Paratransit Fleet Mix Determination

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

At the start of 2011, we worked with Edmonton's Disabled Adult Transit Service (DATS), a dial-a-ride service that provides year-round, door-to-door transportation to over 900,000 individuals who have significant physical and/or cognitive disabilities restricting the use of conventional modes of transportation. The success and reputation of this program has generated greater awareness of DATS, and with an estimated 18% activity limitation of the Edmonton population[1], there is an expected long-term demand for this service. DATS uses a third party contractor to carry customers that they are unable to fit into their schedules. To better serve their clients, DATS needs to identify the different vehicle models and quantities of each model that would allow them to operate effectively and minimize unmet demand.

Our strategy was to evaluate demand and the performance of DATS' current vehicle mix, taking into consideration seat-type usage, transport times and destinations, and vehicle run assignments. In our analysis of the data provided, we examined peak months, weekdays, and hours to determine how DATS treated demand. There was a prioritization for contractors to transport ambulatory clients over DATS, resulting in contractors carrying an average of 57% of total daily customers on the sample days evaluated. We found that the constraint was not the capacity of DATS' vehicles as there were sufficient unoccupied spaces for all time windows. However, when evaluating each individual run, there exists better seat-type configurations that could recapture customers contracted out. We calculated the maximum passengers per seat-type in each vehicle run and looked at various scenarios during peak intervals where DATS had the potential to recover passengers and runs from its contractors. We evaluated and ranked different vehicle models for DATS. Based on our analysis and consideration of DATS' needs, we recommended the purchase of two types of vehicles: the 6 wheelchair-8 flip model and the 8 passenger-4 wheelchair-2 flip model. Compared to their existing fleet mix, a test fleet ratio of 75% of the first and 25% of the second model produced preliminary results indicating DATS' vehicles, using less runs, were able to transport more ambulatory clients and a higher number of total passengers overall.

[1] "Table 2: City of Edmonton Population with and without Activity Limitations, 2001". *Edmonton Social Plan: People with Disabilities*. City of Edmonton Community Services. 2006. pp. 3.

BACKGROUND

A section of Edmonton Transit System, Edmonton's Disabled Adult Transit Service (DATS) enables their customers to interact with the greater community. DATS provides door-to-door transportation to individuals 16 years or older with significant physical and cognitive disabilities that limit the use of conventional modes of transportation. DATS is a shared-ride public service offering both subscription and demand bookings on a first-come, first-served basis.

DATS' reputation of quality service has resulted in annual increases in total demand for trips. In 2009, DATS provided over 922,000 trips, serving approximately 10,000 registered clients. Currently, DATS has 98 vehicles and deploys approximately 95-105 runs per day, which are a collection of bookings assigned to one particular vehicle and driver. Should DATS have insufficient capacity to serve their demand, they have the option of contracting their clients to an independent third party.

While both DATS and the contractors may employ the same vehicle types or configurations, the cost of providing service are different, with contractors currently costing less than DATS per client transported. If both DATS and the contracting service are unable to fit customers due to time or capacity constraints, then the client will be un-accommodated and must find alternative means for transportation. Other sources of unmet demand occur when clients refuse trips if DATS is unable to negotiate acceptable pick-up times that fit their needs.

Of the clients that DATS transports, the main client-type categorizations are: ambulatory (AM), over-sized ambulatory (OA), wheelchair (WC), electric wheelchair (EW), over-sized wheelchair (OW), scooter (SC), over-sized scooter (OS), and walker users (XW). From this, there are two space-types that can be occupied on DATS vehicles: ambulatory and wheelchair. An ambulatory client will require one AM seat. Wheelchairs and electric wheelchairs each take up one WC space. Clients using either walkers or scooters will take up one AM and one WC space. However, persons using scooters have the option of remaining in their scooter during transport as all mobility devices are secured to the vehicle. Additionally, any over-sized client uses twice as many of their respective space-types, with the exception of over-sized scooters which uses two WC spaces and up to one AM seat.

All of DATS' vehicles have configurations that support the concurrent transport of multiple AM clients and persons using mobility devices. For instance, DATS' flip vans can support a maximum of six AM seats and four WC spaces at one time. While the contractor has 92 vehicles that are dedicated to DATS service, these vehicles can serve a maximum of one WC client at a time, with the remaining seats available for AM clients. Most of the existing contractor vehicles are unable to support over-sized wheelchair or scooter users. Unlike DATS' vehicles, where walkers must be secured in a distinct WC space, contractors are able to compress and store walkers in the trunk component. Additionally, the contractor service offers passenger vans which have larger AM capacities than existing DATS vehicles. Thus, embedded in the scheduling system, there is a priority preference for the contractors to take on AM clients.

In terms of loading times, there is a trade-off when attempting to increase the number of clients on a trip. AM clients take two minutes to be seated on the vehicle, while clients using mobility devices take approximately five minutes to load. Each additional AM and WC user inserted into the same trip will require half of its respective loading time. The quality standards that DATS strives for and would like to maintain are: an upper bound trip time of 90 minutes and 30 minute pick up time windows for clients.

