POST-COVID SHIFTS IN BUS PASSENGER TRIP TIMING AND VEHICLE UTILISATION IN CAPE TOWN

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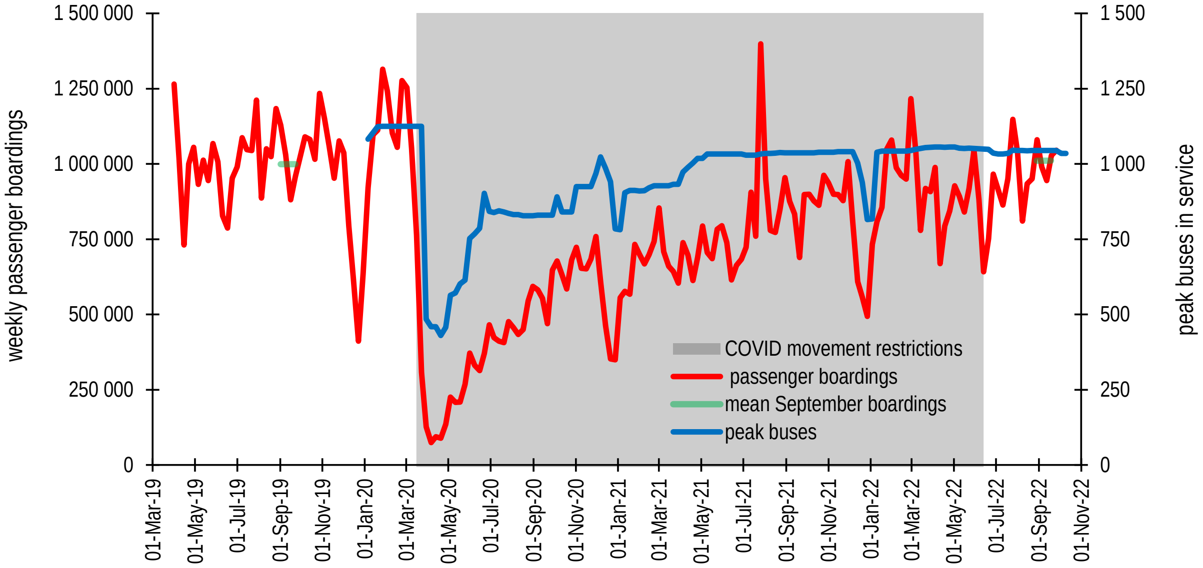
ABSTRACT

Golden Arrow Bus Services' ridership in Cape Town has now recovered to pre-pandemic levels, but a shift in trip timing behaviour has been observed. The purpose of this paper is to explore the nature and extent of this shift, and to consider its impacts on fleet deployment efficiency. Passenger boarding data, from a sample of weekdays before and after COVID-19 movement restrictions, are analysed. Data on peak and off-peak fleet deployment, and on the cost of a bus in service per weekday, are used to develop a rudimentary cost allocation model. It is found that the portion of weekday passenger boardings occurring in peak periods declined by 10.5% after lockdown (and by 5.8% in the peak hour), resulting in a reduction of the peak-to-base ratio from 13:1 to 10:1. It is estimated that fixed costs heavily outweigh variable costs during periods of low demand (fixed costs account for 89% of the cost of system-wide service provision in the midday off-peak hour). Because the peak scales fixed costs, a small reduction in the peak-to-base ratio is found to register a discernible cost efficiency improvement in vehicle fleet utilisation. The number of buses required to service peak demand reduced from 1 124 to 1 040 (a 7% decrease), and the number of buses servicing the off-peak expanded from 200 to 245 (a 22% increase). It is estimated that a 1% decrease in the peak-to-base ratio led to a 0.2% decrease in the daily system-wide service provision cost.

1. INTRODUCTION

South African cities provide hostile operating environments for viable public transport operation. Monofunctional residential land uses located away from city centres create tidal patterns of peak directional flow, which leads to simultaneous under- and over-utilisation of public transport capacity. Residential townships located on, or beyond, city peripheries also increase trip lengths, which increases the cost of route operation. Low population densities limit the number of potential passengers living within the walking catchments of public transport stations and stops, which reduces ridership. Fragmented land use distributions along the service route corridor further lengthen trip lengths, which reduces 'seat renewal' (i.e., the number of passengers occupying an individual seat, and potential fares per seat, over the service route length). Finally, city-wide service network coverage, fragmented land uses, and limited non-commuter demand, in combination, create a large 'peak-to-base ratio' (i.e., the gap between peak and off-peak base ridership demand), which leads to under-utilised service provision capacity for parts of the day.

