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Programma d'agglomerato del Mendrisiotto di quinta generazione (PAM5)

Gentili Signore, egregi Signori

esprimiamo innanzitutto il nostro apprezzamento per la decisione di coinvolgere le associazioni, tra le quali ATA Svizzera italiana, nel processo partecipativo durante l'elaborazione dello studio per il PAM5.

Altrettanto apprezzabile e importante è lo sforzo per contatti più intensi e proficui con le Province di Como e Varese e con i comuni della fascia di frontiera. Sono state recepite le critiche della Confederazione che nel suo esame del PAM 3 scriveva, tra le altre cose: "Fra tutti gli agglomerati transfrontalieri, quello del Mendrisiotto è il solo a non integrare lo spazio transfrontaliero per quanto concerne l'organizzazione e il contenuto". Continuare a "parlare" con i vicini lombardi non potrà che contribuire a migliorare la mobilità transfrontaliera e non solo, dispiace che non tutti i comuni contattati abbiano risposto. E a proposito di proficui rapporti con l'Italia è decisamente buona, per il traffico regionale, la recente notizia di un concordato italo-svizzero sul cabotaggio che consentirà di potenziare la rete transfrontaliera di trasporto bus. Nel 2025 inizieranno inoltre i lavori per l'elettrificazione della linea ferroviaria Como-Lecco che potrà essere collegata con la rete TILO.

Premessa

La nostra Associazione è da sempre attenta alla pianificazione del territorio da cui dipendono sia la mobilità sia la qualità di aria e suolo: crediamo che, rispetto al passato, occorra pianificare prestando maggiore attenzione a dove e come si costruisce, al riscaldamento globale, alle aree verdi dentro e fuori gli agglomerati, alla possibilità di accedere al trasporto pubblico e di spostarsi in bicicletta e a piedi.
Osserviamo infatti che i dati sull'inquinamento rimangono preoccupanti soprattutto per quanto riguarda le PM10 a Chiasso e Mendrisio, dove la media annuale supera sempre il limite fissato dall'ordinanza federale. Anche le concentrazioni di ozono superano molte volte all'anno il valore che potrebbe essere superato, stando all'OIAt, una sola volta. Buona parte della popolazione del Mendrisiotto è pure esposta a valori di inquinamento fonico superiori a quelli ammessi.

Valutiamo positivamente l'importanza che il PAM5 dà al paesaggio, alla necessità di uno sviluppo insediativo centripeto di qualità, agli effetti dei cambiamenti climatici sugli insediamenti (in particolare le isole di calore), allo sviluppo della mobilità lenta, alla valorizzazione degli spazi pubblici e dei beni naturali e culturali.

Il PAM5 introduce due concetti interessanti: quello di "città 15 minuti" e quello di "città-spugna". Sarà importante che questi concetti siano tenuti in considerazione e contribuiscano a migliorare la qualità degli insediamenti quando si interviene su situazioni già presenti o per progetti futuri. È urgente agire secondo i due concetti citati, specialmente nei luoghi densamente popolati e cementificati, in favore della qualità della vita di chi vi abita.
La "città 15 minuti" si basa sul principio di promuovere quartieri con una buona densità di abitanti che possano raggiungere la maggior parte dei servizi a piedi o in bicicletta in 15 minuti: sarà la sfida della pianificazione dei prossimi anni. Si potrebbe, anche in Ticino, cominciare a pensare a quartieri senza auto.

PAM5 e mobilità

1. Mobilità pedonale

Situazione attuale

La mobilità lenta, in particolare quella pedonale, all'interno degli insediamenti, ma non solo, presenta spesso situazioni poco soddisfacenti, soprattutto per alcune fasce della popolazione: bambini, anziani, persone disabili. Al di fuori delle zone pedonali, dove circolano comunque spesso biciclette e monopattini, si trovano molti marciapiedi stretti o in cattivo stato, passaggi pedonali con semafori dove i pedoni sono costretti a lunghe attese e hanno poi pochi secondi per attraversare. Tra una località e l'altra mancano del tutto, su molti tratti, i marciapiedi rendendo gli spostamenti a piedi pericolosi e poco attrattivi, come tra Mendrisio, Castel San Pietro e Morbio Superiore o tra Besazio bassa e Rancate, per fare solo due esempi.
I comuni introducono - o richiedono sempre più spesso l'autorizzazione a farlo - zone 30 per favorire i pedoni e ridurre i pericoli, tra l'altro una vecchia richiesta dell'ATA. Per facilitare il tragitto a piedi casa - scuola 11 Comuni su 15 aderiscono al progetto Pedibus dell'ATA.

Misure previste

Le misure di **riqualifica e sicurezza dello spazio stradale** previste in priorità A riguardano tutte il Comune di Mendrisio:
sono le misure **RSS 1** "Zone moderate nel borgo di Mendrisio", **RSS 2.1** "Riqualifica via Zorzi (autosilo)", **RSS 3** "Riqualifica via Franscini", **RSS 4.1** "Riqualifica via G. Bernasconi (sottopasso - mercato coperto)", **RSS 5** "Riqualifica urbanistica e ambientale intersezione Banchette.

Si tratta di misure volte, riassumendo[1], a riequilibrare i rapporti tra le diverse modalità di trasporto, attuando misure di moderazione per permettere una migliore convivenza tra diversi utenti delle strade, migliorare la qualità dell'ambiente urbano e promuovere una città più vivibile, realizzare un marciapiede di collegamento tra il futuro skate-park e il terminale bus di Mendrisio, (saranno eliminati circa 40 posteggi sul sedime FFS), incrementare superfici permeabili e il contrasto alle isole di calore, potenziare significativamente il collegamento pedonale tra la stazione FFS e la zona scuole (medie e liceo), aumentare la dotazione verde e le superfici permeabili.

Anche le misure di riqualifica e sicurezza dello spazio stradale di priorità B riguardano Mendrisio e andranno a completare progetti avviati col PAM5.

Commento

Stupisce che le misure di priorità A per la riqualifica di strade e marciapiedi e la sicurezza della mobilità pedonale riguardino solo Mendrisio-borgo. **Sono misure importanti che avranno sicuramente effetti molto positivi per chi si muove a piedi.** Rispetto alla situazione attuale un netto miglioramento.
Rimane irrisolta l'assenza di marciapiedi lungo molte strade che uniscono un comune o un quartiere all'altro.
Per ovviare a questo problema vediamo, tra le misure TPC, che Castel San Pietro prevede in priorità A la realizzazione di un percorso misto a valle della carreggiata tra il villaggio e il ponte sul Breggia: un sentiero sulla banchina esterna e una passerella.

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[1] Spiegazioni a beneficio di chi, nel nostro Comitato, non ha potuto leggere il documento nel dettaglio

2. Mobilità ciclabile

Situazione attuale

La rete dei percorsi regionali ha conosciuto, grazie alle misure dei PAM precedenti, significativi sviluppi che hanno permesso di ovviare a importanti lacune di collegamento; tuttavia, **il tasso di spostamenti in bicicletta è più basso rispetto ad altre zone del cantone.** Pur tenendo conto delle differenze del territorio tra le diverse regioni, questo è "sintomatico delle potenzialità ancora inespresse e della necessità di ottimizzazioni della rete stessa e della qualità insediativa per gli utenti di mobilità dolce" (Re pag. 89).
Infatti, se i percorsi ciclabili si trovano spesso lungo strade idonee, alcuni tratti corrono per contro lungo strade di grande transito. Sono molti i punti dove risulta difficile al/alla ciclista convivere col traffico motorizzato. Alcuni punti critici si trovano in concomitanza con le rotonde.

Misure previste

Le misure per il **traffico pedonale e ciclistico** sono numerose e importanti e vanno dalla realizzazione di passerelle e sottopassi a piste ciclabili dedicate alla mobilità ciclabile, percorsi misti. Quelle previste in priorità A sono 15. Particolarmente interessanti:

- la TPC 1 **passerella ciclopedonale** stazione FFS Stabio (Stabio) che permetterà di evitare l'attraversamento della strada trafficata da e per il Gaggiolo che, come si legge nella relativa scheda TPC 1, subirà "ancora maggiore pressione dal traffico a seguito del PoLuMe". Tema sul quale torneremo più avanti.
- la TPC 3 **sottopasso ciclabile alla Croce grande** che collega le piste esistenti verso Mendrisio, Coldrerio e Genestrerio, in un punto strategico di giuntura al centro della regione, caratterizzato da forti volumi di traffico veicolare e velocità relativamente elevate.
- TPC 10.4 **adeguamento tunnel Favre a Chiasso;** questa modifica, che interessa il tunnel sotto il comparto ferroviario di via Favre, permette di migliorare i collegamenti ciclabili ma anche del TP. L'opera comporta una riduzione del calibro stradale (3,50m) per prevedere un marciapiede di ca 2,5 m dedicato al transito dei pedoni e dei ciclisti in direzione sud-nord.
- TPC14.1 e 14.2: buona l'idea di piste transfrontaliere. Sarà importante garantire percorsi sicuri su entrambi i lati del confine. Peccato che siano in priorità C.

Commento

Il PAM 5 prevede **un grosso sforzo per migliorare la mobilità ciclopedonale**, cercando di collegare località, quartieri o comuni con interventi anche rilevanti in zone particolarmente problematiche come la Croce grande tra Mendrisio e Genestrerio. Positivi gli interventi che permettono di migliorare la sicurezza dei percorsi ciclabili (TPC1, 2.1, 2.2, 3, 7.1, 7.2, 8) da Stabio a Capolago.

I lavori principali toccano Mendrisio, Stabio e Chiasso, in quest'ultimo comune rimane per ora in sospeso il superamento della rotonda Kennedy, un punto pericoloso per chi lo affronta in bicicletta ma importante per collegare il Parco delle Gole della Breggia e il Parco del Penz, Morbio e Chiasso. Sarà interessante vedere con quali soluzioni si potrà risolvere questo passaggio, ora previsto in priorità C, sarà verosimilmente oggetto di uno dei prossimi PA.

La misura TPC 4.1 **Percorso ciclabile Serfontana - Ponte Picio** prevede una corsia ciclabile. Dal piano non risulta chiara nel dettaglio la sua realizzazione e in modo particolare se sarà utilizzato nuovo terreno. La strada che dalla rotonda si avvia al Serfontana è a due corsie: da valutare se non sia il caso di toglierne una per ricavare lo spazio per la pista ciclabile senza utilizzare nuovo territorio.

Dove possibile, in particolare su infrastrutture nuove come passerelle e sottopassaggi, andrebbero realizzati percorsi separati per pedoni e ciclisti.

Posteggi per biciclette: visto l'uso sempre più diffuse di biciclette elettriche, e la frequenza dei furti, sarebbe opportuno che alle stazioni si prevedano delle velostation sorvegliate (vedi Bellinzona) e parcheggi presso i grandi centri commerciali più sicuri.

Rete ciclabile locale: i Comuni dovrebbero sviluppare meglio questa rete e in modo particolare negli attraversamenti di strade trafficate. Da promuovere anche il bicibus che permette ai bambini di imparare a muoversi con le biciclette sui percorsi casa-scuola.

Orizzonte 2040: l'incremento dell'uso della bicicletta indicato dal documento (Re pag 68) ci sembra basso rispetto agli investimenti fatti e previsti. Sarebbe necessaria una politica regionale e comunale per promuovere ulteriormente l'uso della bicicletta che preveda ad esempio maggiori sussidi per l'acquisto di City bike, informazione alla popolazione sui vantaggi dell'uso della bicicletta e sui possibili percorsi e i tempi di percorrenza.

3. Trasporto pubblico regionale

a. Ferrovia

Negli ultimi 10 anni **la rete ferroviaria regionale TILO ha conosciuto un importante sviluppo e un successo straordinario** tanto che negli orari di punta i treni sono pieni e vicini alla saturazione.
Ci teniamo a ricordare che ATA aveva proposto di realizzare la ferrovia Mendrisio – Varese nello studio *Ticino 2001* già nel 1987.

b. Bus

Un notevole sforzo è stato fatto da parte del Cantone anche per quanto riguarda il miglioramento della rete bus: in alcune zone, anche del Mendrisiotto, linee e orari sono molto soddisfacenti mentre, complice un territorio complicato, rimane qua e là un margine di miglioramento come del resto è segnalato nei documenti in esame. Purtroppo i bus sono sottoutilizzati al di fuori degli orari di punta: **riteniamo comunque importante mantenere il buon livello dell'offerta per tentare di indurre un cambiamento di mentalità rispetto all'uso del trasporto pubblico** in una regione con un numero di auto per abitanti più alto rispetto alla media cantonale e svizzera.

c. Trasporto aziendale

Alcuni comuni e ditte della regione hanno attuato interessanti piani di trasporto aziendale, ma in molti non vi fanno capo: **crediamo che la tassa di collegamento possa essere un incentivo a forme di trasporto alternative come carpooling e i bus organizzati dalle imprese**.

Misure previste per il trasporto pubblico

Il Gran consiglio ha votato recentemente il credito per alcune misure previste dal PAM 3, tra le quali la realizzazione di **un ascensore che dalla stazione di Balerna** sale fino a una fermata dei bus sulla cantonale tra Chiasso e Mendrisio. Una misura interessante che lo diventerà ancora di più quando sarà realizzata la TP2 (accessibilità alla stazione di Balerna) che porterà alcune linee fino alla Piazza di Balerna, servirà così oltre gli utenti di Balerna anche chi arriva in bus da Breggia, Castel San Pietro, Morbio: peccato che sia in priorità B e dunque vedrà la luce tra parecchi anni.

