

System Dynamics Modelling for hidden family homelessness - A case study in Fort Collins, Colorado

by

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Thesis

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ABSTRACT

Family homelessness is a long-lasting social problem and causes widespread concerns in the United States and throughout the world. Substantial efforts have been made to lift the homeless families out of the vulnerable situation and into opportunities. Despite that the outcomes of these efforts were very remarkable, it is argued that the population size of the hidden homeless families (HHF) - families living temporarily in someone else's residences - are growing. These HHF have not received enough attention from the public and, therefore, lack resources to overcome the housing difficulty. In this study, by focusing on the City of Fort Collins, Colorado, I applied the System Dynamics Modelling approach in order to 1) unravel the factors that resulting in the growing number of HHF, 2) predict possible changes of the HHF population size in the future under the "business-as-usual" scenario and the "budget-reduction" scenario, and 3) propose feasible strategies in the form of a policy model to address the problem. The results suggested that the increase of the stock of HHF can attributed to the unbalance between its total outflow (mainly constrained by the capacity of the assistance programs, especially the availability of the housing choice vouchers and the number of landlords willing to participate in the assistance program) and its total inflow (mainly influenced by the number of evicted families that resulted from the rent burden and the adverse events for individuals). The number of HHF was predicted to increase at the same level under the two scenarios, but the second scenario is expected to have more pronounced effect on the families that are receiving vouchers. Based on the behaviour analysis, a particular strategy, increasing available vouchers by raising private funds, were designed in the model with a "wishful thinking" link to "connect the desired flow with the target flow", and simulation results suggested that the HHF number will decrease as a result of the implementation of the strategies. This study concludes with a discussion of the implications for relevant public policies.

Keywords: system dynamics, hidden family homelessness, tenant-based housing choice vouchers, federal budget cuts

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1. INTRODUCTION

1.1. Background Information

Homelessness is a long-lasting social problem and causes widespread concerns in the United States and throughout the world. When mentioned the homeless, most people may stereotype them as people sleeping and panhandling on the streets, wearing tattered, and experiencing substance abuse or mental illness. It is true that some homelessness, especially the chronic ones, fit this stereotype, but most of them are actually not. One representative of these non-obvious homelessness is the families with children, which typically refer to those households consist of at least one adult and one child under the age of 18 “lack a fixed, regular, and adequate nighttime residence”.

1.1.1 What is the number of homeless families?

Family homelessness is a fast growing group of the homelessness population. According to the Annual Homeless Assessment Report (AHAR) based on the one-night Point-in-Time count (PIT), the number of people in homeless families represent over one-third of the total homeless population (Henry et al., 2016). These homeless families are no different from poor families but just have no roof over their heads (M Shinn, 2009; M. B. Shinn, Rog, & Culhane, 2005).

1.1.2 How do families become homeless?

Several reasons have been suggested to lead to the homelessness. Wolch, Dear, and Akita (1988) concluded that the five most common causes of homelessness are eviction, discharge from an institution, loss of a job, personal crisis (including divorce or domestic violence), and removal of monetary or nonmonetary welfare support. Gould and Williams (2010) illustrated that family homelessness is a consequence of poor economic conditions and insufficient social welfare supports. Hartman & Robinson (2003) and Wood-Boyle (2015) argued that the tenant eviction, mostly due to the nonpayment of rent, is highly related to homelessness. Brush, Gultekin, and Grim (2016) argued that domestic violence is one of the primary causes of housing instability and homelessness for many people especially women and girls. There are also several studies pointed out that the lack of affordable housing¹ is one of the most dominant factors leading to homelessness in the United States (Marybeth Shinn & Weitzman, 1994; Marybeth Shinn et al., 1998).

¹ In general, housing is considered affordable if it costs no more than 30 percent of a household's income.

For children in the homeless families that have to move frequently, the unstable and overcrowded living situation always means a disruption of their routines as well as their relationships with teachers and friends and have long-term negative effects on these children when they transition to adulthood (Park, Metraux, & Culhane, 2005; Schmitz, Wagner, & Menke, 2001).

1.1.3 What efforts can help the homeless families?

Substantial efforts have been made to lift those homeless families with children out of the vulnerable situation and into opportunities. Homeless shelters are places providing beds and foods to avoid those homeless families staying on the streets, and this measure was proven to be not cost-effective (Letiecq, Anderson, & Koblinsky, 1998). Rent assistance and project-based transitional housing were designed to give those families short-term assistance and relevant services to help them overcome the housing crisis (2002). For long-term solutions, there are some existing programs designed to support these families, such as the housing subsidy mainly in the form of the Housing Choice Vouchers (HCV), and the community-based rapid rehousing and the permanent supportive housing (Gubits et al., 2015). Among these programs, the HCV program is proven to be one of the most effective interventions (Gubits et al., 2015; Sard, 2001).

The HCV program, formally known as Section 8, is the largest rental assistance program of the federal government (Ellen, Center, & Wagner, 2017). There are two different types of HCV in the United States: one is the tenant-based vouchers (TBV) and the other is the project-based vouchers (PBV). Both TBV and PBV are government-funded programs that provide subsidy to low-income households in privately owned rental housing. Families with TBV or PBV just need to pay ~30% of their income for the housing rent, and the vouchers will pay the rest. The difference is the portability of the vouchers. The TBV subsidy is tied to the voucher holder, the assistance is portable, meaning it may be used within the jurisdiction where the family lives or within any jurisdiction with an HCV program, while the PBV subsidy is tied to the building, meaning families moving out of a housing will lose the rental assistance.

The HCV program was demonstrated to be very effective in reducing family homelessness in the US. For example, Wood et al. (2008) concluded that the HCV dramatically reduced homelessness, crowding, household size, and the incidence of living with relatives or friends, and resulted in small improvements in neighborhood quality. Similarly, Gubits et al. (2015) suggested that the families received the HCV

experienced less homelessness than those offered other assistances. In addition, this work also revealed that families assigning HCV resulted in significant reductions in child separations, domestic violence, psychological distress, food insecurity, and school mobility. Although both the TBV and the PBV have positive impacts, there are some evidence suggesting that the TBV is more effective than the PBV and is the most prevalent form of housing assistance provided. For example, Turner (1998) concluded that the TBV offers better locational outcomes than the PBV because the TBV supplements what low-income families and individuals can afford to pay for housing in the private market. This assistance can help poor families move out of distressed inner-city neighborhoods to neighborhoods that offer better opportunities and quality of life.

1.2. Problem Formulation

1.2.1 The Ignored Hidden Family Homelessness

As a result of efforts mentioned above, achievements were very remarkable toward ending family homelessness (Khadduri, 2008). According to the PIT count, many programs were put into practice and the number of homeless families decreased these years as a consequence (Henry et al., 2016). However, it is argued that such one-night count underestimates the number of homeless families because it is only cover the families that are temporarily sheltered and that are living on streets and a larger amount of families is hidden from the public attention (Brush et al., 2016). This argument was supported by numerous studies showing that most at-risk or homeless families seek informal shelters (i.e. double-up and move frequently through unstable housing situations), and shelters are taken as their last resort only if they run out of their social network (Brush et al., 2016; Elliott, Young, & Dye, 2011; Mihaly, 1991; Marybeth Shinn, Knickman, & Weitzman, 1991; Simmons, 2017). These families are called the hidden homeless families (HHF) - families living temporarily in someone else's residence - and are as vulnerable as those in emergency shelters (Watson, Crawley, & Kane, 2016).

Because of the difficulty to pinpoint neither the magnitude of the general hidden homeless families nor the families with children, we still do not have a complete figure of them (Brush et al., 2016; Mihaly, 1991). However, we could estimate a big number for them based on some indirect data sources. In the United States, the National Alliance to End Homelessness reworked the data released from the Department of Housing and Urban Development (HUD) in 2014 and estimated that about 7 million

people in poor households living doubled-up in 2014, while only about 640,000 people were surveyed in that year's PIT count, and the number has been increasing since 2005, as shown in Fig. 1-1 (*The state of homelessness in America, 2016*).

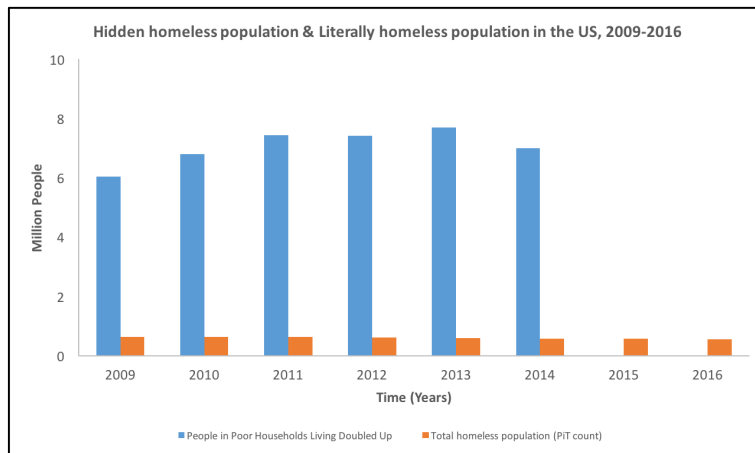


Fig. 1-1. The number of people living doubled-up and the number of total homeless population surveyed in the PiT count in the US, 2009-2016. Source: the data were retrieved from the State of Homelessness in America (2016), while no data are available regarding the number of people living doubled-up in the year of 2015 and 2016.

In order to get deeper understanding about the dynamics of the HHF population, I selected the City of Fort Collins (FC) in the state of Colorado, US as the main study area of this thesis. FC is located in Northern Colorado and is the most populous municipality of Larimer County. It is a mid-sized college city with a 2016 estimated population of 164,207 (data retrieved from American Fact Finder <https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF>) and is home to Colorado State University. FC ranks the 11th of the happiest city in America and attracts thousands of people selecting FC as their choice city (accessible at <http://247wallst.com/special-report/2017/03/07/the-happiest-and-most-miserable-cities-in-america-3/4/>).

Despite of its good reputation, the amount of HHF is also very considerable locally in FC. It is surprising to see that there is an above-average poverty rate in the city and there are still 0.19% of its total population who do not have a roof over their heads (Fig. 1-2).

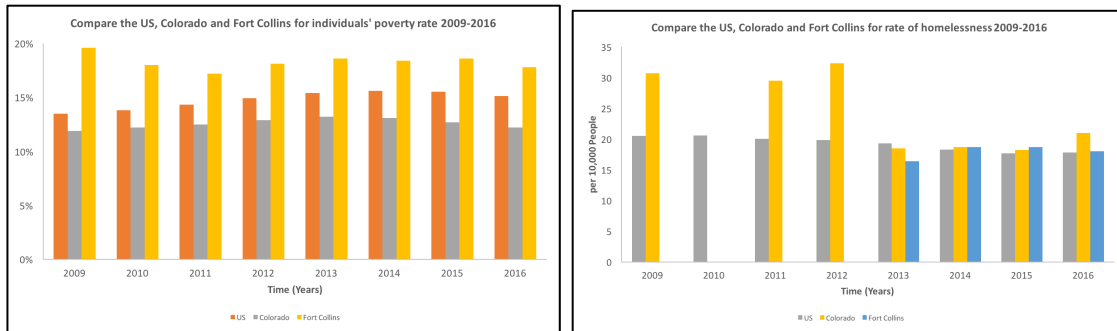


Fig. 1-2. Individuals' poverty rate and the rate of homelessness per 10,000 people in the US, in Colorado and in the City of Fort Collins. Source: U.S. Census Bureau, 2011-2015, 2012-2016 American Community Survey 5-Year Estimates, Homeward 2020², and the 2016 state of homelessness in America. Note: Data regarding the homeless rate in Fort Collins from 2009 to 2012 are not available yet.

Based on the Homeless Education data³ released by the Colorado Department of Education for the McKinney-Vento Education for Homeless Children and Youth (EHCY) Program, about 1110 school children were homeless among its total enrollments of 29,527 in the Poudre School District (PSD)⁴ in the 2015-16 school year, and about 80% of the homeless children are staying doubled-up with friends or other family members (CDE, 2016). This population size remained stable from 2009 to 2016. When excluding 13% of those who are unaccompanied and assuming an average of 1.7 children per family, and adjusted by a 93% proportion of school children in FC, we could estimate that over 400 families annually are experiencing housing crises in FC (Fig. 1-3). This estimation is supported by the sharply increased caseloads (from 98 in the year of 2010 to 2,135 in 2016) of Matthews House that serves families and children at risk of becoming homeless in Colorado (Kyle, 2017a).

² Homeward 2020 is a community dedicated “to make homelessness rare, short-lived, and non-recurring” in Fort Collins.

³ Children and youth in doubled-up situations are considered homeless under the education definition only if they are sharing the housing of others due to loss of housing, economic hardship, or a similar reason.

⁴ PSD, the 9th largest school district in Colorado, encompasses several communities including Fort Collins, Laporte, Timnath, Wellington, Red Feather, Livermore, Stove Prairie, and parts of Windsor.

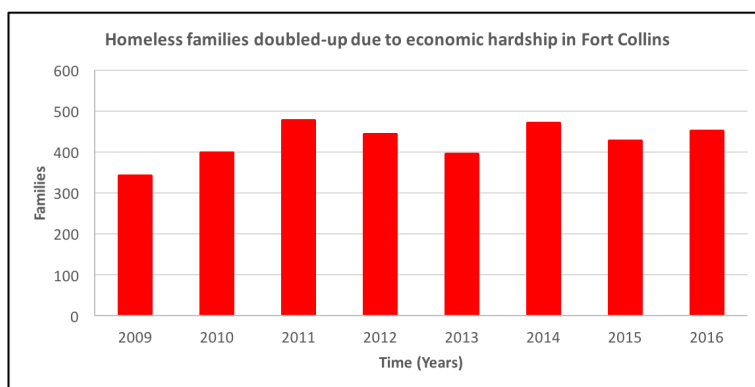


Fig. 1-3. Estimated number of homeless families in Fort Collins doubled-up due to economic hardship. Data Source: estimated from the Homeless Education data produced by the Colorado Department of Education (CDE, 2016).

Despite these large numbers, the HHF have not received enough attention from the public, probably because of either their invisibility or their number is not included by HUD as a prerequisite to receive federal funds. Although doubled-up children and their families are considered homeless under the McKinney-Vento Homeless Assistance Act, this only gives them equal right to education but not qualify them for funding from HUD. As a result, the HHF lack resources to overcome the housing difficulty (Brush et al., 2016; Mihaly, 1991). It is believed that without taking the HHF into account, it is unlikely for FC to meet its goal of ending homelessness by the year of 2020, because the HHF are the main sources of the most vulnerable and visible literally homeless families (LHF)⁵ (*The state of homelessness in America*, 2016).

1.2.2. The federal budget cuts in the United States

Aiming at “spending precious taxpayer dollars only on the highest priorities, and always in the most efficient, effective manner”, the Trump Administration announced the proposed 2018 Budget for HUD in May, 2017. Overall, the budget is 13.2% lower than the 2017 level (OMB, 2017). Based on the analysis of the Affordable Housing Online, the FC would lose \$903,616 per year for HCV, which means 85 homeless families will be affected.

In response to the budget cuts, several agencies planned to take strategies to make their ends meet. According to the research by the Affordable Housing Online, if these

⁵ The literally homeless families define those families that lack a fixed, regular, and adequate nighttime residence, meaning: (1) has a primary nighttime residence that is a public or private place not meant for human habitation; (2) is living in a publicly or privately operated shelter; (3) is exiting an institution where (s)he has resided for 90 days or less and who resided in an emergency shelter or place not meant for human habitation immediately before entering that institution.

reforms were implemented, it is possible that all households benefiting from the program would pay substantially more for housing, even though they would not lose their voucher completely. In FC, the tenant contributions of the voucher holders will be increased from 30% of income to 35%. In addition, tenants would not receive reimbursement for tenant-paid utilities.

The deep federal budget cuts stirred up concern that these unanticipated cuts would devastate thousands of families and communities nationwide in several ways. Firstly, it will obviously downsize the capacity of HCV and dramatically decrease the number of new voucher receivers. Secondly, it is predicted to decrease the administrative expenses of the Public Housing Authorities (PHA) that in charge of the HCV issue and make the process slower. Thirdly, it will also reduce the willing of landlords to rent houses to voucher holders and, therefore, weaken the successful public-private partnership on which the program is based (CBPP, 2017; CITYLAB, 2017).

Therefore, I believe it is necessary and urgent to have a clearer figure of the number of the HHF, unravel the factors leading to the increase of them and have a numerical understanding about how could the fund cuts on TBV influence the number of homeless families, and thus get better preparation for this change and allocate far greater, dedicated resources to lift them up.

1.3 Research Questions

In this study, by focusing on FC, I aimed to get more understanding about the following three questions:

- 1) Why did the number of HHF increase over the past years?
- 2) How will the number of the HHF change under the following scenarios?
 - a. “Business-as-usual” scenario: the scenario when the HHF are not given enough attention as currently.
 - b. “Budget-reduction” scenario: the scenario if the federal funding cuts come into effect.
- 3) What are the feasible solutions to address the hidden family homelessness?

The three questions could be presented by Fig. 1-4.

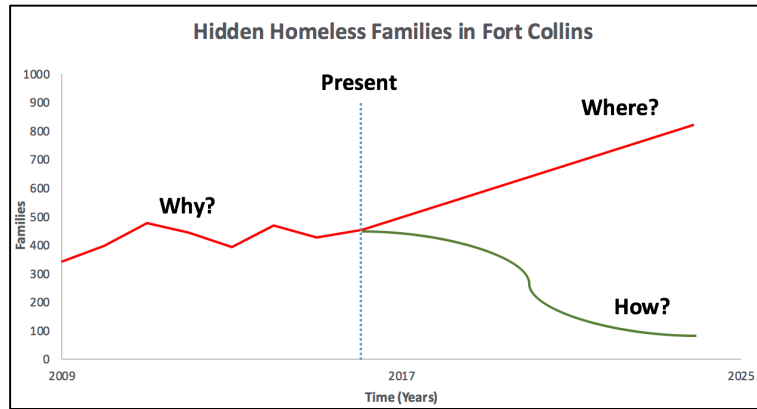


Fig. 1-4. A diagram of the three basic questions in the field of system dynamics (adaptation from Warren (2002)). Note: The problematic dynamic behavior is the increasing number of hidden homeless families. It serves as a reference mode for the modeling. Fig. 1-4 begins in the year 2009 and extends to the year 2025. The number of HHF from 2009 to 2016 was estimated from some indirect data, and the number from 2017 to 2025 is just an example. This time period seems reasonable given the funding allocation delay and the time-consumed landlord pool expansion process.

2. METHODS

As described in the Introduction section, family homelessness is a complex and dynamic systems problem that cannot be solved with static solutions. These problems require adaptive, real-time approaches to intervention and measurement. System dynamics (SD) is a computer simulation modeling method for understanding and alleviating complex systems that change over time. The method uses stocks, flows and feedback concepts to focus our attention on the endogenous feedback structures that give rise to the dynamic behavior in a system (Fig. 2-1), and uses a simulation model to illustrate behavior in that system (Ford, 2010; Sterman, 2000).

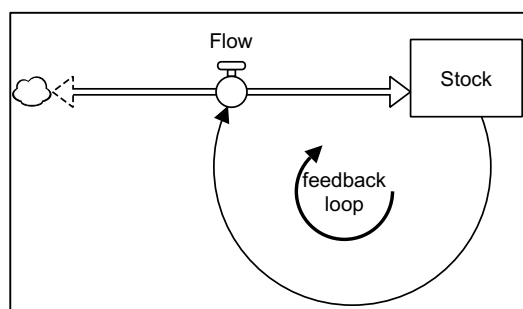


Fig. 2-1. Simple stock and flow structure. Stocks represented by rectangles are the variables in which quantities accumulate over time. Flows represented by arrows and valves are the variables adding to or subtracting from the stocks. Feedback loops denote the causal relationships among the variables.

The SD approach provides a practical way to help policy makers gain insights into the dynamics of social problems. Basically, it involves two steps: 1) building and testing an explanatory model to explain the reasons for the problematic dynamic behavior of the system; and 2) designing and testing a policy model that could be integrated with the explanatory model to alleviate the problem (Wheat, 2010).

In this study, a simulation model was built using the program of Stella Architect, version 1.5 from the Isee Systems Inc. I firstly presented structures with simple stocks and flows to have a grasp of the key factors leading to the increased trend of HHF in FC. Secondly, the model was tested both empirically and theoretically in order to represent the real system and gain more confidence in the underlying structures, and simulation results were analyzed to decipher why the model produced such behaviors. Thirdly, based on the validated structures, the simulation model was run under two scenarios to see how the number of HHF will change. Fourthly, two proposed strategies were designed in the model with “wishful thinking” link to “connect the desired flow with the target flow” (Wheat & Shi, 2011), and simulation results were analyzed to check if the number of HHF shows expected results of the proposed wishful thinking. Finally, this study ended with discussion about the policy implications.

3. QUALITATIVE MODEL

This part presents the qualitative assumptions regarding the three questions to be addressed.

3.1 Why did the number of HHF increase?

It is hypothesized that the stock of HHF is affected by five flows: the evicted families (EF) doubling up with relatives/friends, the HHF entering temporary shelters, the families in temporary shelters becoming HHF again (HHF repeating), the HHF receiving tenant-based vouchers and the HHF receiving other assistances (e.g. the transitional housing, the rapid re-housing, the project-based vouchers or the rental assistance). The two inflows (“EF doubling-up” and “HHF repeating”) add to the stock of HHF while the three outflows (“HHF entering shelters”, “TBV assisted HHF” and “HHF receiving other assistance”) are subtracted from the stock (Fig. 3-1). Therefore, to explain the behavior of the HHF population, I need to understand what causes a change in the flows.

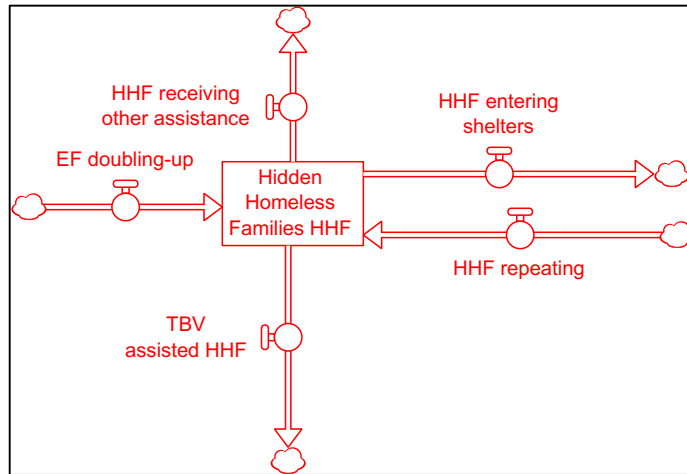


Fig. 3-1. Key stock and flows related to the reference mode. Note: The rectangle represents a stock of families, while the thick arrows and cloud symbols represent flows of families.

3.1.1 What causes the “EF doubling-up” (inflow) to change?

Given the reasons mentioned in the Introduction section and based on the relatively stable evictions shown in Fig. 3-2, I hypothesized that the inflow of “EF doubling-up” in FC is mainly affected by the stock of the evicted families. The stock of EF is mainly influenced by the number of cost-burdened families (CBF) that resulted from the stagnant wages and the rising housing price (Fig. 3-3).

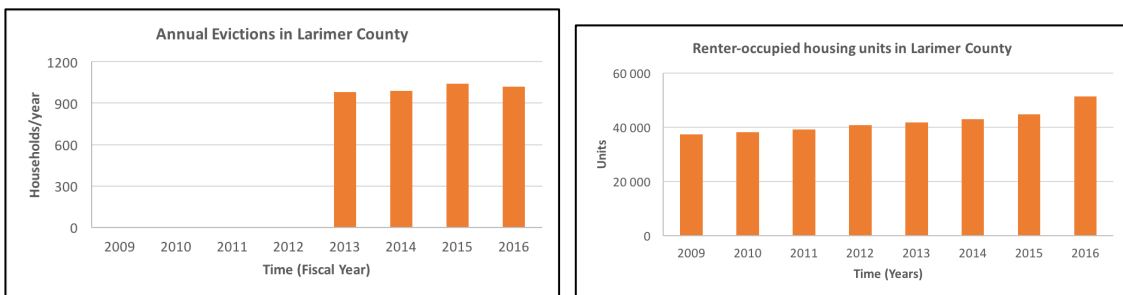


Fig. 3-2. Annual evictions and renter-occupied housing units in Larimer County. Data source: Colorado Judicial Branch Annual Statistical Report and the U.S. Census Bureau, 2010-2015 American Community Survey 5-Year Estimates. No data is available regarding the evictions in Larimer County from 2009 to 2012. The annual eviction rate that defined as the proportion of evictions to total renters was stable at about 2% over the last years.

