Travel Patterns of Urban Linear Ferry Passengers: Analysis of Smart Card Fare Data for Brisbane, Australia

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Word count: 5,452 words text + 8 tables/figures x 250 words (each) = 7,452 words

TRR Paper number: 15-1728

Submission Date: 15 March 2015

ABSTRACT

Urban linear ferry systems are an emerging form of public transport in cities worldwide. This paper investigates travel behavior of passengers using *CityCat* ferries in Brisbane, Australia. We investigate 1,675,821 ferry trip fare transactions made over a six month period using smart cards. Despite use of small vessels and only offering one main route around 2.3% of all paid public transport journeys in the city are made on *CityCat* and related cross-river ferries. The ferries are used more for commuting and university trips during the weekday with significant patronage in the am and pm peak periods. They have consistent use on weekend days. Despite strong use most users are infrequent patrons, suggesting that leisure travel is a significant component of the system. Key terminals with high use rates include those where transfer to cross-river ferry services is possible. The system offers single-stop cross-river travel at many points. But only 15.8% of paid trips in March 2013 were made this way with 84.2% of trips going further up or downriver. Integration with other buses and trains is significant, with around 15% of all ferry journeys linked to another public transport mode. Further investigation into how users are accessing terminals as well as interactions with other modes of public transport is suggested. With expansion planned, the *CityCat* system has potential to contribute further to the city's public transport task. Converting a large number of infrequent riders to more habitual use could increase the system's patronage.

INTRODUCTION

Smart card fare data is becoming an increasingly valuable resource for analyzing travel behavior patterns on public transport systems. An emerging transport mode are new forms of urban ferries proliferating in major cities worldwide. In particular, linear ferry systems that run parallel to coasts or rivers (1) are being installed to help with the public transport task and alleviate transport problems. The aim of this paper is to examine the influential *CityCat* system in Brisbane, Australia, one of the first modern linear ferry systems worldwide, and to clarify the confusion amongst transport planners about how people use such systems, whether mainly for cross-river trips, or more for longer up- or down-river trips. We provide the first analysis of linear ferries using smart card fare data, allowing the examination of passenger's travel behaviour characteristics, how the ferries are being used, and how they fit into Brisbane's public transport system, all of which have important implications for the planning and operation of similar systems.

This paper is organized in six sections: i) provides background information on Brisbane and its public transport system in order to set the context; ii) the concepts and characteristics of the *CityCat* system are introduced; iii) a description of the data analysis and methodology used; iv) results; v) a discussion of their implications; and, vi) a summary of the key operational findings of the study and avenues for further inquiry.

BACKGROUND

Brisbane is Australia's third most populous city, lying on the east coast of Australia, with a population of just over 2 million (2). It is a part of the greater South East Queensland urban conurbation, including the Gold Coast to the south and the Sunshine Coast to the north. Brisbane has a well-developed public transport system incorporating rail, bus and ferry services. There are 432.5 kilometres of track (much of it duplicated in key corridors) on the extensive City Rail network with 11 lines and 214 mostly 3-car vehicles in use (3) albeit frequencies are modest outside AM and PM peak hours. There are also 613 bus routes (4). And there are the 19 *CityCat* and 9 monohull ferries that service 21 kilometres of the Brisbane River and 24 terminals within the urban area. Previously planned and operated by separate authorities, the system is now centrally planned by a multi-modal government authority, Translink, established in 2004, with the intention of unifying the fragmented network and allowing better coordination between modes (5). There are 15 bus operators in the overall SEQ region however the majority of buses within Brisbane City Council's area are run by Brisbane Transport, a division of Council. Buses both compete with and service many of the ferry terminals. Queensland Rail operates the SEQ rail network that services Brisbane and which has stations near some ferry terminals. All the urban ferries are run by Transdev under contract to Brisbane City Council. Fares are integrated across all public transport modes, except taxis, in the SEQ region. In 2008 paper tickets were supplemented with smart cards, branded the "Gocard", and which now represent more than 90% of fare transactions (6). The term "smart card" is used to encompass a broad range of cards that possess computer chips for data storage and processing. Smart card applications for fare payment in public transport has become mainstream in the last 15 years around the world (7). Advantages of smart card systems are: convenience for commuters; increased service effectiveness; travel data collection; travel demand management, discouraging fare evasion and decreasing social conflicts (8). The most beneficial aspect of smart card systems for transport researchers and professionals is the data they offer. Smart card fare data provides geo-spatial time-stamped records that are generally superior to most other forms of data gathering (9). When used pro-actively such datasets are helpful for transportation planners, from the day-to-day operation of the system to the long-term strategic planning of the city network (7). Smart card fare data has been used to explore complex issues such as trip chaining and origin-destination travel by public transport users (10) or jobs-housing balance of bus commuters in Beijing (11) but it is also useful for more applied analysis of existing public transport systems.

