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SAS® GLOBAL FORUM 2020

MARCH 29 – APRIL 1
WASHINGTON, DC

USERS PROGRAM

Monitor Assignment for Students with Disabilities with SAS®: Boston Public Schools

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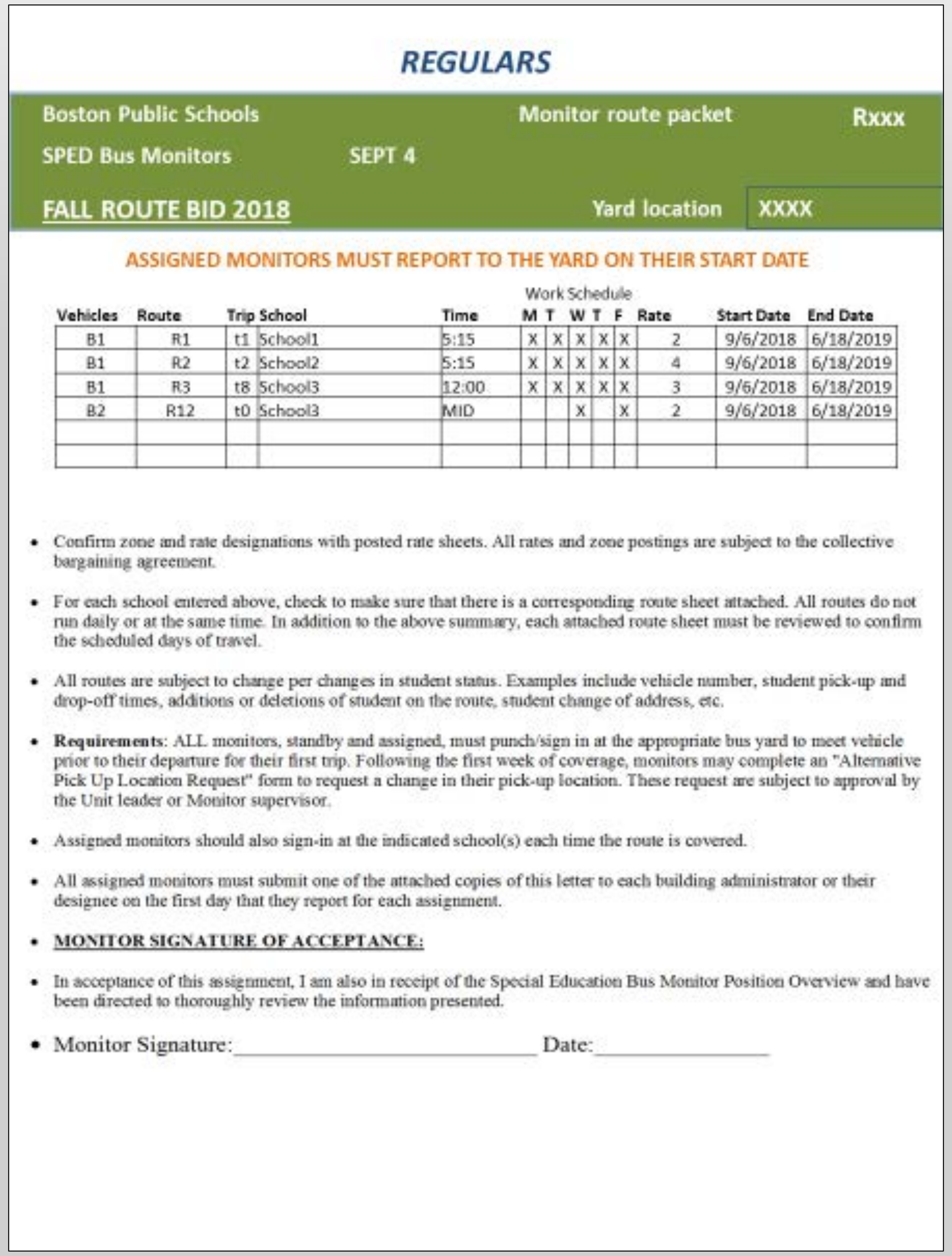
Please use the headings above to navigate through the poster