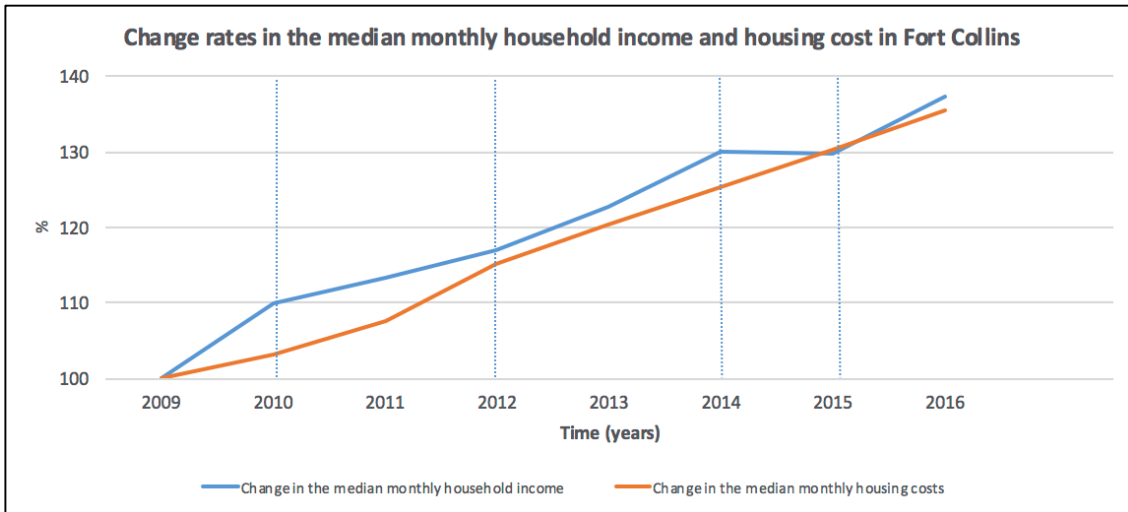


Fig. 3-3. Changes in the median rent and median renter income in the City of Fort Collins, 2009-2016. Note: The inflation-adjusted median monthly rent in FC increased slower than the inflation-adjusted renters' median income from 2009 to 2010, then rent increased faster than the income from 2010 to 2012. From 2012 to 2014, both increased at a similar speed. From 2014 to 2015, the income did not change a lot while the rent increased about 4%. From 2015 to 2016, the household income increased slightly faster than the housing cost. Source: the rate of change was calculated from the U.S. Census Bureau, 2006-2010, 2011-2015 and 2012-2016 American Community Survey 5-Year Estimates. During the years when housing costs increase faster than the household income, the rent took a bigger bite out of renters' monthly income, leaving less money for other expenses like car payments, health care, food and entertainment in recent years. As a result, more renters in FC were forced to spend more than 30 percent of their income on rent, meaning they are living in places they can't comfortably afford (Ferrier, 2016)

This hypothesis could be represented by the following structure (Fig. 3-4).

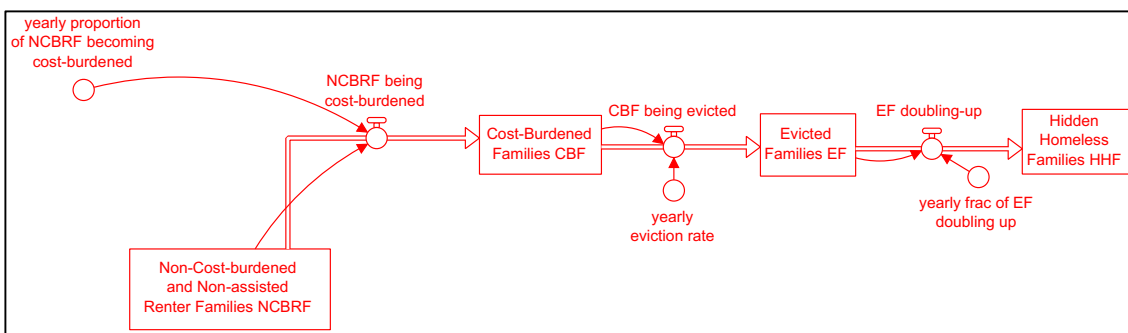


Fig. 3-4. Key factors influence the inflow (“EF doubling up”) of the HHF stock.

3.1.2 What causes the “HHF entering shelters” (outflow) and “HHF repeating” (inflow) to change?

The “HHF entering shelters” could be controlled by many factors, e.g. the temporary shelter capacity, the willingness to move to shelters, the regulation of the shelters and so on. Considering the FC is committed to shelter every family with children either by adding mats for overflow or providing them with motel vouchers whenever they apply

and the temporary shelters are not long-term solutions, the capacity of temporary shelters and details of all other factors were not explicitly considered in this study. The “HHF entering shelters” is set as proportional to the stock of HHF. The “HHF repeating” is thought to be influenced by the stock of literally homeless families and the average length-of-time in shelters. Increasing the length-of-time families are allowed to stay in the temporary shelters could reduce the stock of HHF, but it is not a long-term solution and, therefore, not explicitly considered. As shown in Fig. 3-5, the “yearly frac. of HHF entering shelters” and the “avg. length-of-time shelters” are exogenous parameters in this study (Fig. 3-5).

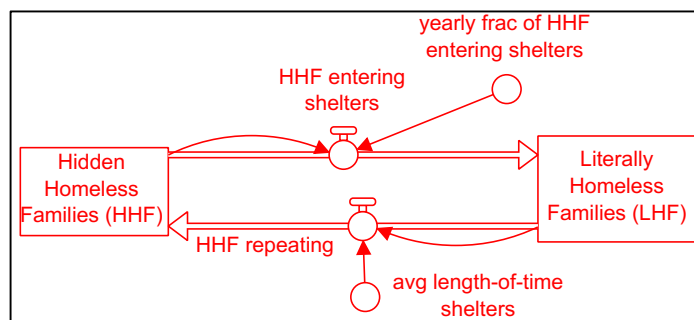


Fig. 3-5. Factors influence the “HHF entering shelters” and the inflow of “HHF repeating”.

3.1.3 What causes the “TBV assisted HHF” and “HHF receiving other assistance” (outflows) to change?

If there is no assistance to help the at-risk or homeless families, which means they have no chance to get rid of the vulnerable situation, the number of the HHF is expected to increase to an extremely high level. However, as mentioned in the Introduction section, there are various existing programs that could help the homeless families. Since the TBV program is proven to be the most effective (Gubits et al., 2015), I will pay more attention on the TBV program among all assistances.

As shown in Fig 3-6, although the number of families receiving vouchers increased stably from 2009 to 2016, it is reported that the demand for housing vouchers far outnumbers its supply, and the door has been closed to those in need of a housing voucher in Fort Collins since 2004 (Kyle, 2015). This shortage reduces local agencies' abilities to help those in need through the program.

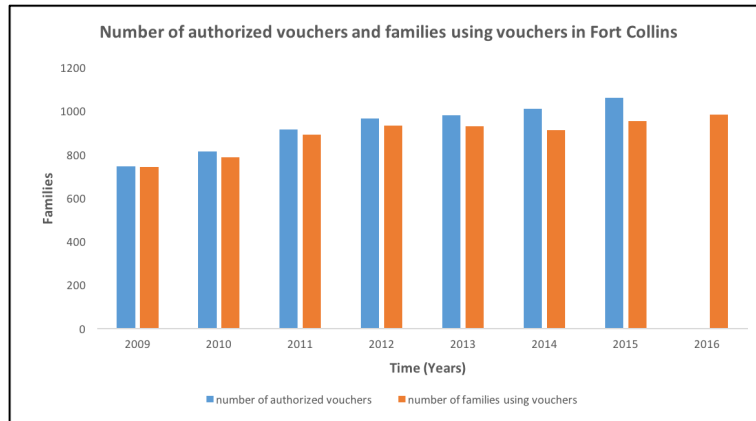


Fig. 3-6. Number of total authorized vouchers and vouchers in use in Fort Collins. Data retrieved from <https://www.cbpp.org/research/housing/national-and-state-housing-fact-sheets-data>.

The number of TBV in use is not only affected by the number of vouchers but also by the amount of available rental units that are willing to accept the voucher (Fig. 3-7). In this study, the availability of the voucher units⁶ and the available TBV are endogenous in order to reveal some important feedback structures that are expected to be responsible for the behavior of the system.

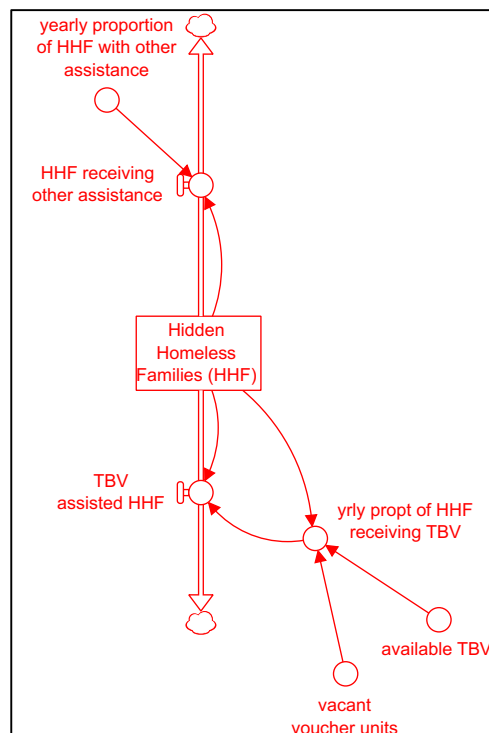


Fig. 3-7. Factors influence the “TBV assisted HHF” and “HHF receiving other assistance”.

To recreate the problem of increased HHF population, the total annual inflows must outweigh the total yearly outflows (Fig. 3-8). In order to answer the first question- why

⁶ By “voucher units”, this study refers particularly to the rental housing of those landlords that are willing to accept vouchers.

the number of HHF increased over the past years- it is necessary to understand why the outflows were less than the inflows. To answer the second question- how the number of HHF population will change- we need to know the development of the inflows and the outflows under the two scenarios. To address the third question, we need to think about what factors could influence the inflows or the outflows.

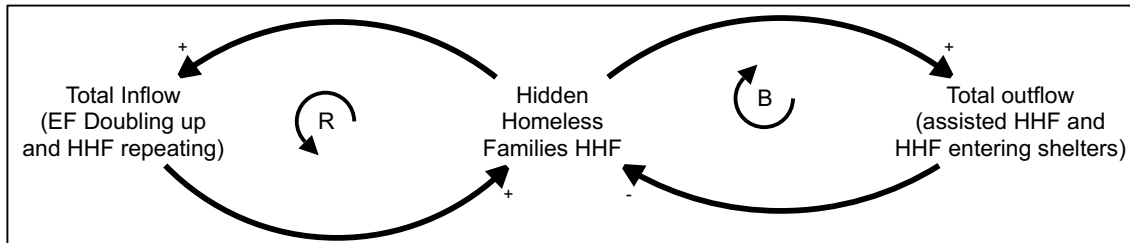


Fig. 3-8. Causal loop diagram (CLD) of family homelessness system highlighting the model’s essential feedback structure. Note: Arrows with add signs (+) indicate positive causal influences and arrows with minus signs (-) indicate inverse causal influences. B1, B2, and B3 represent balancing feedback loops and R1 denotes a reinforcing feedback loop.

3.2 How will the number of HHF change under different scenarios?

a. “Business-as-usual” scenario:

It is hypothesized that, without new strategies, the rent burden, the adverse events, the lack of available vouchers and the short of voucher units will make the inflow larger than the outflow and thus increase the amount of HHF population.

b. “Budget-reduction” scenario:

Three potential effects of the federal budget cuts are discussed in this study. Firstly, the budget cuts will decrease the TBV capacity and thus reduce the issuable vouchers to the at-risk or homeless families; Secondly, it will reduce the administrative fee, as a result less money could be invested to expand the landlord pool; Thirdly, to address the funding shortfall, the Housing Catalyst⁷ is expected to reduce the subsidy standard. Although this strategy makes sure that the families who are living in the assisted housing will not lose their assistance, reducing the actual subsidy will lead to an increase in TBV tenants’ contribution of rent and lengthen their time of accessing the TBV. As a consequence, other families have to wait a longer time to be assisted.

3.3 What feasible strategies could reduce the HHF population?

Based on the above analyses, any policy that focus either on reducing the inflow of the

⁷ The Housing Catalyst is the largest affordable housing developer and property management company in Fort Collins and one of the top performing housing authorities in the country.

stock of HHF or on increasing the outflow of the stock is helpful. To decrease the number of HHF, the total outflow need be larger than the total inflow.

3.4 Model Boundary

Given the purpose of this study, by listing which variables are included endogenously, which are exogenous, and which are excluded from the model, a model boundary is set to help making decision about whether to consider a feedback loop in the model (Table 1).

Table 1. Model Boundary

Endogenous	Exogenous	Excluded
Non-cost-burdened renter families	Family renters growth	Population
Cost-burdened families	Adjusted monthly income	Migration
Evicted families EF	Yearly eviction rate	Unsheltered homelessness
Hidden homeless families HHF	Yearly frac. of EF entering shelters	Domestic violence
Literally homeless families LHF	Yearly fraction of EF doubling up	Shelter capacity
Tenant-based Vouchers (TBV)	Yearly frac. of HHF entering shelters	Project-based HCV
TBV tenants	Avg. length-of-time shelters	Unemployment
Families on waitlist WF	TBV administration time	Effect of TBV on work effort
Eligible applicants EA	Avg. housing searching time	TBV portability
TBV holders	TBV allocation rate	
Landlord pool LP	Landlord increasing	
Voucher units vacancy	Proportion of LP withdrawing	
TBV reserves	Yearly proportion applying for TBV	
Administration fee reserves	Yearly proportion with no interest	
Renewal funding	Yearly proportion of EA to WF	
Payment standard	Cost-burden ratio	
Tenant rent	Inflation rate	
Fair market rent (FMR) ⁸		

4. QUANTITATIVE MODEL

It is believed that, in order to understand what factors influence the inflows or the outflows of the stock of HHF, we need to understand more details regarding how HHF are turning to be homeless and how they can be assisted. In this section, the whole explanatory model was divided into five interacted sectors (Fig. 4-1): the homeless sector, the housing market sector, the voucher sector, the landlord sector, and the funding sector. The homeless sector and the housing market sector illustrate how HHF are turning to be homeless. The voucher sector, the landlord sector and the funding sector explain how they can be assisted. Specifically, the voucher sector introduces the

⁸ The FMR is the 40th percentile of gross rents for typical, non-standard rental units occupied by recent movers in a local housing market. It is established federally.

administration process of families in need applying, being issued and leasing up with the TBV; the landlord sector gives an introduction of the process of landlords being briefed, participating and withdrawing the TBV program; and the funding sector shows the process of subsidy funding and administrative fee incrementing and spending. Most important structures and formulations that are helpful to understand the model theory are presented and described sector by sector.

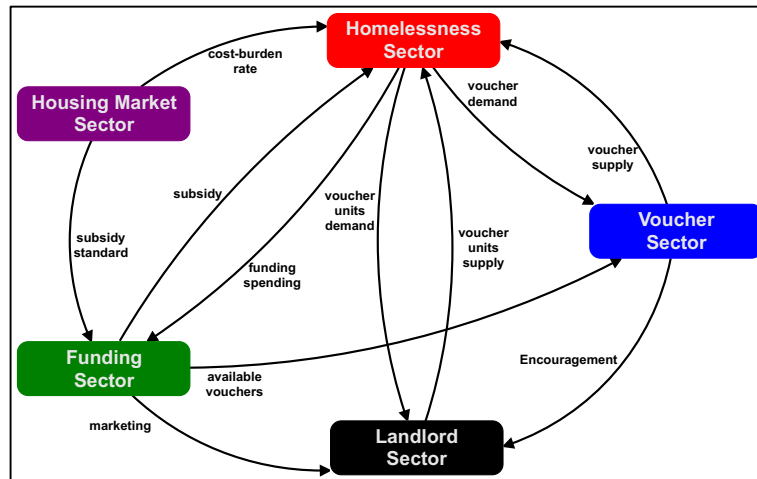


Fig. 4-1. Overview of the family homelessness system.

4.1 The Homelessness Sector

As shown in Fig. 4-2, this sector assumes six states of families before and after being homeless: 1) families living in renter-occupied housing units that are non-cost-burdened (NCBRF), 2) families with rental cost-burden (CBF), 3) families being evicted by landlords due to overcrowding or unable to pay rent (EF), 4) families doubling-up in other relatives or friends' homes (HHF), 5) families living in temporary shelters (LHF), and 6) Families receiving voucher assistance (TBV tenants) or families receiving other assistances (OAF). At-risk or homeless families cycle continuously through the system for both “push” reasons (evictions, time limits on stays, or undesirable features of the places they are staying) and “pull” reasons (desirable features of other housing situations) (Fisher, Mayberry, Shinn, & Khadduri, 2014; Lee, 1966). In the following parts, we will go into more detail regarding each state.

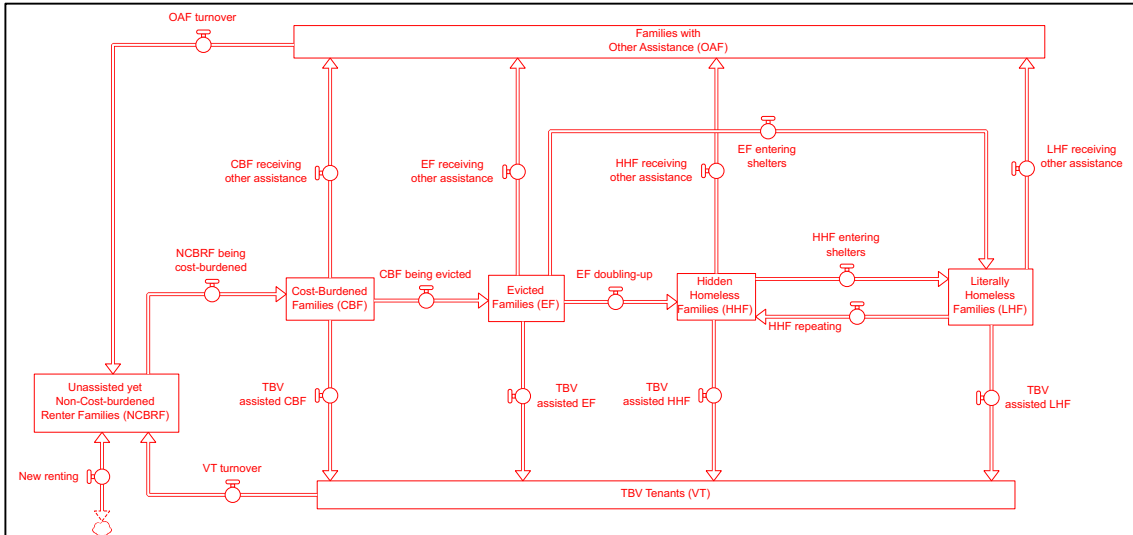


Fig. 4-2. Stock and flow structure representing the different states of renter families. Note: In this model, the cost-burdened families directly move to temporary shelters were excluded because the number is very small. And also, unsheltered families were not taken into account, because its amount is much smaller than other types of homeless families (Khadduri, 2008; Rossi, 1994; Vissing, 2015).

Stock: Unassisted Yet Non-cost-burdened Renter Families (NCBRF)

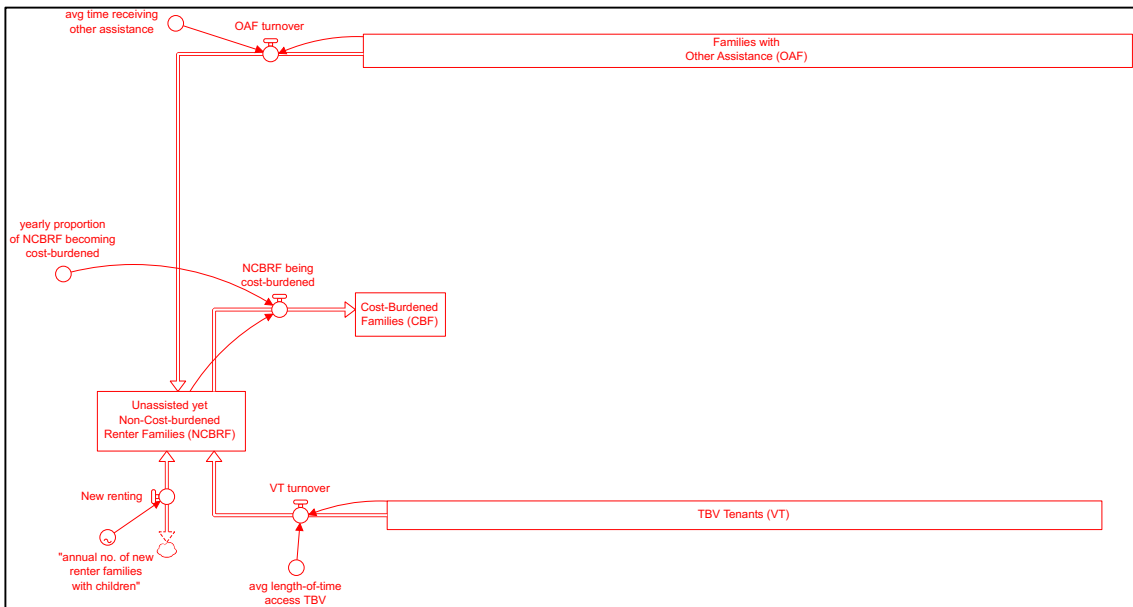


Fig. 4-3. Stock and flow structure of the unassisted yet non-cost-burdened renter-families. Note: circles mean factors and parameters influence families and thinner arrows indicate causal influence.

$$NCBRF = \int (New\ renting + VT\ turnover + OAF\ turnover - NCBRF\ being\ cost\ burdened) dt + NCBRF(0) \quad (1)$$

This stock accumulates the difference between new renting, VT turnover, OAF turnover and NCBRF being cost-burdened. Initially NCBRF is equal to NCBRF (0).

Flow: New renting

$$\text{New renting} = \text{annual no. of new renter families with children} \quad (2)$$

The “New renting” denoting the annual increased number of families join the rental market. This number is affected by many factors, such as the housing vacancy rate, the migration or the economic condition. Considering the scope of this study, these factors are excluded. The “annual no. of new renter families with children” was set as an exogenous value.

Outflow: NCBRF being cost-burdened

$$\text{NCBRF being cost burdened} = \text{NCBRF} * \text{yearly proportion of NCBRF being cost burdened} \quad (3)$$

In HUD’s definition, families are considered as cost-burdened if they pay more than 30% of their income for rent. The “yearly proportion of NCBRF being cost burdened” is endogenously resulted from the system.

The equations of the two inflows, “VT turnover” and “OAF turnover”, will be presented at the end of this sector. The “VT turnover” is given by (29), and the “OAF turnover” is given by (31).

Stock: Cost-burdened Families (CBF)

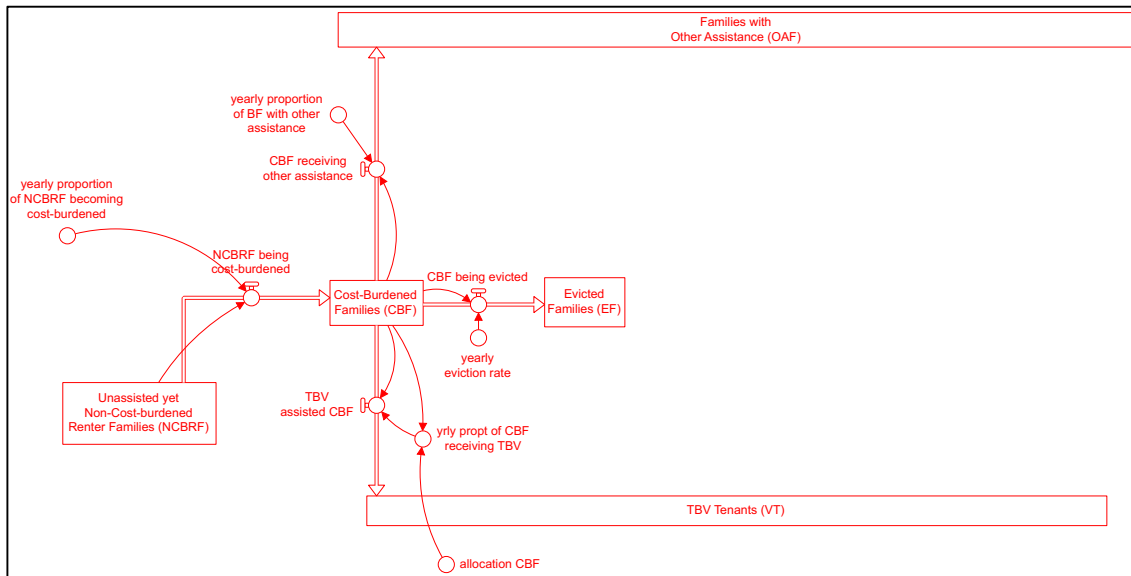


Fig. 4-4. Stock and flow structure of the cost-burdened families.

$$CBF = \int (NCBRF \text{ being cost burdened} - CBF \text{ being evicted} - TBV \text{ assisted CBF} - CBF \text{ receiving other assistance})dt + CBF(0) \quad (4)$$

This stock accumulates the difference between families being cost-burdened, evicted and assisted. Initially CBF is equal to CBF (0).

Inflow: NCBRF being cost-burdened is given by (3).

Outflow: CBF being evicted

$$CBF \text{ being evicted} = \text{yearly eviction rate} * CBF \quad (5)$$

Some of the cost-burdened families will have to face the risk of being evicted by their landlords when they experience an adverse event like job loss or illness, and are unable to pay their rent.

Outflow: TBV assisted CBF

$$TBV \text{ assisted CBF} = \text{yearly proportion of CBF receiving TBV} * CBF \quad (6)$$

$$\text{yearly proportion of CBF receiving TBV} = \text{MIN}\left(\frac{\text{allocation CBF}}{CBF}; 1\right) \quad (7)$$

If without any other help, and assuming the recent faster increase of the housing cost relative to the income (Fig. 3-3) continued, we could imagine that more and more families will be at-risk and homeless families will never be ended. However, both the federal and local government launched various programs to reduce its number. Among those programs, it has evidence that one of the most important measures for lifting family homelessness up is the Tenant-based Housing Choice Voucher (TBV) program. However, because of the limited allocation, only a part of the cost-burdened families is able to lease up with a voucher.

