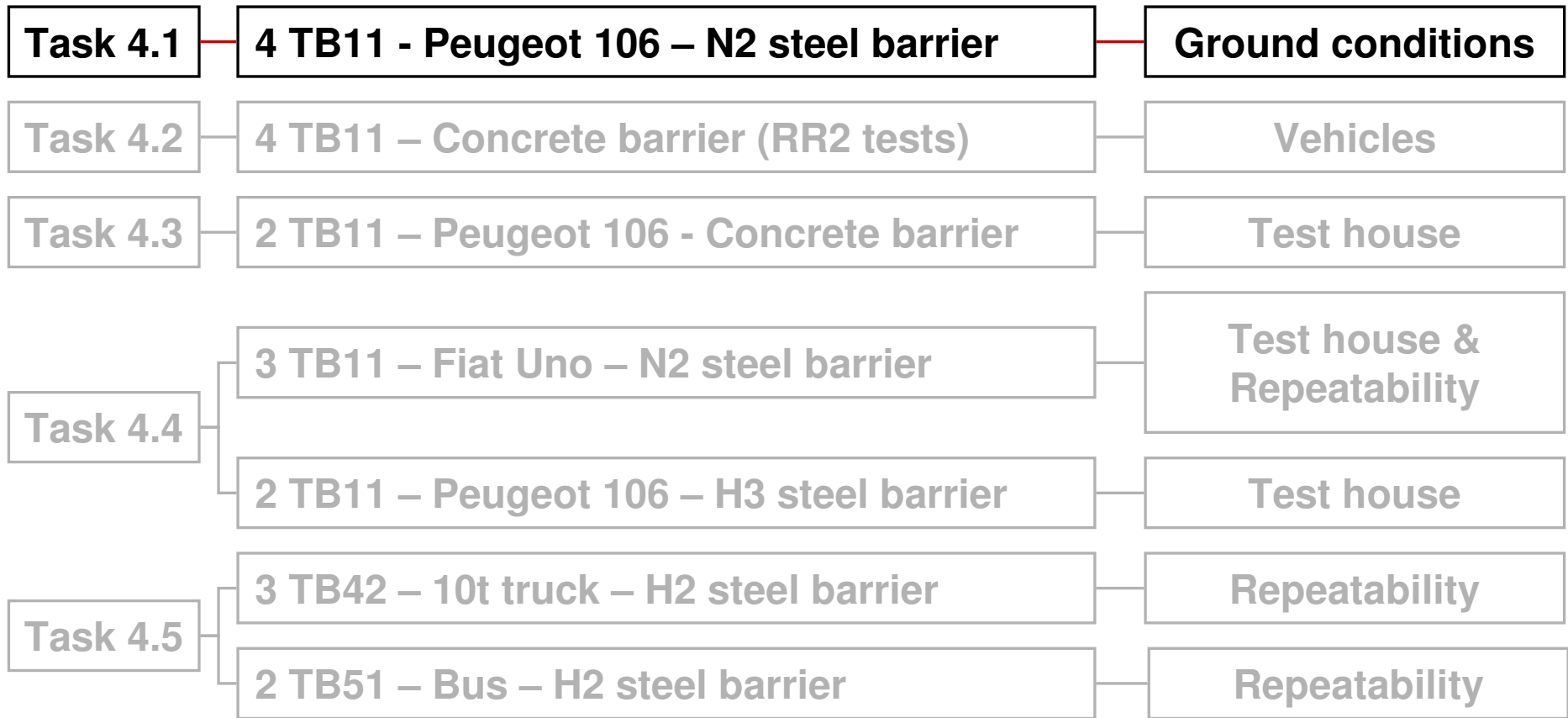
WP4 : Full Scale Tests

TASKS AND TEST MATRIX SUMMARY

Task 4.1	4 TB11 - Peugeot 106 – N2 steel barrier	Ground conditions
Task 4.2	4 TB11 – Concrete barrier (RR2 tests)	Vehicles
Task 4.3	2 TB11 – Peugeot 106 - Concrete barrier	Reproducibility
Task 4.4	3 TB11 – Fiat Uno – N2 steel barrier	Reproducibility & Repeatability
	2 TB11 – Peugeot 106 – H3 steel barrier	Reproducibility
Task 4.5	3 TB42 – 10t truck – H2 steel barrier	Repeatability
	2 TB51 – Bus – H2 steel barrier	Repeatability

20 full scale crash tests performed in 4 test houses

Task 4.1 Ground conditions



Task 4.1 Test matrix

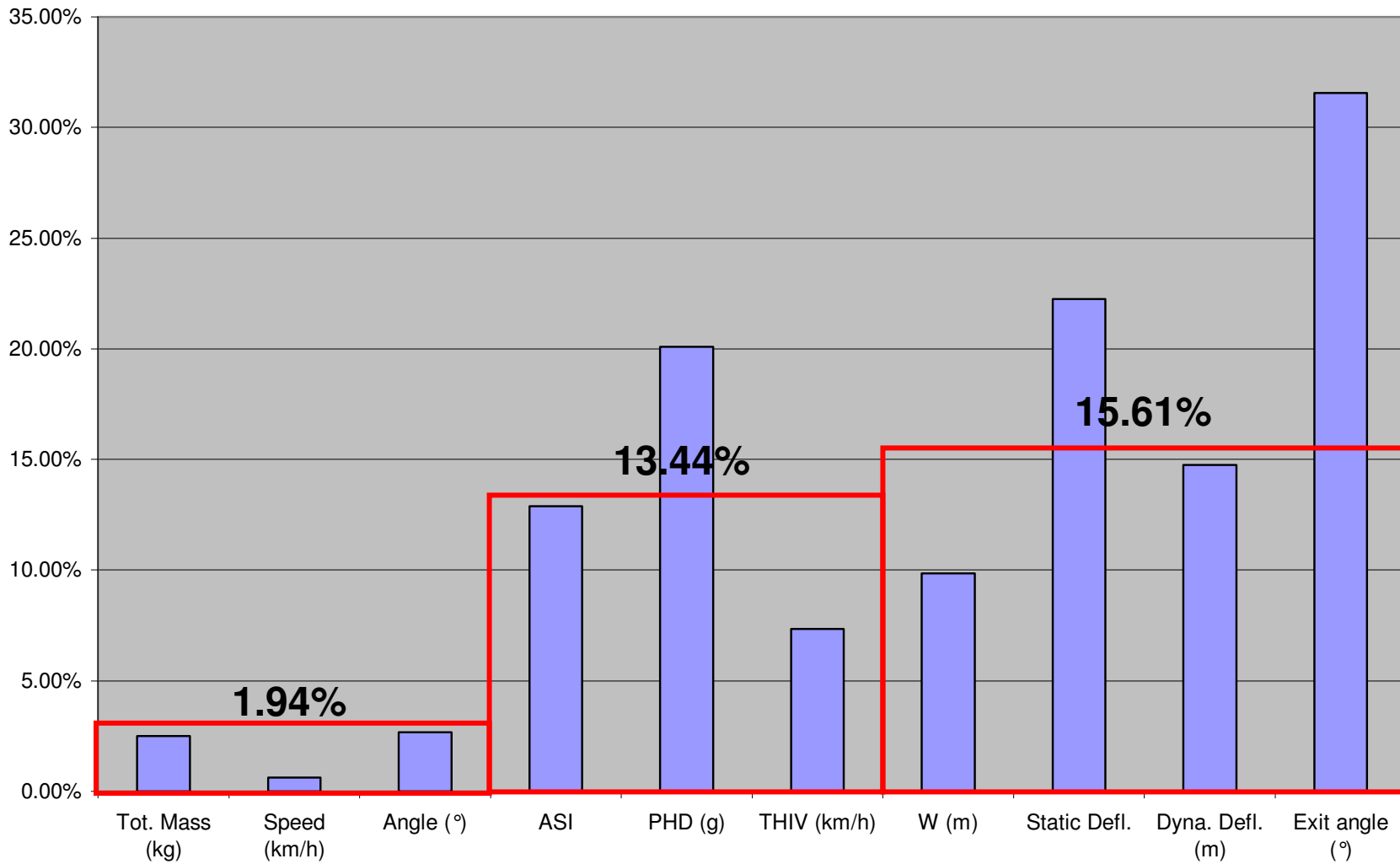
One TB11 test in each of the test houses on the same N2 steel barrier with the same car
(Round Robin on steel barrier)

Test	Vehicle	Barrier	Ground	Test House
TB11	P 106	Steel N2	Asphalt	LIER
TB11	P 106	Steel N2	Concrete	TRL
TB11	P 106	Steel N2	soil 1	AUTOSTRADE
TB11	P 106	Steel N2	soil 2	CIDAUT



Task 4.1 Analysis

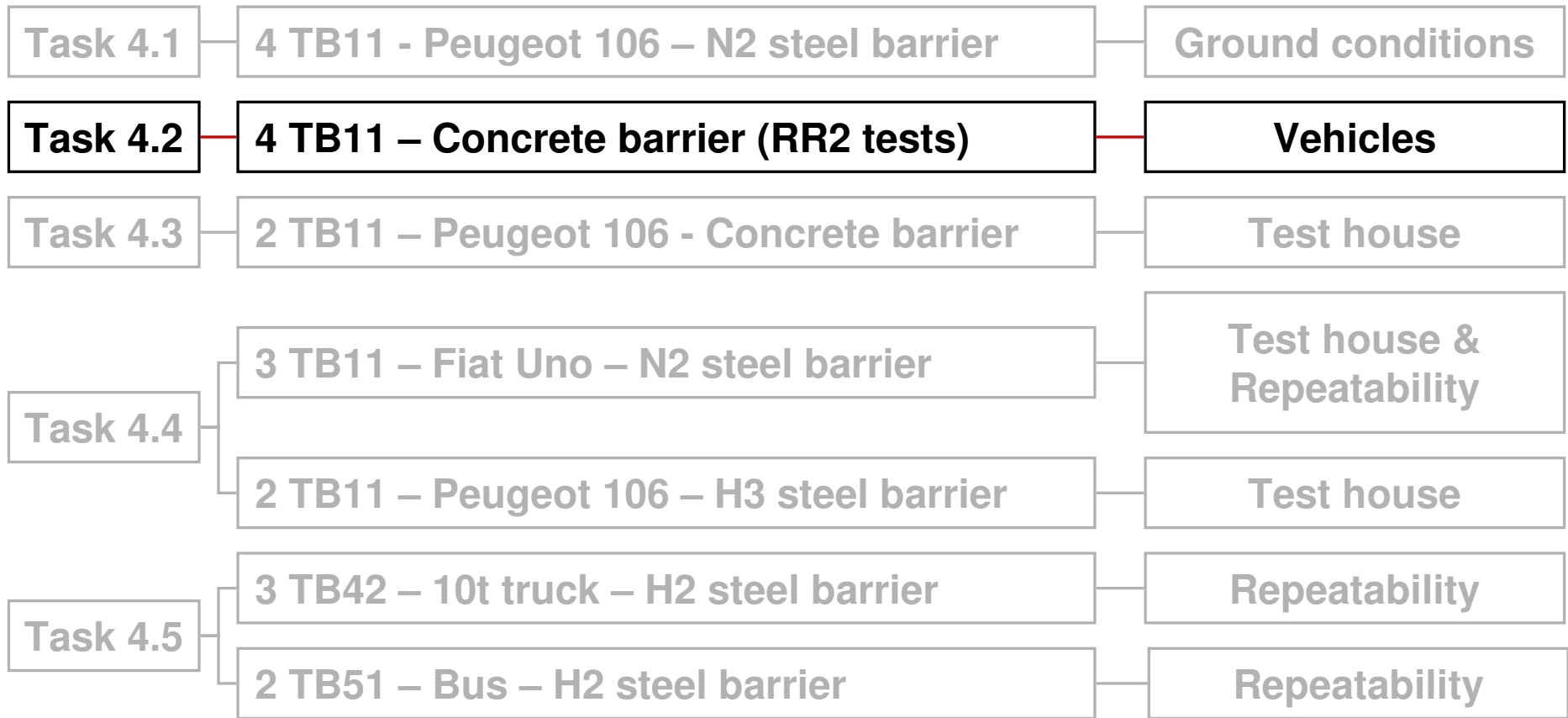
Task 4.1 - Spread repartition



Task 4.1 Conclusions

- **Spread of measured responses is much higher than for test parameters**
- **Conclusion: Soil condition is probably an important factor**