Due pacchetti di misure interessanti **TP3 eTP4** si prefiggono di velocizzare il TP, rispettivamente sull'asse Breggia (Valle di Muggio, Breggia, Morbio) e sull'asse Brusata (Novazzano, Genestrerio) verso i nodi ferroviari.

Le misure TP3.1 e 3.2 la prima in priorità B, la seconda fortunatamente in priorità A, propongono interventi su una strada e una piazza (Chiesa Sant'Anna Morbio Sup.) particolarmente problematiche dove l'incrocio tra auto e bus, figuriamoci due bus, è all'origine di manovre difficoltose e ritardi.

Le misure TP 4.1 (A) e TP4.2 (B) prevedono la realizzazione di tratti di corsia dedicata per i bus su un percorso fortemente caratterizzato dal traffico dei frontalieri in transito dal valico di Brusata che forma colonne negli orari di punta.

Commento

a. Ferrovia

Migliorando l'offerta di Park+Rail, soprattutto oltre frontiera si potrebbe aumentare ulteriormente l'utilizzo della ferrovia, ma visto l'affollamento attuale occorrerebbe aumentare anche la capacità dei treni.
A questo proposito la CRTM dovrebbe intervenire presso il Cantone e la Confederazione affinché si acceleri l'inizio dei lavori per adattare la galleria di Monte Olimpino 1 ai convogli di 4 m così da poter utilizzare i treni a due piani aumentando la capacità anche in vista dell'elettrificazione della linea Como - Lecco.
Il fatto che il numero di frontalieri che entrano in Ticino sia cresciuto mentre il traffico sull'autostrada sia diminuito del 10% nei momenti di punta, **mostra chiaramente come l'offerta del TP sia considerata un'alternativa al TIM**, a patto però che in futuro quest'ultimo non venga di nuovo favorito potenziando la A2.

Riteniamo che **non sia necessario la creazione di nuove fermate FFS** ma che sia preferibile migliorare il TP su gomma sia come frequenza delle corse verso le stazioni, sia come puntualità alle stazioni ferroviarie per garantire le coincidenze con i treni.

b. Bus

Condividiamo l'obiettivo di velocizzare il TP su gomma per garantire migliori coincidenze con i treni alle stazioni. Il forte aumento dell'utenza permette di sostenere questi miglioramenti per avvicinare ancora più persone al TP.
Temiamo tuttavia che gli sforzi proposti in questo PA potrebbero essere vanificati dal PoLuMe, ancorché, se fosse realizzato, in funzione solo dopo il 2040/45.
Di seguito alcune osservazioni su singole linee bus esistenti e aspetti puntuali:

Linea Mendrisio - Chiasso
La tratta è servita da tre linee durante la settimana lavorativa e da due al fine settimana. La linea 3 che parte da Morbio Inferiore non offre nessuna corsa il fine settimana. Invitiamo la CRTM a valutare un aumento dell'offerta della linea 3 anche nel fine settimana per garantire la possibilità di usare il TP per le attività del tempo libero.

Linee della valle di Muggio
Riteniamo positivi i cambiamenti che sono previsti per reintrodurre i collegamenti diretti dalla Valle di Muggio alle stazioni ferroviarie. Il prolungamento delle linee da Muggio e Sagno verso Balerna, oltre a servire gli abitanti della Valle di Muggio, permette anche un miglior servizio per gli abitanti della parte alte di Morbio Inf. che oggi usufruiscono della ferma Morbio Posta con la linea 3 o 5.

Pure interessante è il prolungamento della linea 521 della sponda destra (e non sinistra come indicato nel rapporto) della Valle di Muggio fino alla stazione di Balerna, servendo in questo modo anche gli abitanti della frazione di Gorla del comune di Castel San Pietro. Non è possibile che tali interventi passino in priorità A?

Linea 513 Chiasso - Morbio Superiore - Castel San Pietro - Mendrisio
Importante e necessario l'allargamento della strada dal ponte di Castello fino all'incrocio tra Via Bellavista e Via Valle di Muggio a Morbio Inf. perché come detto permette di velocizzare il traffico TP su gomma e crea un marciapiede per gli spostamenti pedonali. Occorrerà vegliare affinché l'allargamento della strada non invogli a utilizzarla per andare da Chiasso a Mendrisio e viceversa da parte di chi vuole evitare le colonne su altre tratte. Sarà da valutare attentamente l'impatto del PoLuMe non solamente lungo i tratti indicati dall'USTRA, ma su tutto il territorio del Mendrisiotto.

Linea 517 Mendrisio - Genestrerio - Novazzano – Chiasso

Se da una parte anche questo intervento a favore del TP su gomma è visto positivamente, dall'altra si dovrà considerare l'aumento del traffico transfrontaliere che causerebbe il PoLuMe per evitare di dover potenziare (purtroppo) ulteriormente il collegamento stradale verso la dogana di Brusata.

Linea 523 Gaggiolo – Mendrisio

Chiediamo di valutare un potenziamento della linea nei momenti di punta. Visto il successo della linea e l'aumento dell'utenza, sarebbe peccato se i limiti della capacità dei bus non permettesse di incrementare ulteriormente l'uso del TP a favore del TIM. L'adozione di una cadenza di 15 minuti nei momenti di punta permetterebbe di aumentare la capacità di trasporto.

Linee TP su gomma transfrontaliere

Valutiamo positivamente lo sviluppo di linee transfrontaliere. Si dovranno comunque valutare accorgimenti per favorire il loro transito nei momenti di punta, evitando che i bus restino incolonnati assieme al TIM. Questo sviluppo dovrebbe andare di pari passo con **la diminuzione dei posteggi gratuiti presso le aziende** per portare i frontalieri a utilizzare il TP su gomma. Una politica da parte delle aziende verso questo passaggio è importante, aziende che devono prendersi la responsabilità del traffico che generano. Le linee di TP potrebbero diventare linee aziendali con la possibilità di servire meglio tante piccole aziende.

Elettrificazione TP su gomma

Per diminuire le emissioni di CO_2 dovuto all'impiego di combustibili fossili, si intende passare all'impiego di bus elettrici. Se tale opportunità può diminuire le emissioni di gas serra, questo rischia di essere vanificato se l'energia elettrica proviene da centrali che usano fonti fossili (carbone, gas). Sarà quindi indispensabile che l'energia usata per caricare le batterie sia di origine rinnovabile e **le aziende di trasporto investano anche in superfici fotovoltaiche per coprire il loro fabbisogno.** Una collaborazione con le aziende elettriche locali potrebbe anche permettere di creare delle "nuvole" di energia. Quanto immesso nella rete dagli impianti fotovoltaici può essere ripreso dalla rete anche in momenti differenti: la rete diventerebbe una batteria.

c. Trasporto aziendale

Se il Gran consiglio boccerà la tassa di collegamento, si darà un segnale contrario alla volontà di risolvere il traffico e gli ingorghi sull'autostrada e non si avranno a disposizione le risorse necessarie per migliorare la mobilità aziendale e favorire il passaggio dal TIM al TP sia per i residenti sia per i frontalieri.

Il nome "tassa di collegamento" non è forse la scelta migliore, meglio sarebbe stato "costo di collegamento" che indicherebbe i costi che gli utenti causano creando congestioni. Il fatto, inoltre, che la maggior parte dei dipendenti abbia a disposizione un posteggio gratuito, non porta né i datori di lavoro né i dipendenti a promuovere rispettivamente utilizzare i TP, a fare car-pooling oppure a organizzare meglio un trasporto aziendale, che nel rapporto viene indicato come poco realizzabile visto che sul territorio del Mendrisiotto ci sono molte piccole aziende con poche decine di lavoratori.

4. Trasporto individuale motorizzato

Nel Rapporto esplicativo (Re) si può leggere che "il modello del traffico prevede per il 2040 un indebolimento relativo della forte componente di trasporto individuale motorizzato (TIM) verso il trasporto pubblico, il cui trend è già in ascesa".

Dovrebbe contribuire a questa tendenza anche il cambiamento in atto nelle abitudini di consumatori e consumatrici che, come si legge nel Re, acquistano ad esempio sempre di più online. Bisognerà dunque a medio termine ripensare le enormi aree occupate dagli Anni 70 sul fondovalle del Mendrisiotto dai Centri commerciali, grandi divoratori di terreni e grandi generatori di traffico (GGT) con distese di posteggi, contro cui la nostra associazione si è battuta strenuamente.

Purtroppo, la disponibilità di posteggi gratuiti sia sul posto di lavoro sia sotto e attorno i GGT non scoraggia l'uso dell'automobile, la maggior parte (70% stando ai dati del DT) di chi lavora e fa acquisti nel Mendrisiotto si sposta in auto. Il grado di occupazione media delle auto che varcano giornalmente il confine si situa sul l'1.11, verosimilmente non dissimile da quello dei pendolari indigeni. La tassa di collegamento votata in Gran consiglio nel lontano 2015 e dal popolo nel 2016 sarà probabilmente bocciata dal Gran consiglio.

5. Autostrada

a. A2 Mendrisio - Lugano

Per quanto riguarda la A2 condividiamo (sottolineatura compresa) l'analisi che si trova a pag. 102 del Rapporto:
<u>Le conseguenze della congestione autostradale sono piuttosto gravose sul Mendrisiotto. Il traffico si riversa dall'autostrada sulle strade principali. A sua volta questo provoca un travaso di traffico parassitario sulle strade di rango inferiore. Queste perdono di attrattività per la mobilità lenta e il trasporto pubblico accumula ritardi. Ne nasce un circolo vizioso in cui le alternative che potrebbero concorrere a mitigare il problema sono sfavorite dal problema stesso.</u>

Pur sapendo che il PoLuMe non è parte del PAM5, esprimiamo fin da ora **la nostra contrarietà al progetto di potenziamento della A2 Lugano Mendrisio,** (illustrato sempre a pag.102), perché non crediamo che sia la soluzione ai problemi del traffico, siamo anzi convinti che un traffico reso più fluido dall'apertura della terza corsia arriverebbe più rapidamente e con numeri maggiori alle uscite, accentuando i problemi.
Tant'è vero che, come si legge a pag. 103 del Re: "(…) lo studio sugli effetti secondari del PoLuMe ha evidenziato che l'aumento della capacità del tratto autostradale avrà conseguenze sulla rete a sud di Mendrisio, che è opportuno approfondire e mitigare nell'ambito del progetto".
Siamo molto curiosi di vedere come!

A nostro avviso nel PAM 5 manca una valutazione delle conseguenze che il PoLuMe potrebbe avere, se malauguratamente venisse realizzato, su progetti previsti dal PA. La giustificazione, che il PAM5 ha una visione fino al 2040 e che il PoLuMe sarebbe concluso dopo tale data, è solo parzialmente comprensibile visto che i dati del progetto riguardo l'aumento della mobilità sono già conosciuti (vedi rapporto sul traffico del PoLuMe).

Il traffico che "tracimerà" dalla A2 alle strade cantonali e comunali metterà a rischio il fragile equilibrio raggiunto con gli importanti interventi realizzati in questi anni a favore del TP, in modo particolare quello su gomma.

Nel rapporto si indica che saranno adottati tutti gli accorgimenti per limitare i disagi di tale aumento, ma pensiamo che difficilmente si potrà assorbire un maggior numero di veicoli in un intervallo di tempo minore rispetto a quanto accade oggi.

Molti studi internazionali mostrano chiaramente che un potenziamento delle autostrade non ne risolve il congestionamento (alleghiamo uno studio condotto nel 2022 su oltre 500 città più importanti dell'Europa). Se a corto termine sembra che la situazione migliori, a lungo termine si ripresentano le colonne e si ritorna alla situazione precedente l'intervento, ma con un aumento generalizzato del traffico su tutta la rete stradale: **osservando che la capacità dell'autostrada passerà da 3500 veicoli all'ora a 5400 veicoli all'ora non possiamo che essere pessimisti sulle conseguenze per il traffico su tutte le strade del Mendrisiotto**, nonostante gli accorgimenti che si vorranno proporre.

Gli interventi che portano a una diminuzione del traffico e delle congestioni sono lo sviluppo del trasporto pubblico e l'introduzione di tasse causali che vadano a coprire i costi degli ingorghi generati dagli stessi automobilisti

In Ticino, e questo aspetto manca nell'analisi del Rapporto esplicativo, dall'apertura della galleria ferroviaria del Monte Ceneri, e dopo il forte potenziamento dell'offerta di TP, si è osservata una diminuzione di circa il 10% del traffico sull'autostrada tra Chiasso a Lugano nei momenti di punta dalle 6.00 alle 10.00 e dalle 16.00 alle 20.00 tra il periodo 2017/19 e il periodo 2022/23 (vedi grafici allegati elaborati con i dati dei punti di conteggio pubblicati dal DT). Questa diminuzione è dovuta al forte aumento dell'uso del TP da parte sia dei residenti sia dei frontalieri. Il numero di frontalieri che entrano da Chiasso e da Stabio con il TILO è quasi raddoppiato, il numero di passeggeri alle stazioni del Mendrisiotto è aumentato più del 40%.

