A Mathematical Analysis of Scheduling for AWARE

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Abstract

AWARE is a non-profit organization that provides care and services for people with challenging mental health, emotional, and in some instances, physical disabilities [1]. Many of the clients in AWARE residential programs have individual care plans and receive state funding through Medicaid. With the demand for residential programs being extremely high, AWARE must optimize their staffing resources in order to best serve the most amount of people while securing the necessary funds to do so. In this project, we worked with AWARE to develop an algorithm to determine staffing of a home to best maximize the funding they can receive. The algorithm was based on the same ideology behind the greedy algorithms used in graph theory. This was first used to determine the maximum staff size required to fulfill the needs of all the clients. In order to make the model more realistic, a similar algorithm was used to determine a minimum staff model as well. This method can be used in conjunction with the current care based process AWARE uses to ensure the quality of care along with maximum funding.

Contents

List of Figures

List of Tables

1 AWARE

Founded in 1976, Anaconda Work and Residential Enterprises (AWARE) is a nonprofit organization that is dedicated to helping people with developmental disabilities live as independently as possible. Located in Anaconda, Montana, AWARE offers a variety of different programs and services for people of all ages with challenging mental health, emotional, and physical disabilities [1].

One aspect of the organization involves residential care for adults with developmental disabilities that are staffed twenty-four hours a day. These group homes are designed to support each client and ensure their safety while providing them opportunities to experience personal growth and allowing them as much independence as possible. For this program, most of the funding that AWARE receives is from Medicaid and is dependent on the individual needs of each client that resides in the home. This funding not only covers staff wages, but also staff training, building upkeep, and administration costs.

1.1 Proposed Project

AWARE is dedicated to providing the best care for the individuals in their residential homes; however, quality care requires resources and funding. Clients in residential programs have individual care plans (ICP) that outline the Medicaid state funding they qualify for based on their needs. We were asked by AWARE to analyze their current schedules and to develop a staffing model that would allow them to optimize their staffing resources in order to best serve the most people. The well-being of the clients is the main focus of AWARE, so when creating schedules it is important not to understaff as this would make it difficult to provide the best care for each client. However, it is important to not overstaff as the organization can not financially afford it. Therefore, the goal is to find the minimum staff needed without compromising the

care of the clients.

1.2 Provided Data

AWARE provided schedules for two different residential homes. Additionally, we were provided with the individual care plan for each client at these homes. The ICPs provide information for how much Medicaid funding is available for certain services for each client. All the funding is solely based on the staff time that would be required to meet the needs of the client and does not include other resources that may be needed. Based on the type of services required for the clients, staffing needs can be estimated [3]. We worked with this information under a confidentiality agreement to protect the privacy of the clients.

1.2.1 Services

Each ICP outlines the specific services a client requires and the Medicaid funding allotted for each for a fiscal year. Therefore, this tells AWARE how much Medicaid can be billed for each service. The specific services that are needed by the clients in the homes we analyzed are shown in Table 1 [3]. Depending on the service and the need of the client, the service will be billed either by the hour, day, unit, or 15 min session as determined by Medicaid regulations.

Service	**Details**	**Billable Unit**
Congregate Living	care in residential group home	Day or Hour
Day Supports and Activities	activities in facility outside of home	Day
Individualized Supports	behavioral support services	Hour
Supported Employment	support for working client	Day
Therapies	medical services ordered by physician	15 min
Transportation	transport to locations based on needs	Unit

Table 1: Table of Services with Details and Billable Units

2 Project Goal

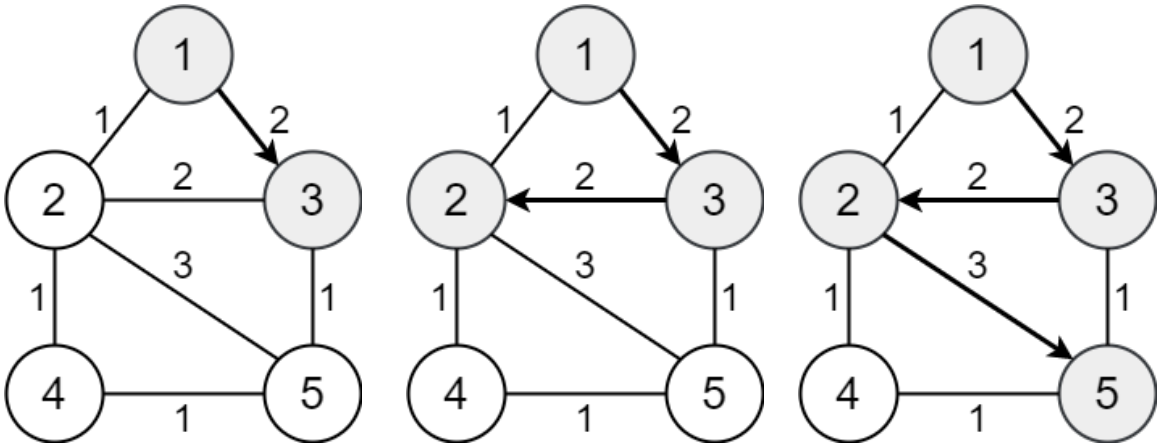
The current staffing system appears to be primarily based on providing the best care for the clients in their residential homes, as it should be. However, as mentioned before, funding is essential to the operation of a nonprofit organization. Based on the proposed project and the provided data, we decided to explore the staffing required to secure the most funds possible while covering the required services of each home. Therefore, since this process for determining staffing requirements is based on funding, it should not be used individually but in conjunction with the care-based methods already used. The ultimate goal is that this work can assist AWARE in creating staff schedules that maximize their funding as they provide top care for their clients. Additionally, the hope is that this could be used as AWARE expands in order to serve more people.