Task 4.2 Round Robin-2 tests



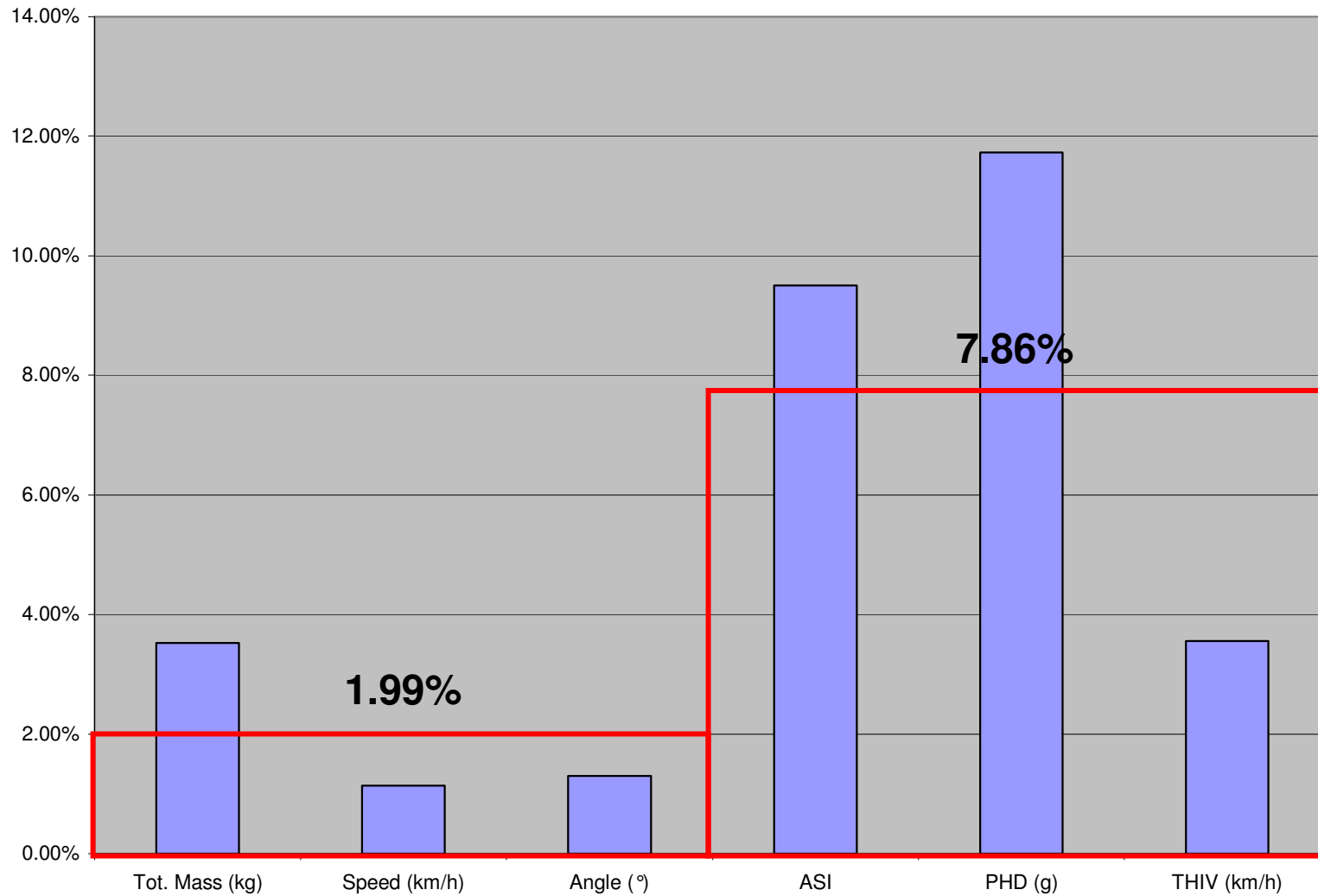
Task 4.2 Test matrix

One TB11 test in each of the test houses on the same rigid barrier with different cars (Round Robin 2)

Test	Vehicle	Barrier	Test House
TB11	Peugeot 206	Concrete	LIER
TB11	Ford Fiesta	Concrete	TRL
TB11	Fiat Uno	Concrete	Autostrade
TB11	Opel Corsa	Concrete	CIDAUT



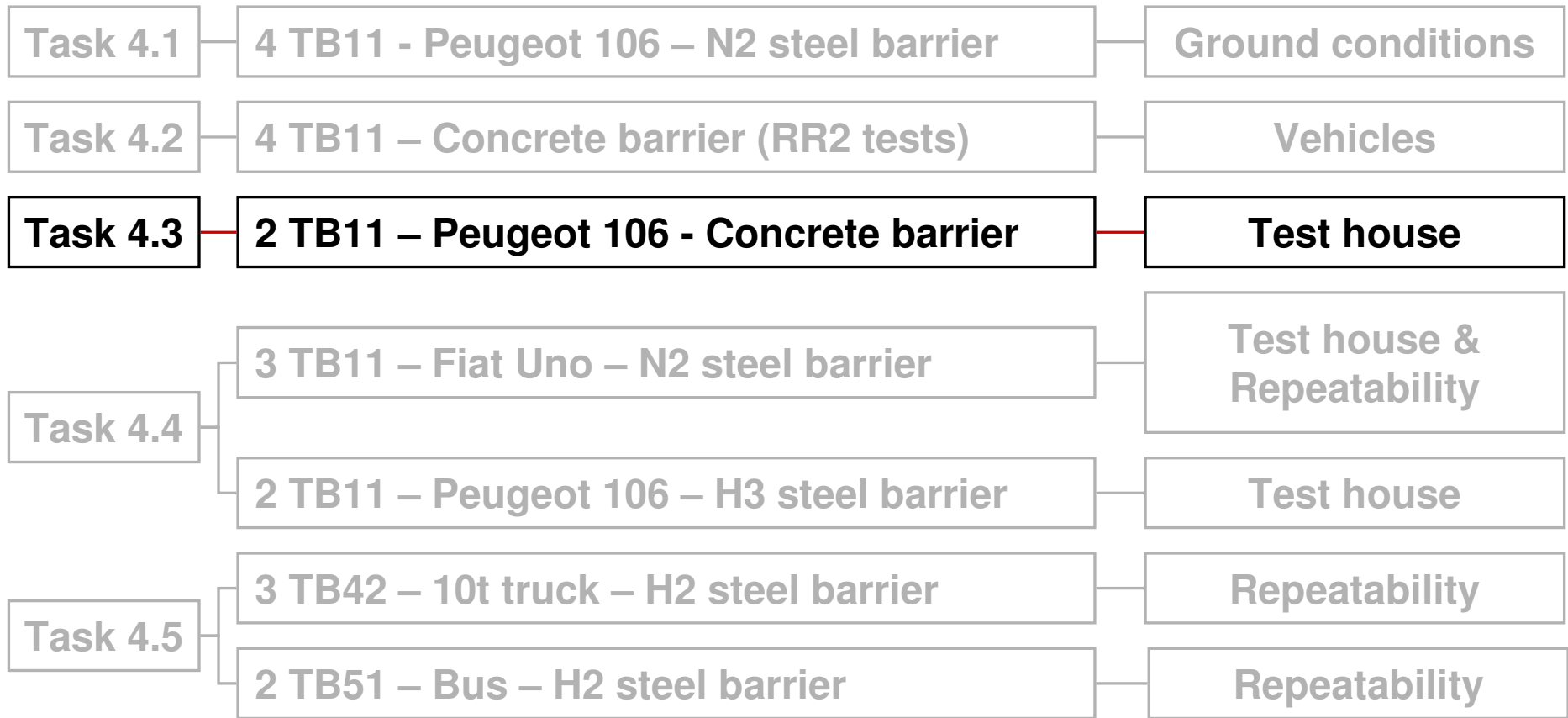
Task 4.2 Analysis



Task 4.2 Conclusions

- **Spread of measured responses is much higher than for test parameters**
- **Conclusion: Characteristics of vehicles such as energy absorption are probably important factors**

Task 4.3 Identical tests



Task 4.3 Test matrix

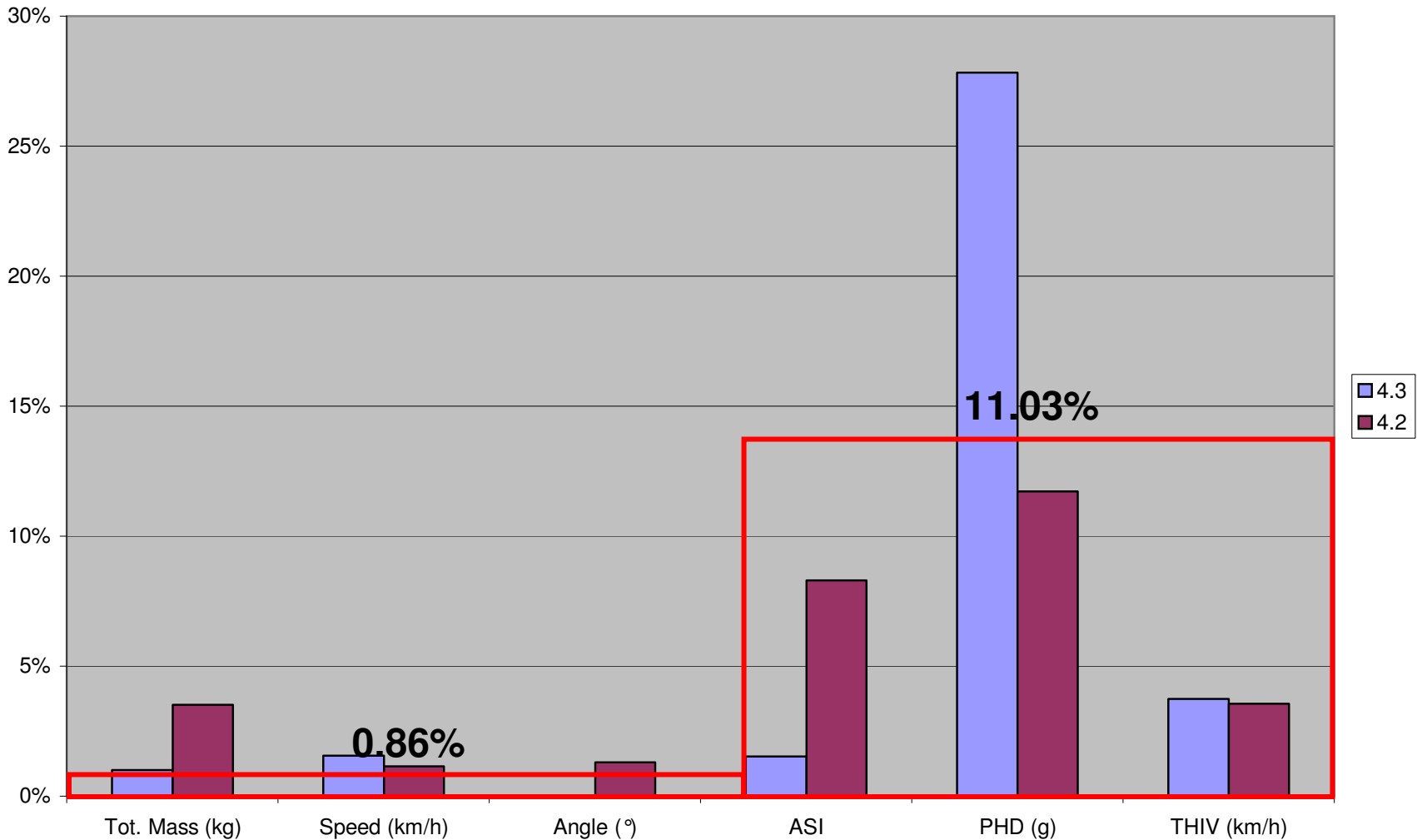
Two more TB11 tests with same car and same concrete rigid barrier

Test	Vehicle	Barrier	Test House
TB11	Peugeot 106	Concrete	TRL
TB11	Peugeot 106	Concrete	LIER



