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Big Data and Urban Transportation in India: *A Bengaluru Bus Corporation Case Study*

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Big Data and Urban Transportation in India: *A Bengaluru Bus Corporation Case Study*

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Abstract

As cities grow, urban transportation is becoming an issue of increasing salience. Simultaneously, big data systems are being introduced into urban transport. This paper analyses the early days of the big data system introduced by India's Bengaluru Metropolitan Transport Corporation, which runs the city's 6,000-plus buses. This has three main components: automated vehicle tracking and electronic ticketing machines which generate gigabytes of data per day, and a linked passenger information system with mobile app. Field interviews and document analysis were used to assess the system.

Only an early, partial and contingent assessment can be given because the system had only been implemented for little over a year. It does work in terms of gathering data and informing both management and passengers, though there are some operational flaws still to be ironed out. Substantive contribution of tactical and strategic value has yet to be seen: it seems easier to apply data-intensity to operational than higher-level managerial processes. However, there is already a sense in which big data is changing both the image of the organisation, and the "imaginary" of politicians and managers: the new view of urban transport systems that big data makes visible. As a result of the latter, plans for removal of bus conductors and of layers of middle management are well advanced.

We also see signs of big data enabling shifts in power: from labour to management, from middle to top management, and potentially towards those with data-related capabilities. There is some greater transparency of organisational activities to the general public, but wider transparency awaits full and sustained opening of transport data to other users.

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A. Introduction

Bengaluru – capital of Karnataka state in India – is a city of ten million people, growing fast and facing severe urban transport problems: since 2001 more than five million vehicles have been added to the city's road and average traffic speeds have dropped from 33kph to less than 5kph (ET 2017). Buses are a key part of the urban transport architecture and Bengaluru Metropolitan Transport Corporation (BMTC) has more than 6,000 buses and nearly 35,000 employees. Every day it carries more than five million passenger journeys over more than 2,000 routes and 8,000 bus stops, collects over US$500,000 in revenue, and its buses travel more than 1.2 million kilometres (BMTC 2017a).

Such an operation requires a large number of operational, tactical and strategic decisions, and generates huge amounts of data which could be used to guide that decision-making. Historically, that data has not been captured or has been captured very inefficiently using human-based or paper-based systems. With growing size and complexity creating increasing decision-related problems, in May 2016, BMTC launched its Intelligent Transport System (ITS); a project initially conceived in 2012 and beginning implementation in 2013. The ITS project involves integrated implementation of over 10,000 Internet-enabled electronic ticketing machines, and over 6,400 online vehicle tracking units, at an initial five-year cost of around US$1.2m (Akshatha 2015).

For the first time, this has enabled capture and use of very large amounts of daily data in digital format. The aim was to create a smart transport system for real-time tracking of buses as well as of passenger trips. It had an internal purpose of helping BMTC managers make more data-intensive decisions: e.g. operational decisions around cash flow, and more tactical decisions regarding planning of bus routes and schedules. And it had an external purpose of enabling passengers to make more data-intensive decisions about journey planning. Such applications also have wider economic and social value:

> "For public bus services, dissemination of accurate information regarding current bus location, arrival time at bus stops, etc. to the traveler will help to reduce the uncertainty and waiting time involved in the use of bus service system and enhance efficiency. Improvements in service efficiency and reduction of waiting time will attract more passengers to this means of public transport, thus easing the traffic burden on the roads" (Vanajakshi et al. 2016:80).

To investigate in more detail, in 2016, author Vanya Rakesh undertook a field study of this new big data system just a few months after implementation. Alongside direct observation of the system in action and analysis of available documentation, the study involved nine interviews with staff at both strategic and operational levels in BMTC, with technical contractors implementing ITS, and with external experts and advisers involved with development of urban transportation in Bengaluru. This was followed in mid-2017 by analysis of additional documentation updating on performance of the system just over a year since implementation.

In what follows, the main human actors and technical components of the system will be outlined, its value at various levels of the organisation will be assessed, and conclusions will be drawn, particularly about the relationship between big data, politics and power.

B. Background and Actors

B1. Background

Bengaluru has a long history of association with ICTs dating back to development of the global South's first analogue computers in the Indian Institute of Science in 1952 (Heeks 2009). In transport, there were some internal administrative computing applications; for example use of digital information systems for inventory control in the Karnataka State Road Transport Corporation from the early 1980s. During the 1990s and stretching onwards into the 2000s and 2010s, bus-related data was not collected in real time. Conductors used paper tickets (see Figure 1) and paper time sheets, where the arrival and departure time of buses at major bus depots were documented by the controller concerned. They also maintained daily trip-sheet data on ticket sales including the temporal pattern of sales; again on paper. There was no data gathered on bus location and hence no way to inform passengers about journeys other than the published timetables.

Figure 1: Paper-Based Bus Ticketing

Source: Ramakrishnan (2015)

This situation was the current one in Bangalore up the advent of ITS. However, there were experiments with use of ICTs:

- A GPS-/satellite communications-based system was installed in Bengaluru in 1999 but only for use on the 200 or so buses hired from private operators. The system did not work well: it was offline so data had to be physically retrieved from each bus. Reports arrived two-three days after journeys had taken place, and were thus of no use for real-time tracking (Prakash 2008). The system was abandoned, having cost around US$120,000.