Tutti questi dati mostrano quanto già visto in altre città del mondo: una buona offerta del TP porta a una diminuzione del traffico.

La realizzazione del PoLuMe, favorendo il TIM e riducendo il tempo di percorrenza (vedi rapporto sul traffico del PoLuMe) avrebbe come conseguenza un travaso dell'utenza dal TP al TIM, un aumento dei viaggi, oggi scoraggiati dalle code, un aumento del consumo di mobilità su strada, come mostrano studi eseguiti a livello mondiale sia in realtà simili alle nostre (Europa) sia in situazioni differenti. Tutto questo è in forte contrasto con l'impegno del Dipartimento del territorio e del parlamento ticinese a favore del TP.

b. Corsia camion

Siamo contrari alla corsia di stoccaggio Tir tra Mendrisio e Chiasso che non farebbe che caricare ulteriormente una tratta già sotto pressione. Dall'apertura del Centro di gestione del traffico pesante a Giornico si ha l'impressione che le code dei TIR siano diminuite. Invitiamo la CRTM a valutare questa eventuale diminuzione come argomento contro la corsia per i TIR, per altro avversata anche dai comuni della regione.

Conclusioni

Come detto all'inizio condividiamo gli obiettivi del PAM5 di porre l'accento sulla qualità del paesaggio, di perseguire uno sviluppo centripeto di qualità riducendo la dispersione degli insediamenti, di insistere su concetti come la "città di 15 minuti" o la "città – spugna, di combattere le isole di calore, di creare aree verdi, di continuare nel potenziamento della mobilità lenta e del trasporto pubblico a favore di una migliore qualità della vita nel Mendrisiotto.

L'auspicio è che gli intenti possano essere concretizzati e non rimanere solo sulla carta. Le difficoltà finanziarie di Confederazione, Cantone e, di riflesso dei Comuni, non lasciano tranquilli riguardo la possibilità di realizzare quanto previsto in tempi ragionevolmente brevi, anche se i miliardi per gli ampliamenti delle strade si trovano…

Ringraziamo tutte le persone e gli enti che hanno contribuito ad elaborare un programma ambizioso, fornendo una fotografia interessante, utile, ma anche critica, di un territorio non facile, senza "abbellire" troppo la situazione.

Vogliate gradire saluti cordiali

Per ATA Associazione traffico e ambiente, sezione della Svizzera italiana

Grazia Bianchi Matteo Mombelli

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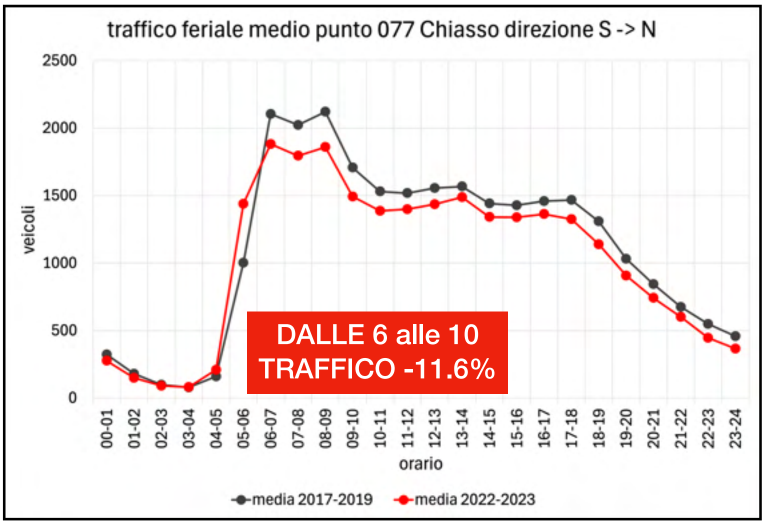
Allegati:

- Grafici del conteggio del traffico sull'autostrada
- Studio degli effetti dell'aumento della capacità delle autostrade nelle città europee

Grafici del traffico feriale medio a Chiasso, Maroggia e Grancia.
Confronto tra le media sugli anni 2017-19 e 2022-23.

CHIASSO AUTOSTRADA

TRAFFICO SULL'AUTOSTRADA: CONFRONTO 2017-19 e 2022-23



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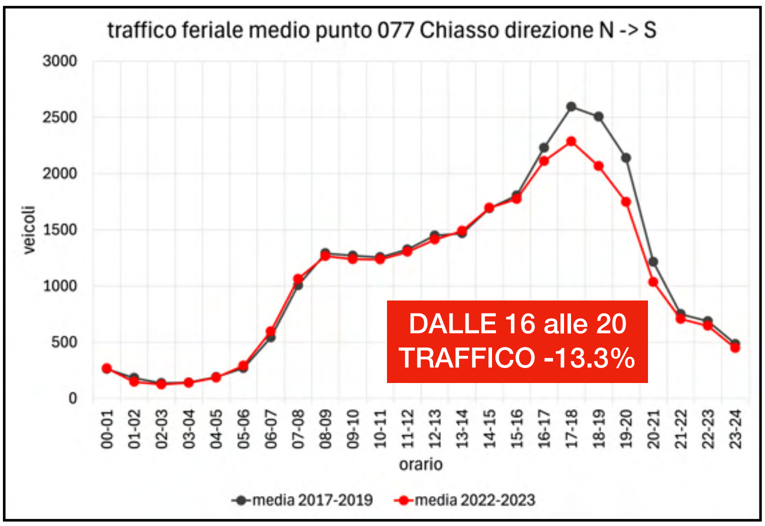

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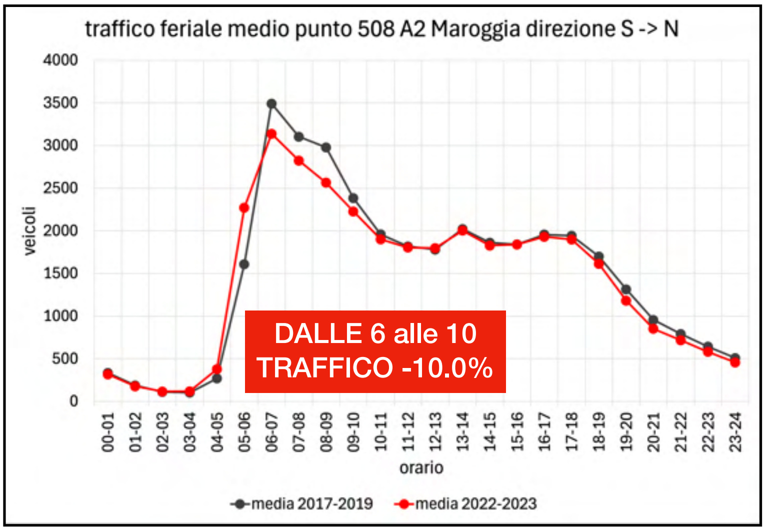

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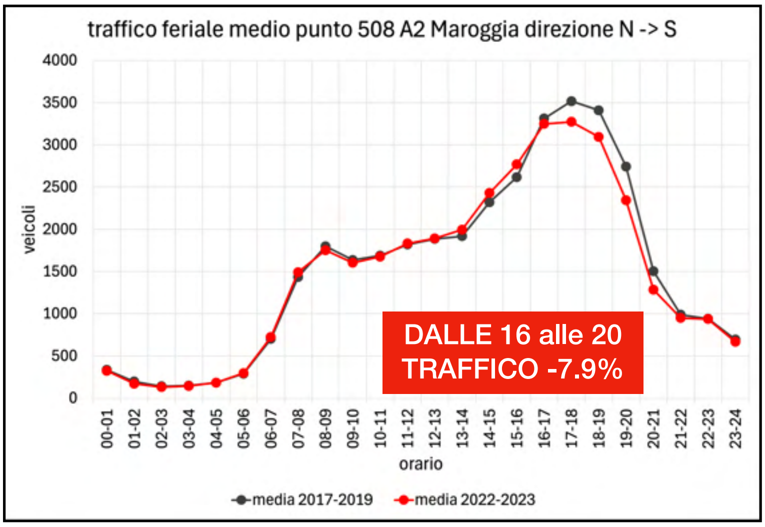
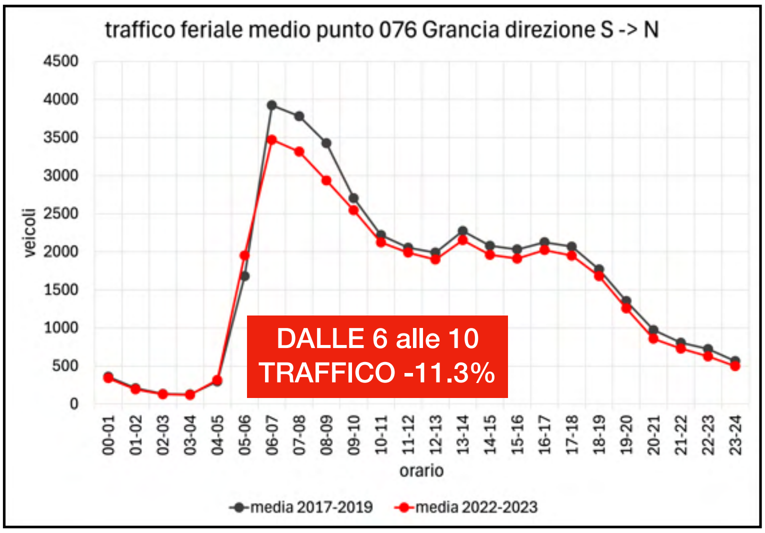


La mobilità del futuro ATA

GRANCIA AUTOSTRADA

TRAFFICO SULL'AUTOSTRADA: CONFRONTO 2017-19 e 2022-23



La mobilità del futuro

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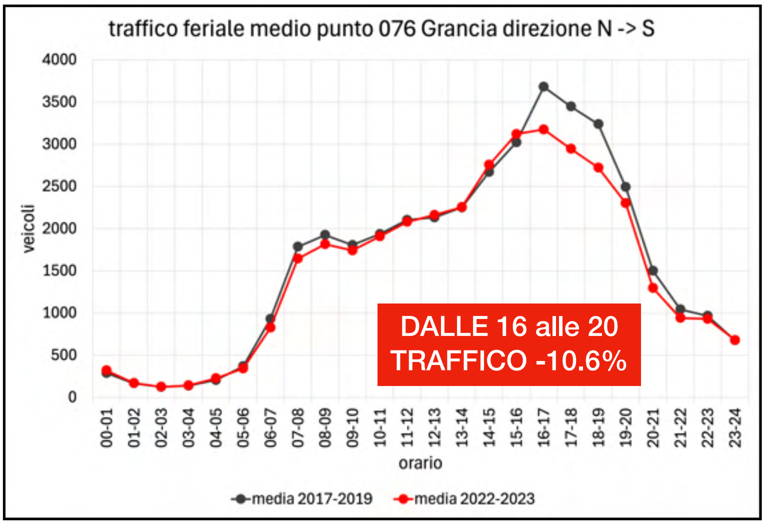

La mobilità del futuro

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Congestion in highways when tolls and railroads matter: evidence from European cities

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Abstract

Using data from the 545 largest European cities, we study whether the expansion of their highway capacity provides a solution to the problem of traffic congestion. Our results confirm that in the long run, and in line with the 'fundamental law of highway congestion', the expansion in cities of lane kilometres causes an increase in vehicle traffic that does not solve urban congestion. We disentangle the increase in traffic due to the increases in coverage and in capacity. We further introduce road pricing and public transit policies in order to test whether they moderate congestion. Our findings confirm that the induced demand is considerably smaller in cities with road pricing schemes, and that congestion decreases with the expansion of public transportation.

Keywords: Congestion, highways, Europe, cities
JEL classifications: R41, R48
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1. Introduction

Road congestion remains one of the most pressing issues in urban areas all over the world. Although the five most congested cities are located in developing countries, recent data indicate that they are followed by Rome, Paris and London, which all present higher values than some large US cities[1] (INRIX, 2019). In the case of Rome, for example, 166 h are lost per driver due to congestion per year. Evidence is growing that traffic congestion has many negative consequences related to employment (Hymel, 2009), pollution and health (Requia et al., 2018; Green et al., 2020; Simeonova et al., 2021) and road fatalities (Pasidis, 2019). All in all, the current cost of road congestion in Europe is estimated to be over 270 billion euro per year (about 1% of its GDP).

Several different options exist for addressing congestion in cities. One of the most common policies has been to expand highway capacity. At times when politicians intend to foster economic growth, the increase in investment in road transportation has an important

1 Taking into account the commute delay attributable to congestion delay, the 10 most congested cities in the world in 2019 were Bogotá, Rio de Janeiro, Mexico City, Istanbul, Sao Paulo, Rome, Paris, London, Boston and Chicago (INRIX, 2019).

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impact as a countercyclical fiscal policy (Leduc and Wilson, 2017). However, one of the main criticisms levelled at the expansion of an intrametropolitan highway network is that this policy may not generate any real improvements in accessibility and in economic growth; the evidence shows that, in the long term, these investments may simply relocate economic activity and leave congestion levels unchanged (Duranton et al., 2020).