Task 4.3 Analysis

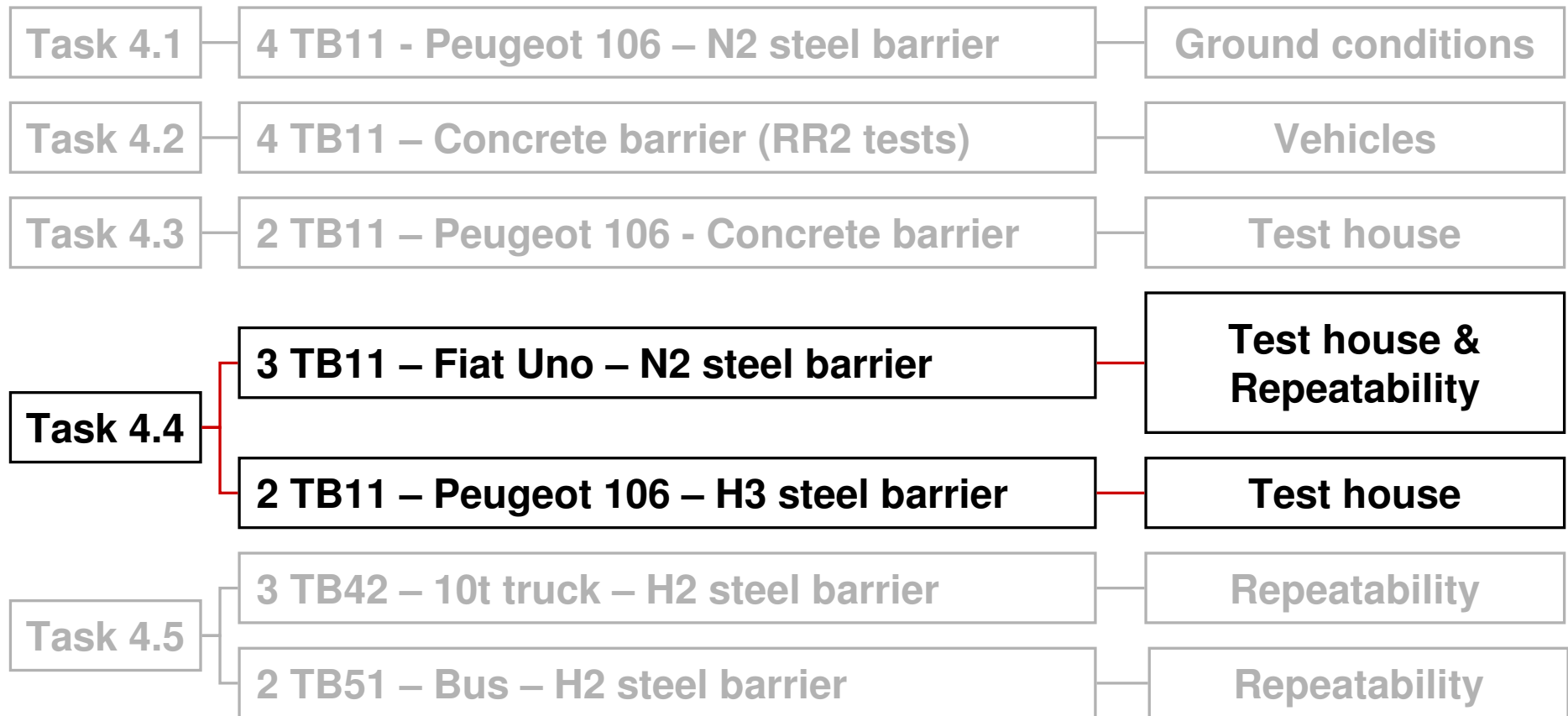
Task 4.3 - Spread repartition



Task 4.3 Conclusions

- **With great care, limitation of result's spread is possible**
- **With exactly the same input, the spread on results is limited (except for PHD)**
- **Good communication and time are needed to allow tests to reach such a low level of scatter**

Task 4.4 Test House & Repeatability



Task 4.4 Test matrix

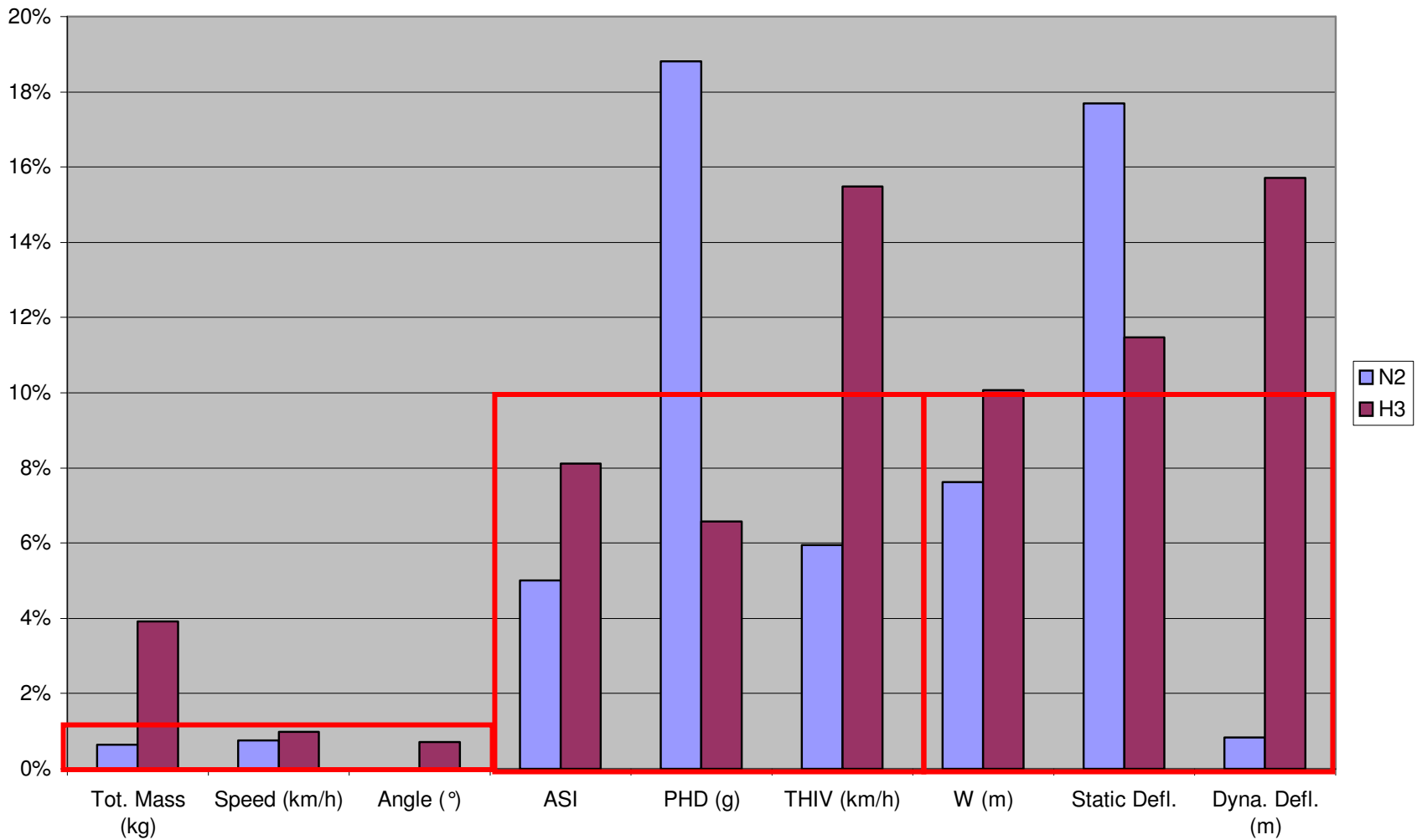
Five TB11 tests with two vehicle types and two barriers: three identical – two at one test house and one at another and two identical test, with the other barrier and vehicle, performed at two different test houses. The barriers are steel barriers with different dynamic deflections

Test	Vehicle	Barrier	Ground	Test House
TB11	Fiat Uno	Steel N2	soil	Autostrade
TB11	Fiat Uno	Steel N2	soil	Autostrade
TB11	Peugeot 106	Steel H3	soil	Autostrade
TB11	Peugeot 106	Steel H3	concrete	TRL
TB11	Fiat Uno	Steel N2	asphalt	LIER



Task 4.4 Analysis

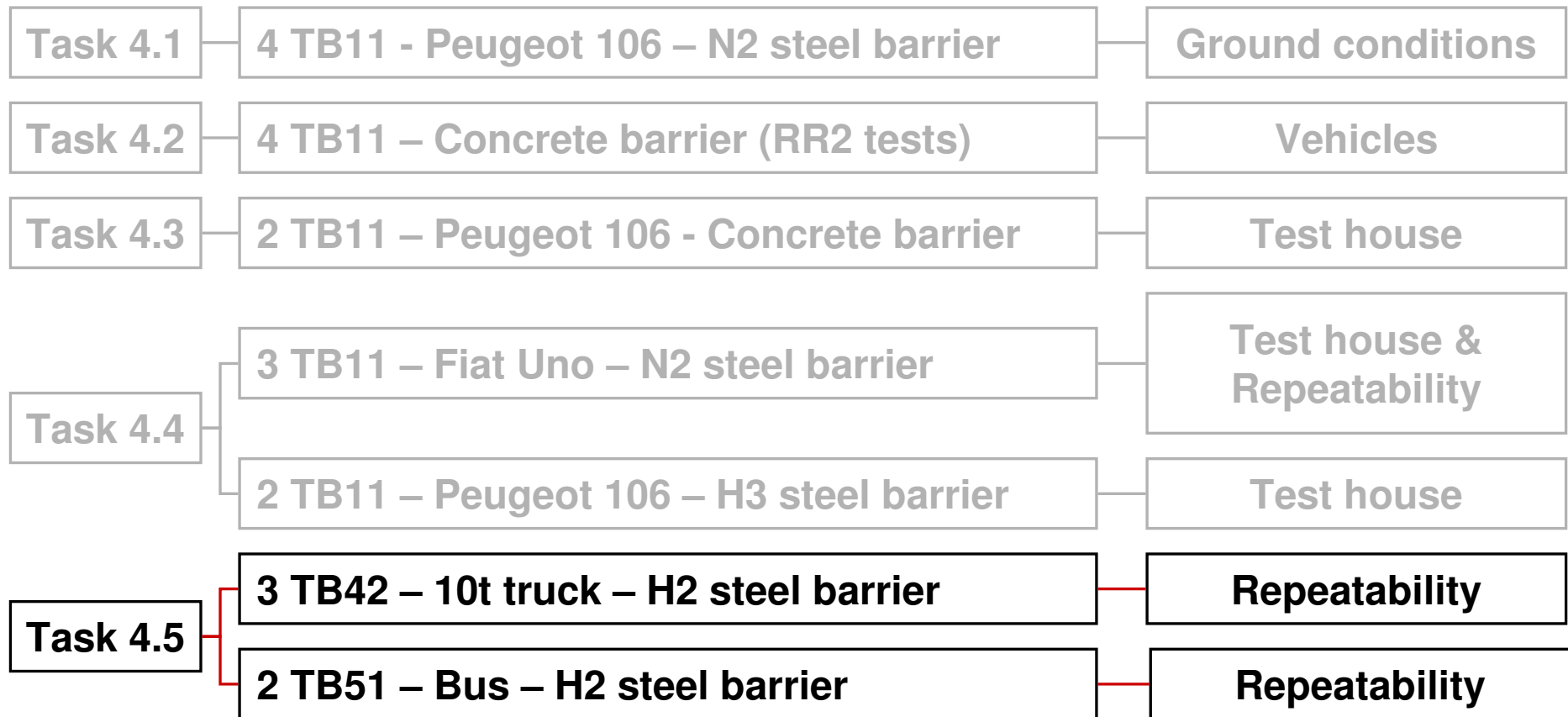
Task 4.4 - Spread repartition



Task 4.4 Conclusions

- **Controlled conditions are needed for good repeatability**
- **Good reproducibility**
- **Ground condition influence identical to previous task**
- **The barrier and/or car model differences well highlighted by the criteria**

