SCALING TRANSPORT SOLUTIONS: A PHASED TRAM-TRAIN STRATEGY FOR LOWER-DENSITY AREAS

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Content

01 Introduction
- Tram-train & lower-density challenge

02 Case study: Ascoli Piceno

03 Methodology
- From targets to Scenarios

04 Results
- Why Tram-train?

05 Towards Implementation
- The ladder Strategy

06 Limits, Recommendations, & Further Research

07 Final Remarks

Tram-Train: What is it?

The tram-train infrastructure **seamlessly integrates** urban tram networks with regional heavy rail, **resolving** differences in **electrification, signalling, gauge profile, platform height and crashworthiness**



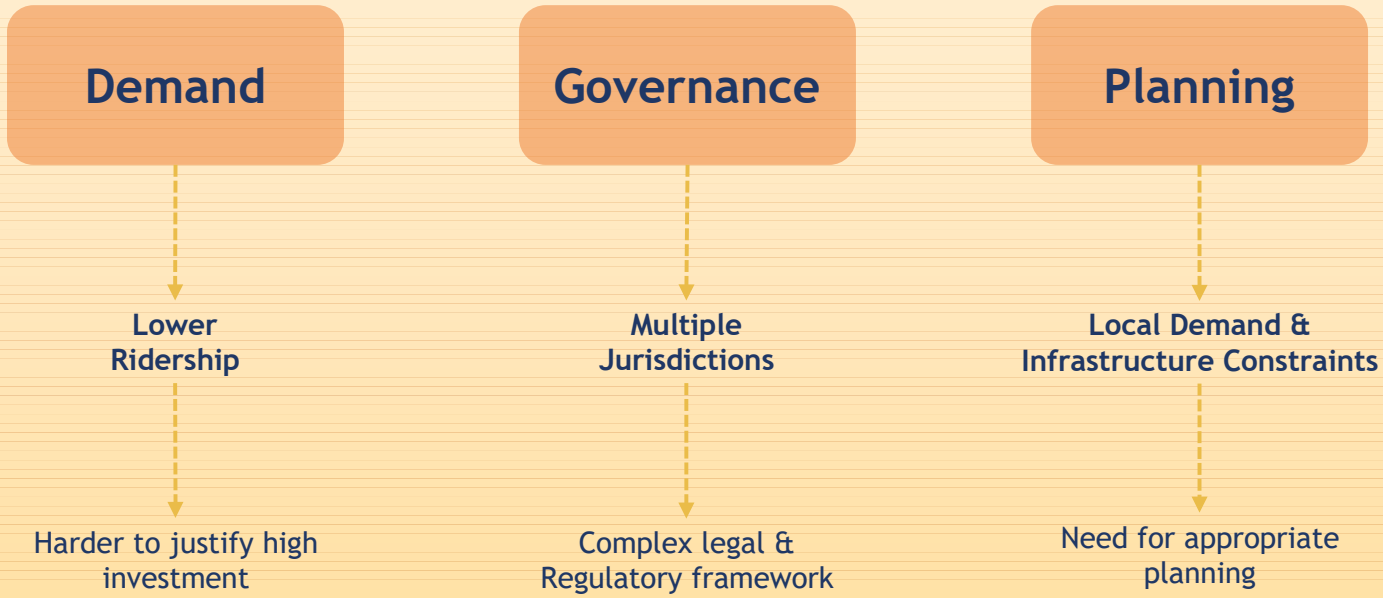
Source: Prior, G. (2025)



Source: Egloff-Schoenen (2020)

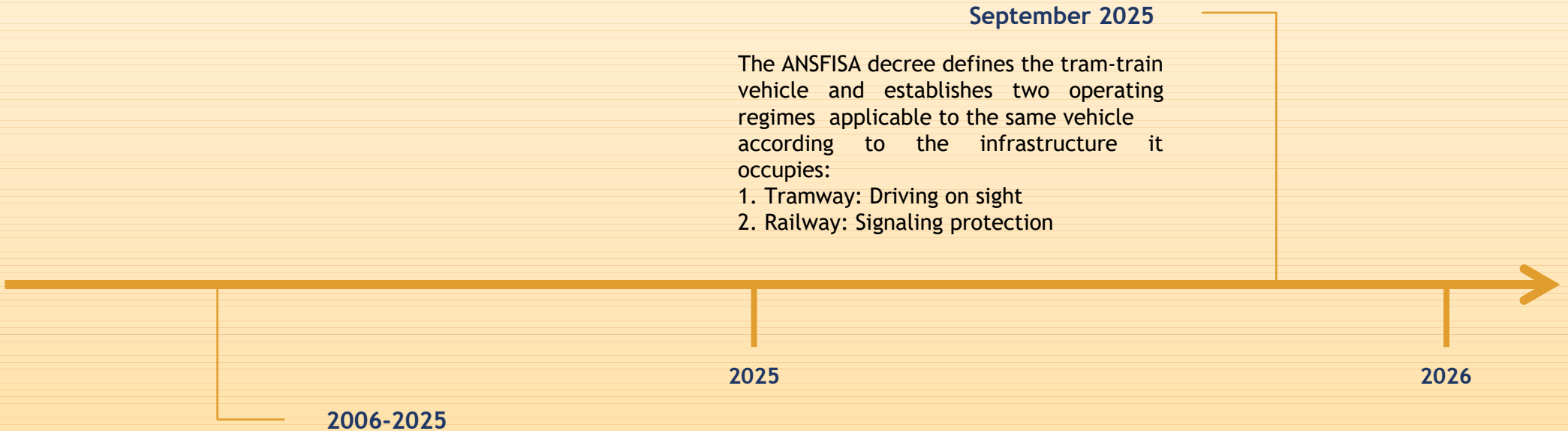
It was initially developed and implemented in the city of Karlsruhe, Germany. Thus the name “Karlsruhe Model”

Why is Tram-Train difficult to Scale?