Outflow: CBF receiving other assistance

$$CBF \text{ receiving other assistance} = CBF * \text{yearly proportion of CBF with other assistance} \quad (8)$$

Stock: Evicted Families (EF)

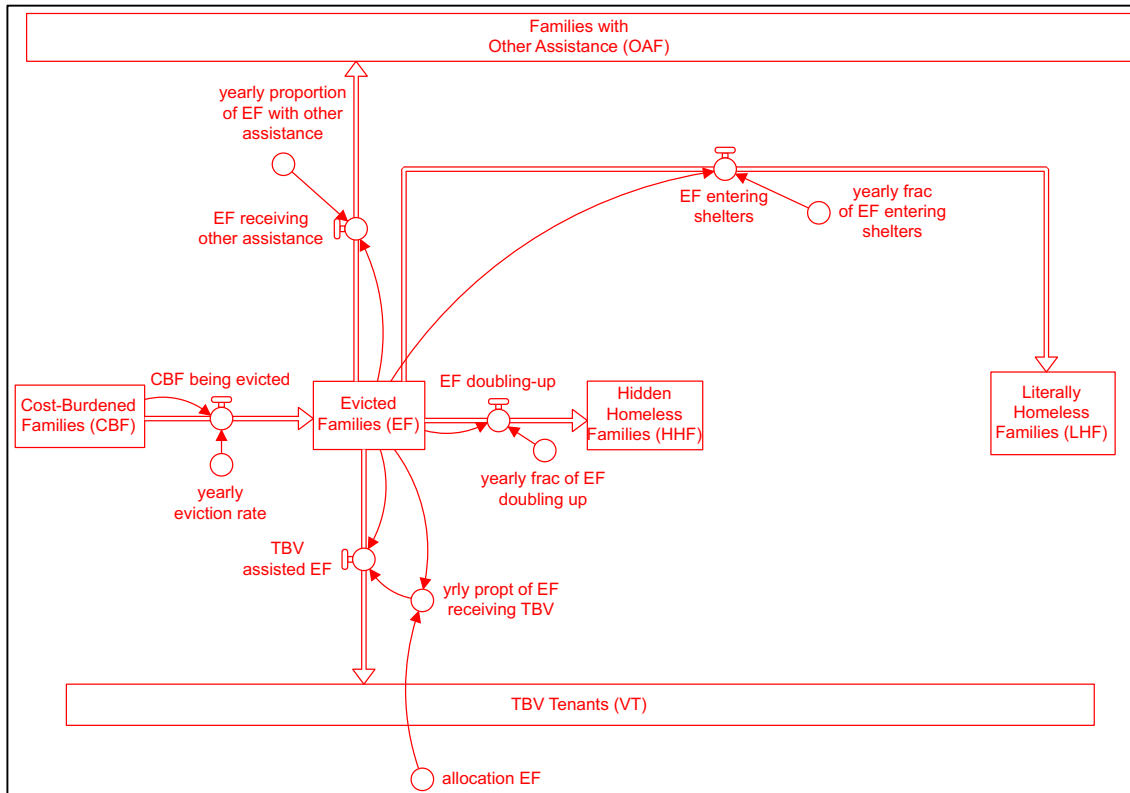


Fig. 4-5. Stock and flow structure of the evicted families.

$$EF = \int (CBF \text{ being evicted} - EF \text{ Doubling up} - EF \text{ entering shelters} - TBV \text{ assisted EF} - EF \text{ receiving other assistance}) dt + EF(0) \quad (9)$$

This stock accumulates the difference between families being evicted, doubling up, entering shelters and assisted. Initially EF is equal to EF (0).

Inflow: CBF being evicted is given by (5).

Outflow: EF doubling up

$$EF \text{ doubling up} = EF * \text{yearly frac. of EF doubling up} \quad (10)$$

Outflow: EF entering shelters

$$EF \text{ entering shelters} = EF * \text{yearly frac. of EF entering shelters} \quad (11)$$

If without any assistance, those evicted families likely only have two choices: either doubling-up with their friends/relatives or moving to temporary shelters if available. Most families tend to choose doubling-up rather than shelters as their first choice unless they have no place but temporary shelters to go (Marybeth Shinn et al., 1991; Watson et al., 2016).

Outflow: TBV assisted EF

$$TBV \text{ assisted } EF = \text{yearly proportion of } EF \text{ receiving } TBV * EF \quad (12)$$

$$\text{yearly proportion of } EF \text{ receiving } TBV = \text{MIN}\left(\frac{\text{allocation } EF}{EF}; 1\right) \quad (13)$$

Similar to the CBF, a part of the evicted families is lucky to lease up with a voucher and get rid of the risk of being homeless.

Outflow: EF receiving other assistance

$$EF \text{ receiving other assistance} = \text{yearly proportion of } EF \text{ with other assistance} * EF \quad (14)$$

Again, only a proportion of the evicted families is lucky to receive other assistances.

Stock: Hidden homeless families (HHF)

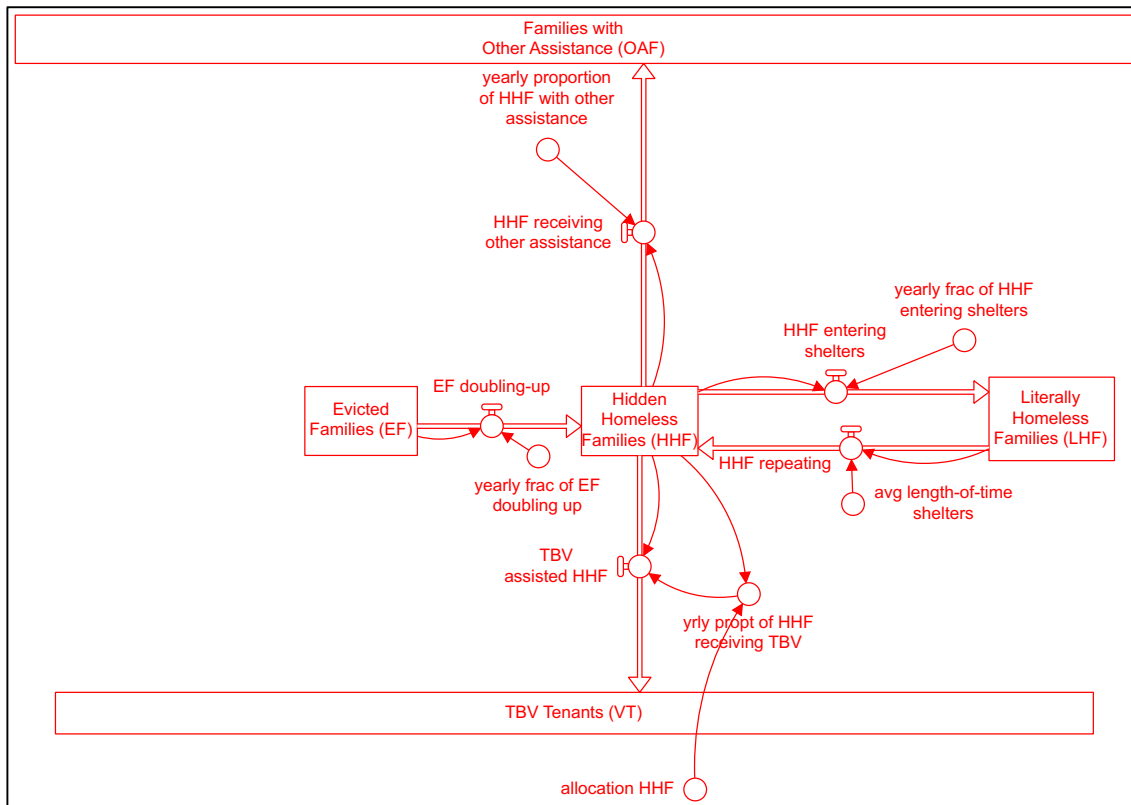


Fig. 4-6. Stock and flow structure of the hidden homeless families.

$$HHF = \int (EF \text{ doubling up} - HHF \text{ entering shelters} + HHF \text{ repeating} - TBV \text{ assisted HHF} - HHF \text{ receiving other assistance}) dt + HHF(0) \quad (15)$$

accumulates the difference between EF doubling up, HHF entering shelters, HHF repeating, TBV assisted HHF and HHF receiving other assistance. Initially HHF is equal to HHF (0).

Inflow: EF doubling up is given by (10).

Outflow: HHF entering shelters

$$HHF \text{ entering shelters} = HHF * \text{yearly frac of HHF entering shelters} \quad (16)$$

Doubling-up is not a stable situation for the HHFs. When they run out of their social network, they have to seek temporary shelters to go through this crisis.

Inflow: HHF repeating

$$HHF \text{ repeating} = \frac{LHF}{\text{avg length of time shelters}} \quad (17)$$

where LHF denotes the literally homeless families.

The temporary shelter is also not a stable living situation for the homeless families. After spending a maximum time in shelters, the homeless families have to move out and double-up again.

Outflow: TBV assisted HHF

$$TBV \text{ assisted HHF} = \text{yearly proportion of HHF receiving TBV} * HHF \quad (18)$$

$$\text{yearly proportion of HHF receiving TBV} = \text{MIN}\left(\frac{\text{allocation HHF}}{HHF}; 1\right) \quad (19)$$

Outflow: HHF receiving other assistance

$$HHF \text{ receiving other assistance} = \text{yearly proportion of HHF with other assistance} * HHF \quad (20)$$

With the help of the TBV program and other assistances, part of the hidden homeless families is able to move to stable housing.

Stock: Perceived Hidden Homeless Families (Perceived HHF)

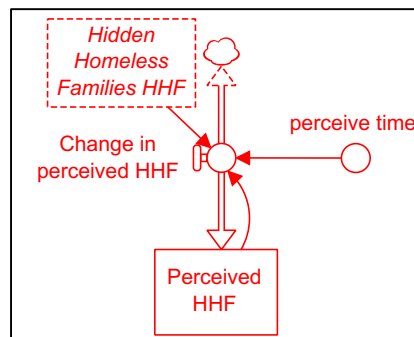


Fig. 4-7. Stock and flow structure of the perceived hidden homeless families.

$$Perceived \ HHF = \int (\text{Change in perceived HHF})dt + HHF(0) \quad (21)$$

$$\text{Change in Perceived HHF} = \frac{\text{HHF} - \text{Perceived HHF}}{\text{perceive time}} \quad (22)$$

Perceived HHF accumulates the difference between HHF and the Perceived HHF, with a certain perceive time. Initially, Perceived HHF is equal to Perceived HHF (0).

Stock: Literally Homeless Families (LHF)

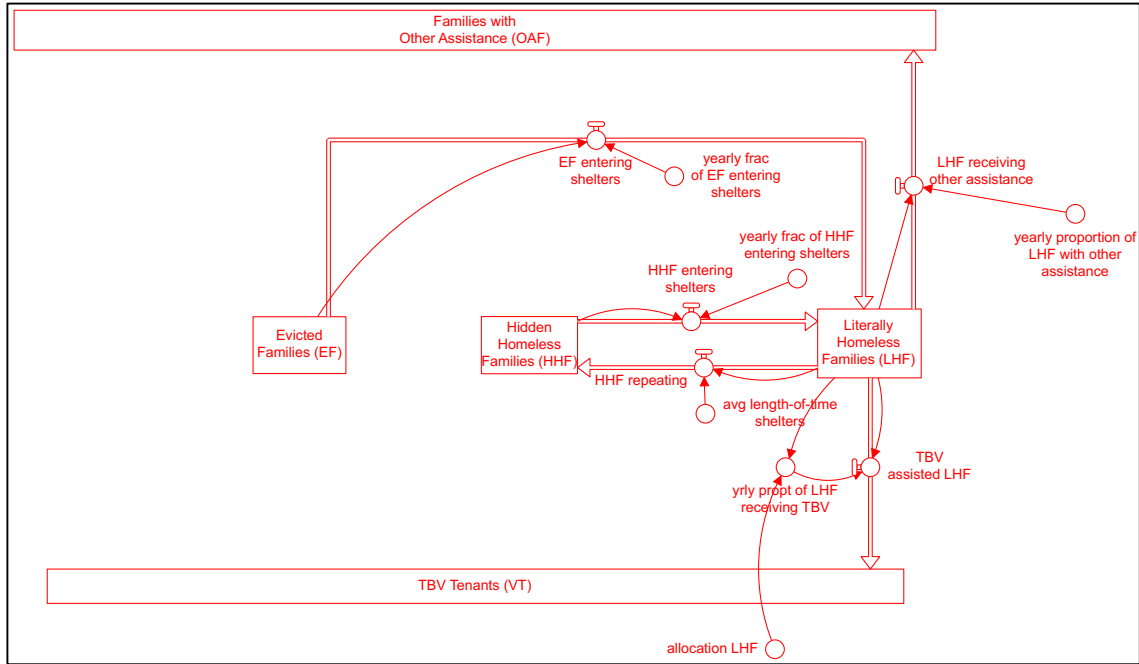


Fig. 4-8. Stock and flow structure of the literally homeless families.

$$LHF = \int (EF \text{ entering shelters} + HHF \text{ entering shelters} - HHF \text{ repeating} - TBV \text{ assisted LHF} - LHF \text{ receiving other assistance}) dt + LHF(0) \quad (23)$$

This stock accumulates the difference between EF entering shelters, HHF entering shelters, HHF repeating, TBV assisted LHF and LHF receiving other assistances. Initially LHF is equal to LHF (0).

Inflow: EF entering shelters is given by (11).

Inflow: HHF entering shelters is given by (16).

Outflow: HHF repeating is given by (17).

Outflow: TBV assisted LHF

$$TBV \text{ assisted LHF} = \text{yearly proportion of LHF receiving TBV} * LHF \quad (24)$$

$$\text{yearly proportion of LHF receiving TBV} = \text{MIN}\left(\frac{\text{allocation LHF}}{LHF}; 1\right) \quad (25)$$

Outflow: LHF receiving other assistance

$$LHF \text{ receiving other assistance} = \text{yearly proportion of LHF with other assistance} * LHF \quad (26)$$

Similarly, some literally homeless families that either lease up with the vouchers or receive other assistances can move to stable housing.

Stock: Perceived Literally Homeless Families (Perceived LHF)

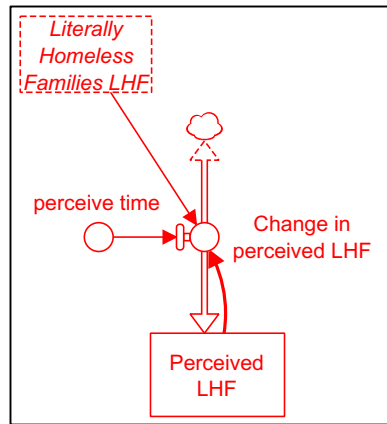


Fig. 4-9. Stock and flow structure of the perceived literally homeless families.

$$Perceived LHF = \int \left(\frac{LHF - Perceived LHF}{perceive time} \right) dt + Perceived LHF(0) \quad (27)$$

Perceived LHF accumulates the difference between LHF and the Perceived LHF, with a certain perceive time. Initially, Perceived LHF is equal to Perceived LHF (0).

Stock: TBV-tenants (VT)

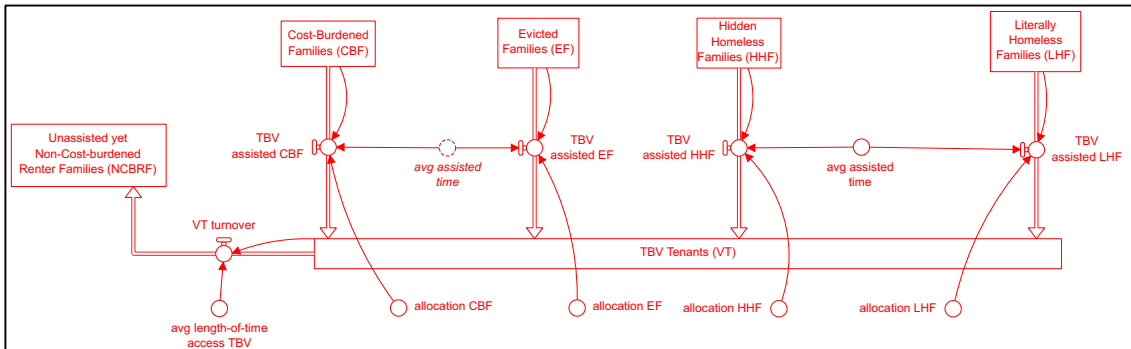


Fig. 4-10. Stock and flow structure of the TBV-tenants.

$$VT = \int (TBV \text{ assisted CBF} + TBV \text{ assisted EF} + TBV \text{ assisted HHF} + TBV \text{ assisted LHF} - VT \text{ turnover}) dt + VT(0) \quad (28)$$

accumulates the difference between TBV assisted CBF, TBV assisted EF, TBV assisted HHF, TBV assisted LHF and TBV-tenants' turnover. Initially VT is equal to VT (0).

Inflow: TBV assisted CBF is given by (6).

Inflow: TBV assisted EF is given by (12).

Inflow: TBV assisted HHF is given by (18).

Inflow: TBV assisted LHF is given by (24).

Outflow: TBV-tenant turnover

$$VT \text{ turnover} = \frac{VT}{\text{avg. length of time access TBV}} \quad (29)$$

After receiving several years' assistance, the families that lease up with vouchers have opportunities to be independent with renting in the private market without vouchers.

Stock: Families with other assistance (OAF)

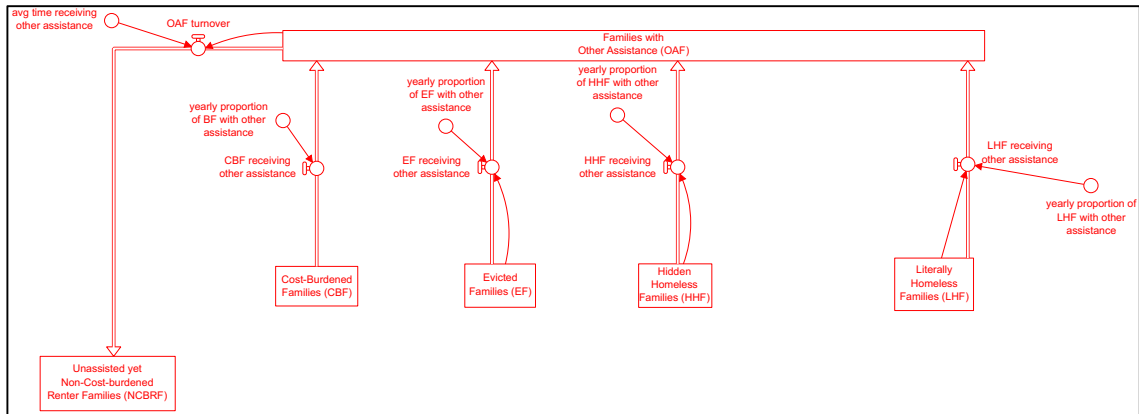


Fig. 4-11. Stock and flow structure of the families with other assistance.

$$OAF = \int (CBF \text{ receiving other assistance} + EF \text{ receiving other assistance} + HHF \text{ receiving other assistance} + LHF \text{ receiving other assistance} - OAF \text{ turnover}) dt + OAF(0) \quad (30)$$

accumulates the difference between CBF receiving other assistance, EF receiving other assistance, HHF receiving other assistance, LHF receiving other assistance and OAF turnover. Initially OAF is equal to OAF (0).

Inflow: CBF receiving other assistance is given by (8).

Inflow: EF receiving other assistance is given by (14).

Inflow: HHF receiving other assistance is given by (20).

Inflow: LHF receiving other assistance is given by (26).

Outflow: OAF turnover

$$OAF \text{ turnover} = \frac{VT}{\text{avg. time receiving other assistance}} \quad (31)$$

Similarly, after receiving several years' assistance, the families have opportunities to be independent to rent in the private market without the any assistance.

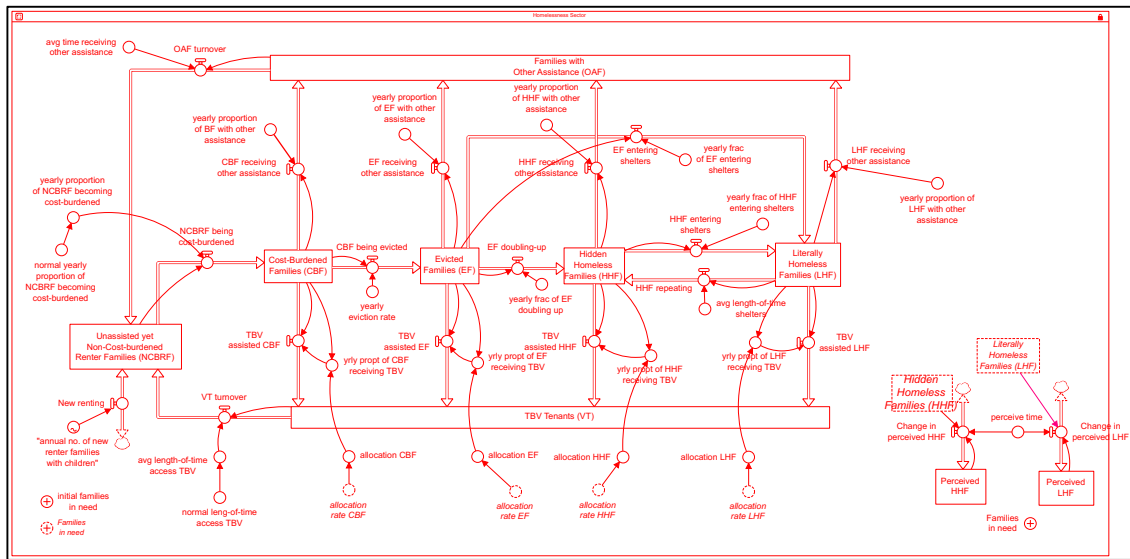


Fig. 4-12. Stock and flow structure representing the family homelessness sector.

Table 2. Parameters and initial values of the homelessness sector.

No.	Parameters and initial stock	Value	Unit
1	Initial NCBRF	2240	Family
2	Initial CBF	3945	Family
3	Initial EF	135	Family
4	Initial HHF	342	Family
5	Initial perceived HHF	342	Family
6	Initial LHF	50	Family
7	Initial perceived LHF	50	Family
8	Initial VT	300	Family
9	Initial OAF	200	Family
10	Annual no. of new renter families with children	180	Family
11	Yearly eviction rate	4.5%	1/year
12	Yearly propt. of CBF receiving other assistances	4%	1/year
15	Yearly propt. of EF/HHF receiving other assistances	8%	1/year
13	Yearly frac. of EF doubling up	40%	1/year
14	Yearly frac. of EF entering shelters	10%	1/year
16	Yearly frac. of HHF entering shelters	8%	1/year
17	Avg. length-of-time shelters	1.5	Years
18	Perceive time	1	Years
19	Yearly proportion of LHF with other assistance	0.5	1/year
20	Avg. time receiving other assistance	7	Years
21	Avg. length-of-time access TBV	7	Years

Data Source:

1. Initial NCBRF: According the US Census Bureau, there were about 36.2% of the total households living in renter-occupied housing units pay less than 30% of their income in 2009. Based on the data, there were 6185 families with children living in renter-occupied housing units. Based on these information, the initial NCBRF was set as 2240 families.

2. Initial CBF: since there were 2240 families of the total renter families without cost-burden, the number with cost-burden was 3945 families in 2009.

3. Initial EF: there were 979 evictions in Larimer County in 2009. Since the number of renter-occupied

housing units in Fort Collins is 60% to that in the Larimer County, and the proportion of families with children to the total households living in renter-occupied housing units is about 23%. Based on this information, I estimated that there were 135 evicted families in Fort Collins.

4. Initial HHF: As mentioned in the Introduction, by calculating the data provided by the Poudre School District, I estimated that there were 342 families that are living in hidden homeless families.

5. Initial Perceived HHF: the initial value of the perceived HHF equals the initial HHF in the model.

6. Initial LHF: based on the PiT count, there were 37 families with children be considered as literally homelessness in 2013, and the data decreased a little after that. Therefore, the number of LHF in 2009 was estimated to be 50 families.

7. Initial Perceived LHF: the initial value of the perceived LHF equals the initial LHF in the model.

8. Initial VT: according to the HUD's housing voucher data, there were 743 vouchers in use, considering there were 40% of families with children, I estimated that the initial TBV tenants is 300 families.

9. Initial OAF: Based on the Colorado Housing Fact Sheet, about 40% of the low-income households receive rental assistance other than housing choice vouchers. Based on the estimation that 300 families receiving housing vouchers, I estimated that 200 families with children receiving assistance other than housing choice vouchers.

10. Annual no. of new renter families with children: The number is set an average number of 180 families per year calculated by data provided by the U.S. Census Bureau, 2016 American Community Survey 5-Year Estimates.

11. Yearly eviction rate: as mentioned in the Introduction section, there were about 1000 evictions in Larimer County in 2009. Adjusted for a 60% of the population in Fort Collins, and estimate about 22.5% of them are families with children, and considering the 3945 families with cost-burden, the yearly eviction rate for cost-burdened families with children was estimated to be 3.5% per year.

12. Yearly proportion of CBF receiving other assistances: Based on the Colorado Housing Fact Sheet, about 20% of low-income households receiving rental assistance in Colorado in 2016, and about 40% of them receive rental assistance other than housing choice vouchers. Based on this information, I estimated that there were about 4% of CBF per year receiving other assistances.

13. Yearly proportion of EF/HHF receiving other assistances: Based on the above information, I estimated that about 8% of EF/HHF receiving other assistances.