The Brisbane Go-card system is a region-wide, zone based scheme in which passengers use one card for buses, trains and ferries. Go-card users pre-purchase credit at designated shops, kiosks, machines at stations, or online, with the option to record credit card details for automated top-up. Fares are automatically collected based on distance and zones travelled as users ride the network. Advantageously for research purposes, all Go-card passengers must tag on when boarding and tag off when alighting from buses and

ferries, or when entering or leaving a train station, using Go-card readers located on-board or on the platform. This provides origin and destination data records for each transaction, which is not common to most smart card systems worldwide. There are four types of Go-cards – adult, child, senior and concession, with 50% fare reduction for cards other than adult. All fare processing is off-board.

URBAN LINEAR FERRY SYSTEMS

There are a number of existing urban linear ferry systems in operation around the world, including examples from Australia (Brisbane, Sydney), Europe (London, Stockholm, Gothenburg, and Copenhagen), North America (New York, San Francisco) and Asia (Bangkok). These share common features of an urban scale, linear route, high speed service, with frequent public service timetabling. Weisbrod and Lawson (12) highlighted the potential for urban revitalization and widespread economic benefit via such ferry systems, as well as traffic congestion alleviation and air pollution reduction. Sipe and Burke have shown the potential for these services to promote Smart Growth by integration of land use around ferry terminals (13) and how these systems can be made more resilient against disasters and used for postemergency transportation (14). Tsai et al. (15) also found significant residential property value uplift surrounding ferry terminals in the Brisbane system. There is little literature on their planning, operation or travel behaviour impacts as yet. A recent report by the New York City Economic Development Corporation on the modest East River Ferry operations in New York showed ridership of 3,200 per weekday with average monthly boardings peaking significantly in the summer months, as well as property value increases around terminals and leveraged urban development (16). But this work did not explore in greater detail how frequently individual passengers board the ferries, how passengers use the system across an average day, and for what type of trips (cross-river or linear). There remains confusion on such questions amongst planners and operators, including whether these systems are just a cost-efficient way to service cross-river travel demands whilst also providing for some linear travel, or whether they are there to primarily service longer distance travel, but also provide for some modest additional cross-river demand. Much of the media reportage on the Brisbane system, for instance, has been on its cross-river functions and reductions in cross-river services due to cost-savings measures, rather than the system's provision of linear travel parallel to the shoreline (17).

Brisbane's *CityCat* fleet has grown from initially four vessels when first introduced in 1996 to 19 vessels at present (18). Brisbane is continuing to expand its network with new vessels and terminals in recent years, with further expansion plans. A map of the system is shown in Figure 1. Note that in addition to the *CityCat* and associated *Cross River* ferries that are the focus of this paper, there is also a set of smaller, less-frequent and free *City Hopper* services that were introduced in the central city area of the river only, servicing tourists and recreational travellers. As these services are free no fares are collected and ridership data is available. The *City Hopper* services attract less than one-tenth of the ridership of the *CityCats*.

