AN ANIMAL TRANSFER LOGISTICS SUPPORT TOOL

FINAL PROJECT REPORT

by

Jake Wagner and Danna Moore
Washington State University

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Pacific Northwest Transportation Consortium (PacTrans)
USDOT University Transportation Center for Federal Region 10
University of Washington
More Hall 112, Box 352700
Seattle, WA 98195-2700

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16. Abstract

To support shelter animal logistics managers, an animal transfer logistics support tool was developed. The tool is composed of two components: 1) a shelter animal allocator and 2) a multi-pickup delivery route scheduler. Together they serve to identify and recommend potential transfer partners for both sending and receiving shelters and to schedule optimal routes for a multi-pickup and delivery transfer vehicle. The tool is still under development, but the current version is freely available online: shelter-logistics-92bc55bb5399.herokuapp.com.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

On average 523,000 shelter animals (mostly dogs and cats) are transferred between shelters throughout U.S. each year. This transfer of animals is largely coordinated through a bootstrapped system of phone-slinging transfer managers, who seek to relocate animals from under-resourced or at-capacity shelters to shelters with space that can provide care and find a suitable home. Too often, however, animals are unable to be moved because of the costs and complex coordination associated with animal transfer logistics.

To support shelter animal logistics managers, this project developed an animal transfer logistics support tool. The tool is composed of two components: 1) a shelter animal allocator and 2) a multi-pickup delivery route scheduler. Together they serve to identify and recommend potential transfer partners for both sending and receiving shelters and to schedule optimal routes for a multi-pickup and delivery transfer vehicle. The tool is still under development, but the current version is freely available online: shelter-logistics-92bc55bb5399.herokuapp.com.

CHAPTER 1. INTRODUCTION

On average 523,000 shelter animals (mostly dogs and cats) are transferred between shelters throughout U.S. each year (Shelter Animal Counts). This transfer of animals is largely coordinated through a bootstrapped system of phone-slinging transfer managers, who seek to relocate animals from under-resourced or at-capacity shelters to shelters with space that can provide care and find a suitable home. Too often, however, animals are unable to be moved because of the costs and complex coordination associated with animal transfer logistics. The objective of this project was to improve the efficiency and availability of shelter animal transportation through a summary of current animal intakes, outcomes, and transfers; a review of animal transfer best practices; and the development of a shelter transfer logistics model.

CHAPTER 2. SHELTER ANIMAL INTAKES, OUTCOMES, AND TRANSFERS

In an average month, shelters record intakes of 138,392 dogs and 134,338 cats. These intakes vary seasonally with breeding cycles, especially for cats. Most intakes are Stray (49.5 percent), Relinquished by Owner (24.6 percent) or Transfer In (17.3 percent) animals from other shelters.

On average, shelters record outcomes of 138,747 dogs and 134,253 cats each month. Most outcomes are adoptions (56.5 percent), although Transfer Out animals represent 15.1 percent, and Euthanized animals represent another 11 percent of outcomes. These are the activities that transfer logistics tools can help to support.

Transfers also vary seasonally, especially for cats, to address seasonal intake volumes. In an average month, approximately 26,976 dogs and 19,664 cats are transferred between shelters. For each state, Net Transfers—the difference in the number of animals transferred in and the number of animals transferred out—are calculated to understand the originations and destinations of transfers. States with more Transfers In than Transfers Out represent destinations for transfer animals, whereas states with more Transfers Out than Transfers In represent origins for transfer animals.

In an average month, Virginia transfers in 1,726 more animals than it transfers out, Colorado transfers in 1,611 more animals than it transfers out, Illinois transfers in 1,585 more animals than it transfers out, and Washington transfers in 1,029 more animals than it transfers out.

In an average month, Texas transfers out 2,230 more animals than it transfers in, California transfers out 1,271 more animals than it transfers in, Tennessee transfers out 898 more animals than it transfers in, and Louisiana transfers out 786 more animals than it transfers in.

Figure 2.1 shows total monthly Intakes and Outcomes from 2018 to 2022. Figure 2.2 shows the share of U.S. Intakes by category from 2018 to 2022. Figure 2.3 shows the share of U.S. Outcomes by category from 2018 to 2022. Figure 2.4 shows total monthly Transfers In and Transfers Out from 2018 to 2022. Figure 2.5 shows a map of net transfers across the U.S.