Task 4.5 Heavy Vehicles



Task 4.5 Test Matrix

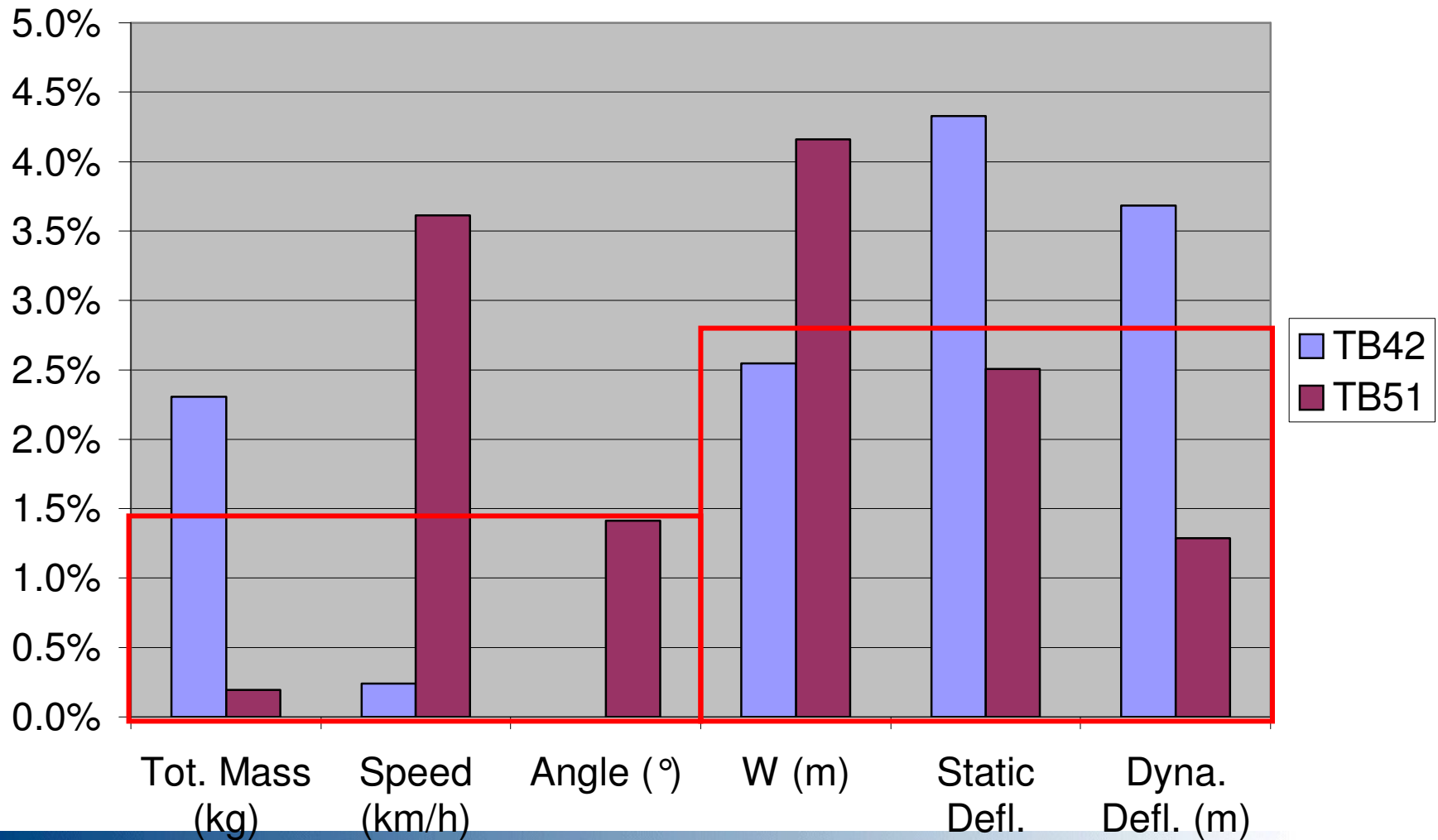
Tests with two different heavy vehicles, TB42 and TB51, one performed identically three times and one performed twice, to evaluate experimental result scatter

Vehicle	Test	Barrier	Nb tests	Test House
HV2 (10t)	TB42	Steel H2	3	LIER
Bus (13t)	TB51	Steel H2	2	CIDAUT



Task 4.5 Analysis

Task 4.5 - Spread repartition

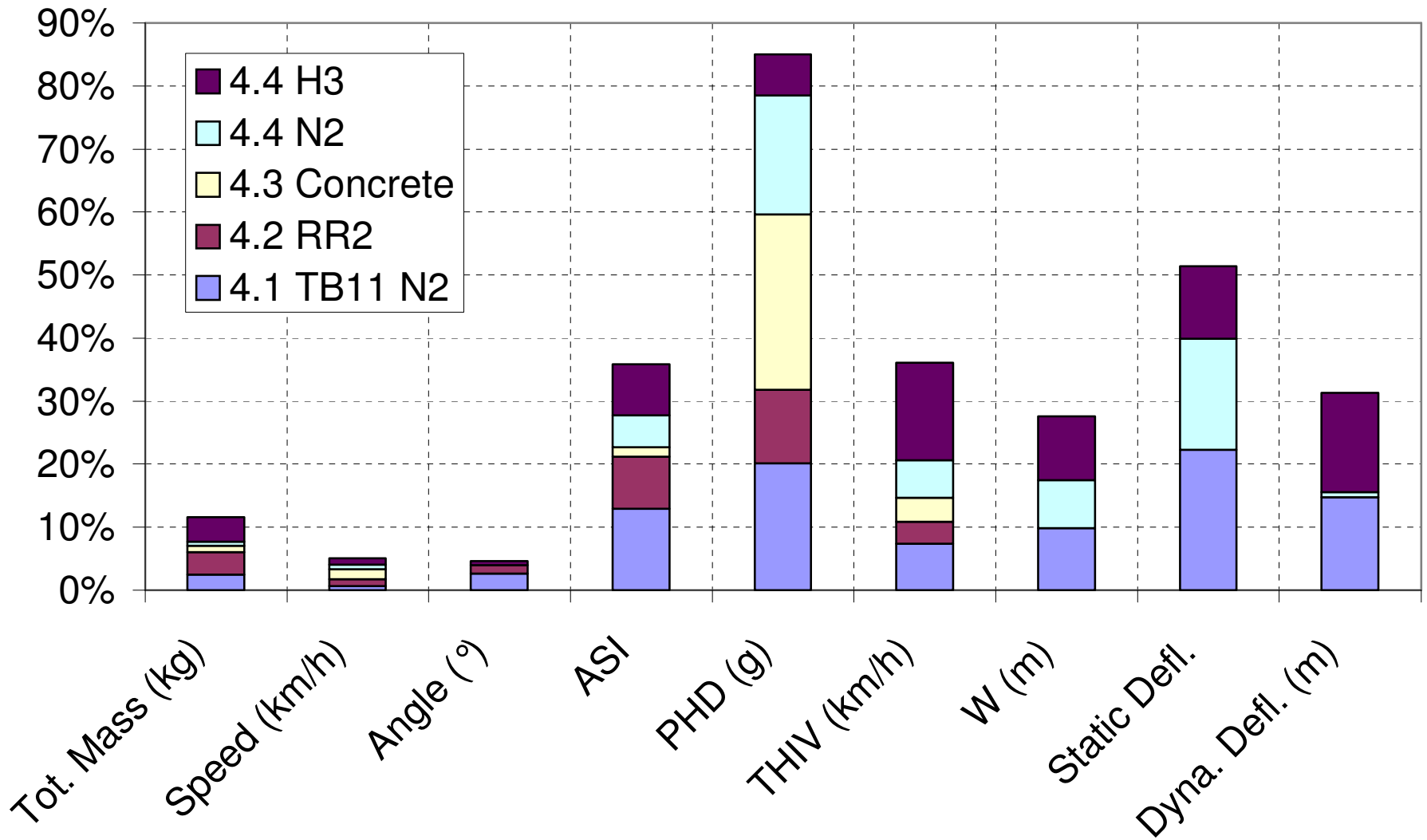


Task 4.5 Conclusions

- **Good repeatability**
- **Light influence of test conditions**

Results overview

Spread repartition



Conclusions

- **Test parameters well controlled by test houses (spread below 2%)**
- **Soil and vehicle make are important parameters**
- **Unacceptable spread for PHD results**

Thank you for your attention...

Definitions

- **Mean value**

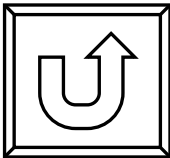
$$\mu = \frac{\sum X}{N}$$

- **Standard deviation**

$$\sigma = \sqrt{\frac{\sum X^2 - N\mu^2}{N-1}}$$

- **Coefficient of variation**

$$CV = \frac{\sigma}{\mu}$$



Task 4.1 Test Conditions

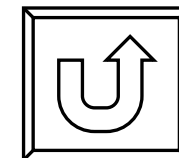
Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
ROB886	LIER	903.00	101.30	20.00
276	AUTOSTRAD	885.50	102.61	20.36
813284BA03	CIDAUT	925.00	101.90	20.50
34QB	TRL	937.00	101.25	21.30

Mean value (μ) 912.63 101.77 20.54

Standard deviation (σ) 22.92 0.64 0.55

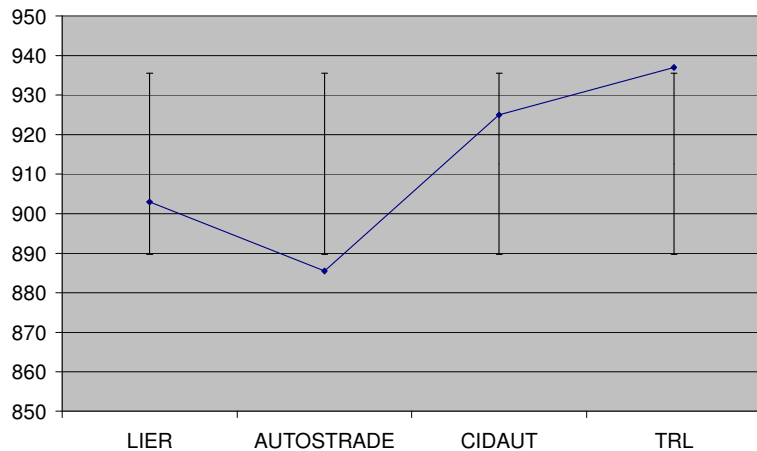
Variance (σ/μ) 2.51% 0.63% 2.67%

Variance (mean) 1.94%

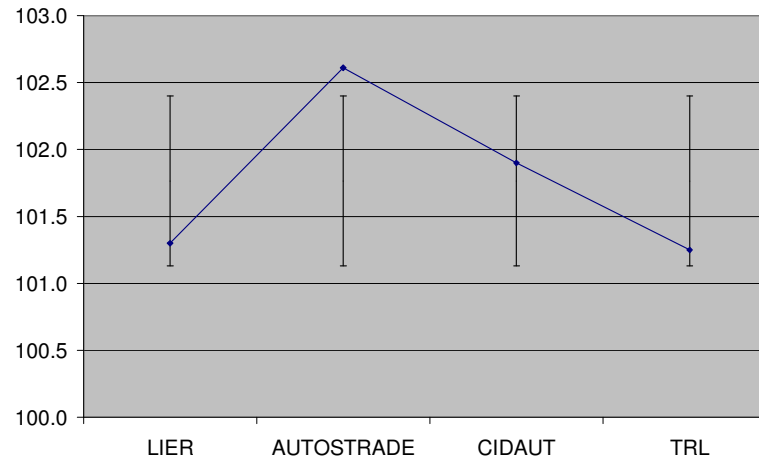


Task 4.1 Test Conditions

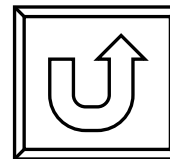
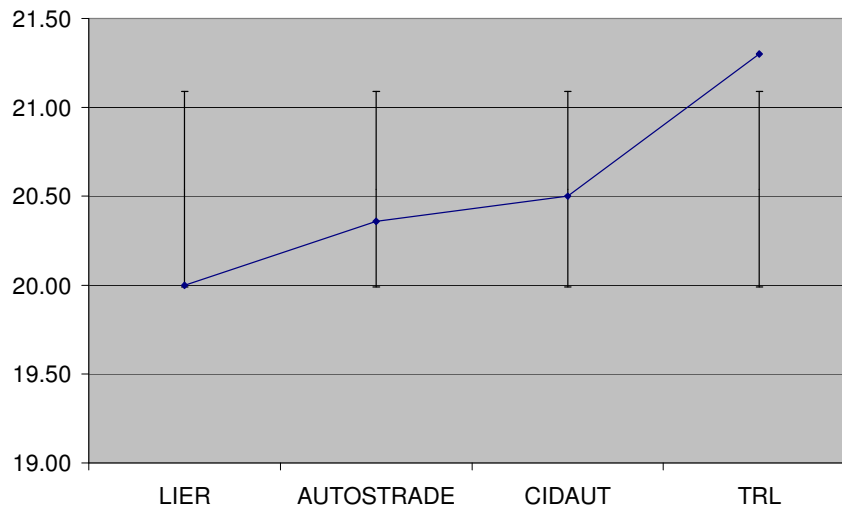
Tot. Mass (kg)



Speed (km/h)



Angle (°)



Task 4.1 Criteria Analysis

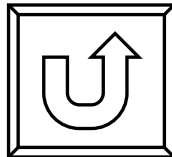
Test	Laboratory	ASI	PHD (g)	THIV (km/h)
ROB886	LIER	0.7	11	24
276	AUTOSTRADE	0.8	16	26
813284BA03	CIDAUT	0.7	10	22
34QB	TRL	0.9	13	22