3 Greedy Algorithm

Based on the information from the ICPs about services and billable units of the clients, we decided to build a model using a greedy algorithm to show the staffing needs based on the services that need to be covered. A greedy algorithm is relatively basic and involves building a model one piece at a time based on which path gives the optimal immediate benefit [2].

3.1 Greedy Algorithm Example

Figure 1 shows an example of a greedy algorithm used to find the maximal-weighted path from node 1 to node 5. Following the algorithm, the first step would be to choose between going from node 1 to node 2 or to node 3. Because the path to node 3 is larger, the path will start with going from node 1 to node 3. The second step is to choose between going from node 3 to node 2 or to node 5. The edge leading to node



(a) Step 1 (b) Step 2 (c) Step 3

Figure 1: Example of Greedy Algorithm

2 is larger and will be chosen next. The third step is to choose between traveling to node 4 or node 5 from node 2. The path leading to node 5 will be chosen for a total path weight of seven.

While this example finds the most optimal path, this is not always guaranteed by the greedy algorithm. For example, if the path connecting node 4 and node 5 had a weight of 4, the path found above would not be optimal. Greedy algorithms may not always find the best solution but they are relatively simple and tend to give a solution that is near the optimal solution.

3.2 Algorithm Application

We applied this algorithm to two of the AWARE residential group home facilities that will be referred to as Home 1 and Home 2. This determined the staff necessary for a group home based on the services required by each client as outlined in the ICPs. The main idea is that a staff member will be assigned to cover a service for a client in order to maximize funding. This involved adding a staff member and assigning that member to the service with the highest funding available and then to the client or clients with the most funding for that service. The staff members in the model

will account for how many staff members would need to be working at the same time throughout the day. Because of this, the model better represents the staff size needed during day hours and not during the night shifts.

4 Applying Greedy Algorithm to Home 1

We started with applying the algorithm to Home 1 because there are only four clients and each only require two services: congregate living and transportation. Each client is under hourly billing for congregate living and unit billing for transportation.

4.1 Maximum Staff Model for Home 1

Initially, the staff model was designed to determine the maximum number of staff members that should be working at a given time. This will ensure that all the services required by the clients will be covered and all funding will be secured. The algorithm operated under the following assumptions.

4.1.1 Maximum Staff Model Assumptions

To determine the maximum number of staff required to provide the needed services for each client, it was assumed that there is no overlap for services. For example, a staff member that is responsible for congregate living care cannot also be responsible for transportation. There was also the assumption that a staff member covering an hourly billed service cannot be shared with other clients. For example, a staff member covering the hourly congregate living care for one client cannot be responsible for any other services or any other clients requiring congregate living care. Daily and unit billable services for multiple clients were combined into one assignment under the assumption that one staff member could meet the service needs for all clients. For example, all clients had day supports and activities as a billable service and this was

treated as one assignment with an associated funding of the combined funds for all clients.