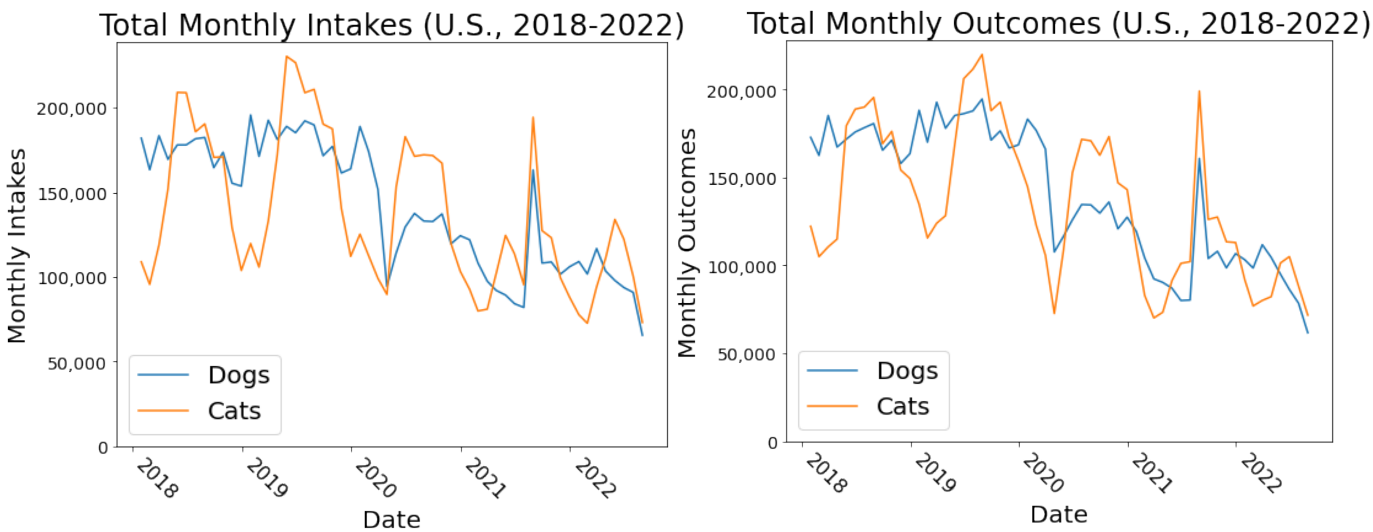

Figure 2.1 Monthly Intakes and Outcomes

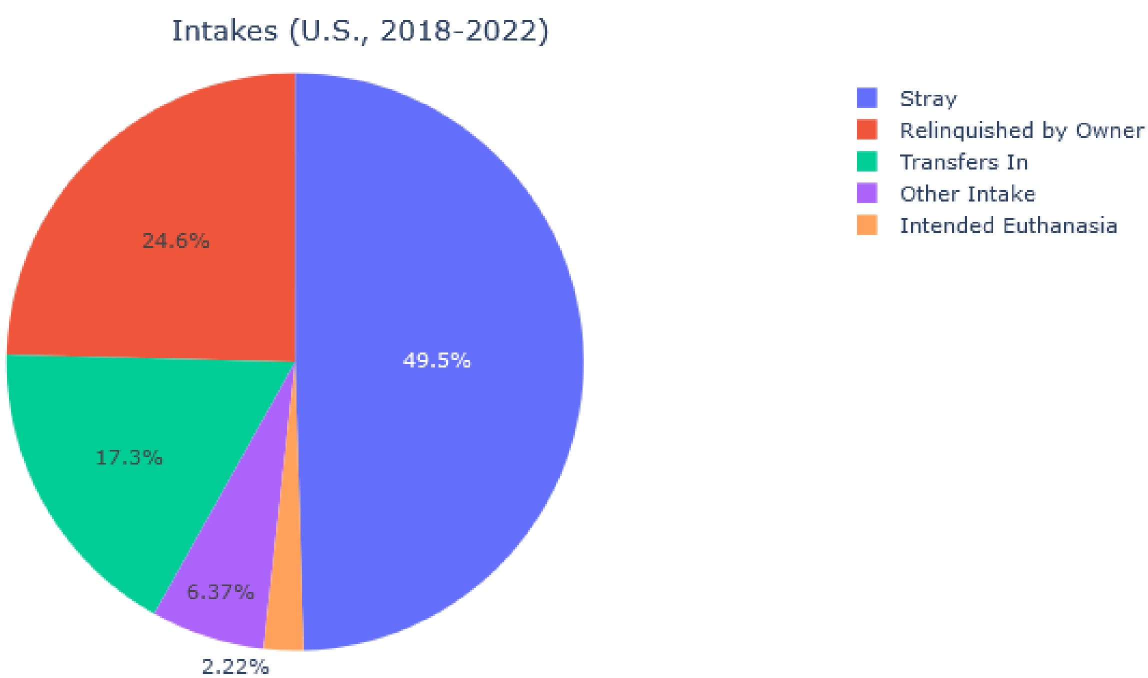

Figure 2.2 Share of Intakes by Type

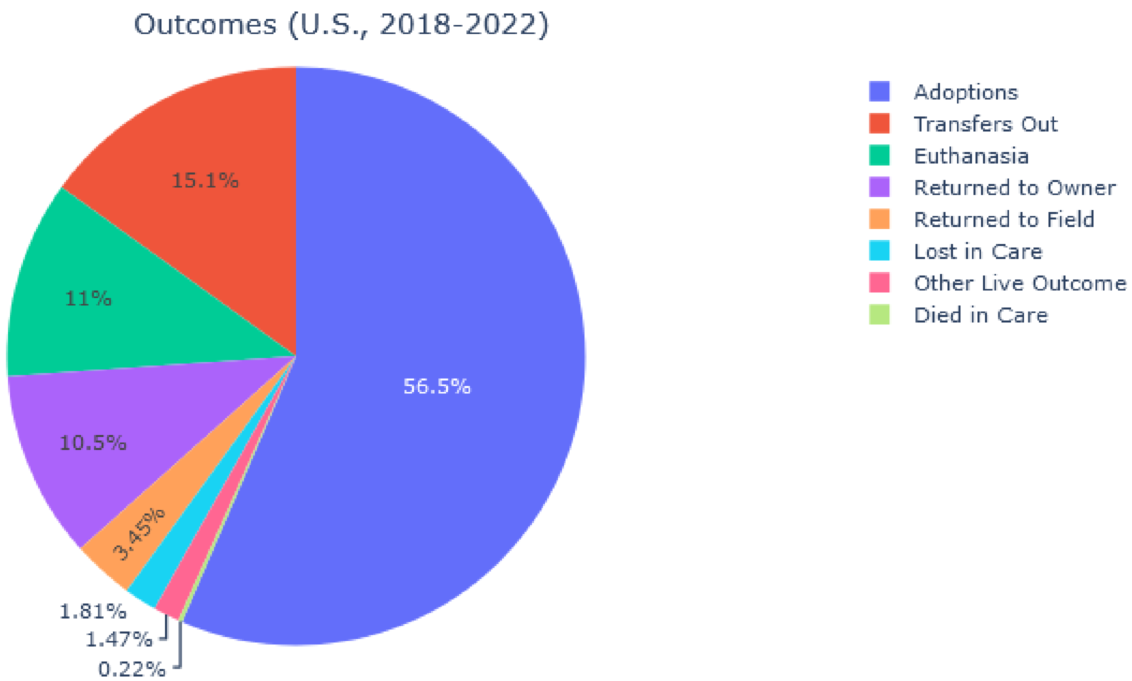

Figure 2.2 Share of Outcomes by Type

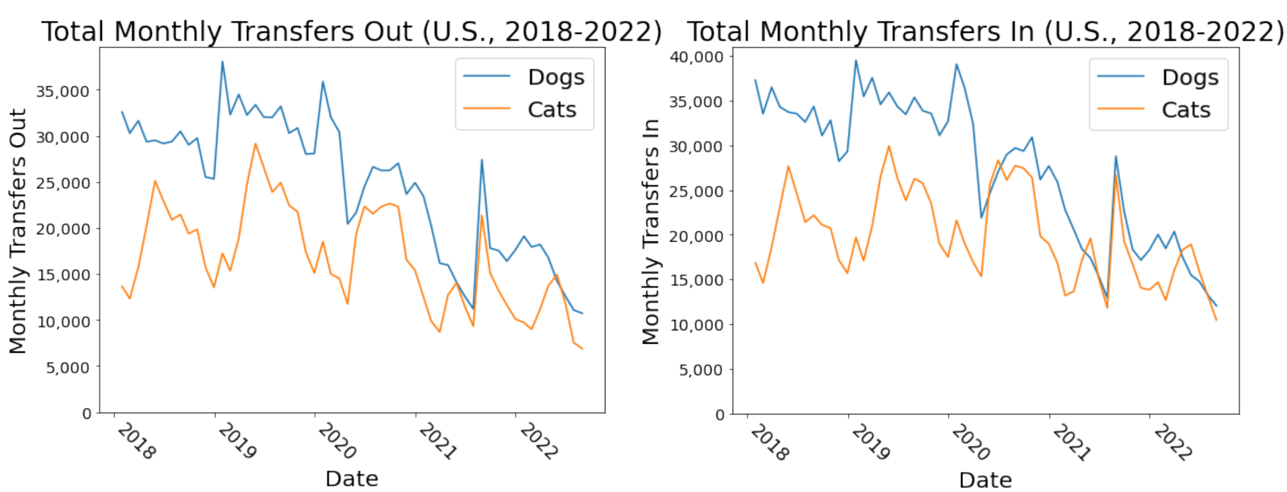

Figure 2.3 Monthly Transfers In and Transfers Out

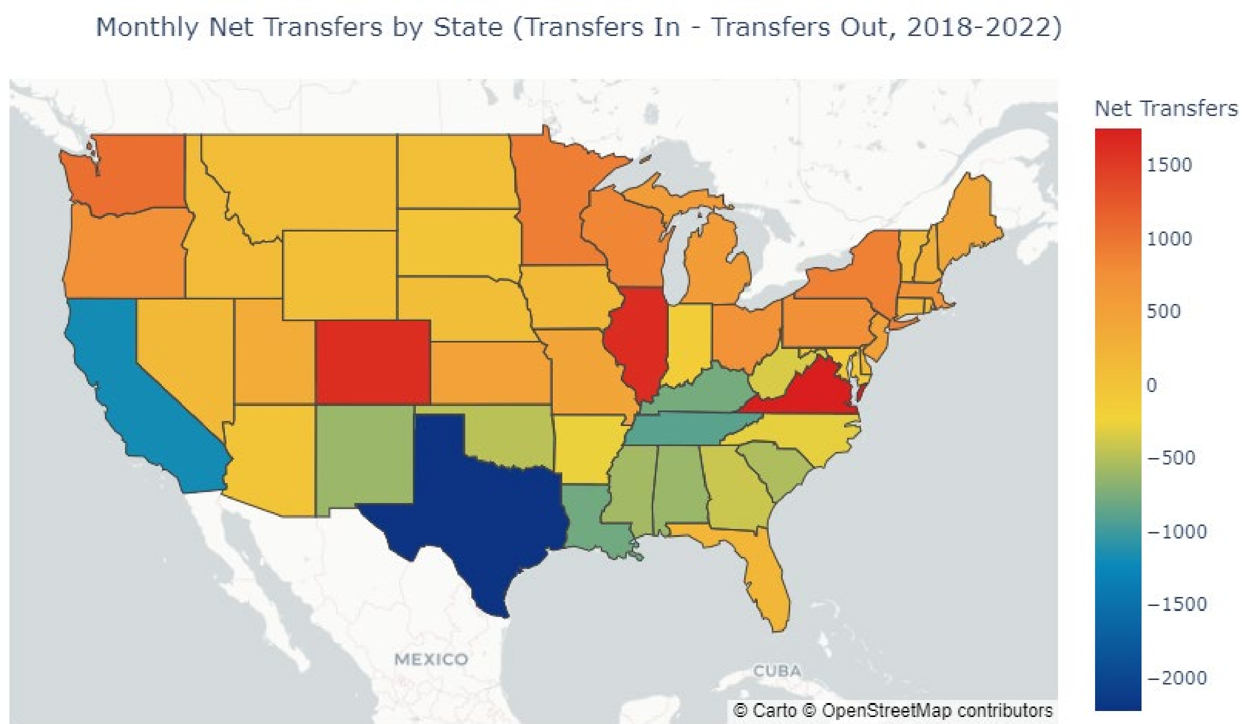

Figure 2.4 Net Transfers

CHAPTER 3. LITERATURE REVIEW: CURRENT AND BEST PRACTICES

Several previous studies have shed light on current and best practices in shelter animal transport. Collectively these studies offer insight into adoption demand, transfer allocation, animal health, spread of disease, and transport program design. The findings and recommendations from each study are synthesized below.

Simmons and Hoffman (2016) aimed to understand the factors that shelters consider when they conduct long-distance animal transfers. Because of regional differences in demand and preference, the authors argued that such programs are an important means for improving adoption and euthanasia rates (p. 1). The authors conducted a nationwide survey of animal shelter staff regarding transport logistics and animal selection to understand these decisions.

Key concerns in animal transfer logistics identified by survey respondents (Simmons and Hoffman (2016)) included funding, shelter space, and transportation arrangements, with almost half of surveyed organizations noting that the receiving entity is