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ASYMMETRIC INFORMATION SHARING IN DIALYSIS PARATRANSIT USING AN AGENCY APPROACH

FINAL REPORT

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15. Abstract

Dialysis patient transit services presents an agency problem (Eisenhardt, 1989) where the county paratransit operator is the agent that provides the principal, the dialysis center, transport of dialysis patients to their centers under conditions of incomplete and asymmetric information. The agent (paratransit) collects riders in need of paratransit services for doctor appointments (Social Service and Elder Services), dialysis appointments (principal), and other transit needs under conditions of incomplete and asymmetric information where the pickups are scheduled with a limited number of vehicles. Asymmetric scheduling information between the dialysis centers (principal) in a county, the para-transit authority (agent), and the patient's knowledge of his/her schedule was the focus of this research where it was discovered that Social Service is another principal in this agency problem. The communication flows between the agencies and the principals was examined in 13 rural North Carolina counties with high demand for paratransit services. Service quality factors that impact the information asymmetry were analyzed with Bayesian analysis. Results of this research showed the impact service factors on information asymmetry and suggests the need for call center technologies and improved paratransit scheduling. A unique contribution to transportation research was the use of probabilistic Bayesian factors in the principal/ agency model that will provide the basis for paratransit route scheduling in the next phase of this research.

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EXECUTIVE SUMMARY

The provision of dialysis patient transit services presents an agency problem (Eisenhardt, 1989) where the local counties provide the paratransit, non-emergency paratransit vehicles, yet the funding sources include federal, state, and local resources. The county paratransit operator is the agent that provides the principal, the dialysis center, with the work of transporting dialysis patients to their centers under conditions of incomplete and asymmetric information. The agent (paratransit) collects riders in need of paratransit services for doctor appointments, dialysis appointments, and other transit needs. Scheduling pickups with a limited number of vehicles in counties creates scheduling and routing problems for the paratransit agencies who are expected to provide dialysis patients to the dialysis centers and other medical appointments at appointed times. Asymmetric scheduling information between the dialysis centers (principal) in a county, the para-transit authority (agent), and the patient's knowledge of his/her schedule is the focus of this research. If a patient is not ready for a paratransit pickup or a paratransit vehicle misses or is late for a dialysis patient pickup this can have a cascading effect on these inter-related actors for the para-transit schedule, to other patients, to the dialysis clinics, on to receiving reimbursement for this transport. This research will seek to identify ways to improve the communication flows particularly in rural areas with fewer scheduling technologies than the urban areas. Results of this field research and analysis have provided specifics on the information asymmetry and the resulting problems which can provide specifics to be used to solicit the for-profit dialysis chains to provide support for communications/scheduling technology to improve the provision of dialysis transport.

DESCRIPTION OF PROBLEM

Patients with kidney disease face many difficulties in getting to and from life-saving dialysis treatments. Typical patients require multi-hour dialysis three times per week. Federal law mandates that these patients are covered under Medicare even if they are under 65 years of age. Medicare, however, does not provide needed transportation to the treatments. Even if they have transportation, many of the patients are too weak to drive after treatment or may find it difficult to find family members to take time to transport them to the treatments.

Para-transit services are offered to provide needed transport to life-saving dialysis centers. Governmental para-transit services are available in some but not all North Carolina's 100 countries. North Carolina is a state where the counties with the most resources are in the central, Piedmont area of the state. The Appalachian area and the Eastern part of the state are largely agricultural areas with lower tax bases and larger counties in terms of square feet. The poverty in these areas does not allow for much funding from county government sources, and a larger proportion of residents have limited means of transport. Limited funding is available through the Elderly/ Disabled Transportation Assistance Program and Medicare. Consequently, public transit mangers need inexpensive yet effective means of scheduling transportation for these patients where dialysis is a life or death matter. Medical transportation needs in rural areas of North Carolina has been a focus of the NCA&T Transportation Institute for over 40 years (Saltzman, 1976; Sulek & Lind, 2000; Sulek & Lind 2005). Advances in digital communication media present opportunities to improve the efficiency of delivering these transit services. Findings regarding technologies used to assist with the scheduling are discussed in this paper. Results of discussions with North Carolina para-transit directors and dialysis clinics on how to provide such technologies to insure the patient is ready when the paratransit vehicle arrives will be presented.

