

OPPORTUNITIES FOR INTRODUCING A SUBURBAN RAIL LINE IN THE PARDUBICE REGION AGGLOMERATION WITH A FOCUS ON THE HOLICE AREA

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ABSTRACT. First/last-mile frictions remain a key barrier to public-transport competitiveness. This paper develops and evaluates an integrated solution for the Pardubice region (Czechia): a direct suburban rail service on the Holice – Pardubice – Heřmanův Městec axis coupled with a station-based Bike+Rail (B+R) system. We combine census-derived mobility data with a transparent fleet-dimensioning model that accounts for adoption, peak simultaneity, daily turnover, and capacity margin. Rail impacts are assessed using Generalized Journey Time (GJT) and conservative short-run elasticities. The results indicate that a moderate, spatially focused B+R fleet distributed across the main interchange nodes, together with direct trains, can meaningfully reduce GJT by removing transfer penalties and smoothing access/egress. To stimulate habitual use without compromising availability, we propose a non-personalized dynamic pricing scheme based on progressive loyalty discounts for B+R trips originating/terminating in station zones and aligned with train time windows. Overall, coupling direct suburban rail with a targeted B+R scheme appears capable of materially improving door-to-door accessibility and strengthening modal competitiveness against car travel. A pilot implementation with subsequent calibration is recommended to validate behavioural responses, operational performance, and economic viability.

KEYWORDS: Bike-rail integration, dynamic pricing, Generalized Journey Time, station-based bike sharing, suburban rail.

1. INTRODUCTION

Public transport in many regions faces the persistent barrier of the “first/last mile,” which heavily affects mode choice. When access to and egress from stations are slow, inconvenient, or unreliable, the generalized cost of travel rises and users shift to private cars. International literature shows that integrating cycling with public transport (Bike+Rail, B+R) systematically reduces these weaknesses by combining the range and flexibility of the bicycle with the speed and capacity of rail. This is not a mere sum of two modes but a synergy: bicycles enlarge station catchment areas, broaden the choice of stations and services (including fast/express segments), and personalize transfers – making B+R more competitive with the car [1, 2].

This study examines the transferability of the Dutch B+R model to the Czech context and applies it to a pilot area in the commuter belt of the regional capital Pardubice. Alongside a proposal for the operational and tariff design of a bike-sharing system connected to public transport, the paper proposes a new suburban rail service linking Holice – Moravany – Pardubice – Přelouč – Heřmanův Městec, centered on the Pardubice hub. The objective is to verify whether combining a new suburban rail line with a B+R system improves door-to-door accessibility and increases the attractiveness of public transport vis-à-vis private car use [1, 2].

The paper first summarizes key insights from the literature and international practice (Theoretical Framework). It then presents the methodology, including pilot-area selection, B+R sizing, and evaluation of the proposed direct rail service. The results presented in next sections provides indicative fleet sizes for the bike-sharing system and expected benefits of the new rail link. The Discussion situates the findings in a broader perspective (including dynamic pricing/yield management), and the Conclusion summarizes the main insights and practical recommendations.

2. THEORETICAL FRAMEWORK

Kager and Harms [1] describe the cycling–rail synergy: bicycles expand station catchments and shorten access/egress times, while rail provides a fast, high-capacity backbone. As a result, travelers gain more feasible options (choosing a more advantageous station or faster service), face lower generalized travel costs, and the combined bike–rail option becomes more competitive with the car. The Netherlands is the European reference case for integrating cycling with public transport. Government and research data indicate that on the home side of rail trips, the bicycle is used in roughly 43 % of journeys, whereas on the destination side it accounts for around 11 %

– shares that have grown over time (e.g., from $\sim 6\%$ to $\sim 43\%$ on the home side between 2005 and 2016) [3–5]. European averages are markedly lower, underlining the exceptionality of the Dutch model. OECD/ITF [1] analyses report similar orders of magnitude ($\approx 47\%$ access, $\approx 13\%$ egress by bike).

Recent national diary evidence from the Netherlands shows that combined bicycle-transit trips are long-distance commutes on average (~ 41 km), with train as the main transit leg in $\sim 82.8\%$ of such trips and bicycle-transit-walk being the most common chain ($\sim 56\%$).

Moreover, users are willing to cover longer access/egress distances to rail than to bus/tram/metro – ≈ 3.8 km access / 2.7 km egress to train versus ≈ 1.5 km / 0.7 km to B/T/M – underscoring the natural fit of cycling with rail and the importance of destination-side facilities [6].

