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An examination of an approach to assist transit in maintain political legitimacy by achieving reliability for passengers and efficiency for the public

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Abstract

This paper examines philosophical frameworks of public transport service delivery — the Strategic Triangle and Service Quality Loop. The first considers the context of a public sector organisation appropriating resource and the second considers how public transport service partners could provide services that passengers perceive to be high quality. The paper proposes the Arbitrated Service Quality framework to synthesis a combined perspective. Then this paper considers the need for efficiency and reliability from the passengers' and public's perspective. This paper posits that Statistical Process Control could support continuous improvement of the aforementioned reliability and efficiency to allow the service partners to deliver the public transport services sought by passengers and the value-for-money sought by the public.

1. Introduction

This paper (2022a) and Hounsell (2022b) form a pair. The case study duality criterion is that '*… while the case study context is always unique, the empirical examination must always be balanced with a more general theoretical examination.*' (Gammelgaard 2017, p. 910) and (Jacoby 1976, 1978). This paper describes the general theoretical examination of why transport operators must deliver an efficient and reliable public transport service to maintain their legitimacy. Then this paper explains how Statistical Process Control (SPC) could theoretically be used to assist in achieving reliable and efficient operations. Then Hounsell (2022b) is a multi-method × multi-trait empirical examination of three transport services in Sydney to assess whether observed running times can be monitored by SPC using either normal distributions or the mean and standard deviations (Campbell & Fiske 1959; Chamberlin 1890).

Public Sector Organisation (PSO) create Public-Value; but which values they should prioritise and how they determine that is addressed by two disparate frameworks.

Those familiar with the transport research at the University of Technology Sydney (UTS) will have encountered our use of the ***Service Quality Loop*** (SQL) framework (EN13816:2002 – CEN 2002, p. 6), as in (Hounsell 2018b, p. 2; Hounsell 2020, p. 15; Hounsell 2021, pp. 13-5).

The ***Strategic Triangle*** is an important framework, from the USA, for examining the context for PSO planning and operations (Moore 1995, 2013). However, reviewing the literature found few explicit mentions of the Strategic Triangle in transport planning or engineering. It is mentioned as a framework in (Brodkey & Macadar 2020); Vella & Nicole (2018), and is used '*to frame the responses*' in James, Burke & Yen (2017, p. 6). The framework is directly used as an intellectual lens in Carli (2011), where it is described as a '*paradigm shift*'. Meanwhile, Woodcraft et al. (2008) provides an interesting discussion on using the model.

This paper discusses the Strategic Triangle and the SQL. Then this paper attempts to reconcile these frameworks and then illustrate them using the customers' needs for transport reliability and the public's need for value-for-money (Economy, Efficiency, and Effectiveness).

The first section is not specifically about a convergent transport discipline, such as planning, engineering, economics, or analytics. This section could be considered divergent transport philosophy — examining theories on transport and land-use systems — it discusses the abstract questions and reasoning that exist within the society behind the transport system. In addition, the first section considers some of the implications of epistemology and axiology on the ability of transport professionals to understand the customers and answer those abstract questions.

Finally, this paper discusses SPC to illustrate the Measurement of Performance in the SQL, and as a mechanism to meet the requirements of Legitimacy in the Strategic Triangle.

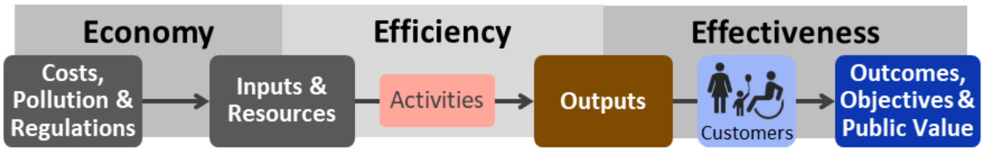
1.1. Key Framework – Economy, Efficiency, and Effectiveness (3E's)

Are our transport operations the best they can be? Do our services meet the needs of our clients, our passengers, and all our customers? That are key question that PSO and their Public Service Managers (PSM) should be regularly asking themselves.

Booz & Company (2011, p. 6) report that the United Kingdom's (UK) National Audit Office defines Value for Money (VfM) as '*The optimal use of resources to achieve the intended outcomes*'; that is, create the intended public value. B&C. believe '*"resources" need to be understood as public money*'. They believe that '*Value is the degree to which [the transport industry] contributes to the achievement of Government objectives …*', and that across the UK administration VfM can be represented by "*three E's*":

> '• **Economy**: how cheaply [the given] inputs can be procured
> • **Efficiency**: the amount of output produced with [the] given inputs
> • **Effectiveness**: the extent to which outputs deliver desired outcomes, or objectives … achieved by ensuring that money is spent on the right combination of outputs' (ibid.)

Figure 1: Value for Money can be represented by "3E's" across the UK government



Based On: (Booz & Company 2011, p. 6) via (Sameni 2012) with (Wholey, Hatry & Newcomer 2004)

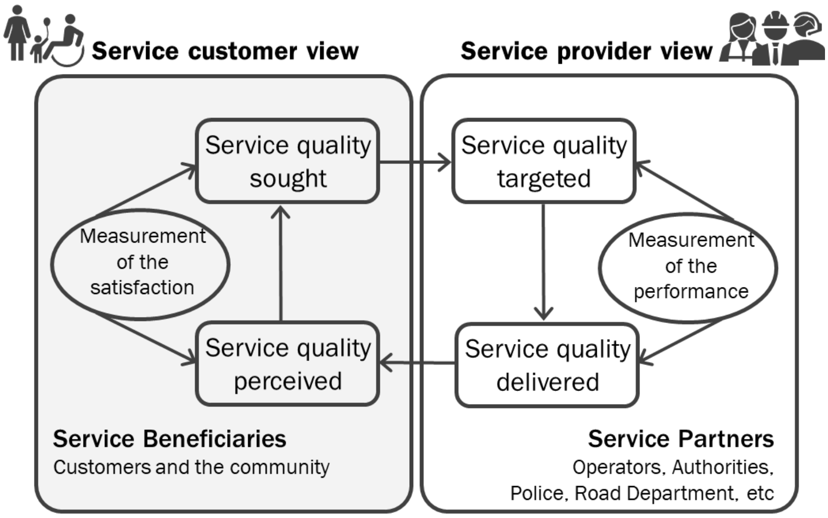
As a thought experiment consider the following list of eight descriptors of Customer Objectives — desirable outcomes — based on Walker (2012). Imagine if the bus network planners for your city and 1,000 random residents from your city were and asked which statements applied to your city's bus network. Which statements do you believe both the planners and residents would agree are true for your city's bus network? This paper focuses on the italicised ones.