- In the early 2000s, there were similar GPS-based pilots which did not sustain in other parts of Karnataka state.
- In 2004, BMTC issued a letter of intent to install online GPS-based tracking for its buses, seeking to overcome limitations of the earlier offline deployment. However, the satellite links often broke down within an urban environment due to line-of-sight obstruction from trees, buildings, flyovers, etc; and the data provided was not linked to bus schedules (Prakash 2008, Vanajakshi et al. 2016). Again, no real-time tracking was possible and this system was also abandoned, having cost around US$100,000.
- Electronic ticketing machines were introduced by BMTC on a number of routes in 2008 but were removed by 2011 due to functionality problems (Ramakrishnan 2015).
- In 2007, Mapunity (see below) launched the Bengaluru Transport Information System (BTIS)[2], which aggregates video and mobile cell tower and other data to try to provide a comprehensive urban traffic information system for individual citizens and city agencies. This system is still in operation.
- In 2010, Mysore began implementation of an Intelligent Transport System, with initial implementation in 2012 and final completion only in late 2016 (Urs 2010, Prasad 2012, Indian Express 2017).

B2. Main Actors

The main actors involved with the Bengaluru ITS big data platform are described below, indicating that this is a public-private partnership. It was implemented on a build-operate-transfer basis.

- Bengaluru Metropolitan Transport Corporation[3]: a government agency that operates the public transport bus service in Bengaluru and which initiated the ITS project. Within BMTC, there are different groupings, such as managerial staff; and also the bus drivers and conductors who operate the services which are the subject of big data capture.
- Trimax[4]: a private sector Indian company that provides a wide range of IT solutions and services. The company has a track record in providing systems for public transport operators across India in states including Maharashtra, Rajasthan and Uttar Pradesh. It is the main implementer of ITS, having been awarded the project through an open tender process organised by BMTC in 2013.
- PricewaterhouseCoopers (PwC): a multinational consulting firm that provides services like audit and assurance. They are consultants for BMTC for the ITS project, and look after the deliverables from Trimax, to ensure they are in compliance with the requirements of BMTC.
- Mapunity Information Services[5]: a private sector Indian company that develops geographic information systems and services primarily for public sector clients. Mapunity is a consultant for BMTC on ITS with respect to its implementation, and has also assisted in drafting an open data policy for the project.
- Passengers: the commuters who use the bus services and are also one of the intended beneficiaries of ITS.

[2] See: http://www.btis.in/
[3] See: http://mybmtc.com/
[4] See: http://trimax.in/
[5] See: http://mapunity.com/

C. Components of the Big Data System

ITS was custom-designed for BMTC to track buses and passenger ticketing, in order to inform not only real-time information-sharing and decision-making, but also medium- and long-term planning of the public transport network. The ITS has four key technological components and is operated from a central Control Room:

Vehicle Tracking System (VTS): comprises two further components: the vehicle tracking unit (VTU) and the Voice Kit. The GPRS-enabled VTU (see Figure 2) was developed by Trimax, and has been installed near the driver's seat in every one of the more than 6,000 BMTC buses operating in the city. It shares real-time location data every 10 seconds, along with vehicle number and shift number (of the driver and conductor of the bus concerned). This short-interval collection of data allows for analysis of the driving pattern, including issues like skipping of bus stops and deviation from planned route, as well as indicating the traffic situation at the buses' current location.

Figure 2: Vehicle Tracking Units

Source: BMTC https://twitter.com/BMTC_Bangalore/status/842619833938329600

Examples of the dashboard displays available at the central Control Room are shown below including an overview of alerts about all buses covered by the system (Figure 3); more detailed drill-down to the level of individual crews (Figure 4); and more detailed drill-down to track an individual bus (Figure 5).

