Making markets work for disability services

Charles Plott[a], Gary Stoneham[b], David Brooks[b], Hsing-Yang Lee[a], Travis Moran[a], Han Seo[a], Veronika Nemes[b], Amy Corman[b].
[a] California Institute of Technology
[b] Centre for Market Design, University of Melbourne

Abstract
Transport services needed by students with disability are funded through the NDIS but there is no implementable, decentralized mechanism to allocate and price these services. This paper reports on a pilot in which the objectives of the NDIS inform the design of a mechanism used to establish a transport network for students with disability. The broad architecture of the mechanism includes a demand-side in which mathematical optimization techniques are applied to implement network-wide service quality attributes and a supply-side in which competition is harnessed through an auction. The transport network created from this mechanism at the Northern School for Autism in Melbourne resulted in a dramatic improvement in service quality at equivalent cost. Key outcomes include: 68% reduction in aggregate travel time for students; reduction in maximum travel time from 2 hours (each way) to around 1 hour; timely arrival of students at school; and a direct service to school. Besides the obvious advantages for students, the main finding of this paper is that many markets/mechanisms needed to implement the NDIS vision are missing and unlikely to emerge autonomously. Where they do, they are unlikely to be efficient, fair or provide the anticipated improvements in service quality. This paper demonstrates that it is feasible to create mechanisms, even at the difficult end of the market design spectrum, that demonstratively improve the service quality and arguably improve economic efficiency.

1. Introduction

The National Disability Insurance Scheme (NDIS) represents a fundamental change in the way services are provided to citizens with disability (NDIS Act 2013 and Productivity Report 2011).[1] Key features of the NDIS include: i) funding certainty for recipients of support; ii) choice and control over the services needed by individuals (client- focused); and iii) delegation of service supply to non-government organisations. These reforms transform the provision of services from the previous centralised approach, where governments allocate resources, to a decentralised mechanism in which individuals make choices and non-government agencies supply services. The NDIS model essentially relies on the emergence of a wide range of transaction mechanisms (markets) to enable NDIS clients to procure the goods and services needed to manage disability. Although the NDIS expands the boundary of markets in the economy, the key constraint on this model is extent to which efficient and trusted markets emerge to facilitate transactions between NDIS clients and suppliers of needed goods and services. As is the case in the broader economy, markets for some goods and services will evolve autonomously, others may emerge but will not be efficient or efficacious whilst others will need to be designed and created.

This paper frames NDIS as a missing market problem. We initially provide a brief description of the market design process (Section 2) and then apply this methodology to design a market needed to allocate transport services for students with disability (Section 3). We report the outcomes from a field pilot in which this mechanism was used to allocate and price transport services (Section 4) and discuss the broader implications for the NDIS (Section 5).

[1] NDIS services fall into 15 categories, and these include, for example, transport, assistance with social and community participation, assistive technology, home modifications, etc. See, the NDIS website for a full list.

2. Market design

Markets are the preferred mechanism of exchange over alternative transaction pathways such as bartering or bilateral transactions because they make it easier, safer and more financially advantageous to transact. The important feature of markets is that resources are allocated through the interaction of market participants who hold private information relevant to the transaction - not by a central planner. Many markets evolve autonomously through a natural selection process in which buyers and sellers choose between competing transaction formats (i.e., eBay vs. a physical shop). This selection process leads to the creation of markets that are: i) *efficient* – they maximise the value created for buyers and sellers including transaction costs; and ii) *efficacious* – deliver the goods or services purchased and ensure suppliers are paid according to the contract. The market evolution process results in a wide range of market formats in which different rules, conventions and codes of practice are needed to: govern behaviour; lead to truthful revelation of information; reveal efficient prices; facilitate coordination and scheduling; thicken markets; and facilitate participation by brokers, financial intermediaries and legal experts (see McMillan 2002). While markets "grow like weeds" (Roth 2002) for many goods and services, they do not evolve in some domains of the economy even though transactions would create value. Markets are missing, for example, where goods and services display public good[2] characteristics (e.g., fundamental research, environmental goods and services, defence, some classes of health services etc.) or externalities (i.e., where the cost of supply is borne by others). For other goods and services, limited competition and infrequent transactions (e.g., government allocation of natural resources or procurement of bespoke goods and services) mean that markets evolve slowly such that they cannot be relied on to be efficient, fair with respect to the distribution of value or trusted to deliver the outcomes anticipated. Markets may also be inefficient, where complexities (discussed below) give rise to transaction costs that erode, or in extreme cases extinguish, value created leading to the missing market problem.

A set of economic ideas, collectively referred to as mechanism/market design and a market design methodology, have emerged from which markets can be designed where they are missing or inefficient. Mechanism/market design is sometimes referred to *reverse game theory* in which the objective (*goal function*) and economic environment are taken as *given* and the task of the designer is to identify the rules and processes that define the *institution* (game) from an almost infinite set of possibilities (see Hurwicz and Reiter 2006). This market engineering process contrasts with the set of economic theories by which we understand evolved institutions such as commodity markets. For example, economists frame commodity markets as a *game* in which the rules and processes that govern transactions are given (i.e., determined through the evolutionary process noted above) and the outcomes are determined through the interaction of self-interested agents (buyers and sellers) according to the rules and proceses that define the market (game). This process is reversed when markets are missing. In this case, all aspects of the mechanism must be designed and created such that it can be trusted to deliver the outcomes expected but displays the economic efficiency properties observed in evolved institutions (e.g., commodity markets). Roth (2002) refers to this and an economic engineering process.