- The transit network takes passengers where they want to go.
- The transit network takes passengers when they want to go.
- *The transit network is a good use of the passengers' time.*
- The transit network is a good use of the passengers' money.
- *The transit network is a good use of the publics' money.*
- *Passengers can trust the transit network.*
- The transit network respects the passengers.
- The transit network gives passengers freedom (to change their plans).

1.2. Key Framework – Service Quality Loop

In a similar vein, CEN (2002) — Figure 2— describes the ***SQL***, which is a theoretical framework outlining the issues of information asymmetry when transport planners are planning the provision of customer focused public transport services. The framework outlines the multiple viewpoints that must be considered during the service planning cycle — Figure 3.

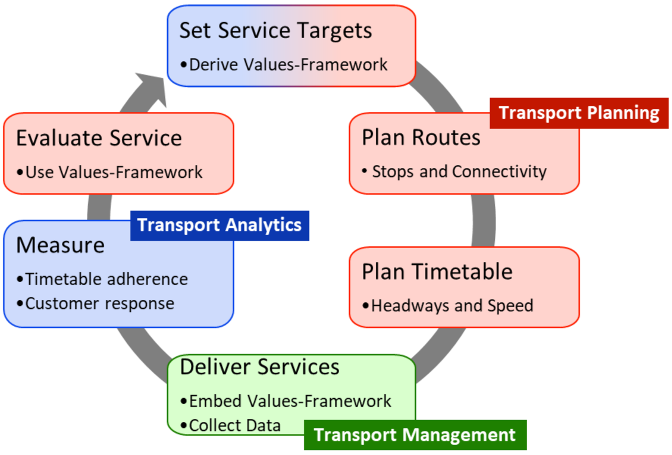
Figure 2: Service Quality Loop (SQL) — EN13816:2002



Based on (CEN 2002, p. 6, Figure 1)

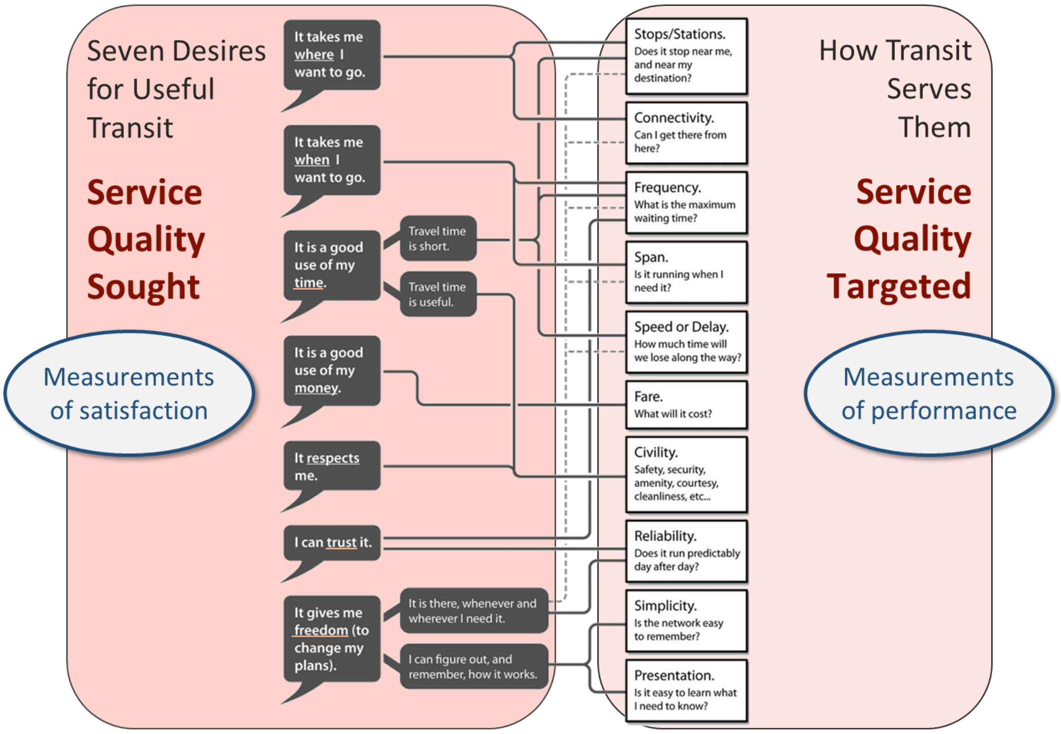
The SQL framework suggests that a theoretical service cycle, should begin with the planners determining the Outcomes and Public-Value sought by customers, then use those to determine the operational service-level targets, before planning the service-routes and timetables. Thereafter, the managers at the service providers are responsible for delivering the services and collecting data to allow the transport analysts to monitor performance to answer the key questions: '***i)*** *How is the transport network actually being delivered?* ***ii)*** *How are passengers responding to the delivered transport network?*' (Hounsell 2020, p. 20).

Figure 3: Theoretical Transport Planning Cycle



There are many different approaches to understanding the subjective qualities sought by customers and how those can be translated to the objectively measurable targets by the transport planner. One elegant approach is outlined in (Walker 2012) and is shown in Figure 4 below. Two key passenger desires identified by Walker during his many years of transport planning are Reliability/Trust and Value for Money.

Figure 4: The SQL and the seven desires for useful transit, and how transit serves them

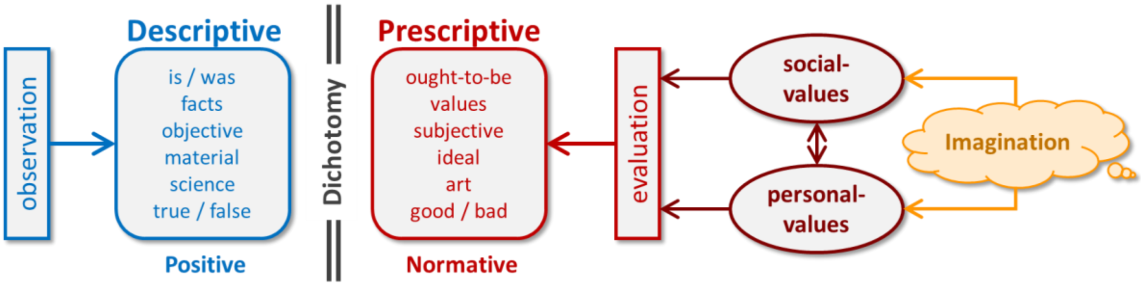


Based On: (Hounsell 2020, p. 47, fig. 29), (Walker 2012, p. 27, fig. 2-1, with credit to Eric Orozco)