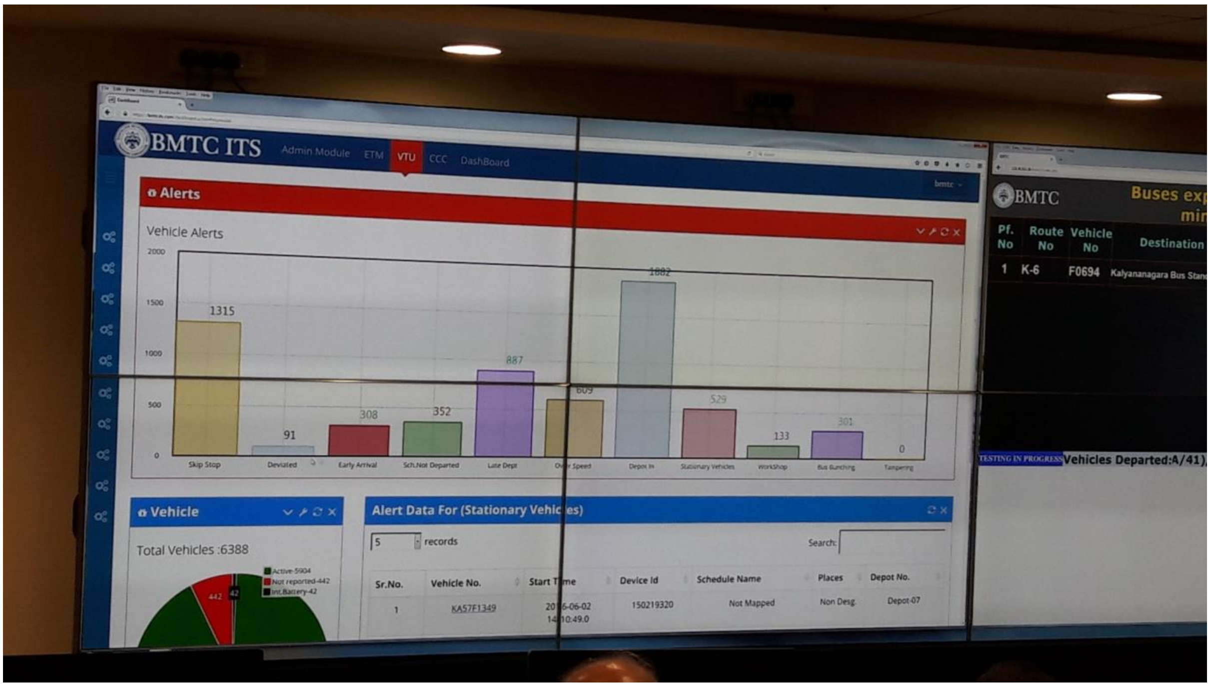

Figure 3: Overview Dashboard of Alerts about Buses

Source: Vanya Rakesh

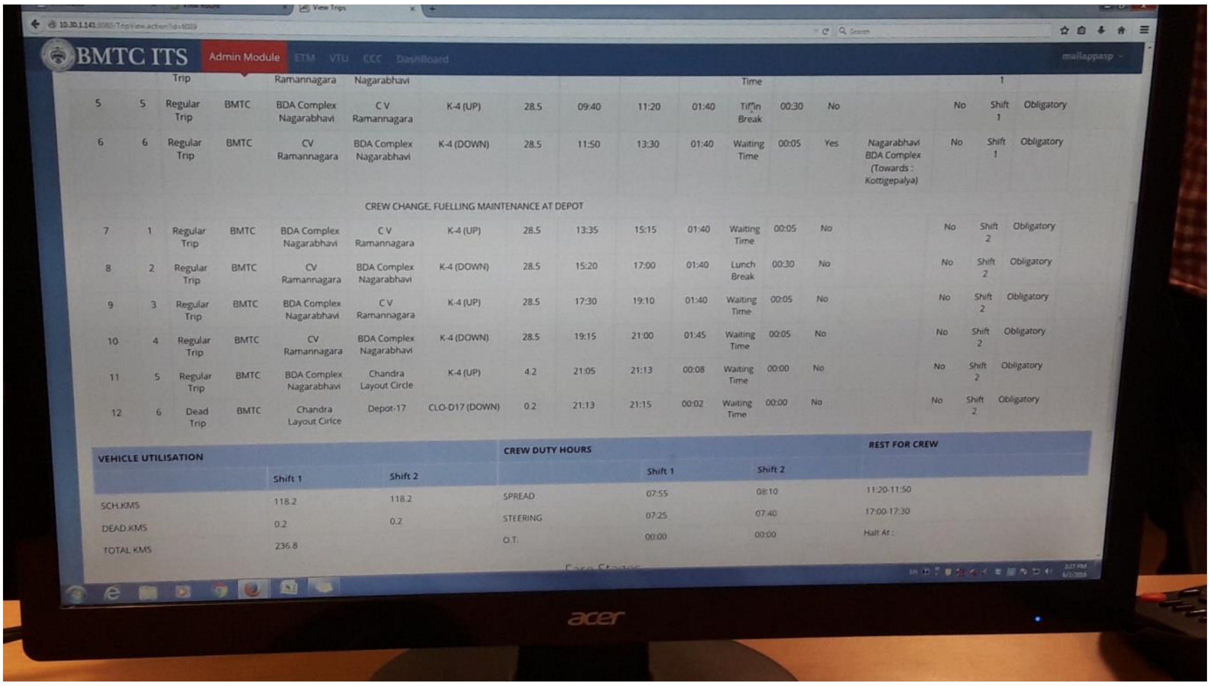

Figure 4: Drill-Down Data on Individual Bus Crews

Source: Vanya Rakesh

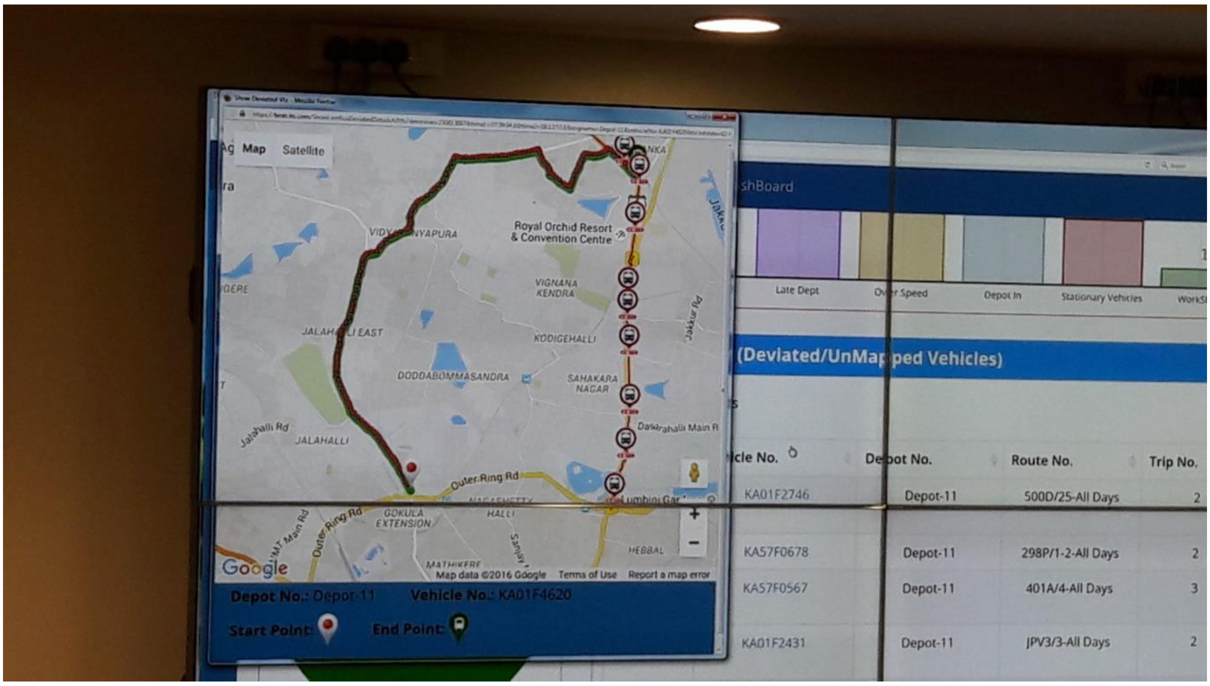

Figure 5: Drill-Down Data on Individual Buses
Source: Vanya Rakesh

This tracking unit transmits data via the mobile (GPRS) network with an estimate that around 20GB of data is received daily by the central servers from the VTUs. The VTU can be used by drivers to inform the Control Room in case of an emergency but the Voice Kit – a microphone and speaker (see Figure 6) – supports two-way communication between the bus and the Control Room. This enables the driver to speak with the Control Room in case of an emergency like an accident or breakdown. It also enables the Control Room as well as the bus depot (the major bus stations, of which there are just over 40 in the city) to contact the bus driver if an alert is triggered such as skipping a bus stop, unauthorised stoppages, change in the route, speeding, etc.

Figure 6: Bus Voice Kit
Source: BMTC https://twitter.com/BMTC_Bangalore/status/842619833938329600

Electronic Ticketing System (ETS): comprises two connected elements – the Electronic Ticketing Machines (ETM) and the Depot Application. The ETM (see Figure 7) is used by the conductors to issue journey tickets to passengers, and it transmits this ticket data to the ITS every five minutes via the mobile (GPRS) network. It is EMV-compliant[6] and allows for card-based and other cashless transactions. The data collected by the ETM includes the bus stop at which a particular ticket was issued, the ticket amount (proxy for destination bus stop), details of the bus, timestamp, etc. The Depot Application is installed at all bus depots and it gathers information from both the ETM and VTU as well as top-down sources. It can then generate information on the crew duty rota, the log sheet for the driver, kilometres travelled and details about fuel usage, ticketing, etc. This information is sent to the desktop application at the ITS Control Room, which generates schedules and timetables. This data is also fed into the ETM, which is used by the bus conductors and is issued when they begin their period of duty.