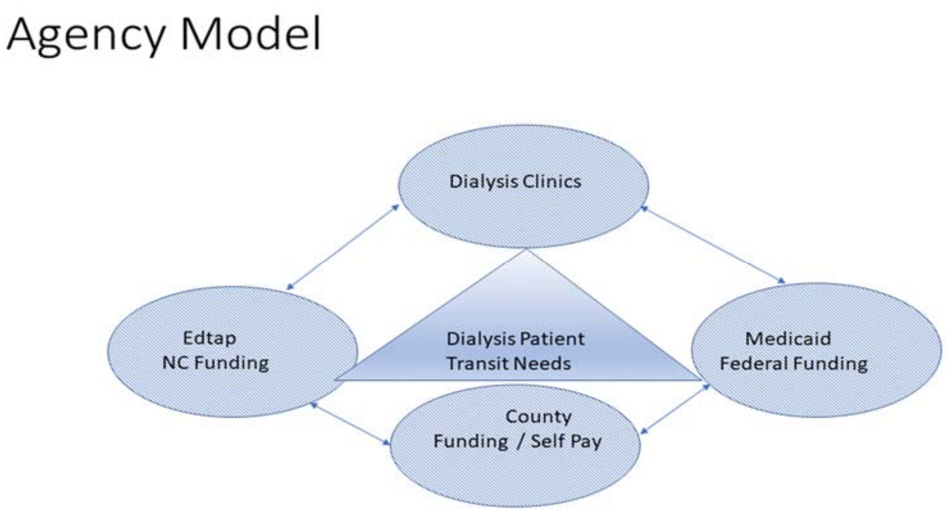
Dialysis transit needs arose with the availability of the artificial kidney machine to cleanse the blood of patients with failing kidneys. Dr. Willem Kolff invented dialysis machines during World War II (Eggers, 2000). They became available on a larger scale with the invention of the shunt by Dr. Belding Scribner (Eggers, 2000). The lifesaving devices became part of the fabric of health care starting in the 70's. The passage of the Social Security Amendments of 1972 (P.L. 92-603); in which Section 299I enabled patients needing dialysis to receive treatment that would be covered by Medicare even if under the age of 65 (Swarminathan et al., 2012). There are about 300,000 people in the United States receiving dialysis treatment for end stage renal disease - ESRD (Kidney Disease Statistics for the United Stated, 2016).

For-profit dialysis chains dominate the market providing most of the dialysis centers in the country (Johnson, 2014). Results of this study show that this is also true in North Carolina. Medicare payments and the efficiency of the for-profit chains have resulted in the dominance of the for-profits in providing dialysis centers even in remote, rural counties in North Carolina. Dialysis annual costs are around $20 billion, and the number of patients rises from 6 to 7 percent annually with one-third of the patients in a minority category. Medicare pays about $60,000 per year per Medicare patient (Swaminathan, Mor, Mehrotra, and Trivedi, 2012).

Not all dialysis patients need assistance in traveling to and from dialysis clinics; however, as the patient's health deteriorates it becomes more difficult for family members to meet patient needs after hours of dialysis treatment the patient is very tired. The paratransit vehicles used for patient transport in the counties include hydraulic lift devices to help with patients who may be in wheelchairs or otherwise immobile.

The provision of these transit services for dialysis patients to dialysis centers presents an agency problem (Eisenhardt, 1989) where the local counties provide the paratransit using non-emergency paratransit vehicles from funding sources that include federal, state, and local resources. Thus, the county paratransit operator is the agent that provides the principal, the dialysis center, with the work of transporting dialysis patients to their centers under conditions of incomplete and asymmetric information. In agency theory (Figure 1) the work carried out in this arrangement is the transport of needy patients from their homes to the dialysis centers and then back to their homes. Thus, the work of transport has been delegated from the dialysis clinics to the paratransit authorities in each county.