14. Yearly frac. of EF doubling up: no specific data was reported regarding the yearly proportion of evicted families doubling up. Based on my calculation, there are 56 new families becoming hidden homeless from 2009 to 2010. And there were about 135 evicted families in 2009. Based on this information, the "yearly frac. of EF doubling up" was estimated to be 40% per year.

15. Yearly fraction of EF entering shelters: data showed that there were about 2.7 million Americans facing eviction in 2015 (McMullen, 2016), and there were about 0.4 million homelessness staying in emergency shelters that year. Based on this information, and considering the families' preference for doubling-up than entering shelters, the "yearly fraction of EF entering shelters" was estimated to be 10% per year.

16. Yearly frac. of HHF entering shelters: according to the 2010 Annual Homeless Assessment Report to Congress, the yearly fraction of hidden homeless families becoming literally homelessness is about 8% per year.

17. Avg. length-of-time shelters: according to Homeward 2020, the average length-of-time a family stays in shelters is about 1.5 years.

18. Perceive time: the time need to conducting survey, collecting data and reporting was estimated to be 1 year.

19. Yearly proportion of LHF with other assistance: because of the vulnerability of the LHF, more programs are aimed to help them. Therefore, “proportion of LHF with other assistance” was estimated to be a larger value of 50% per year.

20. Avg. length-of-time access TBV: it has been demonstrated that families that lease up with the vouchers, after receiving about seven years’ assistance, have opportunities to be independent to rent in the private market without the vouchers (Wood et al., 2008).

21. Avg. time receiving other assistance: no data was found regarding this parameter, the time was set as the same as the “avg. length-of-time access TBV”.

4.2 The Housing Market Sector

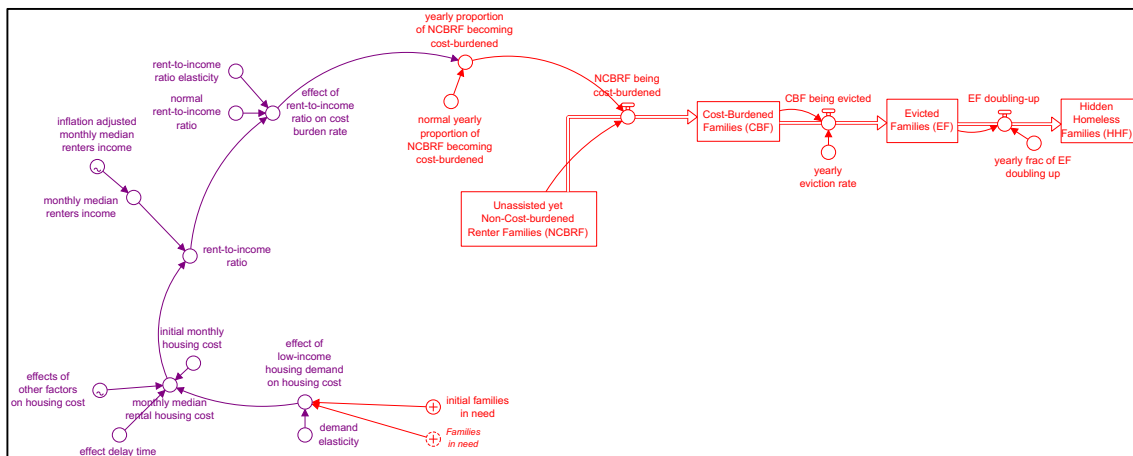


Fig. 4-13. Stock and flow structure representing the housing market sector.

effect of low income housing demand on housing cost =

$$\left(\frac{\text{Families in need}}{\text{initial families in need}} \right) \text{demand elasticity} \quad (32)$$

$$\text{init families in need} = \text{init CBF} + \text{init EF} + \text{init HHF} + \text{init LHF} \quad (33)$$

$$\begin{aligned} \text{monthly median rental housing cost} &= \text{initial monthly housing cost} * \\ &\text{effect of low income housing demand on housing cost} * \\ &\text{effect of other factors on housing cost} \end{aligned} \quad (34)$$

It is argued that the increase of low-income housing demand will increase the housing rent especially in a tight housing market (Susin, 2002). Therefore, in this study, the

“monthly median rental housing cost” is modeled endogenously and could be affected by the number of families in need. Although the housing cost could also be influenced by many other factors in the real world, those effects was set as an exogenous value because of the scope of this study.

$$\text{rent to income ratio} = \frac{\text{monthly median rental housing cost}}{\text{monthly median renters income}} \quad (35)$$

$$\text{effect of rent to income ratio on cost burden rate} = \left(\frac{\text{rent to income ratio}}{\text{normal rent to income ratio}} \right)^{\text{rent to income ratio elasticity}} \quad (36)$$

$$\begin{aligned} &\text{yearly proportion of NCBRF becoming cost burdened} = \\ &\text{normal yearly proportion of NCBRF becming cost burdened} * \\ &\text{effect of rent to income ratio on cost burden rate} \end{aligned} \quad (37)$$

Table 3. Parameters and initial values of the housing market sector.

No.	Parameters and initial stock	Value	Unit
22	Demand elasticity	0.6	unitless
23	Initial monthly housing cost	826	USD/family/month
24	Effect of other factors on FMR		unitless
25	monthly median renters' income	data	USD/family/month
26	Normal rent-to-income ratio	0.3	unitless
27	Rent-to-income ratio elasticity	0.6	unitless
28	Normal yrly. propt. of NCBRF being cost-burdened	0.1	1/year

Data Source:

22. Demand elasticity: based on the historical data provided by US Census Bureau, the FMR was 832 USD/family/month in 2010, and the number was 893 in 2015. The initial families in demand was about 4450 families, and the incremental was about 300 families from 2009 to 2015. Based on this information, the demand elasticity was calculated to be 0.6.

23. Initial monthly housing cost: data retrieved from the US Census Bureau.

24. Effect of other factors on FMR: the effect of other factors was set as an exogenous value varied year by year between 1 and 1.5.

25. Monthly median renters' income: the number was based on the historical data and varied year by year.

26. Normal rent-to-income ratio: based on the HUD's definition, families paying more than 30% of their monthly income is considered as cost-burdened. Therefore, the normal rent-to-income ratio was set as 0.3.

27. Rent-to-income ratio elasticity: no data were reported regarding the rent-to-income ratio elasticity, the number was set as the same as the demand elasticity.

28. Normal yearly proportion of NCBRF being cost-burdened: based on the US Census Bureau, about 75 families added to the stock of CBF in 2010. Considering that some of the CBF being evicted or receiving assistance, it was estimated that about 235 families becoming cost-burdened that year. Since there were about 2400 non-cost-burdened families in 2010, the yearly proportion of NCBRF being cost-burdened was set as 10% per year.

From the above structural analysis, it is known that the family homelessness is a dynamic process. The stock of at-risk or homeless families is influenced by both the

inflows and the outflows of it. If the total inflow is larger than the total outflow, the goal of ending homelessness would never be met.

Although there are various assistance programs can prevent the number of HHF becoming so large, considering the scope of this study, I focused on the TBV program and explored how the TBV program works by three sectors: the voucher sector, the landlord sector and the funding sector, in the following parts.

4.3 The Voucher Sector

An aging chain from applying vouchers, screening, issuing to finally moving to market house is used to trace the sequence of activities that typically occur in a tenant-based Housing Choice Voucher program (Fig. 4.2-1). The following are details regarding each step.

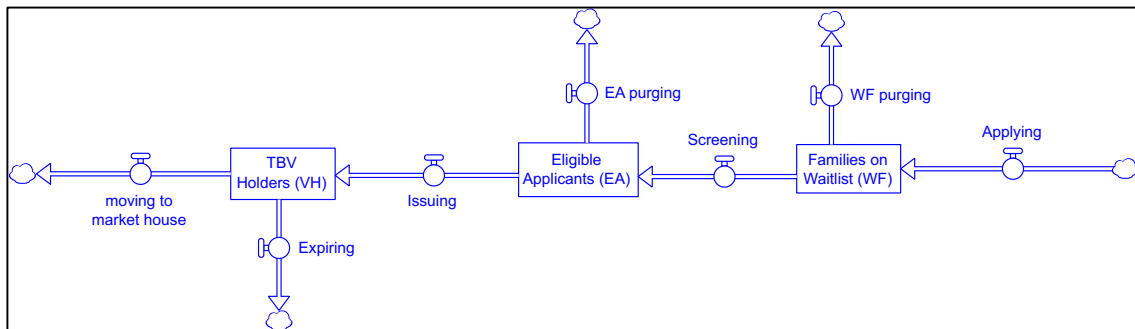


Fig. 4-14. Stock and flow structure representing the TBV administration process.

Stock: Families on waitlist (WF)

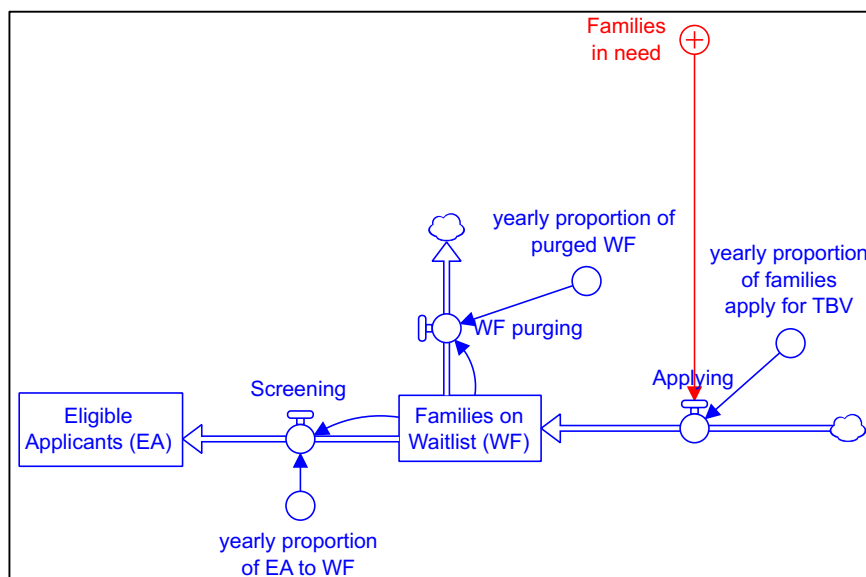


Fig. 4-15. Stock and flow structure of the families on waitlist.

$$WF = \int (Applying - Screening - Purging) dt + WF(0) \tag{38}$$

WF accumulates the difference between TBV applying, screening and WF purging. Initially WF is equal to WF (0).

Inflow: Families applying for TBV

$$\text{Applying} = \text{Families in need} * \text{yearly proportion of families applying for TBV} \quad (39)$$

Where

$$\text{Families in need} = \text{CBF} + \text{EF} + \text{HHF} + \text{LHF} \quad (40)$$

Family in need is defined as the at-risk or homeless family in this study. Its number is the sum of the cost-burdened families, evicted families, hidden homeless families and the literally homeless families included in the model. These families make application to a public housing authority (PHA) and are placed on the PHA's waiting list based on the information they provide without verification.

Outflow: WF go through the screening process

$$\text{Screening} = \text{WF} * \text{yearly proportion of EA to WF} \quad (41)$$

Before issuing a voucher, Housing Catalyst (the Public Housing Authority in the city of Fort Collins) must verify all of the information provided by the family in order to determine whether the family is eligible to receive voucher assistance. It is called the screening process.

Outflow: WF purged from the waitlist

$$\text{WF Purging} = \text{yearly proportion of purged WF} * \text{WF} \quad (42)$$

Those families that are not interested in the vouchers because of any reasons will be purged from the waitlist.

Stock: Eligible Applicants (EA)

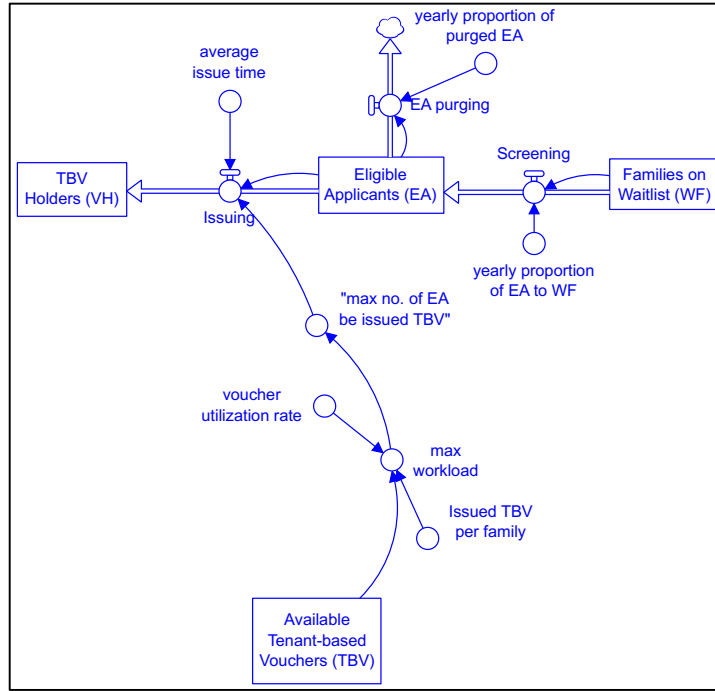


Fig. 4-16. Stock and flow structure of the eligible applicants.

$$EA = \int (Screening - Issuing - EA\ purging) dt + EA(0) \quad (43)$$

accumulates the difference between EA screening, issuing and EA purging. Initially EA is equal to EA (0).

Inflow: Screening is given by (37).

Outflow: EA are purged from the waitlist

$$WF\ Purging = yearly\ proportion\ of\ purged\ WF * WF \quad (44)$$

Those families that are not interested in the vouchers because of any reasons will be purged from the waitlist.

Outflow: Eligible Applicants are issued vouchers

$$Issuing = \frac{MIN(EA; max.\ no.\ of\ EA\ be\ issued\ TBV)}{average\ issue\ time} \quad (45)$$

$$max.\ no.\ of\ EA\ be\ issued\ TBV = max.\ workload - VT \quad (46)$$

$$max.\ workload = \frac{available\ TBV * voucher\ utilization\ rate}{Issued\ TBV\ per\ family} \quad (47)$$

Eligible families are selected by lottery to receive a voucher if it is available.

Housing Catalyst's maximum workload is determined by the number of available TBV and the voucher utilization rate.

Stock: TBV Holders (VH)

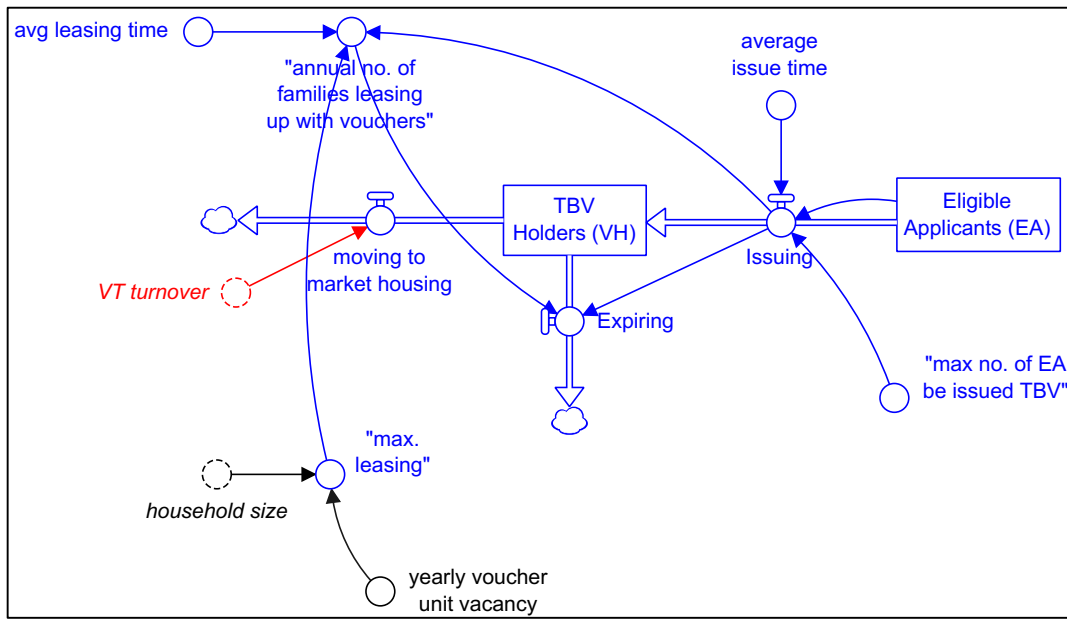


Fig. 4-17. Stock and flow structure of TBV holders.

$$VH = \int (Issuing - moving\ to\ market\ housing - Expiring) dt + VH(0) \quad (48)$$

accumulates the difference between issuing, TBV holders, leasing and TBV expiring. Initially VH is equal to VH (0).

Inflow: Issuing is given by (41).

Part of the families with issued vouchers have opportunities to find a landlord accepting the voucher. The number is not only determined by the number of issuing, but also by the voucher unit vacancy.

$$annual\ no.\ of\ families\ leasing\ up\ with\ vouchers = DELAY(MIN(max.\ leasing; issuing); avg\ leasing\ time) \quad (49)$$

$$max.\ leasing = yearly\ voucher\ unit\ vacancy * household\ size \quad (50)$$

Outflow: Expiring

$$Expiring = DELAY(MAX(Issuing - Leasing; 0); avg.\ expiry\ time) \quad (51)$$

Usually, 60 days' searching time is given to voucher receivers, and they must lease up with the voucher before the searching period ends. If they cannot find an apartment within the given time, their vouchers will be expired.

Outflow: TBV holders moving to market housing

$$Moving\ to\ market\ housing = VT\ turnover \quad (52)$$

After receiving several years' assistance, most of the families are able to be independent.

Stock: Available Tenant-based Vouchers (TBV)

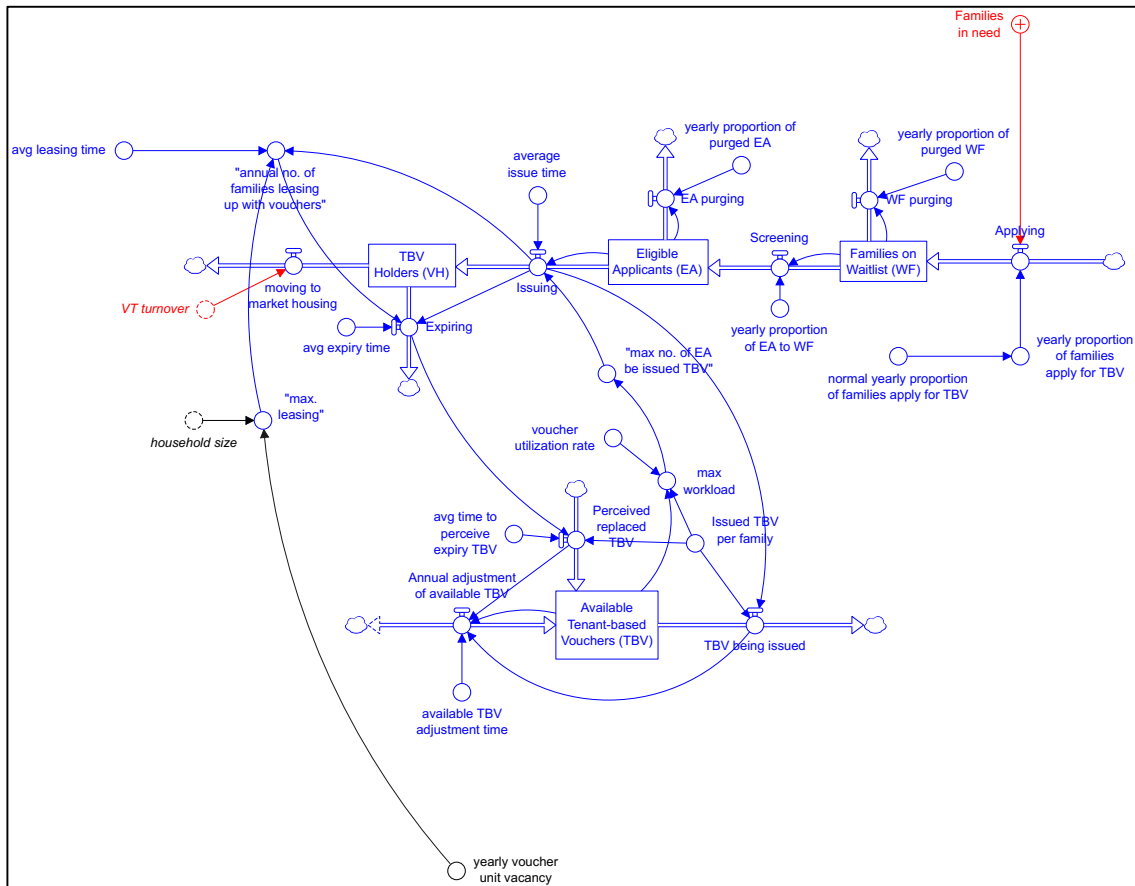


Fig. 4-18. Stock and flow structure of the available tenant-based vouchers.

$$Available\ TBV = \int (Annual\ adjustment\ of\ available\ TBV + Perceived\ Replaced\ TBV - TBV\ in\ use) dt + Available\ TBV(0) \quad (53)$$

This stock accumulates the difference between new TBV, TBV in use and perceived replaced TBV. Initially TBV is equal to Available TBV (0).

Flow: Annual adjustment of available TBV

$$Annual\ adjustment\ of\ available\ TBV = \frac{desired\ available\ TBV - available\ TBV}{available\ TBV\ adjustment\ time} + TBV\ in\ use - Perceived\ replaced\ TBV \quad (54)$$

Inflow: Expired vouchers

$$Perceived\ replaced\ TBV = DELAY1(Expiring * Issued\ TBV\ per\ family; avg.\ time\ to\ perceive\ expiry\ TBV) \quad (55)$$

Outflow: Vouchers in use

$$TBV \text{ in use} = Issuing * Issued TBV \text{ per family} \quad (56)$$

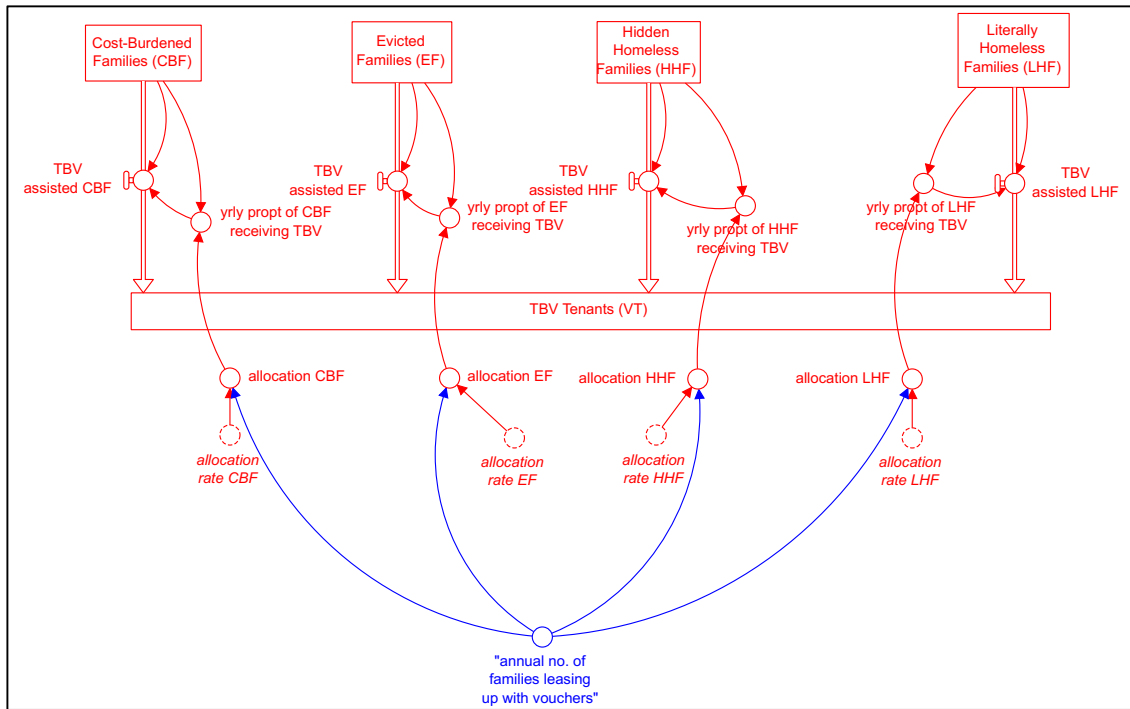


Fig. 4-19. Stock and flow structure representing the at-risk or homeless families receiving TBV.

$$allocation \ CBF = allocation \ rate \ CBF * leasing \quad (57)$$

$$allocation \ rate \ CBF = \frac{CBF}{families \ in \ need} \quad (58)$$

The equation of allocation EF/HHF/LHF is same to the equation of allocation CBF.

Table 4. Parameters and initial values of the voucher sector.

No.	Parameters and initial stock	Value	Unit
29	Initial WF	100	Family
30	Initial EA	100	Family
31	Initial VH	300	Family
32	Initial TBV	300	Family
33	Yearly proportion of families applying for TBV	20%	1/year
34	Yearly proportion of purged WF/EA	40%	1/year
35	Yearly proportion of EA to WF	50%	1/year
36	Issued TBV per family	1	Voucher/family
37	Average issue time	1	Year
38	Average expiry time	1	Year
39	Average leasing time	3/12	Year
40	Available TBV adjustment time	1	Year
41	Average time to perceive expiry TBV	2	Years
42	Voucher utilization rate	1.05	unitless

Data Source:

29. Initial WF: according to PHA Census survey in 2014, there were 90 families on the Housing Catalyst's waitlist for housing choice vouchers, therefore, the number of eligible applicants was set as 100 families in 2009.