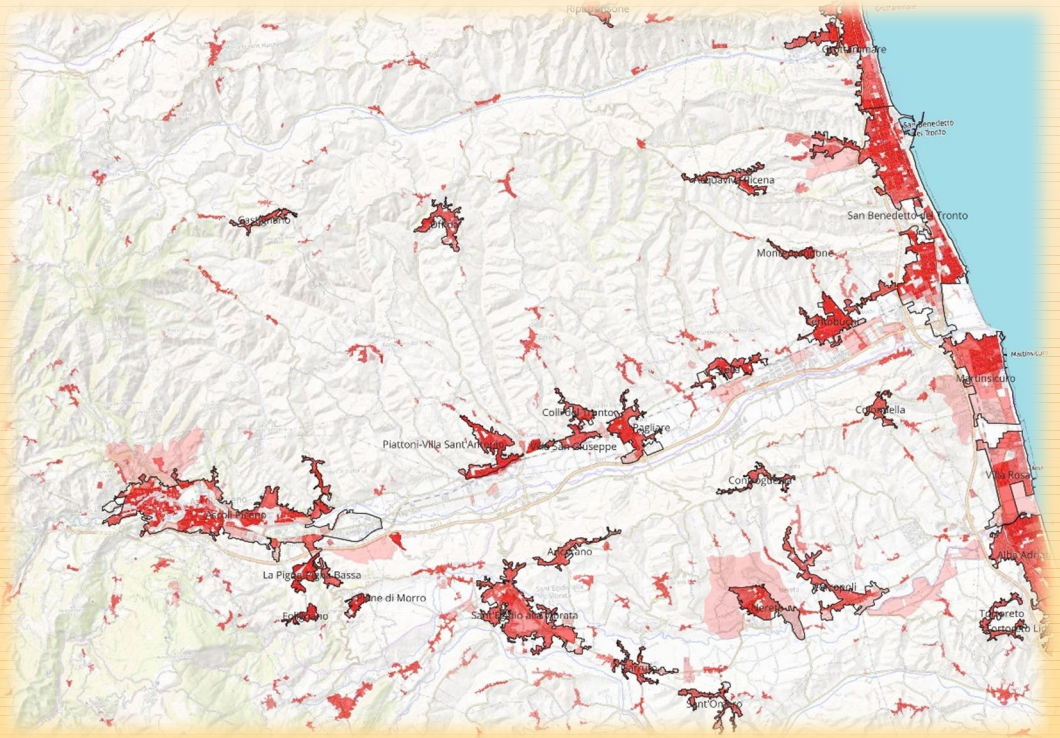
Can the benefits be justified in a lower-density context?

Italian Context



Case Study: Ascoli

A small inland city connected to a coastal urban system



45k
Residents

158 km²
Of inland territory

28km
Electrified railway



Source: Sironi (2025)

Why Ascoli?: Four Connectivity Problems

Railway outside city center → Competition between rail and bus → Public Transport Corridor lost after earthquake → Network without legible central spine



Source: Google Earth(2026)

The terminal station is >1km separated from the historic core, imposing exactly the interchange penalty the tram-train concept exists to remove

Why Ascoli?

Italian SUMPs are prepared under a ministerial framework specifying macro-objectives and indicators. Four features of common practice are relevant, and each is what the **Ascoli plan** departed from

Aspect	Common Italian SUMP practice	Ascoli SUMP | what is different?
Mobility targets	Targets are generally not used as a strong constraint on scenario construction	Ascoli **fixed two quantified targets through backcasting before developing the scenarios**, which could later determine which scenarios were admissible
Scenario construction	Scenarios can combine different measures and interventions, making it harder to isolate the effect of a specific transport choice	Ascoli created **four nested scenarios containing the same plan actions**, while changing the **public transport configuration**. This made the PT alternatives directly comparable
Road capacity	Road-capacity interventions can remain part of the planning framework	Ascoli **proposed no new road capacity anywhere in the plan**
Scenario evaluation	Scenario assessment is not necessarily based on a formal combination of target testing, transport modelling and multicriteria analysis	Ascoli combined **three methods**: transport modelling, backcasting/target compliance, and a **BOCR-structured AHP** to evaluate the alternatives

Methodology

01
Participatory Planning and “Quadro conoscitivo”

02
Backcasting

03
Scenario Building

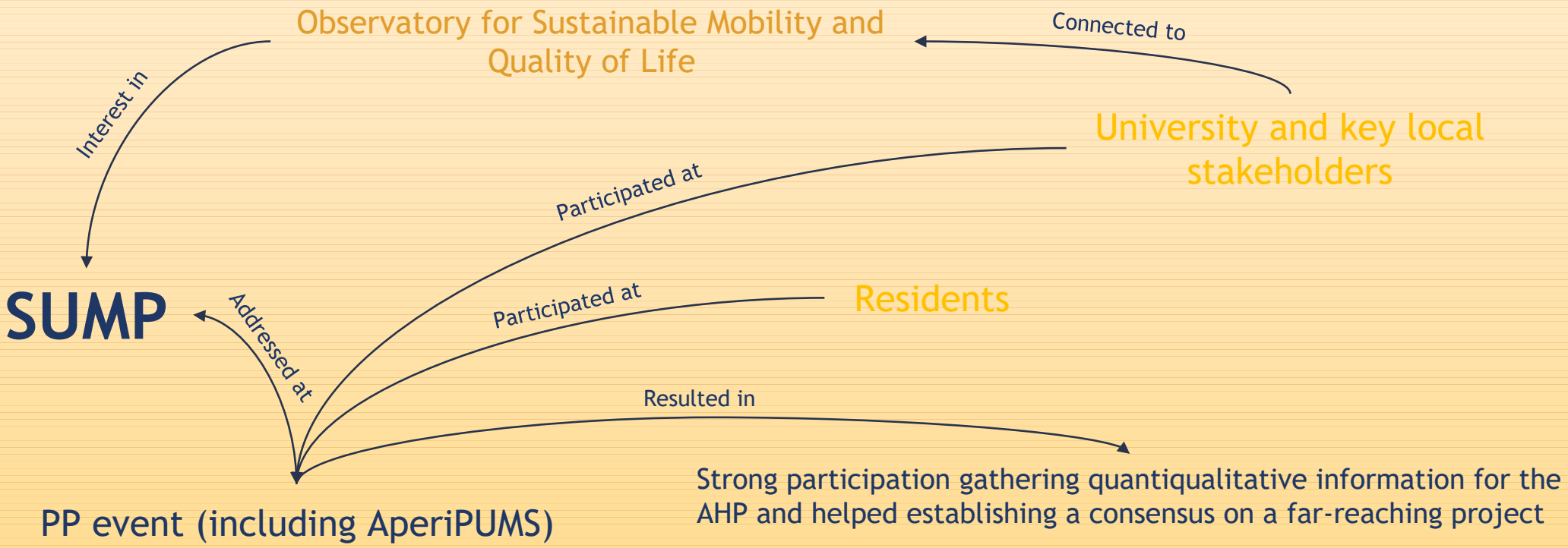
04
No new road capacity approach

05
Transport Model

06
Multi-criteria Analysis

Participatory Planning

The participatory approach and the analysis of context and existing projects/plans (in Italian 'Quadro conoscitivo'), being a mandatory part of SUMP guidelines, are no novelty for a plan. What has been treated differently are the construction and use of their results