- A subset of students with disabilities in the Boston Public Schools (BPS) system require a designated monitor (supervisor) to ride the school bus with them.
- Monitors can ride several bus routes in a given day as long as predetermined rules are satisfied.
- BPS constructs packages of routes for monitors to make their bids at the beginning of the academic year, with a goal of maximizing the number of routes per package while ensuring that all students receive the services they need.
- For a given academic year, BPS manages approximately 3,500 routes scheduled for roughly 625 buses and about 1,350 students requiring different types of monitors.
- As roughly 40% of bus trips have monitors, a particular bus may have some trips with monitors and some without any monitors.
- Each package typically can have 2-7 bus routes or runs in it, comprising a mix of AM and PM runs. Only monitors who have 6 or more runs receive health insurance. Hence, it is beneficial to create these monitor packages in such a manner that maximizes the number of students supervised by one monitor as long as all student needs are met.



REGULARS

Boston Public Schools — Monitor route packet — Rxxx

SPED Bus Monitors — SEPT 4

FALL ROUTE BID 2018 — Yard location: XXXX

ASSIGNED MONITORS MUST REPORT TO THE YARD ON THEIR START DATE

Vehicles	Route	Trip	School	Time	M	T	W	T	F	Rate	Start Date	End Date
B1	R1	t1	School1	5:15	X	X	X	X	X	2	9/6/2018	6/18/2019
B1	R2	t2	School2	5:15	X	X	X	X	X	4	9/6/2018	6/18/2019
B1	R3	t8	School3	12:00	X	X	X	X	X	3	9/6/2018	6/18/2019
B2	R12	t0	School3	MID			X		X	2	9/6/2018	6/18/2019

(Work Schedule: M T W T F)

- Confirm zone and rate designations with posted rate sheets. All rates and zone postings are subject to the collective bargaining agreement.
- For each school entered above, check to make sure that there is a corresponding route sheet attached. All routes do not run daily or at the same time. In addition to the above summary, each attached route sheet must be reviewed to confirm the scheduled days of travel.
- All routes are subject to change per changes in student status. Examples include vehicle number, student pick-up and drop-off times, additions or deletions of student on the route, student change of address, etc.
- **Requirements**: ALL monitors, standby and assigned, must punch/sign in at the appropriate bus yard to meet vehicle prior to their departure for their first trip. Following the first week of coverage, monitors may complete an "Alternative Pick Up Location Request" form to request a change in their pick-up location. These request are subject to approval by the Unit leader or Monitor supervisor.
- Assigned monitors should also sign-in at the indicated school(s) each time the route is covered.
- All assigned monitors must submit one of the attached copies of this letter to each building administrator or their designee on the first day that they report for each assignment.
- **MONITOR SIGNATURE OF ACCEPTANCE:**
- In acceptance of this assignment, I am also in receipt of the Special Education Bus Monitor Position Overview and have been directed to thoroughly review the information presented.
- Monitor Signature:________________ Date:__________