An earlier study of the impacts of COVID-19 on public transport services in Cape Town (Bruwer *et al.,* 2023) revealed that the restriction of public transport operations, linked to the lockdown regulations imposed in March 2020, led to an immediate 94% drop in Golden Arrow Bus Services' (GABS) ridership (from 1 253 000 passenger boardings in week 10 of 2020, to 75 000 passenger boardings in week 15) (see Figure 1)[1]. Because GABS operates services through net cost contracts with the provincial government, it carries considerable revenue risk in relation to decreased ridership. While services are subsidised, a significant portion of revenue is derived from the farebox. It was with some relief, therefore, that in September 2022 – for the first time since operating restrictions were introduced in March 2020 – month-on-month ridership recovered to pre-pandemic levels (3 996 000 passenger boardings in weeks 36-39 of 2019, compared to 4 043 000 passenger boardings in weeks 36-39 of 2022). The drivers of this recovery are likely to be a combination of: returning pre-COVID bus passengers; mode switching from defunct rail services; and spiked 2022 fuel costs that made bus commuting more attractive to choice passengers.



Note: Data include Golden Arrow and Sibanye buses.

Figure 1: GABS' ridership and peak buses in service, before and after COVID-19 movement restrictions

A notable feature of this ridership recovery – and the focus of this paper – is a change in the peak-to-base ratio. Following the hardships South African public transport operators endured over the pandemic described by Luke (2020), could there be an unexpected benefit in the post-COVID-19 period? The purpose of this paper is to explore the nature and extent of the change in weekday boarding patterns, and to discuss associated impacts on fleet deployment efficiency.

The paper is divided into six sections. The following section reviews the relevant literature and develops a conceptual framework to understand and investigate the impacts of changing peak-to-base ratios. Section 3 describes the methods used in assembling and analysing passenger boarding and cost of service provision data. Section 4 presents the findings of the investigation, in terms of boarding patterns, and fleet deployment efficiency. Section 5 discusses the findings, and Section 6 draws conclusions.

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[1] South African COVID-19 lockdown restrictions stipulated that buses could operate at 50% passenger capacity during limited operational hours for the most severe Alert Levels (27 March to 31 May 2020). Restriction on operating hours was lifted on 1 June 2020, however, passenger capacity restrictions were only lifted on 18 August 2020.

2. CONCEPTUAL FRAMEWORK

The idea that COVID-19 had, and will continue to have, disruptive effects on trip-making behaviour is widespread in the literature. Regarding the shorter-term effects of movement restrictions, Barbieri *et al.* (2021), for instance, explored mode use frequency across 10 countries (including South Africa), finding a consistent reduction in public transport use. Porter *et al.* (2021), also in a multi-country study involving South Africa, as well as Jennings and Arogundade (2021) undertook a gendered analysis of reduced mobility, finding that women had been particularly impacted. Jain *et al.* (2022) and Balbontin *et al.*'s (2021) multi-country study (including South Africa) explored increased work from home impacts on trip substitution. Regarding disruptions in the longer-term, Behrens *et al.* (2022) explored trip substitution intentions, finding that increased remote activity participation is likely to endure. With respect to public transport utilisation more specifically, Marra *et al.* (2022) found that passengers have become more variable in their route choices, and Van Wee and Witlox (2021) predicted that peak demands would reduce.

A more targeted search of the literature, for studies that focused on the impact of peak-to-base ratios on the cost of bus services, found two earlier studies that quantified impacts. The first, by Reilly (1977) in the context of New York, used a cost allocation model to estimate that the total cost of bus service provision per passenger was USD 0.48 during the peak period, and USD 0.75 during the off-peak. The second, by Taylor *et al.* (1999) in the context of Los Angeles, used a modified fully-allocated model to estimate that, when viewed from the perspective of system-wide cost rather than per passenger cost, the total cost of operating a peak period bus service was USD 151.01 per in-service vehicle hour, and USD 94.96 per in-service vehicle hour in the off-peak. In sum, this body of literature suggests that, because of the extra vehicles and drivers needed to meet peak demand, it costs more to provide a bus service in the peak than in the off-peak, even if per passenger costs are lower (Gwilliam, 2008; Reilly, 1977; Taylor *et al.,* 1999; Wabe & Coles 1975). No recent publications were found, and none that related specifically to the impacts of shifts in peak-to-base ratios, or to the impact of COVID-19 disruptions on peak-to-base ratios.

Given the paucity of prior explanatory and empirical studies, Figure 2 tests the relationships between peak-to-base ratios, fleet deployment, and the cost of service provision (i.e., including operating and capital costs), conceptually, using a simple hypothetical bus network. The three columns in the figure represent varying peak-to-base ratios: 10:1, 5:1, and 1.2:1.[2] Figure 2(a) illustrates the impact of declining peak-to-base ratios on the required number of buses, for the same total number of daily passenger boardings (250 000). The figure demonstrates that peak demand scales fleet size. Fleet size will in turn scale associated labour and support systems.

Figure 2(b) illustrates the impact of declining fleet requirements on the cost of service provision. The figure demonstrates that the total cost of service provision does not rise and fall at the same amplitude as the fluctuations in passenger boardings and fleet requirements. While the impact of shifting peak-to-base ratios on variable costs (e.g. fuel consumption, tyre replacement, etc.) is relatively small (the mean hourly variable cost ranges from ZAR 25 000 to ZAR 19 000), the impact on fixed costs (e.g. vehicle acquisition, depot and management staff, etc.) is significant (the mean hourly fixed cost ranges from ZAR 57 000 to ZAR 26 000).