Economic theory identifies three key attributes that must be designed into the institutions where the private information of participants influences who gets what. The mechanism must be designed so the dominant strategy of participants is to truthfully reveal information needed to facilitate efficient and effective transactions. A mechanism with this property is said to be information efficient. A mechanism that truthfully reveals private information is referred to *as information efficient*. The mechanism must also contain incentive structures that cause independent actors to make decisions that align with goal function (e.g., the objectives of a government program) –

[2] Where individuals cannot be effectively excluded from benefiting from a good or service and where use by one individual does not reduce its availability to others.

referred to as *incentive compatibility*. A mechanism must also be robust to unwanted and unanticipated outcomes that arise when self-interested actors game the system. For example, agents will not tell the truth if the mechanism does not offer higher agent types (e.g., higher cost types) a better deal. Otherwise, higher types facing any mechanism that punishes high types for reporting will lie and declare they are lower types, violating the truth telling and incentive compatibility constraints. Such mechanisms are *strategy-proof*.

2.1 The market design process

To design a market, the designer must explicitly take into account the incentives of economic agents to behave strategically, in particular, opportunistically and in their own interests. The market designer aims to create *institutions* that provide these agents with the appropriate incentives to reveal the information required for desirable (efficient) allocation and to align their behaviour with what the designer's intention and objective. The design of such institutions (e.g., contracts, auctions, matching markets, remunerations schemes) is the defining feature of market design. The market design process can be implemented in four stages: diagnostic, design, test-bed and implementation/scaling.

Economic diagnosis – Market design is initiated by framing the problem at hand as a transaction. This includes identifying the actors involved in transactions, framing the interaction between actors as the transaction and identifying frictions (referred to as complexities) that. If not addressed, increase transaction costs. Four classes of complexities have been defined by Plott in Nemes *et. al.* (2008).

- *Policy complexities* – Some transaction costs arise from the investment needed by participants to navigate the regulatory environment created by government. Biodiversity offset markets, for example often include complex trading rules needed to limit transactions to like-for-like exchanges.
- *Transaction complexities* - Transaction complexities are frictions that impede assembly and deployment of goods and services. Some goods and services such as electromagnetic spectrum needed for mobile phone networks, create value only when they are secured in packages (e.g. different frequencies are needed to transmit and receive messages at each mobile phone tower). Other transaction complexities including: coordination problems, information asymmetry, non-convexity, synergies between items etc. also create friction within markets, reduce economic efficiency, increase risk (e.g. exposure risk) and can cause markets to fail in extreme cases.
- *Strategic complexities* - strategic complexities arise where behaviour, such as cheap talk, holdouts and posturing impede efficient allocation of goods and services in markets. The scope for buyers and sellers to exercise strategic behaviour is limited in markets where there are many participants and competition is strong
  Time complexities – Buyers and sellers can arrive asynchronously at market leading to costly delays and thin market problems.

Market design - Following the diagnostic stage, mechanism design principles (economic theory) are applied to identify the broad architecture of the mechanism and the fine-scale rules and processes that organise transactions. The first step in this phase involves defining/clarifying the objectives of the mechanism (the *goal function*) and then identifying the rules, processes and incentives structures needed to align the actions autonomous agents with these objectives. As noted earlier, there are almost an infinite number of combinations of rules and processes that define a mechanism and these must be narrowed-down to just those that efficiently achieve the stated objective. This involves choices over: the class of mechanism; incentive structures within the mechanism and contracts; defining participation requirements; bidding rules; winning rules; exit rules; and specific processes needed to overcome complexities.

Test bed – Before a mechanism is implemented, it may need to be tested under laboratory conditions to ensure that it is achieves the outcomes intended and has acceptable economic efficiency properties. Experimental economics techniques have been developed for this purpose (see Plott and Smith 1978). This may include a field pilot to ensure that the mechanism can be implemented in real world conditions.

Implementation and scaling – In this step of the design methodology, the support systems needed to implement the mechanism at scale are designed and created including: probity, pre-qualification, settlement, dispute resolution, market monitoring and reporting systems. A scaling strategy is also needed to ensure that the mechanism and supporting systems are synchronised.

Economic principles are often combined with complementary technologies (e.g., computation, communication and coordination technologies) to design markets. For example, the markets designed to allocate mobile phone spectrum) rely on modern computers to identify the best bids from a very large number of number of permutations and combinations of spectrum allocation alternatives.

The emergence of market design principles and methodologies open-up the prospect of creating market mechanisms for goods and services needed to manage disability services where they are missing or inefficient. If successful, this would establish transaction mechanisms that are safe (they ensure that promises made to supply goods and services are honoured) and efficient (reveal prices that reflect the underlying cost of supply).

The remainder of the paper applies a market design process to one class of disability service – transport services for students with disability. We firstly describe key features of the approach/mechanism (Section 3); apply the market design methodology (Section 4); report the results from a pilot in which a designed market was used to allocate and price transport services (Section 5); and make some observations about the application of market design process to other disability services (Section 6).