An overview of the current system characteristics is provided in Table 1. The system services much of the central business district (CBD) of Brisbane, where the vast majority of government and commercial office employment for the city is located (19) as well as the two largest university campuses – the University of Queensland at St Lucia, which is the final terminal up-river, and the Queensland University of Technology at Gardens Point adjacent to the city centre. Key terminals in the network include Riverside, at which many city workers alight to access the city's main business precinct, the Bulimba and Hawthorne terminals where residents have been serviced by ferries for over a century (the heritage listed Hawthorne terminal dates from the 1920s), the Tennerife terminal opposite Bulimba, which has long been a major crossing point on the Brisbane river, and the university terminals at QUT Gardens Point and the University of Queensland. Burke & Brown (20) found the system had significant walk catchments with the median distance walked from home to the ferry terminals in 2003 being 890m (85th percentile = 1.54km).

METHODS

For this investigation a six month slice of Go-card transaction data was obtained from Translink comprising more than 69 million trips recorded between November 2012 and April 2013 (21). In March 2013 alone, approximately 15 million entries were recorded. The following variables are recorded for

each transaction: operator name, date and time of the trip (at both origin and destination), status of the transaction (boarding and alighting), ticket number, number of passengers, card ID, service ID, journey ID, trip ID, route ID, route direction, boarding stop ID, alighting stop ID and run ID.

Data mining methods were used to process and analyse the data. Data mining is a technique that applies tools from statistics, database management and computer graphics to extract patterns from large data sets. Data mining functions can include: classification, segmentation, description and visualization. This means that categories are assigned to data in comparison to historical data, grouping together sets of data that share some degree of similarity (different metrics are available), and extracting patterns from the data, as well as providing the available information in a format that is understandable to the user (association rules, trees and graphical representations are common) (22).

The data was then cleaned with the aim of removing undesirable details and errors. Also, non-necessary attributes were filtered depending on the requirement of pre-defined queries. That is, for example, bus or train-only journeys were filtered-out from the dataset used for analysis. A set of software products included Microsoft Excel, MATLAB, SPSS, CSVSplitter, and CSVEEditor were utilized. These were used to discover some patterns such as route load profiles, and to compute those fields which were not included in the initial dataset, such as the travel time, distance between an origin and destination, and the transaction time for a vehicle at a stop. For analysis purposes and faster processing, the database was classified into six separate monthly parts using CSV Splitter software.

It is worth noting the limitations of the Go-card data that restrict its application for travel pattern analysis:

- There is no demographic or trip purpose data provided;
- The user's ultimate destination is not necessarily where they touch off;
- The Go-card may be used illegally by more than one person; except for those who register their personal information, it remains completely anonymous.
- Card type e.g. concession is not recorded in the transaction data;
- Trips on the free *City Hopper* service are omitted, given there is no payment required. The dataset for analysis includes only *CityCat*, *Cross River Ferry* and *City Ferry* services for which payment is required (see Figure 1).
- Only 23 days of data was provided for January 2013. The ferry dataset was weighted and expanded to produce a comparable monthly figure. March data was used for more detailed analysis to avoid concerns.

When looking to compare between weekday and weekend travel we chose *Wednesday* and *Saturday* as representative of a typical weekday and weekend day, respectively. For the analysis for origin/destination pairs, transfer patterns and frequency of use, we used March 2013 as representative of typical ferry usage, so as to avoid holiday periods in Australia. The spatial variability of ferry usage was analysed by listing all of the ferry terminals for *CityCat* and *City Ferry* used for getting on or off along the Brisbane River. For this purpose the frequency of use of each stop as an origin or destination was examined.

The following results section breaks down "How are ferries being used in Brisbane?" into a series of secondary questions, the answers to which are presented thereafter.

RESULTS

Of the 69 million total trip transactions, on average, around 11.6 million were conducted using all modes of public transport per month. All ferry trips for the period November 2012 to April 2013 were selected and cleaned, further removing around 2% of records due to inconsistent, missing or unusable data records, including trips where the passenger failed to tag-off their Go-Card or tagged on and off quickly at the same place. This final dataset of 1,675,821 trip transactions was then used for the following analysis. Ferry represented only 2.3% of all Go-card public transport trip transactions made on Wednesday 6th March 2013.