responsible for funding transfers (p. 5). Criteria for dog selection included factors such as breed, age, and size, with breed being the most significant consideration, often influenced by organizational focus and local legislation (pp. 5-6). Although medical requirements lacked uniformity, a majority of organizations enforced quarantine periods and specific medical treatments, although some had no such policies in place (p. 7).

Simmons and Hoffman (2016) found that while organizational partnerships play a crucial role in animal transfers, over half of the respondents stated that their organization had terminated relationships with other shelters, with many citing concerns about deception regarding the behavioral and medical needs of transferred dogs. Despite these challenges, most organizations expressed positive sentiments about transfer programs, seeing them as a means to better serve communities and improve outcomes for shelter dogs (p. 9). However, opinions varied on health risks, with 30 percent perceiving a strong risk of the spread of disease, highlighting the need for a more standardized approach to medical requirements to enhance animal safety (p. 10).

Kreisler et al. (2022) measured the influence of adopting suggested "best practices" for the live release rates of shelter animals. The authors examined the implementation of animal-centric policies at Memphis Animal Services (MAS) to document their impact. The policies enacted by MAS included a focus on managed strategic intake, implementation of a pet owner safety net, the return of stray cats to the field post neutering, shifting the focus of animal control officers, and reducing barriers to pet adoption. By tightening criteria for surrendering animals while providing support to struggling owners, the new intake policy and owner safety net reduced the fiscal burden on shelters while empowering owners to keep their pets (p. 3). The return of stray cats to where they were found also reduced the burden faced by shelters, allowing them to free space for other animals while increasing the odds for lost owned cats to be found (p. 8). MAS was also able to increase adoption rates through the elimination of certain adoption requirements such as home checks (9).

Kreisler et al. (2022) argued that shifting the focus of animal control officers is an important step in improving animal welfare outcomes at shelters. They pointed to the long distances that animal control officers can transport animals as a major hurdle to owners finding lost pets, and the potential fines faced by owners caused them further hardship (p. 4). By prioritizing the reuniting of lost animals with their owners, officers were able to improve outcomes for lost animals while also reducing the numbers of animals at the shelter (8). Kreisler et al. (2022) further suggested the creation of separate teams to handle non-emergency visits to allow animal control officers to prioritize emergency calls (p. 8).