PROBLEM

DATS wants to ensure that the organization evolves as demand for services changes. In part, this requires more effective assignments of clients to the vehicles that can accommodate them. DATS has raised concerns as to possible growth in their client base, specifically potential increases in AM demand. In order to reduce unmet demand and to serve more clients in general, DATS is seeking to become more efficient by reconstructing their fleet mix. They intend to replace vehicles at a rate of roughly 10-15 vehicles per year over five years to better match their current and future demand. DATS has already replaced some of its vehicles.

DATS is seeking to identify the optimal vehicle models and quantities of each model to operate effectively, without adding substantial labour or vehicle resources. DATS' priority is to continue to directly serve WC demand while also increasing the amount of AM clients transported either from recapturing clients from contractors or taking on unmet demand. Other considerations

include minimizing the impact of increasing clients' transportation time when attempting to increase the number of clients on runs. Additionally, DATS would like to minimize the use of its contracting services.

Minor constraints to addressing this problem include lack of access to the scheduling system, inability to change workers schedules to better match demand, and inability to increase resources, having to either maintain or decrease the total number of vehicles in the fleet. DATS also noted that cost minimization should not be the primary priority when determining potential improvements to vehicle fleet mix.

METHODOLOGY

Identification of Performance Metrics

Initially, we sought to increase "revenue-hours", which is a product of trip time duration and the client's billing rate. If we were to implement this metric, the prioritization settings in DATS scheduling model would not reflect those that DATS is actually trying to accomplish. On the surface, revenue-hours appear to be appropriate: an increase in revenue hours can relate to more customers being served by DATS. However, there are additional factors that can contribute to increases in revenue-hours. For example, if DATS drivers were inefficient in their routes, passengers would have longer trips, thereby increasing revenue hours, but decreasing customer satisfaction.

Assessing vehicle utilization was also suggested. DATS defines a vehicle being utilized if there are one or more clients occupying the vehicle. Vehicle utilization may be beneficial in representing whether the scheduling system is minimizing drivers' idle time. It can indirectly refer to how effective drivers are in decreasing dead-heading as they spend more time on value-added transportation (transporting at least one client on the vehicle as opposed to driving an empty vehicle to the next pick-up location). However, this does not provide any information on vehicle model needs.

Rather than using vehicle utilization, seat-type utilization was considered since it attempts to determine discrepancies between available and demanded seat-type capacities and more directly addresses factors to increase the number of people served. This involved aggregating

demand across vehicles for respective seat-types, calculating seat-type availability currently offered by the existing fleet, and matching the demand with capacity to identify any distress in the data. This approach was not appropriate given that while there may be sufficient capacity to meet daily demand, there may be congestion for particular seat-types during peak periods. Therefore, it would be more beneficial to identify seat-type utilization for half-hour or hourly intervals to determine how seat-type demand fluctuates throughout the day. However, no baseline comparison of a desired utilization rate was identified and utilization could be artificially increased by using smaller vehicles that do not have the capacity to serve large groups of customers. In the end, this was considered an ineffective performance measure to determine the efficacy of different vehicle models.

Since per client contracting costs is currently less than DATS' per client cost, the focus should be to increase the customer assignments to DATS vehicles in order to spread the fixed operating costs among more users. An alternative performance measure was identified, focusing on increasing the number of clients transported via DATS vehicles. This was accomplished by comparing the number of clients transported using existing vehicles against the number of clients transported using the proposed vehicle models and quantities.

Data Cleansing

DATS provided booking dates, origin-destination pairs, negotiated pick-up times, trip distances, travel durations, client and associated seat-types, and run assignments for all client trips performed during 2010. Trip end-times were not recorded in DATS modelling system but could be calculated by adding trip durations to the negotiated pick-up times. For evaluative purposes, end-times were critical in determining space-type occupancy and capacity needs.

We were informed that some of the duration entries would be inaccurate due to occasional system glitches. This resulted in recorded travel times of zero or durations that were unreasonable when compared to the distance travelled data. For instance, some entries would require vehicles to be travelling more than 300 km/h, on average, to complete the trip.

It was determined that all entries with travel times of zero or average speeds for trips exceeding 100 km/h would need to be adjusted. To develop proxy durations, average speed factors for

multiple distance ranges were evaluated. That is, for every one kilometer increment, the average time required to travel a specified distance range was calculated to determine the average speed factor. These average speed factors were then multiplied by the distances travelled to determine transport time for entries with missing or inaccurate duration data. The use of multiple average speed factors for different distance ranges was preferred. It produced travel time estimates that more closely matched the durations of actual run data compared to using the overall average distance travelled per hour (speeds exceeding 100 km/h were removed when calculating average distance). The method of using overall average distance travelled per hour had a tendency to significantly under-estimate durations for short travel distances and over-estimate durations for longer distances. Data entry records that had both travel distances and durations of zero were discarded. This accounted for approximately one percent of the data.

A secondary issue involved having to manually add in additional AM clients into trip counts when escorts or mandatory attendants accompanied the client. On average, this meant an increase in of 289 AM clients per day, with a range of an additional 73 to 386 AM clients per day. Alternatively, this meant an average of nine percent increase in total clients per day, with a range of three to an eleven percent increase.