3. Creating markets for disability services

3.1 Current transport services for students with disability

Many children with disability, such as autism, attend special schools that provide specialised teaching and education facilities. These schools enroll students from large urban or rural catchments and rely on bus networks dedicated to transporting students to and from school each day. Students attending these schools have access to a daily bus service between designated assembly locations and the relevant junior or senior campus. In Victoria, student transport services have been funded by the State Governments through the Students with Disabilities Transport Program (Victorian Department of Education and Training). Whilst student travel services are now funded by the NDIS, it is unclear whether they will continue to be managed by the States.

Typically, student transport services are provided by private bus operators with contracts to provide services within a spatially defined region. Contracts are typically allocated through a standard government procurement process based on a sealed-bid tender followed by a negotiation process. Some service quality attributes, such as safety and supervision standards, are implemented through a pre-qualification process; others, such as maximum travel times and the location of collection stations, are specified in the service contract; and others, such as route configurations, are the outcome of profit-motivated decisions made by bus operators.

When applied to the Northern School for Autism (a Special School in Melbourne), the standard government procurement model resulted in a hub and spoke transport model in which students were collected from designated locations, transported to an assembly area (the junior campus of the NSA) from which senior students were shuttled to the final destination (the senior campus). This hub and spoke model is widespread in transport networks including air and rail services because it aggregates passengers from relatively low-density regions (spokes) into hubs from which large, cost-effective vehicles can be used to transport passengers to their final destinations. At the NSA, this service delivery model resulted in:

- Long travel times - The average travel time for student was 66.6 minutes (a.m. service) and 73.48 minutes (p.m. service). Travel time for the most distant student was close to 2 hours each way.
- Multiple-leg trips – For senior students, the travel service included two legs with the hub located at the junior campus
- Lost classroom time – The second leg of the bus service arrived at the senior campus at approximately 9.30 a.m. and departed early at the end of the school day. Late arrival/early departure reduces classroom time by around 20% and also disrupted students not using the travel service.
- Large vehicles - Bus operators relied on large, 55-57-seat buses with low supervision ratios (the ratio of students to chaperones).
- Reduced readiness to learn – Long travel times, multiple-legs, and low supervision ratios caused stress for many students reducing their readiness to learn once they arrived at school. Teachers note that they often had to use valuable classroom time to calm the students down before they commenced learning activities.

4. A designed market for student transport services

In this section we apply the market design methodology to design a mechanism to price and allocate transport services needed for students attending the NSA. As noted above, the we apply a reverse engineering process in which the objective is taken as given and the task is to identify the rules and processes needed to align the decisions of self-interested agents with the stated objectives. health outcomes through organ transplant exchanges (see Roth 2002 for further examples).

4.1 4.1 Economic diagnosis

From an economic perspective, the salient characteristic of transport services is that they are supplied from a network – in this instance a bus network. Along with other network services including: telecommunication, energy, social media and delivery services; transport services; networks characterized by branching and sub-branching infrastructure interest because services can be provided at lower cost (than an individual service provision model e.g., a taxi) because networks increases the transaction space and facilitate coordination between participants. Networks typically require large investments in capital in which fixed costs can be shared across many users. As new participants join a network, they reduce the marginal cost of supply costs to all other users (a positive network externality). Once network capacity is reached, however, each additional participant imposes costs on other users because of congestion (a negative network externality). HERE

Other complexities on the supply-side including lumpy capital, synergies, thin markets etc. also inhibit the emergence of decentralized transaction mechanisms. While some theoretical mechanisms capable of mitigating the network externality problems can be imagined, such mechanisms tend to quickly become non-implementable as the number of participants and quality dimensions increase[3]. Lack of competition on the supply-side, particularly when combined with lumpy capital and other complexities, are however, more challenging impediments to the design and creation of markets for services provided by networks. While markets for network services do evolve, they generally emerge as monopolies, duopolies or other structures in which there is limited competition. They are also characterized Networks also display positive externalities.

4.2 4.2 Mechanism design

In the absence of an implementable decentralised mechanism to price and allocate network services, a hybrid mechanism was developed to exploit the cost advantages of providing travel services from a bus network whilst constraining network externalities to acceptable levels.

On the demand-side of tis maechanism , the key challenge is to develop a process to reveal the preferences of consumers (students participating in the bus services) for goods and services (usually, but not always expressed as valuations). Where services are supplied from networks consumers' decisions and the value they receive is influenced by decisions made by other users of the network. For example, each additional student who joins a travel service, reduces travel costs for all students enrolled in the service (a positive network externality) but also increases travel times for all students (a negative network externality). Monetisation, communication, computation and commitment problems effectively preclude the creation of a decentralised mechanism to reveal the preferences of students for transport services supplied from networks. Aggregating students' preferences based on survey techniques is problematic for the same reasons (Arrow's impossibility theorem – Arrow 1951) and relies on stated, rather than revealed preferences. A three-stage strategy was developed to mitigate (if not resolve) these information and aggregation problems.

Stage 1: Individual service quality standards - Some service quality attributes, such as vehicle safety standards (e.g., seat belts), accreditation, and supervision requirements (e.g., centre isle access for chaperones) are mandated by Government to create a safe and secure service for each student (see Table 1). These service standards were implemented through a pre-qualification process that restricted participation on the supply-side, to compliant bus operators/vehicles.