One of the reasons for the inability of these policies to reduce urban congestion is the induced demand effect, also known as the 'fundamental law of highways congestion' (Downs, 1962, 1992). As a result of the new demand induced by the added road capacity, the travel speed (as a measure of congestion) on an expanded highway reverts to its level prior to its expansion. The induced demand phenomenon has undergone extensive empirical testing; however, the evidence is not conclusive for either short-run or long-run analyses (for an overview, see Hymel, 2019). Many of the earlier studies lack a good identification strategy for explaining the causal links between the increase in highway capacity and its impact on vehicle traffic. Interesting exceptions are the papers by Duranton and Turner (2011) and Hsu and Zhang (2014), which show an elasticity of traffic with respect to highway lane miles of approximately one for both US and Japanese urban areas. A unit elasticity suggests that increasing capacity supply does not reduce traffic congestion, not even partially.

In this paper, we test the 'fundamental law of highway congestion' for 545 metropolitan areas of the EU28 countries during the period 1985–2005. We think that adding new evidence for those cities is an interesting contribution for several reasons. First, we are working with a much bigger sample of cities, compared with the cited papers, and this can also be considered a contribution in a continent where running country analysis is complicated because some of the countries are really small. Second, European cities (as the Japanese ones) are more compact than most US cities, and they are also characterised by a lower degree of car-dependency and the widespread use of public transportation.[2] So, we think that this setting might add new insights to understand how the law performs. Third, taking into account the fact that the EU Regional and Cohesion Funds have funded a considerable portion of the immense highway network development in the last few decades, we think that having results for the European cities is also an important feature in terms of policy implications.

This analysis for the whole of Europe is methodologically challenging because we need to assemble data for many cities of different countries and for a long period. The difficulty is even greater to overcome several identification issues in order to properly estimate the causal effect. The first contribution of this paper is that we combine GIS data for a variety of historical data of transportation networks in Europe in order to obtain unbiased estimates. A second contribution is that we break down the effect of the highway expansion to the capacity effect (number of lanes) and the coverage effect (length of the network). Finally, our third contribution is that we are able to study the heterogeneity of the effects based on the existence of other policies that target congestion in cities. To see whether these policies affect congestion, we first control for the road pricing policies, and then take into account the availability of public transportation (railroads and subways)

2 According to OECD data, the average urban population density in the European metropolitan areas in 2011 was 718 persons per km^2, compared with only 282 in the US. OECD and Eurostat statistics indicate for the same year that car use in Europe was some 42% lower than in the USA. Also Europe is the world's leader in public transit systems: two-thirds of the large European cities have subways compared with only a third in the US (Gonzalez-Navarro and Turner, 2018).

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connecting some city centres with their suburbs. Our average results indicate that, in line with the evidence from the US and Japan, for the European cities there is an induced demand effect for both the capacity and coverage expansion. However, we find that this induced demand is considerable smaller in cities with road pricing schemes, and that congestion falls with public transportation expansions.

It is important to note that, due to the lack of data on travel (demand) speeds, a more direct measure of congestion used in other studies that analyse one city or small group of cities (Adler and van Ommeren, 2016; Bauernschuster et al., 2017; Adler et al., 2021; Russo et al., 2021), we estimate the effect of highway expansion on travel (demand) quantity. We follow the same approach than the closest works to ours, Duranton and Turner (2011) and Hsu and Zhang (2014), which face the same limitation of not being able to access to travel speed data for a big sample of cities and a long period of time.

The remainder of the paper is organised as follows. In Section 2, we begin by describing our data on congestion and highways in European cities and how we process them. Then in Section 3, we discuss our estimation approach and in Section 4, we present the results. In Section 5, we include congestion pricing and the availability of public transportation in cities. Finally, we present the conclusions in Section 6.

2. Congestion and highways in Europe

We use the Functional Urban Area (FUA) (formerly known as Larger Urban Zone (LUZ)), defined by the European Commission (Urban Audit Project) and the OECD as the unit of observation. In common with the Metropolitan Statistical Area in the USA, the FUA consists of a central city (with at least 50,000 inhabitants) and a commuting zone (made up of all municipalities with at least 15% of their employed residents working in the city. The final dataset includes 545 FUAs covering the whole geography of Europe (29 countries).[3]

2.1. Congestion in Europe

We use data from the Road Traffic Censuses conducted by the United Nations Economic Commission for Europe (UNECE). These censuses contain traffic and inventory information on the main highways in Europe (E-Road network) at a very detailed geographical level (road segments) for every 5 years from 1985 to 2005.[4] Specifically, we obtain information on the annual average daily traffic (AADT), the length (kilometre) and the number of lanes of each segment for the years 1985, 1995 and 2005.

To measure traffic congestion, we use the well-known indicator 'vehicle kilometres travelled' (VKT), that is, the kilometres travelled by motor vehicles on the highway network. We first compute its value at the segment level by multiplying the length of each highway segment (kilometre) with its AADT. Then, we compute the VKT at the FUA level by summing the values for all highway segments located within each FUA. Unfortunately, information about travel speeds is not available and, as a result, we measure congestion in terms of quantity.

Table 1 reports the computations of these indicators for our sample of 545 European cities: Average values for both AADT and VKT, and individual VKT values for the top 10 and the bottom 10 cities with population over 1 million inhabitants. Regarding the AADT,

3 Thirty-four cities have not been considered in the final sample due to the lack of congestion data.
4 Unfortunately, more recent censuses for 2010 and 2015 do not cover all European countries, only some of them.

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Table 1. Highway congestion in European cities, 1985–2005

	1985	1995	2005	1985–1995	1995–2005	1985–2005
AADT (vehicles)—FUA	15,900	21,358	27,020	34.3%	26.5%	69.9%
	(15,318)	(19,237)	(21,837)			
VKT ('000 km)—FUA	2,673	3,603	4,586	34.8%	27.2%	71.6%
	(3959)	(4722)	(5426)			
VKT for the top 10 FUAs with population over 1 million ('000 km)						
London (UK)	57,435	62,633	66,830	9.1%	6.7%	16.4%
Madrid (ES)	21,754	20,737	39,644	−4.7%	91.2%	82.2%
Ruhrgebiet (DE)	20,326	28,405	29,964	39.7%	5.5%	47.4%
Frankfurt (DE)	24,217	27,500	28,810	13.6%	4.8%	19.0%
West Midlands (UK)	25,282	25,578	28,608	1.2%	11.8%	13.2%
Berlin (DE)	13,610	20,425	24,930	50.1%	22.0%	83.1%
München (DE)	18,386	19,747	23,111	7.4%	17.0%	25.7%
Amsterdam (NL)	10,969	22,204	22,304	102%	0.5%	103 %
Hamburg (DE)	17,212	22,548	22,169	31.0%	−1.7%	28.8%
Manchester (UK)	16,368	19,421	21,231	18.7%	9.3%	29.7%
VKT for the bottom 10 FUAs population over 1 million ('000 km)						
Leipzig (DE)	4,632	5,849	6,954	26.3%	18.9%	50.1%
Napoli (IT)	3,526	5,877	5,798	66.7%	−1.3%	64.5%
Torino (IT)	1,774	5,272	5,289	197%	0.3%	198%
Porto (PT)	1,081	3,443	5,125	218%	48.8%	374%
Sofia (BG)	2,745	3,495	5,039	27.3%	44.2%	83.6%
Ostrava (CZ)	902	1,227	3,825	36.0%	212%	324%
Krakow (PL)	1,732	2,127	3,753	22.8%	76.5%	117%
Katowice (PL)	1,012	1,856	3,708	83.5%	99.8%	267%
Gdansk (PL)	1,419	1,591	2,806	12.1%	76.4%	97.7%
Bucuresti (RO)	738	1,051	2,135	42.5%	103%	189%

Notes: FUA's values are averages. Standard deviations in parenthesis.

an average European city in 2005 had 15,900 vehicles passing any point of the highway network. Between 1985 and 2005, the number of vehicles increased by 70%. Figure 1(a) and (b) shows that the increase of the AADT was a general feature in all Europe.

VKT figures in Table 1 and Figure 1(c) and (d) also show high levels of traffic on highways and a growth between 1985 and 2005. On average, motor vehicles travelled 2.7 and 4.6 million km in 1985 and 2005, respectively. Focusing on the most populated cities, the top 10 cities had VKT values above the 20 million km. Their traffic grew with rates ranging from 13% in West Midlands (UK) to 103% in Amsterdam (NL). The cities with lowest VKT had values in 2005 between 2 million km (Bucuresti, RO) and almost 7 million km (Leipzig, DE). All these cities experienced significant increases in their traffic levels, between 50% (Leipzig, DE) and more than 300% (Ostrava, CZ; Porto, PT).

2.2. Highways in Europe

To measure the size of the highway network, we compute the so-called 'lane kilometres'. First, we multiply the length (kilometres) of each highway segment with the number of lanes. Then, we sum the resulting values for segments located within each city. As above

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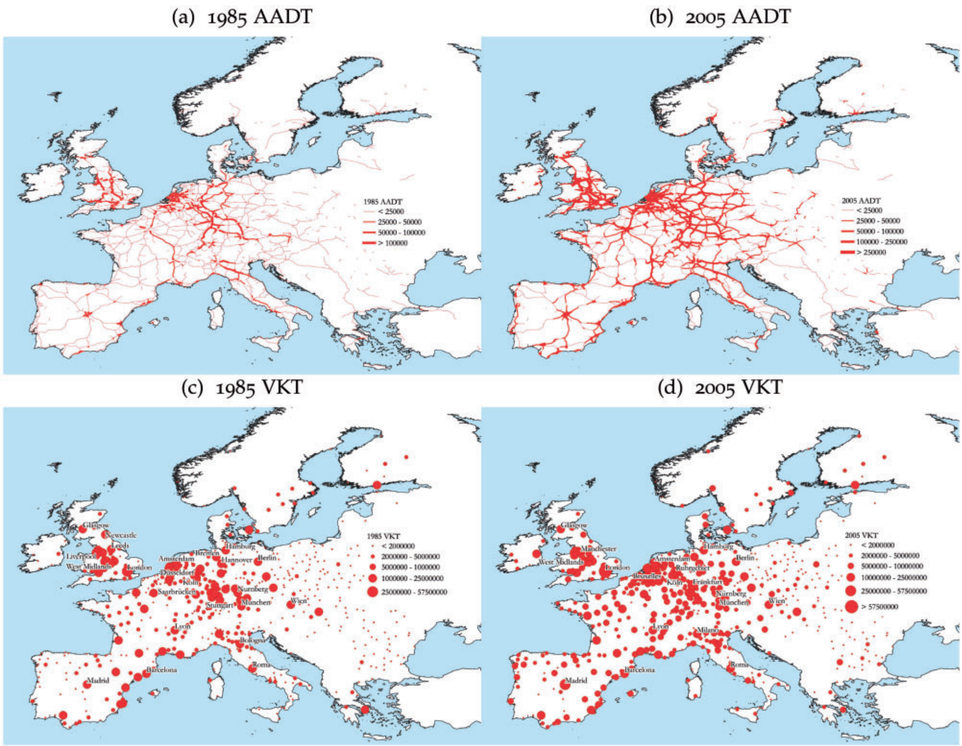

Figure 1. Highway congestion in Europe. (**a**) 1985 AADT. (**b**) 2005 AADT. (**c**) 1985 VKT. (**d**) 2005 VKT.

mentioned, the UNECE Road Traffic Censuses also provide information on segment length and lanes.

Table 2 presents the main characteristics of the highway network in 1985, 1995 and 2005 in Europe and in our sample of 545 cities. For more than 74,000 km of European highways in 2005, almost half of them were located in FUAs. Between 1985 and 2005, the network more than doubled. Figure 2(a) shows the evolution of the highway network in Europe between 1985 and 2005.

Table 2 also reports average computations for the 545 FUAs and shows that highways were extended both in terms of their coverage and their capacity. First, the length of the highway network of an average FUA increased from 127 to 184 km (a 45%) between 1985 and 2005. Second, the average number of lanes per direction also increased from 1.6 to 2.1 in 20 years. As a result, the number of lane kilometres of the average FUA increased from 1,666 in 1985 to 1,884 km in 2005. The high standard deviations of these three variables (in parenthesis) and their related maps in Figure 2(b)–(d) indicate that the European cities show a high degree of heterogeneity.

Figure 2(e) shows a categorisation of the share of tolled highway kilometres in the 545 FUAs. In 2005,[5] an average city had a 25% of tolled highways. However, our sample

5 Unfortunately, only the 2005 UNECE Road Traffic Census provides this kind of information at the highway segment level.

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Table 2. Highways in European cities, 1985–2005

	1985	1995	2005	1985–1995	1995–2005	1985–2005
Total length (km)—Europe	28,196	52,077	74,219	84.7%	74.2%	163%
Total length (km)—FUA	14,747	23,070	35,328	56.4%	53.1%	140%
Average length (km)—FUA	127	139	184	9.4%	32.3%	44.9%
	(106)	(107)	(146)			
Average number of lanes—FUA	1.6	1.9	2.1	18.7%	10.5%	31%
per direction	(0.9)	(1.0)	(1.2)			
Average Lane kilometres—FUA	1,666	1,762	1,884	5.8%	6.9%	13.1%
	(1441)	(1501)	(1575)			

Notes: Standard deviations in parenthesis.

includes cities without tolls (285) and with tolls (260). Among the latter, 77 cities have tolls in all their highways.