Quadro conoscitivo



Backcasting

Process Flow

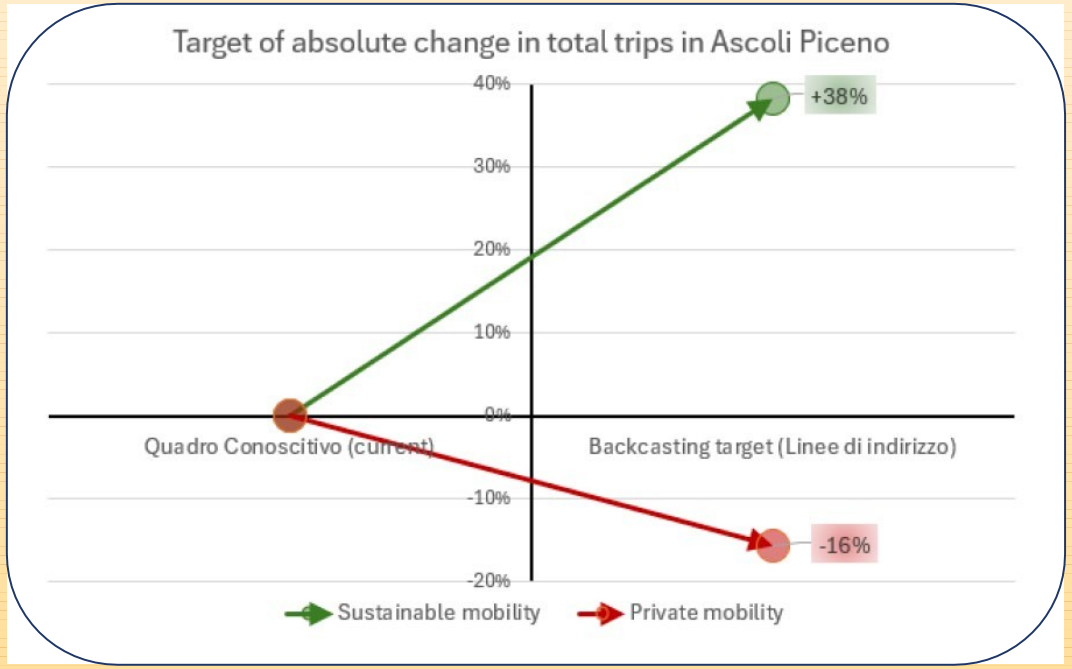
01 Setting Desire outcomes

02 Fixing Targets

03 Exploring Scenarios

04 Admissible?

In this case:



Scenarios Building

Four Scenarios, **one** controlled comparison

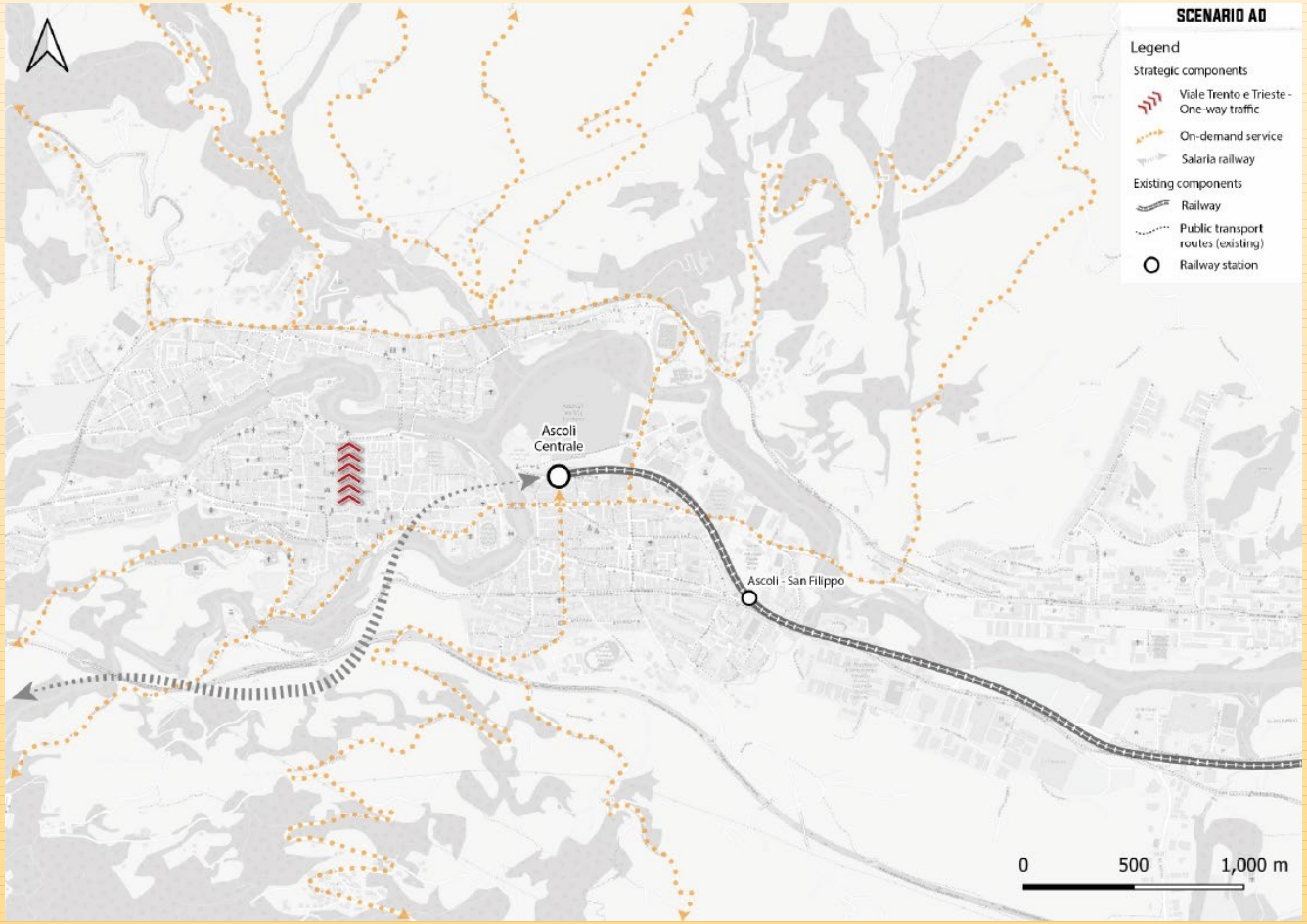
Scenario	**A0** → Demand-responsive
Scenario	**A1** → Bus-centred
Scenario	**B1** →Rail-centred
Scenario	**C1** → Tram-train

Where:
A: No intervention in railway development; B: Suburban style railway service development; C: Tram-train development
0: No major intervention in urban public transport; 1: Reestablishment of a trunk corridor for the urban center