Table 1: Individual service quality attributes

Service attribute	Description		Implementation strategy
Supervision	(i)	Chaperone required on all vehicles.	Pre-qualification
	(ii)	Driver and chaperone require working with children check and first aid training.	Pre-qualification
	(iii)	Chaperone to have ready access to all passengers.	Pre-qualification
Seating	Seat belts with buckle guard for all students		Pre-qualification
Vehicle safety	Vehicle safety and accreditation		Pre-qualification

Stage 2: Network-wide service standards – In the absence of an implementable mechanism for revealing and aggregating individual preferences, the student and professional school community of the NSA were engaged to identify service quality attributes for the network as a whole. The school community collectively identified four network-wide attributes: i) the location of safe and functional

[3] For example, the Vickery Clarke Grove (VCG) mechanism has theoretical application to networks but requires all market participants to place their valuations on all permutations and combinations of service options. This mechanism quickly becomes non-implementable because of computation problems (i.e. it is NP-hard)

collection stations where students assemble, embark and dis-embark to/from the bus service; ii) one-hour limit on the maximum travel time (each way) for any student participating in the bus service; iii) a requirement for the bus service to arrive at school for a 9am start to the school day; and iv) a direct service to campus avoiding the double-leg (hub and spoke) approach of the previous service (see Table 2). Network-wide service standards i), ii) and iii) impose constrains on route design and standard iv) constrains vehicle selection to those with a centre isle (i.e., busses with 20 to 57 seats).

Table 2: Network-wide service quality standards

Service attribute	Description	Implementation strategy
Travel time	No student to travel for more than 1 hour each way	Constraint on route design
Pick-up locations	Locations specified by the NSA.	Constraint on route design
Arrival/departure times	Vehicles to arrive before 9am	Constraint on route design
Transport legs	Direct service from pick-up points to the senior campus of the NSA (remove the shuttle service from the junior campus provided as part of the hub and spoke model)	Constraint on route design
Supervision	Centre isle access required to enable chaperones to assist all students.	Constraint on vehicle selection

Stage 3: Route optimization – In a third stage, a constrained optimization method was developed to identify the minimum number and spatially configuration of routes needed to provide transport services for all participating students within the constraints defined by: safety and services standards mandated for each student (Table 1); network-wide service quality attributes (Table 2) defined by the school community; the location of collection stations; loading times; and travel times between collection stations (see Table 3). Route optimization is broadly understood as the “travelling salesman problem” in which there are a large number of alternative pathways between each collection station and multiple possible starting locations. In the NSA context, 35 collection stations define 1,225 (35^2) location pairs with routes defined by a starting point and sequences of linked pairs. A constrained optimization methodology was developed in which the objective was to minimize the number of routes needed to transport all 79 students to school within 1 hour, given the constraints on vehicle size (20 to 57 seat vehicles), travel times between collection pairs (estimated from Google Maps) and loading times at each collection station (estimated from historical data).

Table 3: Parameters of the NSA route design problem

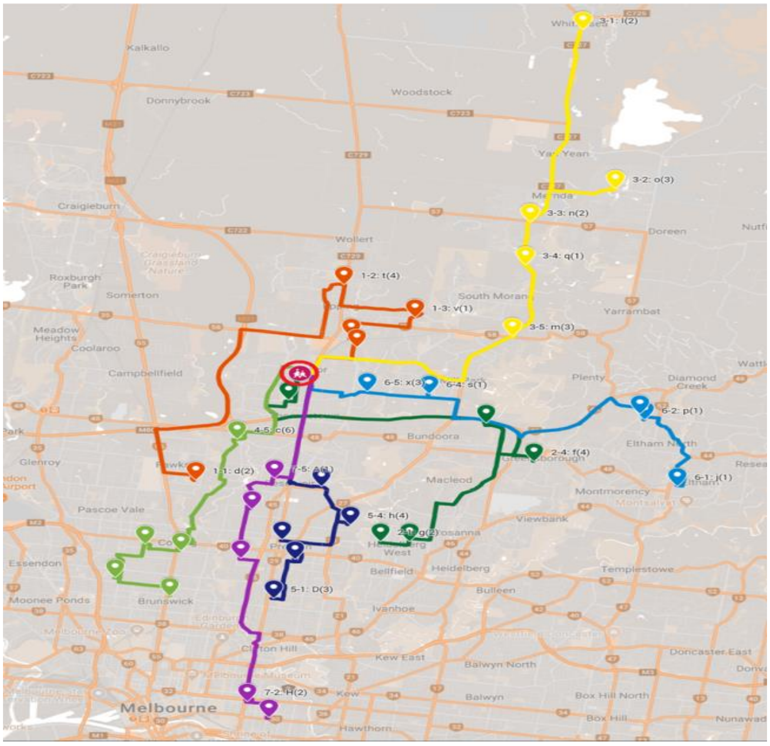
Parameter	Description
Number of passengers	79
Number of designated pick-up stations	35
Number of students at pickup stations	1 – 7
Loading time	90 seconds per child
Minimum bus size	20 seats
Maximum bus size	57 seats
Travel times between pick-up locations	Determined form Google maps at relevant times
Maximum travel time for any student	1 hour
Arrival time at school campus	Before 9am.
Route configuration	Direct service to destination campus

This optimization process identified that a minimum of 7 routes would be needed with each route was defined by: a starting point; a sequence of collection locations (selected from the matrix of 1225 location pairs); the number of students to be picked up at each collection station; and the destination. Table 4 summarises the characteristics of each route. A team of designated drivers were assigned to verify route feasibility with respect to traffic flow, road conditions, obstructions and other practical issues (see Figure 1).