Figure 7: BMTC Electronic Ticketing Machine
Source: Ramakrishnan (2016b)

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[6]EMV is a security framework and technical standard for payment interaction between chipped/smart payment cards and payment devices (EMV stands for Europay, MasterCard, and Visa, the three companies that originally created the standard).

Passenger Information System (PIS): this is the bus location information system, powered by real-time data from the VTS. It provides information about buses going from a particular stop/location: the destination, the route via which the bus will go, estimated time of arrival, etc (see Figure 8). Basic PIS output can be found on display screens at all major bus stations. It also feeds the mobile app (see next) and touch-screen kiosks which give bus times as per the basic display but also trip-planner functionality as per the mobile app.


BMTC Buses arriving in 15 minutes

Pf. No	Route No	Vehicle No	Destination	Via Places	Last Bus Stop Crossed	ETA (Mins)
1	V-360B	FA2298	Kempegowda Bus Station	Chandapura Electronic City Bommanahalli	Lakkasandra	8
1	V-356	F3960	Kempegowda Bus Station	Bommanahalli	Wilson Garden 12th Cross	9
1	K-6	F0700	Kalyananagara Bus Stand	Jayanagara Bus Stand	Wilson Garden 12th Cross	10
1	KBS-3A	F1204	Kempegowda Bus Station	Shanthinagara	Wilson Garden 12th Cross	9

Figure 8: Passenger Information System Display
Source: Bhattacharya (2016a)

BMTC Mobile Application[7]: this is an Android application available from the Google Play store. It is said to have a simple user interface that allows tracking of buses in real-time, including their estimated time of arrival at a specific bus stop (see Figure 9). The app also provides bus timetables, route maps and a trip planner (see also Figure 9). The current number of downloads of the app is in the range 100,000-500,000, with a 3.6 review average. The comments threads and responses from BMTC suggest the corporation has been taking note of and responding to some feedback, with the app currently on version 2.8.3.