Profile Photo

Main Author

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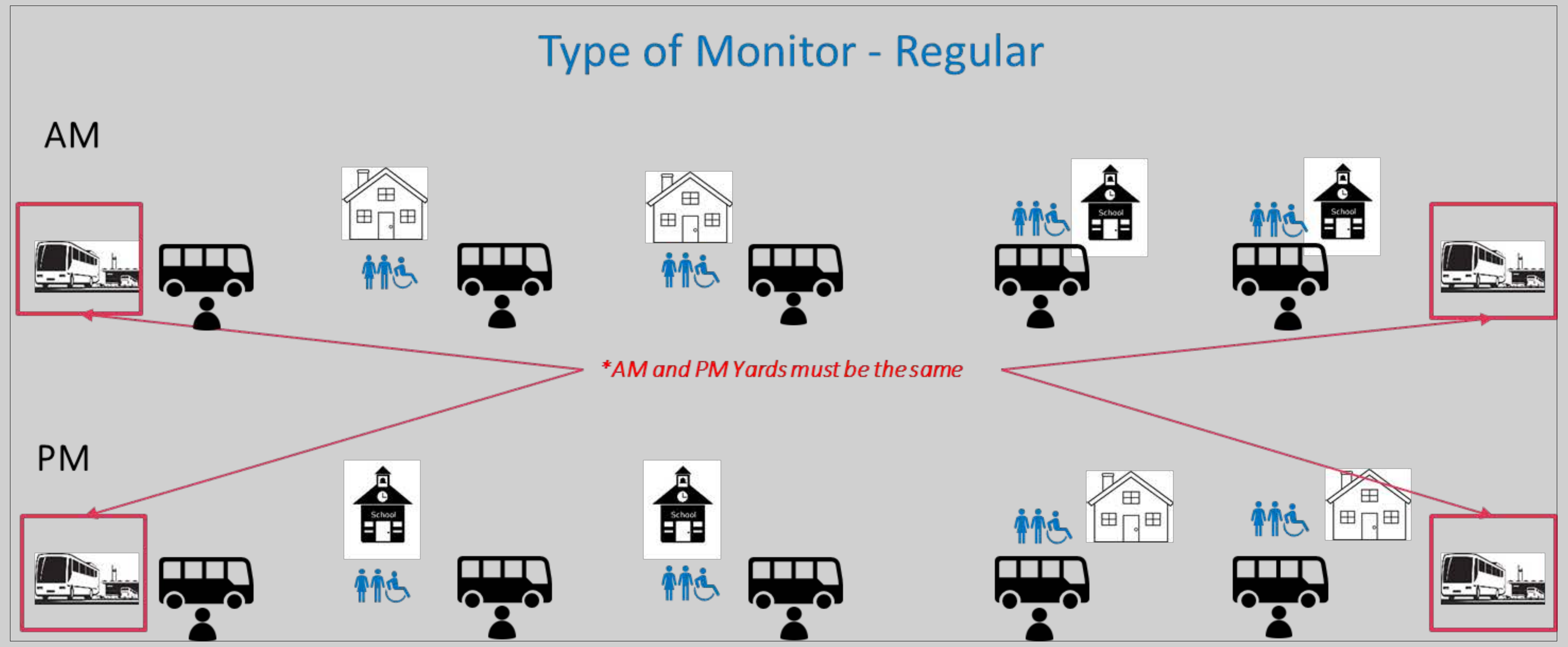