1.3. Key Framework – Is-Ought Dichotomy

<u>It is not possible to derive statements on what ought to be (Prescriptions) from statements of what is (Descriptions)</u> (Blaug 1980). This reality is shown in Figure 5, and it is also known as the Is-Ought Fallacy or Fact-Value Distinction. David Hume concluded that it was not possible to derive a single Values-Framework (morality) or Priority-List from observations of the world. Thus, every person will have a different Values-Framework and Priority-List; with different lifestyle groups and socio-economic groups having very distinct values and priorities. Ohmae (1991) notes that communities observed to be thriving, all have accepted and embraced this reality of ***Values-Pluralism***. <u>Values-Pluralism means that the objectives for and Public-Value expected of the PSO must be derived through an Arbitration Process with the community.</u>

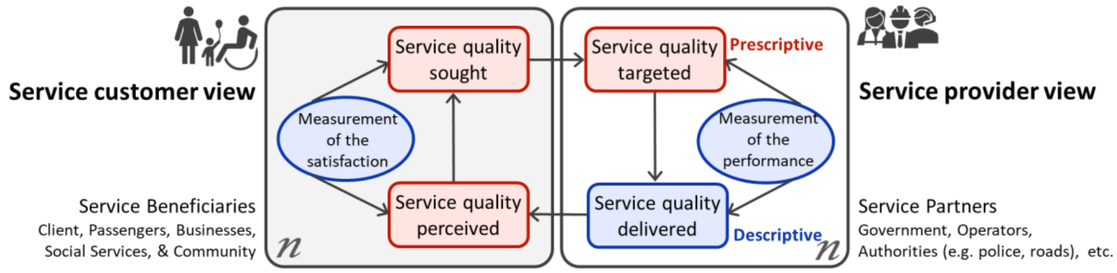
Figure 5: Expanded Hume's Is-Ought Dichotomy – Equivalent Antonyms



Source: (Hounsell 2020, pp. 84, fig. 44)

Returning to the SQL in Figure 2, it is possible to label the components of this continuous improvement cycle based on their Descriptive or Prescriptive character as shown in Figure 6. The perception and targeting activities are all evaluative and, as such, those steps are all Prescriptive. The measurement and analytics activities are Descriptive and examine only data of what was, so they cannot make any evaluations as to whether the service delivery was good or bad. In addition, the elements of the theoretical transport cycle in Figure 3 above was also colour coded by their Descriptive or Prescriptive character, as is Figure 4 above.

Figure 6: Service Quality Loop colour coded by the Is-Ought Dichotomy

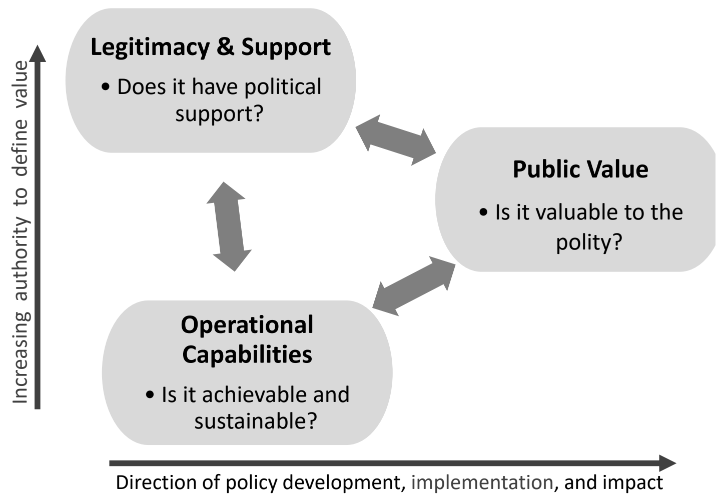


Based On: (Hounsell 2020, pp. 62, fig. 32) from (CEN 2002, p. 6, Figure 1)

1.4. Key Framework – Strategic Triangle

The meta-level ***Strategic Triangle*** from Moore (1995) is a framework to address the issue of Values-Pluralism and Arbitration through the concept of Legitimacy — see Figure 7. Moore describes how the community seeks the provision of infrastructure and services to reduce personal impediments, to improve their productivity, and thus improve their quality of life. Moore states that the community will seek infrastructure and services to create Public-Value.

Figure 7: The strategic triangle



Based on (Moore 2013, fig. 2.1)

Moore describes how communities have limited resources and many (often competing) Values-Frameworks and Priority-Lists. <u>To ensure the Outcomes and allow the creation of the Public-Value the community seeks, the community will delegate to an *Authorised* PSO the ***Legitimacy*** to raise taxes and restrict freedoms, so that the PSO can provide the infrastructure and services.</u>

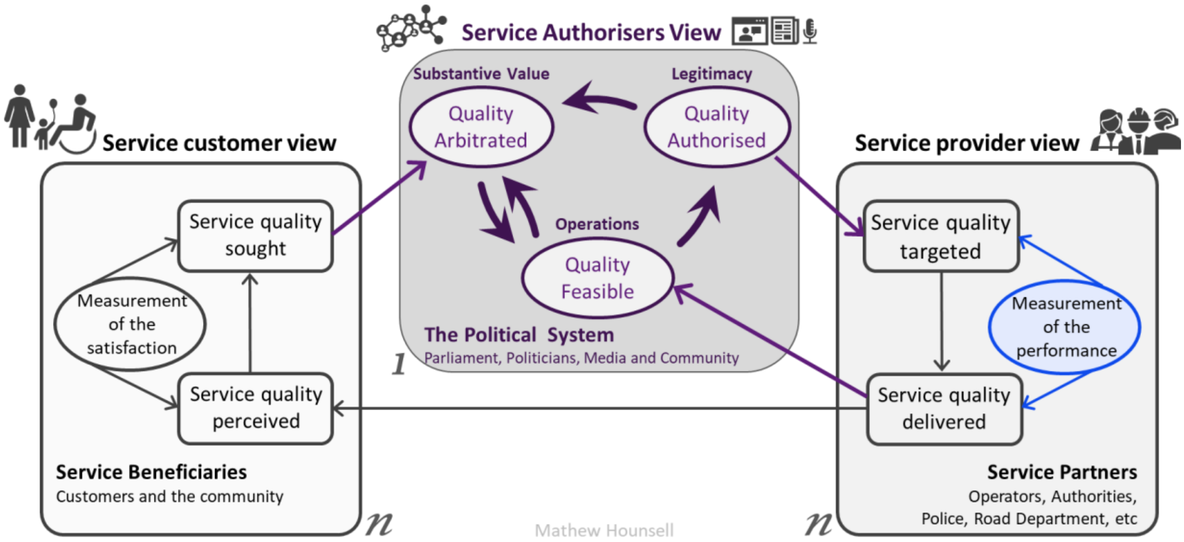
Moore asserts a careful Arbitration Process, as well as Economic, Efficient, and Effective service delivery, are essential components to ensure that ongoing community support provides the Legitimacy for the PSO to continue to Appropriate Resources and Impose Regulations.