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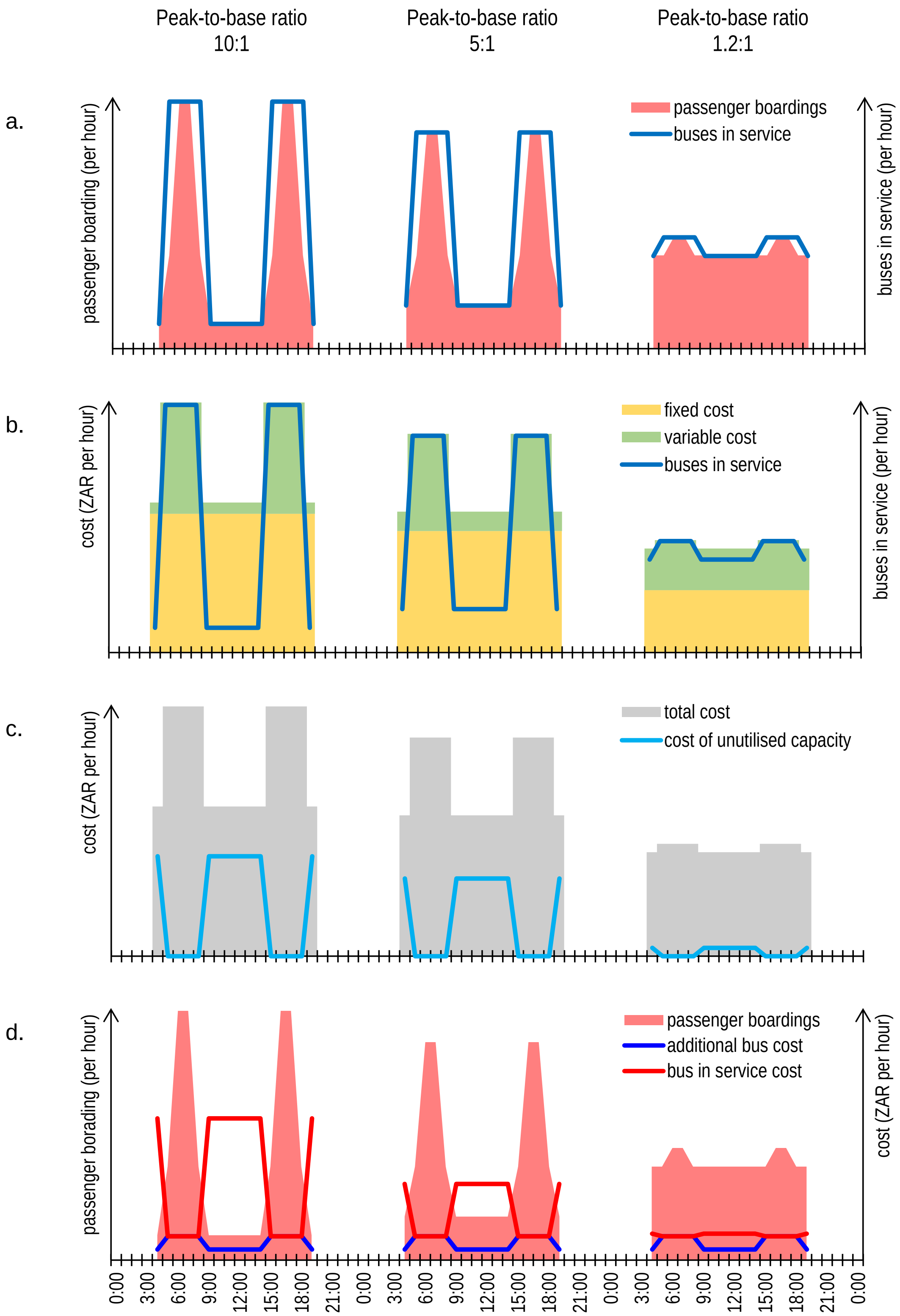
[2] A peak-to-base ratio of 10:1 indicates that ten buses are required in the peak to every one bus operated during the off-peak period. A ratio of 1.2:1 indicates that only 20% more vehicles are deployed in the peak compared to the off-peak period.



Notes: The hypothetical network has 250 000 passenger boardings per day, within a 16 hour service span. Boardings are assumed to be monotonic in all directions. The daily fixed cost per bus is assumed to be R2 500/day (R104/hour), and daily variable cost per bus is assumed to be R2 000/day (R83/hour). It is assumed a bus carries 73 passengers per hour.

Figure 2: Relationships between peak-to-base ratios, fleet deployment, and service provision cost

Figure 2(c) illustrates the share of the hourly total cost of service provision that is allocated to the fixed cost of unutilised bus fleet capacity. The figure demonstrates that, if the rate of passenger boarding was uniform across the service span, there would be no fluctuation in the cost of service provision, and there would be no unproductive expenditure on unutilised service provision capacity. Spiked peak demand results in increases in fixed costs, which impact the cost of service provision in the off-peak. The higher the spike, the greater the expenditure on service provision capacity that is unutilised. As the gap between peak and off-peak demand narrows, so the amount of unproductive expenditure reduces, and the service becomes more viable. The levelling of peak to off-peak passenger demand, however, does not necessarily produce greater profitability, as the released peak buses and drivers may be dispatched in the off-peak to reduce service headways. In this instance, the benefit is not improved viability, but improved passenger quality-of-service.