30. Initial EA: no data were found regarding this parameter, the number was set as the same as initial WF.

31. Initial VH: according to HUD's housing voucher data, there were 743 housing vouchers distributed in 2009 in Fort Collins, approximately 40% of them were distributed to families with children. Based on this information, the number of voucher holders was estimated to be 300 families in 2009.

32. Initial TBV: Considering there were about 300 families receiving housing vouchers in 2009, and the door for housing vouchers has been closed, the number of initial TBV was also set as 300 families, which is the same as the initial TBV tenants.

33. Yearly proportion of families applying for TBV: data about the proportion of at-risk or homeless families applying for TBV was not available. The number was estimated to be 10% per year.

34. Yearly proportion of purged WF/EA: no data were found regarding the purged fraction, according to the Housing Catalyst in Fort Collins, the response rate for families who come to the top of the list and turn in their eligibility packet is about 30%. Therefore, the number was estimated as 40% per year.
the number was estimated to be 40% per year.

35. Yearly proportion of EA to WF: According to housing catalyst, the maximum income level for a 3-people household is \$34,600, and applicants that meet the income requirement will be considered as eligible. Based on the US Census Bureau data, there are about 50% of the households living in renter-occupied housing units earn less than that level. Therefore, the number was estimated to be 50% a year.

37. Average issue time: the voucher funds were renewed year by year, therefore, I estimated the vouchers are also issued year by year.

38. Average expiry time: according to HUD, usually, 60 days' searching time is given to voucher receivers, and they must lease up with the voucher before the searching period ends.

39. Average leasing time: according to the Housing Catalyst, the success rate for the families leasing up with a voucher is about 70%. Based on this information, I estimate it takes 3months for the families to lease up with their vouchers, therefore, about 70% could lease up within the expiry time.

40. Available TBV adjustment time: Given that HUD allocates its funding year by year, the time need to update the stock of TBV was estimated to be 1 year.

41. Average time to perceive expiry TBV: Given that the Housing Catalyst adjust its TBV year by year, I estimated it takes one year for the Housing Catalyst to perceive all the expired vouchers.

42. Voucher utilization rate: based on HUD's data, the voucher utilization rate of the Housing Catalyst changed every year. An average number of 1.05 was used in the model.

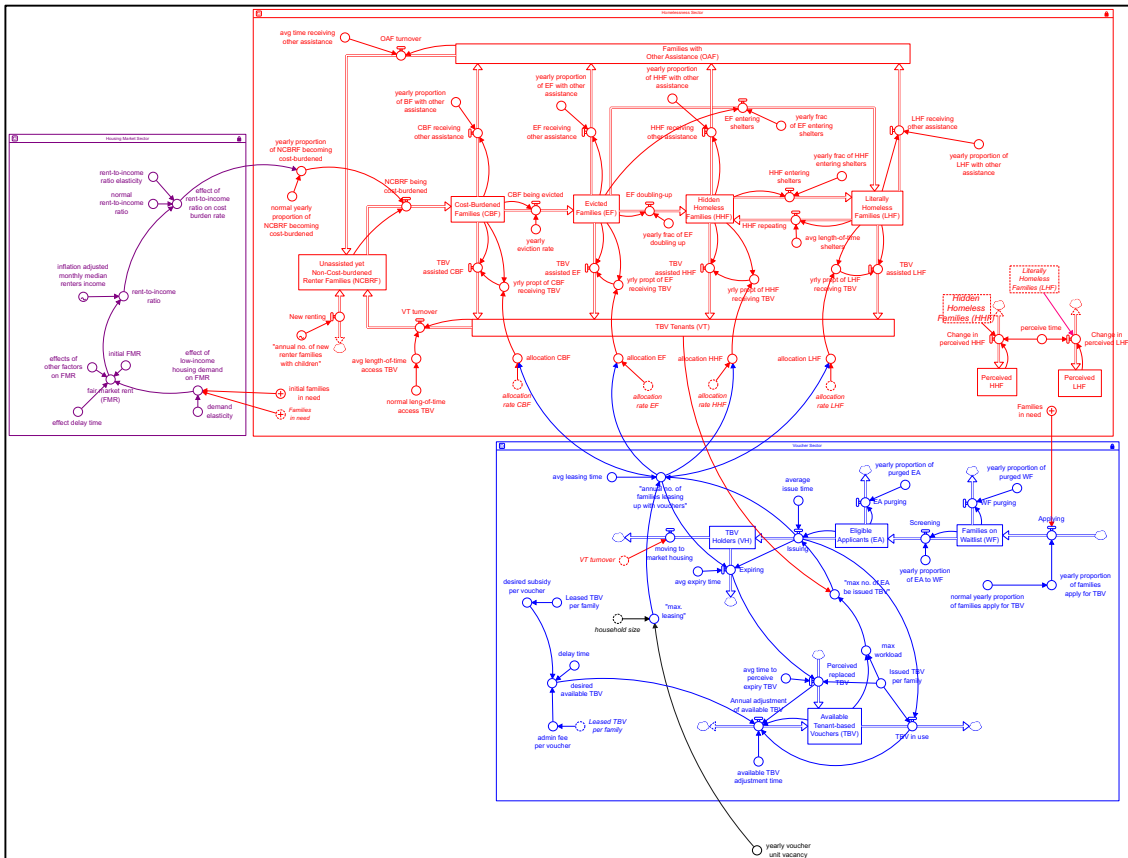


Fig. 4-20. Stock and flow structure representing the homelessness sector, the housing market sector and the voucher sector.

4.4 The Landlord Sector

This structure represents the process of landlord participating the TBV program, those landlords need be briefed first.

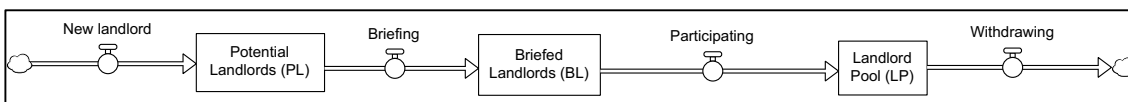


Fig. 4-21. Stock and flow structure representing the landlord participation process.

Stock: Potential Landlord (PL)

$$PL = \int (new\ landlord - Briefing)dt + PL(0) \tag{59}$$

accumulates the difference between new landlord and landlord briefing. Initially PL is equal to PL (0).

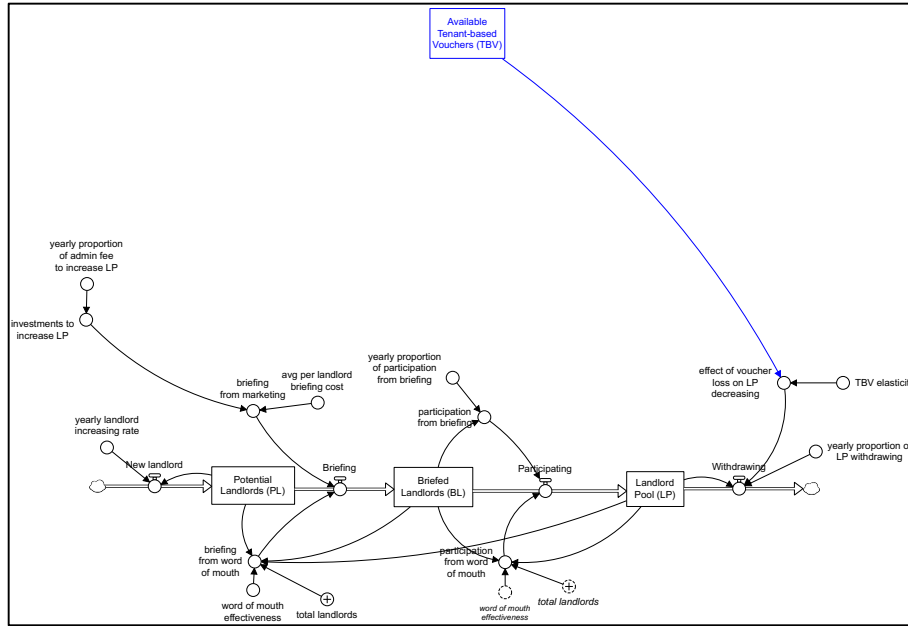


Fig. 4-22. Stock and flow structure of the landlord sector.

Inflow: New landlord

$$New\ landlord = yearly\ landlord\ increasing\ rate * PL \quad (60)$$

Outflow: Landlord briefing

$$Briefing = Briefing\ from\ marketing + Briefing\ from\ word\ of\ mouth \quad (61)$$

$$Briefing\ from\ marketing = \frac{investments\ to\ increase\ LP}{avg\ per\ landlord\ briefing\ cost} \quad (62)$$

$$Briefing\ from\ word\ of\ mouth = \frac{BL+LP}{total\ landlords} * word\ of\ mouth\ effectiveness * PL \quad (63)$$

Stock: Briefed Landlord (BL)

$$BL = \int (Briefing - Participating) dt + BL(0) \quad (64)$$

accumulates the difference between landlord briefing and landlord participating. Initially BL is equal to BL (0).

Inflow: Landlord briefing is given by (60).

Outflow: Landlord participating

$$Landlord\ participating = participation\ from\ briefing + participation\ from\ word\ of\ mouth \quad (65)$$

$$Participation\ from\ briefing = yrly\ propt\ of\ participation\ from\ briefing * BL \quad (66)$$

$$\text{Participation from word of mouth} = \frac{LP}{\text{total landlords}} * \text{word of mouth effectiveness} * BL \quad (67)$$

Stock: Landlord Pool (LP)

$$LP = \int (\text{Participating} - \text{Withdrawing}) dt + LP(0) \quad (68)$$

accumulates the difference between landlord participating and landlord withdrawing. Initially LP is equal to LP (0).

Inflow: Landlord participating is given by (64).

Outflow: Landlord withdrawing

$$\text{Landlord withdrawing} = \text{yearly proportion of LP decreasing} * \text{effect of voucher loss on LP decreasing} * LP \quad (69)$$

In my model, there is initially not enough voucher units to rent to every TBV holder, as illustrated by Ferrier (2015). Then the stock of landlord pool is increased as a result of more and more landlords being briefed and becoming interested in participating the TBV program either because of the effect of word of mouth or because of the effect of marketing.

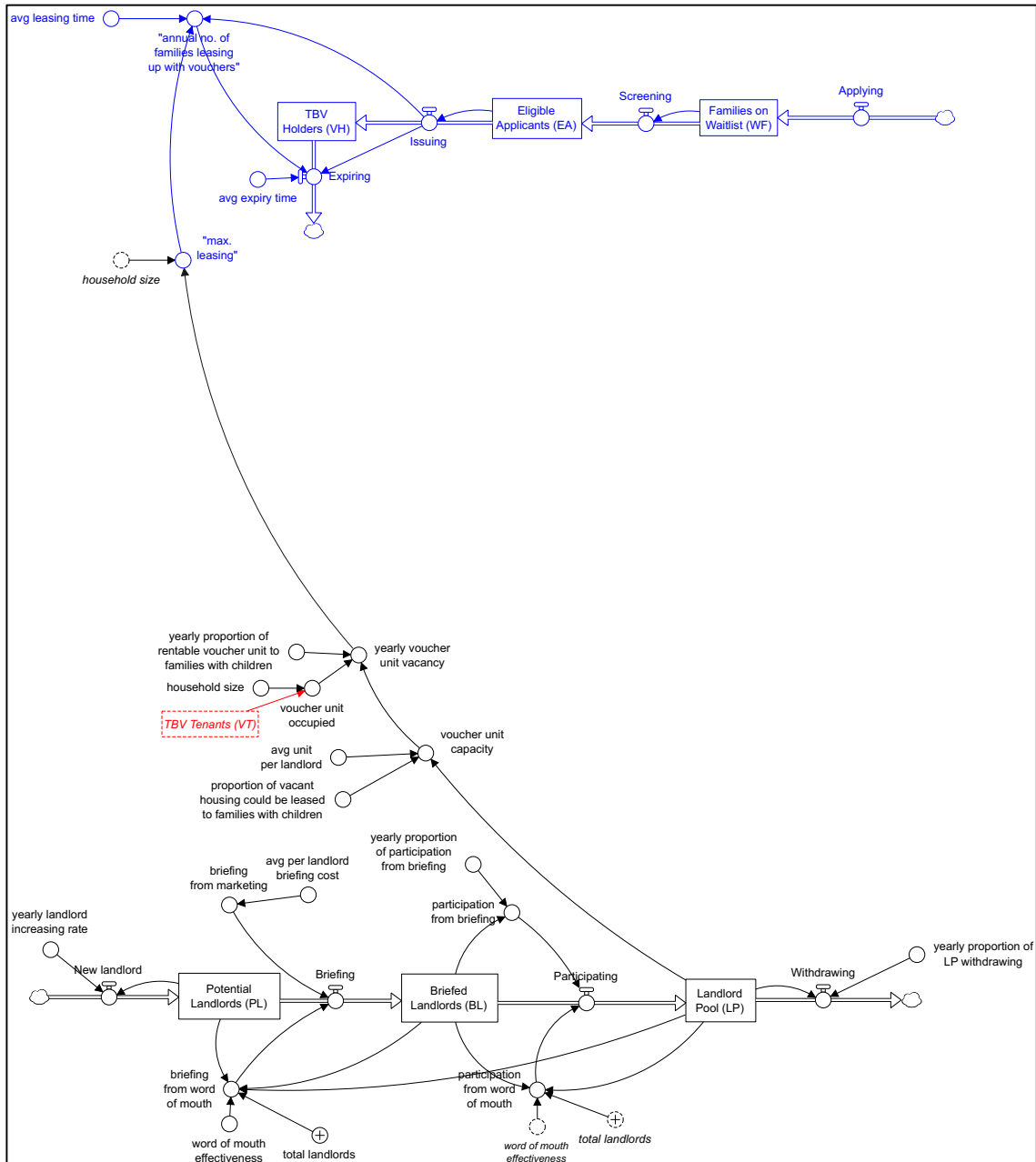


Fig. 4-23. Stock and flow structure representing how voucher units affect voucher leasing.

$$\begin{aligned}
 & \text{voucher unit capacity} = LP * \text{avg unit per landlord} * \\
 & \text{proportion of vacant housing could be leased to families with children} \quad (70) \\
 & \text{yearly voucher unit vacancy} = \text{MAX}(\text{voucher unit capacity} - \\
 & \text{voucher unit occupied}; 0) * \text{yearly proportion of rentable voucher unit} \quad (71)
 \end{aligned}$$

Table 5. Parameters and initial values of the landlord sector.

No.	Parameters and initial stock	Value	Unit
43	Avg. unit per landlord	2.2	Unit/landlord
44	Initial potential landlords	11,000	Landlords
45	Initial briefed landlords	150	Landlords
46	Initial landlord pool	273	Landlords
47	Yearly landlord increasing rate	0.9%	1/year
48	Word of mouth effectiveness	0.2	unitless
49	Avg. per landlord briefing cost	1000	USD/landlord
50	Yearly proportion of participation from briefing	0.3	1/year
51	Normal yearly proportion of LP withdrawing	5%	1/year
52	Proportion of vacant housing could be leased to families with children	0.5	unitless

Data Source:

43. Avg. unit per landlord: according to the US Census Bureau, there were about 48 million rental units in the US in 2017. According to the Rental Protection Agency, there were about 22 million landlords in the US that year. Based on this information, I calculated that a landlord has approximately 2.2 housing unit on average.

44. Initial potential landlords: according to the US Census Bureau, there were about 25 thousand rental units in the City of Fort Collins in 2010, I assume that the number did not change a lot compared to the year of 2009. Divided by an average of 2.2 housing unit per landlord, it was estimated that there were 11,000 potential landlords in 2009.

45. Initial briefed landlords: no data were found regarding this parameter, the number was estimated to be 150 landlords.

46. Initial landlord pool: the number was set as 273 landlords to be the same as the number of the TBV tenants.

47. Yearly landlord increasing rate: calculated by data provided by Rental Protection Agency.

48. Word of mouth effectiveness: it is estimated that 1 in 5 landlords could be influenced by those landlords who were willing to participate in the TBV program.

49. Avg. per landlord briefing cost: no data were found regarding this parameter, the number was estimated to be 1000 USD/landlord.

50. Yearly proportion of participation from briefing: I estimated that 3 in 10 landlords that are briefed is willing to participate.

51. Normal yearly proportion of LP withdrawing: I estimate 1 in 20 landlords will withdraw from the landlord list.

52. Proportion of vacant housing could be leased to families with children: I estimated that half of the rental units could be leased to families with children.

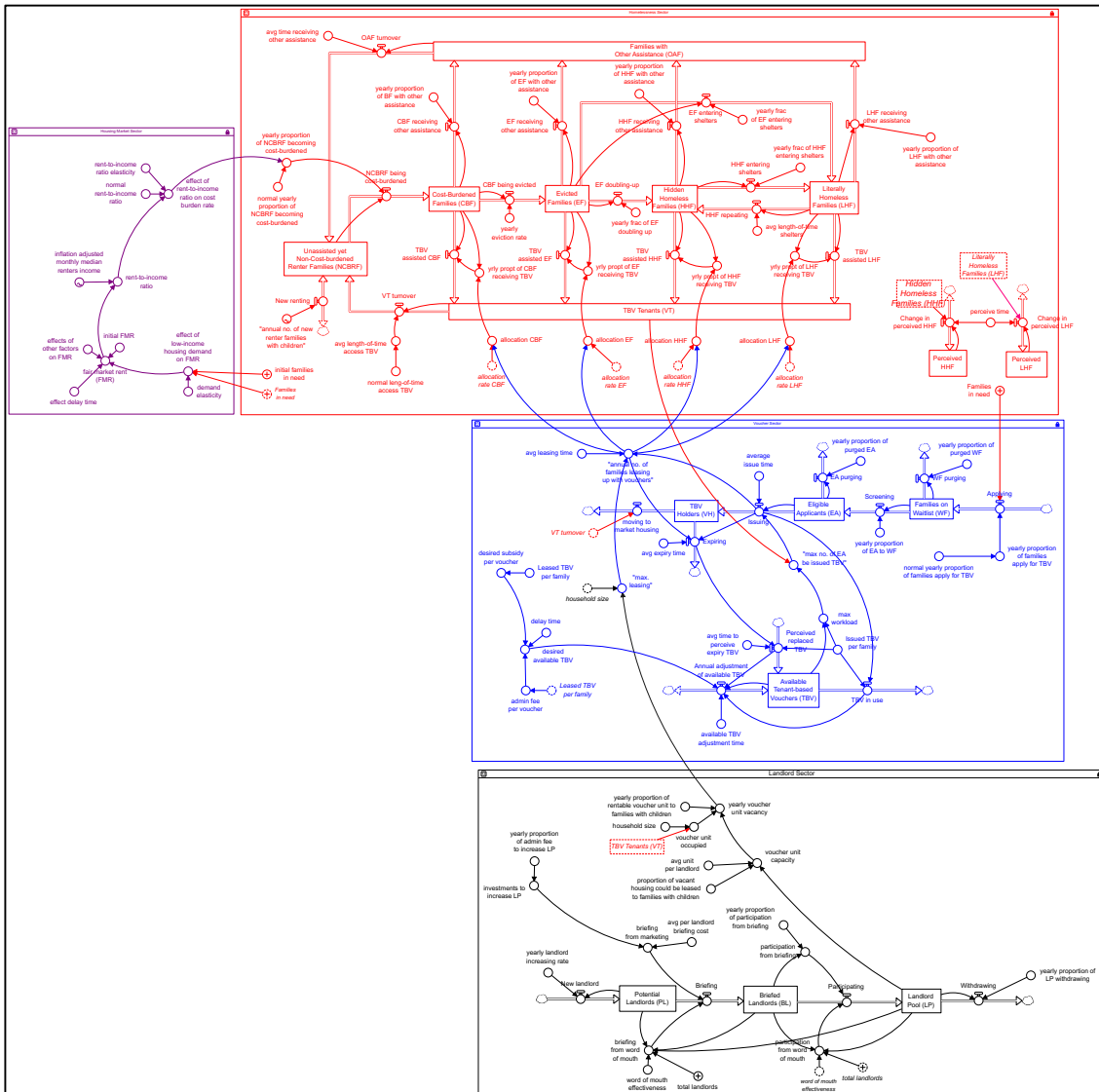


Fig. 4-24. Stock and flow structure representing the homelessness sector, the housing market sector, the voucher sector and the landlord sector.

4.5 The Funding Sector

Stock: Subsidy Funds (SF)

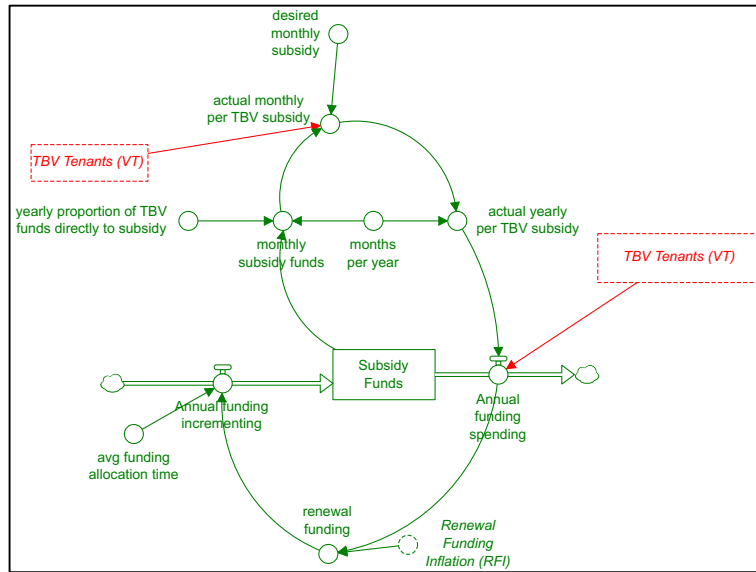


Fig. 4-25. Stock and flow structure of the subsidy funds.

$$SF = \int (Annual\ funding\ incrementing - Annual\ funding\ spending) dt + SF(0) \quad (72)$$

accumulates the difference between funding incrementing and funding spending. Initially SF is equal to SF (0).

When funding is available to support new tenant-based vouchers, HUD publishes a Notice of Funds Available (NOFA) in the Federal Register telling PHAs how and when to apply and what criteria will be used to select PHAs to receive funding. The funds received through this process at any one time are referred to as funding incrementing. These funds are spent to give rent assistance directly to the landlords.

Outflow: Funding spending

$$Annual\ funding\ spending = actual\ yearly\ per\ TBV\ subsidy * VT \quad (73)$$

$$Actual\ monthly\ per\ TBV\ subsidy = MAX (MIN (\frac{monthly\ subsidy\ funds}{VT}; desired\ monthly\ subsidy); 0) \quad (74)$$

Subsidy are paid to those eligible families based on the desired monthly subsidy standard, but with a limitation of the subsidy funds.

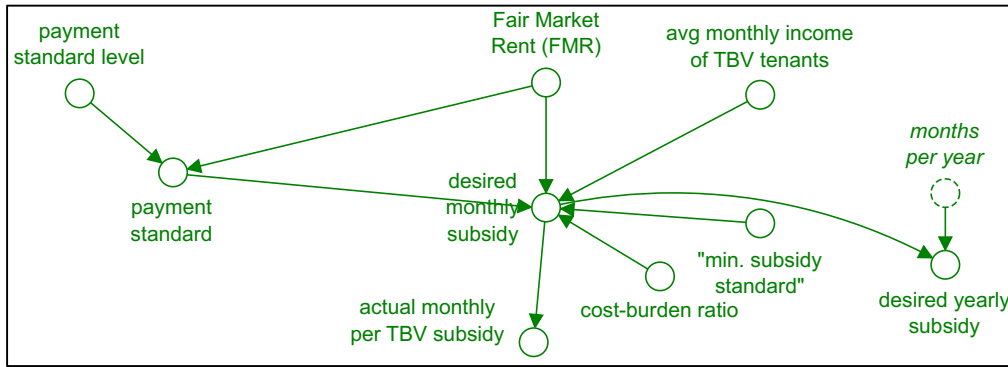


Fig. 4-26. Factors influence the desired monthly subsidy.

$$\text{Desired monthly subsidy} = \text{MAX} (\text{MIN}(\text{FMR} - \text{cost burden ratio} * \text{avg. monthly income of TBV tenants}; \text{payment standard}); \text{min subsidy standard}) \quad (75)$$

$$\text{payment standard} = \text{fair market rent} * \text{payment standard level} \quad (76)$$

The payment standard is the maximum subsidy that a PHA can pay for a family, based on the size of the unit the family will occupy. When a participating family leases a unit, the amount of the subsidy is reduced by amounts paid by the family.