1.5. Framework – Arbitrated Service Quality

Moore's Strategic Triangle is a meta-level framework that does not address Service Delivery not Service Analytics, while the SQL is a macro-level framework that does not address Arbitration nor Authority. To address those limitations, an initial framework is provided in Figure 8 below that combines these two. In this proposed framework, the Outcomes sought by the numerous Beneficiaries and the required Resources, are Arbitrated by the Political System.

When a publicly supported and feasible balance of Outcomes, Resources, and Regulation is Arbitrated, then a service can be Authorised, and the Service Targets determined. As the service is delivered, the operational performance and empirical passenger response are measured, and fed back into the Political System for future Feasibility analysis.

Figure 8: Initial Service Quality Cycle Framework 2021



Source: Mathew Hounsell — Author's Concept

Note that Overeem (2012) and Moore (1995) both concluded that the Political System permeates society, and that PSM are an integral part of that political system, providing valuable domain expertise and insights, as well as suggesting innovative solutions.

1.5.1. An example of values frameworks and arbitration — TfNSW

In 2020, the Australian Bureau of Statistics (ABS) reported that New South Wales (NSW) had nearly 8.2 million residents[R1] and more than 0.8 million business [R2]. These nine million entities, with their differing values, delegate to the Parliament the Authority to Arbitrate values, raise taxes, and take actions to construct infrastructure — such as roadways, metros, stations, etc — as well as for the operation of public transport services — such as Sydney Metro, the Inner West Light Rail (IWLR), as well as the CBD and South-East Light Rail (CSELR).

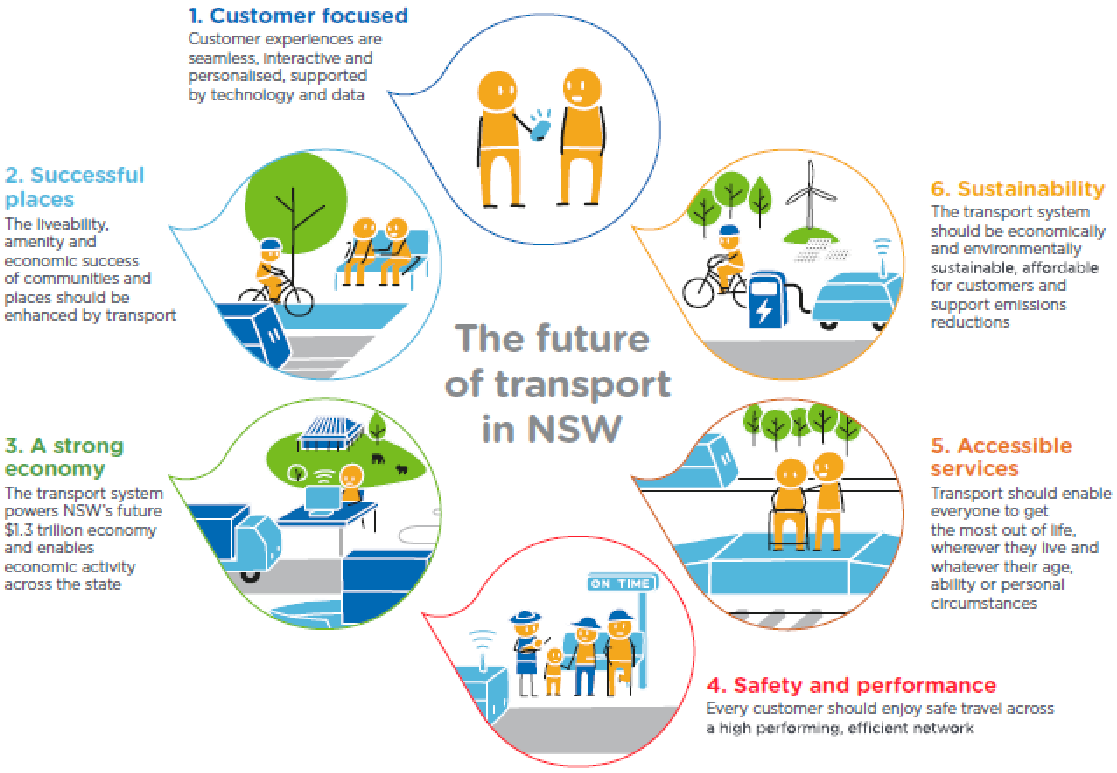
The parliament has created a delegated administrative body in Transport for NSW (TfNSW), that oversees the Service Partners created to deliver public transport — such as Sydney Metro corporation— and which also contracts additional service partners to operate services — such as the ALTRAC consortium (IWLR and CSELR) and MTR Australia (Sydney Metro).

The operators provide Measurements of Performance — such as Patronage, On Time Running (OTR), Excess Wait Time (EWT), Injury Rates — as well as Measurements of Satisfaction — such as the Customer Satisfaction Index (CSI) — to the Political System via publicly available dashboards, open-data, annual reports, and papers presented to their Authoriser (Parliament).

TfNSW outlined the department's primary Values-Framework as the six principles in Figure 9 below (TfNSW 2021, pp. 8-14). An Efficient and Reliable network is specifically addressed in Principle 4, although it can be argued that increasing Reliability, as well as reducing Waste to increase Efficiency are also essential for a strong economy, successful places, sustainability and being customer focused. For this paper, the two most important principles are:

> '1. Customer focused — Vision: Customers' experiences and their end-to-end journeys are seamless, interactive and personalised, supported by technology and data. …
>
> 4. Safety and performance — Vision: Every customer enjoys safe travel, regardless of transport mode or location, across a high-performing, integrated and efficient network.' (TfNSW 2021, pp. 8-14)

Figure 9: TfNSW Future Transport Strategy 2056 — Six state-wide principles



2. Service Quality Sought — Reliability and Trust

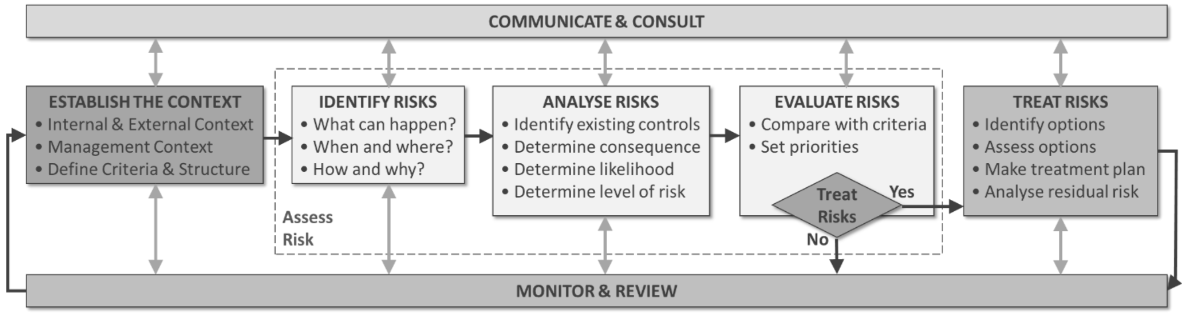
To meet the Authoriser's and the passengers' Objectives (i.e. to be Effective), Service Partners must collaborate to deliver Reliable and Efficient transit services. The SQL defines Service Partners as all entities responsible for the delivery of a service. For example, Sydney's bus network is utterly dependent on the roads division of TfNSW for lane space, bus stop placement, and traffic signalling to give priority to high-capacity transit. Unfortunately, observations of public transport operations indicate that Reliability and Efficiency may not be priorities for operational practices in Australia (Hounsell 2018b, 2020).