4.1.2 Building the Maximum Model for Home 1

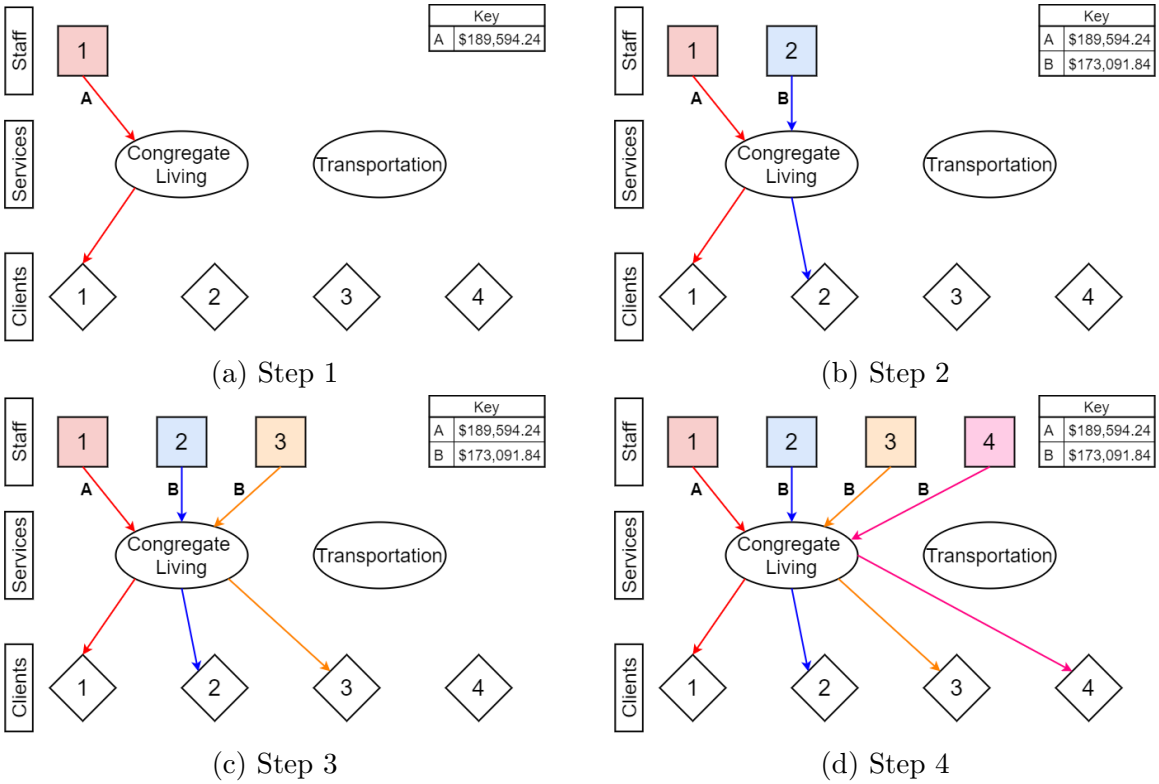
Based on the greedy algorithm, the staff members will first be applied to congregate living because there is more funding available for that service. The steps of the algorithm are shown in figure 2. The first step assigns a staff member to congregate living and client 1 because that client has the most funding assigned in their ICP. Under the previously explained assumptions, this staff member can only be responsible for the congregate living needs of one client that is billed hourly so this is all this staff member can be assigned. Because the other three clients at this home have the same funding available for congregate living billed hourly, the next three steps assign staff members to cover congregate living for the other three clients. The final step assigns a fifth staff member to cover transportation for all four clients as shown in figure 3.

4.1.3 Analyzing Maximum Model for Home 1

According to this model in figure 3, the maximum staff size needed to cover the required services at Home 1 is five. Table 2 shows the amount of billable funds accessible based on each staff member and their assignments. This simple model shows that all the funding will be secured and all service needs will be met. However, it is unrealistic to have a staff this size due to the funds that would have to go towards staff wages. Therefore, another model with different assumptions is necessary for a better estimation of staff needed.

4.2 Minimizing the Staff Model for Home 1

Theoretically, when using the greedy algorithm, one staff member could cover every service for all clients. This would be the most ideal based on funding as it would



(a) Step 1

(b) Step 2

(c) Step 3

(d) Step 4

Figure 2: Algorithm Steps for Maximum Staff Model for Home 1

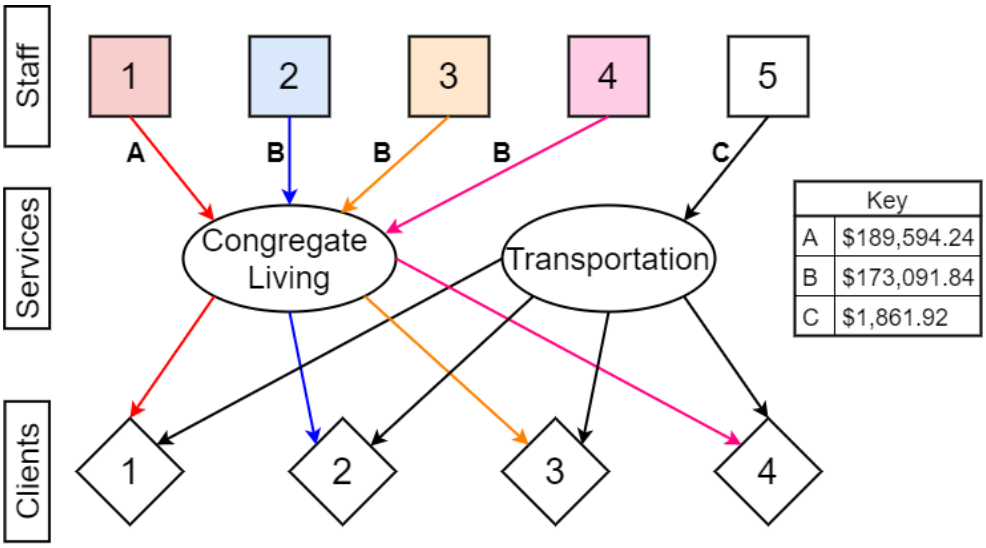


Figure 3: Maximum Staff Model for Home 1

Staff	Services	Clients	Funding
1	Congregate Living	1	$189,594.24
2	Congregate Living	2	$173,091.84
3	Congregate Living	3	$173,091.84
4	Congregate Living	4	$173,091.84
5	Transportation	1,2,3,4	$1,861.92