Figure 1 Agency Model



The goals of the principal and the agent may not be in alignment. The agent (paratransit) collects riders in need of paratransit services for doctor appointments, dialysis appointments, and other transit needs. Scheduling these pickups with a limited number of vehicles in counties creates scheduling and routing problems for the paratransit agencies. Further, the principal in this study has a set schedule where patients come to the dialysis clinic in three to four-hour windows on a Monday, Wednesday, Friday or a Tuesday, Thursday, Saturday schedule. Asymmetric information for scheduling often exists between the dialysis centers (principal) in a county, the para-transit authority (agent), and the patient's knowledge of his/her schedule. If a patient is not ready for a paratransit pickup or a paratransit vehicle misses or is late for a dialysis patient pickup this can have a cascading effect on these inter-related actors from the para-transit schedule, to other patients, to the dialysis clinics, on to receiving reimbursement for this transport.

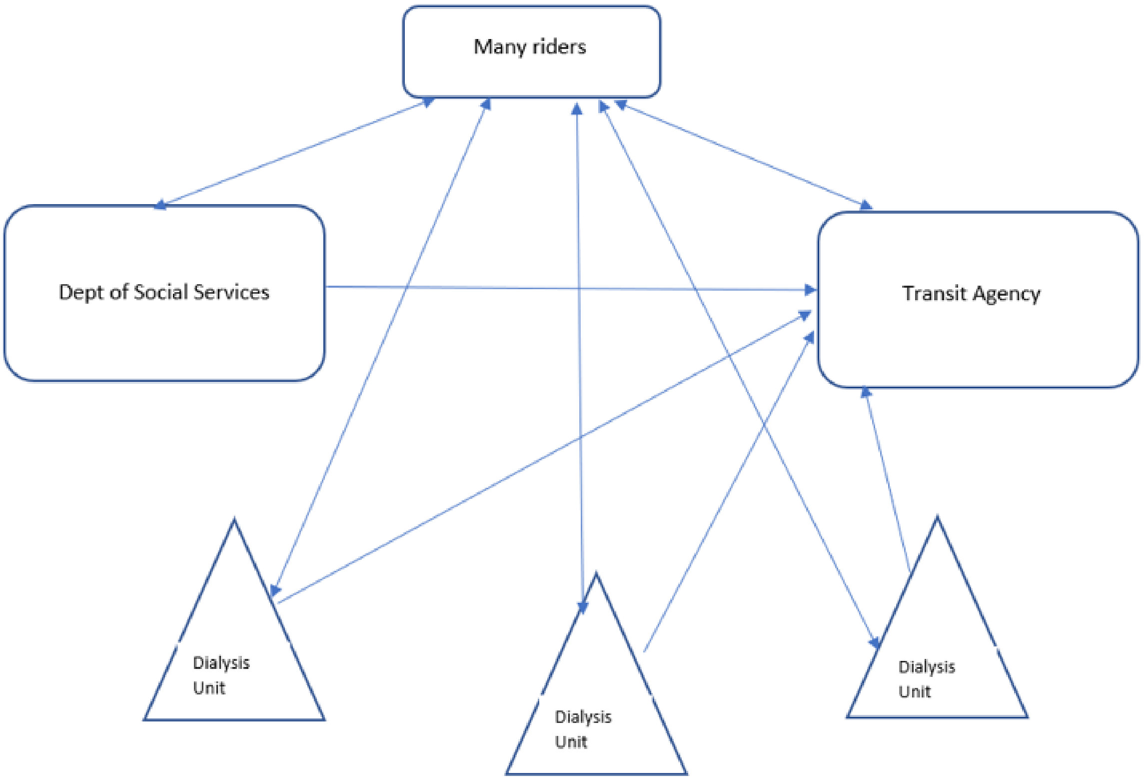
Most dialysis clinics (principals) have a social worker who works with the dialysis patients (agents) to obtain transportation. All patients who receive dialysis are deemed disabled, and qualify for Medicaid within the Medicare income guidelines, thus Medicaid will pay their travel costs within their guidelines. Other funding sources, if available, are used to supplement the cost of transportation to and from dialysis. Also, there is some federal funding from the Home and Community Block Grant federal program for those over the age of 60. There is a North Carolina program entitled the Elderly and Disabled Transportation Assistance Program (EDTAP) that provides transportation for those over the age of 60 and deemed disabled. There is a budget set for EDTAP based on the county population, and the funds are prone to be depleted before year end. Most dialysis patients are on a fixed income so that the part of the transportation cost the disabled patient pays often is more than he/she can afford. All these sources and grants from the Federal Transportation Agency are used to buy the para-transit vehicles.