According to Albalate and Bel (2012), tolls in Europe are mostly used to finance construction and maintenance costs of highways. However, more recently some cities have adopted congestion pricing policies—the so-called urban tolls—in order to reduce the impact of traffic (congestion, noise and pollution). Figure 2(e) shows the 14 cities that, according to https://www.urbanaccessregulations.eu, apply ‘congestion prices’ in 2020.

3. Empirical strategy

3.1. Pool, panel and first difference

In this section, we introduce the empirical framework used to estimate the effect of the highway network expansion on the level of congestion. Increasing the supply of highways is expected to lower the cost of motor vehicle use in the short run because of the increase in the overall highway capacity in a city, which decreases traffic congestion. However, this reduction in the major component of the cost of motor vehicle use might affect the travel decisions of individuals regarding the mode and quantity of travel. The ‘fundamental law of highway congestion’ suggests that the long-term average effect of increasing the supply of roads will be that induced demand will bring the level of congestion back to its initial level (or even to a higher one).

To empirically study the role played by highways improvements on highway congestion, we index cities by i and years by t, and estimate the following equation:

$$\begin{aligned}\ln(\text{VKT}_{it}) = \beta_0 + \beta_1 \times \ln(\text{Lanekm}_{it}) \\ + \beta_2 \times \ln(\text{Population}_{it}) + \beta_3 \times \text{Socioeconomy}_{it} \\ + \beta_4 \times \text{Geography}_i + \beta_5 \times \text{History}_i + \epsilon_{it}\end{aligned} \quad (1)$$

where VKT_{it} refers to the VKT and measures the kilometres travelled by motor vehicles in the highway network. The main explanatory variable is Lanekm_{it} and refers to the number of highway lane kilometres. Population_{it} is the number of inhabitants from official population censuses provided by the DG REGIO of the European Commission. Socioeconomy_{it} is a vector of characteristics including income, proxied by GDP; unemployment rate; and

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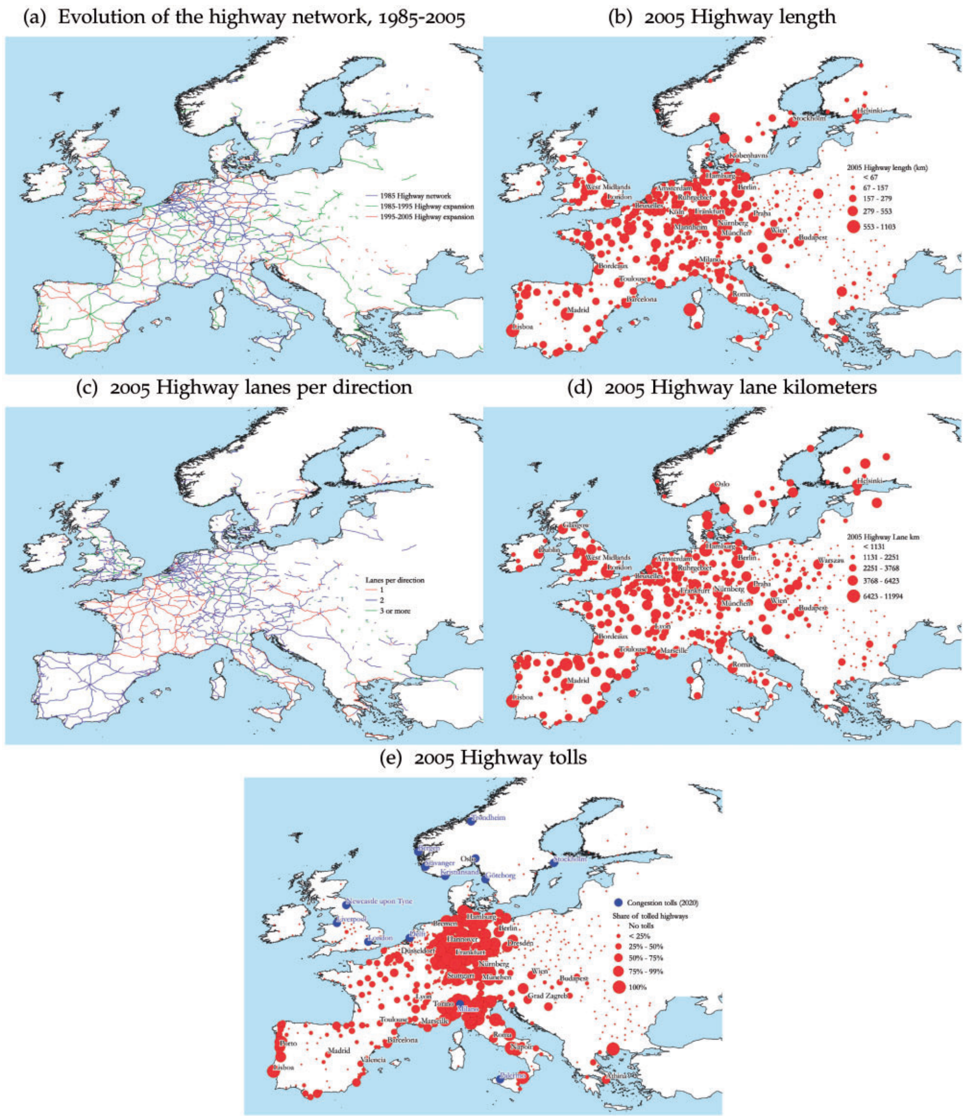

Figure 2. Highways in Europe. (**a**) Evolution of the highway network, 1985–2005. (**b**) 2005 highway length. (**c**) 2005 highway lanes per direction. (**d**) 2005 highway lane kilometres. (**e**) 2005 highway tolls.

industrial composition, proxied by the shares of employment in manufacturing, in financial and business services and in non-market services. Since there are no data available at the FUA level, all three variables are computed using data from the NUTS3 in which the FUA is located. Geography$_i$ includes controls for physical geography such as total land area (km^2); a suburbanisation index, which is the share of the central city area; the altitude (metres), elevation range (metres) and the terrain ruggedness index computed *à la* Riley

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et al. (1999) using the Digital Elevation Model over Europe (EU-DEM)[6]; and the logarithm of the distance (metres) to the closest coast from the centroid of the central city. Finally, History_i adds two types of historical controls. First, dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850.[7] Second, three controls for more recent history (the 20th century): The logarithms of the decennial levels of population between 1960 and 1980.

With data describing a panel of cities, we can partition ϵ_{it} into permanent (δ_i) and time-varying (η_{it}) components. By so doing, we can remove all time-invariant city effects by estimating Equation (1) using city-fixed effects (Equation (2)) or its first-difference version (Equation (3)):

$$\begin{aligned}\ln(\text{VKT}_{it}) = \beta_1 \times \ln(\text{Lanekm}_{it}) \\ + \beta_2 \times \ln(\text{Population}_{it}) + \beta_3 \times \text{Socioeconomy}_{it} + \delta_i + \eta_{it}\end{aligned} \tag{2}$$

$$\begin{aligned}\Delta\ln(\text{VKT}_{it}) = \beta_1 \times \Delta\ln(\text{Lanekm}_{it}) \\ + \beta_2 \times \Delta\ln(\text{Population}_{it}) + \beta_3 \times \Delta\text{Socioeconomy}_{it} + \Delta\eta_{it}\end{aligned} \tag{3}$$

where Δ is the first-difference operator.

3.2. Instrumental variables

When the random element of traffic congestion is uncorrelated with highways, we can estimate Equations (1)–(3) by ordinary least squares (OLS). However, highway lane kilometres are expected to be endogenous to VKT because of reverse causation (e.g. congestion fostering highway expansion), measurement error (e.g., highways mismeasured because some may have just opened or are about to be opened) and omitted variables (e.g. geography, amenities or economic structure leading to more highways).

To address concerns of endogeneity, we rely on IV estimations (limited-information maximum likelihood, LIML). We use the digital vector maps created and used by Garcia-López (2019) to built instruments based on the ancient road and railroads in Europe: The main and secondary roads during the Roman Empire (McCormick et al., 2013), the main trade routes in the Holy Roman Empire in the 15th century (Ciolek, 2005), the postal roads in 1810 according to A. Arrowsmith's map[8] and the railroad network in 1870 (Marti-Henneberg, 2013). Figures A.1 and A.2 in Appendix A.1 shows their location in Europe and Barcelona, respectively.

Since, by definition, these historical instruments are *time-invariant*, we follow Baum-Snow (2007) and Garcia-López (2012, 2019) and adopt a 'shift-share' approach *a la* Bartik (1991) using each historical (rail)road as the 'share' component and the evolution of the highway network as the 'shift' component. Specifically, we compute each *time-variant* historical instrument by multiplying its historical length (in kilometres) by the fraction of the highway network kilometrage in each country completed at each year and excluding each city's own contribution.

6 The original GIS raster maps are available in https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem.

7 These dummies are computed using information from the Digital Atlas of Roman and Medieval Civilizations (DARMC, http://darmc.harvard.edu) and from Bairoch et al. (1988).

8 See the David Rumsey Map Collection (http://www.davidrumsey.com) for the original paper maps.

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As common sense suggests, historical transportation networks may be relevant because modern networks are not built in isolation from them. On the contrary, it is easier and cheaper to build new infrastructures close to old infrastructures. Duranton and Turner (2011, 2012), Garcia-López (2012) or Garcia-López et al. (2015), among others, show that the stocks of historical (rail)roads are indeed highly correlated with the stocks of modern transportation networks in the US, Barcelona and Spain, respectively.

We econometrically test the relevance of each *time-variant* historical (rail)road in Appendix A.2. Specifically, Table A.1 shows OLS results when we regress the highway lane kilometres on the length of each ancient (rail)road (kilometre) following a pooled strategy (Columns 1–3, Equation (A.1)) and panel-fixed effect strategy (Columns 4 and 5, Equation (A.2)). We also follow a first-difference strategy regressing the changes in the highway lane kilometres on changes in the length of each ancient (rail)road (kilometres) (Columns 6 and 7, Equation (A.3)), and adding the lag of VKT while controlling for geography, history and country-fixed effects (Columns 8 and 9) or for FUA-fixed effects (Columns 10 and 11). According to Murray (2006), valid instruments should have significant effects on modern highway lane kilometres and high first-stage F-statistics. First-stage results show that both Roman roads and the 1870 railroads predict the congestion level when we follow a pooled regression strategy (Columns 1 and 2). However, when we use a panel-fixed effect and first-difference regressions (Columns 4, 6, 8 and 10), only the Roman roads predict both the levels and the changes in the highway lane kilometres. Results also show first-stage F-statistics are near or above Stock and Yogo (2005)'s critical values, in particular when only Roman roads are used as instrument.

Our *time-variant* historical instrument also needs to be exogenous. As Garcia-López (2019) explains in detail, its 'shift' element is exogenous because, by construction, it refers to the length of the highway network that would have existed in each year had governments allocated highway construction uniformly across Roman roads within the countries. The 'share' component, the length of Roman roads, may also be exogenous because Roman roads were not built to anticipate the current traffic congestion levels in European cities. On the contrary, they were built to achieve military, administrative and commercial goals between different parts of the Roman Empire (Garcia-López et al., 2015; Garcia-López, 2019). However, since geography and history have influenced both the evolution of European cities and its transportation networks, the exogeneity of the Roman instrument hinges on controlling for those characteristics as in the pooled regression strategy (Equation (1)). Alternatively, we can add city-fixed effects as in Equation (2) or estimate a first-difference regression as in Equation (3).

4. Does the fundamental law of highway congestion apply in Europe?

4.1. Main results

The fundamental law of highway congestion has been confirmed in the US (Duranton and Turner, 2011) and Japan (Hsu and Zhang, 2014). In this section, we investigate whether this (more than) proportional increase in congestion levels when highways are expanded also applies in Europe.

Table 3 reports OLS and LIML results in Columns 1–5 and 6–7, respectively, when we regress the log of VKT on the log of highway lane kilometres. In Columns 1 and 6, we follow a pooled strategy and estimate Equation (1) without control variables. In Columns

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Table 3. The effect of highways on traffic congestion, OLS and IV results

Dependent variable:	ln(VKT)									
	OLS results					IV results				
	Pool		Panel			Pool		Panel		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
ln(Lane km)	1.072^{a}	0.831^{a}	1.315^{a}	0.686^{a}	0.695^{a}	2.077^{a}	1.558^{a}	2.710^{a}	1.285^{a}	1.205^{a}
	(0.036)	(0.034)	(0.099)	(0.097)	(0.097)	(0.271)	(0.272)	(0.598)	(0.337)	(0.314)
ln(Population)		0.815^{a}		−0.080	−0.048		0.545^{c}		0.097	0.101
		(0.223)		(0.363)	(0.364)		(0.283)		(0.363)	(0.364)
Geography		✓					✓			
History		✓					✓			
Socioeconomy		✓			✓		✓			✓
Country FE		✓					✓			
FUA FE			✓	✓	✓			✓	✓	✓
Year FE		✓		✓	✓		✓		✓	✓
Adjusted R^2	0.60	0.89	0.31	0.70	0.71					
F-S *F*-stat						22.88	12.01	16.15	19.90	19.79
Instrument						ln(Km of Roman r.)		ln(Km of Roman roads)		

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

2 and 7, we add all control variables. Columns 3–5 and 8–10 show results when we follow a fixed panel strategy and estimate Equation (2) gradually adding time-variant explanatory variables: the log of lane kilometres in Columns 3 and 8, the log of population and year-fixed effects in Columns 4 and 9 and socioeconomic controls in Columns 5 and 10. Table 3 also reports first-stage statistics for the LIML regressions (which use the log of the *time-variant* length of Roman roads as instrument), and all of them are near or above Stock and Yogo (2005)'s critical values.