These outcomes are enabled by institutional integration (e.g., the OV-fiets public transport bike and extensive station bike parking) and simple product logic. Core principles – simplicity of the product, institutional embedding within door-to-door rail services, and a twin-pillar approach (secure parking for private bikes + public station bikes) – serve as the reference frame for this study, adapted to the Pardubice Region (IREDO integrated system).

Reference model: OV-fiets in the Netherlands. OV-fiets is a station-based (primarily out-and-back) public bike system for the last mile from the rail station. It is owned and operated by the national railway (NS) and tightly integrated with the public transport identity and payment system (OV-chipkaart with billing via “Mijn NS”). In parallel, NS offers extensive guarded/unguarded station bike parking and lockable boxes. This twin-pillar model – public bikes at the destination station and secure storage of one’s own bike at the origin – explains both high access shares and meaningful destination-side use [2, 7, 8].

According to the NS annual report for 2024 [7], OV-fiets registered about 5.9 million rentals, with a fleet of approximately 22 000 bikes across ~ 282 locations. NS also operated roughly 193 000 guarded and 328 000 unguarded parking spaces for private bikes, plus 10 400 lockable boxes. The first 24 hours of parking are free at selected stations (with OV-chipkaart identification). On average, this implies around 268 trips per bike per year and $\sim 20\,900$ trips per location per year, with strong heterogeneity across stations. By 2024, about 70 % of the fleet had new e-locks controlled by personal OV-chipkaart; the number of fully unattended facilities rose to 93 (with 45 added during the year), and further expansions are planned.

OV-fiets is a straightforward 24-hour product integrated into the transport account. As of 1 January 2025, the price is € 4.65 per 24 hours (no subscription; a one-cent identity verification when linking the account). The maximum rental period is seven days; after 72 hours a surcharge of € 5 per additional

24 hours applies. Return at a different location is permitted for a flat € 10 fee (not for e-bikes). Billing is monthly via “Mijn NS”. An individual OV-chipkaart with activated OV-fiets access is required (activation is free; account linking triggers the € 0.01 verification). Reservations are generally not offered – the system relies on adequate peak capacity and fast turnover. NS combines guaranteed capacity at major hubs with operational rebalancing to maintain availability.

OV-fiets is part of NS’s door-to-door portfolio (alongside bike parking, P+R, taxis, car-sharing). It is governed by the NS Stations division in cooperation with the infrastructure manager (ProRail) and municipalities. This enables integrated capacity planning (linking station parking and bikes), shared investments in locks/dispensers/IT, and unified performance indicators – e.g., bike availability upon train arrival, facility cleanliness/safety, and customer satisfaction. Linking OV-fiets to the transport account (OV-chipkaart/Mijn NS) provides unified user identity, monthly clearing, and detailed analytics at the station/time level for capacity tuning and operational measures (e.g., pre-peak rebalancing).

In summary, the Dutch OV-fiets model demonstrates that a simple, fully integrated service can generate high usage and strong synergies with rail. These principles inform the pilot design for the Pardubice Region, while accounting for local institutional and spatial specifics (IREDO, station typology, cycling conditions).

3. METHODOLOGY

Pilot area selection Holic – Moravany – Pardubice – Přelouč – Heřmanův Městec axis was selected based on:

- **Pardubice as a regional magnet and rail junction:** As the regional capital and a natural transport-economic hub, Pardubice attracts substantial daily commuting flows from surrounding towns and villages along key rail lines. At the city scale, conditions are favorable for everyday cycling and its integration with rail: cycling accounts for approximately 14 % of trips, and over 50 % of all trips are shorter than 3 km (more than 70 % shorter than 5 km) – distances where the bicycle is naturally competitive [9, 10].
- **Favorable geography:** The Polabí lowlands provide flat terrain and minimal gradients – highly supportive of everyday cycling. The Pardubice area exhibits above-average cycling shares within the Czech Republic [10].
- **Existing rail infrastructure:** All settlements lie on lines within IREDO and have suitable rail frequencies, creating potential for combined rail-bike travel.
- **Road network developments:** New bypasses around Pardubice and Sezemice are likely to im-

prove driving conditions; to avoid a modal shift to cars, public transport must enhance its multi-modal offer [11, 12].

To gauge demand, we used 2021 Census data (Czech Statistical Office, mobility module) on work/school commuting by mode [13]. For each node, we identified the maximum daily number of regular in-/out-commuters. We consider two demand scopes for B+R sizing:

- (I) Rail-only: system sized solely by rail passenger volumes at the station.
- (II) Intermodal node (rail + bus): system sized by total public transport use in the node, including bus services.