A coordination problem between these agencies (dialysis units, patients, and para-transit operators) exists. The principal (dialysis clinic) cannot verify that the agent (para-transit authority) has behaved appropriately due to asymmetric information sharing. Another issue is that of risk sharing that arises when the principal and agent have different attitudes towards risk. Dialysis clinics and patients know that the dialysis treatment is necessary for patient survival. The paratransit operators are aware of this risk, yet they must transport many such patients under the scheduling and information difficulties noted above. The problem here is that the principal and the agent may prefer different actions because of these different risk preferences.

The provision of dialysis patient transit services presents an agency problem (Eisenhardt, 1989) where the local counties provide the paratransit, non-emergency paratransit vehicles, yet the funding sources include federal, state, and local resources. The county paratransit operator is the agent that provides the principal, the dialysis center, with the work of transporting dialysis patients to their centers under conditions of incomplete and asymmetric information. The agent (paratransit) collects riders in need of paratransit services for doctor appointments, dialysis appointments, and other transit needs. Scheduling pickups with a limited number of vehicles in counties creates scheduling and routing problems for the paratransit agencies who are expected to provide dialysis patients to the dialysis centers and other medical appointments at appointed times. Asymmetric scheduling information between the dialysis centers (principal) in a county, the para-transit authority (agent), and the patient's knowledge of his/her schedule is the focus of this research. If a patient is not ready for a paratransit pickup or a paratransit vehicle misses or is late for a dialysis patient pickup this can have a cascading effect on these inter-related actors for the para-transit schedule, to other patients, to the dialysis clinics, on to receiving reimbursement for this transport. This research identified ways to improve the communication flows particularly in rural areas with fewer scheduling technologies than the urban areas. Results of this field research and analysis have provided specifics on this information asymmetry and the resulting problems which provided specifics to the for-profit dialysis chains to provide support for communications/scheduling technology to improve the provision of dialysis transport. Thus, this research evaluated the asymmetric information flow between principals, agents, and patients in dialysis transport, and developed systems to make this information flow more efficiently in rural counties enabling optimal use of the paratransit vehicles.

Transit on Demand services transport patients who are classified as disabled under the Americans with Disability Act. Once enrolled in dialysis treatment, a patient is considered disabled and can receive paratransit, on demand services for their dialysis treatments. Besides transporting dialysis patients these paratransit vehicles also transport others covered by Medicaid and other disabilities including seniors who need transit to doctor's offices and for prescriptions. Besides these services, riders can request rides for Ride to Work programs and to senior centers for organized activities. Thus, the call centers for these county on demands transit services are receiving requests from the Department of Social Services for riders falling under their domain, from social workers at dialysis centers requests rides for dialysis patients who do not have other means for transit, and from individuals who will pay per ride for these services. The schedules for the day are set in the morning based on the requests or cancellations received the day before. When riders cancel on the day of travel then the dispatcher radios the driver. Sometimes the no-shows happen at pickup. This swirl of information occurs where the agent (paratransit) provides services for the principals (Department of Social Services, dialysis units, and riders) in transporting the riders to and from their destinations (Figure 2.)