Jarret Walker wrote *"In the hundreds of hours I've spent listening to people talk about their transit needs, I've heard seven broad expectations that potential riders have of a transit service that they would consider riding*". As shown above, one of the seven demands for service quality sought repeatedly was that "*I can **trust** it*" — i.e. the passenger's Objective (Walker 2012).

Now, consider that statement in the context of the concise AS/NZS 4360:2004 – Risk Management Guidelines, as in Figure 10 (AS & NZS 2004). Public transport passengers do not control the vehicles they use to achieve mobility. Therefore, **for passengers to Trust the transit service, *the common Risks to passengers from using transit must be controlled by the transit operator.*** For example, the Risk of missing a bus caused by it running early are often treated by directing drivers to depart stops only when scheduled.

However, with Unreliable/Untrustworthy services, the passengers must themselves work to control their risk. After determining the specific consequences and likelihoods, and then evaluating those against their personal criteria, the passenger will decide how to treat their Risks. One common Risk Control of transit passengers in NSW is constant planning. Another is wasting a significant amount of time by leaving early and catching an earlier service. Alternatively, the passenger can shift to a more Reliable mode or corridor. As an example, the passenger could use the Light Rail from Randwick to treat the risks of heavy traffic and variable travel times on Cleveland St for buses, because the tram uses a dedicated right of way.

Figure 10: AS/NZS 4360:2004 – Risk management guidelines



If a lackadaisical transit operator has not controlled the Operational Risks, then the passengers cannot Trust those transit services. If that is the case, passengers must actively Plan each trip, as well as constantly undertaking Planning Checks at every stage of their journey — in case they need to activate their Contingency Planning. In fact, in very Unreliable services, passengers will even undertake Planning Checks while in the vehicle to prepare for disruptions.

Planning uses the more energy intensive and demanding high level System 2 cognition. Due to the likelihood of suffering losses, &/ sanctions, the uncertainty creates a sense of stress raising passenger's cortisol levels (Ashcraft & Radvansky 2010; Kahneman 2011; Vague 2012). Unreliable public transport is actually more physiologically unpleasant than Reliable transport.

Figure 11: Passenger process for using risk-mitigating planning on an unreliable multi-modal journey

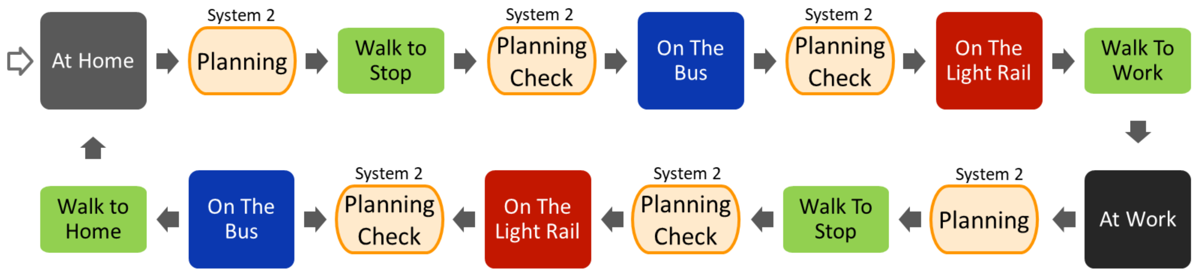


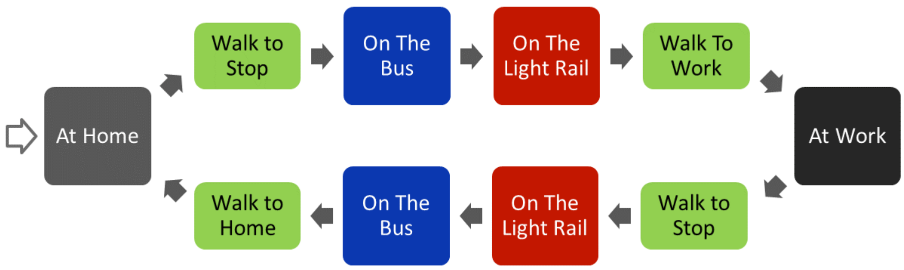
Table 1: An example of the stressful risks passengers must mitigate when using unreliable buses

Event	Consequence	Cascading Consequences
When using the bus, the bus reaches the arrival stop later than scheduled.	The bus reaches the arrival stop later than scheduled.	• The passenger arrives later than planned • They suffer reputational / financial loss — i.e. they suffer social / personal sanctions.
When using the bus, the bus reaches the departure stop as scheduled but there is heavy traffic enroute.	The travel time is longer than scheduled.	• The bus reaches the arrival stop later than scheduled. • The passenger arrives later than planned • They suffer reputational / financial loss

Event	Consequence	Cascading Consequences
When using the bus, the bus reaches the departure stop as scheduled but is stopped by every traffic light enroute.	The travel time is longer than scheduled.	• The bus reaches the arrival stop later than scheduled. • The passenger arrives later than planned • They suffer reputational / financial loss
When using the bus, the bus reaches the departure stop earlier than scheduled.	The customer misses the expected service.	• The passenger has to seek an alternative transport option • They have to expend additional effort and will suffer stress • They arrive later than planned • They suffer reputational / financial loss

In contrast, passengers undertaking regular journeys with transit operators committed to providing Reliable and Trustworthy service can forgo the constant Planning Checks and are able to operate with low-stress using low-energy habit (System 1). If the services are Reliable, and thus Trusted, the passenger will be able to relax and make use of the travel time for other activities such as doing work, reading a book, playing a game, or even looking at the scenery.

Figure 12: The simpler passenger process for taking a multi-modal journey in a reliable system



A lackadaisical operator hoping for the best while running a "set and forget timetable" will not be actively Controlling the Risks for their passengers, thus they will not deliver a service the passenger can Trust — a service where the passenger can relax. Thus, they will not deliver the service the passenger sought thus they will deliver an Ineffective Low-Quality Service.