Table 2: Funding per Staff Member for Maximum Model of Home 1

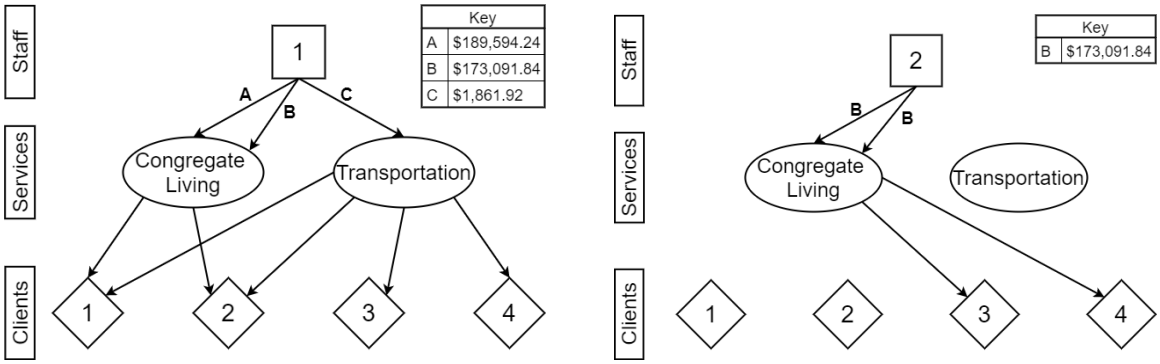
minimize the cost of the staff. However, this is unrealistic as it is unlikely that one staff member would be able to effectively cover everything in one group home of four clients. This is significant because if the staff member cannot meet the full needs as outlined in the ICP, not only will there by health concerns due to lack of optimal care but the full funding will not be received. Therefore, when working to minimize the total staff members needed at one time, certain assumptions and limits needed to be made.

4.2.1 Minimizing Staff Model Assumptions

In order to minimize the staff, we needed to assume that there can be overlap between services so one staff member can cover multiple services. To prevent a staff member from being assigned more than they can handle, each staff member can only be responsible for a maximum of three assignments. Another assumption is that a staff member covering an hourly billed service can meet the needs of a maximum of two hourly billed clients throughout a day. This is based on the fact that hourly clients require at least 10.95 hours of staff time per 24 hour day [3]. Overall, it is ideal to allow as much overlap as possible without overwhelming one staff member with too many tasks as mentioned above.

4.2.2 Building the Minimum Staff Model for Home 1

This model explores the service assignments and funding acquired by each staff member when working to minimize the staff. This will be done by following the



(a) Step 1: Staff Member 1 (b) Step 2: Staff Member 2

Figure 4: Algorithm Steps for Minimum Staff Model for Home 1

greedy algorithm and the above assumptions by assigning tasks based on highest funding to one staff member until they can handle no more assignments. At this point, another staff member position will be added. This will be repeated until all services are covered. Therefore, for Home 1, the first step will be to assign staff member 1 with congregate living for client 1 and client 2. Because these are both hourly billed services, the staff member cannot be assigned another hourly billed service but can cover the next highest service that is not hourly billed. So staff member 1 is also assigned transportation for all clients. The second step is to add staff member 2, which is assigned to cover congregate living for client 3 and client 4. These individual steps are shown in figure 4 and the final model is shown in figure 5. Table 3 shows the services covered by each staff member and the total funding that will be acquired for the work of each. This model shows that if all services are covered fully by the staff member they are assigned then all funding can be received. The model will also cut costs for AWARE as there are only two staff members instead of the five in the maximum model.

4.2.3 Applying Assignment Alternation to Minimum Model of Home 1

While the minimum model could result in the maximum funding with the lowest staff costs, as mentioned before, it is important that the services are completely