Monthly and daily variation: So how were the ferries being used? The number of trips made each month from November 2012 to April 2013 is shown in Figure 2a. As with the New York system (16) there is a

slight decline observed in ferry use around December – February, which may relate more to school and university holidays in Australia rather than weather (it being summer in Brisbane). The trip rates also vary a little across each weekday, as shown in Figure 2b. It was found that there was no significant discrepancy among weekdays in December, January, and February. However, for the three other months, this difference was greater, with slightly less transactions recorded on Mondays and Fridays than the other weekdays, and more transactions on Saturdays than Sundays.

Variation by time of day: The number of transactions made by time of day varied quite significantly between weekdays and weekend days, as shown in Figure 4. The graph shows the pattern of use for Wednesday 6th March 2013 as a typical weekday and Saturday 9th March as a typical weekend day. On weekdays, as expected, the AM and PM peak periods have strong passenger trip numbers compared to the off-peak and evening. This suggests the ferries are being used by city commuters during these periods. On weekends though, from 10AM to 8PM, there is a relatively constant pattern, albeit nowhere near at the rates of use in the weekday peak. There is again modest use of the ferries late evening. These same patterns were observed to repeat every week i.e. following Wednesdays and Fridays produced similar results.

Temporal patterns across months. Next we looked at the differences in the period of travel made within the day. Figure 5 show that the distribution of trips during the peak/non-peak hours is relatively similar among the six months. The highest volume of ferry usage was reported for the peak PM period, followed by the midday period. Significant was the high amount of peak AM trips. This graph also confirms that the difference in temporal patterns during the six month period is not overly significant, with the reduction in AM peak trips in December and January, presumably due to the closure of workplaces and universities for summer holidays, being the most pronounced change.

Origin/destinations: The AM peak boardings and alightings for Go-Card transactions at each terminal made in March 2013 are shown Figure 6, below. Some terminals attract significantly more passengers. The most important terminals for boardings are in suburban areas, particularly downstream of the CBD at Bulimba and Hawthorne. The Riverside terminal in the heart of the CBD dominates alightings in the AM Peak with more than 26,000 alightings, with Teneriffe and the University of Queensland terminals also having more than 7,000 alightings.

Transfers to bus and rail: In March 2014, 85.8 per cent of ferry trips were made independent of any other public transport. 14.2 per cent of public transport journeys that incorporated a ferry trip involved transfer to either bus or rail. This is a greater proportion of passenger inter-modal transfer than found in Greater Brisbane between the bus and rail networks alone. Key terminals where this behaviour was apparent included South Bank, which is co-located near key busway and rail stations, and Teneriffe, where a high frequency bus to the central business district departs directly from the ferry terminal.

Linear or cross river? A question remains about whether passengers are using the ferry system for simple cross-river trips, or for longer, linear trips up or down-river. Given the Council that introduced the *CityCats* sought to produce longer trips to work and university up- and down-river, is the system meeting its objectives, or is it just servicing cross-river trips that could be better serviced by new bridges? To explore

this the ferry Go-card transactions were further disaggregated to identify those trips made explicitly on the *CityCat* route, the *Cross River* routes between Norman Park and New Farm Park, Teneriffe and Bulimba, and Eagle Street with both Thornton Street and Holman Street. Journeys made at key cross-river origin-destination pairs on the *CityCat* route were then also identified to isolate the set of transactions that represent simple, one-stop, cross-river trips from the set of transactions that represent longer linear trips along the

CityCat route. For all of the 316,236 trip transactions made on the ferry system in March 2013 some 49,851 (15.8%) were classified as cross-river trips, and 266,385 (84.2%) were linear trips. Further, for those travelling linear journeys on the *CityCats* the average weekday travel time is 16min and travel distance is 7.4km, which is relatively long. Though the system is therefore focused more on longer, linear trips, particular terminals have a much stronger cross-river function than others. For instance, 40.3 per cent of all transactions recorded as boarding at Bulimba during March 2013 used the ferry for a simple cross-river trip to Teneriffe and alighted there. Reflecting its lesser cross-river potential, only 13.1% of transactions recorded as departing New Farm Park proceeded cross-river to Norman Park. 9.9 per cent of trip transactions departing from South Bank 1 and 2 terminals alighted at North Quay 1 and 2 but only 2.9 per cent alighted at QUT Gardens Point.