Bradley and Rajendran (2021) evaluated the drivers of the duration that animals stayed in shelters. They pointed to the overabundance of animals at shelters as a key driver of unwanted outcomes such as euthanasia and argued that by creating a model to predict the duration of stay for animals, they could reduce these unwanted outcomes (p. 1). The researchers identified robust predictors of an animal's duration of stay through their models. Notably, very young or old age, larger or smaller size, and a multicolored coat emerged as strong indicators, enhancing the accuracy of length-of-stay predictions (p. 4). Conversely, factors such as gender, animal type, middle age, colors other than multicolor, and medium size did not exert a significant influence on the duration of stay (p. 5).

Johnson and Cicirelli (2014) analyzed the impacts of a policy adopted by San Jose Animal Care and Services (SJACS) to neuter feral cats and return them where they were found rather than euthanize them. Because of the large number of cats entering local shelters, upwards of 70 percent of intakes were euthanized in 2009 (1). The Shelter Neuter Return policy (SNR) was adopted to reduce the number of feline intakes, rate of euthanasia, and reproductive ability of feral cats. While the expense of this program was approximately $72 per cat, Johnson and Cicirelli (2014) credited it with reducing overall shelter expenses by decreasing the cat population in the shelter by 3,000 per year (8). Furthermore, it allowed for more positive outcomes for captured felines by allowing them to return to where they were caught rather than be euthanized, with the euthanasia rate decreasing to 3.4 percent for healthy feral cats (9). With these successes, the authors recommend the implementation of similar programs in other communities that wished to reduce the cost and quantity of feral cats, noting comparable results for such programs in Florida and New Mexico (p. 15).

Reese (2022) explored the relationship between outcomes for shelter animals and the types of communities they were in. They argued that just as the socioeconomic conditions of a community can affect the type of animal shelters found in that community, the type of animal shelter can affect outcomes for the animals they care for (p. 1). These types of animal shelters were categorized as municipal versus nonprofit, and open versus limited intake. The author also noted the differences in outcome based on how the animals arrived, observing that animals brought in by animal control officers tended to stay longer and face a higher likelihood of euthanasia (p. 3).

Reese (2022) found that communities with lower education levels or that faced higher amounts of economic stress were more likely to be served by municipal shelters. These municipal shelters were associated with a higher intake of strays and a higher euthanasia rate (p. 10). Conversely, nonprofit shelters were associated with increased amounts of animals relinquished by owners and a decreased euthanasia rate (p. 11). Additionally, their increased capacity resulting from their ability to choose their intakes allowed them to receive more animals from transfer programs, reducing the burden on over-capacity shelters while further reducing euthanasia rates (p. 12).

To address these issues, Reese (2022) suggested deepening cooperation between nonprofit and municipal shelters. While large numbers of animals are already transferred from municipal to nonprofit shelters, this could be expanded to include more animals with medical or behavioral needs (p. 14). This shift could be accompanied by spay/neuter programs, allowing shelters to spread the burden of animals that need extra care while reducing overall capacity (p. 14). Finally, community programs focused on increased access to veterinary and support services could sever the link between low-income communities and negative outcomes for shelter animals (p. 15).

Jacobson et al. (2020) highlighted the potential risks of heartworm spread from inter-shelter dog transfers. While these transfers are useful for reducing euthanasia or handling natural disasters, they carry the risk of transferring disease. Heartworm, in particular, may pose an issue in these programs because of the high rates of discordance in heartworm testing results between transferring programs (p. 2). To better understand the prevalence of this disease, testing was conducted on shelter dogs in a low prevalence region of Ontario, Canada, to see the rates of infection in each area from which dogs were transmitted.

From their results, Jacobson et al. (2020) found that much of the disagreement between shelters on heartworm testing stemmed from the use of different kinds of tests (3). When both shelters used antigen tests, there was 91 percent agreement between their test results, but when one shelter used antigen testing while the other used microfilaria tests, the rate of differing results greatly increased (4). Based on these findings, the authors suggested that shelters focus on improving testing and preventative care capabilities. Additionally, more strategic testing of received animals could ensure that the cost and risks of incoming dogs is more accurately reported (p. 6).

DiGangi et al. (2021) analyzed the risk of the spread of parvovirus in puppies that undergo long-distance transport. Disease spread is an important concern in animal relocation programs, and as the authors argued, it is especially important for puppies because of their overrepresentation in such programs (p. 2). By tracking the outcomes of puppies transported by the American Society for the Prevention of Cruelty to Animals, the authors looked to identify factors that may affect the risk of parvovirus.