Data Pattern Identification

Since we had no access to the scheduling model used to assign clients to vehicles, our initial approach was to simulate vehicle runs in Microsoft Excel. This effort quickly failed as the capabilities of Excel did not match DATS' Trapeze SQL software. We turned our focus on assessing trends in the data. From the individual records provided, we evaluated monthly, weekday, and daily demand and the associated space-type usage. This information would then be used to decide which days represented the current upper bounds for demand. These days would be further examined to determine space-type demand for 15 minute intervals since approximately 80% of DATS trips have short travel durations.

While this type of information demonstrated aggregate distribution of client types, it did not necessarily reflect space-type demand throughout the day. More pertinent was identifying how many people were on a vehicle at one time and what space-types they used. This was

accomplished by sorting clients by run assignments. Two sample days for each of three sample months from the past year were evaluated. Once run assignment groups were determined, using negotiated pick-up times and the calculated end-times, we were able to capture the number of clients on the vehicle throughout the day and the seat-types they occupied. For every run, we assessed how the number of seats and space-types usage changed when clients boarded and exited the vehicle. From this information, we were able to determine the frequency distributions of the maximum number of AM, WC, and total seat-types demanded for both DATS and contractor runs throughout the day. This information was then used to determine the vehicle models that could support the demand.

ANALYSIS

Aggregate Space-type Demand

March had the largest total demand, while February and November had higher percentages of daily demand exceeding 3300 clients. Weekday evaluations revealed that Wednesdays had the largest demand as well as the highest demand in each space-type category. Peak hours were identified to occur longer during the morning (7:30-10:00 am) while the late afternoon (2:30-4:00 pm) had a shorter duration but higher demand over the half hour intervals, indicating potential stress periods. Client-type distributions were consistent between days and are summarized in the following table:

Figure 1: Client-type distributions.

Client-type	AM	OA	WC	EW	OW	SC	OS	XW
Percent	61.25%	0.47%	17.21%	5.93%	0.75%	2.08%	0.04%	12.27%

While the majority of users were AM, DATS had expressed their desire to keep WC clients a priority in their scheduling. From the six sample days evaluated, on average, the contractors would be responsible for transporting approximately 57% of total clients for the day. Of this 57% of total customers transported, 80% were AM, 16% XW, 2% WC, 1% EW, and 1% SC users. Of the 43% of total customers DATS served, on average, 34% were AM, 1% OA, 7% XW, 36% WC, 16% EW, 2% OW, and 4% SC users.

In having a prioritization for WC clients, a large amount of capacity was going unused in the DATS fleet. Initially, we supposed that time-windows was the constraint preventing DATS from claiming additional AM clients. In some situations this was true, but by looking at entries with the same origin-destination pairs and negotiated pick up times, and then assessing which vehicles were used to transport customers, we found some clients were unnecessarily being outsourced to contractors.

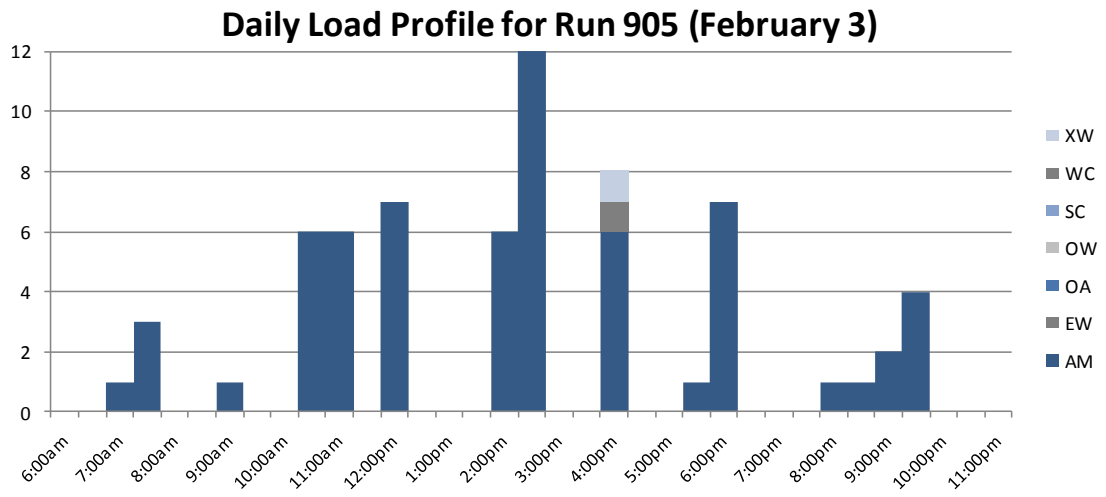
With DATS' priority to serve WC clients in their own vehicles, there is unintended priority of placing AM to contractors. This initially seems logical, but it does not work to support the overall goals of DATS to serve more clients. The intended purpose of including contractor vehicles in the scheduling model is to accommodate extra customers who would not be able to be served by DATS, not for contractors to be the primary service provider of AM clients. The current prioritization system in the scheduling model does not capture this and since the majority of DATS clients are AM, more clients will be served by contractors. Approximately 75% of total AM clients per day are contracted out. This results in an inadvertent reliance on contractors over DATS and represents a significant opportunity for DATS to regain customers through better space utilization in their own vehicles.