Table 4: Routes defined for the NSA

Route#	AM Minutes	# Stops	Student numbers	AM Km	PM Km	Daily Km
1	55	5	10	27.46	27.81	55.27
2	57	5	13	26.4	26.37	52.77
3	59	5	11	33.32	31.25	64.57
4	57	5	13	19.48	18.79	38.27
5	53	5	16	17.43	16.68	34.11
6	46	5	9	20.89	22.09	42.98
7	57	5	7	20.82	20.77	41.59

Figure 1: Routes designed for NSA students



4.2 The supply-side of the mechanism

The supply-side of the mechanism was framed as a procurement auction in which pre-qualified bus operators compete for contracts to provide services for one or more of the 7 routes identified. A contract was specified for each route based on the information reported in Table 4 and Figure 1 with the winner of each contract to provide transport services for 600 school days (3 years). Prior to the auction, a precise description of the routes including starting points, pick-up locations and sequences, travel distances, estimated travel times, number of students at each pick-up location and destination were publicly made available.

Auction format and bid formation **–** An open, descending price, continuous, simultaneous, multiple-item auction (see Plott, 1997; and Plott, Lee and Maron, 2014) was designed to allocate the 7 routes defined above. This auction format addresses a range of complexities including: information asymmetry (private values held by bus operators); multiple heterogeneous items (routes) that are substitutable to varying degrees; and strategic behaviour arising from the thin market problem. If not addressed, these complexities would increase transaction costs and or reduce efficient allocation of the items on offer (see Table 5). This auction format has been applied to ascending auctions (see Demange, Gale, and Sotomayor 1986, Milgram 2000, Plott and Salmon 2004 and Kwasnica and Sherstyuk 2013) but not to procurement (descending price auction) applications. This mechanism allows bus operators to place improving bids on any route at any time during the course of the auction to become a provisional winner. An activity clock was reset following placement of each improving bid and the auction concluded when no new bids were placed on any route within the time defined by the countdown clock. Winners were identified as bidders who placed the last bid on each route once the countdown clock expired. No negotiation was allowed following the conclusion of the auction.. This closing rule was preferred over a fixed time auction (i.e. as used in eBay) because: it creates an incentive for bid activity, mitigates sniping, and can be expected to result in lower prices in the procurement context. Bids in the auction were defined in terms of a daily rate with the term of each contract set at three-years. Being a descending-price auction, starting prices were set at $1550 per day per route with a decrement of $25. For the standard school year of 200 days per year over three years, the starting value of each contract was $930,000 with the decrements translating to $15,000.

Only three bidders were pre-qualified for the auction and a number of auction design choices and protocols were made to mitigate scope for collusive behaviour. These included: pay-as-bid (first-price) pricing, a reserve price, restricting interaction and communication between bidders during the auction, and the appointment of an independent probity officer. In addition, bidders were not told how many pre-qualified bidders participated at the auction and were also given bid IDs that made it difficult for them to make assumptions about number of participating bidders. Bidders were required to arrive at the bidding location at specific times and were escorted to their specific bidding rooms.

Table 5: Complexities and auction design

Complexity	Description	Design response
Hidden information	Bus operators know their valuations for routes. This information is not available to government administrators.	Competition between bidders harnessed in an auction to reveal low-cost suppliers.
Multiple items	Seven routes offered to the market.	Multi-unit auction
Heterogeneous costs to provide services along different routes	Each supplier likely to have a different minimum supply price for each route because of within-firm efficiency differences, location advantages, etc. For example, routes that start near the depot may reduce the cost of providing travel services.	Open auction format – included rounds of bidding in which supply prices can be revised. Simultaneous auction in which all routes are held open at the same time. This allows bidders to change the mix of routes and bids on routes so that the market identifies the ”best” allocation of routes and the price. Electronic auction platform allows rounds of bidding to be completed quickly and naturally.
Thin market	Three bidders completed pre-qualification process.	Pay-as-bid auction pricing rule.

		Reserve price set for routes. Measures implemented to restrict scope for collusive behaviour during the auction (e.g. restrict access to mobile phones, private bidding rooms).
Strategic behaviour	Posturing, delaying strategies, hold-outs and other behaviours can reduce auction efficiency.	Activity rules introduced through a countdown clock. Standard bid decrement of $25 was specified for the auction. Independent probity officer appointed with specific powers to halt the auction.

Auction implementation - The auction was held at the experimental economics laboratory of the University of Melbourne. Contracts were exchanged immediately the auction concluded with the price determined by the final (winning) bid for each route. The auction was hosted on an electronic platform that allowed participants to place bids on routes of interest through a bidding interface (see Figure 2). Each bidder's screen displays: routes available; currently winning bid (daily dollar amount) for each of the seven routes; provisionally winning bids for any of the routes (colour highlighted bid); the bid placement and bid revision capabilities ("Submit offers"); and; a countdown clock.

Figure 2: Bid screen: auction of contracts for bus routes

5. Outcomes

In this section we report the service quality, cost-effectiveness and transaction cost outcomes achieved from the mechanism described above. We

5.1 Service quality outcomes

Four service quality outcomes are reported from data collected by NSA staff and travel logs maintained by bus operators over the first term in which the new transport network was in operation.