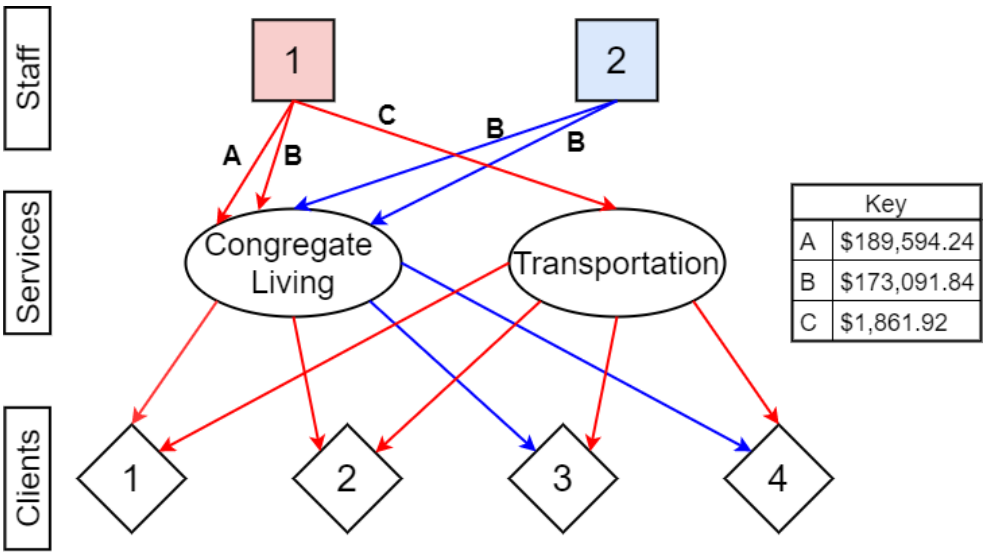


Figure 5: Minimum Model for Home 1

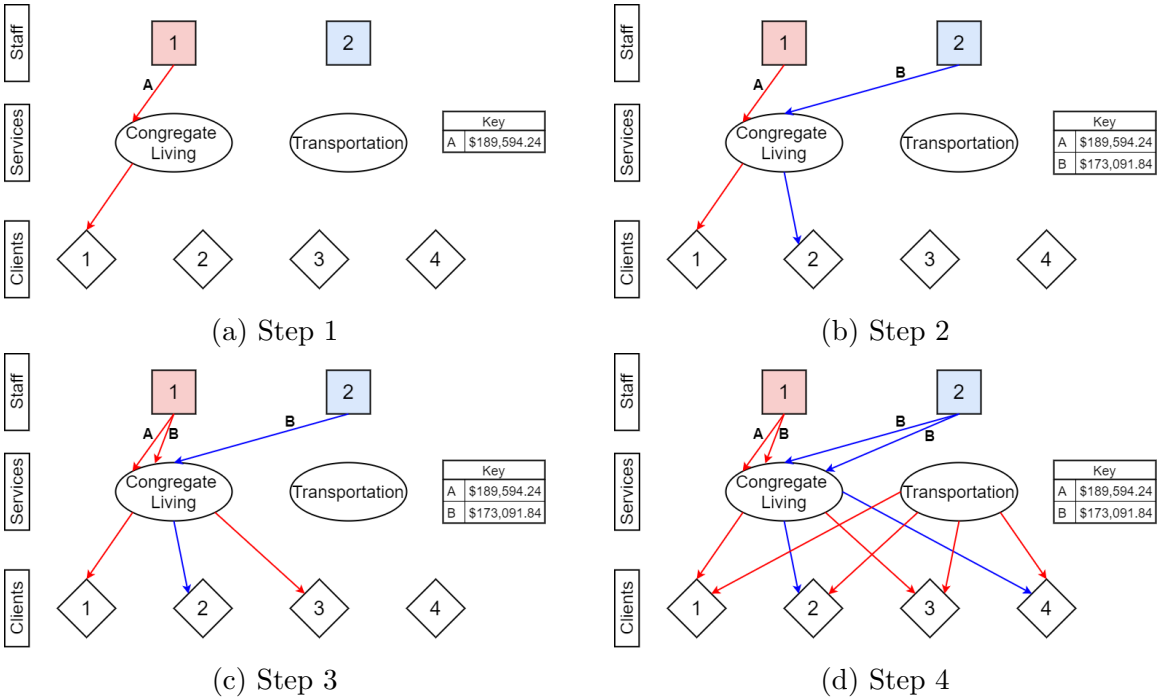
Staff	Services	Clients	Funding	Total Funding
1	Congregate Living	1	$189,594.24	$364,548.00
	Congregate Living	2	$173,091.84	
	Transportation	1,2,3,4	$1,861.92	
2	Congregate Living	3	$173,091.84	$346,183.68
	Congregate Living	4	$173,091.84	

Table 3: Funding per Staff Member for Minimum Model of Home 1

fulfilled. In an attempt to make the model more realistic to the services a single staff member could complete, the minimum staff model can be altered to assign services in an alternating system. Under the assumption that more funding indicates more time and care is required for that service, spreading out the funding among the staff members should make the work load assigned to each more manageable. Therefore this model will follow the following assumptions:

- The staff size is the same as the minimum model.
- Each staff member can have a maximum of three assignments, two of which can be hourly billed services.
- Services are assigned in order of highest funding to lowest funding.
- Each staff member is given one assignment at a time starting with staff member 1 then staff member 2 and so on. This continues until all services are assigned.
- If a staff member is already assigned two hourly billed services, any additional hourly services will be assigned to the next staff member able to cover it.

When applying this model to Home 1, the first step assigned staff member 1 with congregate living for client 1 and the second step assigned staff member 2 with congregate living for client 2. The third step assigned staff member 1 with congregate living for client 3 and the fourth step assigned staff member 2 with congregate living for client 4. The final step assigned staff member 1 with transportation for all clients in the home. Figure 6 shows these steps. The final model is shown in figure 7 and staff assignments with the associated funding are shown in table 4. In this specific home, client 2, client 3, and client 4 all have the same funding allocated for congregate living. Because of this, there is no variation in funding for each staff member in this alternating model when compared to the minimum model. However, these two types



(a) Step 1 (b) Step 2

(c) Step 3 (d) Step 4

Figure 6: Algorithm Steps for Minimum Staff Model with Alternation for Home 1

Staff	Services	Clients	Funding	Total Funding
1	Congregate Living	1	$189,594.24	$364,548.00
	Congregate Living	3	$173,091.84	
	Transportation	1,2,3,4	$1,861.92	
2	Congregate Living	2	$173,091.84	$346,183.68
	Congregate Living	4	$173,091.84	

Table 4: Funding per Staff Member of Minimum Model for Home 1 with Alternating Assignments

of models will likely show variation in other residential group homes, especially ones with more clients and more service types.