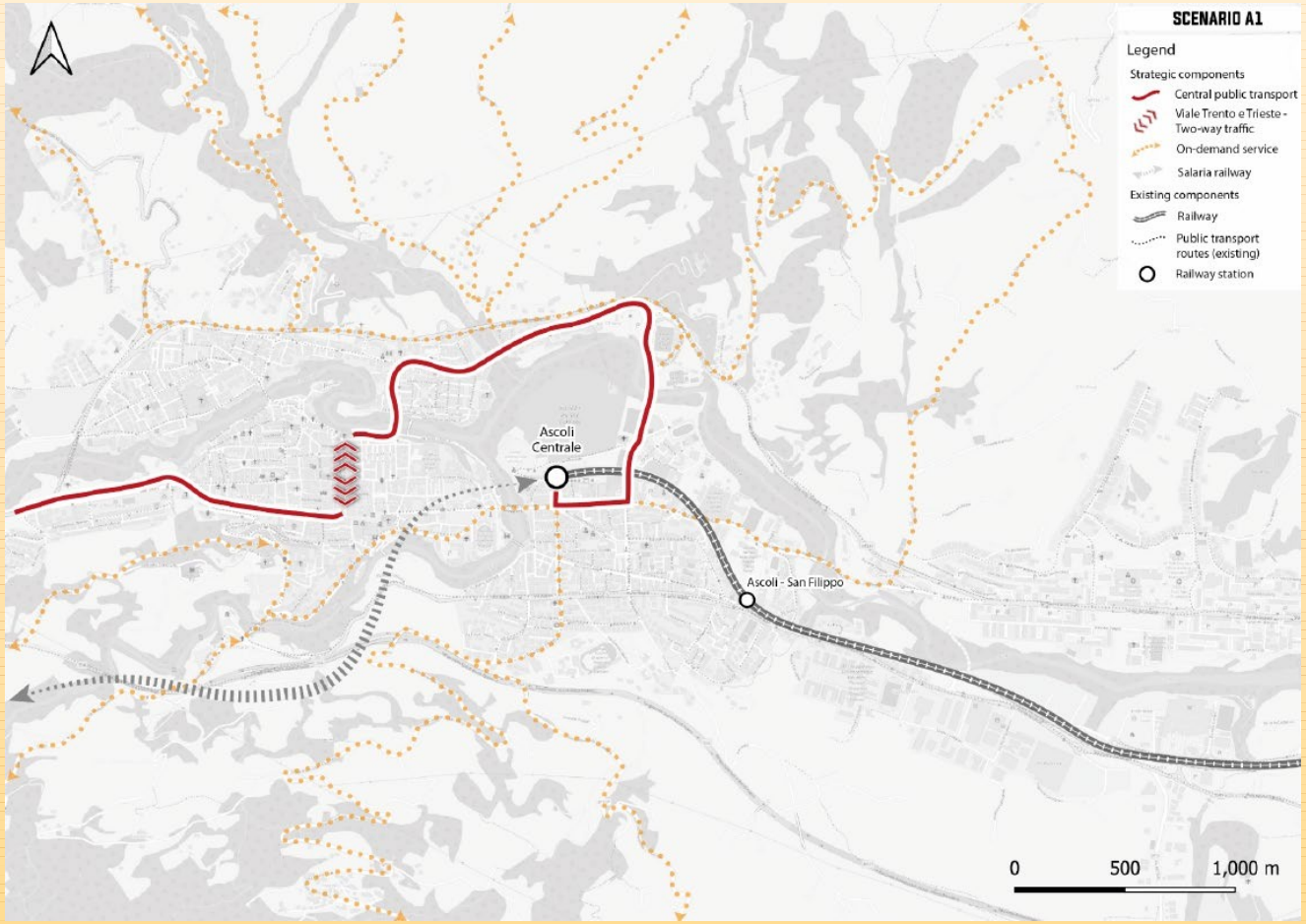
Scenarios Building

Scenario	Non-PT plan actions	Public transport configuration	New rail infrastructure
Current	none	Current network	none
Reference	Committed only (Biciplan, Salaria railway, Tronto bridge)	Current network	Salaria railway (national connection to Rome)
A0	All	demand-responsive transport in low-density areas; existing rail and bus roles retained; no central pass-through	Salaria railway
A1	All	A0 + restored bidirectional central urban corridor; urban bus network fully redesigned onto a few strong axes	Salaria railway
B1	All	A1 + increased rail frequencies, additional suburban stops, buses progressively converted to feeders	New train stops and loops
C1	All	B1 + tram-train conversion of the suburban service, urban penetration Stazione FS – Porta Romana, bus restructured as local distribution	New train stops, tramway RoW in the city core