Maximum travel time – Table 5 reports the actual travel times recorded for each route in the travel network created for students attending the NSA. For route 1, for example, the actual travel time exceeded the network standard of 1 hour (established by the school community) by 2 minutes for the a.m. service but bettered the standard by 5 minutes for the p.m. service. Across the entire network, the 7 routes bettered the network standard by 41 minutes. Table 5 also includes travel times estimated (based on Google Maps) for the route optimization process (Section 3.1). This comparison indicates that estimated travel times were an accurate predictor of travel times for the p.m. service but systematically underestimated travel times for the a.m. service.

Table 5. Travel time for new routes

Route	Travel time (minutes)							
	Actual a.m. (modelled)	Actual p.m. (modelled)	Actual daily	Actual vs modelled		Difference between actual and network standard (1 hour)		
				a.m.	p.m.	a.m.	p.m.	total
1-Fawkner	62 (55)	55 (55)	117	+7	0	+2	-5	-3
2-Heidelberg	58 (57)	56 (52)	114	+1	-1	-2	-4	-6
3-Whittlesea	65 (59)	62 (59)	127	+6	+3	+5	+2	+7
4-Brunswick	47(57)	50 (57)	97	-10	-7	-13	-10	-23
5-Northcote	62 (53)	55 (53)	117	+9	+2	+2	-5	-3
6-Eltham	65 (46)	41 (46)	106	+9	-5	+5	-19	-14
7-Richmond	60 (57)	61 (57)	121	+3	+4	0	+1	+1
Network total	**419 (384)**	**380 (384)**	**799**	**+35**	**-4**	**-1**	**-40**	**-41**

Travel time – The network service created for the NSA dramatically reduced travel time for all students participating in the travel service. At the aggregate level, aggregate travel time across all students was 68% lower than the previous service. Travel time reductions for each student are reported in Figure 3. For the student closest to the NSA campus, for example, travel times were reduced from 29 minutes to 4 minutes by the new service. For the most distant student travel time reduced from 115 to 54 minutes4. Table 6 reports travel times for the marginal student in each quartile defined by travel time. Students living closer to the school campus experienced significant, but smaller reductions in travel times (but larger percentage gains) than more distant students. The marginal student in the first quartile, for example, recorded a 32-minute (68%) reduction in travel time and the marginal student in the fourth quartile recording a 61-minute (53%) reduction in travel time. Students living in close proximity to the NSA campus realized large relative reductions in travel time with the new service because they travel directly to the senior campus eliminating travel to the junior campus needed under the previous hub and spoke service.

Service timeliness and directness - Under the previous transport service, buses were scheduled to arrive at the junior campus for a 9 a.m. start to the school day with the subsequent shuttle service arriving at the senior campus at around 9.30 a.am. The demand-side optimization process developed as part of the new mechanism created a network of direct services allowing for timely arrival of students at the senior campus. Across the full year, timely arrival of the bus service at the senior campus increased education time by around 200 hours per year for each travelling student. It is also less stressful for students (avoiding transfer to the shuttle service at the junior campus), and minimizes disruption of other students attending the senior campus.

[4] Note, this graph compares only those students included in the previous service and the new service.

Figure 3: Comparative travel times for individual students

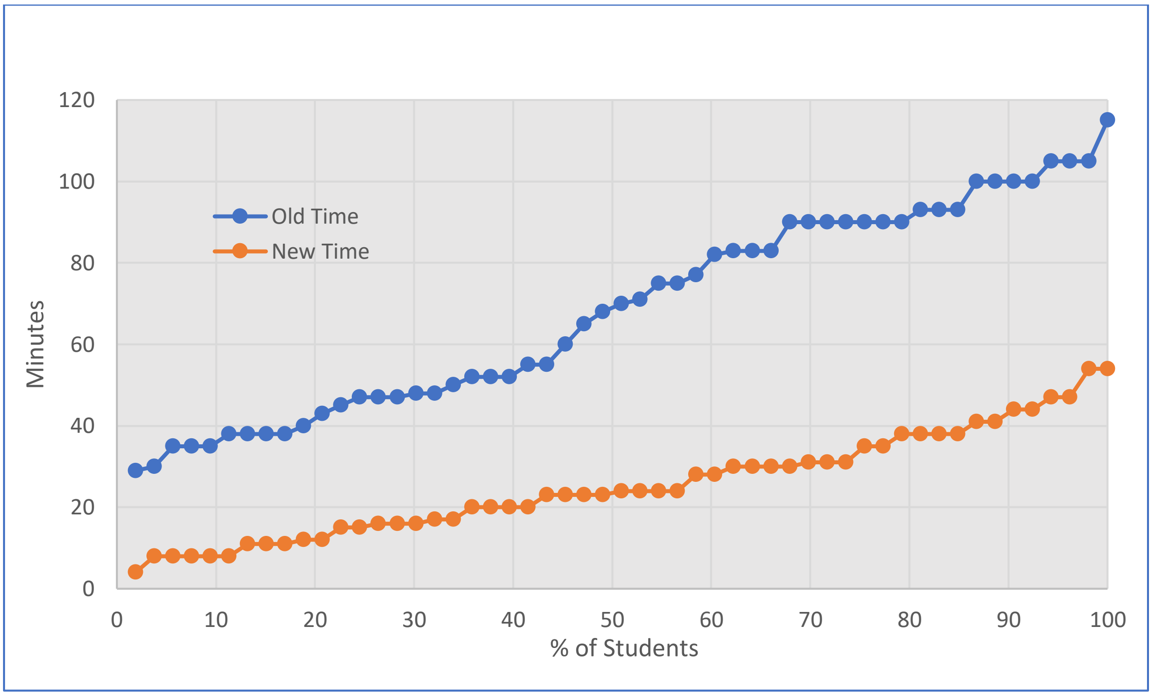


Table 6: Maximum travel time by quartile of students -comparison of previous and new