This minimized model with alternating assignments is likely more realistic for AWARE as it minimizes the cost associated with staff wages. However, it is crucial that the assignments are reviewed in order to ensure that each staff member will be able to handle the given work load.

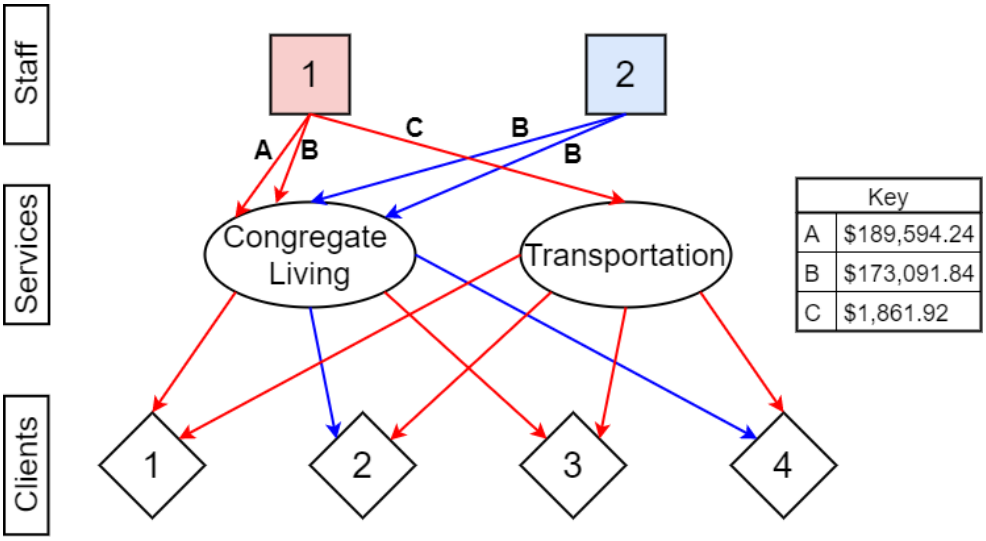


Figure 7: Minimum Model for Home 1 with Alternating Assignments

5 Applying Greedy Algorithm to Home 2

After applying the algorithm to Home 1 under multiple conditions, we applied the algorithm again to Home 2. This home is more complex as it has seven clients and a total of six services. The different types of transportation outlined in the ICPs were combined into one service labeled transportation under the assumption that one staff member could cover the three different transportation needs.

5.1 Maximum Model for Home 2

This maximum model for Home 2 follows the same assumptions applied to Home 1 with staff members only being able to cover one service at a time and hourly billable services being unable to overlap with other hourly or daily billable services. Following the greedy algorithm as in Home 1, the staff members were assigned to the services with the most funding available and then to the client(s) with the most available funding. The final staff model is show in figure 8 with a staff size of nine. The services are abbreviated in this figure and are explained in table 8. The service and client(s) assigned to each staff member along with the funding that is associated with

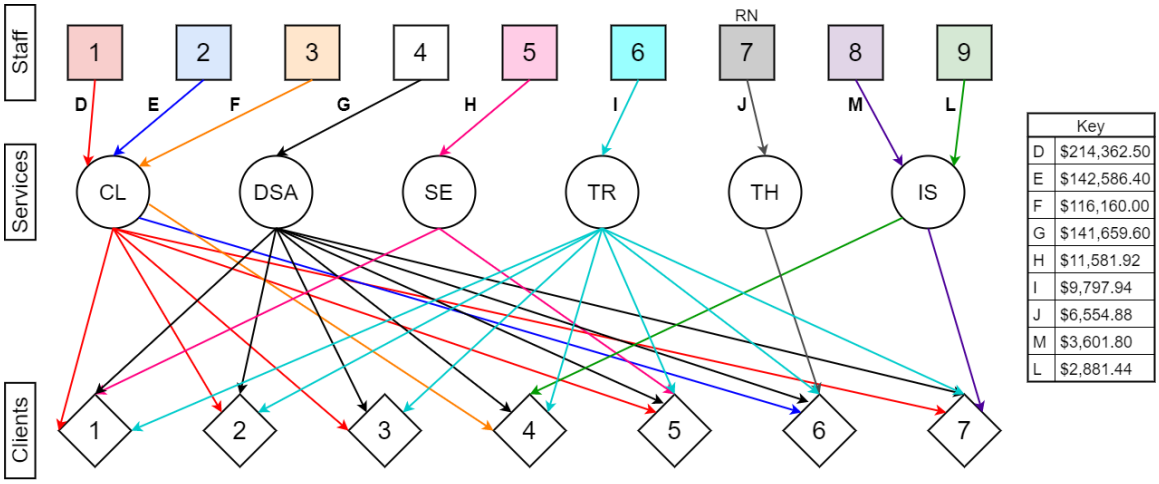


Figure 8: Maximum Staff Model for Home 2

Staff	Services	Clients	Funding
1	Congregate Living (Daily)	1,2,3,5,7	$214,362.50
2	Congregate Living (Hourly)	6	$142,586.40
3	Congregate Living (Hourly)	4	$116,160.00
4	Day Supports and Activities	1-7	$141,659.60
5	Supported Employment	1,5	$11,581.92
6	Transportation	1-7	$9,797.94
7 (RN)	Therapies	6	$6,554.88
8	Individualized Supports (Hourly)	7	$3,601.80
9	Individualized Supports (Hourly)	4	$2,881.44

Table 5: Funding per Staff Member for Maximum Model of Home 2

that is shown in table 5. Based on the requirements of the therapy service, staff member 7 has to be a registered nurse (RN) and this would have to be taken into consideration during scheduling. Again, the maximum model ensures that all services will be fully covered and all funding can be acquired, but this is unrealistic as the large staff size would be too costly for AWARE.