Figure 2(d) illustrates the hourly cost of a bus in service during the peak of off-peak periods. It also illustrates what the marginal cost of deploying an additional bus would be in the peak and off-peak periods. High peak-to-base ratios exaggerate the variation in individual bus deployment cost (between ZAR 1 125 and ZAR 188 in the case of a peak-to-base ratio of 10:1, compared to between ZAR 206 and ZAR 188 in the case of a peak-to-base ratio of 1.2:1). The figure demonstrates that the cost per bus in service is highest in the off-peak, but that, conversely, the marginal cost of adding an additional bus is lowest in the off-peak. In practice, if additional passengers in the off-peak did not require the deployment of additional buses, because they are running at lower occupancies, the marginal cost would be close to zero as the seats are being provided already.

3. METHOD

The investigation of GABS' ridership in Cape Town involved the assembly of two datasets: the first relating to weekday passenger boardings; and the second to the daily cost of service provision.

Weekday passenger boarding data were assembled in 15-minute intervals across a 24-hour period. The data were obtained from GABS' automated fare collection system, linked to a global positioning system which enables the exact time and location of each passenger boarding to be recorded. Because fare collection is still possible by both a multi-ride travel card (called a *Travel Smart Gold Card*) and on-board cash payment, however, boardings recorded through the automated fare collection system needed to be supplemented by a labour-intensive extraction of boarding data from cash fare payments. Consequently, the sample of days before and after COVID-19 lockdown restrictions is small. Only data from four weekdays were sampled (4 and 24 February 2020 in the pre-lockdown period, and 14 September and 13 October 2022 in the post-lockdown period). A limitation of the method is therefore that the findings provide an indication of the direction of change, rather than statistical representativity.

Daily cost of service provision data, in the form of a per bus per day cost, were obtained from the GABS finance department. The daily cost was estimated by adding: the fixed cost of a bus; the daily cost of a driver; and the bus operating cost per kilometre multiplied by the mean daily kilometres travelled. To enable an analysis of service provision costs by quarter-hourly intervals, quarter-hourly costs were estimated by dividing the daily cost by 92 (24 hours multiplied by four). These quarter-hourly cost rates per bus were then multiped by the estimated number of buses in service during each 15-minute interval, to produce a total cost of service provision for the entire service network. The rise and fall of fleet deployment in the peak shoulders were estimated on the basis of passenger to vehicle ratios. A further limitation of the method is therefore that quarter-hourly fleet operating costs are simple estimations drawn from the daily cost value, rather than empirical observations that take account of variations of cost across the service span.

A more accurate analysis of the impact of shifting peak-to-base ratios on operating cost would require more temporally disaggregated cost data, in a cost allocation model like that described by Stopher *et al.* (1987), Levinson (1978), and Taylor *et al.* (1999).

4. FINDINGS

The findings of the investigation are presented in terms of: changes in GABS' passenger trip timing distribution; and the impacts of an altered peak-to-base ratio on fleet deployment efficiency.

4.1 Boarding Patterns

Figure 3 presents the percentage change in 15-minute boarding intervals, before and after the COVID-19 lockdown restrictions. A small decrease can be observed in the morning and afternoon peak periods (05:15-07:00 AM and 16:00-17:15 PM respectively), and a larger increase can be observed in the midday off-peak periods. The mean percentage change in the peak periods was -4.4%, compared to +19.8% in the midday off-peak periods. The drivers of this shift from peak to off-peak are likely to be: enduring disruptions to shift work for 'blue collar' passengers (as companies shortened shifts rather than retrenched staff); the increased attractiveness of less expensive off-peak fares in a cost-sensitive passenger market; and a COVID-19 legacy of greater flexibility in working hours amongst 'white collar' passengers. Relatively fewer passenger boardings were found to occur in the evening off-peak period after lockdown (-28.5%), perhaps also due to adjustments in shift work, or to changes in activity schedules that were imposed by curfews and have endured.