Mean value (μ) 0.79 12.50 23.43

Standard deviation (σ) 0.10 2.51 1.72

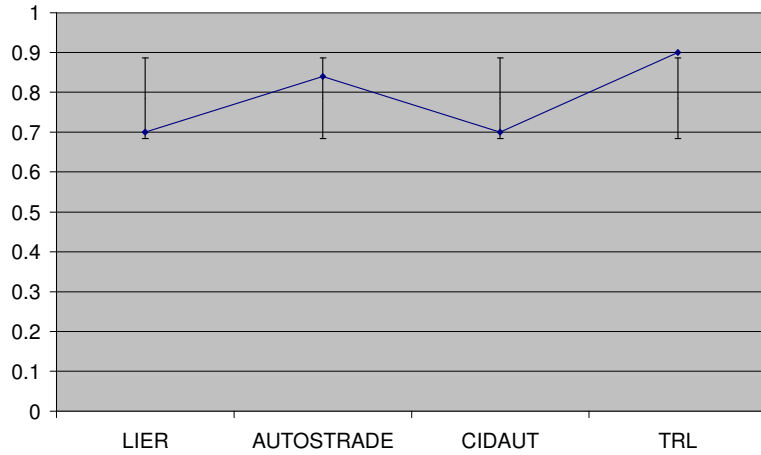
Variance (σ/μ) **12.89%** **20.09%** **7.33%**

Variance (mean) 13.44%

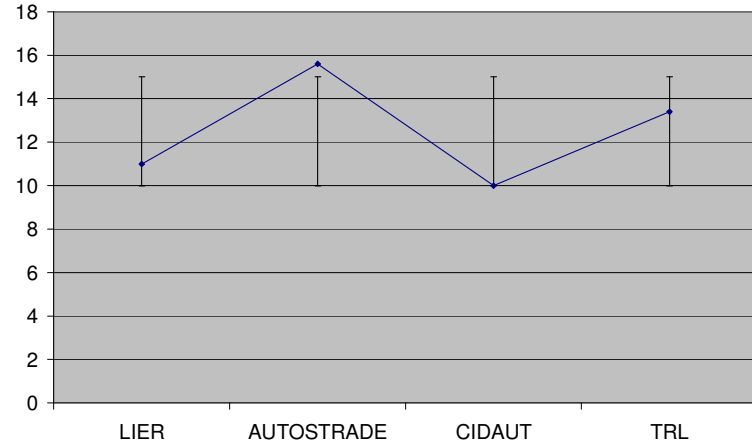


Task 4.1 Criteria Analysis

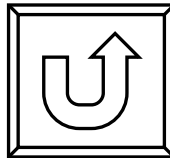
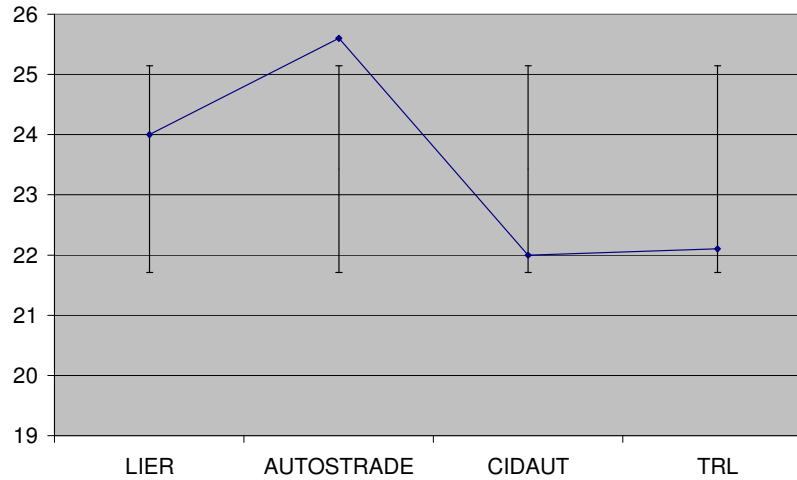
ASI



PHD (g)



THIV (km/h)



Task 4.1 Result Analysis

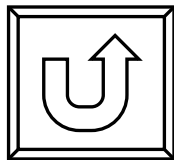
Test	Laboratory	W (m)	Static Defl.	Dyna. Defl. (m)	Exit angle (°)
ROB886	LIER	0.8	0.49	0.7	8.5
276	AUTOSTRADE	0.8	0.43	0.7	
813284BA03	CIDAUT	0.9	0.55	0.8	5.7
34QB	TRL	0.7	0.32	0.6	11

Mean value (μ) 0.80 0.45 0.68 8.40

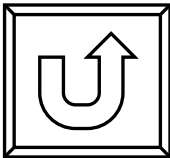
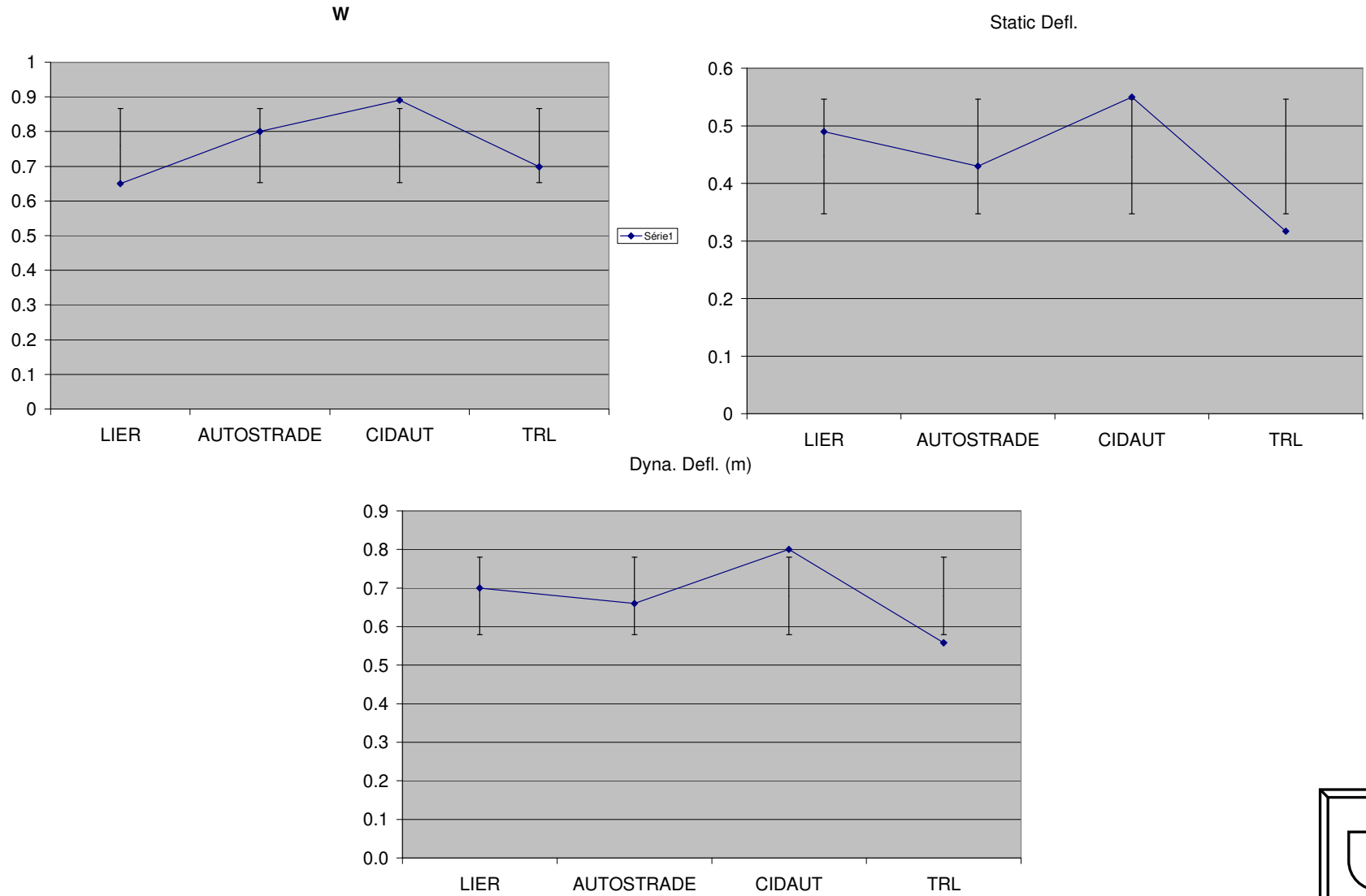
Standard deviation (σ) 0.08 0.10 0.10 2.65

Variance (σ/μ) 9.84% 22.25% 14.74% 31.56%

Variance (mean) 15.61%

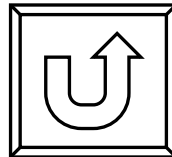


Task 4.1 Result Analysis

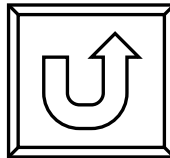
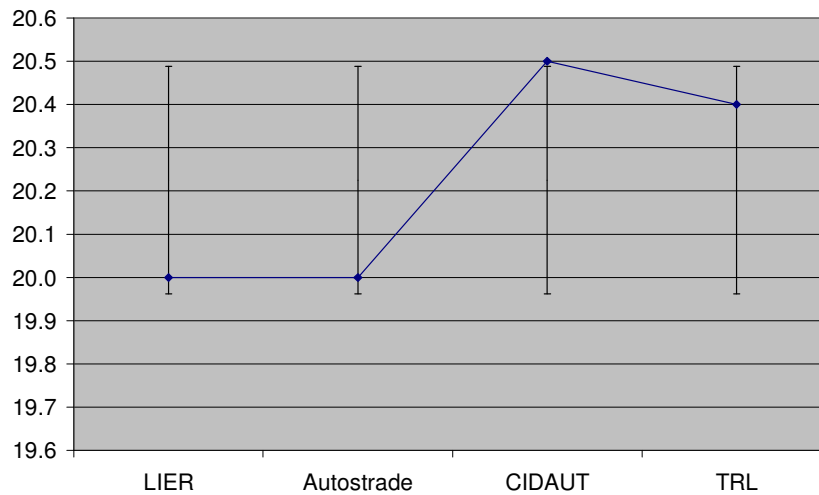
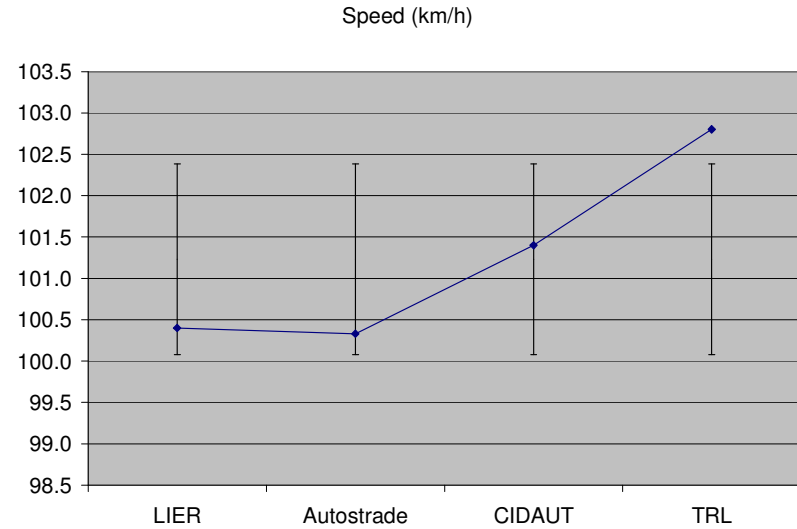
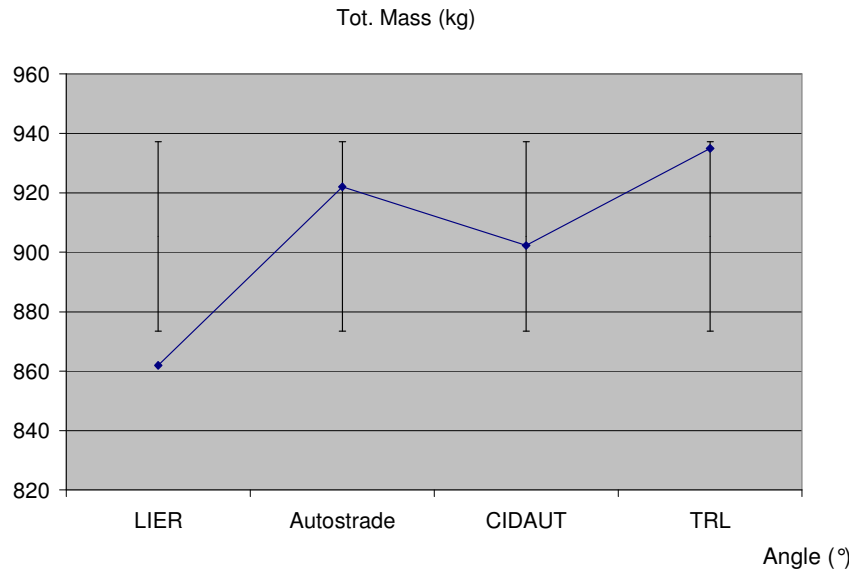