Furthermore, this prioritization issue in the scheduling model led to significant problems when group bookings had both AM and WC clients. All individuals in a group have the same origin-destination pairs and time windows, so theoretically the minimum number of vehicles should be deployed to accommodate these customers. That is, these vehicles should be filled to its greatest extent. However, we found examples in the data (in the table below) where the scheduling model would actually split these groups into different trips, served by both DATS and contractors, even though DATS fleet vehicles had sufficient capacity to accommodate all members of the group. This inefficiency would suggest that vehicle capacity and space type is not necessarily a limiting constraint; however, it would be beneficial for DATS to include some vehicles with increased AM capacity should AM demand increase in the future. This offers DATS greater flexibility and would also enable DATS to reclaim a portion of their AM clients more easily, particularly large group AM trips that are currently served by contractors or multiple DATS vehicles.

Figure 2: Split Group Bookings (February 3rd, 2010)

PICKUP ADDRESS	DROPOFF ADDRESS	SPACE TYPE	+1 AM	PASSENGER TYPE	RUN	Pick Up Time	Drop Off Time
1100 YOUVILLE DRIVE WEST NW	6832 39 AVENUE NW	WC	AM	CLI1,MA1	111	2:45 PM	2:48 PM
1100 YOUVILLE DRIVE WEST NW	6832 39 AVENUE NW	WC	AM	CLI1,MA1	111	2:45 PM	2:49 PM
1100 YOUVILLE DRIVE WEST NW	6832 39 AVENUE NW	WC	AM	CLI1,MA1	EXTRA1	2:45 PM	2:49 PM
13160 127 STREET NW	11107 132 STREET NW	WC		CLI1	172	4:15 PM	4:25 PM
13160 127 STREET NW	11115 132 STREET NW	AM		CLI1	905	4:15 PM	4:21 PM
13160 127 STREET NW	11115 132 STREET NW	AM		CLI1	905	4:15 PM	4:21 PM
13160 127 STREET NW	11127 132 STREET NW	AM		CLI1	905	4:15 PM	4:21 PM
13160 127 STREET NW	11127 132 STREET NW	AM		CLI1	905	4:15 PM	4:23 PM
2905 113 AVENUE NW	13160 127 STREET NW	AM	AM	CLI1,ESC1	901	2:15 PM	2:30 PM
2905 113 AVENUE NW	13160 127 STREET NW	AM		CLI1	901	2:15 PM	2:36 PM
2905 113 AVENUE NW,	13160 127 STREET NW	WC	AM	CLI1,ESC1	123-B	2:15 PM	2:36 PM

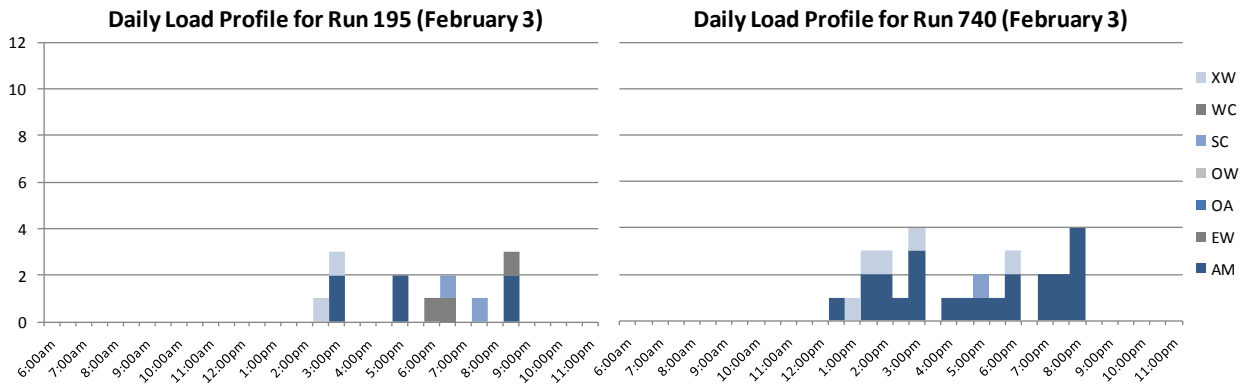
Figure 3: Daily Load Profile for a Contractor Vehicle (Run 905 on February 3rd, 2010)



Another possibility to reclaiming clients is to swap DATS scheduled runs that have low utilization with contractor runs with high utilization. In the data, we noticed that for a sample day, one contracted vehicle was accommodating twice as many customers as one of the DATS fleet vehicles with a similar capacity. The only issue that we found with this recommendation is WC customers would sometimes be swapped over to the contractor fleet, which is the client type DATS emphasized they were interested in keeping. If possible, a post-swap analysis could be

conducted to check for this occurring, which would lead to the WC clients being reassigned to other routes if they were unintentionally swapped.