Frequency of use: Ferry users were categorized based on their frequency of use of the ferry system to identify whether users were frequent ferry passengers or not. Figure 7 shows that the vast majority of Go-cards used for transactions are used with very low travel frequency, being used for only 1 or 2 trips. Though some passengers may use more than one Go-card, and though the majority of trips are made by more frequent travellers, a very large proportion of those who do use the ferries do so only occasionally. Further, this indicates that the ferries are therefore used by a much wider cohort of the Brisbane community than previously imagined.

DISCUSSION

For a modest service the ferries are performing well. That in March 2013 well over 60,000 different Go-cards were used on the ferries suggests around 3 per cent of the greater Brisbane population of just over 2 million used the system that month. This is in a city where total public transport mode share in 2009 was only 9.5 per cent (2009 being the last year such data was captured) and with a large bus and rail system (23). There is seasonal variation with ferry trip rates highest in March and lowest in January. This is likely due to the long university and workplace holidays over the December-January period in Australia rather than the effects of cold weather that underlie similar patterns in New York (16). There is also daily variation, with Tuesday to Thursday having the highest patronage, and the least use on Sundays. There are notable AM and PM peaks in use during weekdays, which likely prove challenging for the system operators. The more steady rates of boardings and alightings during the day over the weekend, particularly between 9am and 5pm, presumably make for smoother operations and ease of scheduling.

It was shown that the terminals with the highest trip productions (generation and attraction) were Bulimba, Hawthorne, Teneriffe, Riverside (in the CBD) and the University of Queensland (UQ). That the CBD and the city's largest university anchor so much trip-making is understandable. But locations such as suburban and residential Bulimba's strong production of AM Peak ferry boardings is of more interest. Notably, Bulimba, Teneriffe and Hawthorne had strong property value increases surrounding the terminals identified in research by Tsai et al. (15) and there has been significant development of medium density apartments and townhouses in close proximity to these sites. What makes such precincts work to produce large numbers of ferry boardings, especially given these suburbs are also serviced by high-frequency buses to the CBD, is worth further investigation.

Though not reported here due to space constraints the Go-card data shows that at Bulimba many passengers cross the river to access the *City Glider* high frequency bus at the Teneriffe terminal, others journey downriver to the same approximate end destination as that bus service in the CBD by alighting at Riverside, and others take a bus from near the Bulimba terminal all the way to the CBD avoiding the ferry altogether. Further exploring the choice behaviour of passengers in such circumstances to use ferry versus other modes may potentially identify the premium that linear ferry services offer passengers over bus or rail travel, even where travel times may be longer, due to the increased comfort, amenity and scenic potential of urban ferries. In addition, though it was shown that transferring between bus or rail and the ferry system is significant, how these transfers are being made has not been analysed in greater detail and is outside of the scope of this paper. Further studies could investigate these questions using both the Go-card data and additional sources such as household travel surveys and intercept surveys of passengers. This could explore

car, walk and bicycle access and egress from ferry terminals, as well as the role of public transport.

The results suggest that although the *CityCats* and related cross river ferries provide significant potential for basic cross-river trips directly across the Brisbane River, most paying ferry passengers are taking up the potential for longer, linear trips parallel to the shoreline. Though the smaller capacity and free *CityHopper* ferries that are not part of the Go-card dataset are omitted from this analysis, there is no doubt most ferries users in Brisbane use the system for linear trips. The system therefore acts more like a bus route along a corridor rather than as an efficient way to service multiple cross-river travel demands.