Task 4.2 Test Conditions

Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
ROU664	LIER	862.00	100.40	20.00
S69	Autostrade	922	100.33	20
00B112002	CIDAUT	902.30	101.40	20.50
13NB	TRL	935.00	102.80	20.40
Mean value (μ)		905.33	101.23	20.23
Standart deviation (σ)		31.86	1.15	0.26
Variants (σ/μ)		3.52%	1.14%	1.30%
Variant (mean)		1.99%		

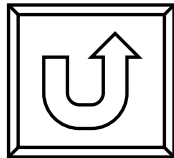


Task 4.2 Test Conditions



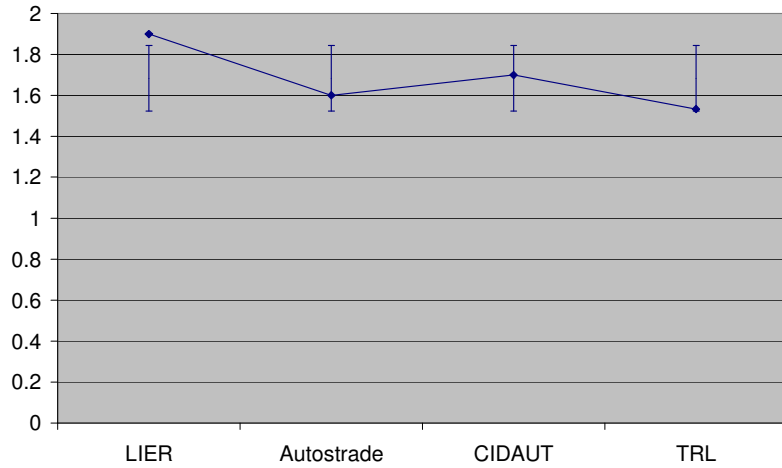
Task 4.2 Criteria Analysis

Test	Laboratory	ASI	PHD (g)	THIV (km/h)
ROU664	LIER	1.9	15	32
S70	Autostrade	1.6	20	31
00B112002	CIDAUT	1.7	18	30
13NB	TRL	1.9	18	29
Mean value (μ)		1.77	17.77	30.51
Standard deviation (σ)		0.15	2.08	1.08
Variance (σ/μ)		8.31%	11.73%	3.56%
Variance (mean)		7.86%		

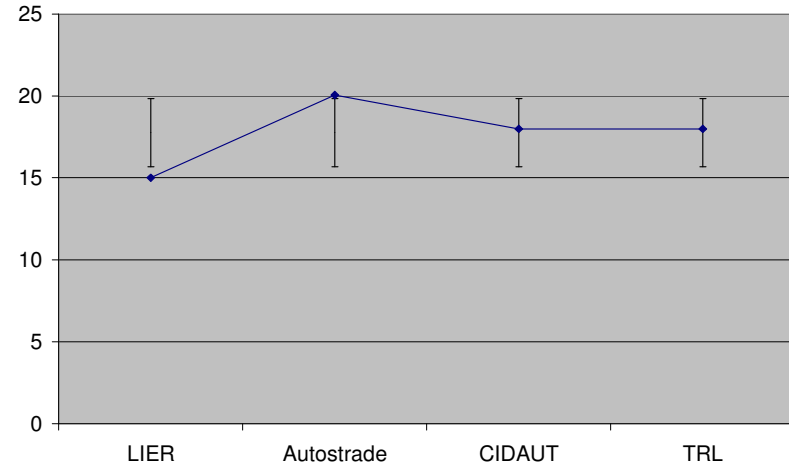


Task 4.2 Criteria Analysis

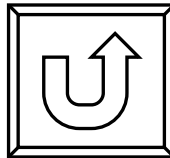
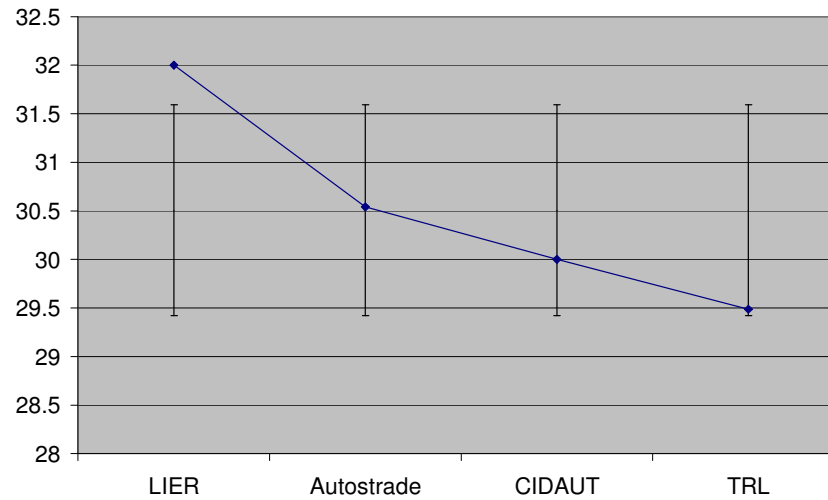
ASI



PHD (g)



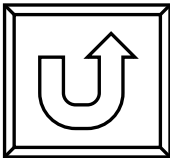
THIV (km/h)



Task 4.3 Test Conditions

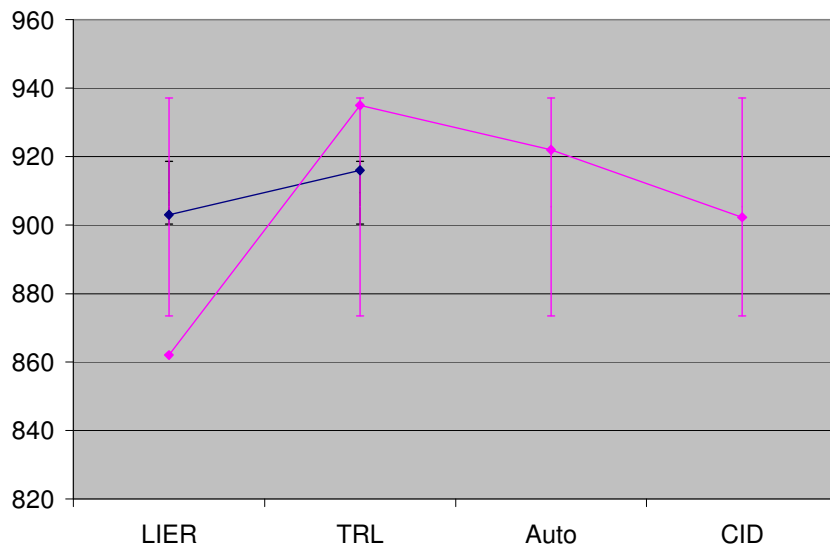
Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
ROB981	LIER	903	100.89	20
B3089	TRL	916	103.15	20

Mean value (μ)	909.5	102.02	20
Standard deviation (σ)	9.19	1.60	0.00
Variance (σ/μ)	1.01%	1.57%	0.00%
Variance (mean)	0.86%		

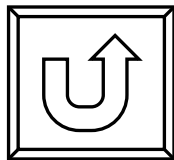
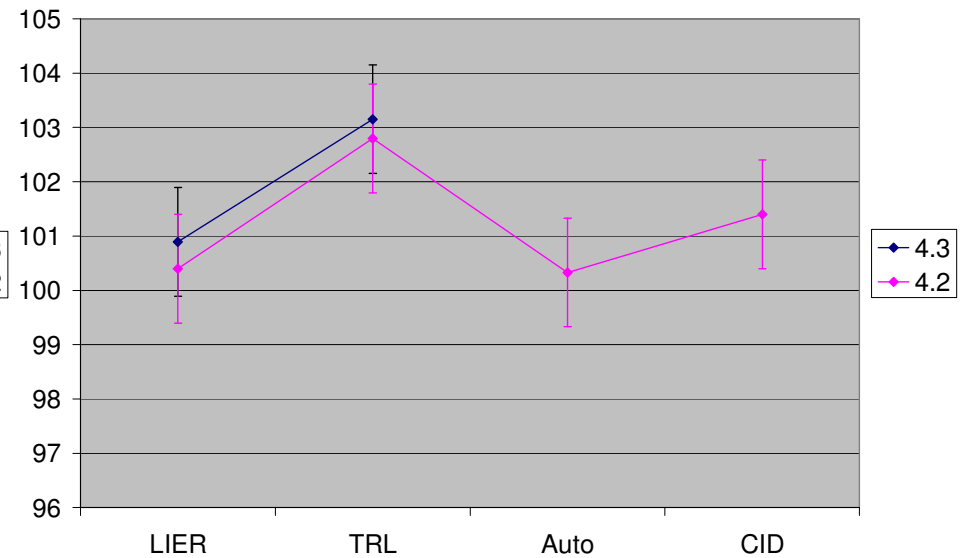


Task 4.3 Test Conditions

Total Mass



Speed



Task 4.3 Criteria Analysis

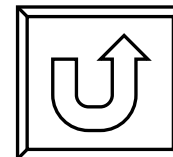
Test	Laboratory	ASI	PHD (g)	THIV (km/h)
ROB981	LIER	1.87	10	33
B3089	TRL	1.83	14.9	31.3

Mean value (μ) 1.85 12.45 32.15

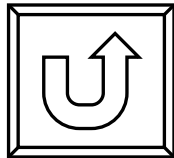
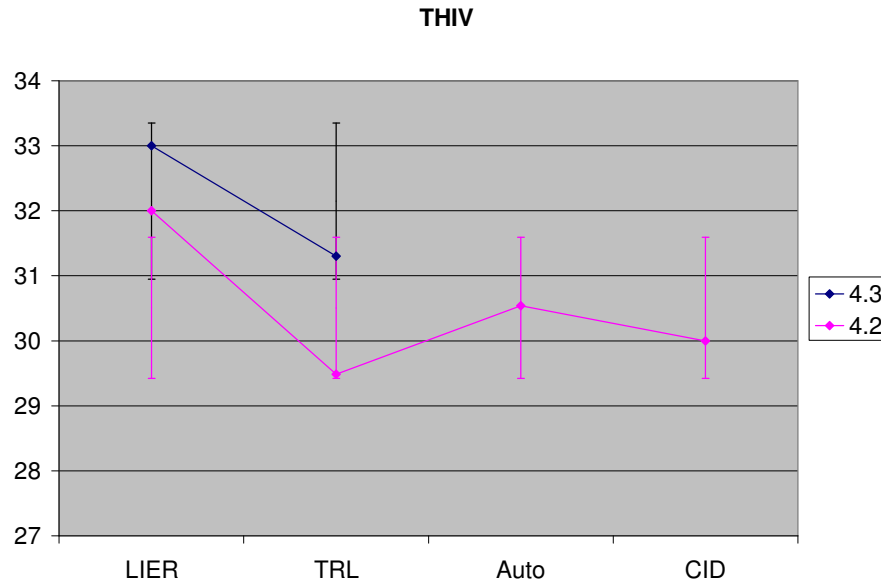
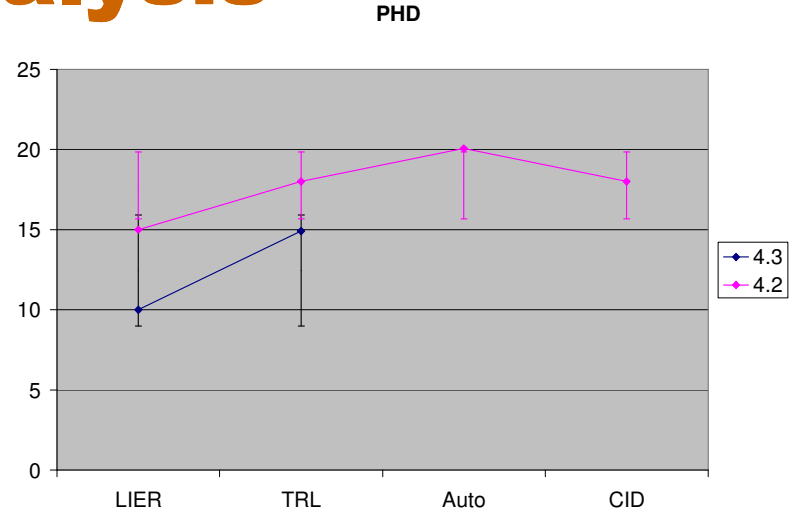
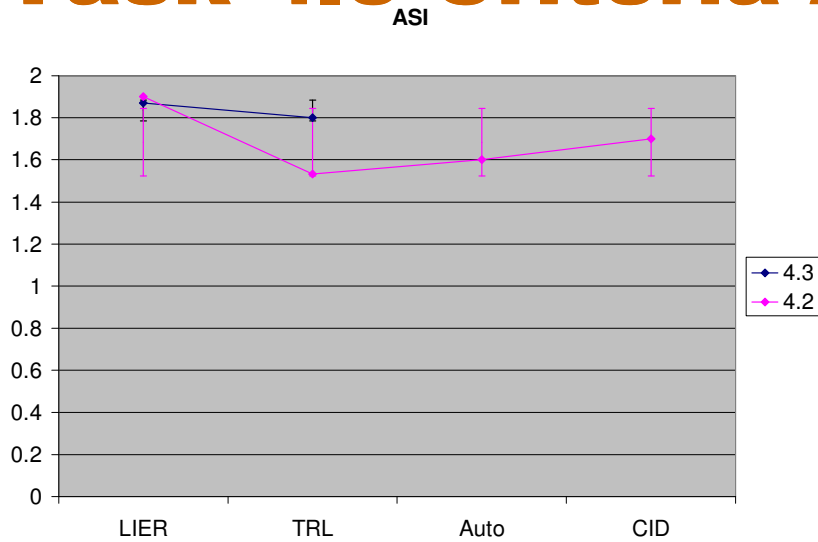
Standard deviation (σ) 0.028 3.465 1.202