The estimated OLS coefficient of interest is positive and significantly different from zero in all specifications and shows that a 1% increase in the log of lane kilometres increases the VKT between 0.7% (Column 5) and 0.8% (Column 2). After addressing concerns of endogeneity, LIML counterparts in Columns 7–10 show a higher impact of highways on congestion between 1.2% and 1.6%, respectively.

Appendix B provides additional results following a pooled strategy. In Table B.1, we estimate Equation (1) for each year: 1985, 1995 and 2005. OLS and LIML results are between 0.8–0.9 and 1.3–1.8, respectively, and are not statistically different from their

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counterparts in Table 3. In Table B.2, we show that the estimated coefficient of interest is quite stable when we gradually add explanatory variables to the pooled regression.

We also perform a set of robustness checks in Table C.1 of Appendix C. First, to address endogeneity concerns about the population variable (Duranton and Turner, 2011), in Panel A we follow the pooled strategy and estimate Equation (1) instrumenting the population variable with two time-invariant instruments: the average temperature and the average precipitation of the FUA. In Column 1, we only instrument population and in Column 2, we simultaneously instrument the two endogenous variables. In both cases, the associated first-stage statistics are above and close to the Stock and Yogo (2005)'s critical values, respectively. Furthermore, the OLS and LIML results are in line with those in Columns 2 and 7 of Table 3.[9]

Second, we are worried that some country-specific shocks may have affected both the evolution of highways and congestion at the country level. To allow the countries to have different time trends, in Panel B, we follow the panel-fixed effect strategy and estimate Equation (2) adding country-specific linear trends in Columns 3 and 4. Both OLS and LIML results hold. To test for the possible impact of the European Union integration process, we have introduced a time dummy to control for the year in which each country was part of the EU. The results remained the same.

Third, another potential concern is that the increase in highway traffic and the highway development are both affected by the supply of other roads that are not classified as highways.[10] In Panel C, we estimate Equation (2) adding the length of secondary roads and the length of local roads as explanatory variables. Since these two additional variables are also endogenous, we instrument them in Column 6 using the *time-variant* lengths of the 15th c. trade routes during the Holy Roman Empire and of the 1810 post routes.[11] The related first-stage F-statistic is near the Stock and Yogo (2005)'s critical value. Results for the lane kilometres are not statistically different from those in Columns 2 and 7 of Table 3. Interestingly, the expansion of secondary roads decreases highway congestion, but the effect is quite small (0.02–0.03).

Finally, we also test for the functional form of the effect under study. One might expect that the effect of highway expansion on traffic congestion depends crucially on the extent of the highway network in each city. In Panel D, we add the square of the log of lane kilometres. Results show that this quadratic term is not statistically significant and its value is very close to zero. Furthermore, the estimated coefficient for lane kilometres is in line with previous results.

Now we change our empirical strategy and follow the first-difference approach by estimating Equation (3). Table 4 presents OLS and LIML results in Columns 1–5 and 6–10, respectively. Columns 1–3 and 6–8 show results when we gradually add time-variant explanatory variables: Only the change in lane kilometres (Columns 1 and 6), adding the

9 There is a considerable increase of the lane kilometre coefficient in Column 2. However, it is important to note that in Column 1, where we just instrument the population variable, the estimated coefficient for lane kilometres is very similar to the one we obtain when we do not instrument any variable (Table 3, Column 2). This makes us confident that when we do not instrument the population variable, we are not biasing the results of lane kilometres. This is similar to what Duranton and Turner (2011) explain when studying the possible endogeneity of the population variable.

10 We use data of secondary and local roads provided by the EC DG-REGIO (for more details, see Stelder, 2016).

11 We build these instruments using the 'shift-share' approach explained in Section 3.2. The length of each historical (rail)road is the 'share' component and the evolution of the country transportation network (excluding each city's own contribution) is the 'shift' component.

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Table 4. The effect of highways on traffic congestion, OLS and IV results: First difference

Dependent variable:	Δln(VKT)									
	OLS results					IV results				
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Δln(Lane km)	0.632[a]	0.633[a]	0.638[a]	0.520[a]	0.243[a]	1.190[a]	1.177[a]	1.249[a]	1.104[b]	1.138[a]
	(0.103)	(0.103)	(0.103)	(0.092)	(0.063)	(0.328)	(0.361)	(0.375)	(0.438)	(0.306)
Lagged ln(VKT)				−0.161[a]	−1.057[a]				−0.131[a]	−0.874[a]
				(0.020)	(0.048)				(0.039)	(0.088)
Δln(Population)		0.044	0.065	0.407	−0.066		−0.050	−0.051	0.139	−0.138
		(0.355)	(0.366)	(0.262)	(0.279)		(0.353)	(0.351)	(0.257)	(0.166)
Geography				✓					✓	
History				✓					✓	
ΔSocioeconomy			✓	✓	✓			✓	✓	✓
Country FE				✓					✓	
FUA-fixed effects					✓					✓
Adjusted R^2	0.32	0.32	0.33	0.41	0.80					
F-S *F*-stat						23.58	22.01	21.26	14.12	16.22
Instrument						Δln(Km of Roman roads)				

Notes: 1090 observations (545 cities × 2 first-difference periods) in each regression. Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

change in population (Columns 2 and 7) and including the changes in socioeconomic controls (Columns 3 and 8). Since all time-invariant factors drop out of Equation (3), we add geography, history and country dummies as control variables in Columns 4 and 9, and add FUA-fixed effects in Columns 5 and 10. Moreover, we also add the logarithm of the lagged VKT in Columns 4–5 and 9–10. Table 4 also reports first-stage statistics for the LIML regressions (which use the log of the *time-variant* change in the length of Roman roads as instrument), and all of them are above Stock and Yogo (2005)'s critical values.

Results for the OLS regressions show elasticities of the change in lane kilometres ranging between 0.2 in the most demanding specification (Column 5) and 0.6 in the *pure* first-difference specification (Column 3). After instrumenting lane kilometres with the *time-variant* Roman road instrument, LIML results for the different specifications are quite stable and show an elasticity around 1.2%. Both OLS and LIML results are in line with those using pooled and panel-fixed effect approaches in Table 3.

The fundamental law of highway congestion states that a capacity expansion of highways produces a (more than) proportional increase in highway congestion levels. LIML results when using pooled, panel and first-difference empirical strategies confirm that this

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law also applies in European cities. Focusing in our preferred specification in Column 10 of Table 3 that follows a panel-fixed effect estimation, a 1% increase in the highway lane kilometres increases the VKT by 1.2%. This elasticity is slightly higher than the one obtained by Duranton and Turner (2011) for the US (1.02) and almost the same than the estimated by Hsu and Zhang (2014) for Japan (1.24).

A qualifier is important here. While the previous conclusions apply for the point estimates, the picture is mixed when we take into account their confidence intervals. For the case of the pooled results, their IV-estimated coefficients are statistically higher than 1, indicating that highway expansions cause a more than proportional increase in travel quantity (VKT). However, panel and first-difference results report IV point estimates that are not statistically different from 1 and, in most cases, from 0.7, indicating a (less than) proportional increase in VKT. In other words, when we consider confidence intervals, it is not totally clear whether the fundamental law applies. We explore this question in more detail in Section 5.2, in which we introduce the effects of public transportation that, in the case of the European cities, we consider a more robust and not biased specification.

4.2. Coverage and capacity effects

A highway network can be extended by increasing the number of lanes, that is, its 'capacity.' Another way is extending the length of existing routes or creating new ones, that is, increasing the 'coverage' of the highway network. After confirming that the fundamental law apply to European cities, we now turn our attention to study whether the effect of an increase in highway provision is related to a 'coverage effect' and/or to a 'capacity effect.'

Based on previous main results, we depart from our preferred panel-fixed effect approach to estimate an equation that consider both the length of the highway network and the average number of highway lanes[12]:

$$\begin{aligned}\ln(\text{VKT}_{it}) = \beta_{1a} &\times \ln(\text{Km of highways}_{it}) \\ &+\beta_{1b} \times \text{Average number of lanes}_{it} \\ &+\beta_2 \times \ln(\text{Population}_{it}) + \beta_3 \times \text{Socioeconomy}_{it} + \delta_i + \eta_{it}\end{aligned} \tag{4}$$

It is important to notice that these two variables are also endogenous and, as a result, need to be instrumented. For the case of the length of highways, Garcia-López (2019) shows that historical (rail)roads and, in particular, Roman roads, are good predictors of this variable. Table A.2 of Appendix A.3 reports first-stage OLS results when we regress the log of kilometres of highways on the log of kilometres of our *time-variant* historical (rail)roads conditional on controls. In Column 1, we separately include the four old (rail)-roads and find that only Roman roads has a positive and significant effect. In Column 2, we only include the Roman roads and confirm its effect. In both cases, the first-stage F-statistic is near Stock and Yogo (2005)'s thresholds.

As shown by Garcia-López (2012), Garcia-López et al. (2015) and Garcia-López et al. (2017a, 2017b), the location of modern highways is also related to the location of historical (rail)roads. In fact, when mapping these old (rail)roads we realise that most of them are located very close to each other (see, e.g. the case of Barcelona in Figure A.2). This could mean that, conditional on the geography, building additional lanes is easier and cheaper in

12 We consider the number of lanes in each highway segment and compute the average for each city.

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Table 5. The effect of highways on traffic congestion, IV results: Length and lanes

Dependent variable:	ln(VKT)				
Instrumenting:	Length [1]	Lanes [2]	Both [3]	Lanes [4]	Both [5]
ln(Km of highways)	2.293[a] (0.561)		1.146[a] (0.288)		1.287[a] (0.208)
Number of lanes		2.117[a] (0.493)	2.198[a] (0.369)	2.702[a] (0.513)	2.540[a] (0.333)
ln(Population)	−0.557 (0.895)	1.226[a] (0.363)	0.162 (0.400)	1.137[a] (0.421)	−0.019 (0.398)
Socioeconomy	✓	✓	✓	✓	✓
FUA FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
First-Stage *F*-statistic	11.52	26.29	7.65	11.78	8.47
Instruments	ln(Roman roads)	Number of all historical (rail)roads	ln(Roman roads) Number of all historical (rail)roads	Number of each historical (rail)road	ln(Roman roads) Number of each historical (rail)road

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

those highway segments where we also find more old (rail)roads in parallel. Based on this idea, we instrument the average number of highways lanes with the average number of historical (rail)roads.[13] Column 3 of Table A.2 shows first-stage results when we consider the average number of *all* historical (rail)roads. In Column 4, we separately consider the average number of *each* historical (rail)road. In both cases, estimated coefficients are positive and significant. The related first-stage *F*-statistics are above the Stock and Yogo (2005)'s thresholds.

Table 5 reports LIML results of estimating different specifications of Equation (4). First, we separately consider the logarithm of the highway length (Column 1) and the average number of lanes (Columns 2 and 4). Later, we jointly include both variables in Columns 3 and 5. Since both variables are expected to be endogenous, we instrument them with the above mentioned instruments: The length of historicals (rail)roads (Columns 1, 3 and 5), the average number of all historical (rail)roads (Columns 2 and 3) and the average number of each historical (rail)road (Columns 4 and 5). These LIML results show positive effects of extending highway routes and increasing lanes. In particular, our preferred results in Column 3 indicate that doubling the highway network, either by increasing the highway length by 100% or by building one additional lane in all highway segments, causes a 114% and a 212% growth in the VKT, respectively. These elasticities confirm both the coverage and capacity effects, being the latter more important. In Appendix D, we confirm these results using the log of the number of lanes as explanatory variable.

13 For each year and highway segment, we compute the number of historical (rail)roads that are located in parallel less than 1 km. Then, we compute the average for each city.

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5. Do tolls and public transportation matter?

Compared with US cities, there are at least two prominent features in European cities: The use of tolls, and the massive investment in public transportation, in particular, in railroads. In this section, we study whether these two characteristics affect the fundamental law of highway congestion.

5.1. Tolls

As discussed in Section 2.2, in 2005 almost half of the cities included in our sample had tolls (260 out of 545) and, on average, these tolls affected 25% of the highway network. To analyse the role of these tolls, we depart from the panel-fixed effect approach to estimate an equation that includes the interaction of our main explanatory variable:

$$\begin{aligned}\ln(\mathrm{VKT}_{it}) = {} & \beta_1 \times \ln(\text{Lane km}_{it}) \\ & + \beta_2 \times \ln(\text{Lane km}_{it}) \times \text{Tolls}_i \\ & + \beta_3 \times \ln(\text{Population}_{it}) + \beta_4 \times \text{Socioeconomy}_{it} + \delta_i + \eta_{it}\end{aligned} \qquad (5)$$

Table 6 shows results for Equation (5). In Column 1, we interact lane kilometres with a dummy for cities with tolled highways. In Column 2, the interaction variable is a dummy for cities with 25% or more of tolled highways. Finally, we directly interact lane kilometres with the share of tolled highway segments in Column 3. Results are essentially identical and show that (1) highway improvements increase congestion, (2) the effect is smaller in cities with tolls and (3) fundamental law is mainly related to cities without tolls or with a low percentage of tolled highways. In particular, and focusing on our preferred specification in Column 3 (using a continuous interaction), a 1% increase in lane kilometres increases congestion by 1.9% in cities without tolls and by only 0.3% (=1.9–1.6) in cities with tolls in all their highways (100% share of tolled highways). Some simple computations show that the fundamental law applies to cities with a share of tolled highways below 56%. These results can be regarded as novel evidence in line with recent literature suggesting that the solution to traffic congestion is the adoption of 'congestion' pricing policies (Santos, 2004; de Palma et al., 2006; Eliasson and Mattsson, 2006; Leape, 2006; Winston and Langer, 2006).