DiGangi et al. (2021) found that rates of parvovirus infection were higher in younger puppies, with those 12 weeks or younger more likely to be diagnosed than puppies 13 to 19 weeks old (p. 4). Surprisingly, they found no link between the number of days from intake to transfer or number of vaccinations received to the risk of infection (pp. 6-7). Additionally, the number of days between vaccination and transport also showed no effect (p. 7). These findings led the authors to conclude that the receipt of at least one modified live virus vaccination and implementation of thorough sanitation and quarantine procedures are the most effective ways to prevent the spread of parvovirus (p. 9)

Anderson et al. (2019) investigated the potential for spread of diseases from the translocation of dogs. This movement can range from a family moving abroad and bringing their pets, to the import of a dog for commercial purposes such as breeding or competition, to the movement of animals from less reputable institutions such as puppy mills (p. 3). Risks can arise from the method through which these animals are transported, as the health screening and care provided to animals can vary greatly. In some cases, animals may face overcrowding, insufficient removal of animal waste, and other stressors that can increase the risk of infectious diseases (p. 5). While this can pose risks to the animals through the potential spread of disease, it can also affect individuals involved in the transport if they come in close contact with an animal infected with a zoonotic disease such as rabies (p. 5).

Because of these risks, Anderson et al. (2019) recommended taking action to mitigate the chances of disease spread. While they acknowledged that enforcing mandatory health screening for all transported animals may be infeasible, they argued that educating stakeholders motivated by a desire to help—such as the public, shelters, and veterinarians—may allow for these groups to take steps individually to reduce these risks (p. 10). Furthermore, increased pressure from these groups, as well as regulations imposed by various levels of government, may motivate those who are more profit-driven to comply with these measures to stay in business (p. 11).

DiGangi and Walsh (2022) provided insight into the logistics and proper care of animals during transport. This included considerations related to animal relocation programs, which aim to balance population discrepancies between areas of high demand and high supply (p. 1). Ensuring the proper preparation and operation of vehicles is key for the safe transport of animals. While organizations with a small number of animals may rely on volunteers driving their personal vehicles, those that consistently move a larger population may need to operate a specified vehicle. This could be a commercial vehicle owned by the shelter or a third-party service. Proper outfitting is crucial, including sufficient kennels, ventilation, and emergency access (p. 7). Standard operating procedures must be established to outline the type of vehicle, distance, routes, driving standards, and emergency plans. Drivers should receive training in first aid and safety equipment usage (p. 7). For additional peace of mind, a contract with a towing company or a secondary vehicle that follows the primary transport can help in emergencies (p. 8).

Monitoring and ensuring the well-being of animals during transport is essential (DiGangi and Walsh (2022)). Monitors for carbon monoxide, temperature, and humidity should be utilized to track animal wellness (p. 10). Using pheromone sprays, calming music, and safe, edible enrichment can help occupy animals during the journey (p. 12). Shelters must also carefully time the vaccination of transported animals, considering factors such as health history and available resources during travel and at the destination shelter (p. 17).

Addressing behavioral health and special cases is crucial in animal transport programs (DiGangi and Walsh (2022)). Animals selected for transport should be able to be easily handled by multiple people and capable of withstanding the stress of transport (p. 19). While sedatives may be considered to reduce animal stress during transport, caution must be exercised in their implementation (p. 22). Because of a significant proportion of puppies and kittens, transfer programs should implement accommodations and protocols for the care of juvenile animals, including housing un-weaned animals with their mother and providing adequate bedding for insulation (p. 23). In the case of transporting feral cats, the use of a covered cage is recommended to reduce animal stress (p. 23).

Garrison and Weiss (2014) conducted a comprehensive survey to examine respondents' preferences and considerations when adopting dogs. Although over half expressed a willingness to consider a shelter dog, only 39 percent eventually adopted from shelters (p. 9). The survey revealed that 40 percent of respondents were willing to drive more than 60 miles to obtain their preferred dog, with those preferring breeder-sourced dogs showing greater willingness to travel than shelter adopters (p. 11). Nearly half of the participants emphasized the importance of animal shelters offering a diverse range of dog types (p. 13).

Garrison and Weiss (2014) found the source of adoption and the dog's age to be the most critical factors, outweighing considerations such as risk, breed, and color (pp. 12-13). Positively viewed traits included puppies and shelter-sourced dogs, while seniors and pet store-sourced dogs were perceived more negatively (p. 13). Additionally, almost half of respondents said they would delay adoption until finding their preferred dog, suggesting the potential for revisiting shelters facilitated by animal relocation programs (p. 14). The survey underscored that shelters with a greater dog variety are more likely to align with adopters' preferences, and this emphasized the positive impact of animal relocation programs for boosting shelter traffic and adoptions (pp. 15-16).

CHAPTER 4. TRANSFER LOGISTICS SUPPORT TOOL

To support shelter animal logistics managers, the researchers developed an animal transfer logistics support tool. The tool is composed of two components: 1) a shelter animal allocator, and 2) a multi-pickup delivery route scheduler. Together they serve to identify and recommend potential transfer partners for both sending and receiving shelters and to schedule optimal routes for a multi-pickup and delivery transfer vehicle. The tool is still under development, but the current version is freely available online: shelter-logistics-92bc55bb5399.herokuapp.com.

4.1. Shelter Animal Allocator

The shelter animal allocator is designed to efficiently allocate animals from sending shelters to receiving shelters. The allocator identifies a set of recommended transfers between sending and receiving shelters that is based on shelter capacity constraints, transfer demand, and travel costs. This recommended set of transfers minimizes travel costs while meeting shelter transfer demand for each shelter within the user-specified region.