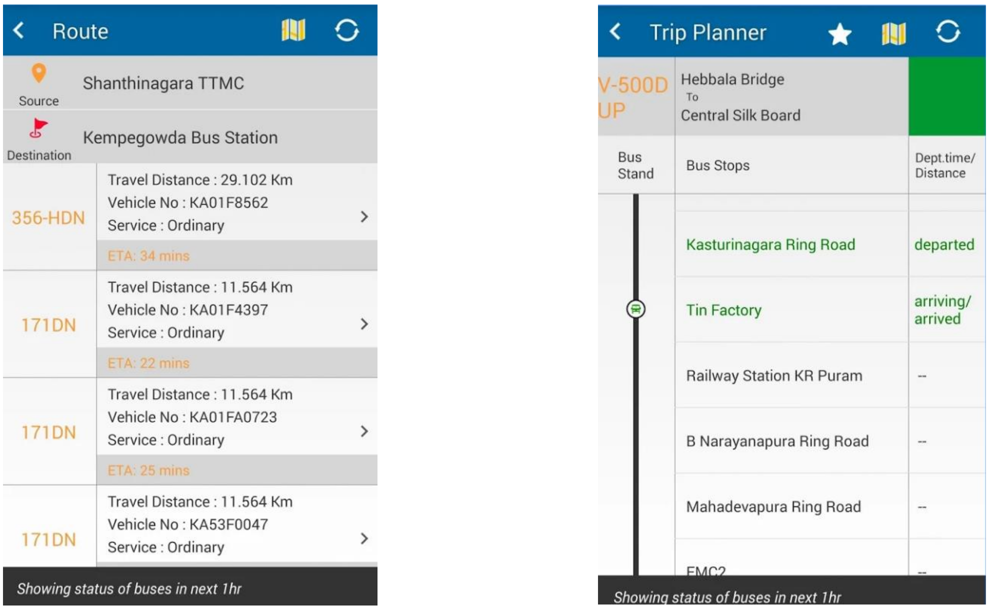

Figure 9: BMTC Mobile App
Source: https://play.google.com/store/apps/details?id=com.bmtc.mybmtc

[7]See: https://play.google.com/store/apps/details?id=com.bmtc.mybmtc

ITS Control Room: data from vehicle tracking and ticket sales are transmitted to servers – maintained by Trimax but owned by BMTC – located at the Karnataka State Data Centre. From there, data can be accessed at a number of locations but primarily at the ITS Control Room (see Figure 10). This is the 24/7 operations centre of the ITS, with a video wall consisting of six large LCD screens showing location information and other key monitoring and performance indicators (see Figures 3-5 above). There is space for up to twenty people including operators, technicians, and BMTC officials (see Figure 11). The Control Room also has a two-way communication system with all buses, and thus functions as a point-of-contact for emergency incidents.

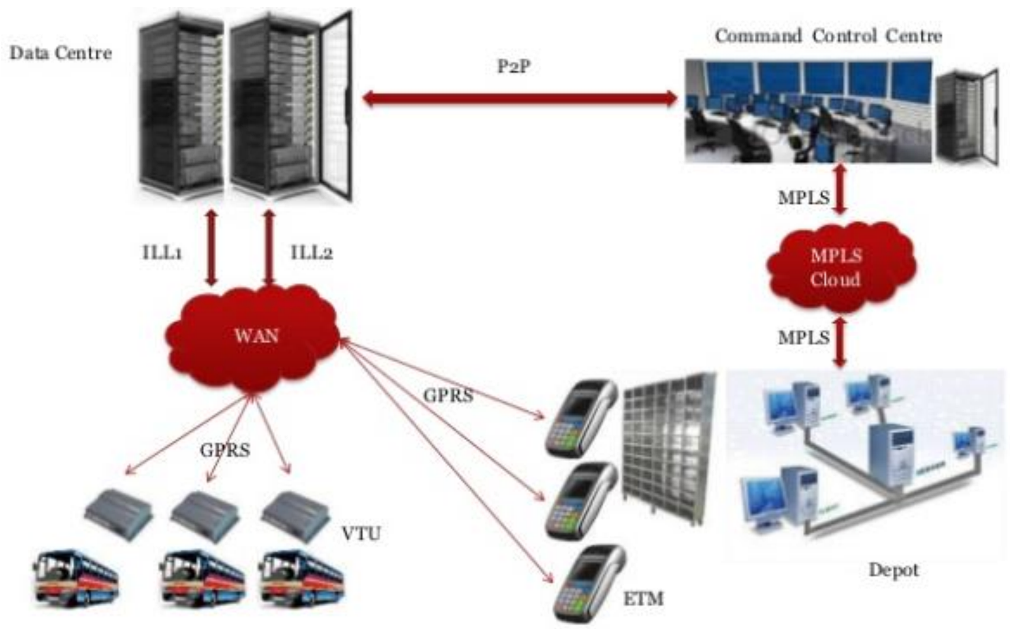

Figure 10: ITS Architecture[8]
Source: Mishra (2016)

Figure 11: BMTC Control Room
Source: BMTC (2017e)

[8] MPLS: multi-protocol label switching; ILL: Internet leased lines;; P2P: peer-to-peer; WAN: wide area network

D. System Implementation

There have been significant delays in ITS implementation – it was initially expected to go live in mid-2014 – but much of this may well be down to technical issues (Akshatha 2015, Bhattacharya 2016b)[9]. One might have anticipated one cause of delays to be resistance from bus crews, yet managers interviewed claimed the system was easily and readily accepted by the workforce, who have undergone training sessions on the new system (see Figure 12) albeit after rather than before installation of the ICT in some cases (Akshatha 2016). Lack of resistance is unexpected because BMTC staff strikes were a relatively regular occurrence during 2016 (Chatterjeel 2016) and 2017 (Reddy 2017, The Hindu 2017). And there has been reported concern from drivers and conductors about the surveillance that tracking systems provide e.g. in the sister implementation of ITS in Mysore (NITI 2015).