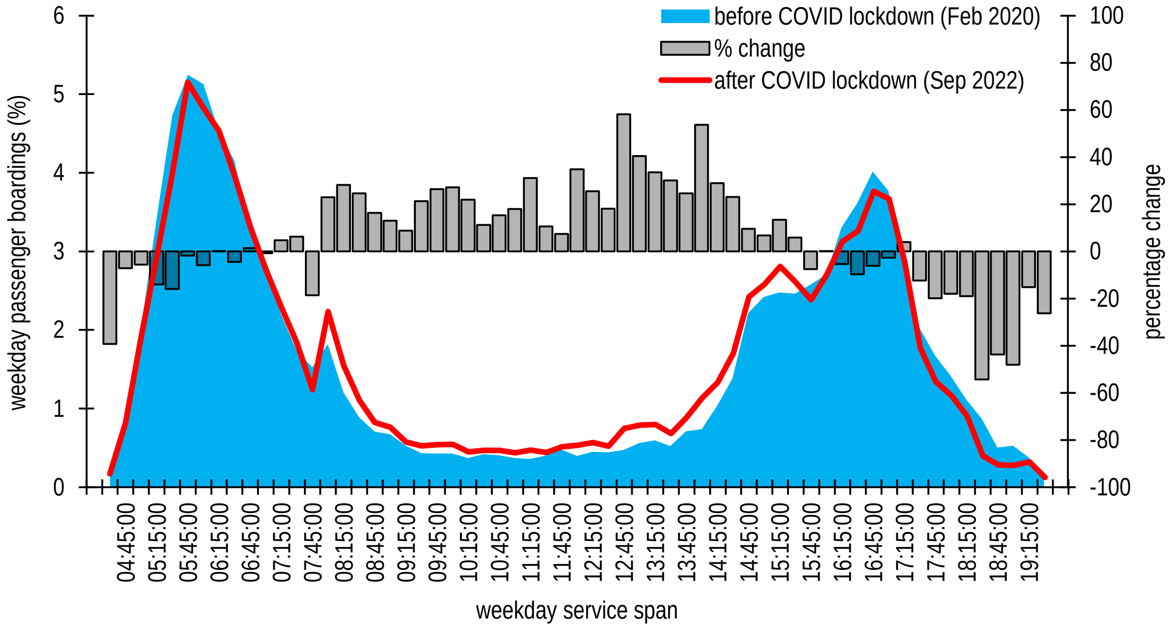
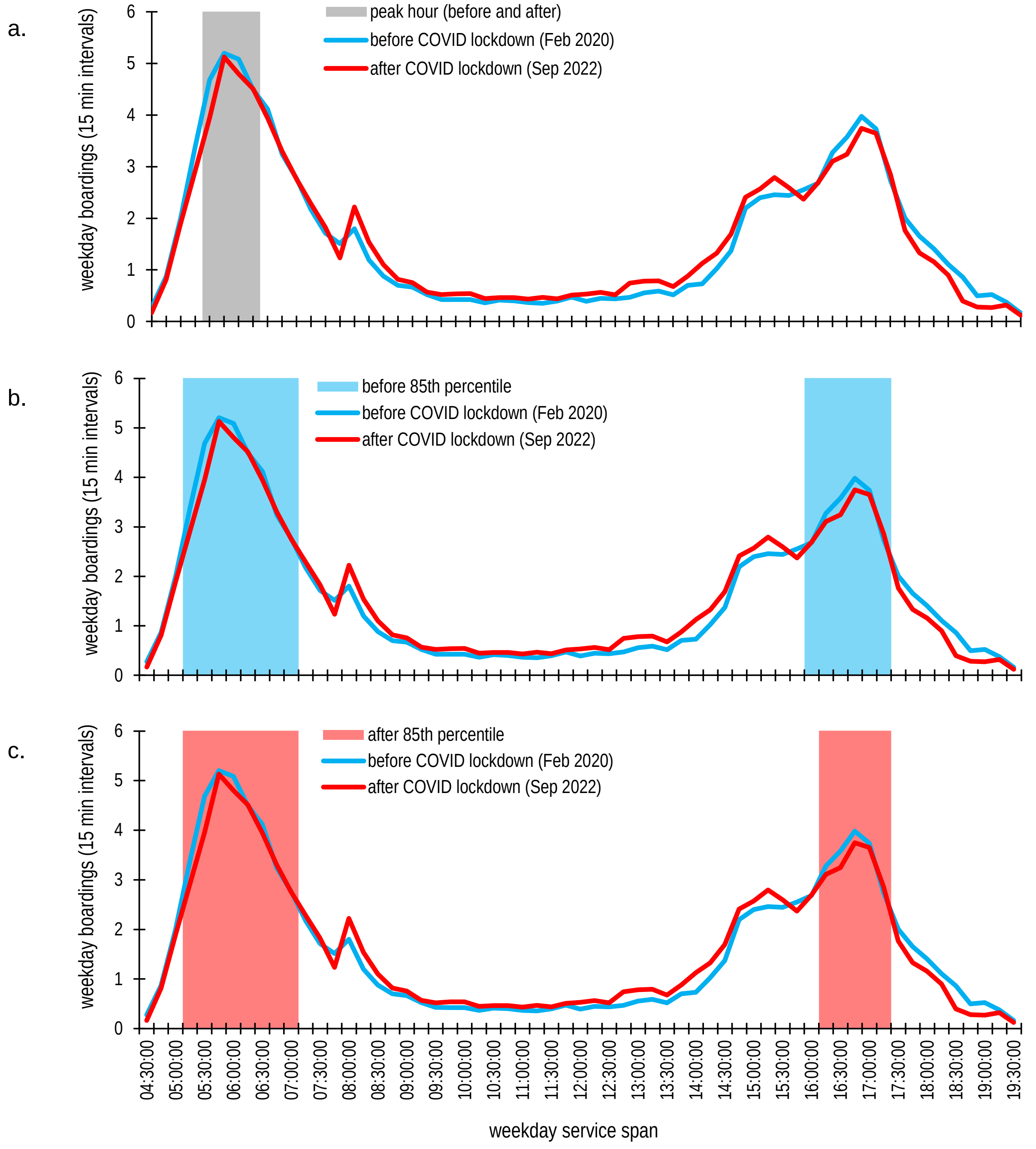