Figure 4: Daily Load Profile Comparison (DATS Run 195 and Contractor Run 740 on February 3rd, 2010)



Vehicle Space-type Usage

Although aggregate space-type demand provides us general information regarding expected total client-type demands throughout the day, this is not sufficient to determine vehicle model needs as we cannot assume that these client-type ratios present itself equally in each vehicle run assignment. A typical dial-a-ride problem requires consideration for scheduling when determining fleet mix. As the scheduling system cannot be adjusted, an unconventional approach was taken to determine vehicle sizes and fleet mix.

From the sample days evaluated, the highest number of AM, WC, and total passengers were calculated for each run to find the upper bounds of space-types and total capacity demands. This is summarized in Figure 5.

Figure 5: Average Frequency of Maximum Passengers

Average Frequency of Max Passengers per Seat Type (Random Samples)							
DATS' Frequency				Contractors' Frequency			
# of Seats	MaxAM	MaxWC	Max Total	# of Seats	MaxAM	MaxWC	Max Total
0	2	0	0	0	0	3	0
1	13	7	1	1	1	30	1
2	34	35	7	2	3	29	1
3	22	36	14	3	14	6	5
4	13	13	27	4	20	1	15
5	6	7	17	5	14	0	17
6	3	0	12	6	7	0	14
7	3	0	8	7	2	0	6
8	1	0	5	8	2	0	5
9	0	0	5	9	1	0	2
10	0	0	1	10	2	0	2
11	0	0	0	11	0	0	1
12	0	0	0	12	2	0	1
13	0	0	0	13	1	0	1
14	0	0	0	14	1	0	1
15	0	0	0	15	0	0	0
16	0	0	0	16	0	0	0
Total	97	97	97	Total	70	70	70

Frequency Legend
40
30
20
10
0

** Samples from 2010: Feb. 3, Feb. 9, Jun. 9, Jun. 17, Nov. 10, and Nov. 26*

While the maximum number of AM clients on a DATS vehicle is eight, which is also the maximum capacity of AM seats on a flip van, there are situations where higher AM demands cannot be met by DATS' existing fleet. As demonstrated on the contractor's side, the maximum AM passengers on at one time is higher than DATS because they have the higher AM capacities. If DATS intends to recapture clients from contractors, an efficient means would be to have additional AM capacity to take on large AM group trips. If DATS had vehicles with larger capacities, especially of the AM seat type, they could have saved in resources (used less vehicles and therefore. fewer drivers) or saved in costs (not contracting the clients out). It is important to note that DATS also needs to maintain their current WC capacity in order to continue to take this demand in their vehicles.

Vehicle Size Selection

On average, the seat utilization in each vehicle is approximately 20%. Seat utilization refers to percentage of AM and WC seats currently being occupied. Since vehicles are typically under-capacitated, a switch to larger vehicles was considered unnecessary. Smaller sized vehicles would also not be appropriate as historical data shows instances where demand exceeds current vehicle capacity. This is mostly applicable to AM demand involving larger group trips, requiring DATS to outsource to contractors or use multiple vehicles. Smaller vehicles also do not allow for growth in the long run. The current vehicle size was therefore the basis for subsequent fleet mix analysis.

Background on Vehicle Models

Vehicle models can consist of permanent AM spaces, designated WC spaces, as well as versatile flip AM seats which are attached to the wall of the vehicle. These flip seats, when unused, can be flipped up to allow for WC spaces. AM seats can be single seats or double seats. Double seats are attached so there is no option of flipping only one of the two seats up. Although the option of having flip seats results in higher costs, the client does not want costs to be considered when determining vehicle models. In order for a space to be suitable for WC use, there has to be sufficient room to fit a wheelchair. WC spaces require a tie down system and a storage system which is available when flip AM seats are unused. There is also an option of having spaces which are reserved for WC only (designated WC spaces). Blueprints were provided by the vehicle supplier of DATS.

Individual vehicle configurations can have a mix of flip and permanent AM seats as well as designated WC spaces. Configurations are the different combinations of AM and WC spaces that can occur within a vehicle model. Also, one AM seat does not necessarily convert to one WC seat. In some cases, one AM seat is equal to one WC space, but in other vehicles, two AM seats equal one WC space. Thus, for vehicles that can be reconfigured, there can be different trade-offs between AM seats and WC spaces depending on the vehicle model.

Vehicle Model Selection

Using historical demand data and qualitative criteria, the following steps were developed to determine which vehicle models would be most appropriate to meet DATS' demand.

Step 1: List all possible configurations of AM and WC capacities for all vehicle models.

The vehicle blueprints were not useful when comparing different models and their configurations. Since some vehicles had flip seats that could alter seat-type and total capacities, a physical count of the number of seats available for each possible configuration was determined. As an example, Figure 6 summarizes all possible configurations and the associated space-type capacities for Vehicle Model 2:

Figure 6: Configurations for Vehicle Model 2

Vehicle Model 2		
1 Pass+5WC+6DBl Flip +1 Sng Flip		
AM	WC	Sum
0	5	5
1	5	6
2	4	6
3	4	7
4	4	8
5	4	9
6	3	9
7	3	10
8	2	10
9	2	11
10	2	12
11	2	13
12	1	13
13	1	14
13	0	13

Step 2: Remove vehicle models that have limited capacities for either seat type.