Variance (σ/μ) 1.53% **27.83%** 3.74%

Variance (mean) 11.03%



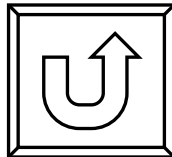
Task 4.3 Criteria Analysis



Task 4.4 Test Conditions

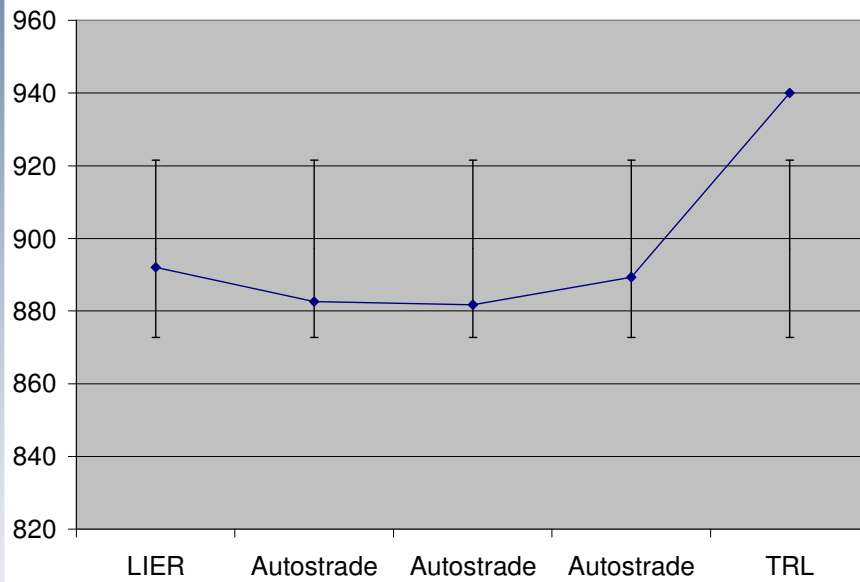
Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
ROB887	LIER	892	101.7	20
275_robust	Autostrade	882.6	103.06	20
277_robust	Autostrade	881.8	103.02	20
Mean value (μ)		885.47	102.59	20.00
Standard deviation (σ)		5.67	0.77	0.00
Variance (σ/μ)		0.64%	0.75%	0.00%
Variance (mean)		0.46%		

Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
278_robust	Autostrade	889.3	102.26	20
09RB	TRL	940	103.7	20.2
Mean value (μ)		914.65	102.98	20.10
Standard deviation (σ)		35.85	1.02	0.14
Variance (σ/μ)		3.92%	0.99%	0.70%
Variance (mean)		1.87%		

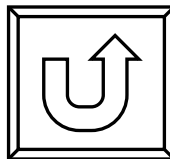
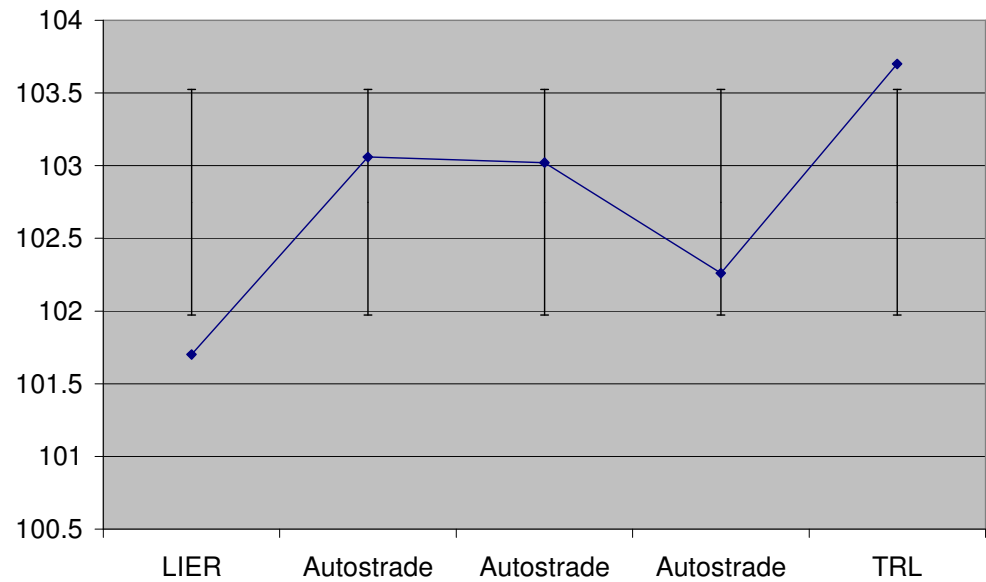


Task 4.4 Test Conditions

Total Mass (kg)



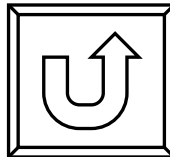
Speed (km/h)



Task 4.4 Criteria Analysis

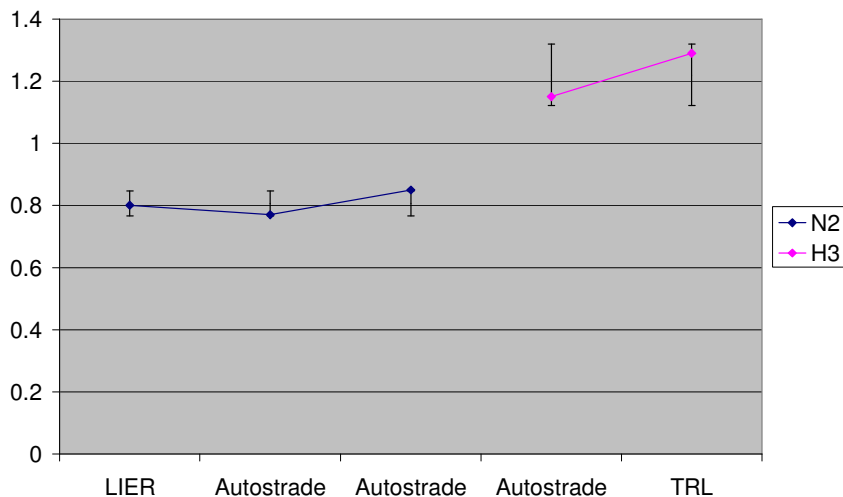
Test	Laboratory	ASI	PHD (g)	THIV (km/h)
ROB887	LIER	0.8	9	22
275_robust	Autostrade	0.77	12.4	22.3
277_robust	Autostrade	0.85	13	24.5
Mean value (μ)		0.81	11.47	22.93
Standard deviation (σ)		0.04	2.16	1.37
Variance (σ/μ)		5.01%	18.81%	5.95%
Variance (mean)		9.92%		

Test	Laboratory	ASI	PHD (g)	THIV (km/h)
278_robust	Autostrade	1.15	8.2	24
09RB	TRL	1.29	9	29.9
Mean value (μ)		1.22	8.60	26.95
Standard deviation (σ)		0.10	0.57	4.17
Variance (σ/μ)		8.11%	6.58%	15.48%
Variance (mean)		10.06%		

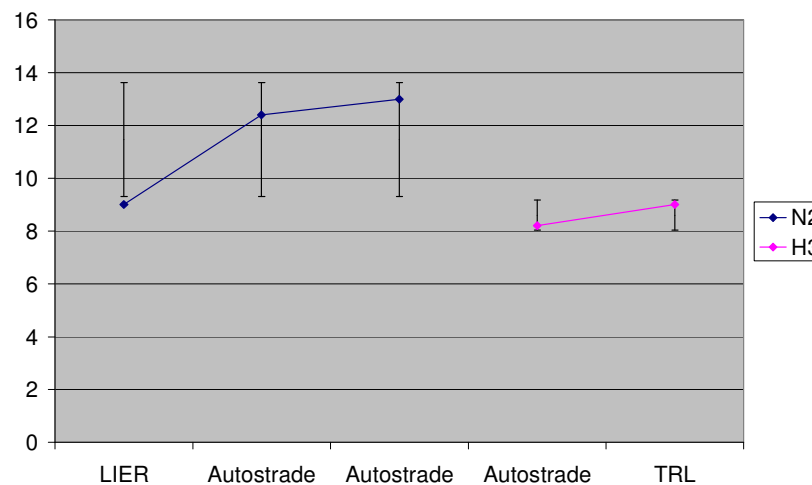


Task 4.4 Criteria Analysis

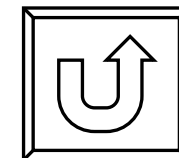
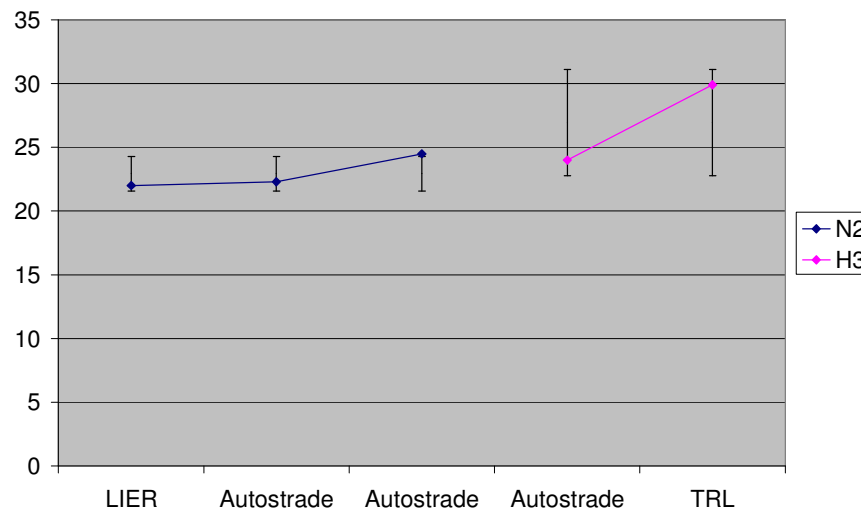
ASI