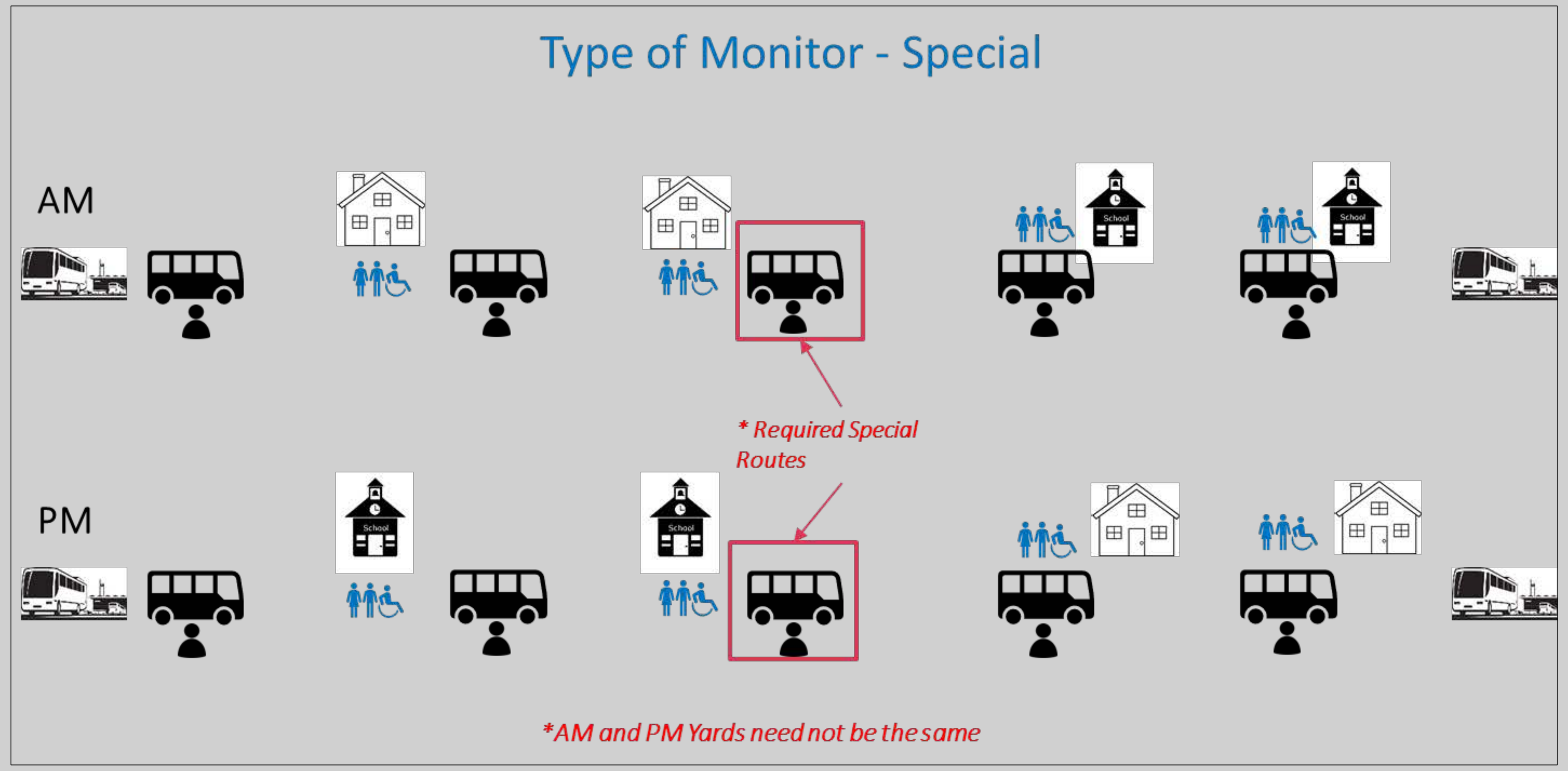
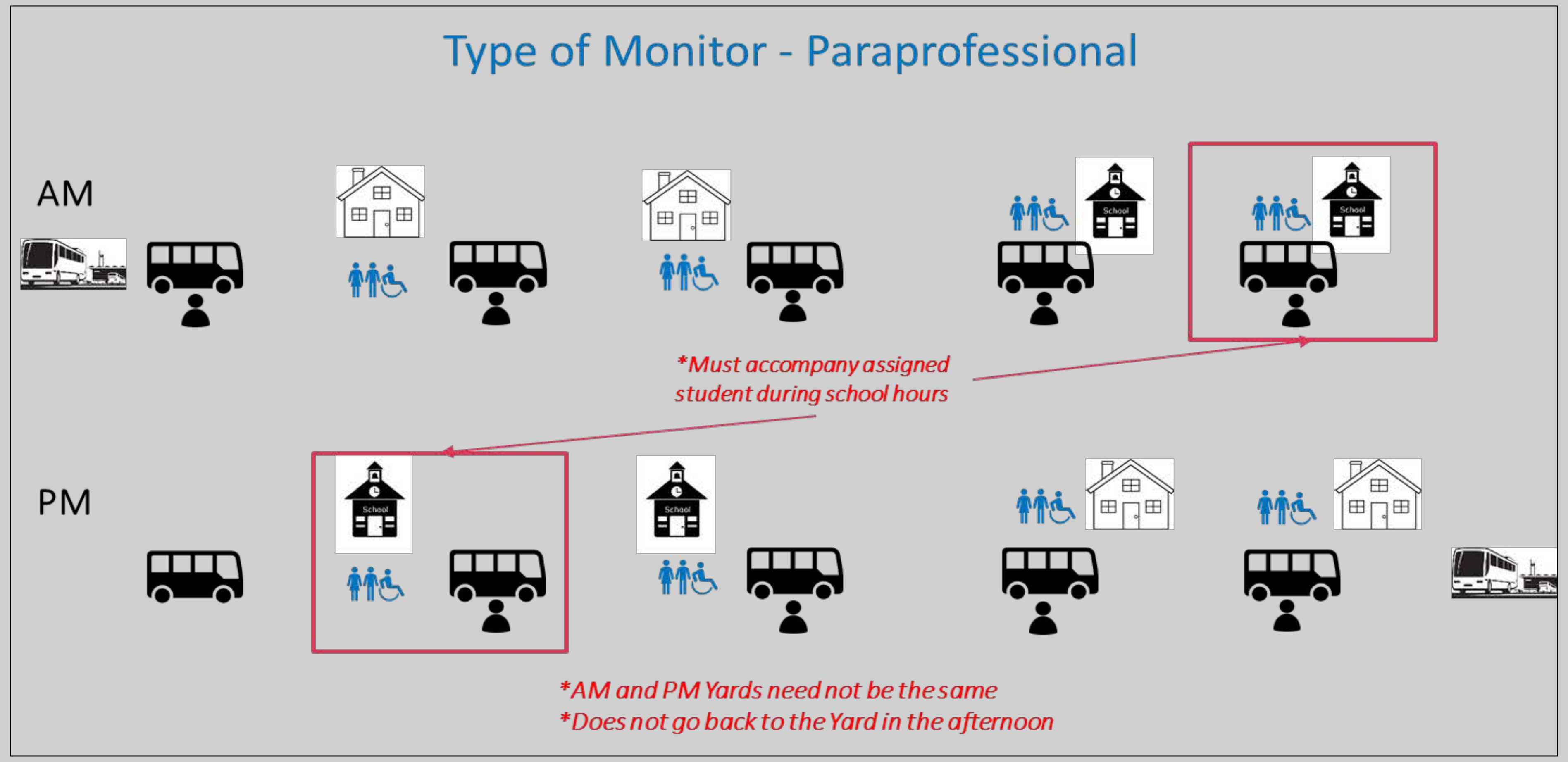
Problem Description