5.2 Minimizing the Model for Home 2

Similar to Home 1, we needed to reduce the staff members for the home because the maximum model was unrealistic. Following the same algorithm and assumptions as used in Home 1, we were able to explore the funding for a minimum staff model

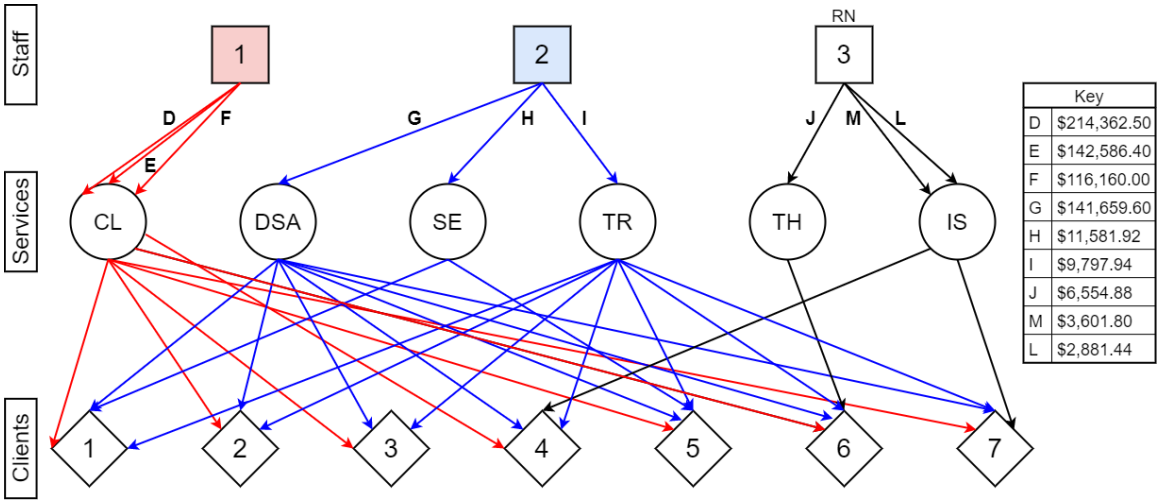


Figure 9: Minimum Model of Home 2

by making assignments to one staff member and adding additional staff members as needed.

5.2.1 Building Minimum Model of Home 2

Based on the algorithm, the first step assigned staff member 1 congregate living for all the clients that are billed daily (clients 1,2,3,5,7), client 6 who is billed hourly and client 4 who is billed hourly. This is all that staff member can be assigned so staff member 2 is added and for the second step is assigned day supports and activities, supported employment, and transportation. The final step added staff member three and assigned therapies and individual supports for client 7 and client 4. Therefore, it can be recommended that a staff size of a minimum of three is needed for home 2. The final model is shown in figure 9 and table 6 shows the assignments and funding for each staff member. If each staff member is able to fulfill their assigned services, this would cut staffing costs for AWARE compared to the maximum staff model.

5.2.2 Applying Assignment Alternation to Minimum Model of Home 2

The minimum model of Home 2 can now be altered to include the alternation of assignments like done for Home 1 to make the model more realistic. This was done

Staff	Services	Clients	Funding	Total Funding
1	Congregate Living (Daily)	1,2,3,5,7	$214,362.50	$473,108.90
	Congregate Living (Hourly)	6	$142,586.40	
	Congregate Living (Hourly)	4	$116,160.00	
2	Day Supports and Activities	1-7	$141,659.60	$163,039.46
	Supported Employment	1,5	$11,581.92	
	Transportation	1-7	$9,797.94	
3 (RN)	Therapies	6	$6,554.88	$13,038.12
	Individualized Supports (Hourly)	7	$3,601.80	
	Individualized Supports (Hourly)	4	$2,881.44	