The recommended allocation is identified by solving a system cost minimization problem subject to supply and demand constraints:

$$\min_{v(o,d)} \sum_{o,d} v(o,d) * c(o,d),$$

where $v(o,d)$ is the number of animals transferred from origin, o, to destination, d, and $c(o,d)$ are the travel costs from origin, o, to destination, d,

subject to:

$$\sum_{d} v(o,d) \leq S(o),$$

$$\sum_{o} v(o,d) \geq D(d),$$

where the first constraint ensures that the number of animals transferred from the origin shelter do not exceed the number of animals available, and the second constraint ensures that the number of animals transferred to a receiving shelter do not exceed intake capacity.

4.2. Multi-Pickup and Delivery Route Scheduler

Given a set of transfers, the multi-pickup and delivery route scheduler identifies the optimal driving schedule for pickup and deliveries. This scheduler can be used either by individual shelters to optimize their pickup and delivery scheduling or collaboratively within a region to maximize the efficiency of shelter animal transfers. The user can define the set of transfers to be made, the starting location of the vehicle(s) (depot), and the capacity of the vehicles. Then optimal routes are identified on the basis of user inputs and travel costs. The output is a pickup and delivery schedule that minimizes total travel costs subject to meeting transfer demand and vehicle capacity constraints.

The pickup and delivery problem is solved by modifying the Google OR-Tools Vehicle Routing with Pickups and Deliveries solver (https://developers.google.com/optimization/routing/pickup_delivery) to allow for multiple visits. Multiple visits allow total transfers to or from each shelter to exceed vehicle capacity. The objective of the scheduler is to minimize total travel costs while meeting paired pickup delivery requests and satisfying all scheduling constraints. Scheduling constraints include the following:

- total animals in the vehicle cannont exceed vehicle capacity,
- pickups from a source shelter must be picked up before delivery,
- upon pickup, animals can only be delivered to their delivery pair,
- total route distance cannot exceed a user-specified distance,
- no animal can travel more than twice the shortest distance between its origin and destination shelters.

4.3. Support Tool in Action

An example of the transfer logistics support tool is provided below. Here we have used the allocator to identify transfer partners within Washington state. The tool identifies optimal transfer partners among shelters that have animals available to be transferred, and the suggested quantity of animals to be transferred between each shelter (Table 4.1). The recommended transfer partners and transfers are the outcome of the system cost minimization problem.

Table 4.1 Transfer Allocator Example from Washington State

Origin	Destination	Species	Value
EVERETT ANIMAL SERVICES	PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY	Dogs	36
HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY	REGIONAL ANIMAL SERVICES OF KING COUNTY	Dogs	1
HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY	SEATTLE HUMANE	Dogs	14
HUMANE SOCIETY OF JEFFERSON COUNTY WA	CAMANO ANIMAL SHELTER ASSOCIATION	Dogs	1
JOINT ANIMAL SERVICES	HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY	Dogs	1
JOINT ANIMAL SERVICES	KITSAP HUMANE SOCIETY	Dogs	4
KITSAP HUMANE SOCIETY	SEATTLE HUMANE	Dogs	4
NORTH BEACH PAWS	PAWS OF GRAYS HARBOR	Dogs	1
NORTH BEACH PAWS	SOUTH PACIFIC COUNTY HUMANE SOCIETY	Dogs	1
PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY	HOMEWARD PET ADOPTION CENTER	Dogs	1
REGIONAL ANIMAL SERVICES OF KING COUNTY	SEATTLE HUMANE	Dogs	7
SEATTLE HUMANE	MOTLEY ZOO ANIMAL RESCUE	Dogs	16
SPOKANE HUMANE SOCIETY	SPOKANIMAL	Dogs	7
SPOKANIMAL	SPOKANE HUMANE SOCIETY	Dogs	1
WHATCOM HUMANE SOCIETY	ANIMAL PROTECTION SOCIETY FRIDAY HARBOR	Dogs	6
WHATCOM HUMANE SOCIETY	HUMANE SOCIETY OF SKAGIT VALLEY	Dogs	1
WHATCOM HUMANE SOCIETY	THE NOAH CENTER	Dogs	18

Then an optimal schedule can be identified to satisfy monthly pickup and delivery needs for dogs within Washington based on output from the allocator. The user can select the starting and ending points (depot) for each route; for this example we selected Seattle Humane. The user can also select the vehicle capacity ; for this example we selcted a vehicle capacity of 15 dogs. Using these parameters, and the set of transfers recommended by the allocator, the pickup and delivery problem is solved. The optimal schedule, shown in Table 4.2, involves two routes, each starting and ending at Seattle Humane and travelling a combined distance of 1,301 miles.