Quartile	Old Routes: Previous service (minutes)	New Routes: Auctioned service (minutes)	Reduction in travel time for marginal student (minutes)	Travel time saving as a percentage of previous time
1st	47	15	32	68 %
2nd	70	24	46	66%
3rd	90	35	55	61%
4th	115	54	61	53%

5.2 Cost and efficiency

The cost-effectiveness and economic efficiency properties of the mechanism are determined by both sides of the mechanism developed to create a student travel network for the NSA. In the absences of a decentralized revelation mechanism on the demand-side, our analysis of cost-effectiveness and economic efficiency is confined to the supply-side (the auction). Auctions (markets) are efficient if no change in the ranking of winners or the prices at which items (contracts) are exchanged results in an improvement in welfare. It is not possible, however, to quantify economic efficiency for auctions because bidders do not reveal the highest/lowest price they are willing to accept/pay. Bidding reveals "drop out" prices determined by unsuccessful bidders. In the absence of counterfactual information, we analyse bidding behaviour in the auction against theoretical expectations and compare prices with market rates.

Bidding behaviour – The auction relies on competition between bus operators to determine the allocation of routes and the prices paid to supply contracted services. Figure 4 reports the log of all bids recorded during the auction. The auction opened at the starting value of $1,550 per route (reserve price) with over 200 bids placed in just under 15 minutes of bidding. The log of bids displays a dynamic structure of price formation in which there appears to be a series of price wars between a pair of bidders (e.g. bidders 321 and 322) that continue bidding down the price of individual routes until one of the two drops out to focus on an alternative route. Bidder 323 joined in competitive bidding on only three routes of interest. Once the price on individual routes was bid down, some price adjustment across selected routes was observed. The auction resulted in bidder 322 winning five routes with the remaining two routes allocated to bidder 321. Bidder 323 participated aggressively but won no routes. Table 7 reports that the winning prices varied from $640/day (for route 1) to $825/day for route 7 with prices reflecting characteristics of the route (e.g. length, collection stations and student numbers) and the valuations of each bus operator (e.g. proximity of routes to depots, operating efficiency).

Even though there are only three bidders participating in the auction, bidding behaviour during the auction display no evidence of collusion or the strategic bid reduction that might be expected in such thin markets. Experimental studies by Li and Plott (2005) and Brown, Plott and Sullivan (2009)) have shown that colluding bidders typically recognize the fragility of collusive arrangements and do not return to the market after having stopped bidding in a seemingly collusive agreement. This pattern of bidding behaviour was not observed in the auction of school routes with all bidders repeatedly returning to a market to compete for routes.

Figure 4: Time Series of All Bids on All Routes by all bidders

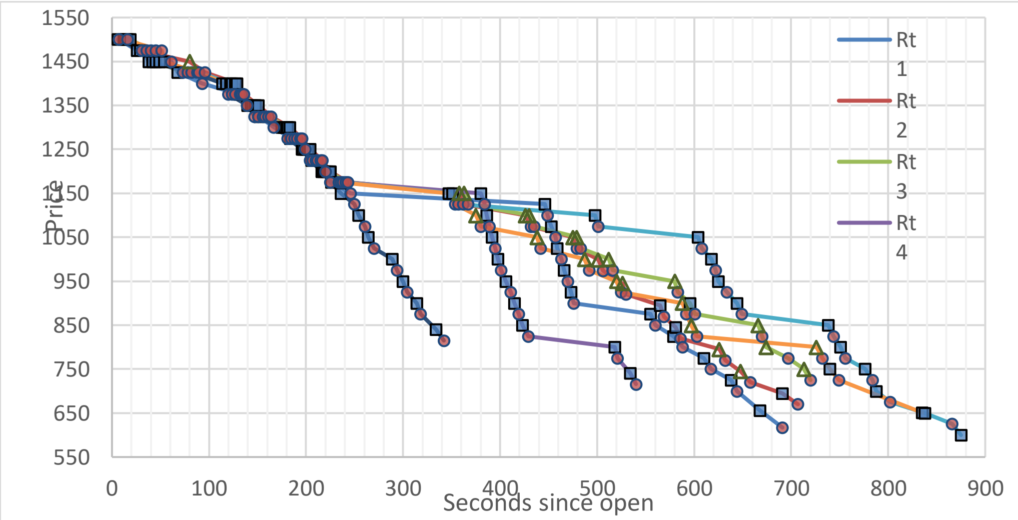
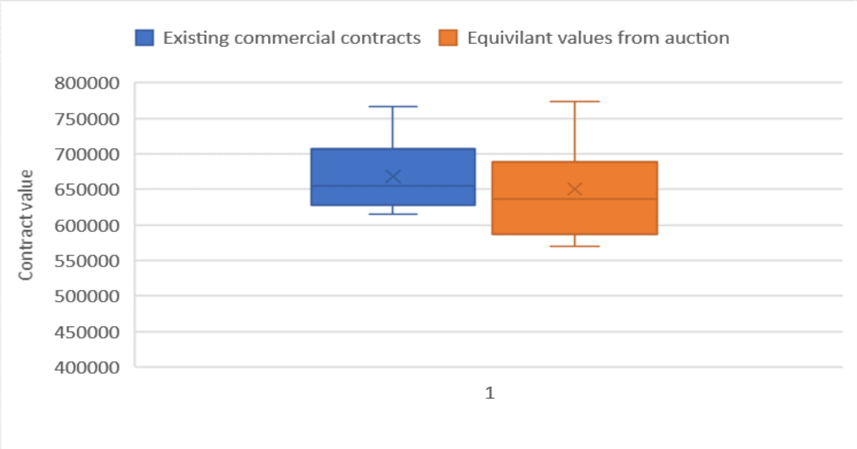