Table 6: Funding per Staff Member for Minimum Model of Home 2

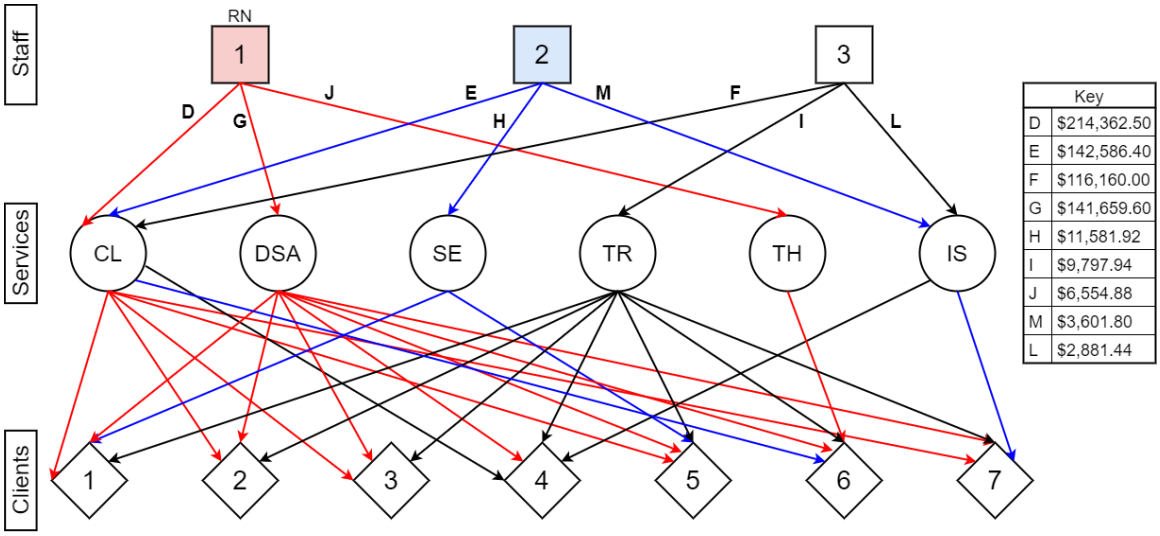


Figure 10: Minimum Model for Home 2 with Alternating Assignments

by assigned the three staff members assignments based on highest available funding and by assigning them one at a time starting with staff member 1. This final model is shown in figure 10 with the assignments and associated funding for each staff member shown in table 7. As before, it is imperative that consideration is given to the assignments to make sure that are manageable for the staff members to accomplish.

6 Application of this Project

AWARE can apply this greedy algorithm to their residential group homes to assist them in staffing their homes in such a way that maximizes funding. As previously

Staff	Services	Clients	Funding	Total Funding
1	Congregate Living (Daily)	1,2,3,5,7	$214,362.50	$362,576.98
	Day Supports and Activities	1-7	$141,659.60	
(RN)	Therapies	6	$6,554.88	
2	Congregate Living (Hourly)	6	$142,586.40	$157,770.12
	Supported Employment	1,5	$11,581.92	
	Individualized Supports (Hourly)	7	$3,601.80	
3	Congregate Living (Hourly)	4	$116,160.00	$128,839.38
	Transportation	1-7	$9,797.94	
	Individualized Supports (Hourly)	4	$2,881.44	

Table 7: Funding per Staff Member of Minimum Model for Home 2 with Alternating Assignments

mentioned, this algorithm should be used along with knowledge of what each service at the home fully entails.

First, the services of the clients in the home can be ordered from highest funding to lowest funding available. This will follow the assumptions in the maximum model where each assignment is separated by service and billable unit. For example, clients with an hourly billed congregate living service would each be one assignment but all the daily billed congregate living clients would be combined into one assignment.

The next step would be to follow the algorithm in the minimum model where one staff member is assigned services starting with the highest funded service until the staff member cannot handle any more assignments. At this point, another staff member can be added and assigned tasks. This process is repeated until all services are covered. AWARE can add additional assumptions or limits to this algorithm to better model a realistic work load for each staff member.

Once a minimum staff model is created, the assignments can be analyzed by someone at AWARE that fully understands the individual needs of the clients in the home, the capabilities of the staff, and the attention, time, and care required for each service. The assignments can then be rearranged to ensure that each staff member will be able to successfully cover the assigned services. One method of rearrangement could be to assign services through alteration as done above. Additional staff members

can be added as well in order to be able to completely meet the needs required by the services.

Overall, the first step of ordering services based on funding can be compared to how services are ranked in terms of quality of care, which could provide insight regarding which services should be covered fully first. The algorithm can help decide the staff size and show how much more funding would be available if another staff member is added. This would aid in deciding if adding an additional staff member will be a wise choice economically.

7 Further Exploration

With more time and a deeper understanding of the services provided in the group residential homes of AWARE, this project could be continued for a larger impact. One way would be to expand the models to account for the needs at different times of the day. Certain services are more applicable during certain hours of the day and it is likely that fewer staff are needed at night versus during the day. This model could also be made more accurate with a better understanding of what services are more compatible with one another. Knowing which services are easily covered by one person could help with the staff assignments and providing a more realistic model. This and other adjustments could be made to create model that better combines the optimization of funding and quality care simultaneously.

Additionally, it could be helpful to be able implement these algorithms in a computer program that would allow schedules to be built based on the required services and Medicaid funding available to each client at the home as outlined in individualized care plans. This would allow for better application to new homes or in assisting in staff adjustments based on new clients entering a home.

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[2] "Greedy Algorithms". (n.d.). Retrieved March 2020, from https://www.geeksforgeeks.org/greedy-algorithms/

[3] *Montana Developmental Disabilities Program Services Manual*. (2019).

A Acknowledgements

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B Appendix

Abbreviation	Service
CL	Congregate Living
DSA	Day Supports and Activities
IS	Individualized Supports
SE	Supported Employment
TH	Therapies
TR	Transportation

Table 8: Table of Service Abbreviations