The results on inter-modal connections at locations such as Teneriffe suggest further research is needed to identify user preferences for ferry travel relative to other public transport modes and to further quantify the premium planners should expect from the increased comfort and amenity of urban ferries. The authors seek to advance this research agenda soon using the same dataset.

Many of Brisbane's ferry users were shown to use these services relatively infrequently. The vast majority of Go-cards used for ferry transactions in March 2013 were for only one or two trips, many of which represent one return journey. A challenge for these systems may be in converting these travellers into a larger set of regular daily riders to further boost patronage.

Further research is required to understand the travel behaviour of market segments on such systems, including how tourists, students and others use them. Such segmentation is not yet possible based on the type of information currently available in Go-card data releases. For instance, the different types of Go-card cannot be differentiated and one cannot therefore distinguish student travel patterns from other users. Given a major terminal for passengers is the University of Queensland (also the largest employment center outside of the CBD other than the airport) data on student ferry travel would be valuable. The lack of socio-demographic data also limits interrogation of equity and other variables in relation to ferry travel.

CONCLUSIONS

This paper looked at the Brisbane linear ferry system and has demonstrated how smart card data can be used to profile a system's usage. It has been shown that although these ferry systems may be a minor mode in the overall public transport task they can move significant numbers in their corridor, attract sizeable longer-distance linear patronage, and not just service cross-river travel as is often presumed. Further, they can attract use from a significant proportion of a city's population, including commuters and tourists. Users are clearly willing to combine urban ferry trips with other public transport modes, including for longer linear ferry trips. This information should help with the planning and design of similar systems, as cities such as Washington D.C. and Abu Dhabi consider following Brisbane's lead.

ACKNOWLEDGEMENTS

The views expressed are solely those of the authors and do not represent the views of any institution. The authors take full responsibility for all errors and omissions. The authors would like to acknowledge the support of *Translink* and other officers of the Queensland Department of Transport and Main Roads. The support of Mark Hickman and Neema Nassir of the University of Queensland is highly appreciated.

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FIGURE 4 Typical weekday/weekend travel distribution (Source: *Translink*, 2013)

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FIGURE 6 (a) AM peak boardings per terminal (above); (b) AM peak alightings per terminal (below) (Source: *Translink*, 2013)

FIGURE 7 Frequency of ferry users (Source: *Translink*, 2013)

Year introduced	1996
Management	Terminals owned by Brisbane City Council
	(BCC) [most buses in the area of the <i>CityCat</i> network are operated by a division of BCC, passenger rail services are operated by the Queensland Government]; ferries managed under contract by <i>Transdev</i>
Total vessels	19 <i>CityCats</i> , 9 smaller Monohull ferries
Maximum cruising speed	25 knots
<i>CityCat</i> ferry capacity	149 or 162 passengers per vehicle
Total service area	21 km of the Brisbane river
Travel time for one-way <i>CityCat</i> trip along the entire route	76 minutes
Number of terminals	24
Fare structure	Integrated ticketing; fares integrated to same zonal structure and price as broader Brisbane (<i>Translink</i>) public transport fares; one-way cross-river adult fare US\$2.96, full route oneway fare \$4.12; no monthly passes; 50% concession fares are available to children, fulltime students, pensioners, seniors and defence force veterans.

TABLE 1 Brisbane *CityCat* characteristics (Source: Burke and Sipe 2013; *Transdev* 2014; *Translink* 2014)

FIGURE 1 *CityCat* network map (Source: Translink, 2013)

FIGURE 2 (a) Monthly variation in ferry passenger trips; (b) Daily variation in ferry passenger trips (Source: *Translink*, 2013)

FIGURE 3 Daily variation in ferry travel (Source: *Translink*, 2013)

Wednesday, 6th March 2013

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FIGURE 4 Typical weekday/weekend travel distribution (Source: *Translink*, 2013)

FIGURE 5 Peak and off peak variation in ferry travel (Source: *Translink*, 2013)

FIGURE 6 (a) AM peak boardings per terminal (above); (b) AM peak alightings per terminal (below) (Source: Translink, 2013)

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