Finally, in Appendix E, we follow an alternative empirical strategy based on estimating Equation (2) for two subsamples: Cities with tolls versus without tolls. Results reported in Table E.1 confirm that highway tolls mitigate the induced demand effect of highway expansions.

Two additional qualifiers are important here. First, the above results assume that tolls in Europe are exogenous to traffic because, as discussed in Section 2.2, at that period they were mostly used to finance construction and maintenance costs of highways (Albalate and Bel, 2012). Additionally, only 14 of our 545 cities have recently adopted 'congestion' pricing policies in order to reduce the impact of traffic (congestion, noise, pollution, etc.), and, when we do not consider them in the analysis, the results hold. However, it might still be that endogeneity is not fully addressed if governments allocate tolls in those highway segments with most traffic. Therefore, the above results should be read with caution.

Second, if we consider the confidence intervals as in Section 4.1 for the lane kilometres coefficient in Column 3, there is small probability that the coefficient could be 0.89 (below 1 indicating a less than a proportional impact). What is clear is that, considering the confidence intervals, the toll road impact is always negative and significantly different

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Table 6. The effect of highways on traffic congestion, IV results: Tolls and interactions

Dependent var.:	ln(VKT)			
Interacting:	All tolled cities [1]	Above 25% tolls cities [2]		Share of tolled highways [3]
ln(Lane km)	1.903[a]	2.106[a]	ln(Lane km)	1.894[a]
	(0.560)	(0.743)		(0.629)
ln(Lane km) ×Dummy tolls	−1.203[b]	−1.454[b]	ln(Lane km) ×Share tolls	−1.598[b]
	(0.527)	(0.685)		(0.785)
ln(Population)	−0.020	−0.063	ln(Population)	−0.049
	(0.276)	(0.284)		(0.281)
Socioeconomy	✓	✓	Socioeconomy	✓
FUA FE	✓	✓	FUA FE	✓
Year FE	✓	✓	Year FE	✓
First-Stage *F*-stat	11.18	7.62	First-Stage *F*-stat	4.50
Instruments	ln(Km of Roman roads) ln(Roman) × Tolls	ln(Km of Roman roads) ln(Roman) × 25% Tolls	Instruments	ln(Km of Roman roads) ln(Roman) × Share tolls

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

from zero. In the next section, we study this question in detail by also controlling for the effect of the supply of public transportation.

5.2. Public transportation

Now we turn our attention to public transportation and, in particular, the railroad network. In Europe, it was mainly built during the 19th and 20th centuries and nowadays there are more than 225,000 km of rail lines. At the FUA level, the network expanded from 32,000 to 52,000 km between 1985 and 2005. On average, the network increased more than 60%, from 59 to 96 km. Some examples of the more recent railroad expansion are the construction of the Regional Express Rail (RER) network in Paris (Garcia-López et al., 2017a, 2017b) or the introduction of the high-speed rail in Germany (Ahlfeldt and Feddersen, 2018), Spain (Albalate et al., 2017) and the UK (Heblich and Simpson, 2018).

We study the effect of railroads[14] on congestion by estimating a version of Equation (2) which includes the length of railroads as explanatory variable:

$$\begin{aligned}\ln(\text{VKT}_{it}) = \beta_1 &\times \ln(\text{Lane km}_{it}) \\ &+\beta_2 \times \ln(\text{Km of railroads}_{it}) \\ &+\beta_3 \times \ln(\text{Population}_{it}) + \beta_4 \times \text{Socioeconomy}_{it} + \delta_i + \eta_{it}\end{aligned} \quad (6)$$

14 Unfortunately, there is no data available for all the cities and the period of our analysis on public buses.

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Table 7. The effect of highways on traffic congestion, IV results: Public transportation

Dependent variable:	ln(VKT)		
		Interacting with the share of subways	
	[1]	[2]	[3]
ln(Lane km)	2.208[a]	1.408[a]	1.407[a]
	(0.531)	(0.324)	(0.344)
ln(Km of railroads)	−0.533[b]	−0.488[b]	−0.562[b]
	(0.270)	(0.240)	(0.268)
ln(Km of railroads)		−0.660[c]	−1.384[c]
×Share of subways		(0.393)	(0.760)
ln(Population)	−0.605	−0.351	−0.394
	(1.048)	(0.513)	(0.564)
Socioeconomy	✓	✓	✓
FUA FE	✓	✓	✓
Year FE	✓	✓	✓
Share of subways		✓	✓
First-Stage *F*-stat	4.98	3.31	2.12
Instruments	ln(Km of Roman roads) ln(Km of 1870 railroads)	ln(Km of Roman roads) ln(Km of 1870 railroads)	ln(Km of Roman roads) ln(Km of 1870 railroads) ln(1870 Rail) × % Subways

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

Since the stock of railroads may also depend on the level of highway congestion, now we have to deal with an additional endogenous variable. To do so, we follow Garcia-López (2019), which shows that the 1870 railroad network is a good predictor of the length of modern railroads. Table A.3 of Appendix A.4 reports first-stage OLS results when we regress the log of kilometres of railroads on the log of kilometres of our *time-invariant* historical (rail)roads conditional on controls. In Column 1, we separately include the four old (rail)road networks and find that only the 1870 railroads has a positive and significant effect. In Column 2, we only include the 1870 railroad network and confirm its effect. In both cases, the first-stage *F*-statistic is near Stock and Yogo (2005)'s thresholds.

Column 1 of Table 7 reports LIML results when we estimate Equation (6). They confirm the positive effect of lane kilometres on travel quantity. If we consider the confidence interval, as in Section 4.1, the IV point estimate is now significantly higher than 1, indicating that highway expansions cause a more than proportional increase in VKT. As a result, when we estimate a more complete empirical specification, which includes the supply of public transportation, we confirm that the fundamental law of highway congestion applies in European cities (with more than proportional effects).

On the other hand, the results for railroads are also very interesting. Their estimated coefficients in all three columns of Table 7 are significant and, more important, negative. They indicate that the supply of public transportation (railroads) directly moderate

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highway congestion in terms of (travel) quantity. In particular, a 1% increase in the length of the railroad network decreases congestion (VKT) by 0.5%.

Subways are important in the largest European cities because a high proportion of their mobility is based on this transportation mode (Gonzalez-Navarro and Turner, 2018). In our sample, 32 cities have a subway network within their cores and connecting with their suburbs. The subway network of the average city had 52 km in 2011 and it represented around 14% of the total railroad length. To study whether subways also matter for congestion, we estimate Equation (6) including the interaction[15] between the railroad length and the share of subways. Column 2 shows LIML results when we only instrument lane km and railroad length. Our preferred specification in Column 3 reports LIML estimates when the interaction term is also instrumented. In this case, results confirm (1) the fundamental law of highway congestion (with a VKT elasticity above 1) and (2) the above mentioned negative effect of railroads on congestion. Furthermore, the negative estimated coefficient for the interaction term shows that (3) the more important the subways in the railroad network, the higher the reduction of congestion. In particular, a 1% increase in the length of the railroad network decreases congestion by 0.6% in a city without subways, by 0.8% in a city with the average share of subways (14%) and by 1.3% in a city where subways are 50% of the total railroad network.

In summary, the above results point out that railroads serve to free up highway capacity by taking drivers off the highways and putting them in trains. These findings are in contrast to those of Duranton and Turner (2011), who find no effect of public transit on congestion. However, their empirical evidence is based on regular buses, which are as prone to traffic congestion as motor vehicles. On the contrary, our findings are in line with those of Anderson (2014), Adler and van Ommeren (2016), Bauernschuster et al. (2017), Adler et al. (2020) and Russo et al. (2021), who find that public transit generates large congestion relief benefits.

6. Conclusions

In this paper, we provide evidence that the 'fundamental law of highway congestion' holds for the cities of Europe, but also that well-designed public policies can moderate this congestion. We use data for the 545 largest European cities to estimate the elasticity of a measure of congestion with respect to highway expansion. The results indicate that this elasticity is in the range close to 1. This suggests that expansion of the highway network induced the demand for car travel, and so, on average, the level of congestion remained roughly unchanged in the period 1985–2005. In other words, we show that investments in highways did not effectively relieve traffic congestion. We also break down the type of expansion into coverage (the network length) and capacity (number of lanes); we find that both effects were significant in explaining the increase in traffic especially the capacity effect. Controlling further for road pricing and public transportation policies, our results indicate that cities with these policies in place suffer less congestion.

15 We use an empirical strategy based on an interaction term (instead of directly using the length of the subway network as explanatory variable) because, unfortunately, we only have GIS maps and data for subways in 2011.

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It is important to note that in this paper we estimate the effect of capacity on travel quantity, rather than travel speed which would had been a preferred measure. This is the measure used by other papers on congestion analyses (see, e.g. Adler and van Ommeren, 2016; Bauernschuster et al., 2017; Adler et al., 2020; Russo et al., 2021). In those papers, the analysis is done for one city (Rome or Rotterdam) or, in the case of Bauernschuster et al. (2017), for the five largest cities in Germany. Unfortunately, these data are not available for all the cities and the period we use in our analysis. Our measure of congestion is the indicator VKT which is a good approach for the travel demand quantity. This indicator is also the one used in the papers more related to what we do with also a big sample of cities from which obtaining speed data information is not possible. This is the case of Duranton and Turner (2011) (for 228 MSA in the US) and Hsu and Zhang (2014) (for 189 urban employment areas in Japan).

The increase in traffic that we show could be related to many different reasons as changes on individual's behaviour in their daily activities, migration of people and economic activity or increases on commercial transportation. Understanding those mechanisms would had also been a very interesting exercise. However, due to the sample of cities we use (more than 500 cities from 28 different countries) it is not feasible to assemble the data we would need to test for all these possible mechanisms.

These findings have major implications for transportation policies, given the persisting severity of traffic congestion in worldwide urban areas where the reduction of car use has become a priority. Only a few cities have established congestion charges and public transport systems are under financial pressure. It is clear that there is great deal of scope for the design of good policies. Related to our results, it is well known that public acceptance of road pricing schemes is very low. People are not willing to pay in order to be able to drive and, on the other hand, the evidence seems to show that this policy might be regressive. A good way to proceed would be to introduce urban tolls and use the revenues obtained to improve public transportation.

Supplementary material

Supplementary data for this paper are available at *Journal of Economic Geography* online.

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Appendix A: Historical roads and railroads in Europe

A.1 Maps

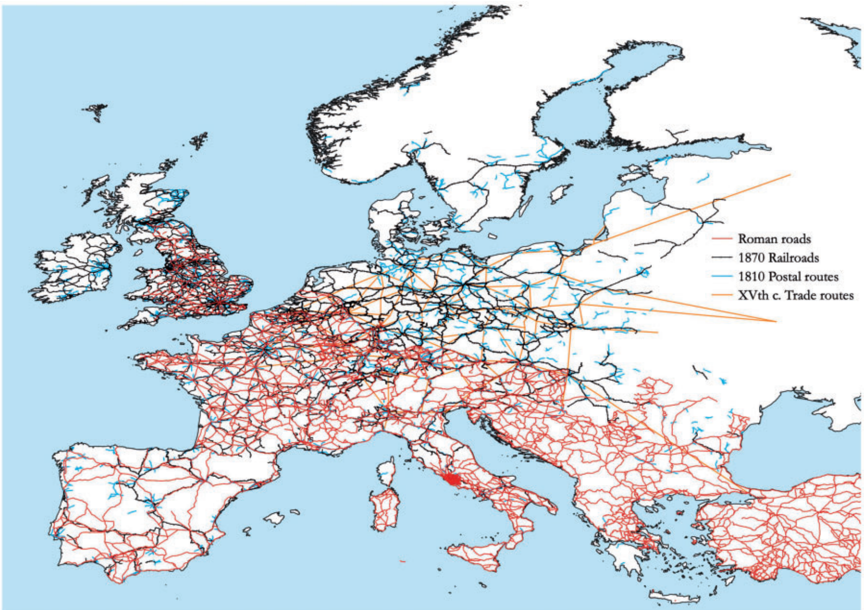

Figure A1. Historical roads and railroads in Europe.