Figure 3: GABS' passenger boarding profiles, before and after COVID-19 movement restrictions

Figure 4(a) presents passenger boarding during the peak hour. The peak hour remained the same in the before and after lockdown periods: 05:30 to 06:30 AM. In the before period, 48 096 passengers boarded in the peak hour (19.4% of daily boardings), compared to 39 903 boardings in the after period (18% of daily boardings). The peak-to-base ratio on the sample days in the pre-lockdown period was 13:1, while the ratio on the sample days in the post-lockdown period reduced to 10:1. To put this into some perspective, Taylor *et al*. (1999) observed a mean peak-to-base ratio of 2.1:1 across 27 large public transport operators in the United States (ranging between 1.4:1 and 3.1:1). Onderwater (2019) estimated a peak-to-base ratio of 8:1 for South African Metrorail services, and 2.5:1 for European train services.



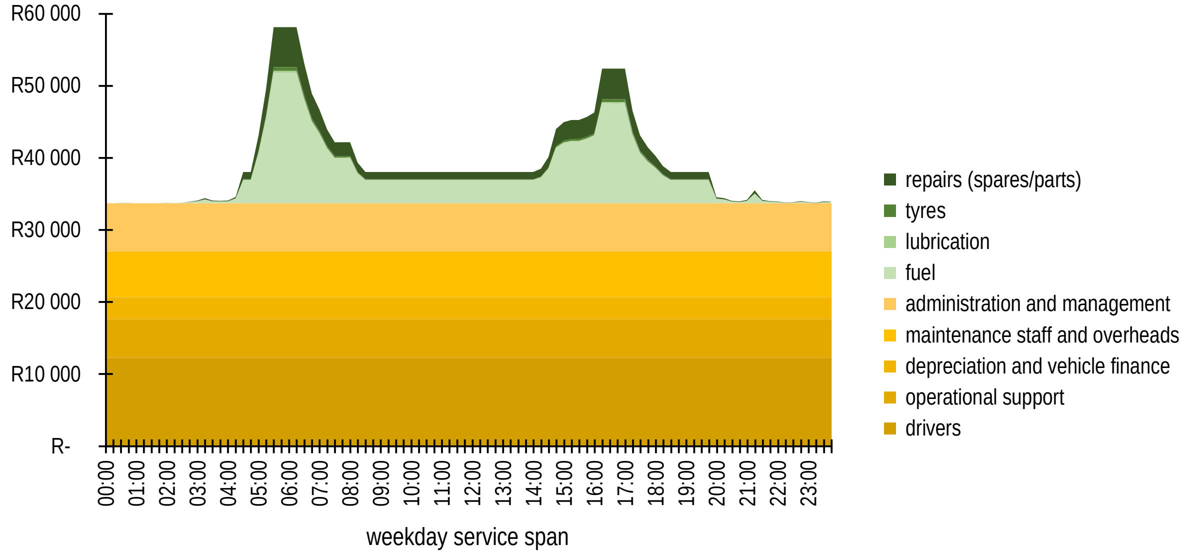
Note: Peak periods are defined as passenger boardings in 15-minute intervals above the 85th percentile.

Figure 4: GABS' passenger boarding peak hours and peak periods, before and after COVID-19 movement restrictions

Figure 4(b-c) presents passenger boarding during peak periods. In this analysis, peak periods are defined as boardings in 15-minute intervals that fall above the 85th percentile. By this definition, the portion of daily trips starting in the morning and afternoon peak periods declined by 10.5% after lockdown. Before the lockdown, 130 849 passengers boarded in the peak periods (52.9% of daily boardings), compared to 103 936 boardings after the lockdown (47.8% of daily boardings).

Table 1: Service provision cost components, per bus

		24-hour weekday	15-minute interval	
Fixed costs	drivers	R1 047	R10.91	21.1%
	operational support	R457	R4.76	9.2%
	depreciation and vehicle finance	R260	R2.71	5.2%
	maintenance staff and overheads	R544	R5.67	11.0%
	administration and management	R567	R5.91	11.4%
	sub-total	*R2 875*	*R29.95*	*58.0%*
Variable costs	fuel	R1 546	R16.10	31.2%
	lubrication	R22	R0.23	0.4%
	tyres	R43	R0.45	0.9%
	repairs (spares/parts)	R472	R4.92	9.5%
	sub-total	*R2 083*	*R21.70*	*42.0%*
Total cost per bus		R4 958	R51.64	100%