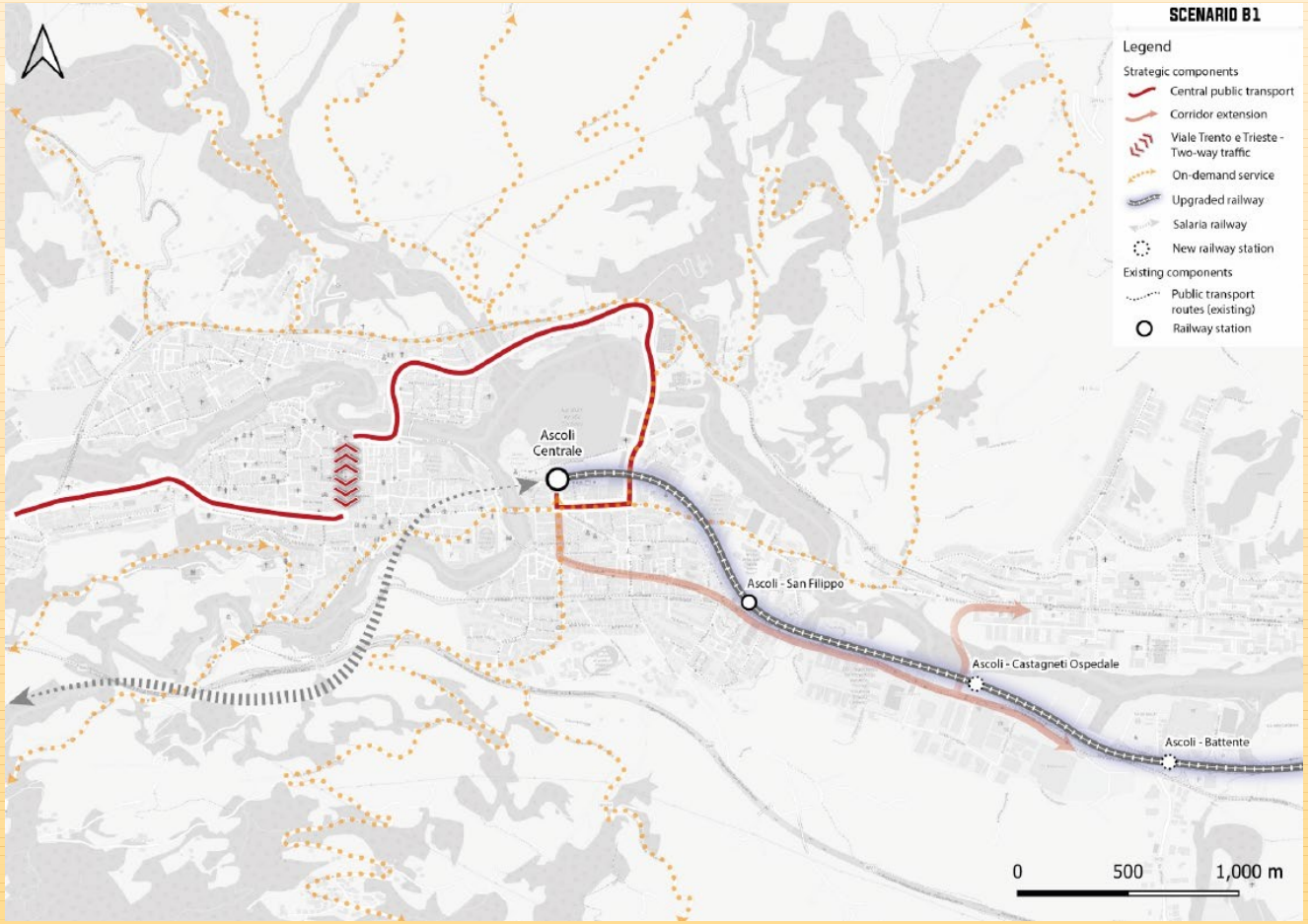
Scenarios Building: A0



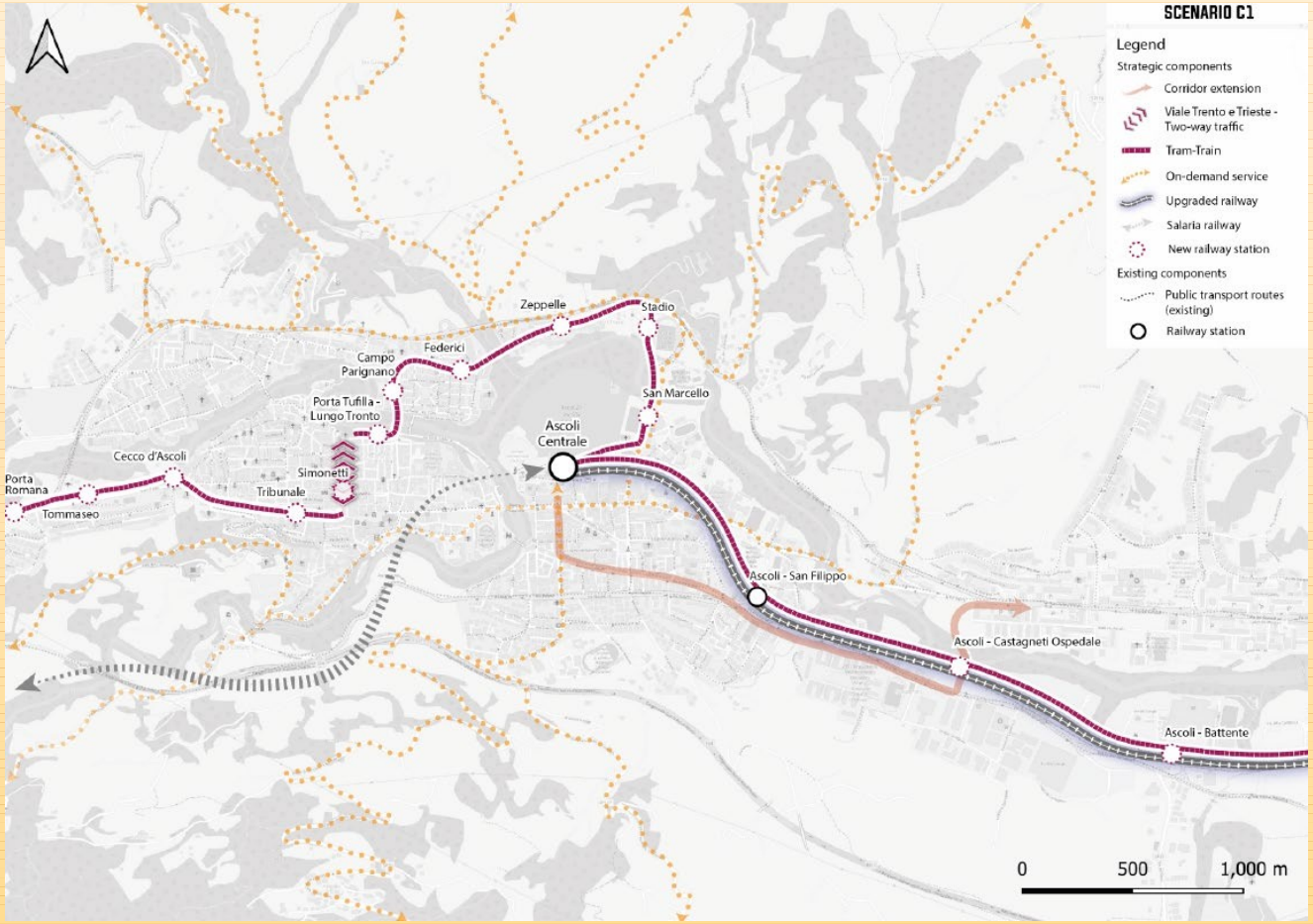
Scenarios Building: A1



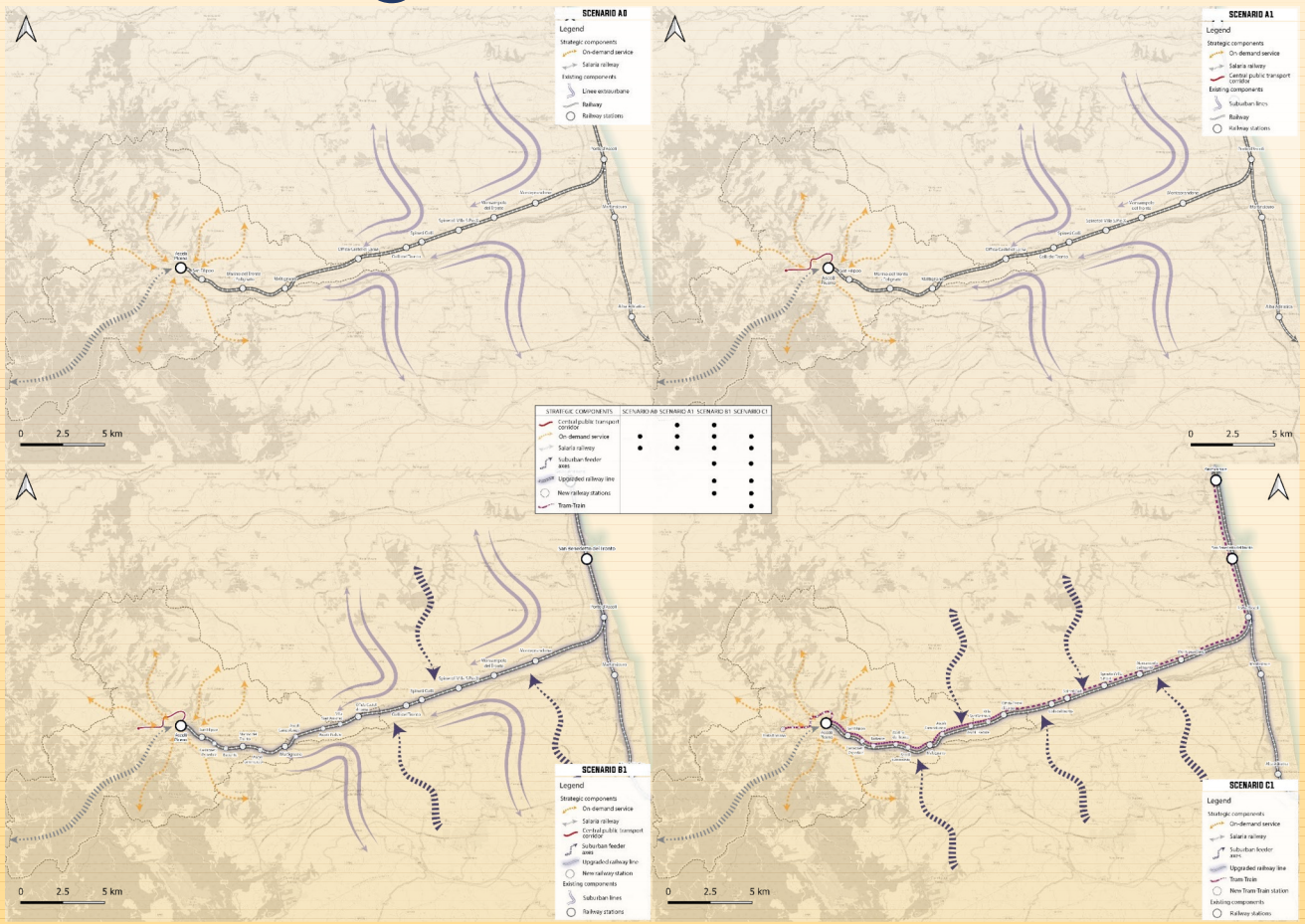
Scenarios Building: B1



Scenarios Building: C1



Scenarios Building: Extraurban



No new road capacity

→ Although unusual, the plan's entire supply-side intervention is: **public transport, cycling and street space reallocation**

→The car mode share **falls in every scenario without any offsetting capacity effect** to disentangle