Table 4.2 Transfer Scheduler Example from Washington State

Start route from SEATTLE HUMANE
Pickup 10 dogs from SEATTLE HUMANE - 10 Animals in vehicle
Deliver 10 dogs to MOTLEY ZOO ANIMAL RESCUE - 0 Animals in vehicle
Pickup 1 dogs from HUMANE SOCIETY OF JEFFERSON COUNTY WA - 1 Animals in vehicle
Deliver 1 dogs to CAMANO ANIMAL SHELTER ASSOCIATION - 0 Animals in vehicle
Pickup 5 dogs from WHATCOM HUMANE SOCIETY - 5 Animals in vehicle
Deliver 5 dogs to THE NOAH CENTER - 0 Animals in vehicle
Pickup 10 dogs from WHATCOM HUMANE SOCIETY - 10 Animals in vehicle
Deliver 6 dogs to ANIMAL PROTECTION SOCIETY FRIDAY HARBOR - 4 Animals in vehicle
Deliver 4 dogs to THE NOAH CENTER - 0 Animals in vehicle
Pickup 10 dogs from WHATCOM HUMANE SOCIETY - 10 Animals in vehicle
Deliver 1 dogs to HUMANE SOCIETY OF SKAGIT VALLEY - 9 Animals in vehicle
Deliver 9 dogs to THE NOAH CENTER - 0 Animals in vehicle
Pickup 6 dogs from EVERETT ANIMAL SERVICES - 6 Animals in vehicle
Deliver 6 dogs to PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY - 0 Animals in vehicle
Pickup 10 dogs from EVERETT ANIMAL SERVICES - 10 Animals in vehicle
Deliver 10 dogs to PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY - 0 Animals in vehicle
Pickup 10 dogs from EVERETT ANIMAL SERVICES - 10 Animals in vehicle
Deliver 10 dogs to PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY - 0 Animals in vehicle
Pickup 10 dogs from EVERETT ANIMAL SERVICES - 10 Animals in vehicle
Deliver 10 dogs to PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY - 0 Animals in vehicle
Pickup 1 dogs from PAWS PROGRESSIVE ANIMAL WELFARE SOCIETY - 1 Animals in vehicle
Deliver 1 dogs to HOMEWARD PET ADOPTION CENTER - 0 Animals in vehicle
Pickup 1 dogs from SPOKANIMAL - 1 Animals in vehicle
Pickup 7 dogs from SPOKANE HUMANE SOCIETY - 8 Animals in vehicle
Deliver 1 dogs to SPOKANE HUMANE SOCIETY - 7 Animals in vehicle
Deliver 7 dogs to SPOKANIMAL - 0 Animals in vehicle
Pickup 2 dogs from NORTH BEACH PAWS - 2 Animals in vehicle
Deliver 1 dogs to PAWS OF GRAYS HARBOR - 1 Animals in vehicle
Deliver 1 dogs to SOUTH PACIFIC COUNTY HUMANE SOCIETY - 0 Animals in vehicle
Pickup 4 dogs from JOINT ANIMAL SERVICES - 4 Animals in vehicle
Pickup 5 dogs from HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY - 9 Animals in vehicle
Deliver 4 dogs to KITSAP HUMANE SOCIETY - 5 Animals in vehicle
Pickup 4 dogs from KITSAP HUMANE SOCIETY - 9 Animals in vehicle
Deliver 9 dogs to SEATTLE HUMANE - 0 Animals in vehicle
End route at SEATTLE HUMANE

Start route from SEATTLE HUMANE
Pickup 1 dogs from JOINT ANIMAL SERVICES - 1 Animals in vehicle
Pickup 1 dogs from HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY - 2 Animals in vehicle
Deliver 1 dogs to HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY - 1 Animals in vehicle
Pickup 9 dogs from HUMANE SOCIETY FOR TACOMA and PIERCE COUNTY - 10 Animals in vehicle
Deliver 1 dogs to REGIONAL ANIMAL SERVICES OF KING COUNTY - 9 Animals in vehicle
Deliver 6 dogs to SEATTLE HUMANE - 3 Animals in vehicle
Pickup 7 dogs from REGIONAL ANIMAL SERVICES OF KING COUNTY - 10 Animals in vehicle
Deliver 6 dogs to SEATTLE HUMANE - 4 Animals in vehicle
Pickup 6 dogs from SEATTLE HUMANE - 10 Animals in vehicle
Deliver 6 dogs to MOTLEY ZOO ANIMAL RESCUE - 4 Animals in vehicle
Deliver 4 dogs to SEATTLE HUMANE - 0 Animals in vehicle
End route at SEATTLE HUMANE

CHAPTER 5. CONCLUSION

Improvements in shelter animal transfer logistics can offer cost savings, improve animal welfare, and increase access to shelter animals for adoption. At the root of the tool developed in this work is collaboration and coordination among shelters. This of course is complicated, and it requires increased access to data to improve planning and efficiencies. For example, the proposed transfer allocator tool relies on information about transfer supply, demand, and capacity at each shelter, which requires updated data.

The transfer logistics support tool provided here is still a work in progress, and therefore it can benefit from many improvements. An updated stream of data needs to be acquired to make the transfer allocator useful. The transfer allocator may also need to include additional constraints on transfer volumes, for example, information that shelters cannot send more than 10 animals to the same shelter within any given month. Additional constraints in the scheduler are also being considerind, including limitations on the total distance of each route and limitations on the amount of time any one animal must spend in transit.

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