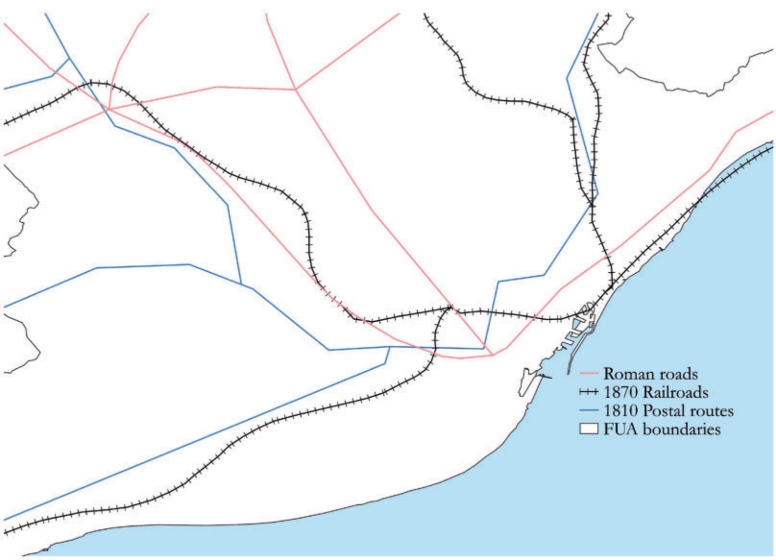

Figure A2. Historical roads and railroads in Barcelona.

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A.2 First-stage results for highway lane kilometres

To econometrically test the relevance of each *time-variant* historical (rail)road, we estimate the following first-stage equations and show their results in Table A.1:

$$\begin{aligned}\ln(\text{Lanekm}_{it}) = \gamma_0 + \gamma_1 \times \ln(\text{Historical(rail)roadkm}_{it}) \\ +\gamma_2 \times \ln(\text{Population}_{it}) + \gamma_3 \times \text{Socioeconomy}_{it} \\ +\gamma_4 \times \text{Geography}_i + \gamma_5 \times \text{History}_i + \epsilon_{it}\end{aligned} \tag{A.1}$$

when we follow a pooled regression approach (Equation (1)). Results are in Columns 1–3

Table A1. Historical (rail)roads and modern highway lane kilometres, OLS results: First stage

Dependent variable:	ln(Lane km)						Δln(Lane km)					
	Pool			Panel			First-difference					
	[1]	[2]	[3]	[4]	[5]		[6]	[7]	[8]	[9]	[10]	[11]
ln(Roman roads)	0.026[a]	0.025[a]	0.025[a]	0.037[a]	0.038[a]	Δln(Roman r.)	0.034[a]	0.034[a]	0.028[a]	0.028[a]	0.034[a]	0.034[a]
	(0.007)	(0.007)	(0.007)	(0.009)	(0.009)		(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
ln(15th c. trade r.)	0.002											
	(0.007)											
ln(1810 post r.)	0.011											
	(0.008)											
ln(1870 railroads)	0.029[a]	0.027[a]		0.008		Δln(1870 rail)	0.006		0.002		0.011	
	(0.008)	(0.008)		(0.008)			(0.008)		(0.008)		(0.011)	
ln(Population)	✓	✓	✓	✓	✓	Δln(Population)	✓	✓	✓	✓	✓	✓
Socioeconomy	✓	✓	✓	✓	✓	ΔSocioeconomy	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓			Geography			✓	✓		
History	✓	✓	✓			History			✓	✓		
Country FE	✓	✓	✓			Country FE			✓	✓		
FUA FE				✓	✓	FUA FE					✓	✓
						Lagged ln(VKT)			✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	Year FE	✓	✓	✓	✓	✓	✓
F-S *F*-stat	5.22	10.36	12.01	10.55	19.79	F-S *F*-stat	11.13	21.26	7.92	14.12	8.44	16.22

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in pooled and panel regressions (Columns 1–5) and 1090 observations (545 cities × 2 periods) in first-difference regressions (Columns 6–11). Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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$$\ln(\text{Lanekm}_{it}) = \gamma_1 \times \ln(\text{Historical (rail)roadkm}_{it}), \\ +\gamma_2 \times \ln(\text{Population}_{it}) + \gamma_3 \times \text{Socioeconomy}_{it} + \delta_i + \eta_{it} \quad \text{(A.2)}$$

when we follow a panel-fixed effect approach (Equation (2)). Results are in Columns 4 and 5

$$\Delta\ln(\text{Lanekm}_{it}) = \gamma_1 \times \Delta\ln(\text{Historical (rail)roadkm}_{it}) \\ +\gamma_2 \times \Delta\ln(\text{Population}_{it}) + \gamma_3 \times \Delta\text{Socioeconomy}_{it} + \Delta\eta_{it} \quad \text{(A.3)}$$

when we follow a first-difference approach (Equation (3)). Results are in Columns 6–11.

A.3 First-stage results for highway length and number of lanes

Table A2. Historical (rail)roads and modern highway length and lanes, OLS results: First-stage

Dependent variable:	ln(Km of highways)			Number of lanes	
	[1]	[2]		[3]	[4]
ln(Km of Roman roads)	0.043[a]	0.050[a]	Number all hist. (rail)roads	0.119[a]	
	(0.015)	(0.015)		(0.023)	
ln(Km 15th c. trade routes)	−0.017[b]		Number of Roman roads		0.183[a]
	(0.007)				(0.040)
ln(Km of 1810 post routes)	0.011		Number 15th c. trade routes		0.174[a]
	(0.010)				(0.046)
ln(Km of 1870 railroads)	0.010		Number of 1810 post routes		0.097[b]
	(0.010)				(0.049)
			Number of 1870 railroads		0.157[a]
					(0.046)
ln(Population)	✓	✓	ln(Population)	✓	✓
Socioeconomy	✓	✓	Socioeconomy	✓	✓
FUA FE	✓	✓	FUA FE	✓	✓
Year FE	✓	✓	Year FE	✓	✓
F-S *F*-stat	5.15	11.52	F-S *F*-stat	26.29	11.78

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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A.4 First-stage results for modern railroads

Table A3. Historical (rail)roads and modern railroads, OLS results: First-stage

Dependent variable:	ln(Kilometres of railroads)	
	[1]	[2]
ln(Kilometres of Roman roads)	−0.019	
	(0.012)	
ln(Kilometres of 15th c. trade routes)	0.006	
	(0.013)	
ln(Kilometres of 1810 post routes)	0.011	
	(0.020)	
ln(Kilometres of 1870 railroads)	0.308[a]	0.311[a]
	(0.083)	(0.075)
ln(Population)	✓	✓
Socioeconomy	✓	✓
FUA FE	✓	✓
Year FE	✓	✓
First-stage *F*-statistic	5.75	17.41

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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Appendix B: Additional results

Table B1. The effect of highways on traffic congestion, OLS and IV results: Years

Dependent variable:	ln(VKT)					
	OLS results			IV results		
	1985 [1]	1995 [2]	2005 [3]	1985 [4]	1995 [5]	2005 [6]
ln(Lane km)	0.904[a] (0.043)	0.813[a] (0.039)	0.768[a] (0.040)	1.832[a] (0.342)	1.310[a] (0.225)	1.844[a] (0.264)
Population	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓
History	✓	✓	✓	✓	✓	✓
Socioeconomy	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Adjusted R^2	0.88	0.90	0.88			
First-stage F-statistic				11.92	11.89	14.11
Instrument				ln(Km of Roman roads)		

Notes: 545 observations in each regression. Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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Table B2. The effect of highways on traffic congestion, OLS and IV results: Gradual

Dependent variable:	ln(VKT)									
	OLS results					IV results				
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
ln(Lane km)	0.969[a]	0.752[a]	0.896[a]	0.882[a]	0.831[a]	1.480[a]	1.617[a]	1.519[a]	1.529[a]	1.558[a]
	(0.026)	(0.031)	(0.033)	(0.033)	(0.034)	(0.150)	(0.313)	(0.233)	(0.256)	(0.272)
Population		✓	✓	✓	✓		✓	✓	✓	✓
Geography			✓	✓	✓			✓	✓	✓
History				✓	✓				✓	✓
Socioeconomy					✓					✓
Country FE					✓					✓
Adjusted R^2	0.797	0.830	0.852	0.855	0.887					
F-S F-stat						29.51	13.04	15.89	12.82	12.01
Instrument						ln(Km of Roman roads)				

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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Appendix C: Robustness checks

Table C1. The effect of highways on traffic congestion: Robustness checks

Dependent variable:	ln(VKT)										
Robustness:	Panel A:			Panel B:			Panel C:			Panel D:	
	Instrumenting pop			Linear trends			Other roads			Non-linearity	
	IV	IV		OLS	IV		OLS	IV		OLS	IV
	[1]	[2]		[3]	[4]		[5]	[6]		[7]	[8]
ln(Lane km)	0.723^{a}	2.312^{a}	ln(Lane km)	0.695^{a}	1.206^{a}	ln(Lane km)	0.686^{a}	1.444^{a}	ln(Lane km)	0.713^{a}	1.230^{a}
	(0.062)	(0.534)		(0.097)	(0.314)		(0.098)	(0.394)		(0.033)	(0.165)
						ln(Km second. r.)	−0.021^{b}	−0.029^{b}	(ln(Lane km))^2	−0.029	−0.262
							(0.010)	(0.011)		(0.020)	(0.21)
						ln(Km local roads)	0.013	−0.012			
							(0.011)	(0.020)			
ln(Population)	✓	✓	ln(Population)	✓	✓	ln(Population)	✓	✓	ln(Population)	✓	✓
Socioeconomy	✓	✓	Socioeconomy	✓	✓	Socioeconomy	✓	✓	Socioeconomy	✓	✓
Geography	✓	✓	FUA FE	✓	✓	FUA FE	✓	✓	FUA-fixed effects	✓	✓
History	✓	✓	Year FE	✓	✓	Year FE	✓	✓	Year-fixed effects	✓	✓
Country FE	✓	✓	Country trend	✓	✓						
Year FE	✓	✓									
Adjusted R^2			Adjusted R^2	0.71		Adjusted R^2	0.71		Adjusted R^2	0.83	
First-stage F-stat	12.06	4.66	First-stage F-stat		19.79	First-stage F-stat		5.30	First-stage F-stat		3.71
Instruments		ln(Roman)	Instruments		ln(Roman)	Instruments		ln(Roman)	Instruments		ln(Roman)
		Temperature, precipitation			ln(1810 Post), ln(15th c. Trade)						ln(Rom)×ln(Rom)

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Geography controls include the logarithm of the FUA area, a suburbanisation index, which is the share of the central city area, the mean and range of FUA elevation, the mean surface ruggedness for each FUA and the logarithm of the distance to the closest coast from the central city centroid. History includes the logarithms of FUA population in 1960, 1970 and 1980, and dummy variables for historical major cities in 814, 1000, 1200, 1450 and 1850. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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Appendix D: Coverage and capacity effects using the log of lanes

Table D1. The effect of highways on traffic congestion, IV results: Log of lanes[TQ1]

Dependent variable:	ln(VKT)				
Instrumenting:	Length [1]	Lanes [2]	Both [3]	Lanes [4]	Both [5]
ln(Km of highways)	2.293[a]		1.103[a]		1.170[a]
	(0.561)		(0.323)		(0.189)
ln(Number of lanes)		3.659[a]	3.514[a]	4.302[a]	4.062[a]
		(0.894)	(0.665)	(0.761)	(0.507)
ln(Population)	✓	✓	✓	✓	✓
Socioeconomy	✓	✓	✓	✓	✓
FUA FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
First-Stage F-stat	11.52	23.70	5.08	12.90	9.23
Instruments	ln(Roman roads)		ln(Roman roads)		ln(Roman roads)
	ln(Number of all historical (rail)roads)			ln(Numbers) of each historical (rail)road	

Notes: 1,635 observations (545 cities × 3 decades (1985–2005)) in each regression. Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicates significant at 1%, 5% and 10% level, respectively.

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Appendix E: An alternative approach to analyse the role of tolls

As an alternative, but also complementary approach to the one developed in Section 5.1 to analyse the role of tolls, we consider an empirical strategy based on subsamples. Specifically, in Table E.1, we split our sample of cities and run separate regressions. First, in Columns 1 and 2, we compare cities without tolls (285) with cities with tolls (260). Second, in Columns 3 and 4, we compare cities with less than 25% of tolled highways (343) with cities with 25% or more of tolled highways (202). All LIML results point out in the same direction: The effect of lane kilometres on VKT is higher in cities without tolls or with less than 25% of tolled highways than in cities with tolls or with more than 25% of tolled highways. Furthermore, LIML results show that the fundamental law is only related to cities without tolls or with less than 25% of tolled highways, with elasticities of 1.13 and 1.34, respectively. As a whole, these results confirm the ones obtained using an empirical strategy based on interactions (Section 5.1).

Table E1. The effect of highways on traffic congestion, IV results: Tolls and subsamples

Dependent variable:	ln(VKT)			
	Without versus with tolls		Below versus above 25% tolled highways	
	Without [1]	With [2]	Below [3]	Above [4]
ln(Lane km)	1.132[c]	0.856[a]	1.335[b]	0.589[c]
	(0.680)	(0.328)	(0.529)	(0.328)
ln(Population)	✓	✓	✓	✓
Socioeconomy	✓	✓	✓	✓
FUA FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Observations	855	780	1029	606
FUA	285	260	343	202
First-Stage *F*-stat	4.82	11.16	7.72	9.44
Instrument	ln(Km of Roman roads)	ln(Km of Roman roads)	ln(Km of Roman roads)	ln(Km of Roman roads)

Notes: Socioeconomic characteristics are the log of the GDP, the share of employment in manufacturing, the share of employment in finance and business services, the share of employment in non-market services and the unemployment rate. Robust standard errors are clustered by FUA and are in parenthesis.
a, b and c indicate significant at 1%, 5% and 10% level, respectively.

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