The transport model

28,370 links

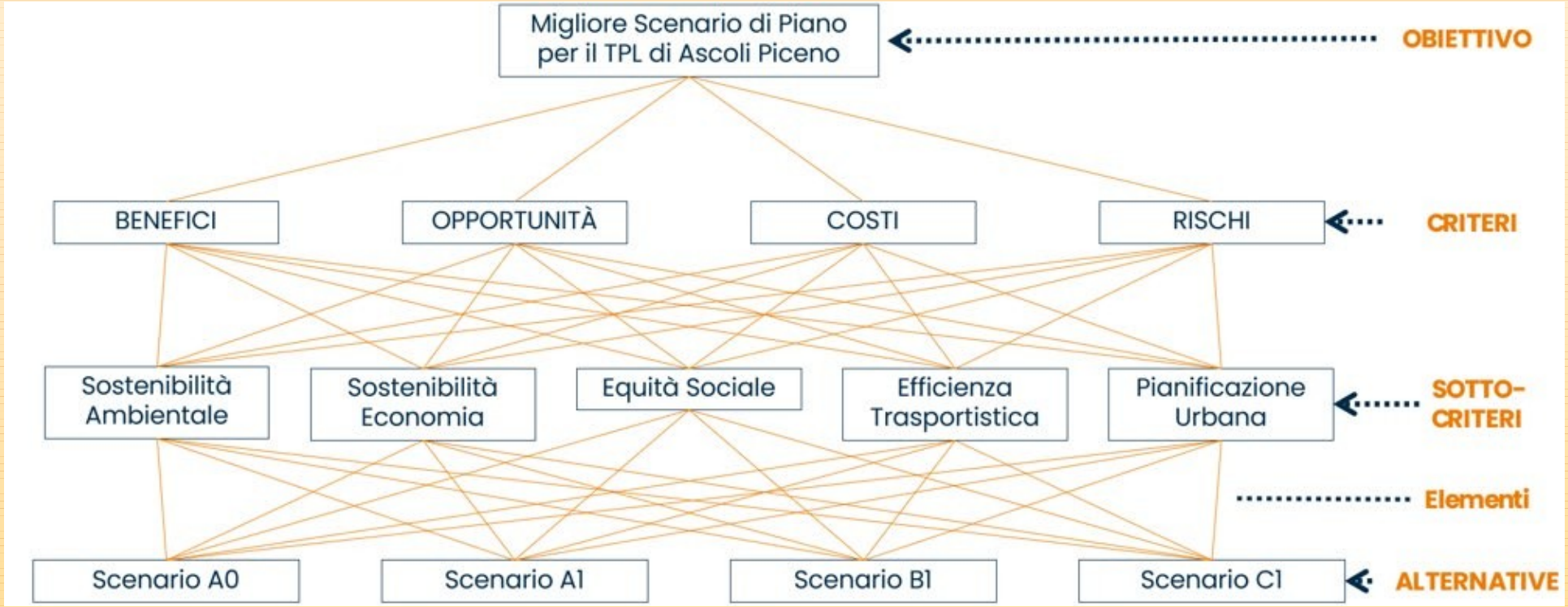
Weekday morning peak

Private demand: FCD

PT demand: ISTAT 2011 commuting matrix

R^2 = 98% turning movements and **96%** screenlines

Multicriteria Analysis



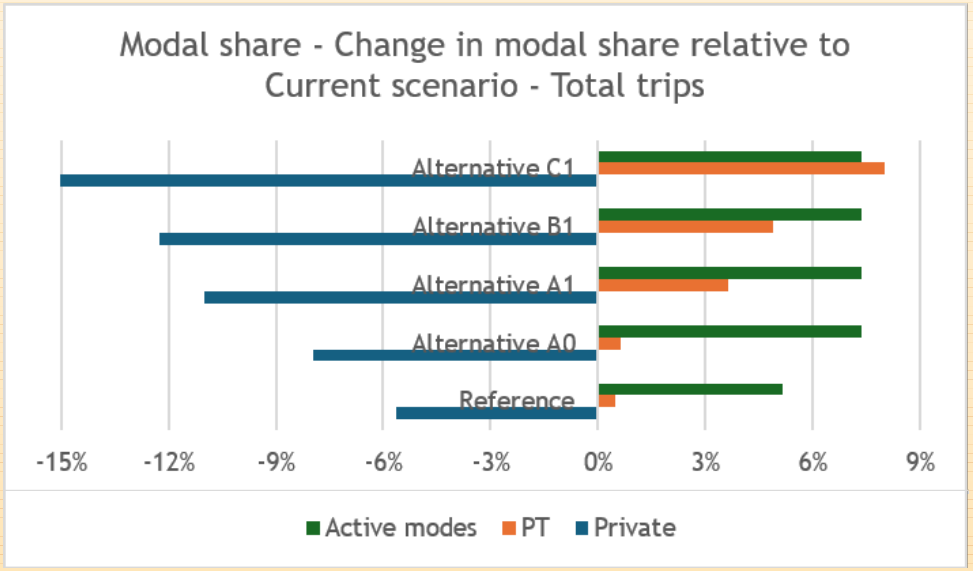
Multicriteria Analysis

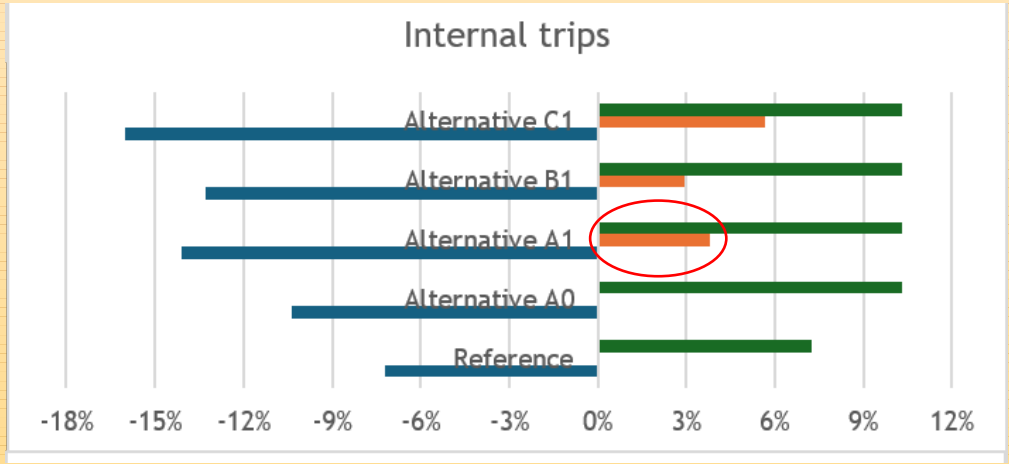
BOCR	Criteria	Elements
Benefits	Environmental	Reduction of greenhouse gas emissions
		Reduction of air pollution
	Economic	Increase in fare / tariff revenue
	Social	Consistency with local expectations
		Territorial equity
	Mobility	Modal split
		Spatial accessibility
		Reliability and regularity
		Travel times
	Urban Planning	Synergy with other urban projects
		Increase in urban resilience
Opportunities	Environmental	Acoustic impact
	Economic	Commercial enhancement of economic activities
		Reduction in road maintenance costs
		Increase in property value
	Social	Territorial equity
		Inclusivity
	Mobility	Road safety
	Urban Planning	Connection between different cities in the province
		Creation of a new urban image
		Improvement of urban quality

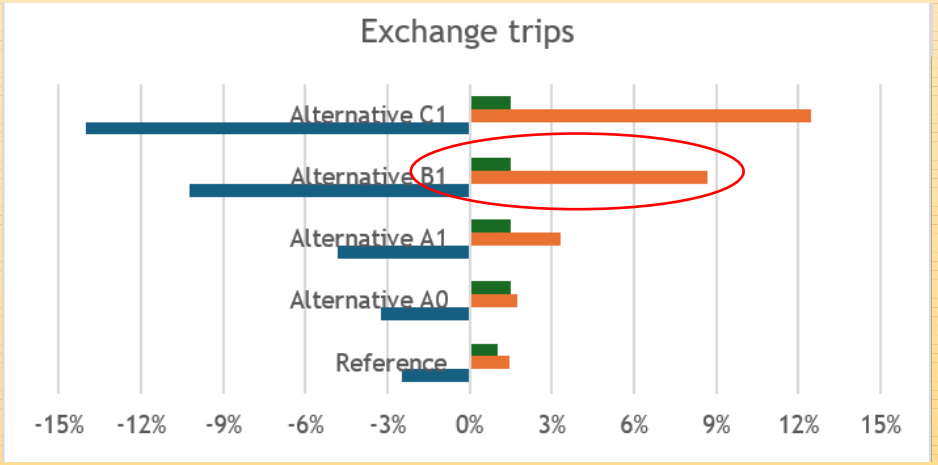
Multicriteria Analysis

Costs	Economic	Investment costs
		Financial sustainability
		Operational costs
	Social	Construction times
		Reduction of revenue for local commerce during construction
	Mobility	Redesign of vehicular space
Risks	Economic	Shortage of national and/or regional funding sources
	Social	Opposition to the project
	Mobility	Substantial changes to traffic circulation schemes
	Urban Planning	Presence of territorial / regulatory constraints

Results


Modal share - Change in modal share relative to Current scenario - Total trips
Alternative C1
Alternative B1
Alternative A1
Alternative A0
Reference
-15%
-12%
-9%
-6%
-3%
0%
3%
6%
9%
Active modes
PT
Private


Internal trips
Alternative C1
Alternative B1
Alternative A1
Alternative A0
Reference
-18%
-15%
-12%
-9%
-6%
-3%
0%
3%
6%
9%
12%