Because DATS has two space demand types, both of which need to be met, sufficient seats of each type are required. Vehicle models with limited capacities for either seat type are therefore removed from future considerations. This is determined by looking at Figure 5 which shows the average frequency of maximum passengers for AM seat types. Summing the maximum frequencies for DATS and contractors, we can see that for AM clients the range is from 0-14,

with the most common occurrences between of 1-5 passengers. Similarly, the average frequency of maximum passengers for WC seat type ranges from 0-5 clients with the most common occurrences of 1-4 WC passengers. There is a need to consider the sum of the frequency for DATS and contractors because this is more representative of actual demand. Contractors take on the excess demand that DATS vehicles are unable to fulfill either because of scheduling issues or vehicle capacity issues. Picking vehicle models that better match demand distribution can allow DATS to recapture some of the demand from the contractor. At minimum, potential vehicle models must have a capacity of 5 AM seats and 4 WC spaces since DATS intends to maintain its current WC capabilities while take on additional AM clients. These numbers represent the upper bound of the *common occurrences* for both seat-types and thus, if DATS wants to take on additional clients, this minimum provides a benchmark.

Figure 7: Comparison of Maximum Seats by Space-type for Vehicle Models

Maximum Seats		
Vehicle Model	**AM**	**WC**
1	15	1
2	13	5
3	10	3
4	6	4
5	2	5
6	5	4
7	12	3
8	12	4
9	4	5
10	13	4
11	6	3
12	6	4
13	16	6
14	12	2
15	8	3
16	12	4
17	9	1
18	10	2

Removed	

From Step 2, Vehicle Models 1, 3, 5, 7, 9, 11, 14, 15, 17 and 18 were removed. Only eight models remain for subsequent analysis.

Step 3: Remove vehicle models which have AM capacities that are dominated.

A similar evaluation would not be effective for considering maximum WC capacity as the remaining model have similar WC capacities.

The remaining models have AM capacities which vary from a maximum of five AM seats to a maximum of 16 AM seats. To narrow down the remaining choices, vehicle models which have their maximum AM capacity dominated should be removed since there are vehicles which can outperform them. Figure 8 shows how vehicle models listed along in the top row dominate vehicles listed in the column. A score of 1 is awarded to a vehicle model if its maximum AM capacity is greater than the compared vehicle.

Figure 8: Matrix of Dominating Vehicle Based on AM Capacity

Vehicles along the top dominate vehicles listed on the left

Max AM Capacity	Capacity	13	6	5	12	13	6	16	12
Capacity	**Vehicle Model**	**2**	**4**	**6**	**8**	**10**	**12**	**13**	**16**
13	**2**	-	0	0	0	0	0	1	0
6	**4**	1	-	0	1	1	0	1	1
5	**6**	1	1	-	1	1	1	1	1
12	**8**	1	0	0	-	1	0	1	0
13	**10**	0	0	0	0	-	0	1	0
6	**12**	1	0	0	1	1	-	1	1
16	**13**	0	0	0	0	0	0	-	0
12	**16**	1	0	0	0	1	0	1	-
	Total Score	5	1	0	3	5	1	7	3

Dominated Vehicles that were removed

From Step 3, Vehicle Models 4, 6, and 12 are removed leaving Models 2, 8, 10, 13, and 16.

Figure 9: Maximum AM and WC Seats Provided by Vehicle Models

Maximum Seats		
Vehicle Model	**AM**	**WC**
2	13	5
8	12	4
10	13	4
13	16	6
16	12	4

Versatility is advantageous if DATS wants to take on as many clients as possible. From the five remaining models, Vehicle Model 13, which has no permanent AM seats, dominates in terms of versatility, which refers to the different configurations that are possible. It also has the highest AM capacity of 16, the highest WC capacity of six, and the highest total capacity for any combination. Since changes are not possible for the current scheduling system, higher flexibility is beneficial. Higher capacity can allow for growth in the long run.

There are some disadvantages associated with this vehicle model in that DATS drivers will have to take time to reconfigure vehicles as demand changes throughout the day. This adds to the loading time and adds to the workload of drivers. Drivers have to be more aware of the order in which clients are picked up and loaded as the vehicle model is completely flexible. Higher capacity vehicles will result in higher loading times if all seats are used. In the vehicles selected, the primary goal was to increase AM capacity and AM clients served. The increase in loading time will not have a significant impact since AM clients generally have low loading times.

Based on data analysis, it is infrequent for AM demand at one time to exceed 12 passengers. As such, it would be appropriate to choose another model to supplement Vehicle Model 13.

Step 4: Consider qualitative criteria.

At this point, the four remaining vehicle models are quite similar in terms of configuration. Some vehicle models may have more AM seats compared to other models, but the trade-off may be one less WC space-type or vice versa. As a highly versatile vehicle model has already been chosen, a less versatile vehicle is appropriate. A less versatile vehicle model is less costly, saves time as there is less need to reconfigure vehicles and therefore, is less work for drivers. Vehicle Model 2 should be eliminated because Vehicle Model 13 encompasses all of Model 2's configurations and has higher overall AM and WC capacity.