Figure 2



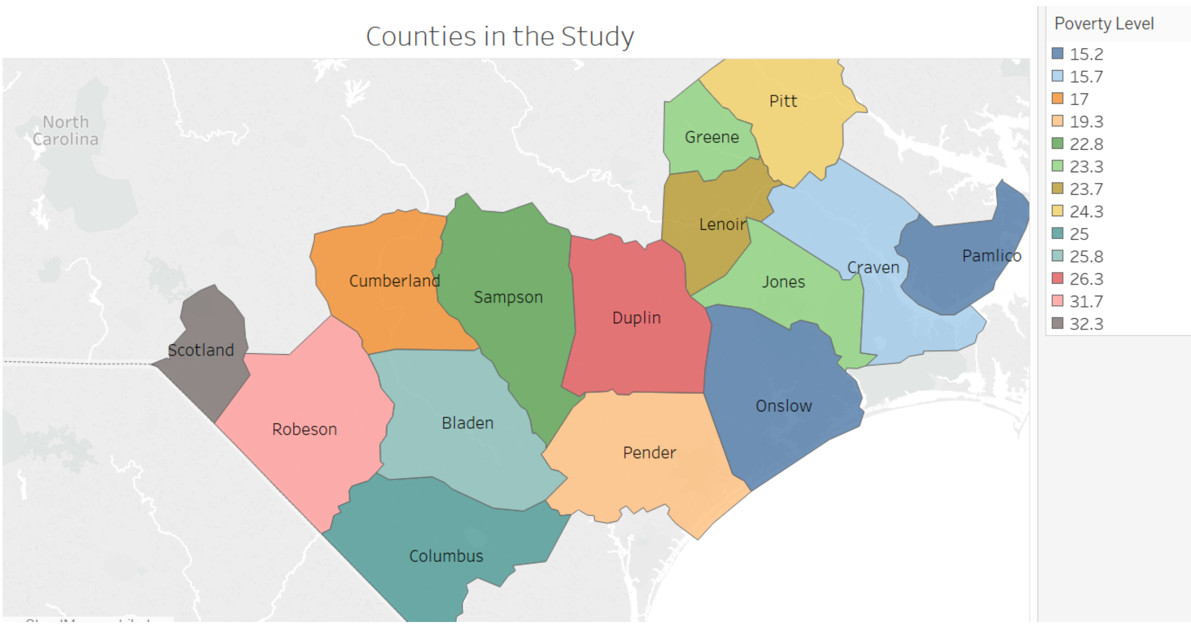
Service quality

Quality is illusive for services such as transportation service where the perception of service can be the results of many factors that influence the rider. While measurement of quality is illusive as noted by Crosby (1979) and Takeuchi and Quelch (1983), Parasuraman, Zeithaml, and Better (1985) showed that three dimensions of services are intangibility, heterogeneity, and inseparability. Since transit service depends on the quality of the ride delivered at that point in time, the service is an intangible delivery that satisfied the agreement between the rider and the transit provider and the nature of the quality of this intangible may vary from one rider to another. The second-dimension heterogeneity is supported in performance quality of the ride that varies from ride to ride. Since transit service is labor intensive, the interaction between the rider and the transit provider in the production of the transit service and its consumption is inseparable. Service quality is more difficult to evaluate than goods' quality as transit service involves both the outcome of the service (ride in a timely manner) and the process of obtaining and experiencing that ride. The physical quality consists of the aspects of the service such as the paratransit vehicle, the comfort of the seating while the interactive quality involves the timeliness of the pickup and delivery, the process of scheduling a delivery and pickup (Gronross, 1982). Parasuraman et al. (1985) note that the key determinants of service quality are reliability, responsiveness, competence, access, courtesy, communication reliability, security, understanding, and tangibles of the service.

APPROACH AND METHODOLOGY

The context for this research consists of 15 counties in the Eastern part of North Carolina. These counties are characterized by a high level of poverty and are in the “stroke” belt. Kidney failure is a related outcome of the hypertension in this area and results in a relative high demand for dialysis given the population of these counties. The counties are relatively rural and many of the counties have large land area.

Figure 3 Counties in the Study



The United States Census Bureau determines poverty status by comparing annual income to a set of dollar values called poverty thresholds that vary by family size, number of children and age of householder. If a family before tax money income is less than the dollar value of their threshold, then that family and every individual in it are in poverty. For people not living in families, poverty status is determined by comparing the individual's income to his or her poverty threshold. The poverty thresholds are updated annually to allow for changes in the cost of living using the Consumer Price Index (CPI-U). They do not vary geographically.

The ACS is a continuous survey and people respond throughout the year. Since income is reported for the previous 12 months, the appropriate poverty threshold for each family is determined by multiplying the base-year poverty threshold (1982) by the average of monthly CPI values for the 12 months preceding the survey month.

The service gap was determined from the perspective of the dialysis social workers in terms of the transit service provided to dialysis patient. The service gap items are shown in Table 1.