Table 7: Final auction prices

Route	Auction final price	winning Seller ID
1	640	322
2	675	322
3	735	322
4	725	322
5	610	321
6	660	321
7	825	322

Cost-effectiveness – Cost-effectiveness of the allocation process was evaluated by comparing prices achieved from the auction with prices for a sample of eleven existing commercial contracts for similar transport services sourced from the Government website. All contract prices were standardized to account for the duration of the different contracts. This comparison illustrated in Figure 5 shows that the average equivalent contract prices achieved through the auction was slightly lower (3% - not significant) compared with the commercial contracts reported. However, the auction mechanism results in a wider spread of contract prices as shown in Figure 5. This suggests that the auction mechanism allowed the market to set prices based on the characteristics of the routes and private information held by each of the bus operators.

Figure 5: Comparison of auction outcomes with existing commercial contracts



The box width is determined by the median price of the bottom half or 1st and 3rd quartiles.

Transaction costs administrative effort - A significant investment is typically needed to design, test and refine auctions applied to real-world allocation problems. This investment is recovered for allocation problems involving private information because auctions establish a more efficient bargaining process than bilateral negotiation. Auctions rely on competition between proponents to resolve information asymmetry whereas bilateral negotiation creates an advantage for the informed party (bus operators) at the expense of the uninformed party (the government agency in the transport case). This advantage can be illustrated from the log of bids reported in Figure 4 which shows that over 200 bids were lodged during the 15-minute duration of the auction (an average bid interval of around 4 seconds). Features of the bidding environment created in the auction such as: clearly defined items (spatially defined routes); strategy-proof bidding rules that mitigate hold-ups, posturing, cheap talk and other unwanted behaviours (activity clock); improve the confidence and participation by bidders. In contrast, the standard government procurement process involving an initial sealed bid followed by bilateral negotiation is time consuming and subject to strategic behaviour by bus operators.

6. Conclusions

If civilization is measured by how it treats its weakest members[5], then Australia can be proud to have introduced the NDIS. However, the vision of the NDIS for secure funding, choice and control (client focus), and the emergence of a non-government service providers, relies on an assumption that markets for disability services will "*grow like weeds*" (Roth 2002). Whilst markets for commodities and many services do emerge autonomously as efficient and trusted institutions, they do so only under specific conditions that do not generally apply to services needed to support disability.

[5] Attributed to the novelist Pearl Buck.

These services often need to be tailored to the highly specific needs of individuals and display a range of policy, transaction, strategic and timing complexities that prevent the emergence of competitive, efficient markets. Where they do emerge autonomously, markets for disability services are likely to be thin, involve high transaction costs and are unlikely to distribute value fairly to recipients of NDIS support.

In the absence of an implementable, decentralised mechanism to allocate and price transport services, we developed a hybrid mechanism. Intractable preference revelation and aggregation problems on the demand-side were mitigated (if not resolved) through a planning process in which mathematical techniques are used to identify the minimum number of routes needed to implement mandated service standards for each travelling student and network-wide service quality attributes and defined by the school community. On the supply-side an open, descending-price, continuous, simultaneous, multiple-item auction was designed to allocate and price these routes through competition between pre-qualified privately owned bus operators. This mechanism achieved three outcomes:

- *A significant improvement in service quality* – Key improvements include: a 68% reduction in aggregate travel time for all students; a reduction in the maximum travel time from 2 hours to around 1 hour; timely arrival of students at school; and a direct, less stressful travel service to school. These improvements substitute learning and family time for travel time.
- *Reduced transaction costs* – Although some initial investment was needed to design and create an auction, it dramatically reduced the time previously required to negotiate with bus operators from many months to 15 minutes and can be reused at low cost.
- *Efficient and cost-effective allocation of contracts* – Improved service quality and reduced transaction cost were achieved at costs that are comparable with previous contracts. While the overall efficiency of the mechanism is difficult to determine, the supply-side of the mechanism appears to allocate transport contracts efficiently and cost-effectively based on the absence of collusive bidding behaviour.

Besides the obvious advantages for students, the main finding of this paper is that many markets/mechanisms needed to implement the NDIS vision are missing, are unlikely to emerge autonomously, and where they do, they are unlikely to be efficient, fair or provide the anticipated improvements in service quality. It is feasible, however, to create mechanisms, even at the difficult end of the design spectrum (i.e., for services supplied from networks) that demonstratively improve the service quality and arguably improve economic efficiency.

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