Figure 10: Comparison of Configuration of Vehicle Models (Vehicle Model 2 and 13)

Vehicle Model 2		
1 Pass+5WC+6DBl Flip +1 Sng Flip		
AM	WC	Sum
0	5	5
1	5	6
2	4	6
3	4	7
4	4	8
5	4	9
6	3	9
7	3	10
8	2	10
9	2	11
10	2	12
11	2	13
12	1	13
13	1	14
13	0	13

Vehicle Model 13		
6WC+8 Flip		
AM	WC	Sum
0	6	6
1	5	6
2	5	7
3	5	8
4	5	9
5	4	9
6	4	10
7	4	11
8	4	12
9	3	12
10	3	13
11	2	13
12	2	14
13	1	14
14	1	15
15	1	16
16	1	17
16	0	16

Of the remaining vehicle models, Vehicle Model 16 would best complement Vehicle Model 13. It has the highest number of fixed AM seat types, consistent with the intention to recover single AM demand and AM group trips from contractors. Of the remaining vehicle models, it has the least number of flip seats meaning less time is required to reconfigure vehicles. Additionally, it dominates Vehicle Models 8 and 10 in certain scenarios (as highlighted below). Although Vehicle Model 10 has a maximum AM capacity of 13 seats which is higher than Vehicle Model 16's 12 seats, the benefit from one additional AM seat is minimal.

Figure 11: Comparison of Configuration of Vehicle Models (Vehicle Model 8, 10, and 16)

Vehicle Model 8		
4 Pass+4WC+4 Flip		
AM	WC	Sum
0	4	4
1	4	5
2	4	6
3	4	7
4	4	8
5	3	8
6	3	9
7	3	10
8	3	11
9	2	11
10	2	12
11	2	13
12	2	14
12	1	13
12	0	12

Vehicle Model 10		
5 Pass+4WC+4 Flip		
AM	WC	Sum
0	4	4
1	4	5
2	4	6
3	4	7
4	4	8
5	4	9
6	3	9
7	3	10
8	2	10
9	2	11
10	2	12
11	2	13
12	1	13
13	1	14
13	0	13

Vehicle Model 16		
8 Pass+4 WC+2 Flip		
AM	WC	Sum
0	4	4
1	4	5
2	4	6
3	4	7
4	4	8
5	4	9
6	4	10
7	4	11
8	4	12
9	3	12
10	3	13
11	2	13
12	2	14
12	1	13
12	0	12

Figure 12: Configurations of Selected Vehicle Models (Vehicle Model 13 and 16)

Configuration 13		
6WC + 8 Flip		
AM	WC	Sum
0	6	6
1	5	6
2	5	7
3	5	8
4	5	9
5	4	9
6	4	10
7	4	11
8	4	12
9	3	12
10	3	13
11	2	13
12	2	14
13	1	14
14	1	15
15	1	16
16	1	17
16	0	16

Configuration 16		
8 Pass+ 4 WC + 2 Flip		
AM	WC	Sum
0	4	4
1	4	5
2	4	6
3	4	7
4	4	8
5	4	9
6	4	10
7	4	11
8	4	12
9	3	12
10	3	13
11	2	13
12	2	14
12	1	13
12	0	12

RESULTS & RECOMMENDATIONS

Test Results

From our analysis, two vehicle types were chosen: a 6 WC + 8 flip vehicle (Vehicle Model 13) and an 8 Pass + 4 WC + 2 flip vehicle (Vehicle Model 16). These vehicles, at a respective ratio of 75% and 25% of total fleet size, were tested.

Simulated runs were conducted. One test report provided counts of the client-types DATS transported using the test fleet mix compared to the current fleet for March 17th, 2011. The second test report included a comparison between current and test fleet mix for March 17th, 2011 with details of all runs for DATS and contractors, shift time for the run, total passengers carried per run, and total passengers for the day. Overall, the two reports showed higher AM clients and total number of passengers served by DATS; however, this does not necessarily suggest the test mix is the best.

Test Report 1

The vehicle models selected were intended to increase the number of AM passengers, while maintaining the number of WC clients, DATS directly served. Live daily data and a test scenario including 11 of their new vehicles, a 75% ratio of the remaining fleet size to 6WC+8 flip, and 25% of the remaining fleet size to 8Pass+4WC+2 flip was compared.