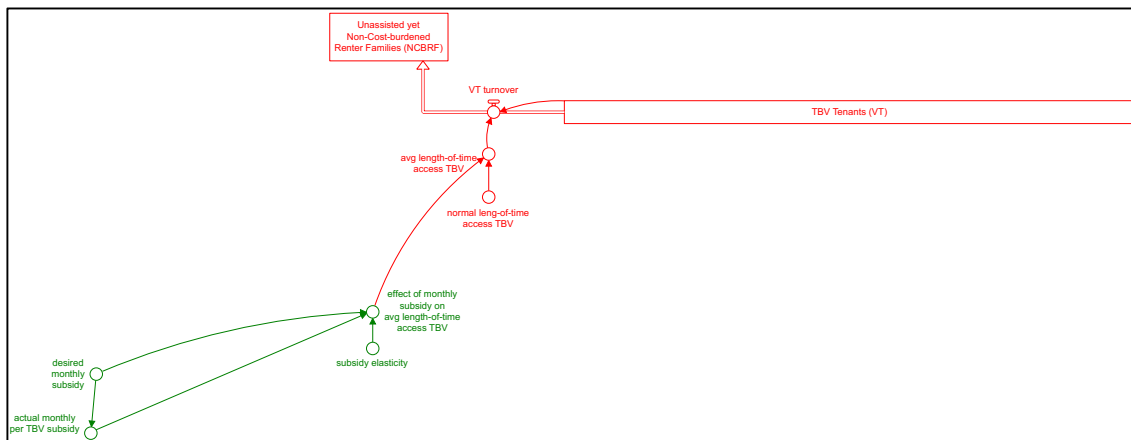


Fig. 4-27. Effect of monthly subsidy on average length-of-time access TBV.

$$\text{effect of monthly subsidy on avg length of time access TBV} = \left(\frac{\text{actual monthly per TBV subsidy}}{\text{desired monthly subsidy}} \right)^{\text{subsidy elasticity}} \quad (77)$$

$$\text{avg length of time access TBV} = \text{normal length of time access TBV} * \text{effect of monthly subsidy on avg length of time access TBV} \quad (78)$$

The bigger the difference between the actual subsidy and the desired subsidy, the longer time for the TBV tenants need to become independent.

Inflow: New funding incrementing

$$\text{Annual funding incrementing} = \text{DELAY}(\text{renewal funding}; \text{avg funding allocation time}) \quad (79)$$

$$\text{Renewal funding} = \text{Historical}(\text{Funding spending}; \text{Time} - 1) * (1 + \text{renewal funding inflation}) \quad (80)$$

HUD calculates a PHA's current-year funding by looking at the amounts used by the PHA in the previous year, with an adjustment.

Stock: Administrative Fee Reserves (ARF)

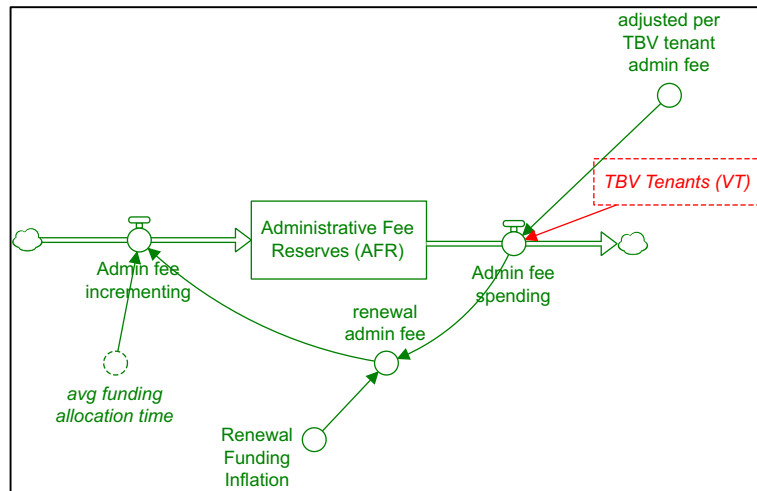


Fig. 4-28. Stock and flow structure of the administrative fee reserves.

$$AFR = \int (\text{Admin fee incrementing} - \text{Admin fee spending}) dt + AFR(0) \quad (81)$$

Similar to the subsidy funds, the admin fee reserve accumulates the difference between admin fee incrementing and spending. Initially AFR is equal to AFR (0).

Outflow: Admin fee spending

$$\text{Admin fee spending} = \text{adjusted per TBV tenant admin fee} * VT \quad (82)$$

Inflow: Admin fee incrementing

$$\text{Admin fee incrementing} = \text{DELAY}(\text{renewal admin fee}; \text{avg funding allocation time}) \quad (83)$$

$$\text{Renewal admin fee} = \text{Historical}(\text{admin fee spending}; \text{Time} - 1) * (1 + \text{renewal funding inflation}) \quad (84)$$

The admin fee is also renewed based on the previous year's spending with an adjustment.

Table 6. Parameters and initial value of the funding sector.

No.	Parameters and initial stock	Value	Unit
53	Initial subsidy funds	3,000,000	USD
54	Initial administrative fee reserves	175,000	USD
55	Renewal funding inflation	2%	unitless
56	Avg. funding allocation time	1	Year
57	Yearly proportion of TBV reserves to subsidy	1	1/year
58	Cost-burden ratio	0.3	unitless
59	Payment standard level	1.1	unitless
60	Subsidy elasticity	-0.8	unitless
61	Adjusted per TBV tenant admin fee	400	USD/family/year
62	Yearly proportion of admin fee to increase LP	0.1	1/year

Data Source:

53/54. Initial subsidy funds/ administrative fee reserves: no data were found regarding the number. Since initially there are 300 families receiving vouchers. It was assumed that the funds was slightly larger than the amount needed to cover the existing TBV tenants.

55. Renewal funding inflation: Based on the data provided by HUD, the “renewal funding inflation” changed every year. The number was set as an average of 2% in the model.

56. Avg. funding allocation time: HUD allocate its funding year by year.

57. Yearly proportion of TBV reserves to subsidy: it is assumed that all of the subsidy reserves could be used to help those families.

58. Cost-burden ratio: Based on HUD’s definition, the subsidy is aimed to help the renters not spending more than 30% of their income.

59. Payment standard level: Payment standards are set by the PHA at levels between 90 percent and 110 percent of the HUD-published Fair Market Rent (FMR) for the metropolitan or other area, based on the PHA’s knowledge of the local rental market. The number was set as 110 percent of the FMR for Housing Catalyst.

60. Subsidy elasticity: the number was estimated to be -0.8.

61. Adjusted per TBV tenant admin fee: the number was estimated to be 400 USD family⁻¹ year⁻¹.

62. Yearly proportion of admin fee to increase LP: the number was estimated to be 10% per year.

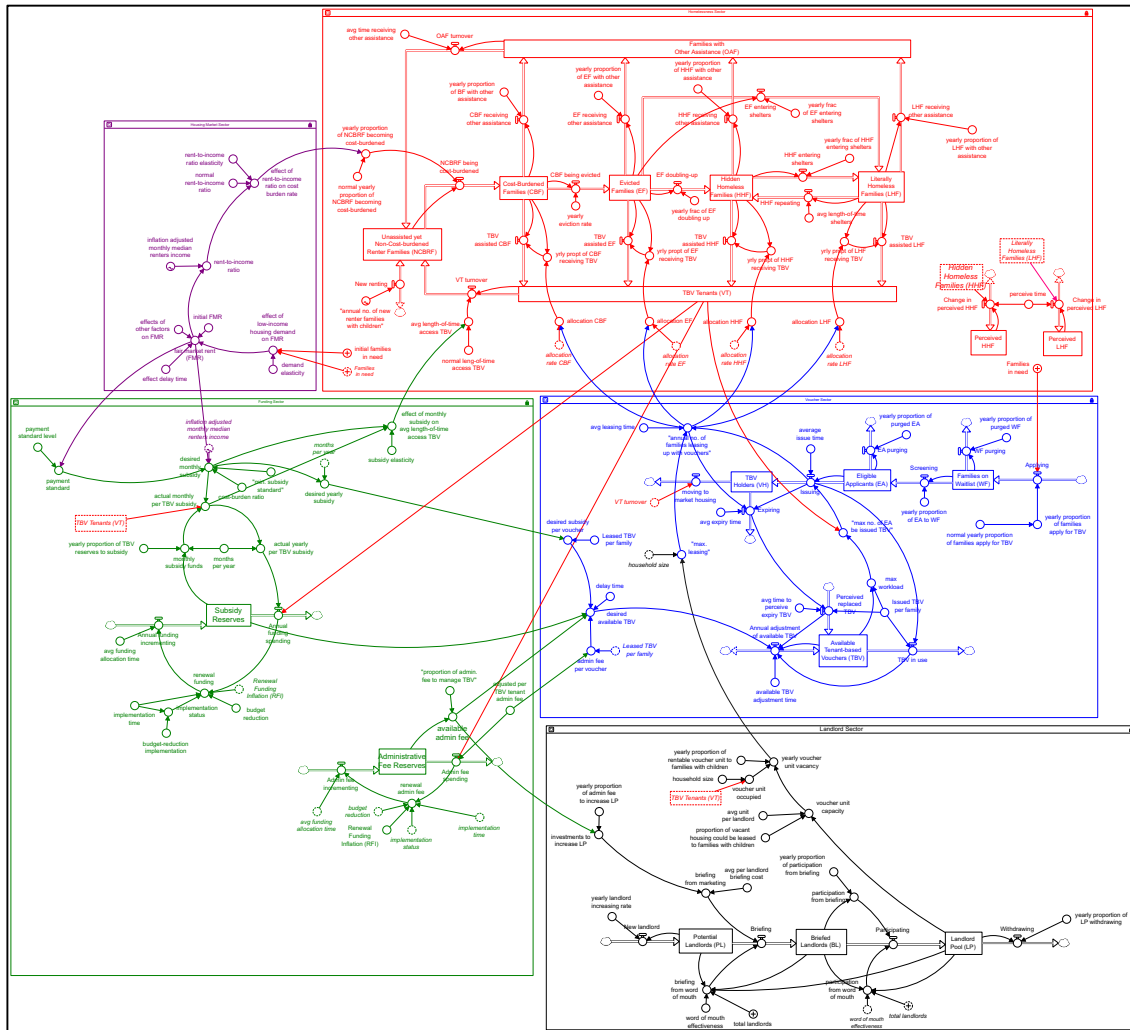


Fig. 4-29. Stock and flow structure representing the homelessness sector, the housing market sector, the voucher sector, the landlord sector and the funding sector.

5. MODEL VALIDATION

By referring the model structure, parameter values and equations to the literature and real data in the previous section, we have partially done structure confirmation and parameter confirmation tests which were mentioned in (Barlas, 1996). The model also has passed the dimensional consistency test checked within the Stella Architect software. In this part, we will conduct more validation tests.

5.1 Initialize the family homeless system in equilibrium

Before conducting the validation tests, we need to firstly adjust the presented model in equilibrium. As shown in Fig. 5-1, in this equilibrium state, inflows and outflows equal to each other, when proper values were chosen for some important parameters.

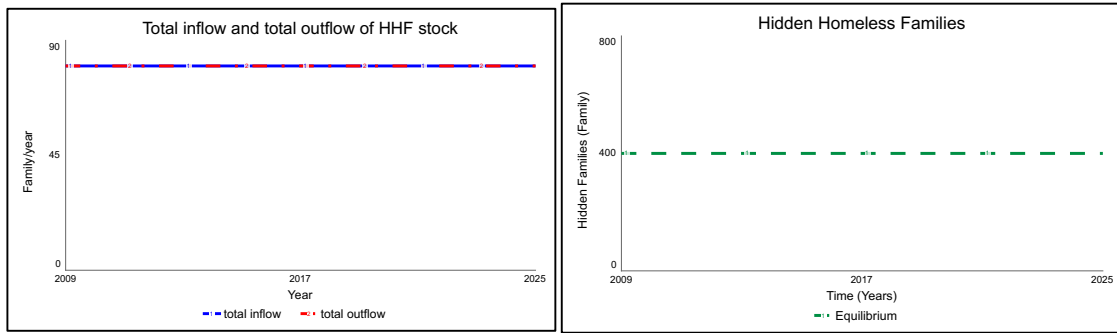


Fig. 5-1. The number of hidden homeless families when the model is in equilibrium. Under this state, the number of hidden homeless families was set to 400 over the entire simulation period.

What to mention is that, in equilibrium,

$$EQ \text{ available TBV} = (EA + VT) * \text{issued TBV per family} \quad (85)$$

which means that the “max. no of EA be issued TBV” equals the number of EA in equilibrium.

And

$$EQ \text{ initial TBV reserve} = \text{available TBV} * \text{desired subsidy per voucher} \quad (86)$$

$$EQ \text{ initial admin fee reserve} = \text{available TBV} * \frac{\text{admin fee per voucher}}{\text{proportion of admin fee to TBV}} \quad (87)$$

Which means that the desired available TBV is equal to available TBV in equilibrium.

Some parameters and their values necessary to keep the model in the equilibrium state were listed in the appendix.

5.2 Shock Tests

5.2.1 Yearly eviction rate shock tests

As shown in Fig. 5-2, if the yearly eviction rate increased by 50% since 2010,

$$\text{Yearly eviction rate shock volume} = \text{yearly eviction rate} + STEP(50\% * \text{yearly eviction rate}; 2010) \quad (88)$$

the inflow, “EF doubling up”, of the HHF jump to a higher level, and the amount of HHF increases since then.

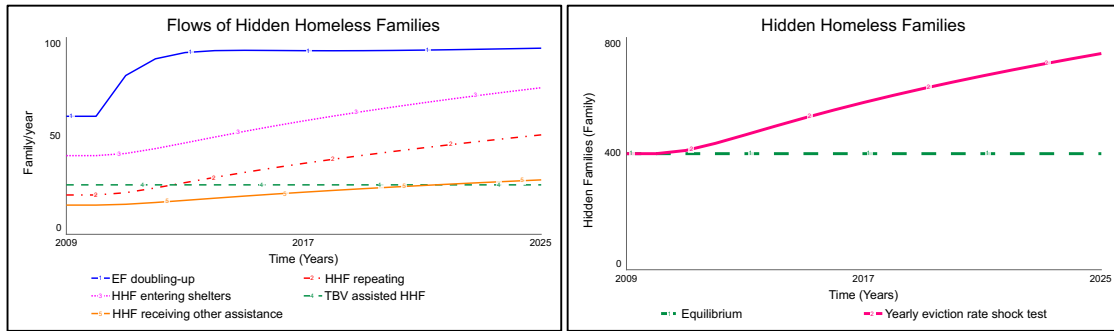


Fig. 5-2. Yearly eviction rate shock test.

5.2.2 Eligible applicants and renewal funding shock tests

In equilibrium, the number of available TBV equals the total TBV tenants and the eligible applicants. As shown in Fig. 5-3, if both the eligible applicants and the renewal funding inflation (RFI) increased since 2010, the number of HHF decreased after a delay.

$$\text{Applicants shock volume} = \text{yearly proportion of families applying for TBV} + \text{STEP}(50\% * \text{yearly proportion of families applying for TBV}; 2010) \quad (89)$$

$$\text{RFI shock volume} = \text{EQ RFI} + \text{STEP}(20\%; 2010) \quad (90)$$

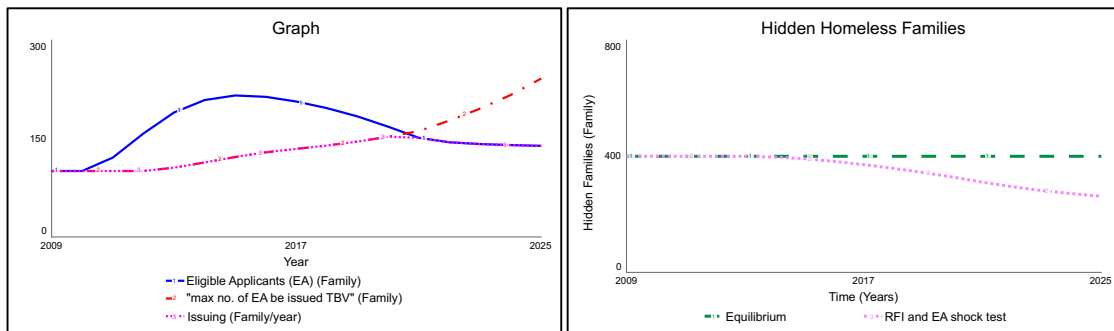


Fig. 5-3. Eligible applicants and renewal funding shock test.

5.3 Extreme-condition test

The extreme-condition test involves assigning extreme values to selected parameters and comparing the model-generated behavior to the anticipated behavior of the real system under the same extreme condition (Barlas, 1996).

As shown in Fig. 5-4, if there were no families being cost-burdened,

$$\text{normal percent of renter families with cost burden} = 0 \quad (91)$$

the number of “EF doubling up” will decrease to 0, and the HHF will eventually be eliminated.

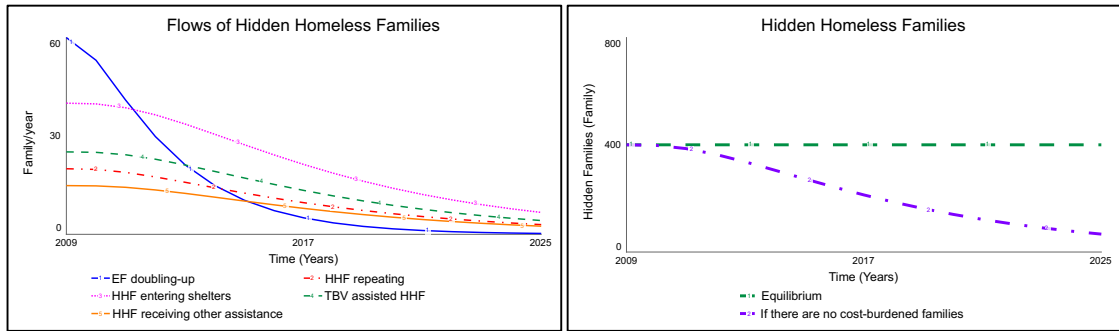


Fig. 5-4. Sketch of possible response if there were no families becoming cost-burdened.

5.4 Reference behavior pattern test

Generally, as shown in Fig. 5-5, the simulated behavior successfully replicates the general increasing trend shown in the reference mode, probably due to the most critical factors that influence the inflows or the outflows of the stock of HHF are successfully illustrated in the model.

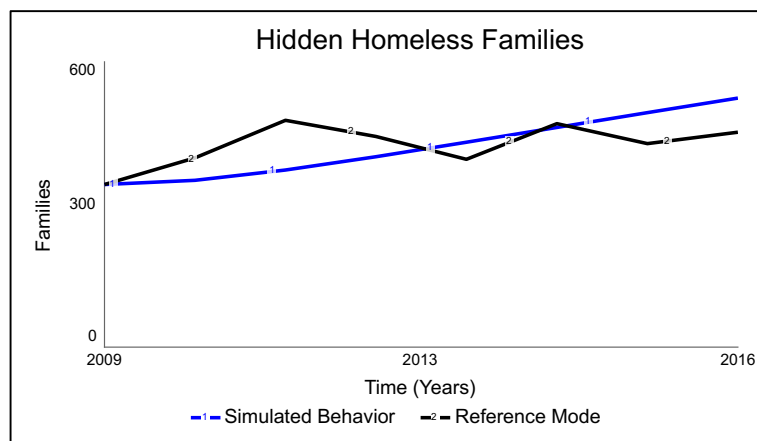


Fig. 5-5. The simulated results and the historical data of the HHF number.

Only compared the simulated results with the reference mode is insufficient to make sure the model truly represents the process of families receiving tenant-based vouchers, since the number of HHFs being assisted by TBV is only about 15% of the total families receiving TBV. Therefore, the simulation results of the “available TBV” and the “TBV tenants” were compared with their historical data to check if the model represents the reality.

As shown in Fig. 5-6, the simulated results of the number of “available TBV” fits well with the historical data from 2009 to 2014, after that the simulated number decreased a little while the historical number kept increasing. The simulated behavior of the “TBV tenants” is slightly lower than the historical data. I believe the difference is acceptable,

since the specific data of the authorized vouchers for families with children and their vouchers in use are unavailable and was calculated.

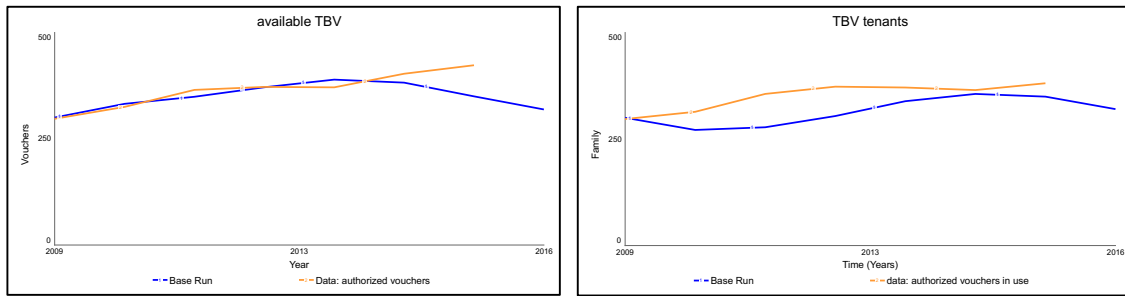


Fig. 5-6. The simulated results and the historical data of the “available TBV” and “TBV tenants”.

Note: The Housing Voucher data provided by the CBPP only showed the total amount of the authorized vouchers and vouchers in use, no data about families with children are specified. Based on the 2016 annual report of the Housing Catalyst, about 40% of the vouchers were used by families with children. The percent was used when calculating the number of available vouchers for families with children and their vouchers in use.

5.5 Sensitivity tests

As we mentioned in the Quantitative Model section, the data of some parameters, including the “fraction of EF doubling up”, the “yearly proportion of LHF with other assistance” and the “avg. time receiving other assistance” in the homelessness sector, the “yearly proportion of families in need apply for TBV” in the voucher sector, the “initial briefed landlords” and the “word of mouth effectiveness” in the landlord sector, and the “initial subsidy funds” in the funding sector, were unavailable and their numbers were just estimation. In this part, sensitivity analyses were conducted to check if the uncertainty of these parameters could influence the number of HHF, the number of available TBV or the number of TBV tenants.

As shown in Fig. 5-7, the exact number of HHF differed a little but the increasing trend still holds true when the “fraction of EF doubling up” changes. The changes of “yearly proportion of LHF with other assistance” and “avg. time receiving other assistance” parameters do not have significant effects on the number of HHF.

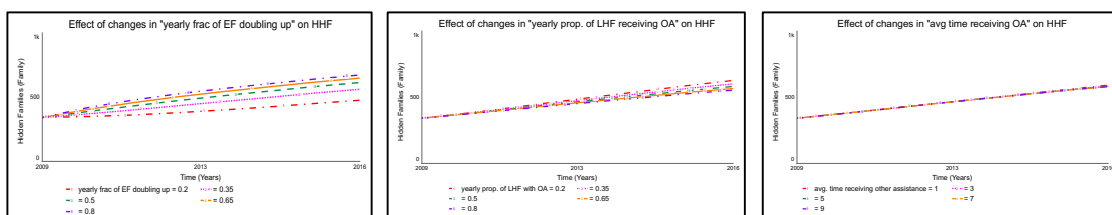


Fig. 5-7. Sensitivity analysis of the HHF number as a function of “yearly frac. of EF doubling up”, “yearly proportion of LHF with other assistance” and “avg. time receiving other assistance”.

As shown in Fig. 5-8, if the “initial subsidy funds” is too little to cover the initial TBV tenants, the available TBV will show a big difference, otherwise the change of the “initial subsidy funds” does not have significant effect on the number of available TBV.

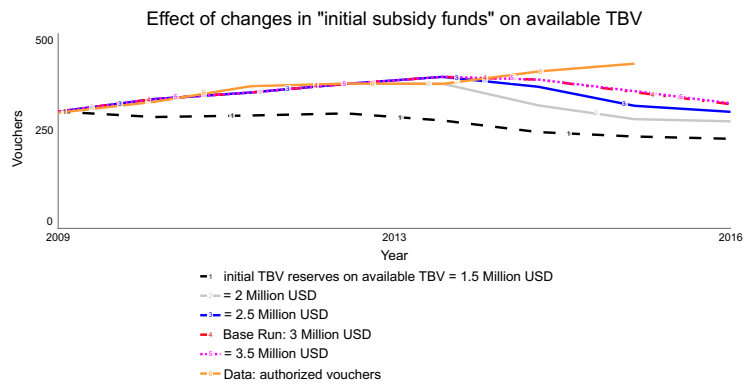


Fig. 5-8. Sensitivity analysis of the available TBV as a function of “initial subsidy funds”.

As shown in Fig. 5-9, the number of TBV tenants shows a similar trend when the “yearly proportion of families apply for TBV”, the “initial briefed landlord”, or the “word of mouth effectiveness” changes, except the case when the “word of mouth effectiveness” is very low.

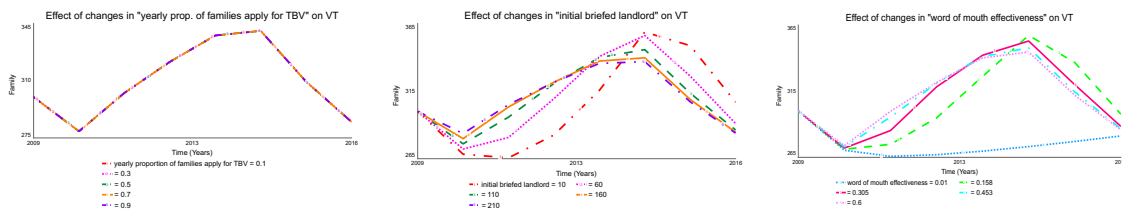


Fig. 5-9. Sensitivity analysis of the number of TBV tenants as a function of the “yearly proportion of families apply for TBV”, the “initial briefed landlord”, and the “word of mouth effectiveness”.

The above sensitivity tests reveal that the model is insensitive to those estimated parameters.

Based on the results of the above shock tests, the extreme-condition tests, reference behavior pattern testing and sensitivity tests, we can conclude that the simulation results are consistent with the expected behavior of the real system.