Figure 12: ITS Bus Driver Training (Mysore)
Source: NITI (2015)

Direct interviews with bus crews and labour unions would be required to investigate this in detail but in none of the BMTC strike reports are ITS or its component technologies mentioned, and reports of bus crew interviews mention complaints about malfunctioning of equipment rather than surveillance (Ramakrishnan 2016a). Relevant factors here may be:

a) Benefits to bus crews of the new system. There is a saving of time and complexity at least for bus conductors given they now just have a single machine instead of many types of tickets, and they no longer need to complete trip-sheets (Ramakrishnan 2015).
b) Potential disbenefits as yet unrealised. Some of the surveillance capacities of the system may not yet have been put into operation. There is conflicting evidence here. The interviewed depot manager (see below) claimed the system had reduced "ticketing pilferage" but it was unclear if this covered theft by bus crews. And reports of conductors "booked" for allowing ticketless travel in February 2017 (BMTC 2017d) and report of a July 2017 strike relating to a conductor being suspended over not issuing tickets (The Hindu 2017), indicated this happened through oversight of human ticket inspectors rather than anything based on ITS/ETMs.
c) Potential disbenefits as yet unrecognised. It may be that bus crews do not recognise that electronic ticketing is a first step towards driver-only buses: something which is already part of BMTC's plans (Philip 2017a).

[9] Technical and project management (procurement, financing, requirements) challenges were the main issues identified in the Mysore ITS implementation (Prasad 2012).

There has been an admission of “a lot of resistance” to ITS within the Corporation (Bhattacharya 2016b). But this seems to have come more from the managerial level: something which may well have impacted the limited progress in terms of changes to managerial processes, as discussed next.

E. System Value

Value of ITS can be assessed at four levels:

i. Technical Operations. The main ITS components that either gather or utilise big data were working but not yet fully working as intended:

- A discussion with a manager at Yelahanka bus depot indicated problems with the Vehicle Tracking System, but this was largely relating to the Voice Kit and poor sound quality that made two-way communication hard or impossible in some cases. There was no direct evidence that VTUs themselves are not working following the switch from GPS to GPRS communication, though lack of GPRS signal availability in some parts of the city was identified as a problem in the Mysore ITS project (Prasad 2012).
- Though the ETM system is operational – hop on a BMTC bus and you will see them in use – there are some problems. Bus crew complain about short battery life, system crashes and connectivity errors with the electronic ticketing machines (Ramakrishnan 2016a), and problems with the system have partly explained delays with introduction of smart card payment (The Hindu 2016).
- The Passenger Information System public screen and kiosks do operate in some locations. They were praised by interviewed passengers for the assistance they provide, and comment in 2017 was seeking a roll-out of the system to individual bus stops rather than complaining about non-operation (Philip 2017b). However, they are not universally functional. For example, in Domlur bus depot, three screens and one kiosk had been installed, but none were working at the time of a visit in 2016. Figure 13 shows at the top the public display screens, and on the bottom the kiosk touch-screen which was frozen on this image.

Figure 13: Passenger Information System Display Examples
Source: Vanya Rakesh

- The Mobile Application does in reality provide information about bus arrival times as per Figure 8 but the interface and usability are problematic. On testing in 2016, the app begins by asking users which bus number they are interested in: not helpful for those who don't already know the bus network. The app did not give details on specific bus routes, making it difficult to identify which buses to take e.g. for commuting. Other reports indicate missing buses and missing arrival time data (Akshatha 2016). By mid-2017, the app had been improved but problems still remained (CM 2017): it took a minute for the home screen to load; the Kannada language option leads back to English text; and a test of the route planner found no record of the bus stop on the system even though it exists in reality, and that planning could only cope with a single bus linking two stops, not with a multi-bus journey; overall, "this app is incredibly buggy and slow". Mid-2017 reviews of the app (including a number of the four- and five-star reviews) also complain about lack of accuracy in terms of bus locations and timing, and a more general review of such systems in India reports potential design-reality gaps:

> "The accuracy of arrival time prediction is poor, perhaps because of deficiencies in algorithms used for prediction. In most cases, the details of the prediction algorithms are not available since they were implemented by an external agency. Many of these implementations used methodologies developed for western countries that have homogenous traffic, which may not be suitable in the heterogeneous Indian traffic conditions." (Vanajakshi et al 2016:21)[10]

Operationally, then, the picture appears to be glass half-full, glass half-empty. A number of these problems may be teething troubles which will be resolved, and that are not unexpected in a system the size and complexity of ITS. However, the persistence of some problems a year since implementation and the sense that BMTC may be addressing smaller issues but not larger ones (CM 2017) gives some cause for concern.

ii. Operational Management. Operational management means, for example, management at the level of individual bus depots. The ITS dashboard is available to managers here with the intention that they are now able to monitor each and every bus in real-time, keep a track of revenue generated each day via the ETM and conduct audits for verification, and also keep a better record of duty schedules for all the employees. The first was not previously possible and the latter two were previously done manually. The manager at one depot reported the following:

- Introduction of the ETM had made end-of-day audit and cash reconciliation easier, and had led to a reduction in revenue discrepancies, and a reduction in the number of cases of "ticketing pilferage".
- Traffic police would previously issue fines – which the depot manager had to handle – for claimed traffic violations by bus drivers. In a number of cases these were known to be fake but there was no mechanism e.g. to check whether a bus was in fact speeding, or was stopped as a result of an accident. Though imperfect and not providing all necessary data (e.g. it cannot unequivocally tell if a bus has jumped a red light), data from the Vehicle Tracking System allowed some cross check. As a result – perhaps the perception as much as the reality of vehicle tracking – the number of fake fines issued was said to have significantly reduced.
- There are problems with the ETM system but it was claimed that bus crews would try to refuse to work if the system is not available for use on a particular day.