In contrast, a customer focused operator will work with the service partners to deliver a Reliable transport service that controls the Risks that are faced by passengers through the use of a transport network the customers do not control — i.e. an effective service. Risk Management is one an example of a Continuous Improvement Cycle that when embedded in the culture of an organisation and implemented by all staff allows the PSO to deliver High-Quality Services.

3. Service Efficiency and Legitimacy

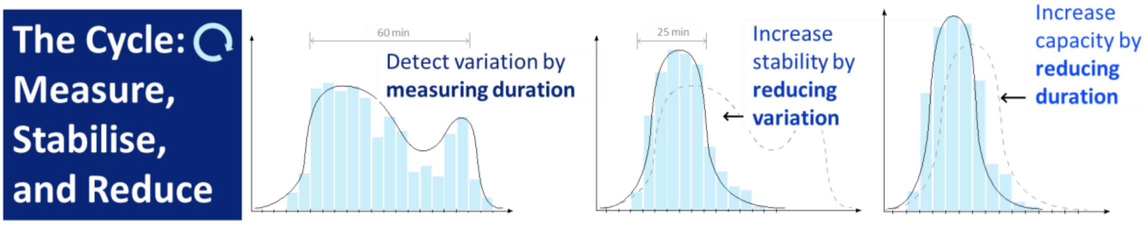
Moore makes it clear that since the public only grants Authority to the PSOs to deliver services that provide the ***Arbitrated Public Values***, the PSO loses their Legitimacy if they undertake unauthorised activities or if they waste the public's taxes though inefficient operations. As such, it essential for a PSO to continuously improve its Efficiency in producing Public-Value.

For example, during the 2021-21 Financial Year the NSW Transport Cluster had Authorised expenses of $15.835 billion and a capital expenditure of $15.242 billion[R3]. To maintain Legitimacy the cluster must operate Efficiently while appropriating $3,790 per capita in taxes.

One way to achieve Economy and Efficiency is through Continuous Operational Improvement focussing on reducing Waste as in Lean processes (Fercoq, Lamouri & Carbone 2016) or the

Measure, Stabilise and Reduce (MSR) framework outlined by Dr M.E. Zeibots (McRoberts-Smith 2020; Mileusnic 2017; Murdoch 2017; Samra 2017; Smalley 2017) in Figure 13.

Figure 13: How controlling runtime variability using MSR can improve how services are delivered



3.1. Statistical Process Control

Since the PSO must continuously improve service Efficiency, it needs to constantly measure:

i) How are the services being delivered?
ii) How are their customers responding to the delivered services?
iii) Are the services being reliably delivered? And
iv) Is there any waste during service delivery that can be eliminated?

In a natural system, even one under as tight control as a manufacturing process, the measurements of key parameters will often form a normal distribution. As such measuring the system and controlling variance is a key technique for reducing Waste and achieving Efficiency. The wider business community has expanded upon the principles of SPC since the early twentieth century, and this work was refined by luminaries such as W.E. Deming, and then into frameworks such as Six Sigma (Brussee 2006; Deming 1982, 2018).

In theory, SPC can be used to improve the Reliability and Efficiency, thus maintaining Legitimacy for transit operations. This section provides a theoretical examination of a possible mechanism for using SPC with transit; while Hounsell (2022b) provides the empirical examination to test if three Sydney operations have the characteristics that could that approach.

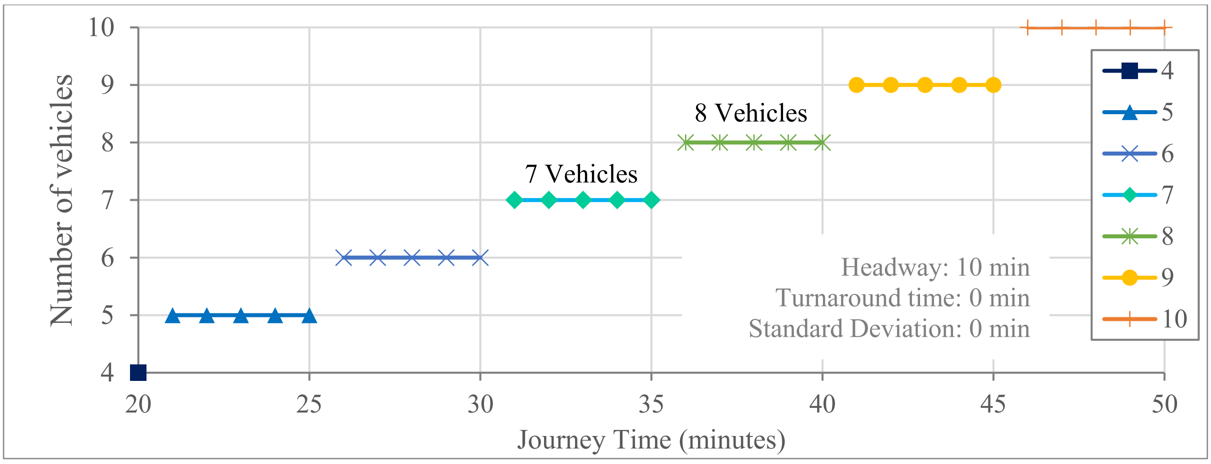
To exemplify the use of SPC in public transport operations, consider one of the key parameters that determines service Efficiency: the delivered end-to-end runtime (**e**) which is the time to travel in-service from the first stop to the last stop. As shown in Equation 1 and Equation 2 below as well as Figure 14 below, the number of vehicles and crew required to deliver a service (**V**) for a targeted vehicle-headway (**h**) and given turn-around times (**f** and **l**), is proportional to the key variable of delivered end-to-end runtime (**e**). To simplify the text, this paper naively assumes inbound and outbound runtimes are equal, and the turn-around-times are uniform.