Table 1 Service Gap

1. Waiting list for transportation
2. Cost is prohibitive
3. Not operating on days needed
4. Center is not in the service are of the transportation provider
5. Patient is not in the service area of the transportation provider
6. Patient is not eligible to receive service from the transportation provider
7. Transportation provider doesn't transport non-ambulatory passengers
8. Patient needs more assistance than transportation provider provides
9. Center is too far from patient's home
10. Transportation provider's funding has all been spent

Responses to these questions were averaged to form the Service Gap for each county.

% Calls

The measures for the % of Calls from Social Services, from Dialysis Clinics, and from individuals not covered by Medicaid was obtained from each of the counties providing the On-Demand Transit Service. These percentages are based on the perception of the transit manager for a typical service day in each of the counties in Figure 3.

Trips per Square Miles

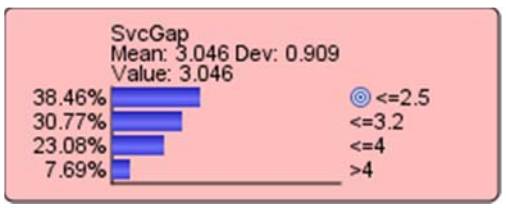
The number of dialysis trips per square miles were determined from trip data for each county. The number of rural trips per square miles were also determined from trip data for each county.

% Ambulatory and % Seniors

The % of riders not ambulatory and the % seniors were determined from conversations with the transit managers in each county.

Methodology:

In Bayesian analysis uncertainty is addressed in terms of entropy. Here the uncertainty relates to the service gap for paratransit services. Entropy will be used to quantify the uncertainty manifested in the probability distribution of the service gap and the factors impacting that service gap. We can compute the entropy from the marginal probability distribution of the service gap for the counties under study.



These discretization levels were defined in the data import. The definition of entropy for a discrete distribution is:

$$H(X) = -\sum (P(x)\log_2 P(x))$$

Entering the percentages from above for each service gap level, we obtain:

$H(SvcGap) = -(.3846 \times \log_2(.3846) + .3077 \times \log_2(.3077) + .2308 \times \log_2(.2308) + .0769 \times \log_2(.0769)) = 1.83$

In information theory, the unit of information is a bit, thus the use of base 2 for the log. To get a sense of how much or how little uncertainty 1.83 for Service Gap represents, we compare it to two entropy states: "no uncertainty" and "complete uncertainty". In no uncertainty the probability of one bin (or state) of SvcGap is 100%. Say the P(SvcGap <= 2.5 = 1. Then the entropy of this distribution would be:

$H(SvcGap) = -(1 \times \log_2(1) + 0 \times \log_2(0) + 0 \times \log_2(0) + 0 \times \log_2(0)) = \log_2(1) = 0$

This means that no uncertainty has zero entropy. Maximum uncertainty exists when all possible states of distribution are equally probable or a uniform

H(SvcGap) = -(.25 x $\log_2$ (.25) + .25 x $\log_2$(.25) + .25 x $\log_2$(.25) + .25 x $\log_2$(.25)) = 2.0

Bayesian networks are being widely used in machine learning (Ghahramani, (2015) where the naïve Bayesian classifier has produced some impressive results. The assumptions of naive Bayesian are that the predictive attributes are conditionally independent for the model and there are no latent attributes affecting the model. Bayes' theorem relates the conditional and marginal probabilities of events. If we have two events A and B and the probability of B is not zero, then:

$$P(A|B) = P(A)\ x\ \frac{P(B|A)}{P(B)}$$

P(A) is the prior probability where it is not conditioned on any information about B. P(A|B) is the conditional probability of A, given B. P(B|A) is the conditional probability of B given A. P(B) is the prior or marginal probability of B. $\frac{P(B|A)}{P(B)}$ is the Bayes factor known as the likelihood ratio.

Dynamic Bayesian networks can track variables whose values change over time by representing multiple copies of the state variables for each time step. Thus, using a Bayesian model at a given time period, the model can continue to receive data in later time periods and machine learn from the observations and adjust the network accordingly.