This represents just one view at one moment in time, but it does suggest there have been some changes at the level of front-line management in BMTC.

[10] The report goes on to note the complexity and challenges faced by a prototype application that sought to provide more accurate arrival time prediction based on those "heterogeneous Indian traffic conditions".

iii. Tactical Management. This means, for example, management of routing and scheduling. At the time of the 2016 field study, these other uses of the big data seemed to be potential rather than reality. For example, there were aspirations among BMTC interviewees to use the data to rationalise routes, schedules and bus operations in order to better respond to daily and seasonal patterns of demand for public transport, and to enhance efficiency in the operation and management of crews. The potential is there. It is claimed that even by 2012, Mysore's ITS application had cut 28 bus crew and seven buses (from an application across 400 buses) from the schedule through route optimisation based on ITS data (NITI 2015). And it was claimed that by 2016 ITS-based route optimisation and reduction of staffing and overtime in Mysore had cut annual operational costs by US$900,000 (Indian Express 2017). But this had not happened in Bengaluru in 2016 and there have been no subsequent reports of this during 2017. Indeed, only five schedules were changed during 2016-17 compared with an average of 176 being changed in previous years suggesting, if anything, a negative relation between the arrival of big data and re-scheduling (BMTC 2017c).

iv. Strategic Performance. Finally, one may judge ITS at the level of strategic contribution. ITS may have won several awards (BMTC 2017b) and is certainly providing additional functionality to BMTC at lower levels. But, as yet, this has not been seen in terms of broader urban transportation goals. We can judge on the basis of the four BMTC goals to which ITS was intended to contribute (Mishra 2016, BMTC 2017c):

- Service reliability: 14% of services were cancelled in 2016-17 compared to an average 6.5% in the previous five years.
- Citizen centricity: PIS and the mobile app have been steps forward but they are not fully operational or effective as yet in providing information and journey planning support for travellers. Passenger-journey numbers were down by about 200,000 per day in 2016-17 compared to the previous year, so aspirations of helping to move more passengers onto the buses were not yet realised.
- Revenue management: there is little internal data on this but overall passenger revenue fell by 8% during 2016-17 compared to an average 10% growth over the previous five years, and as noted above there is a mixed picture of impact at the micro-level of "ticketing pilferage".
- Organisational capabilities: fleet utilisation fell below 90% for the first time in 2016-17 while costs per km were at their highest-ever level.

There are of course many internal and external factors other than ITS that contribute towards organisation-wide performance, but this does show a lack of any short-term impact of ITS on strategic performance indicators. It also suggests a lack of contribution as yet to even wider measures of urban transportation relating to journey times, pollution, etc.

F. Conclusions

Any conclusions about this big data system must be contingent: field interviews were conducted only a few months after the system went live in 2016, and later data was analysed little more than a year after implementation. Given the scale of investment and operational functionality, it is highly unlikely that the system will be abandoned – one commentator notes "ITS has become too big a project to fail" (Bhattacharya 2016b) – and more likely that it will gather operational momentum and impact over coming years. There are a number of operational shortcomings identified but by, say, 2020 those could well be just a distant memory.

There have been challenges with the technical implementation of this big data project, and socio-technical change to administration and management has really barely begun: bus crew, administrative and managerial staff are in process of making the changeover from decades of paper-based working to digital-/data-intensive processes. One clear conclusion is that big data systems take a long time to implement; perhaps particularly in the public sector and certainly particularly for large and more complex systems involving thousands of material objects and tens of thousands of people. Pure technical implementation has taken several years, and integration into – and revision of – BMTC business processes is going to take several years more. What is provided here can therefore only be seen as an early and interim assessment.

In terms of value, ITS is largely potential rather than actuality. Some operational benefits have been seen though these undershoot full value, and tactical and strategic value – at least in overt terms – is yet to be seen. But it will be at least a year or two before one can assess the success or failure of big data in relation to these higher-level values. At present, then, much of the data gathered is what Gartner (n.d.) call "dark data ... the information assets organizations collect, process and store during regular business activities, but generally fail to use for other purposes". Put another way, the organisation in many processes waits at the start of the information value chain (see Figure 14), waiting to turn the data it has into meaningful information, decisions, actions and results.

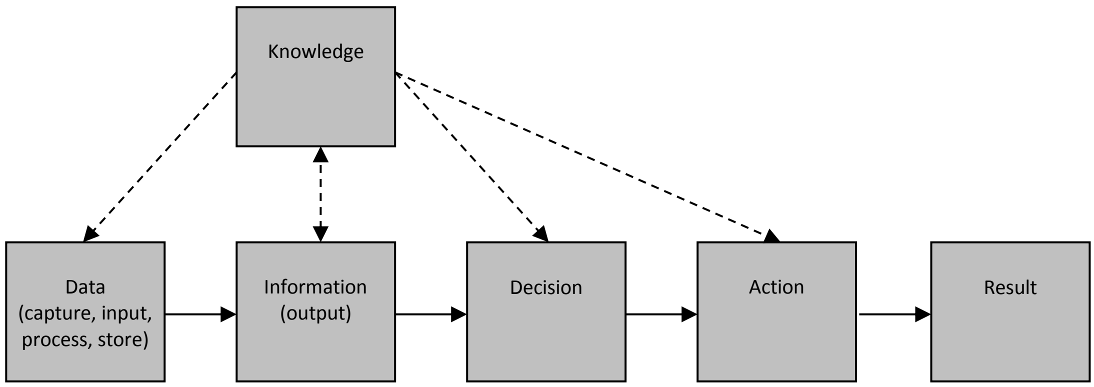

Figure 14: The Information Value Chain
Source: Heeks (2018)

Notwithstanding the recency of the application, we can still try to make an assessment – drawing on earlier work in India's electricity sector (Sengupta et al 2017) – of the relation between big data, power and politics; looking at two aspects.