- Each bus typically has 3-4 routes, each in the AM and PM, some of which require monitors.
- After exhausting options in which the monitor stays on the same bus, packages can be made in which monitors switch buses at schools or stay on the bus to make connections. Students requiring monitors need either their own monitor or in other cases can share a monitor with other students. Specific monitor individuals are sometimes designed for a subset of students.
- Monitors need to arrive and leave from the same bus yard in the morning and afternoon.
- Building the packages manually can take anywhere between 1 to 2 weeks.
- **SAS optimization** was used to develop a reusable Mixed Integer Linear Programming (MILP) model to maximize the number of routes within a package, while ensuring full coverage.







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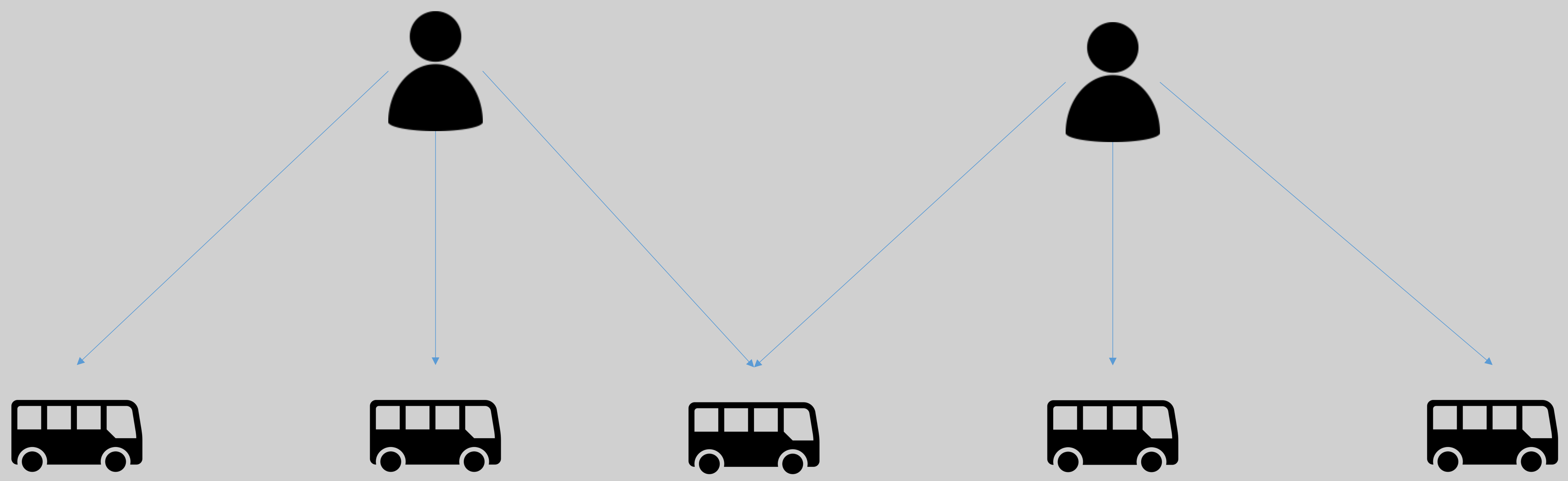
Intuitive Mixed Integer Linear Programming (MILP) Formulation