For the variables in this network for a time slice during the summer of 2018, we have:

$$P(c_1, x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8)$$
$$= P(c_1)P(x_1|c)P(x_2|c_1)P(x_3|c_1)P(x_4|c_1)P(x_5|c_1)P(x_6|c_1)P(x_7|c_1)P(x_8|c_1)$$

Where

$c_1 = Service\ Gap$

$x_1 = \%Not\ Amulatory$

$x_2 = \%Calls\ Social\ Services$

$x_3 = Poverty$

$x_4 = \%Seniors$

$x_5 = Dialysis\ Trips\ per\ Square\ Mile$

$x_6 = \%\ Calls\ NonMedicaid$

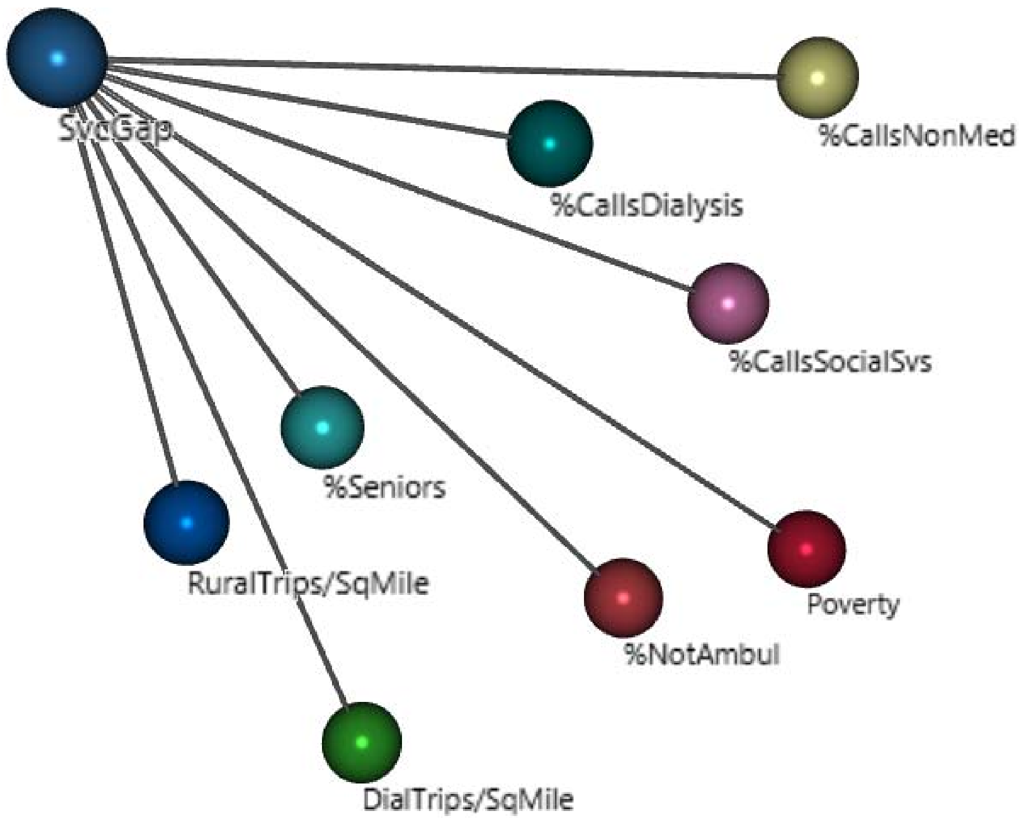
$x_7 = Rural\ Trips\ per\ Square\ Mile$

$x_8 = \%\ Calls\ Dialysis$

Here x_1 through x_8 are continuous variables and conditionally independent of each other (G^2 is not significant) so a Gaussian distribution was used for the attributes.

Naïve Bayesian analysis of the Service Gap against x_1 through x_8 produced the model in Figure 4.

Figure 4: Native Bayesian Model



From the Bayesian analysis, the mutual information was determined between the outcome variable (C) which represents Service Gap and one of the 8 predictor attributes x_i . The Mutual Information between C and x_i is:

$I\ (X, C) = H(X) - H(X|C)$ where H is entropy from the equation (#above)

Which is equivalent to :

$$I(X, C) = \sum_{x \in X} \sum_{c \in C} p(x, c) \log_2 \frac{p(x, c)}{p(x)p(c)}$$

Which is

$$I(X, C) = \sum_{c \in C} p(y) \sum_{x \in X} p(x|y) \log_2 \frac{p(x|y)}{p(x)}$$

This provides the Mutual Information between the target (Service Gap) and the predictors x_1 through x_8 as shown in Table 2.