The second scope reflects reality in Pardubice, Přelouč, and Heřmanův Městec, where intermodal hubs (rail+bus) operate; B+R infrastructure could serve a wider user base than rail passengers alone. Although the Dutch B+R concept primarily targets rail, we expect non-negligible use in connection with regional buses in the Pardubice context.

The maximum daily rail passenger counts (rail-only) are approximately [13]:

- Holic – 118,
- Moravany – 124,
- Přelouč – 363,
- Pardubice – 2 337,
- Heřmanův Městec – 26 persons.

When including total public transport in the node (rail + bus), the maxima rise to roughly [13]:

- Holic – 681 (need to build terminal),
- Přelouč – 871 (existing terminal),
- Heřmanův Městec – 315 (existing terminal),
- Moravany – 137 (need to build terminal),
- Pardubice – 4 700 persons (existing terminal).

We size primarily for this intermodal scenario as it better represents potential B+R use.

International B+R planning guidance follows a simple principle: fleet size derives from the number of public transport users at the station and the share likely to choose a bike for the last mile. BiTiBi Guidelines [2] suggest provisioning for about 10–15 % of daily demand at larger hubs and 5–8 % at smaller stations, with an absolute minimum of 6 bikes even in very small places (a visibility floor).

A crucial parameter is the adoption factor: in early phases only a fraction of potential users will engage. Practice suggests realized use of about 80 % of the theoretical potential; $\alpha \approx 0.8$ [14] is thus a cautiously optimistic planning assumption (literature: ~ 0.6 – 0.85).

We apply the following sizing framework, linking daily public transport flows with utilization parameters:

- A – arrivals in the decisive time window (e.g., morning peak);
- p_{LM} – target share using a bike for the last mile (NL: 0.11–0.14; we assume 0.08 for a conservative Czech pilot);
- α – adoption factor (0.8);
- σ – simultaneity (share of demand concentrated in the main peak, typically 0.55–0.70; assume 0.6);
- τ – daily turnover per bike (uses/day in station-based systems, typically 1.2–1.6; assume 1.4);
- β – capacity buffer for irregular peaks/outages (0.20).

The fleet size is then estimated by Equation (1):

$$N_{kola} = \frac{A \cdot p_{LM} \cdot \alpha \cdot \sigma}{\tau} \cdot (1 + \beta). \quad (1)$$

If the result falls below the minimum recommended capacity (5–10 bikes), the fleet is raised to that minimum [2].

We apply this to each node on the pilot axis using intermodal (rail + bus) daily maxima (A values above). Quantitative outcomes are reported.

4. IMPROVEMENTS FOR THE RAILWAY OPERATIONS

Evaluating the direct rail service. We compare current travel times (with transfers) to expected times with a through service, using Generalized Journey Time (GJT): in-vehicle time + weighted waiting (typically 1/2 headway) + transfer penalty (fixed disutility of transferring due to uncertainty, walking, orientation, etc.). International evidence places the fixed transfer penalty in the low single- to low double-digit minutes (often 5–15 min, depending on node quality and coordination) [15], with lower values for well-coordinated rail transfers and higher for bus-bus.

A practical decision procedure is: (i) compute change in GJT if transfers are removed; (ii) apply conservative short-run demand elasticities to time/GJT (≈ -0.3 to -0.5) to estimate patronage growth [16]; (iii) run sensitivity tests for transfer quality (short vs. longer waits, delay variability) and different transfer-penalty assumptions within literature bounds. This yields conservative growth estimates reflecting both time savings and the qualitative benefit of eliminating transfers.

Current vs. proposed rail service. Today, **Holic – Pardubice** requires a transfer at Moravany (on the mainline Praha – Česká Třebová). Total journey times range roughly **29–36 min** toward Pardubice and **29–31 min** in the reverse; the transfer typically adds **~4–9 min** of waiting. **Pardubice – Heřmanův Městec** involves a transfer at Přelouč to branch line 015; total times depend on combinations and waits (**~31–45 min**), with some connections offering only **~2 min** to/from fast services [17–19].

A **through train** Holice – Pardubice would **eliminate the Moravany transfer**, saving approximately **3–8 min** of in-vehicle/waiting time depending on pathing and, crucially, removing a **~5–10 min** transfer penalty from GJT. Overall, GJT could fall by **~8–18 min (20–40 % vs. current ranges)**. Short-run demand elasticities of -0.3 to -0.6 imply order-of-magnitude patronage gains in the **high single to low double digits** (e.g., ~ 6 – 24 %) in the short run, with larger long-run effects.