$$Monitors = \{\text{Set of Given Monitors}\}$$

$$Nodes = \{\text{Set of Routes}\}$$

$$Assign_{m,r} = \begin{cases} 1 \text{ if monitor } m \text{ rides the route } r \\ 0 \text{ otherwise} \end{cases}$$



- This was a very straightforward approach to solving the problem.
- However, it uses millions of variables and constraints, which makes the model non-scalable.
- It did not take advantage of the underlying network structure of the problem.

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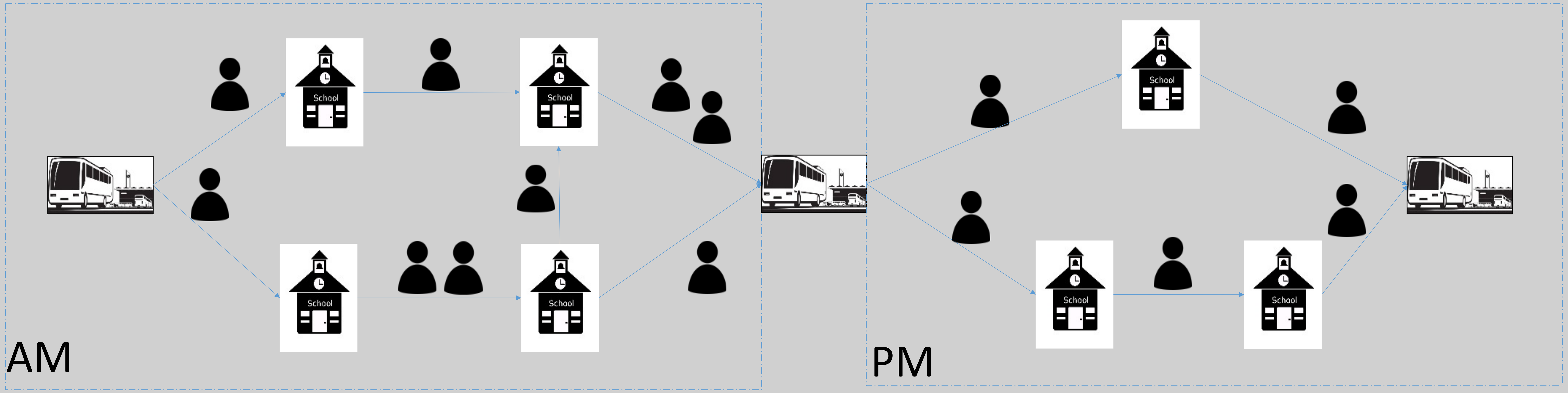
Network Flow

$$Monitors = \{\text{Set of Given Monitors}\}$$

$$Nodes = \{\text{Set of Schools}\} \cup \{\text{AM\_YARD, PM\_YARD}\}$$

$$Arcs = \text{Routes that connect schools}$$

$$Assign_{m,arc} = \begin{cases} 1 \text{ if monitor } m \text{ is assigned to } arc \\ 0 \text{ otherwise} \end{cases}$$



- This was a simple network flow model, with the schools and the bus yards as nodes and the bus routes connecting them as arcs.
- Some side constraints were also added for the special monitors and to ensure that the regular monitors arrive and leave from the same bus yard.
- Since this model also had a large number of constraints and variables, a binary search method was used for faster convergence to the optimal solution.
- This model was able to solve a smaller instance (summer), but could not be scaled to solve for a larger instance (fall).