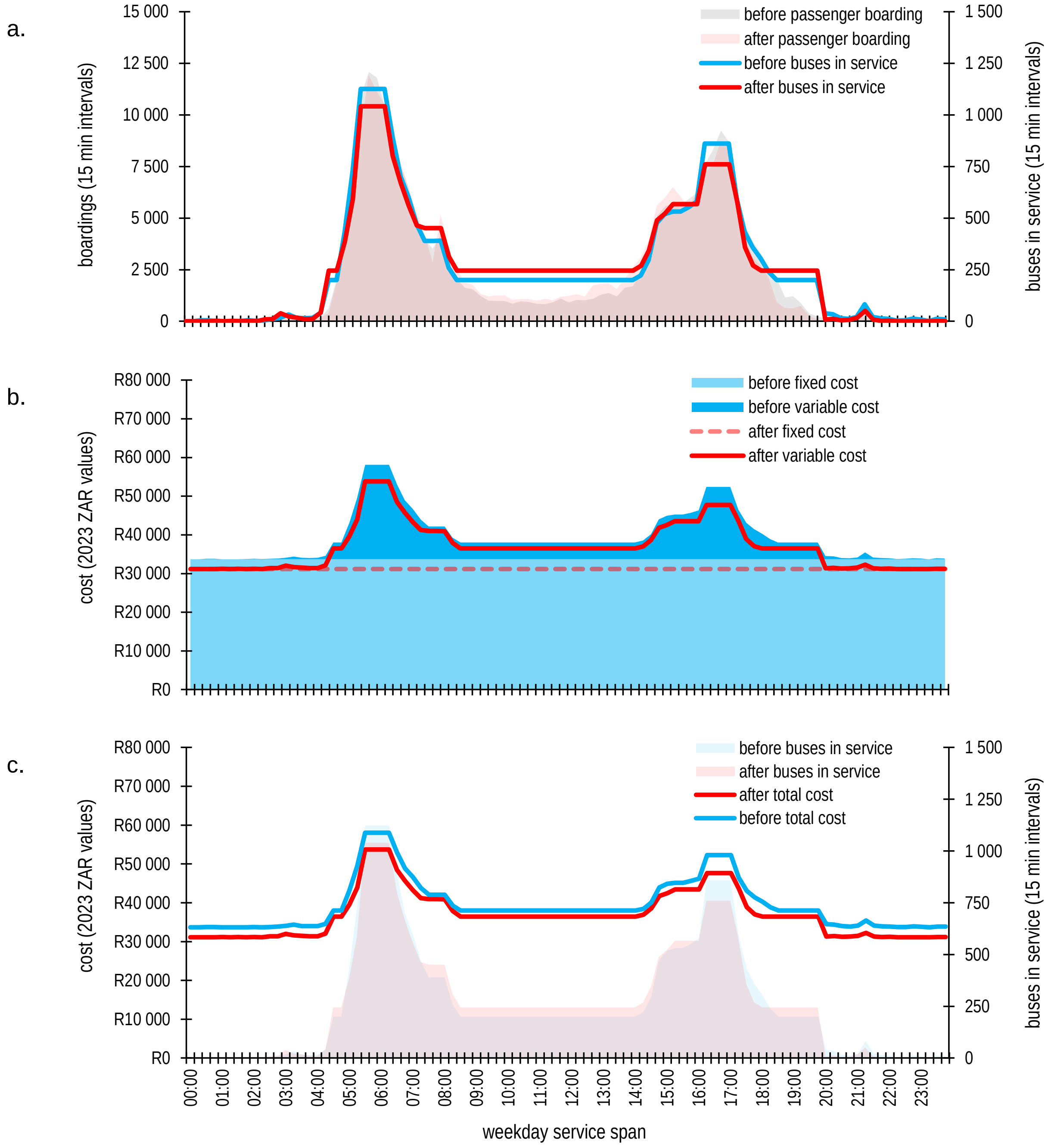
Notes:

1. Cost values reflect the pre-pandemic daily boarding profile. Peak and base off-peak fleet deployment values are actual observations. Fleet deployment values during the peak shoulder are estimated based on peak and off-peak bus occupancies.
2. Costs are estimated in 2023 ZAR values. Quarter-hourly fixed and variable costs per bus in service, are estimated by dividing the daily cost by 92 (24 hours multiplied by four 15-minute intervals).

Figure 5: Fixed and variable service provision cost components, by time of day

4.2 Fleet Deployment Efficiency

Table 1 presents the components of the cost of service provision per bus. The table indicates that fixed costs (drivers, operational support, depreciation and vehicle finance, maintenance staff and overheads, and administration and management) at 58%, outweigh variable costs (fuel, lubrication, tyres, and repairs) at 42%. The most significant fixed cost is driver salaries (21%). The most significant variable cost is fuel consumption (31%).



Notes:

1. To enable comparison, total daily passenger boardings are standardised (at 232 393 boarding/weekday).
2. Peak and base off-peak fleet deployment values are actual observations. Fleet deployment values during the peak shoulder are estimated based on peak and off-peak bus occupancies.
3. To enable comparison, daily fixed and variable costs are held constant across both time periods (in 2023 ZAR values). Quarter-hourly fixed and variable costs per bus in service, are estimated by dividing the daily cost by 92 (24 hours multiplied by four 15-minute intervals). Hence the quarter-hourly fixed cost of service provision per bus is estimated at R30, and the quarter-hourly variable cost of service provision per bus is estimated at R22.