For **Pardubice – Heřmanův Městec**, a through service requires a **directional reversal at Přelouč**. The dwell needed for the reversal reduces pure runtime savings, but removing the transfer still reduces GJT by eliminating transfer penalties and wait-time risk (notably with current **~2 min** critical connections). The qualitative gain in reliability and comfort remains material [17–19].

Several operational variants exist (extensions of current services or a new hourly link Holice – Pardubice – Heřmanův Městec with turnback at Pardubice). Detailed timetabling and diagrams are beyond scope; indicative capacity and timing suggest feasibility.

Longer-term infrastructure options. Over a longer horizon, **infrastructure upgrades** could further reduce times. On **Holice – Moravany**, higher line speeds may be attainable within the existing alignment [20], leveraging renewed track structure and adding superelevation in curves; a key prerequisite is appropriate line-side train protection (without code transmission, a regulatory cap of **Vmax 100 km h⁻¹** applies). Upgrading **nine** level crossings to active protection and adapting six existing PZZ installations to meet warning-time requirements would be needed; signal siting changes (e.g., an advance signal for Moravany) and station interlocking in **Holice** are also foreseen.

In **Moravany**, Hanzlík [20] proposes adding a **crossover between tracks 4 and 6** (60 km h^{-1} both ways) and **extending platform 4**, shortening meets and speeding through movements (current crossovers permit 60 km h^{-1} with certain constraints). With direct services, these measures could reduce **Holice – Pardubice** times to $\approx 20 \text{ min}$, or $\approx 17 \text{ min}$ for semi-fast patterns. Such a package requires higher investment but illustrates the upper bound of time savings on the relation [20].

5. CONCLUSIONS

Under the intermodal (rail + bus) scenario, the recommended fleet on the Holice – Moravany – Pardubice – Přelouč – Heřmanův Městec axis totals roughly **224 bikes**. Indicative station allocations are about **23 in Holice, 29 in Přelouč, 11 in Heřmanův Městec, 6 in Moravany, and 155 at Pardubice**. These reflect conservative assumptions: ~ 8 % choose a bike, 80 % adopt the service; ~ 60 % of demand is concentrated in the main peak; a bike turns over ~ 1.4

times/day; and a 20 % capacity buffer is added. Minimum floors are applied to the smallest nodes (e.g., Moravany).

Indicative **operating costs (OPEX)** at **€ 600–700 per bike per year** [21] imply **€ 134–157 k/year** for ~ 230 bikes (cf. **€ 66–77 k/year** for ~ 110 bikes in a rail-only sizing). **Capital expenditure (CAPEX)** comprises bikes (incl. potential e-bikes), racks/locks, parking elements, IT integration (identity and payments within IREDO), and basic information/marketing; CAPEX is annualized according to asset life (bikes typically 5 – 7 years). A larger scale enables economies in unit costs for locks, stations, and IT.

The study adapts a proven **Bike+Rail** concept to the Pardubice Region. It proposes a new suburban rail service Holice – Pardubice – Heřmanův Městec coupled with a station-linked bike-sharing system. Using commuting data [13] and conservative literature parameters, we sized the fleet at approximately 230 bikes across five nodes (Holice, Moravany, Pardubice main, Přelouč, Heřmanův Městec) under an intermodal (rail + bus) scenario. We also quantified benefits of direct services: on Holice – Pardubice, removing the transfer could lower GJT by ~ 20 – 40 % (~ 8 – 18 minutes), implying single- to low double-digit short-run demand growth; on Pardubice – Heřmanův Městec, benefits are more qualitative (reliability/comfort), given operational constraints, yet still meaningful for perceived quality.

Combining a new rail link with B+R promises substantial door-to-door gains. By lowering first/last-mile barriers and speeding the mainline segment, public transport becomes more competitive with the car, supporting stabilization or reversal of carward shifts. We further propose yield-management-inspired dynamic pricing – a loyalty discount for frequent B+R users – as a transparent, manageable instrument to bolster usage without harming availability.

A key contribution is showing that established international approaches (Dutch B+R) can be contextualized using local data and simple analytics for a Czech region. A pilot implementation – deploying station bikes with a trial direct rail link – should be the next step to observe real behavior, calibrate parameters (adoption, actual bike shares, pricing effects), and refine economic/operational aspects. Such evidence would support scaling B+R and advancing sustainable door-to-door mobility in the Czech Republic.

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