F1. Big Data and the Politics of Transportation

First, looking at the broader politics of BMTC, it is regarded as a heavily-politicised organisation: "a corporate entity only by name" (Menezes 2017b) and one that is dogged by claims and perceptions of corruption across all levels (e.g. Ramakrishnan 2016a, Fatima & Natrajkumar 2017, Menezes 2017b). In such circumstances, organisational image will be seen as important by senior officials and there is certainly a sense of the big data system being applied as veneer.

The focus has been on the external interface of the organisation and public relations rather than changes to internal decision-making: lots of media-related promotion about ITS and attention to the (albeit still functionally-challenged) PIS and mobile app. This is of a piece with other changes such as free wi-fi or smart cards or better buses on routes used by wealthier passengers which are seen as a) playing to the politically-vocal middle classes rather than more marginalised groups; b) at most using big data to address petty front-line corruption while doing nothing to address deeper-rooted and higher-level corruption. Such innovations are also aimed at political decision-makers outside BMTC in the Karnataka State legislature, seeking to present the image of a modern and progressive organisation. ITS and the image it helps create may thus have made some contribution to the decision in 2017 for the first large-scale investment in new buses for at least three years: with 3,000 being purchased (Fatima & Natrajkumar 2017, Menezes 2017b).

As well as the image, we can say that big data has also changed the "imaginary" within BMTC: it changes what is "visible" within the city, and to whom (Taylor & Broeders 2015). In particular we can see that the daily operations of the bus fleet and bus crews were largely opaque to management prior to ITS, but they are becoming increasingly visible and thus changing the perceived picture of BMTC that managers hold in their heads. Big data is thus changing the landscape of what is seen to be possible within the organisation. Alongside the investment in new buses (which probably relates to the imaginary of politicians as much as managers), signs of this are also reflected in:

- Revival of plans for driver-only buses – a change trialled in the 1990s but then abandoned – but now seen as possible by managers; something they specifically link to the advent of ITS (Philip 2017a).
- Stripping out a management layer: removing the five divisional offices with 400 staff that sit between the central office and the depots. Although planned for early 2017 it was unclear at the time of writing if this change had occurred. However, the restructuring was seen to only be feasible with the arrival of ITS:

  "The transition to a two-tier administrative system will be smooth, thanks to the now-functional Information [*sic*] Transport System, says Ekroop Caur [*BMTC's Managing Director*]. 'While bus routes and schedule, procurement, accounts and labour welfare were discussed at the central office, BMTC's divisional office was largely responsible for supervision and disciplinary enquiries. Now, we can track the movement of buses and real-time data on ticket fare collection through technology,' she explained" (Menezes 2017a).

F2. Big Data-Associated Changes in Locus of Power

Second, we can assess shifts in the locus of power in and around BMTC.

As seen in the Indian electricity case study (Sengupta et al. 2017), there are already signs of an upward shift in power from labour to management which we can judge in relation to three resource features of criticality, control and commutability (*ibid.*):

- Criticality: bus crews remain critical to BMTC operations so little has changed here.
- Control: the autonomy of bus crews has been significantly reduced with the advent of big data. Their location, bus speed, following of route and schedule are all now trackable; and ticketing processes are similarly more controlled via the ETM. Of course, some prior autonomy may have been used to meet their own self-interests, but there is now significantly more management surveillance of bus crew activity.
- Commutability: automation of operations is steadily eroding the role of and necessity for two-crew operations, and pressure for substitution of the conductor's role with digital technology will continue to grow.

There are also shifts in power from middle to central management. Whether actually restructured yet or not, the writing is on the wall for divisional offices. Big data systems enable central management to directly access performance data from the front-line of operations, and to automatically undertake and communicate performance management; obviating the need for intermediating management layers. Within central management there will also be a shift towards those who manage and use big data such as the senior members of the central Control Room team, but only once big data starts to form a greater part of the managerial decision-making processes within BMTC.

In the electricity case study there was a clear shift in power from public to private sector; the latter represented by the big data system operator, which was a multinational IT firm. Such a shift is less clear as yet in relation to ITS, where Trimax is less than 10% the size of BMTC. Certainly there will be big data system capabilities which Trimax holds and BMTC does not, but ownership of data and systems is quite clearly in the hands of the Corporation[11].

Finally, we can consider power shifts between the Corporation and the general public and civil society. Notwithstanding their flaws, PIS and the associated mobile app have resulted in some greater operational transparency: passengers can more readily understand what BMTC is supposed to deliver; these technologies provide a greater public engagement with transport services; and there is at least the promise that passenger behaviour will be taken into account more in future planning. Publicly-available higher-level performance data remains at an aggregated and annual level as it did in pre-ITS times, but this could change if the ITS dataset was opened up to public use. There have been plans for BMTC to open up the real-time data, thus allowing individuals and organisations to make use of it (Akshatha 2016, Bhattacharya 2016c). Release of data was promised for June 2017 (ET 2017) but at the time of writing there was no visible sign of it.

[11] There may be a wider story about shifting public/private sector boundaries, with BMTC being accused of increasingly acting like a private firm, and with half of the new buses ordered being run on contract by private operators (Fatima & Natrajkumar 2017).

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