Table 2 Service Gap

Nodes	Mutual Information Gain
SvcGap	
%CallsNonMed	0.4684
%Seniors	0.4136
RuralTrips/SqMile	0.4009
Poverty	0.3727
%CallsDialysis	0.3255
%CallsSocialSvs	0.2878
DialTrips/SqMile	0.2674
%NotAmbul	0.2188

FINDINGS, CONCLUSIONS, RECOMMENDATIONS

While this research is for one-time period, Bayesian can be used to not only address association but to examine causation in time series data. This research can be scaled to look at many transit systems over time to see if these relationships hold and to be able to make predictions. Bayesian can be learned from pure theory or learned from data.

Bayesian networks are probabilistic and handle uncertainty "natively". A Bayesian network can work with probabilistic inputs, probabilistic relationships, and deliver probabilistic outputs. Bayesian networks do not have to distinguish between independent and dependent variables. The Bayesian network represents the entire joint probability of the system studied. One can represent such a continuous distribution in terms of its mean and standard deviation.

This research has shown that information asymmetry is linked to the power of lower order participants. As Simon (1991) showed in decision making the individuals seeks a satisfactory solution rather than an optimal one. In agency theory the individuals in the agency are boundedly rational and the information is distributed asymmetrically between the riders and the dialysis clinics, Social Services, transit agencies.

Thus, this context of the agents to carry out the transit needs of the riders is a situation with many information linkages that need to be monitored for dialysis transit, doctor appointments, medicine refills, and senior center activities. Also, the goals of the agents differ and can vary with the demand for transit and the availability of resources and funding. This was shown in this research. Since agency theory assumes that individuals are boundedly rational and that information is distributed asymmetrically throughout the organization, the focus of this research has been to examine the optimal structuring of the information flows.

Information is a commodity in agency theory with an associated cost. To manage the information flows will require a call center to manage the information flows from Social Services, from dialysis clinics, and from riders. This investment in information systems will permit the control of agent opportunism providing a means to control this opportunism. Further research will focus on the call center which is the gateway to route scheduling using the inputs of riders, dialysis clinics, and social service agencies.

Positivists agency theory focus on identifying situations where the principal and the agent are likely to have conflicting goals and then describe governance mechanisms that limit the agent's self-serving or inefficient behavior. Governance mechanisms can help to address the agency problem. When the contract between the principal and the agent is outcome based, the agent is more likely to behave in the interests of the principal and information systems can be used to curb agent opportunism. The information system informs the principal about what this agent is doing making it easier to curb agent opportunism because the agent will realize that he or she cannot deceive the principal. So, a contract between principal and agent that is outcome based will result in the agent acting in the interests of the principal. When the principal has information to verify agent behavior the agent is more likely to behave in the interests of the principal.

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APPENDIX

Publications, presentations, posters resulting from this project:

[1] Lind, M. and Hensley, R. (2018). Public dialysis transport efficiency using digital media. Presentation at the Hawaii International Conference on System Sciences, Hilton Waikoloa Village, Big Island, Jan. 2-6.

[2] Lind, M. and Hensley, R. (2018). Public dialysis transport efficiency using digital media. Presentation to the North Carolina A&T State University College of Business and Economics Brownbagger's Group, Feb. 26., Greensboro, NC.

[3] Lind, M. (2018). Poster presentation on dialysis study. North Carolina Public Transit Association, April 22-23,Wilmington, NC.

[4] Lind, M. and Hensley, R. (2018). Asymmetric information sharing in dialysis paratransit using an agency approach. Presentation made at CATM Nov 5^{th}, Blacksburg, VA.

[5] Lind, M. and Hensley, R. (2018). Asymmetric information sharing in dialysis paratransit using an agency approach. Presentation made at Decision Sciences Institute meeting Nov. 18-19, Chicago, IL.