Equation 1: Key fleet equations

Cycle Time	Number of Vehicles	*Cycle Time*	Vehicle Headway
$r = 2e + f + l$	$v = r/h$ $V = \lceil v \rceil$	$r = vh$	$h = r/v$

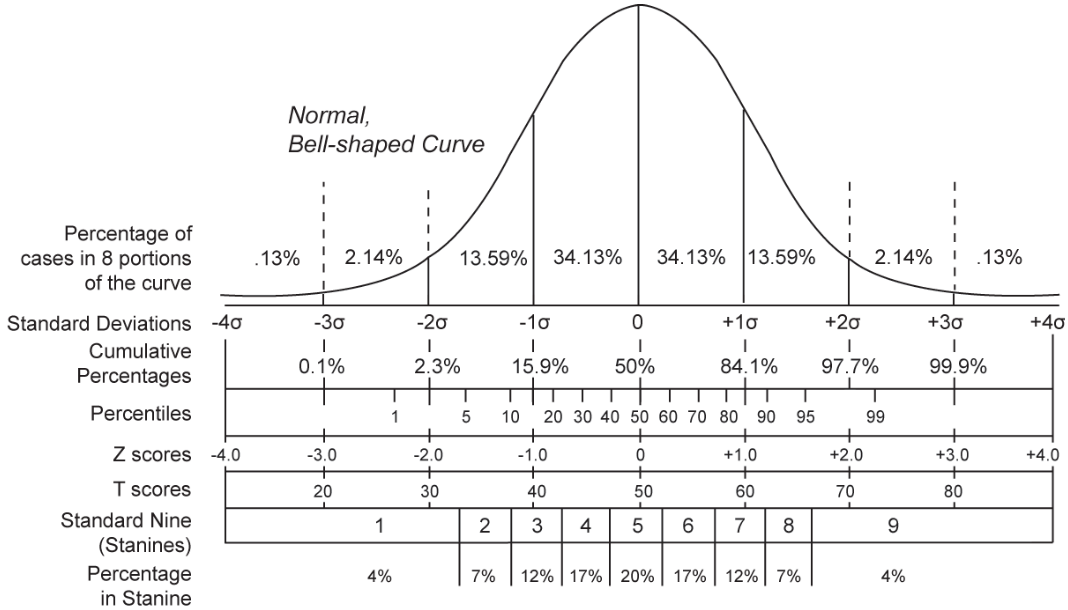
Figure 14 shows the size of the fleet (vehicle and crews) required to operate a service is determined by the end-to-end runtime. That example shows that reducing the end-to-end runtime by just two minutes from 36 minutes to 34 minutes would allow the deployed fleet to be reduced by one unit. As Moore outlines, *savings from operational Efficiency* can be *returned to the public*, or with public support, they can be *reinvested to generate additional Public-Value*. These plots assume zero turnaround time to highlight the relation between the number of vehicles and the variability in end-to-end running time.

Figure 14: Number of vehicles by symmetric end-to-end runtime per runtime for a 10-min headway.



The six-sigma method approach to achieving SPC is through monitoring the mean ($\bar{e}$) and the standard deviation (σ_e) of the product or service because in a normal distribution 99.8% of the values will be less than three standard deviations from the mean. Therefore, if the manufacturing or service delivery is able to produce products or deliver services where the variance of the Outputs are controlled ($\bar{e} - 3\sigma_e \geq e_{min}$ and $\bar{e} + 3\sigma_e \leq e_{max}$) then the Output will be reliably less than the upper tolerances of the process 99.9% of the time.

Figure 15: Normal Distribution: graphical representation of confidence interval breakdown[R5]



It is important to note that this type of SPC, does not measure Reliability from the failure rates (late running), instead, it is continuously monitoring the key metrics of delivered services, to detect any process failures when those key metrics leave the acceptable tolerances. For this type of SPC to work, either the runtimes ($\mathbf{e}$) need to be normally distributed, or the mean ($\bar{e}$) and the standard deviation (σ_e) need to be useful in constructing an estimator — Hounsell (2022b) demonstrates that can be the case for transit.

Public transport operations in NSW, are currently too variable to realistically contemplate achieving process control with 99.9% Reliability (Hounsell 2018b). As such Hounsell (2018a) identified a more modest goal of 97.7% Reliability, which translates to four-sigma or $\bar{e} + 2\sigma_e$. Therefore, if during natural operations the end-to-end runtime of a service is normally distributed, then the upper tolerance allowed to have 97% confidence that the headway will be maintained — without needing additional vehicles — is dependent on the minimising the standard deviation of the end-to-end runtimes ($\boldsymbol{\sigma_e}$).

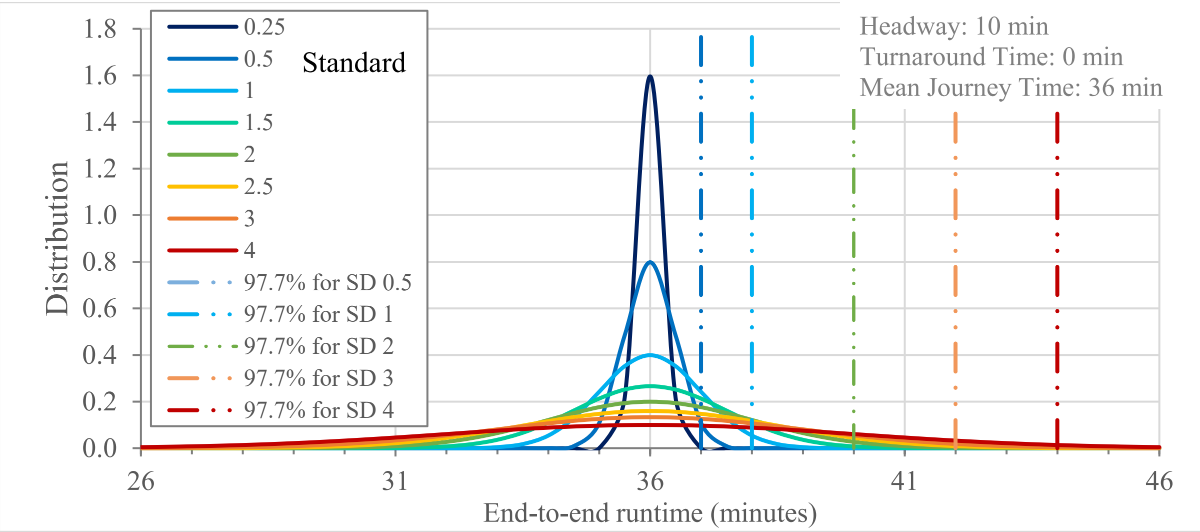
Most bus routes are managed by timetables — those services are unnatural — their runtimes will not be normally distributed because the vehicles will have waits at key stops for prolonged periods to compensate for late running due to traffic. However, in situations where the runtimes are reliable, they can be operated without waits in the timetable for traffic delays, e.g. as BRT.

Equation 2: End-to-end runtime including variation for a given number of vehicles at a given headway[E2]

97.7% Confidence	$e_{normal} = \bar{e} + 2\sigma_e$	$\therefore V = \left\lceil \dfrac{2\bar{e} + 4\sigma_e + f + l}{h} \right\rceil$
99.9% Confidence	$e_{normal} = \bar{e} + 3\sigma_e$	$\therefore V = \left\lceil \dfrac{2\bar{e} + 6\sigma_e + f + l}{h} \right\rceil$

For example, Figure 16 shows that transport planning for a public transport service with a mean end-to-end runtime of 36 minutes, and a standard deviation of 4 minutes, would need to assume that the end-to-end-runtime took 44 minutes to have 97% confidence that any given headway could be maintained. A service with 0-minutes standard deviation would give a cycle time of 72-minutes and take 8 vehicles, but a service with a standard deviation of 4-minutes would take a cycle over 88 minutes and need 9 vehicles to operate.