Figure 6: Estimated GABS' fleet deployment cost efficiency, before and after COVID-19 movement restrictions

Using the 15-minute interval values derived in Table 1, Figure 5 presents the components of the cost of system-wide service provision, disaggregated across a 24-hour weekday.

The figure indicates that fixed costs heavily outweigh variable costs during periods of low demand. During the peak hour, fixed costs account for 58% of total cost, whereas during the midday off-peak hour they account for 89%. Outside the service span, fixed costs account for 100% of cost.

Figure 6 estimates the impact of the changed peak-to-base ratio on fleet deployment and cost efficiency. Figure 6(a) presents the relationship between passenger trip timing profile and buses in service. A notable feature of the post-lockdown recovery in GABS' ridership is that, whereas in February 2020 the number of 'peak buses' required to service peak demand was 1 124 (from a total fleet of 1 171 buses), in September 2022 the number required was 1 044 (a decrease of 7%). This peak bus requirement has remained at ~1 040 until the time of writing (February 2023). Simultaneously, GABS deployed an additional 45 buses to off-peak operations, resulting in an expansion from 200 to 245 buses (a 22% increase).

Figure 6(b) estimates the impact of the bus fleet redeployment on fixed and variable costs, in 15-minute intervals across the day. During the peak hour, fixed and variable costs both decreased by 8.1%. During the midday off-peak hour, fixed and variable costs decreased by 8.1% and 13.2% respectively.

Figure 6(c) presents the relationship between the bus fleet redeployment and total cost. It is estimated that a small reduction in the peak-to-base ratio (from 13:1 to 10:1) can register a discernible cost efficiency improvement in vehicle fleet utilisation. During the peak hour total service provision costs decreased by 8.1%, and during the midday off-peak hour they decreased by 9.8%. Across the entire 24-hour weekday, service provision costs decreased by 6.6%. By these estimations, a 1% decrease in the peak-to-base ratio led to a 0.2% decrease in daily system-wide service provision cost.

5. DISCUSSION

The findings presented in this paper are consistent with the general consensus found in the earlier brief review of the international literature: viz. because of larger fleet and labour requirements, it costs more to provide a bus service in the peak than in the off-peak, but the total cost of service provision per passenger is higher in the off-peak because of constant fixed costs scaled by peak demand. Comparison of findings with the only study with a comparable metric suggests the direction of change, if not the scale, is similar. Reilly (1977) found that the total cost of bus service provision per passenger was USD 0.48 in the peak hour and USD 0.75 in the off-peak (a +56% increase in the off-peak). When the 2022 GABS data are analysed as system-wide service provision cost per passenger, the cost was ZAR 5 in the peak and ZAR 35 in the off-peak (a +593% increase in the off-peak). The considerable difference in the off-peak increase is possibly due to the sixfold greater peak-to-base ratio in Cape Town compared to Los Angeles (10:1 vs. 1.7:1).

The recognised cost efficiency benefit, among bus operators in Cape Town, of reducing the peak-to-base ratio by shifting passengers from the peak to the off-peak is evidenced by the fact that both GABS and MyCiTi services offer off-peak fare discounts. In the case of GABS, the discount is 45% of the peak fare. In the case of MyCiTi, the discount is in the region of 25%. Gwilliam (2008) notes that when fare discounts are made available to designated groups in other parts of the world, they are often limited to off-peak periods so that they may serve as both instruments of welfare distribution and economic efficiency.

6. CONCLUSION

This paper set out to explore the nature and extent of the change in GABS weekday boarding patterns before and after COVID-19 lockdown restrictions, and to discuss associated impacts on fleet deployment efficiency.

With regard to weekday boarding patterns, analysis revealed that the portion of passenger boardings occurring in peak periods declined by 10.5% after lockdown (and by 5.8% in the peak hour), resulting in a reduction of the peak-to-base ratio from 13:1 to 10:1. The mean percentage change in 15-minute boarding intervals was -4.4% during peak periods, and +19.8% during midday off-peak periods.

With regard to fleet deployment efficiency, it was estimated that fixed costs heavily outweigh variable costs during periods of low demand (accounting for 89% of the cost of system-wide service provision in the midday off-peak hour). Because the peak scales fixed costs, a small reduction in the peak-to-base ratio was found to register a discernible cost efficiency improvement in vehicle fleet utilisation. The number of buses required to service peak demand reduced from 1 124 to 1 040 (a 7% decrease), and the number of buses servicing the off-peak increased from 200 to 245 (a 22% increase). It was estimated that a 1% decrease in the peak-to-base ratio led to a 0.2% decrease in the daily system-wide service provision cost. These conclusions suggest that, following the hardships public transport operators endured during the COVID-19 pandemic, there may indeed have been at least one enduring disruption that was beneficial.

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