6. BEHAVIOR ANALYSIS

From the simulated behavior, we can see that the number of HHF increased from 2009 to 2016. In this part, I will try to answer why the number of HHF increased and how the number will change in the future. To this end, results were obtained by simulations using the program of Stella Architect, version 1.5 with the following simulation

specifications: Integration Method: Runge-Kutta (4th order); Time Unit: Years; Time Step: 1/16; Time Horizon: 17 years from 2009 to 2025.

6.1 Why did the number of HHF increase?

As shown in Fig. 6-1, the number of HHF increased because the total inflow adding to the stock was larger than the total outflow subtracted from the stock.

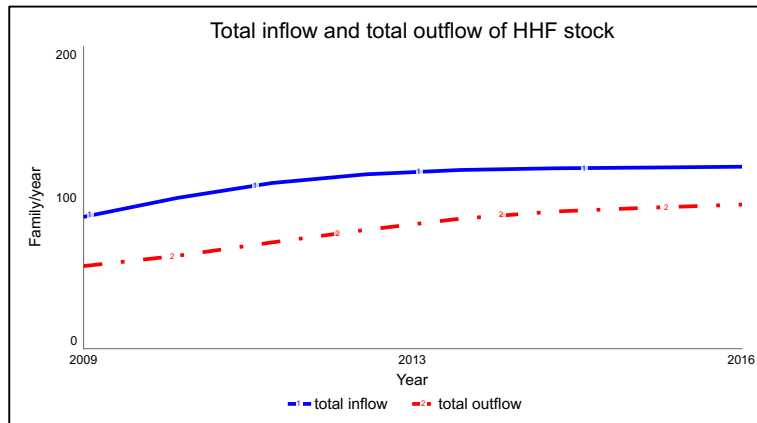


Fig. 6-1. Total inflow and total outflow of the HHF stock in base run.

Specifically, the total inflow is the summary of “EF doubling up” and “HHF repeating”, the total outflow is the summary of “HHF entering shelters”, “TBV assisted HHF” and “HHF with other assistance”. I will explore each flow in the following parts.

6.1.1 The increased inflow of “EF doubling up” leading to an increased number of HHF.

After checking the inflows and outflows of the HHF stock, I found that the increased number of HHF is mainly caused by the inflow, “EF doubling-up”, among the five flows (Fig. 6-2), meaning that the number of HHF increased when a large number of evicted families doubled-up due to some reasons.

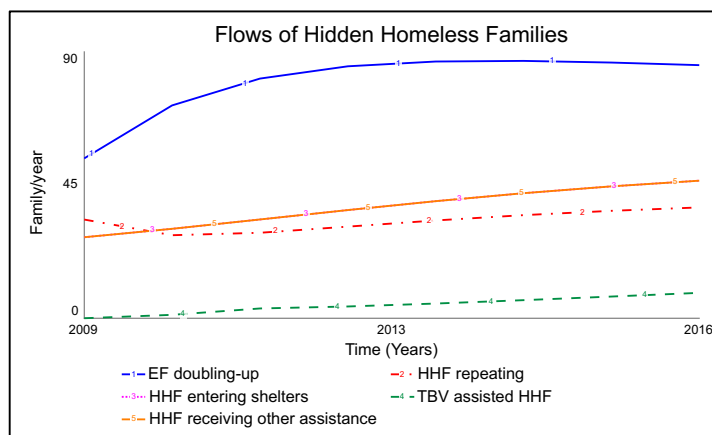


Fig. 6-2. The flows of hidden homeless families in base run.

Further, I found that the number of “EF doubling-up” increased as a result of the increasing number of EF. Specifically, with the faster increase of the housing rent than the income, many renter families were cost-burdened and at imminent risk of homelessness. When experiencing an adverse event, some of these cost-burdened families were fortunate to receive a rent assistance to overcome the crisis, while the rest were most likely to be evicted by their landlords due to the limited capacity of rent assistance in the city of FC. As a result, more evicted families doubled-up with their friends/relatives (Fig.6-3).

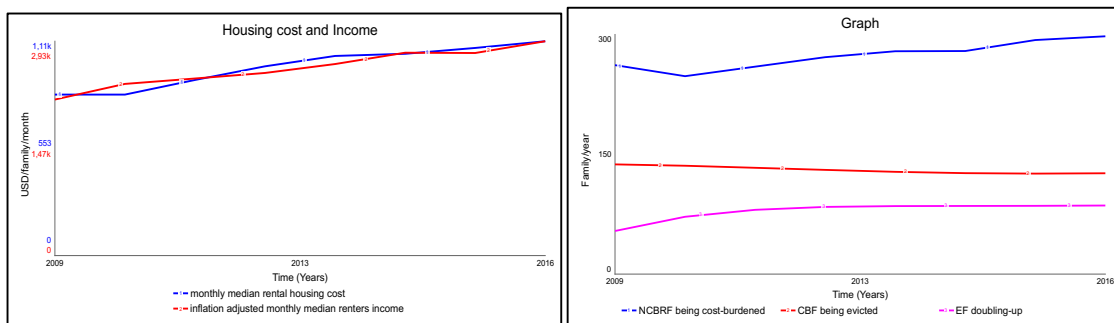


Fig. 6-3. Annual number of renter families being cost-burdened and the being evicted.

6.1.2 The increased but limited outflow of “TBV assisted HHF” and “HHF with other assistance” keep the number of HHF at its historical level.

As shown in Fig. 6-4, if there were no assistance⁹ to help the at-risk or homeless families, which means they have no chance to get rid of the vulnerable situation, the number of the HHF is expected to increase to an extremely high level.

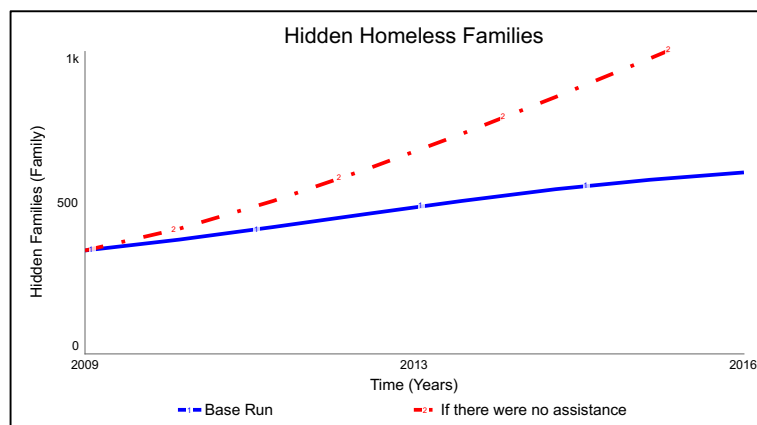


Fig. 6-4. The number of HHF if there were no assistance to help the HHF.

It is the assistance programs that keep the number of HHF from increasing very fast. The effect of the TBV and other assistance programs on reducing the HHF was shown

⁹ If there were no assistance, the “yearly proportion of families receiving other assistance” is 0/year, and the “subsidy reserves” is 0 USD in the model.

in the following loop (Fig. 6-5), with a closer attention paid to the TBV program. After an administration process from submitting application to finally be issued a voucher, some of the HHF were fortunate to lease an apartment and got rid of the risk situation.

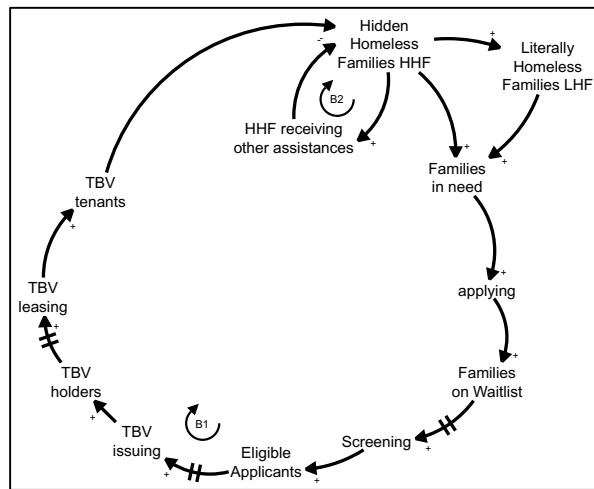


Fig. 6-5. The feedback loop illustrating the effect of TBV and other assistances on ending HHF.

We can imagine that if there were no limit on the assistance, all of the at-risk or homeless families will be assisted, and the HHF population will eventually decrease to 0.

However, in reality, both the TBV capacity and the capacity of other assistances are limited. The lack of TBV and the short of other assistances made the total outflow of the stock of HHF less than its inflow, and were responsible for the increased HHF population.

As shown in Fig. 6-6, there was a large number of eligible applicants every year (represented as “screening”), but the annual number of families be issued vouchers (represented as “issuing”, constrained by the available TBV) and the “annual number of families leasing up vouchers” (constrained by the “voucher units vacancy”) were much less than the number of eligible applicants.

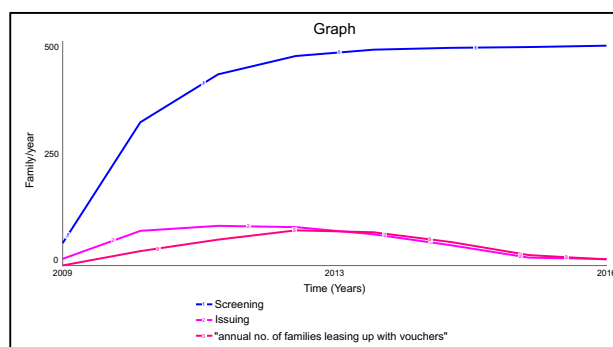


Fig. 6-6. The annual no. of families that go through the screening, issuing and leasing processes.

The effect of the lack of the TBV program, in the form of either available TBV or voucher units, on the HHF population could be represented in Fig. 6-7.

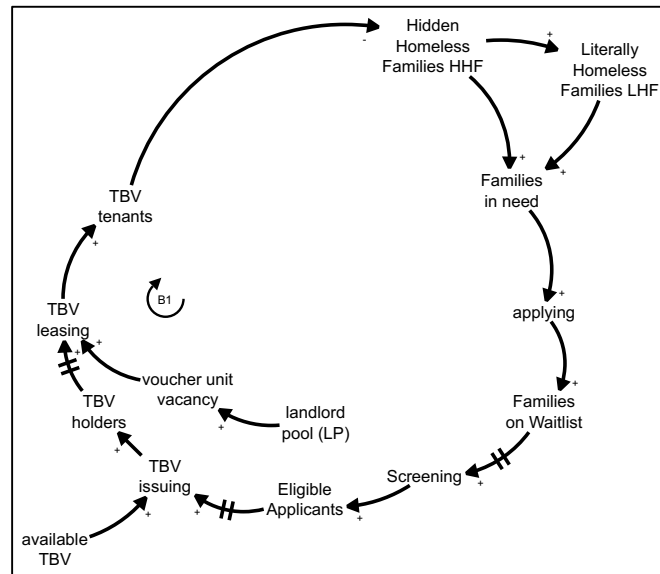


Fig. 6-7. The limit of TBV on HHF.

Further, I found that the main factor that affected the number of HHF shifted from the restriction of “yearly voucher unit vacancy” to the limit of available vouchers during the past years. As shown in Fig. 6-8, before the year of 2013, the voucher issuing was larger than the number of yearly voucher unit vacancy. The increased number of HHF was mainly resulted from the restriction of voucher units during this period. However, with the expansion of the landlord pool, either as a result of marketing or because of the word of mouth, the annual number of voucher unit vacancy exceeded the available vouchers. The increased trend of the HHF population was mainly resulted from the restriction of available vouchers after the year of 2013.

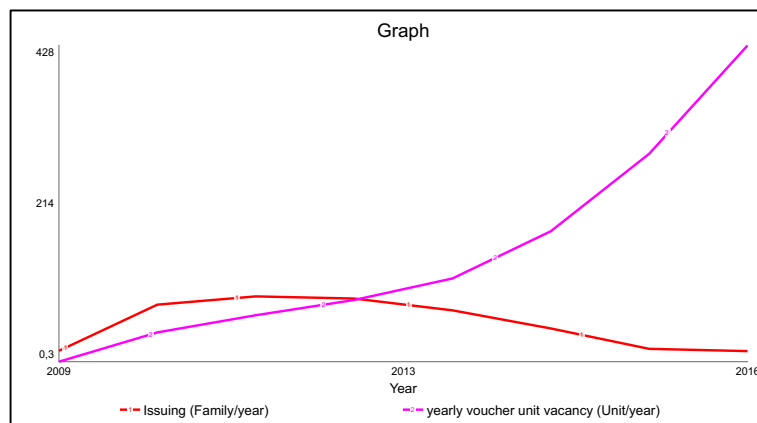


Fig. 6-8. Shift between the limit of voucher units and the limit of available TBV.

The reason why the number of “issuing” decreased significantly after 2014 is that the number of TBV tenants exceeded the maximum number of families the subsidy reserve

could cover after the year of 2014 (Fig. 6-9). Therefore, not so many vouchers could be issued unless some TBV tenants quit.

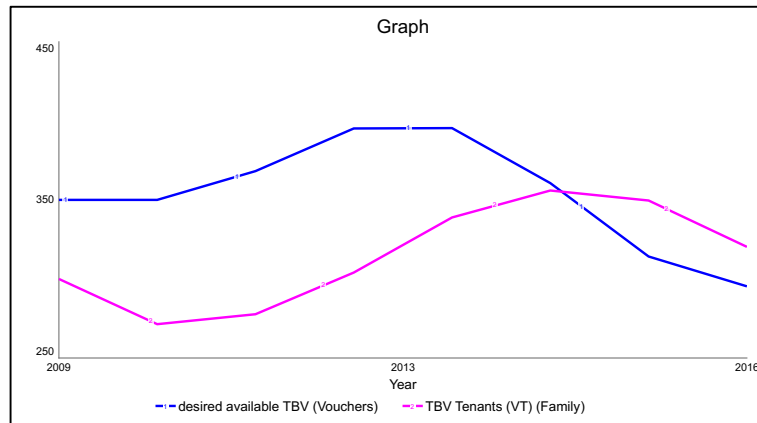


Fig. 6-9. TBV tenants and the desired available TBV the subsidy could cover.

6.2 How will the number of HHF change?

This part mainly shows the simulation results under two scenarios: the “business-as-usual” scenario and the “budget-reduction” scenario.

6.2.1 The “Business-as-usual” scenario

The “business-as-usual” scenario was run focusing on the question: how will the number of HHF change, if they are not given enough attention as currently?

As shown in Fig. 6-10, if there are no new policies to help the hidden homeless families, their amount will keep increasing in the future.

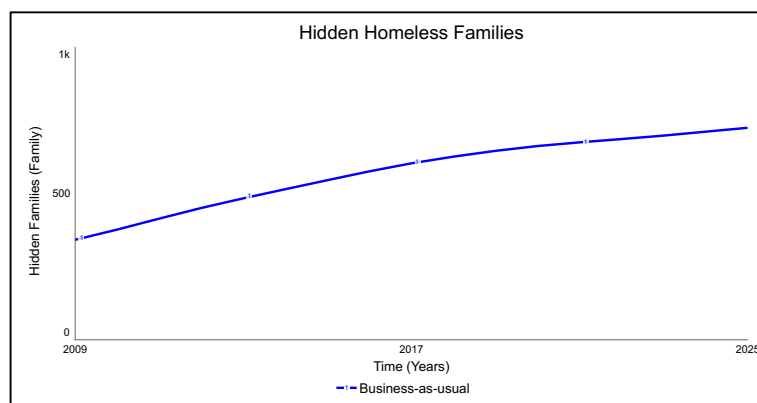


Fig. 6-10. Number of hidden homeless families in the “Business-as-usual” scenario.

The increasing trend is mainly because the high number of “EF doubling up” far outweighs the number of HHF receiving assistance, especially the number of “TBV assisted HHF” (Fig. 6-11) under the influence of the factors explored in the 6.1 section.

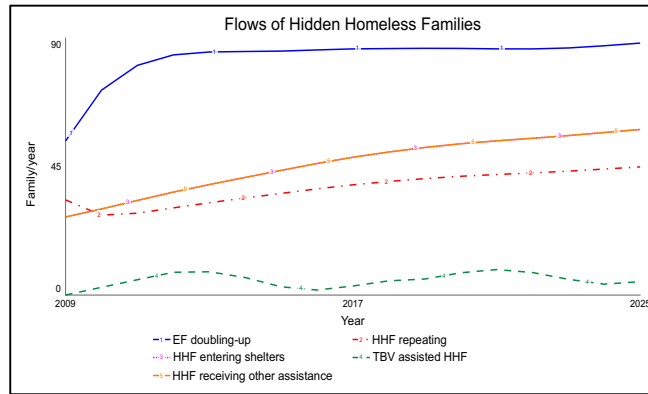


Fig. 6-11. Flows of the number of HHF in the “business-as-usual” scenario.

What to mention specifically is the unexpected cycles of the “TBV assisted HHF”. As shown in Fig. 6-12, the number of “TBV tenants” increased after 2010, followed by an increase of the “annual funding spending”. However, because of the delay of the funding allocation process, the “annual funding incrementing” lagged behind, and the subsidy funds decreased. As a result, the desired number of vouchers that the subsidy funds could cover was lower than the number of “TBV tenants”. In order to assist all the families, the “actual monthly per TBV subsidy” had to be shrunk. When the “annual funding incrementing” caught up with the “annual funding spending”, and the number of “TBV tenants” decreased to fit the subsidy funds, both the subsidy reserve and the actual monthly subsidy increased. Therefore, the number of “TBV tenants” increases again after a delay. This process repeats about every 6 years, and this is the reason why the number of “TBV assisted HHF” cycles over time.

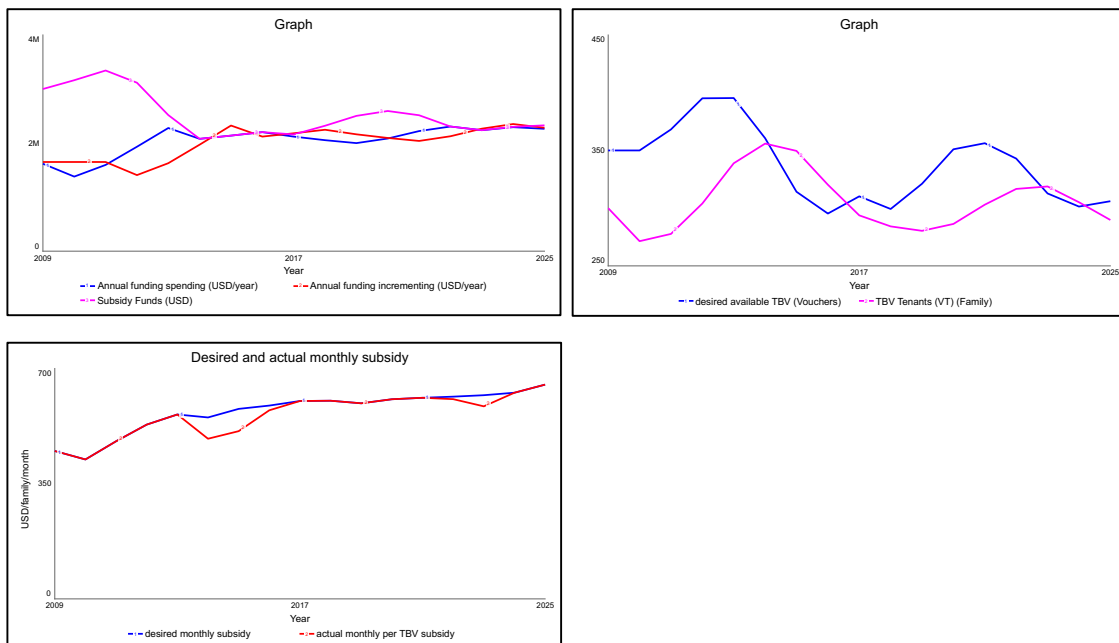


Fig. 6-12. Changes of the “subsidy funds”, the “TBV tenants” and the “actual monthly subsidy”.

The effect of the funding incrementing delay on the number of HHFs could be illustrated by the following loops.

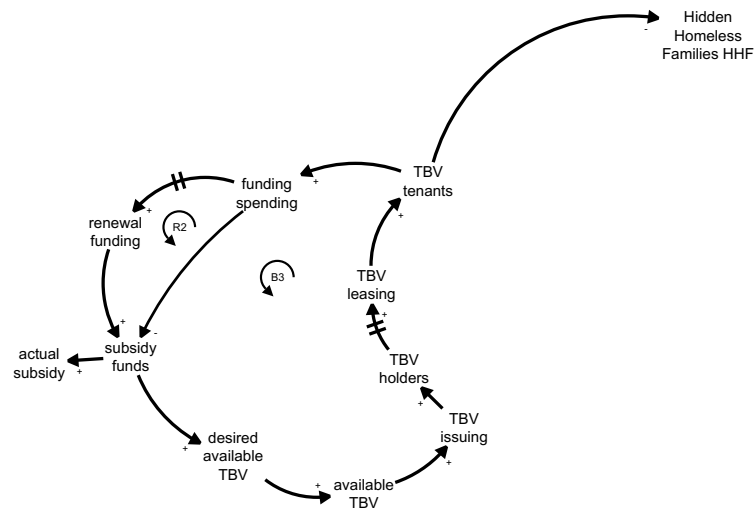


Fig. 6-13. The effect of the funding incrementing delay on the number of HHFs.

The above mentioned simulation results were based on the assumption that the housing cost will increase faster than the monthly median income in the future, while how the rent-to-income ratio will change is uncertain. In this sensitivity test, the rent-to-income ratio was set either as a moderate value of 0.3 or a lower value of 0.2 from 2018 on, to compare with the “business-as-usual” scenario. As shown in Fig. 6-14, the change of the rent-to-income ratio does not significantly influence the number of HHF.

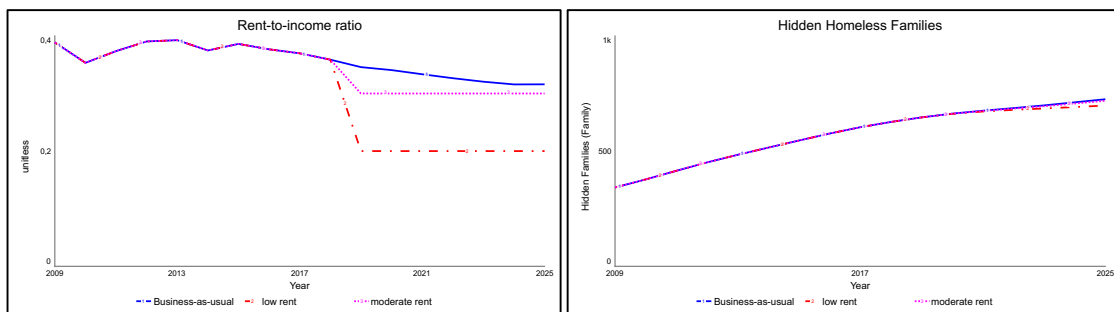


Fig. 6-14. Sensitivity analysis of the HHF number as a function of rent-to-income ratio.

6.2.2 The “Budget-reduction” scenario

This scenario is aimed to understand the question, how will the amount of HHF change if the federal budget is reduced since 2018?

renewal funding

$$= \text{History}(\text{funding spending}; \text{time} - 1) * (1 + RFI) * (1 - \text{Step}(BR; BRIT) + \text{Step}(BR; BRIT + 1))$$

Budget reduction (BR)

$$BR = \text{History}(\text{funding spending}; \text{time} - 1) * BRR$$

Budget reduction rate (BRR) is 13.2%¹⁰.

Budget reduction implementation time (BRIT) is the year in 2018.

As shown in Fig. 6-15, if there is a reduction of HUD funding from 2018, the number of hidden homeless families will not show any difference.

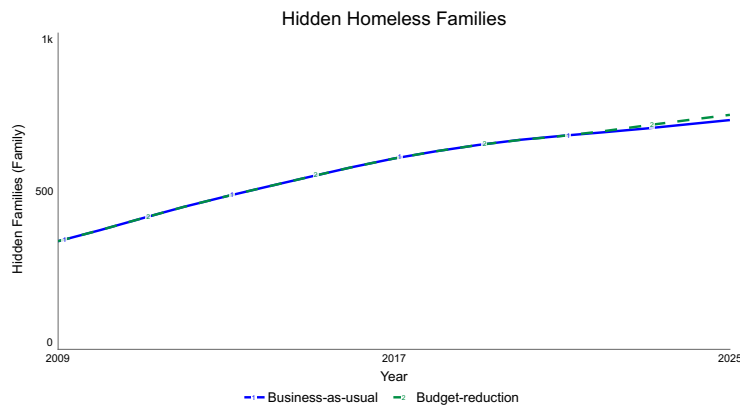


Fig. 6-15. Number of hidden homeless families if the federal budget cuts are implemented in 2018.

However, this does not mean the budget reduction does not have any influence on the family homelessness system. According to the simulation results, the federal budget cuts mainly have three effects.

Firstly, the budget cuts will decrease the desired available TBV and thus reduce the issuable vouchers (Fig. 6-16).

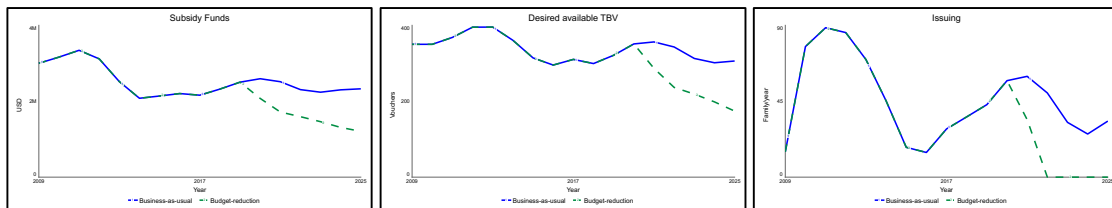


Fig. 6-16. Changes in the available TBV and issuing if the budget cuts are implemented in 2018.