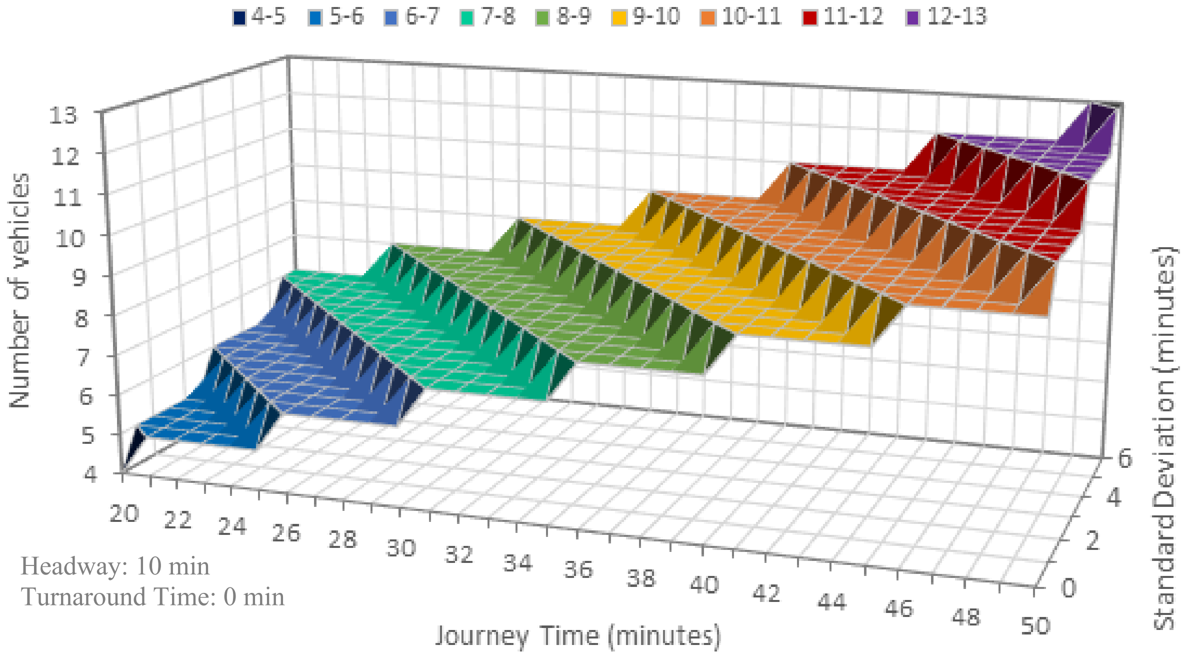
Figure 16: Distribution for a mean journey time of 36 minutes per standard deviation



The three-dimensional plot of these curves is shown in Figure 17 below. Plotting a three-dimensional curve is unusual, but this plot clearly shows that the number of vehicles needed for a service is dependent on the end-to-end runtime and its standard-deviation. Figure 17 combines Figure 14 on the x-axis and y-axis — it even uses the same colour scheme — and the standard deviation from Figure 16 on the z-axis.

Figure 17 shows that for a 10-minute vehicle headway, a 20-minute end-to-end runtime, and 0 minutes of standard deviation, a service would need 4 vehicles to operate. Following along the z-axis, the plot shows that with just 1-minute of standard deviation, the number of vehicles increases to 5. Continuing to the end of the z-axis the plot shows that a standard deviation of 6 minutes increases the number of vehicles needed to 7. Note: assumes 0-minutes to turnaround.

Figure 17: Number of vehicles for a given symmetric end-to-end runtime and a given standard deviation



4. Discussion

Every entity in a community, has differing Values-Frameworks. The Political Process is used to Authorise the imposition of taxes and regulations to achieve a carefully Arbitrated set of Objectives — in an Arbitrated Service Quality. A community has a limited pool of Resources that it can divert to the satisfaction of Objectives through services like education, healthcare, or transport. The resources that are Appropriated to provide transport are then not available for the community to either investment privately or spend on other public services. Thus, the PSO has no Authority to waste public Resources with Inefficient or Ineffective operations.

When the operations are controlled, then the operators can focus on reducing the running time to deliver a faster service or higher frequencies, i.e. Measure, Stabilise, Reduce, and Improve. There will always be variation in running times while delivering a public transport service, but that variation can be controlled. Indeed, that variation must be controlled and minimised in order to deliver an Economic and Efficient transport service. *Since the PSO was only authorised to Appropriate the minimum necessary Resource to operate the services, the variation in running times must be controlled for the PSO to retain its Legitimacy*.

This paper shows that there is a theoretical reason for, and a theoretical ability to, use SPC to improve delivered (and planned) end-to-end public transport running times; while the companion paper, Hounsell (2022b), provides the empirical examination to demonstrate that delivered end-to-end running times have the necessary characteristics to support SPC.

What is more, if the PSO uses measurements and SPC to control and minimise running time variability they can deliver a more Reliable public transport service. A more Reliable transport can be Trusted by passengers, and thus it will then be more relaxing and attractive.

A public transport service that is continually improving its effectiveness by meeting the customers Objectives for Trust and Value for Money will be perceived as Higher Quality than the previous unreliable service, *that should increase the mode share for sustainable transport*, which will then provide even more benefits to the community by reducing externalities.

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6. Endnotes

E1 – Matt Faber is the Associate Director for Transport for the Australian Infrastructure Plan at Infrastructure Australia. In his examination of Hounsell (2020), he suggested that the Strategic Triangle from Moore (1995), 2013) should be discussed as the primary framework for examining the context for transport planning and transport engineering.

E2 – There will also be natural/normal variation in the turn-around times, i.e. $f = \bar{f} + 2\sigma_f$

7. References

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R2	ABS 8165.0 Counts of Australian Businesses, including Entries and Exits, June 2016 to June 2020 https://www.abs.gov.au/statistics/economy/business-indicators/counts-australian-businesses-including-entries-and-exits/jul2016-jun2020
R3	NSW 2021-2022 - Budget Paper 4: Agency Financial Statements - Chapter 8: Transport Cluster https://www.budget.nsw.gov.au/sites/default/files/2021-06/8.%20Transport-BP4%202021-22%20Budget%20Paper.pdf
R4	Normal Distribution: graphical representation of confidence interval breakdown and relation of the confidence intervals to the z- and t-scores. https://commons.wikimedia.org/wiki/File:Normal_distribution_and_scales.gif

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