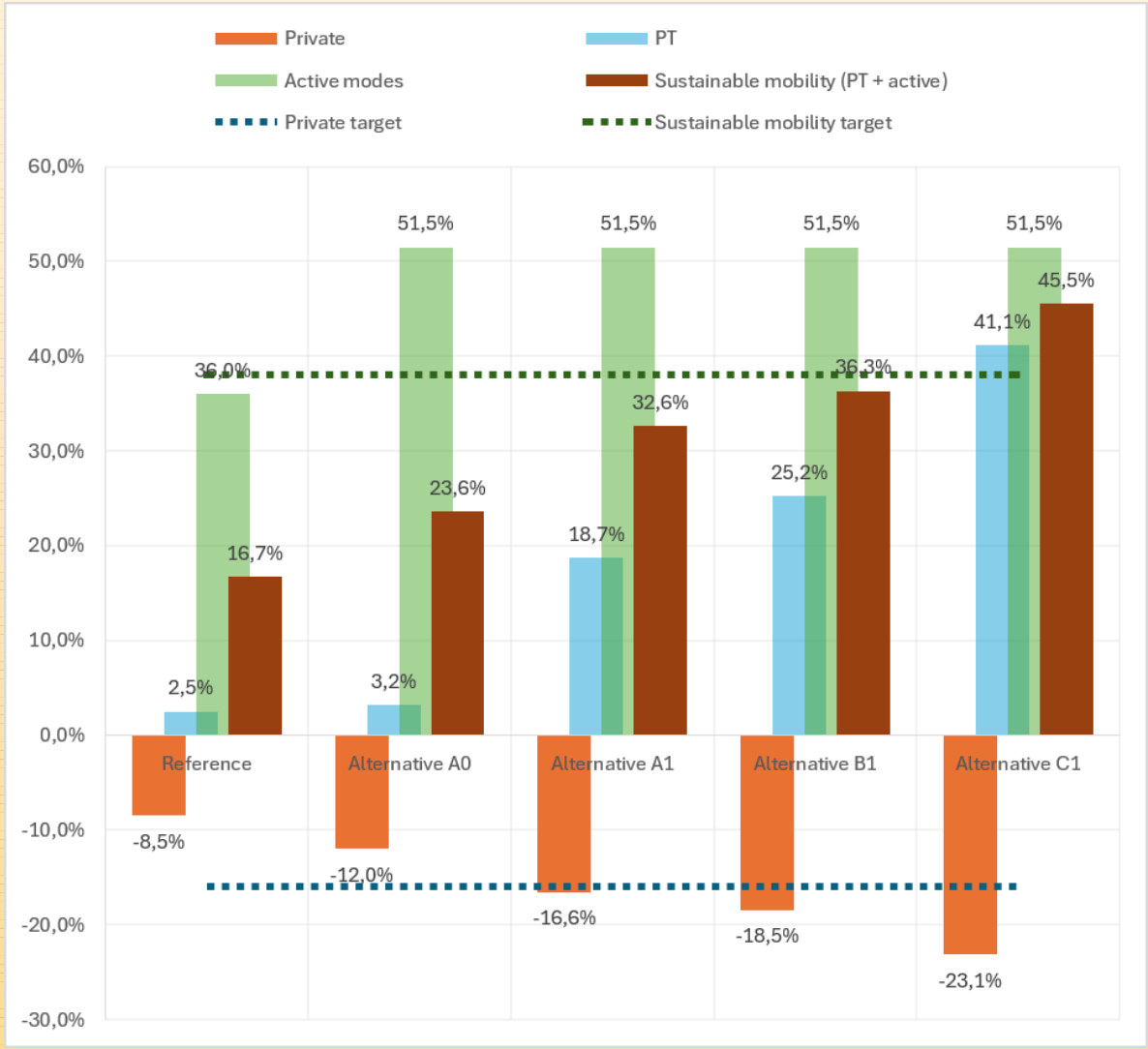

Exchange trips
Alternative C1
Alternative B1
Alternative A1
Alternative A0
Reference
-15%
-12%
-9%
-6%
-3%
0%
3%
6%
9%
12%
15%

Results: Final results of AHP

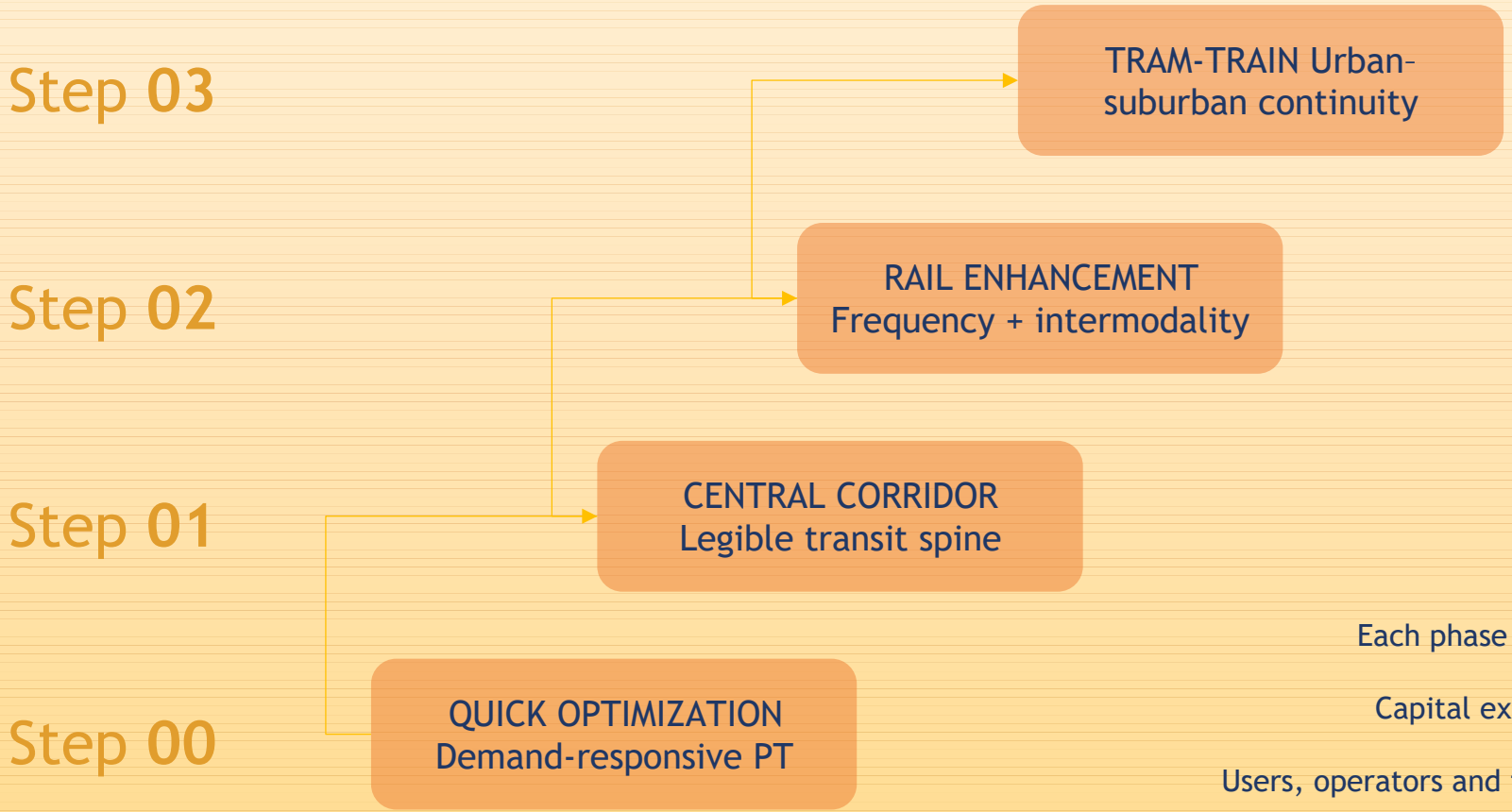
					FINAL WEIGHT	RANKING	FINAL WEIGHT	RANKING	FINAL WEIGHT	RANKING	
RESULTS	**B**	**O**	**C**	**R**	B*O*1/C*1/R		B+O-C-R		B^(1/2)*C^(-1/2)*O^(1/2)*R^(-1/2)		MEDIAN RANKING
A0	0,18	0,09	0,15	0,10	1,13	4	0,02	4	1,06	4	4
A1	0,27	0,09	0,13	0,09	2,09	2	0,14	3	1,45	2	2,33
B1	0,46	0,14	0,27	0,12	1,89	3	0,20	2	1,37	3	2,66
C1	0,81	0,19	0,31	0,23	2,21	1	0,47	1	1,49	1	1,00

Results

Scenario C1: Not only best score, but also the only scenario able to hit the targets



Towards Implementation: The ladder strategy



Why a ladder?

Minimize risk

Each phase can be evaluated before the next

Spread investment

Capital expenditure is distributed over time

Ensure system readiness

Users, operators and infrastructure progressively adapt

Limitations

ONE CASE

Single case → only one observation

No induced or suppressed demand

FIXED DEMAND

NO COSTING YET

No complete capital or operating cost figures exist for the scenarios

Transferibility

WHAT CAN BE TRANSFERRED?

SET TARGETS FIRST
Targets should be fixed before scenarios

ISOLATE THE DECISION
Hold non-relevant interventions constant

TEST EVERY SCENARIO
A target should be checked against every alternative

MATCH THE CORDON TO THE FUNCTION
Municipal boundaries should not obscure supra-municipal effects

Further Research

- Use ISTAT municipal commuting matrices to estimate corridor-relevant trips excluded by the municipal cordon and re-scale the C1 incremental effect
- Check against stress test for AHP and transport model
- Quantify costs (investment and O&M)
- Check the methodology in other low-density contexts

Final Remarks

1

The tram-train was not an advocacy choice

2

It was the only scenario satisfying both quantified targets

3

Its implementation is conceived as a progressive ladder, not a single leap