The results show an increase in AM and WC passengers transported, meeting our expectations. Compared to the existing fleet, 166 additional AM clients, 43 escorts, and13 mandatory attendants were transported with the new fleet mix. In terms of wheelchair users, there was a net increase of 122 WC clients served. In total, over 323 passengers were reclaimed, which is approximately a 10% increase when compared to the total actual daily demand transported. There was also an increase in number of clients served in every category, except OW and SC. This is summarized in the following figure:

Figure 13: Comparison of Client-types Transported Using the New and Current Fleet Mix

	CLI								CU6		ESC		MA		Total
	AM	EW	OA	OW	SC	WC	XW	Total	AM	Total	AM	Total	AM	Total	
New	580	183	6	15	34	603	104	1525	2	2	155	155	105	105	1787
Current	414	124	5	20	63	535	99	1260	0	0	112	112	92	92	1464
Difference	166	59	1	-5	-29	68	5	265	2	2	43	43	13	13	323

Test Report 2

Test Report 2 provided data about runs, run time, distance travelled, and passenger counts for both contractors and DATS. The results showed that DATS was able to regain 199 more clients with the new fleet mix, using seven less vehicle runs, compared to its current fleet. Assuming that run schedules are unchanged, there is a possibility of serving more clients if the seven unused runs were deployed to capture unmet demand or recapture more clients from the contractor. Although these results are favorable to our vehicle model selection and vehicle ratio, it does not allow us to see if the vehicles were well utilized, and they do not allow us to examine whether the issue of splitting group booking or same origin-destination pairs with similar time windows still occurs.

The current test results have proved very positive for our vehicle selections. The incorporation of these new vehicles has already shown more passengers transported by DATS vehicles while utilizing fewer resources (less runs). We strongly believe that the selected vehicle models will allow DATS to serve more of the Edmonton community.

We would recommend additional testing to increase confidence in our selection of vehicle proportions.

Sensitivity Analysis

To gain better insight as to whether this vehicle model and mix is suitable, a sensitivity analysis is recommended to determine whether ratio of 75-25 provides the best result. This can be accomplished by testing various vehicle ratios. Keeping in line with our previous notion that our primary vehicle is the most versatile and has the highest capacity, we should have more of these vehicles. We have developed the following steps to determine what would be the optimal fleet mix:

Perform simulations using March 17th, 2011 data:

a) Test a fleet ratio of 100% 6WC + 8 flip and 0% of 8 Pass + 4WC + 2 flip

If this test results in a higher number of passengers served on DATS vehicles compared to the results from the 75-25 test for March 17th, 2011, this is a better solution.

Aside from the previous qualitative considerations, we would suggest that DATS commit to purchasing only the 6WC-8 flip vehicle model.

If the test results in a lower number of passengers served on DATS vehicles compared to the results from the 75-25 test, perform the following test:

b) Test a fleet ratio of 50% 6WC + 8 flip and 50% of 8 Pass + 4WC + 2 flip

If this test results in higher number of clients served on DATS vehicles compared to the results from the 75-25 test for March 17th, 2011, then this purchasing strategy would be recommended.

We would advise against purchasing more of the 8 Pass + 4WC + 2 flip vehicle model beyond 50% as we believe that in the long run, this would be less accommodating to increases in demand, changes in demand types, and changes in scheduling.

If both tests yield results less than the 75-25 test, then we would conclude that the initial test is the optimal purchasing strategy for DATS.

Vehicle Replacement Phasing

Based on the sensitivity analysis results, attempt to replace existing vehicles with 6WC + 8 flip first as this allows for increased ability to handle future changes in demand. Additionally, since this model has the highest AM, WC, and total capacities, it will allow DATS to impact the community more by being able to recapture and take on take large AM groups immediately. There is no preference for which of the existing vehicles models to phase out since both models have similar capacities.

Using Resources Efficiently

- Use conventional buses for trips with the same origin-destination pairs and time windows that exceed 16 AM passengers; and
- If costs are determined by a per person basis, contract out long duration trips that carry one or two passengers as to not tie up DATS resources.

Vehicle Use

In order to save drivers effort and time, a basic configuration should be determined for the 6WC + 8 flip vehicles at the beginning of a shift. For instance, the default space-type seating arrangement can involve 8 AM seats in the front and 4 WC spaces in the back to emulate the ease of reconfiguration seen in the 8 Pass + 4WC + 2 flip vehicle. Drivers would change the vehicle configuration as demand necessitates it.

CONCLUSION

DATS' fleet sizing problem, like any dial-a-ride problem, presents a difficulty in meeting a given demand with limited resources and restricting time-constraints. Unique to DATS' problem is a seat-type factor which opens a new dimension to a traditional logistical problem. In order for DATS to improve their capabilities for future growth while maintaining the current demand, we recommended aspiring to increased vehicle versatility. The increased flexibility offered by the proposed 6 wheelchair-8 flip vehicle will allow DATS to be more adaptable if demand changes for different seat-types. Both this vehicle and the 8-passenger-4-wheelchair-2-flip vehicle recommended will facilitate the reclamation of a substantial amount of AM clients currently outsourced to a third party contractor. We are confident that the selected vehicle models will positively impact DATS day-to-day operations, as preliminary results show an increase in total passengers transported. Further analysis is required to determine the optimal amount of each vehicle to add to the existing fleet, but intuitively, if cost is not a consideration, the more flexible vehicle will alleviate the most congestion in the DATS model. Ultimately, it is the replacement of less flexible vehicles with more flexible models that will allow DATS to become more efficient with their fleet, leading to a reduction in costs, and inevitably enabling them to have a greater impact on the Edmonton community.

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