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Integer Multicommodity Network Flow

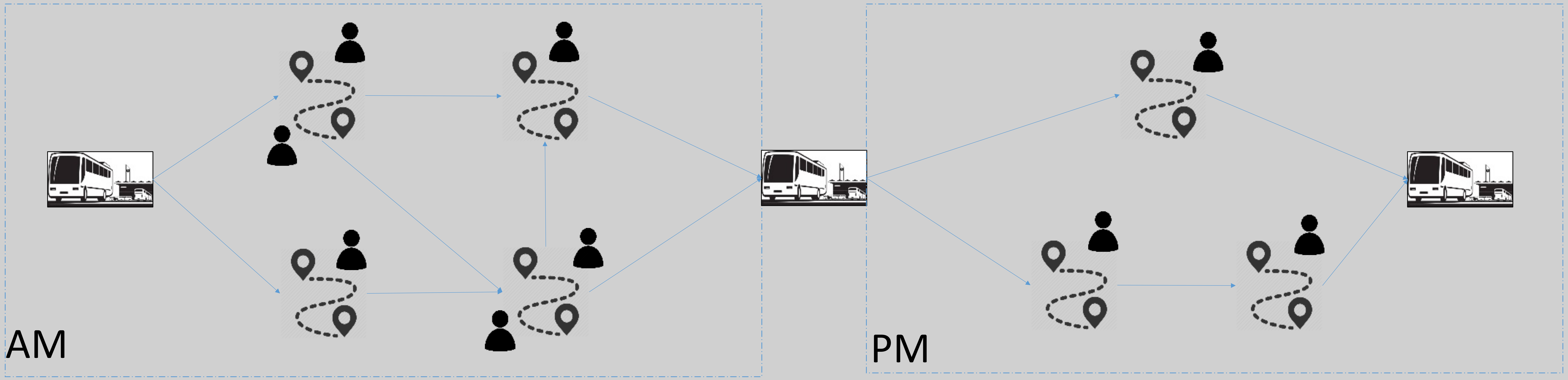
$$Monitors = \{\text{Set of Special Monitors}\} \cup \{\text{Yards for regular monitors}\}$$

$$Nodes[m] = \{\text{Set of Routes}\} \cup \{\text{AM\_YARD, PM\_YARD, PARAPROFESSIONAL}\} \text{ for monitor } m$$

$$Arcs[m] = \text{Set of arcs connecting routes which make feasible connections for monitor } m$$

$$NumVisits_{m,i} = \text{number of visits made by monitor } m \text{ to node } i$$

$$Flow_{m,i,j} = \text{number of monitors of type } m \text{ traversing arc from node } i \text{ to node } j$$



- This was an integer multicommodity network flow model, with the bus routes as nodes and the set of feasible connections as arcs.
- The monitors were considered as the commodity flowing on the arcs. The special monitors were treated as binary commodities, while the regular monitors were treated as integer commodities.
- The objective was to minimize the number of monitors needed or the total number of packages, which in turn maximizes the number of routes within a package.
- To find the individual packages, the optimal solution from the MILP was decomposed into directed cycles using **SAS network solver**.

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Current Status

- Current method of manually creating monitor packages takes ~1 week, while **SAS Optimization** model takes ~20 minutes to run.
- Using **SAS Output Delivery System** (ODS) Statements, the process of printing the packages in individual pages of an editable .rtf file was also automated.
- Validating packages built using SAS Optimization on anonymized data.
- More capabilities, like maintaining student-monitor relationship over different weekdays and minimizing bus transfers, are being worked on.