Secondly, as we mentioned before, in order to cover all the TBV tenants, the Housing Catalyst have to decrease the “actual monthly per TBV subsidy”. As a result, the families who are receiving vouchers have to depend on the assistance for a longer time (Fig. 6-17).

¹⁰ The simulation results under the “budget-reduction” scenario are based on the hypothesis that the budget reduction will reduce by about 13.2% in 2018. Although it is uncertain how the budget will change, this analysis could shed some lights on how the budget reduction will influence the at-risk or homeless families.

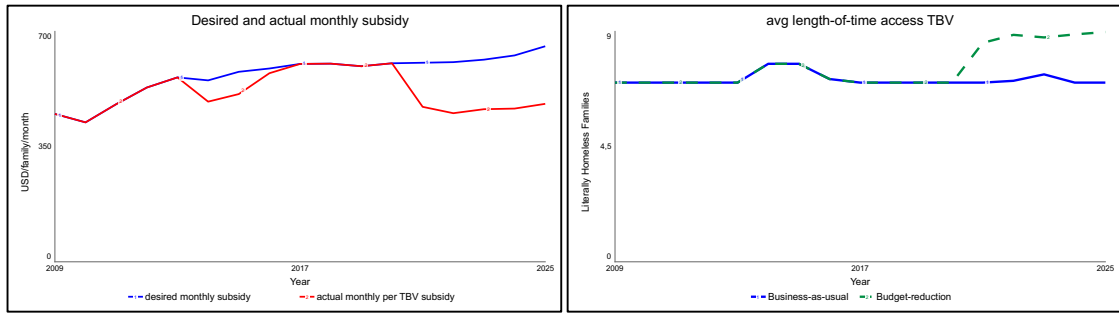


Fig. 6-17. The TBV tenants’ average length-of-time access TBV if the budget cuts are implemented.

Thirdly, it is hypothesized in the Qualitative Model section that the funding cuts will reduce the number of voucher units. After checking the simulation results, I found that the administrative fee will be decreased, which means less money will be invested to expand the landlord pool. Therefore, the number of “landlord briefing from marketing” is expected to decrease. However, because of the word-of-mouth impact is greater than the briefing effect, the number of voucher units is not influenced (Fig. 6-18).

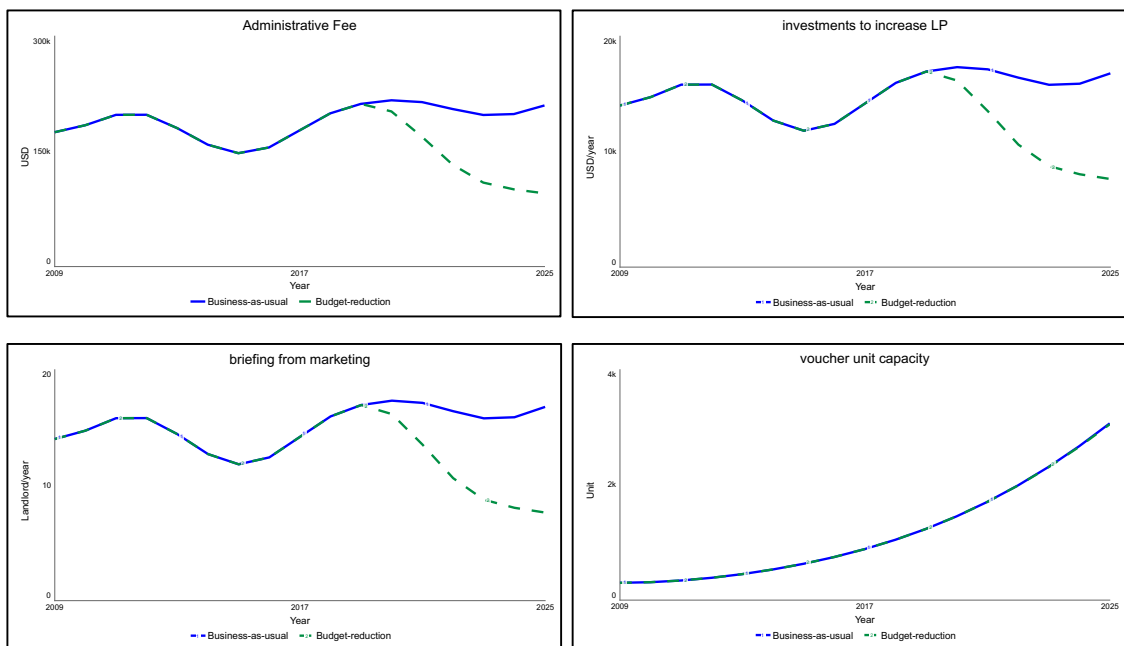


Fig. 6-18. Changes in the marketing investments if the federal budget cuts are implemented in 2018.

In conclusion, the federal funding reduction does not have more significant influence on the number of HHF than in the “business-as-usual” scenario. However, the reduction will negatively affect the TBV tenants.

7. POLICY DESIGN

7.1 Current strategies

Currently, in the City of Fort Collins, many agencies have programs dealing with the family homelessness issue. As shown in Table 7, the programs were classified based on the flows of the HHF stock they are targeted.

Table 7. Current crisis response system for homeless families in Fort Collins.

Target flow	Assistance	Agencies
EF doubling up	Rent assistance	Homelessness Prevention Initiative; Neighbor to Neighbor (N2N)
HHF entering shelters	Temporary shelters; Domestic violence shelters;	Catholic Charities; Crossroads Safehouse
TBV assisted HHF	Section 8 voucher units	Housing Catalyst; Neighbor to Neighbor (N2N)
HHF receiving other assistance	Public Housing; Rapid Re-housing; Single room occupancy	Housing Catalyst; Faith Family Hospitality; Housing Catalyst

Source: Homeless Gear in Fort Collins, <http://homelessgear.org/ovof/ovof-family-resources/>. Note: the types of assistance available are included but not limited to those listed in this table.

Among all the programs, giving them a place to live is proved to be the most cost-effective (Gubits et al., 2015). As housing policy for low-income households has shifted from large-scale public housing developments into vouchers that participants use to find housing in the private market, the tenant-based voucher assistance ends up playing a vital role in the lives of low-income renters. However, the TBV program did not reach its full potential because the lease-up rate among TBV holders is very low in the US. This is consistent with our findings that the short of the available vouchers and available voucher units restrict the outflow of the HHF stock and are responsible for the increase of HHF.

7.2 Proposed strategies

There are numerous obstacles to successfully lease-up with a voucher, including perceived discrimination, tight rental markets, bureaucratic delays, limited experience with the program, household size, health issues (Pashup, Edin, Duncan, & Burke, 2005), social networks (Boyd, 2008) and problems with landlords (Boyd, Edin, Clampet-Lundquist, & Duncan, 2010). Based on the results of this study, I found that the number of hidden homeless families is closely related to the number of available vouchers after the year of 2016. Therefore, a strategy, increasing available vouchers by raising private funds, is proposed.

As shown in Fig. 7-1, the desired amount of private funds is determined within the system given the targeted number of HHF. A wishful thinking link is added between the desired private funding and the inflow of annual private funding incrementing.

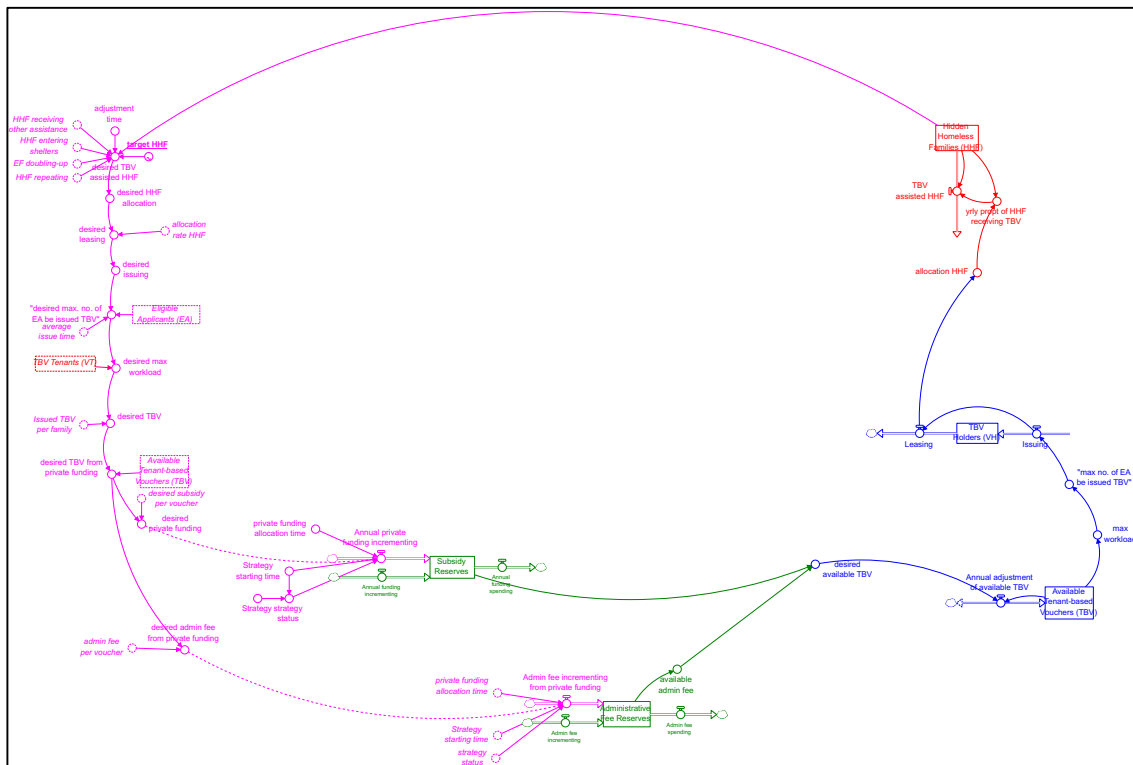


Fig. 7-1. Strategy structure.

After implementing this strategy, I found that the number of HHF becomes lower than the number in the “business-as-usual” scenario after about a two and half years’ delay. Ideally, if there are sufficient private funds and all the families in need apply for TBV (“yearly proportion of families apply for TBV” = 1/year), the hidden family homelessness will eventually be eliminated in the future (Fig. 7-2).

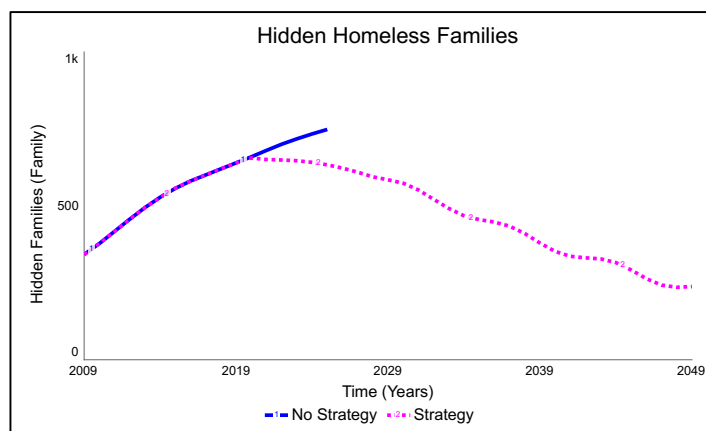


Fig. 7-2. Effect of the proposed strategy on hidden homeless families. Note: the model simulated to 2049 just to show the decrease of the HHF, although in reality many things will change for a so long time frame.

The amount of private funds needed to meet the goal of ending HHF is listed in the below table.

Table 8. Desired private funds and admin. fee needed to meet the goal of ending HHF.

Year	Annual private funding (thousand USD per year)	Annual Admin fee (thousand USD per year)	Subtotal (thousand USD per year)
2019	1,829	279	2,108
2020	1,493	214	1,707
2021	681	99	780
2022	0	0	0
2023	0	0	0
2024	0	0	0
2025	0	0	0
2026	189	39	228
2027	487	116	603
2028	631	178	809
2029	521	184	705
2030	353	151	504
2031	210	116	326
2032	90	98	188
2033	3	107	110
2034	4	98	102
2035	5	140	145
2036	4	160	164
2037	3	148	151
2038	3	110	113
2039	2	72	74
2040	3	64	67
2041	4	137	141
2042	5	155	160
2043	4	129	133
2044	2	73	75
2045	1	32	33
2046	1	41	42
2047	3	94	97
2048	5	150	155
2049	5	158	163
		Total (Million USD)	9.88

8. DISCUSSION

The number of homeless families with children has increased alarmingly since the 1980s. It was estimated that people in families with children representing 35% of the total homeless population in the US in 2016 (Henry et al., 2016). For this systematic social problem, multiple factors, such as the domestic violence, the rent burden, the poverty resulted from the unforeseen financial crisis, and the lack of voucher units, have been suggested to be responsible for the family homelessness (Schmitz et al., 2001). Because of its increasing trend (*The state of homelessness in America*, 2016), there is a growing concern about the vulnerability of the unstable living situation to the children and their families (Guarino, Rubin, & Bassuk, 2007). Despite the fact that many efforts, such as the subsidy assistance mainly in the form of the HCV, the

transitional housing, and the rapid re-housing, have been made in the past years to lift these families with children up in the US (Gubits et al., 2015), the family-homelessness problem still exists. In the study area of this thesis, the City of Fort Collins, Colorado, the one-night PiT count shows the number of literally homeless families increased from 2016 to 2017 (Kyle, 2017b). This could be attributed to the possibility that there is a large amount of families living temporarily in someone else's residence (*The state of homelessness in America*, 2016). These families are named hidden homeless families (HHF), literally means that they are hidden from the public and are insufficiently helped, but are very vulnerable to becoming literally homeless (Brush et al., 2016; Mihaly, 1991). Without addressing the issue of HHF, it is unlikely to meet the goal of eliminating the literally homeless families. In order to allocate appropriate resources to help the HHF, I constructed a system dynamics model with the HHF number as the stock and the possible associated factors as inflows and outflows, to get a thorough understanding about 1) the reasons why the number of hidden homeless families increased, 2) how the number of hidden homeless families will change under different scenarios that will most probably happen in the near future, and 3) what feasible strategies could be suggested to reduce the number.

8.1 The advantages of System Dynamics approach

Although many studies have been conducted to raise the public's awareness of the hidden family homelessness (Ahrentzen, 2003; Brush et al., 2016; Mihaly, 1991; Vacha & Marin, 1993), most of these studies only presented sort of qualitative models showing causal relationships without the actual parameters, functional forms, external inputs, and initial conditions needed to fully specify and test the models. System Dynamics modeling is an excellent approach for researchers to understand and anticipate changes over time in puzzlingly complex systems.

Sterman (2000) introduced that it is easy for our policies to create unanticipated side effects because we tend to hold an event-oriented worldview to interpret experience and solve problems. For example, in the homelessness case, it is perceived that people receiving government assistance do not work because the safety net and the social welfare discourage them from working. Relying on this perception, the Trump administration cut hundreds of thousands of vouchers from the Section 8 Program, and insisted that people will find jobs and save money to avoid losing their housing. That claim, however, is based on a dangerous misunderstanding of who is assisted by these

programs. Actually, most of the voucher holders are working or unable to work, and it is unlikely for them to increase their income (Pyke, 2017). Instead of saving money for the tax payers, the funding cuts would significantly reduce the number of families being assisted because it will decrease the capacity of the available vouchers from the section 8 program, which is facing a severe shortage of resources. To response to the funding shortfall and cover as many families as possible, it seems like reducing the subsidy standard could be a way. However, the subsidy reduction will increase the tenants' share of their rent and they have to depend on the assistance for a longer time. Therefore, it is imperative to have a systematic view of the whole dynamic system and make the correct response from the very beginning.

With SD models, we are able to represent the feedback process, time delays, and nonlinearities to determine the dynamics of the system, which could help us to better understand how our actions in the real system would affect the at-risk or homeless families. Based on the underlying structure, we could obtain a better understanding about the sources of policy resistance and design more effective policies. Moreover, testing a model constructed using the SD method, which is now one of the most popular forms of computer simulation, can speeds and strengthens the learning feedbacks.

8.2 Estimation of the number of hidden homeless families

Jay W. Forrest, the founder of System Dynamics, repeatedly emphasized that the first task in modeling is to re-create the problem. To recreate the problem of hidden family homelessness, we need to understand the magnitude of this problem, i.e. know how big the number is. In this study, I used the education data from the Poudre School District to estimate the number of hidden homeless families in FC, and use other relevant data sources like the caseload of the Matthews House to validate this estimation. However, how to properly quantify the number of homeless has historically been a difficult and costly venture. It is known that the current PiT count is problematic because not only some vulnerable populations, such as the children, are hide from the public view and are not taken into account, but also the fact that the PiT count is just a snapshot. The amount of homeless, however, is a stock changes over time rather than a static number and people often cycle in and out of homelessness. With this in mind, some attempts have been made trying to capture more accurate data of this population. For example, the current hidden homeless estimation in some communities derived from interviewing

households in the Continuum of Care¹¹ (CoC) if a hidden homeless person lived on their or their neighbor's property. Agans et al. (2014) proposed to use neighborhood reporting approach as a way to measure hidden homelessness, in which respondents were asked to report the number of hidden homeless on their residential property and any hidden homeless on their neighbor's property. Hunter (2016) suggest that the PiT counts should be complemented by other information gathering approaches, such as period prevalence counts, which collect administrative data over the course of a year, or the creation of a by-name list, a real-time registry of people who enter and exit homelessness within a community.

In the study area of FC, data collection is now considered as one of the biggest issues concerning the homeless problem. The Director of the Social Sustainability in FC said even though the rate of homelessness in Fort Collins has been relatively stable, current data gathering resources are not as robust for decision making. By partnering with the Housing First Initiative and Homeward 2020 Programs, the FC seeks to gather appropriate data for its Ten-Year Plan, which seeks to “make homelessness rare, short-lived and non-recurring”, and direct its limited resources in the most impactful place. Collaboration with others like the Poudre School District's McKinney-Vento liaisons are also focused on to identify the homeless students.

8.3 The reasons why the number of hidden homeless families increased.

Several studies have been conducted to figure out either the reasons why the families doubling-up or what assistances could help them out (Agans et al., 2014; Ahrentzen, 2003; Gould & Williams, 2010; Gubits et al., 2015; Hartman & Robinson, 2003; Rog & Buckner, 2007; Sard, 2001; M Shinn, 2009; Turner, 1998; Vacha & Marin, 1993). However, most of them are just qualitative studies. I argue that can we reduce its number only if we have a clear mind about the process of families becoming doubled-up and allocate enough resources to help the hidden homeless families based on the underlying reasons. Therefore, having quantitative figures about both the inflows and outflows are critical.

¹¹ The CoC Program is designed to assist individuals (including unaccompanied youth) and families experiencing homelessness and to provide the services needed to help such individuals move into transitional and permanent housing, with the goal of long-term stability.

This study setup a model with the number of hidden homeless families as a stock by applying the theory of stocks and flows in the field of system dynamics, and explored the effects of the addition of inflows and subtraction of outflows of this stock. The behavior showed that the total inflow into the stock was larger than the total outflow from the stock, which is the reason why the number of hidden homeless families increased over the past years. Specifically, the number of evicted families doubling-up due to the rental cost-burden was larger than the number of HHF receiving assistances. It also suggested that the insufficient capacity of the TBV program first in the form of the voucher unit vacancy and then in the form of available vouchers is the main reason why the outflow was smaller than the inflow.

8.4 The change of the number of hidden homeless families in the future

In order to allocate sufficient resources to help the hidden homeless families, we need to understand how such population size will change in the near future.

The model analyzed the number of hidden homeless families under two scenarios: 1) the “Business-as-usual” scenario, and 2) the “funding-reduction” scenario. First, under the “Business-as-usual” scenario, it was estimated that, without additional strategies, the amount of the hidden homeless families will increase as a result of the bigger total inflow than the total outflow. Second, the federal budget cuts will not have a big difference on the number of HHF, however, the funding shortfall would result in a decreased subsidy to the tenants that are receiving vouchers. These findings could be helpful for local authorities and homelessness charities for addressing the family homeless issue.

8.5 The feasible solutions to address the hidden family homelessness

Despite the expected increasing trend of HHF, they still have not received enough attention. Even the HUD’s definition of homeless does not count them as homeless. Therefore, conceptual changes are firstly needed if we want to end the hidden family homelessness. It is suggested that including the HHF in the PiT count can help to shed some lights on who is experiencing homelessness that was hidden from the public attention and what services are needed to help them (Brush et al., 2016). According to the analysis of this study, it is obvious that any policies either targeting the inflows or the outflows could have an impact on the stock of HHF. However, if the policy is insufficient to make the outflow larger than the inflow, the stock will keep increasing

and the problem will not be successfully addressed. Based on the simulation results, it is critical to increase the capacity of the assistance programs, mainly in the form of available vouchers, in order to make the outflow larger than the inflow. Although the federal funds are expected to decrease, the number of available vouchers could be increased by raising private funds or other resources.

8.6 Policy Implications

Children are the future of the world. Experiencing vulnerable situation in their childhood could have long-term negative impacts on their life when they transition to adulthood (Guarino et al., 2007). This problem will also result in a lot of costs for the society. Preventing children and their families from experiencing homelessness should be prioritized and can enhance the quality of their life.

Although the proposed strategy seems to work in the model, the strategy might be too simplistic relative to the real setting. The potential for misperceptions to influence model building, stock estimates, judgements of results, etc., implies that a minimum of dialogue between policy makers, the homeless, landlords, agency managers, sociologist and statisticians should be institutionalized. The model presented in this study could serve as a tool to initiate the engagement of the stakeholders, and get them involved in the family homelessness system.

8.7 Limitations and future work

The aim of this study is to advance the policy discussion, not to resolve it completely, and there remain many questions about the underlying reasons for misperceptions and about policy design. Firstly, the family homeless is a complex issue and is related to social issues like the poverty, welfare, equality, human rights, among others. This study only focused on the economic issue while other reasons leading to family homelessness are excluded. To eliminate the problem, we need to expand the boundary to cover these social issues as well. Secondly, birth, deaths and migration are excluded in this study. Previous research has indicated that the immigrant population lives to a higher extent in rented housing, in less attractive neighborhoods and in more overcrowded conditions. Immigrant is also thought to be closely associated with the increase of the hidden homeless families. Therefore, further studies need to take population growth into consideration. Thirdly, some of the parameters in this model were arbitrarily assigned to certain values when first-hand data are not available. Therefore, the simulated behavior

presented in this thesis might be different when more precise values of these parameters were available and applied in the model. Fourthly, although the policy model suggested that increasing vouchers by raising private funds is critical to address the problem, the cost-effectiveness analysis is not completed in this study and the real challenge is to think about how to implement the suggested strategy. Finally, for most families, housing assistance alone is not enough to recover from homelessness and achieve self-sufficiency. Policies focusing on long-term family stability are critical.

9. CONCLUSION

By focusing on the hidden homeless families, this study modelled the processes of families being at-risk, becoming homeless, and being assisted by the tenant-based housing choice vouchers. The model behaves as expected from the real world observations.

By the system dynamics modelling, this study shed lights into multiple aspects of the family homeless system: 1) the rental cost-burden contributed to families becoming at-risk and will increase the number in the future, 2) the tenant-based vouchers play a vital role in preventing the at-risk families from becoming homeless and moving the homeless families out of the unstable situation, but the assistance capacity is insufficient to keep pace with the demand, that is the reason why the at-risk or homeless families increased and will keep increasing in the future, 3) the capacity of tenant-based vouchers was limited by the number of voucher units but will mainly constrained by the number of available vouchers which is fundamentally the funding availability.

Overall, the modelling results of this study showed us that housing vouchers are of great help to the homeless families, and future policies should focus on increasing more funds to make more vouchers available. The system dynamics model and the results presented in this study could be a useful tool to estimate the demand of housing vouchers and engage the stakeholders in the family homelessness system during the policy implementation process.

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11. APPENDIX

Table 9. Parameters and their values used to keep the model in equilibrium.

Parameters	Value	Units
EQ annual no. of new renter families	0	Family/year
EQ initial NCBRF	2000	Family
EQ initial CBF	3000	Family
EQ initial evicted families	100	Family
EQ initial hidden homeless families	400	Family
EQ initial literally homeless families	30	Family
EQ initial VT	1700	Family
EQ yrly. prop of CBF with other assistance	0.0306415160763	1/year
EQ yrly. prop of EF with other assistance	0.4	1/year
EQ yrly. prop of HHF with other assistance	0.0325	1/year
EQ yrly. prop of LHF with other assistance	0.23333333	1/year
EQ CBF/EF/HHF/LHF allocation rate	0.25	unitless
EQ initial families on waitlist	784.4444444	Family
EQ initial eligible applicants	280.158730159	Family
EQ initial TBV	1980.15873016	Vouchers
EQ initial PL	4000	Landlord
EQ yrly. landlord increasing rate	0.0552854582693	1/year
EQ initial briefed landlords	600	Landlord
EQ yrly. proportion of participation from briefing	0.342763270183	1/year
EQ initial LP	1600	Landlord
EQ yrly. proportion of LP withdrawing	0.138213645673	1/year
EQ initial TBV reserves	5,940,476.19048	USD
EQ admin fee reserves	990,079.365079	USD
EQ renewal funding inflation	0	unitless
EQ inflation adjusted monthly median income	2500	USD/family/month
EQ fair market rent	1000	USD/family/month

Note: parameters not listed in the table are the same as the original setting.