PHD



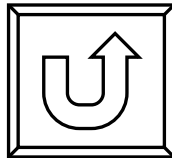
THIV



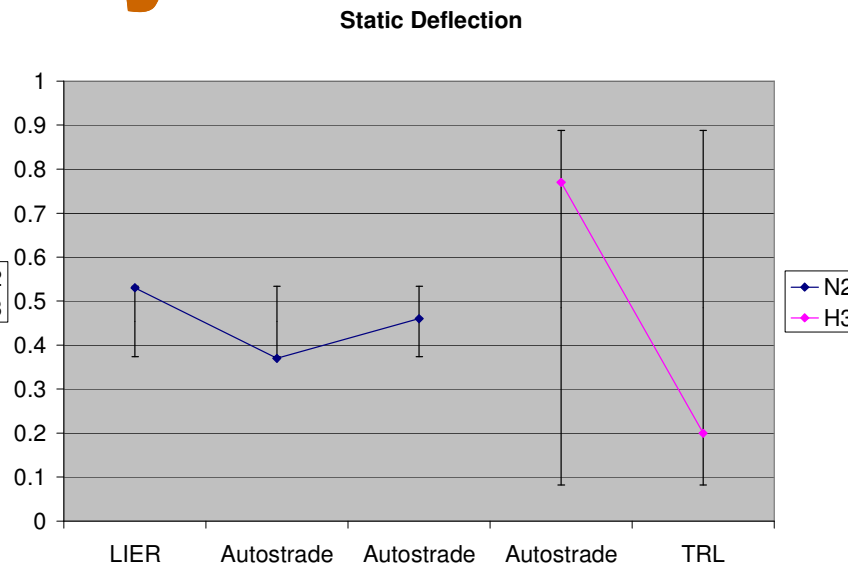
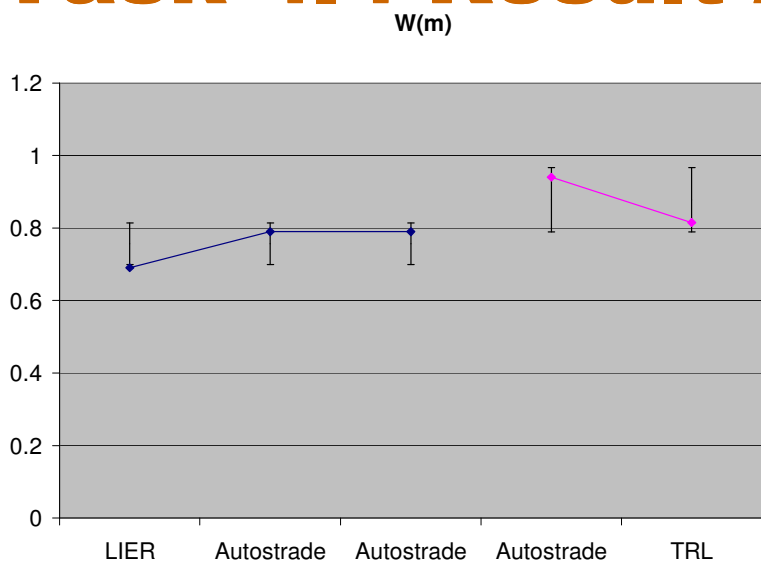
Task 4.4 Result Analysis

Test	Laboratory	W (m)	Static Defl.	Dyna. Defl. (m)
ROB887	LIER	0.69	0.53	0.7
275_robust	Autostrade	0.79	0.37	0.69
277_robust	Autostrade	0.79	0.46	0.69
Mean value (μ)		0.76	0.45	0.69
Standard deviation (σ)		0.06	0.08	0.01
Variance (σ/μ)		7.63%	17.69%	0.83%
Variance (mean)		8.72%		

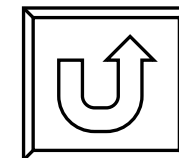
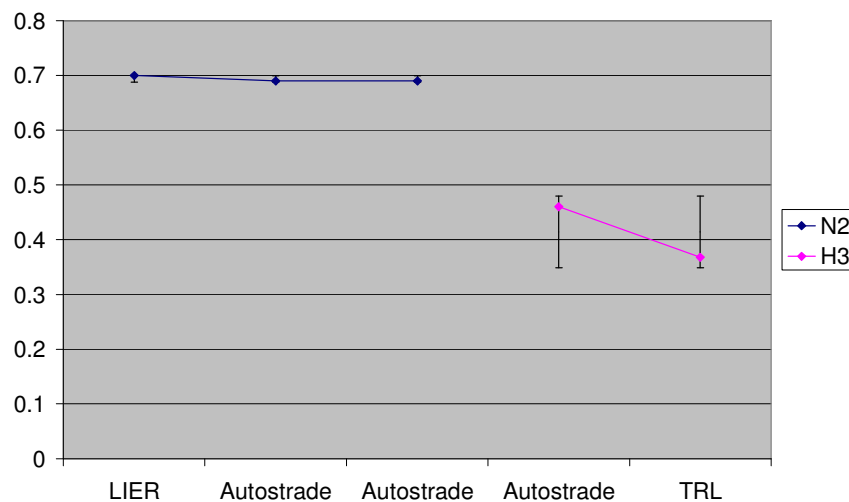
Test	Laboratory	W (m)	Static Defl.	Dyna. Defl. (m)
278_robust	Autostrade	0.94	0.17	0.46
09RB	TRL	0.815	0.2	0.368
Mean value (μ)		0.88	0.19	0.41
Standard deviation (σ)		0.09	0.02	0.07
Variance (σ/μ)		10.07%	11.47%	15.71%
Variance (mean)		12.42%		



Task 4.4 Result Analysis



Dynamic Deflection



Task 4.5 TB42 Test Conditions

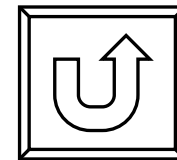
Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
ROB873	LIER	9740	72.3	15
ROB874	LIER	10170	72	15
ROB875	LIER	10100	72	15

Mean value (μ) 10003.33 72.10 15.00

Standard deviation (σ) 230.72 0.17 0.00

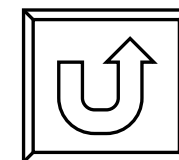
Variance (σ/μ) 2.31% 0.24% 0.00%

Variance (mean) 0.85%



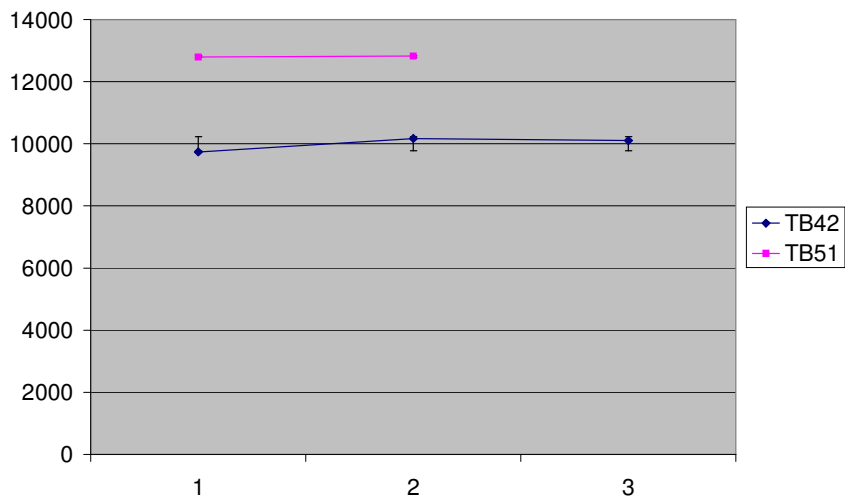
Task 4.5 TB51 Test Conditions

Test	Laboratory	Tot. Mass (kg)	Speed (km/h)	Angle (°)
813284BH01	CIDAUT	12787	74.3	20.2
813284BH02	CIDAUT	12822	70.6	19.8
Mean value (μ)		12804.50	72.45	20.00
Standard deviation (σ)		24.75	2.62	0.28
Variance (σ/μ)		0.19%	3.61%	1.41%
Variance (mean)		1.74%		

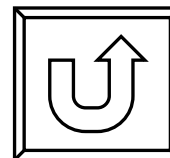
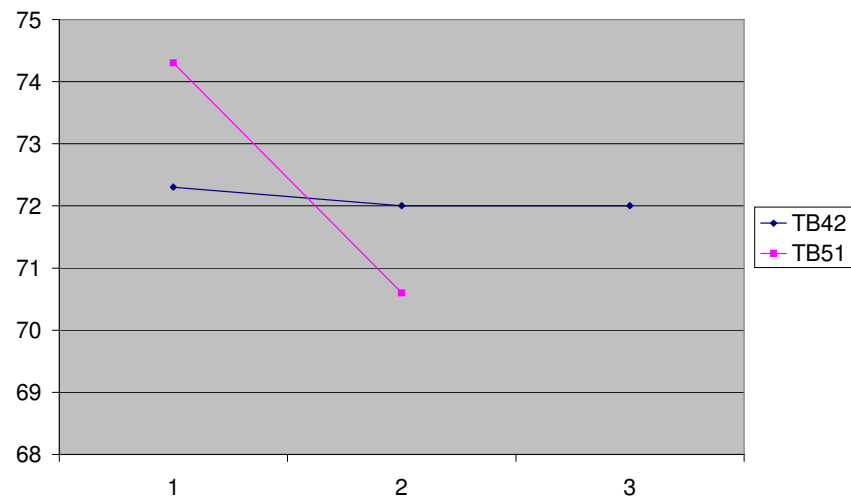


Task 4.5 Test Conditions

Total Mass

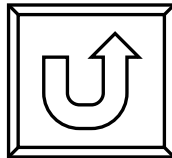


Speed



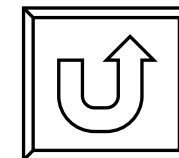
Task 4.5 TB42 Result Analysis

Test	Laboratory	W (m)	Static Defl.	Dyna. Defl. (m)
ROB873	LIER	2.3	1.3	1.6
ROB874	LIER	2.3	1.4	1.6
ROB875	LIER	2.2	1.3	1.5
Mean value (μ)		2.27	1.33	1.57
Standard deviation (σ)		0.06	0.06	0.06
Variance (σ/μ)		2.55%	4.33%	3.69%
Variance (mean)		3.52%		



Task 4.5 TB51 Result Analysis

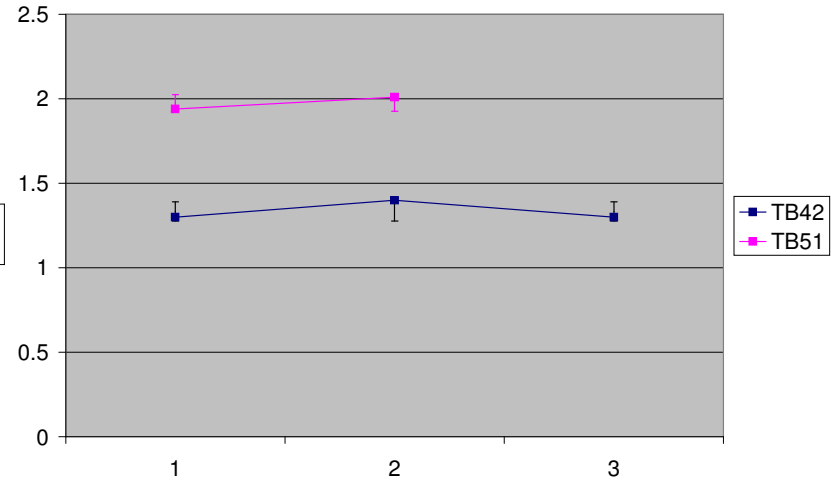
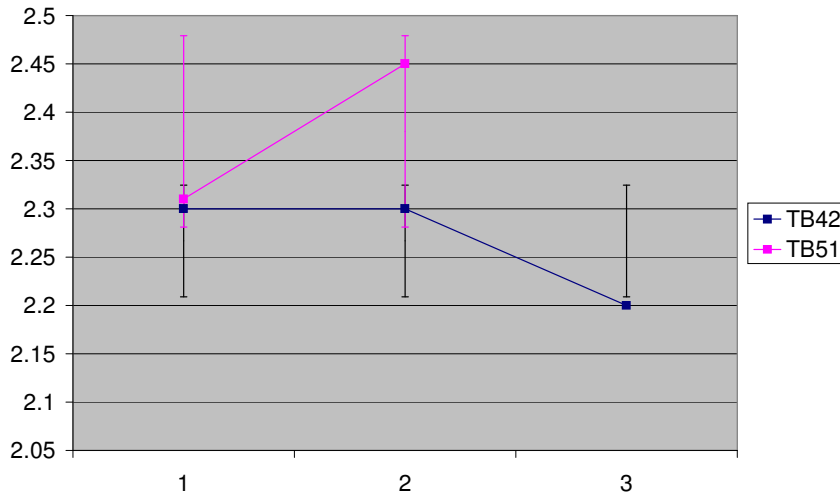
Test	Laboratory	W (m)	Static Defl.	Dyna. Defl. (m)
813284BH01	CIDAUT	2.31	1.94	2.18
813284BH02	CIDAUT	2.45	2.01	2.22
Mean value (μ)		2.38	1.98	2.20
Standard deviation (σ)		0.10	0.05	0.03
Variance (σ/μ)		4.16%	2.51%	1.29%
Variance (mean)		2.65%		



Task 4.5 Result Analysis

W (m)

Static Deflection



Dynamic Deflection

